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Mobile location services for the next generation wireless network

Saowanee Thongthammachart Schou

TABLE OF CONTENTS

Abstract

Mobile location services exploit mobile location technologies for determining where a mobile user is geographically located. This information can then be used for providing location-specific content to the mobile user. The mobile location services can be used, for example, for finding points of interest, getting weather information, and tracking the whereabouts of a child. Mobile location services gained a great deal of interest in 2000, and they were envisioned by the business players in the mobile service market as one of the few service categories where the mobile users would be willing to pay for the usage. Since 2000, we have seen countless mobile location services commercially deployed in different parts of the world, and the services have been adopted more enthusiastically by the mobile users in Asia, especially in Japan and South Korea, compared to other parts of the world. However, the overall usage of the mobile location services is still not very high compared to other entertainment and messaging services. The mobile location services are currently not the important part of the mobile data services, and the services have obviously not yet met the hyped expectation of the mass-market adoption that was expressed in 2000. This thesis examines and analyzes the existing mobile location technologies and services to identify the factors that inhibit the take-off of the existing mobile location services. These factors provide indications and ideas of, e.g., what to emphasize, what to avoid, and what to improve when developing a mobile location technology and a mobile location service in the future.

Based on the qualitative studies of the existing location methods and services made in this thesis, the lack of location methods that can provide accurate location information in closed environments and dense urban areas and the lack of adaptability and offerings tailored to different users' requirements in different contexts of use are the main inhibitors to the take-off of the existing mobile location services. Based on these findings, a new conceptual location method has been proposed in this thesis to resolve the lack of indoor location capability, and a conceptual service architecture for adaptive mobile location services has been developed to facilitate the provision of compelling mobile location services for the future network. The developed service architecture allows the mobile location service to be adapted to best fit with the user requirements/preferences in the current contexts of use, which is one of the missing parts that limit the adoption of the mobile location services available today.

Resume

Mobile lokationstjenester udnytter mobile lokationsteknologier til at fastlægge den geografiske lokation af en mobil bruger. Denne information kan bruges til at stille lokationsafhængig indhold til rådighed for brugeren. Mobile lokationstjenester kan for eksempel bruges til at finde interessepunkter, få information om vejrforhold eller til at finde et barns opholdssted. Mobile lokationstjenester fik stor opmærksomhed omkring år 2000, og tjenesterne var af aktørerne i mobilbranchen udset til at være en af de få servicekategorier, hvor mobile brugere ville være villige til at betale for brugen. Siden år 2000 er utallige kommercielle mobile lokationstjenester taget i brug i forskellige områder af verden, og tjenesterne er blevet taget mere entusiastisk i brug af de mobile brugere i Asien, specielt i Japan og Sydkorea, sammenlignet med de øvrige områder. Sammenlignet med andre underholdnings- og meddelelsestjenester er det samlede brug af mobile lokationstjenester dog stadig ikke særlig stort. De mobile lokationstjenester ses ikke i dag som en vigtig del af de mobile datatjenester, og udbredelsen af tjenesterne har tydeligvis ikke opfyldt forventningerne fra år 2000. Afhandlingen undersøger og analyserer de eksisterende mobile lokationsteknologier og –tjenester for at bestemme de faktorer som forhindrer 'take-off' af de eksisterende lokationstjenester. Disse faktorer giver indikationer på og ideer for hvad der for eksempel bør fremhæves, undgås eller forbedres i forbindelse med udviklingen af fremtidige mobile lokationsteknologier og lokationstjenester.

Baseret på de kvalitative studier af de eksisterende lokationsmetoder og tjenester foretaget i afhandlingen ses det, at manglen på lokationsmetoder som kan give nøjagtig lokationsinformation i lukkede omgivelser og i tæt bymæssig bebyggelse, samt manglen på tilpasningsevne og produkter tilpasset til forskellige brugeres krav i forskellige sammenhænge er de primære hindringer for 'take-off' af de eksisterende mobile lokationstjenester. Baseret på disse opdagelser er der i afhandlingen foreslået en ny konceptuel lokationsmetode for at håndtere de manglende lokationsmuligheder i indendørs omgivelser, og en ny konceptuel arkitektur for adaptive mobile lokationstjenester er udviklet for at lette tilvejebringelsen af mobile lokationstjenester på det fremtidige netværk. Den udviklede arkitektur gør det muligt at tilpasse mobile lokationstjenester bedst muligt efter brugerens krav og ønsker i en given sammenhæng, hvilket er en af de manglende elementer som begrænser indførelsen af mobile lokationstjenester i dag.

Acknowledgements

up with all my long nights in front of the computer. Finally, the rest of my thanks go to my son Tim for constantly reminding me that life is certainly more than work.

Saowanee Thongthammachart Schou

May 2008

1 Introduction

The requirements of technologies and services are partly driven by social trends. One important trend that is changing our society is globalization. In the globalized society, the mobility of goods, services, labor, technology as well as capital will increase throughout the world. More and more people will be away from their family and friends, living, working or traveling in unfamiliar areas e.g. foreign countries. As people are becoming more mobile and moving more often in unfamiliar areas, the availability of information related to the current context (e.g. location) becomes very important in their daily life, as this information is attached to almost any everyday activity (e.g. finding out what to do, where to go, where to obtain cash, etc.). Being able to know the current location and activities of family and friends who may live or travel in another part of the world would also be very useful. Mobile location services (MLSs) will make it possible for people to receive information relevant to them in a specific context of use[1].

Mobile location services[2] refer to mobile services that provide information based on the geographical location of people or objects. Mobile location services exploit location technologies[3] for determining where the user is geographically located, thus making the provision of different mobile location services possible. Mobile location services can be used for e.g. emergency purposes as well as for business related purposes such as location sensitive charging, traffic updates, workforce management, fleet management and asset tracking. The location of children or elders and even pets can also be provided and an alert sent when they move inside or outside a pre-defined area. Friend-finder services provide the user with the opportunity to keep a list of his friends together with an indication of where they are located at the moment. Mobile dating enhanced with location tracking enables partner-search by matching profiles in close proximity. The possibilities of the services utilizing location information are endless, and the mobile user can potentially benefit greatly in many everyday activities from the possibilities provided by mobile location services. However, the same mobile location services that bring all the benefits to the user also raise several privacy and data protection

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[1] Context of use is the environment where the service is used.
[2] A list of mobile location service categories and detailed descriptions of different mobile location services can be found in chapter 5.
[3] See chapter 4 for standard mobile location technologies.

issues due to their capability of collecting, storing, using and disclosing a lot of personal information. By observing the location of a user, his behavior patterns can be derived and this can provide marketing and sales organizations, hucksters, tricksters or even criminals the opportunity to benefit on, or directly harm, the user *(Beeson et al. 2002)*. For many people, location information is perceived to be very sensitive, and they are becoming increasingly conscious of the privacy implications of disclosing their whereabouts *(Appelbe 2003; Gadzheva 2007)*. People are becoming more concerned and more demanding with regards to the protection of their personal privacy, and there are a number of privacy concerns that keep bothering their minds *(Lam, 2005)*. The privacy concern is undoubtedly one of the potential problems inhibiting the adoption rate of mobile location services, and this issue must be addressed in order to enhance the user comfort and facilitate the take-off of mobile location services.

Mobile location services gained a great deal of interest in 2000 and 2001 *(Jesty & Winterbottom 2005)* where they were considered as "the next big thing" of mobile data services and one of the few service categories where users would be willing to pay for the usage *(Gadzheva 2007; Mitchell & Whitmore 2003)*. Since 2000 countless mobile location services have been launched on 2G and 3G networks in different parts of the world. The areas with the greatest attention to providing mobile location services are Asia, especially Japan and South Korea, Western Europe and North America, especially in the US, each with very different technologies, different business models and different outcomes. The launch of mobile location services in the US market is mainly driven by the wireless Enhanced 911(E911) mandate, while the European and Asian markets, on the other hand, are driven mainly by competition, leading to earlier deployment of mobile location services than in the US *(Ackerman et al. 2003; Gadzheva 2007)*.

In Asia, the services have been introduced on different mobile network standards: PDC, CDMA and UMTS, and the GPS-based location method is the most common method used for location determination. With the introduction of mobile location services in Asia, companies are now able to offer new services that they were previously unable to offer. Real-time navigation services (2D and 3D), pet tracking services and object tracking services are now available, as well as child tracking services for parents. Also, telematics-related services, which are confined to vehicles and uses GPS navigation in the car for location determination, have gained increasingly attention from the users in Asia. The car connects to the mobile network using a built-in communication unit in the car, and the telematics-related services can thereby provide, e.g., up-to-date traffic information, and conduct remote diagnosis of car troubles and report accidents. The service providers in Asia are actively marketing their services and pushing different models of terminals[4] that

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[4] The terms "handset" or "mobile station" are used to identify the communication device that connects to GSM and GPRS networks and the term "user equipment" (UE) is used for identifying a device that is connected to 3G networks. In this thesis, the term "mobile terminal" or "terminal" is a

have functions supporting the use of mobile location services. Mobile location services have been taken up more enthusiastically by mobile users in Asia, especially in Japan and South Korea, compared to Western Europe *(Schou 2008a)*[5]. However, the usage of mobile location services in Asia is still not very high compared to other entertainment and messaging services[6]. The main inhibitor to the adoption of the existing mobile location services in Asia is the inaccuracy of location technologies in urban, underground and indoor environments, and a lack of adaptability and offerings tailored to different users' requirements *(De La Vergne et al. 2006; Shen et al. 2007)*.

In Western Europe, mobile location services have been introduced on the current GSM/GPRS/UMTS networks. Most mobile operators have not deployed high accuracy location technologies in their networks and mobile terminals. The most common location solution used in Western Europe is the Cell-ID, where each cell has a known location and approximate radio footprint, and the location of the user is known to be within the cell's radius which can vary between 100 m to 20 km *(Openwave 2004)*. While the Cell-ID provides limited location accuracy, it has been much cheaper than any alternative solutions. Different kinds of mobile location services have been introduced in Western Europe. Leading services include those that allow friends to find each other, parents to locate their children and people to find points of interest around a given location *(De La Vergne et al. 2006)*. These services are offered by mobile operators or other service providers, but so far only few people have adopted mobile location services and the services have definitely not met the hyped expectation of mass-market adoption that was expressed in 2000. One of the leading terminal manufacturers (Nokia) recently launched a smart mobile terminal with embedded GPS and world map. This has the potential to increase the penetration of the mobile location service market, but the lack of location availability in dense urban areas, underground, and in indoor environments still can not be solved with this new terminal. Similar to Asia, the available mobile location services offered in Western Europe also lack the adaptability to match the requirements of the users.

In North America, the Federal Communications Commission (FCC) has done a favor for mobile location services in the U.S., by forcing network operators to provide location information[7] at the accuracy of 50 to 300 meters for emergency services *(FCC 2007)*. Different kinds of mobile location services have been offered commercially in the US ranging from map download, tracking services, to navigation service *(3gtoday 2007)*. Similar to Japan and South Korea, most of the available services are based on gpsOne on CDMA networks. Mobile location

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common term used to identify a mobile communication device that connects to all standard mobile networks.

[5] Please refer to appendix A for a list of publications made during this Ph.D. study.

[6] Ibid.

[7] Location information is a set of data describing an individual's location at a specific time.

services are not yet considered as successful services in North America, due to the limited number of subscribers. However, ABI research has predicted that the number of location service subscribers will reach more than 20 million in 2011 *(Fabris 2006)*.

Mobile location services are based on the underlying location technologies that enable the identification of the location of a mobile terminal and its owner. Several mobile location technologies are available and most of them are suitable for in outdoor environments. Among the emerged location technologies, Cell-ID is the most widely-used location technology today. This is because the Cell-ID does not require any modification to either the handset or the network. One of the shortcomings of the Cell-ID is that its accuracy is degraded considerably in rural areas, due to larger cell sizes. Another well-known location method, being the popular solution in the US and Asia is GPS-based location solutions. GPS is highly accurate and relatively cheap, but the GPS location solution is not appropriate in indoor environments due to loss of line-of sight leading to signal blockage or fading *(Barnes 2003)*. With an estimated 70% of location requests coming from indoor environments *(De La Vergne et al. 2006)*, GPS on its own is not sufficient to meet a broad range of market requirements. Different location techniques have been proposed to be used in indoor environments. These techniques are often referred to as local location techniques and usually make use of short-range and medium-range wireless networks such as Bluetooth, WLAN, etc., for determining the location of persons or objects in limited-range areas *(Pagonis & Dixon 2004)*. The accuracy of these indoor location technologies is very high compared to the location methods based on the mobile networks. These indoor location solutions can possibly be used to compensate for the lack of high accurate location capability in indoor environments of the location methods used on mobile networks (e.g. GPS-based methods, Cell-ID, etc.). In order to realize this idea, a new mechanism for handling the location roaming and location update between different kinds of wireless access networks is required, and this mechanism is currently not available.

New possibilities for the mobile location services are likely to emerge from the next generation wireless network. The term "next generation wireless network" refers to a unified multimedia network that combines different kinds of existing and emerging wireless access technologies, e.g. mobile networks (2G, 3G), WiMax, WiBro, Bluetooth and WLAN *(Reynolds & Jin-Kyu 2004; Srivastava & Kodate 2005)*. The unified multimedia network will allow interconnections between different kinds of wireless access technologies, and the user can roam seamlessly on the common IP network *(Kappler et al. 2007; Reynolds & Jin-Kyu 2004; Makaya & Pierre 2007; Srivastava & Kodate 2005)*. The network is expected to be IP-based and more specifically based on IP version 6 (IPv6)[8], which has a number of attractive features for supporting new multimedia services. The service environment

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[8] Ibid.

of the next generation network is envisioned to be open, allowing users to access any service regardless of geographical location, terminal model, access network, network operator and service provider *(ITU-T 2005; Reynolds & Jin-Kyu 2004)*. It is expected that service providers and content providers will be able to provide their services and content independently from the operators *(Reynolds & Jin-Kyu 2004)*, and that location and charging information can be transferred among networks and applications[9]. This will open up new opportunities for service providers to provide new-concept mobile location services which have not been possible on the current networks and current service environments.

1.1   Basic components of mobile location services

A mobile location service is one of the most complex data services that can be made available to the mobile user. It requires a number of new components to be added to the mobile network, and a number of stakeholders must be involved in developing, delivering and monetizing mobile location services, e.g. network operators, location technology venders, terminal manufacturers and service and content providers. The complex technical and commercial relationship among the stakeholders in the mobile location service market can be illustrated through the four main components required for providing mobile location services: Mobile network, mobile terminal, mobile location technology and application and content server (see figure 1-1).
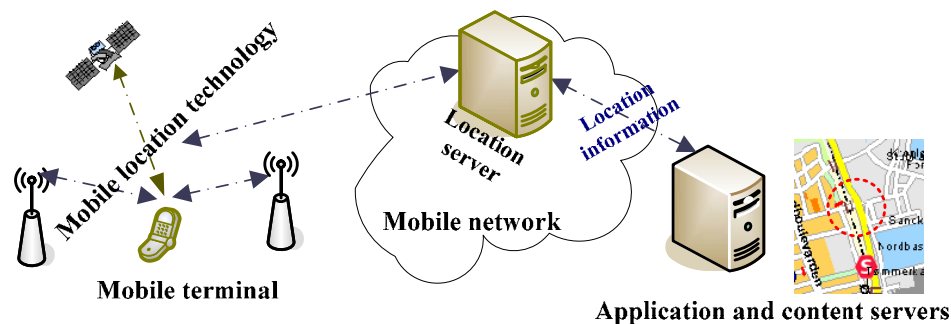
Figure 1-1: The basic components of a mobile location service include mobile network, mobile terminal, mobile location technology and application and content servers.

In figure 1-1, when a mobile location service subscriber accesses the mobile network, his location is detected by the location technologies, which may either be added in the terminal or at the network. This location information is sent to the location server which is located on the mobile network. The location server maintains the location information of all the mobile location service subscribers on

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[9] Ibid.

the network. The location information will be shared with the application and content server and other third parties upon request.

In the following sub-sections, the roles of the four basic components of mobile location services are described together with the roles of the involved stakeholders.

1.1.1 Mobile network

The mobile network acts as a bridge linking the mobile user with a mobile location service provider. The mobile network forwards the user request to the service provider and the service provider sends the requested information back to the user via the mobile network. For mobile location services the network may send assisted information to the location technology located in the terminal, and this information is used for calculating the location of the terminal. The mobile network is owned and managed by the network operator, and the network operators are the most influential stakeholders in realizing the mobile location services. The network operators provide communication services (physical connectivity) to mobile users by giving them access to the network and services. The network operators may also provide network-related information such as location information and billing services to third parties (e.g. service providers). In order to make mobile location services available, it requires a number of new components to be added to the mobile network. The availability of mobile location services is therefore highly dependent on the network operators, and mobile location services will only be realized if the network operators decide to deploy the appropriate infrastructure for mobile location services on their networks.

1.1.2 Mobile terminal

In the context of mobile location services, a mobile terminal is an electronic device which a user uses to access information services based on the location information provided by the location technology or defined by the user. The mobile terminal can be any terminal that can connect to a mobile network (e.g. mobile phone, PDA, Laptop with mobile network access card, or a navigation and communication unit in a vehicle). The desired location can be the user's own location, the location of his friends or family members or any location specified by the user. The location-based information can be delivered to the user in the form of text, picture, voice or multimedia. The mobile terminal may also provide assisting information to the network and this information is used by a location technology to calculate the location of the terminal on the network side.

The realization of mobile location services also depends on the availability of mobile terminals that can support the deployment of mobile location services. The terminal manufacturers therefore play an important role in realizing mobile location services, as they can increase the capabilities of the terminal and thereby make it more desirable for mobile location services. Location methods that require

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modifications to the terminal (e.g. A-GPS and E-OTD)[10] will only be practical if the terminal manufacturers agree to add the appropriate technology in the terminal in a way that makes the price, terminal size, and battery life acceptable to the users. The terminal manufacturers also play an important role in improving the user experience towards mobile location services. They can, for example, add a short key for mobile location services on the terminal, and this will allow the users to accomplish their tasks more easily and faster. They can also decide to produce a terminal with high resolution display and large processor and memory, which will, for example, be able to support 3D navigation services.

1.1.3 Mobile location technology

The mobile location technology is the core of mobile location services. It is the system used for determining the location of the user who is carrying the mobile terminal and connecting to the mobile network. The location technologies can be divided into three groups according to where the location calculation is performed: Terminal-based[11], terminal-assisted[12] and hybrid location solutions *(3GPP 2005)*. For terminal-based location methods, the location calculation is performed by the mobile terminal, and additional software and/or hardware is required in the terminal. For terminal-assisted methods, the location calculation is performed by the network based on radio signals send from the mobile terminal, and consequently these methods require no expensive hardware in the mobile terminal. For hybrid location methods, the location calculation is performed by two or more of the terminal-based and/or terminal-assisted methods. The location information obtained by the location technology will be sent to the location server on the mobile network. The location server converts the location information provided by a location technology into data that can be used by other components in the mobile location service environment. This converting function is handled by middleware in the location server[13]. The location server may also handle user privacy with respect to the use of location information of specific users.

Various location solutions have been developed by different venders, providing different levels of location accuracy and response time. Some solutions have been adopted and many have failed for technical or commercial reasons. Not all the location methods can be adopted by the network operator, the possible location technologies depend on the network standards deployed by the network operators[14]. The location determination infrastructure providers have to develop their location

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[10] See section 4.2.2 and 4.2.5.

[11] A terminal-based location method is sometimes called network-assisted location method.

[12] A terminal-assisted location method is sometimes called network-based location method.

[13] Middleware is the software layer that lies between the operating system and the applications on each side of the system. In the mobile location service environment, the most common use of middleware is in the location server *(Chamberlain 2004)*.

[14] See section 4.3.

solutions based on existing mobile network standards. The network provider will only adopt the solutions provided by the location determination infrastructure providers if they believe that they will benefit from doing so. More detailed descriptions of mobile location technologies can be found in chapter 4.

1.1.4   Application and content server

Application and content servers are owned by service and content providers. A service provider offers different kinds of mobile location applications and services (based on the location information obtained by a mobile location technology) via a mobile network to a user requesting the content (e.g. traffic information, weather information, restaurant list, etc.) provided by the content provider.

The application server maintains different kinds of mobile location applications. In some cases, the application server may also maintain the content like in the case of the application server proposed in OpenLS *(Bychowski et al. 2005)*. The application server may also contain other service-related information, requirements (e.g. specifically required terminal) and rules of using the service (e.g. privacy rules) .

The availability of application and content depends on the service and content providers. These people are depending on many business players when they are developing and deploying the services. They must provide their service and content according to the available network and location determination infrastructure. They also depend on the terminal manufacturers for the availability of a sufficient amount of MLS-compatible terminals having the appropriate operating systems or execution environment. However, the service and content providers is one of the stakeholders who increase the availability of the services and this could increase the number of subscribers, thus making the mobile location services more interesting for all the business players involved. It should be noted that new services may also come from other parties than the service and content providers, e.g. the network operators or terminal manufacturers.

1.2   Key elements determining the success of a service

The success of any service or product is mainly driven by marketing, technology and user experience *(Bernardos et al. 2007; Norman 1999)*. Marketing emphasizes on presenting characteristics that affect the service adoption to the users *(Norman 1999)*. However, the marketing alone is not able to bring the service to the successful level. Even the best marketing will (in general) not make a service become a success if the service is designed using inappropriate technology and if it provides a negative user experience[15]. The technologies define which service functions are possible and not possible, how much time it will take to develop a

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[15] Ibid.

service and what it will cost. Technology is the service enabler and a good marketing attracts new users to the service. However, the main factors driving the success of a service are not only the technology and marketing. The critical determinant of the success of a service is the willingness of the users to continue paying for the service. Even the service using the best technology and best marketing will fail if no one wants to keep paying for it. It is most likely that the users will only continue paying for a service if they get a positive user experience from using the service. Marketing, technology and user experience drive the success of a service in different phases of the service's life cycle, as illustrated in figure 1-2.
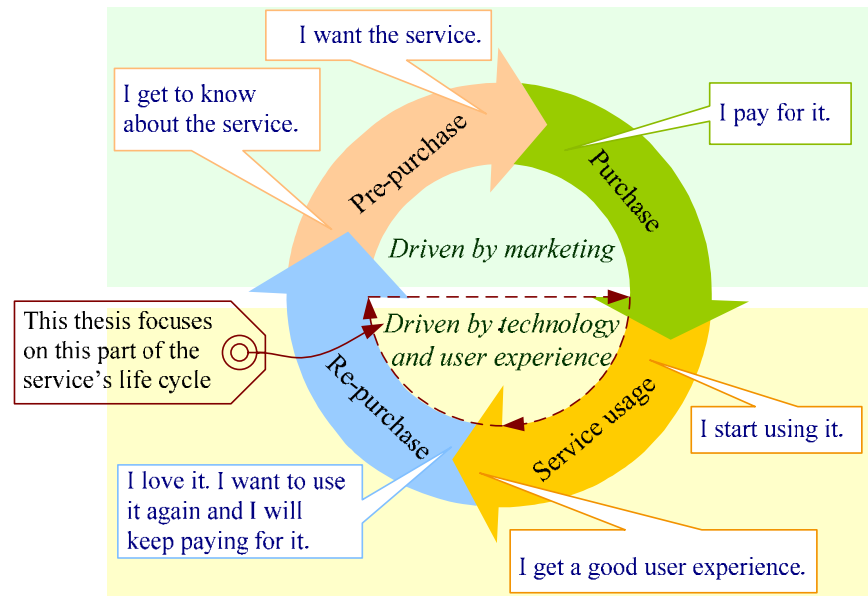
Figure 1-2: The life cycle of a service or product include four different phases: Pre-purchase, purchase, service usage and re-purchase *(Nokia 2006)*. Marketing mainly influences the pre-purchase and purchase phases of the service's life cycle, and technology and user experience mainly influence the service usage and re-purchase phases of the service's life cycle *(Normann 1999)*.

As illustrated in figure 1-2, the marketing mainly drive the pre-purchase and purchase phases of the service's life cycle and technology and user experience mainly drive the service usage and the re-purchase phases of the service's life cycle *(Normann 1999)*. Marketing attracts new users to the service, and if the service provides a positive user experience during the service usage phase, the user is likely to continue using and paying for the service[16]. If the user gets a negative user experience, the service will most likely not reach the re-purchase phase of its life

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[16] Ibid.

cycle and this will lead to the failure of the service[17]. The focuses of this thesis are on the service usage and re-purchase phases of the service's life cycle[18].

The following sub-sections describe the importance of the marketing, technology, and user experience to the success of a service.

1.2.1 Marketing

Marketing plays an essential role in positioning the service in the market *(Norman 1999)*. Positioning is the act of establishing what people think about the service and the company. It determines how people perceive the service of the company. People adopt the service based on their perceptions, not on reality; unless they have used the service themselves or have referred to friends that have experience with the service[19]. The primary emphasis of marketing is on those characteristics that affect the adoption of the service[20]. Strong marketing activities and advertisements are ways that can differentiate one company from the next, and it can have a positive effect on a company's service offering, if the marketing is done right *(Tan 2006)*.

1.2.2 Technologies

Having the appropriate technologies is obviously one of the fundamental keys driving a successful service. It is the technologies that enable possible new functions, better quality and lower costs *(Norman 1999)*. A compelling mobile location service relies mainly on a location technology that can provide appropriate location accuracy and response time for the specific service and a mobile network that allows the information to be sent to the user with an attractive speed. Other technologies such as those allowing the information to be presented to the user in an attractive way are also important. Descriptions of mobile and location technologies can be found in chapter 2 and 4.

1.2.3 User experience

User experience is the experience the user gets from using a product or service in a particular context of use *(Arhippainen & Tähti 2003)*. The user expectation is the key behind the user experience, and a good user experience will only be formed if the service can, in different use contexts, function as or better than the users have expected *(Schrammel & Tscheligi 2006; Hiltunen 2002)*. User experience is becoming more and more dominant in the mobile service market as technology is becoming more and more mature and the technological features of the services that the general users have been looking for can generally be provided by the mobile

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[17] Ibid.
[18] See section 1.3 for the objectives of the thesis.
[19] Ibid.
[20] Ibid.

technologies available today[21]. At this stage, the users will look for a better user experience provided by the services and user experience will play a key role in the service adoption decisions *(Normam 1999)*. As a mobile user naturally uses a mobile service from different places at different time with different social aspects, the context of use plays an important role in differentiating the user experience. The same service may appear differently to the users if it is used in different contexts, and this gives different user experiences[22] *(Forlizzi & Ford 2000)*. The user experience towards a service cannot be controlled completely but it can be partly managed. Managing the user experience requires an understanding of the principles of the user mental model and the context of use. The user experience concept is described in more details in chapter 3.

1.3   Thesis objectives and research questions

Mobile location services have been commercially available since 2000 and they were expected to become a success especially in the 3G era, where the mobile location service is one of the main service categories that should be made available for the 3G users *(UMTS Forum 2001)*. As of July 2007, 391 commercial 3G operators have launched 3G services in 135 countries and there are currently 1,095 models of 3G terminals worldwide *(3gtoday 2007)*. Different mobile location services are currently available on 3G as well as 2G networks, but it seems like the time for mobile location services has not yet arrived. Despite several waves of improvement, mobile location services are not a clear success story for mobile operators *(Betti 2005)*. Despite continuous efforts to improve the location technology, the emerged solutions have not yet reached the expectations of most of the users and operators, especially in indoor environments where the service is often unavailable or degraded[23]. Providing a successful service is apparently difficult and challenging. Appropriate location technologies need to be chosen, the user experience needs to be managed, the use contexts need to be considered, and the user privacy needs to be handled. The road to success for mobile services is a long and difficult one, and this is especially true in the case of mobile location services. This thesis explores the technological and user experience issues limiting the success of the existing mobile location services, and comes up with solutions and suggestions of how to overcome or minimize some of these problems.

The thesis is divided into two parts. The first part of the thesis is an exploratory study of standard mobile location methods and mobile location services commercially available in Asia and Western Europe. Asia and Western Europe are chosen as focus areas, since these parts of the world are different in terms of mobile technology standards adopted by the network operators as well as social and

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[21] See section 2.3 for the discussion of the relationship between the mobile technology's life cycle, user's behaviors and the dominance of user experience.
[22] See section 3.4 for the description of the influence of context of use to the mobile user experience.
[23] Ibid.

cultural aspects (use context) of each society. In Asia, the thesis focuses on the most advanced mobile service markets, Japan and South Korea. The second part of the thesis involves the conceptual design of a new location method and new service architecture for adaptive mobile location services on the next generation wireless network. Case studies of new-concept mobile location services[24] based on the conceptual service architecture are made to explore and demonstrate the applicability and value of the architecture.

The objectives of the first part of the thesis are to provide an examination and analysis of:

- Standard mobile location technologies and their strengths and weaknesses.
- Factors influencing the adoption of mobile location technologies of network operators in Asia and Western Europe.
- Existing mobile location services offered in Asia and Western Europe and their strong points and shortcomings.
- The influence of the elements forming the mobile user experience on the adoption of the services in reality.

The following research questions were formulated and used as a guide throughout this part of the thesis.

1. Mobile location services have been available since 2000 and a lot of efforts and investments have been put into the development of mobile location technologies and services. Different location solutions are currently available for the operators. Delivering of multimedia services can easily be done with the data rate provided by the current mobile network technologies and various models of advanced mobile terminals are available in the market. It seems like the technologies for mobile location services are out there, so why have we not seen a breakthrough of mobile location services?

2. What are the main barriers of the mobile location services offered in Asia and Western Europe, and how can these barriers be overcome?

The results of the above-mentioned examinations and analyses will build an understanding of the capabilities and limitations of different location methods and services, and of the current status of the mobile location services market in Asia and Western Europe. The factors influencing the adoption of location technology of the network operators and the factors influencing the adoption of mobile location services of the users in both of the regions are also discovered through the above-

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[24] The term 'new-concept mobile location services' refers to mobile location services on the next generation wireless network which are based on the conceptual service architecture, and which provides new possibilities which are not possible with the current mobile location services.

mentioned studies. This discovery will provide the ideas of what should be emphasized when developing a mobile location service in the future.

As previously discussed at the end of the introduction part of this chapter, the next generation wireless network is expected to be an IPv6-based unified network with a number of attractive features for supporting new multimedia services. The second part of the thesis explores how the new features of the next generation wireless network can be applied to sustain the development and deployment of new-concept mobile location services. The main objectives of this part of the thesis are to develop a new conceptual location method and to develop a conceptual service architecture for mobile location services utilizing the features of the next generation wireless network. The new conceptual location method aims to compensate the shortcomings of the existing mobile location technologies. A conceptual service architecture is then developed based on theories, concepts and ideas from the field of user-centered design (user experience, context of use, and privacy). The objectives of this part of the thesis are to examine and analyze:

- Trends in next generation wireless network.
- Features of the next generation wireless network that can facilitate the development of mobile location technologies and services.
- Indoor location detection applying the characteristics of Bluetooth and WLAN.
- User experience management.
- Context-based service adaptation.

The results of the studies above will enable the discovery of the technological features of the next generation wireless network that can be applied to determine the location of mobile users, and how these features can be utilized to support the development of mobile location services. Ideas of managing the user experience towards the mobile location services in different use contexts will also be gained. The obtained knowledge will be used as input for the further step of the thesis, which has the objectives of developing:

- A new conceptual location method utilizing the features of the next generation wireless network with the purpose of compensating for the shortcomings of the existing mobile location methods. In this thesis, the developed conceptual location method is called the IPv6-based location method.

- A conceptual service architecture for adaptive mobile location services with the purpose of facilitating the deployment of new-concept mobile location services. The service architecture consists of a set of concepts, rules and guidelines for constructing, deploying, and operating the services. The

service architecture identifies the components required to build the services, describes how the components are combined, and how they interact.

The following research questions were formulated and used as a guide in this part of the thesis.

3. How is the next generation wireless network expected to turn out?
4. Are there any features of the next generation wireless network that can be applied to develop a new location method that can compensate for the shortcomings of the existing mobile location technologies and services? And how can these features be applied?
5. User experience is one of the key elements determining the success of any service in the current and future network. To be a success, the mobile location services on the next generation wireless network should provide a positive user experience at different contexts of use. How can the user experience concept be integrated in the conceptual service architecture?
6. How can the conceptual service architecture be used for providing different kinds of new-concept mobile location services on the next generation wireless network in different contexts of use, and what are the advantages and shortcomings of the new-concept mobile location services utilizing the conceptual services architecture in comparison with the existing mobile location services in different contexts of use?

As discussed above the main objectives of the second part of the thesis are the development of a new conceptual location method as well as a new conceptual service architecture for providing mobile location services, and from the research questions it can be seen that the focus is on the technologies (especially mobile location technology and the features of mobile technologies facilitating the development of mobile location services) and the user experience aspects. These elements are two of the key elements determining the success of a (mobile location) service as discussed in section 1.2. From the discussion in section 1.2, it is also clear that the market perspective is a key element affecting the success of a service, but in this thesis, the focus is on the elements affecting the service usage and re-purchase phases of the service's life cycle[25].

1.4   Research methodology

According to Leedy & Ormrod (*Leedy & Ormrod 2001)*, the research methodology will be dictated by the nature of the required information (or data) that can be used for finding the answers to the defined research questions. To answer different types

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[25] See figure 1-2 in section 1.2.

of research questions, different kinds of information or data (qualitative[26] or quantitative[27]) are required, and the required information or data will indicate which research strategy and research method are appropriate to be used for such research questions[28]. Based on the thesis objectives and research questions presented in the previous section, the thesis involves a wide range of topics, and a large amount of qualitative information is needed to cover the complete range of topics of this thesis. It can also be seen from the thesis objectives and research questions that the thesis is exploratory by nature[29]. Due to the nature of the thesis, the type of research questions, and the type of information needed for exploring the research area, an exploratory study approach sustained by qualitative research is the most appropriate method for this thesis. To carry out this type of approach, a hybrid research strategy encompassed with four different qualitative research methods (historiography, content analysis, interview and case study) has been chosen to facilitate this research work. The conceptual model of the research methodology used in this thesis is shown in figure 1-3.

Hybrid research strategy

Exploratory study approach

Historiography	Content analysis	Interview	Case study
Based on literature survey	Based on literature survey	Based on unstructured interviewing	
Used for research questions # 1, 2 & 3	*Used for research questions # 1-6*	*Used for research questions # 3 & 4*	*Used for research question # 6*
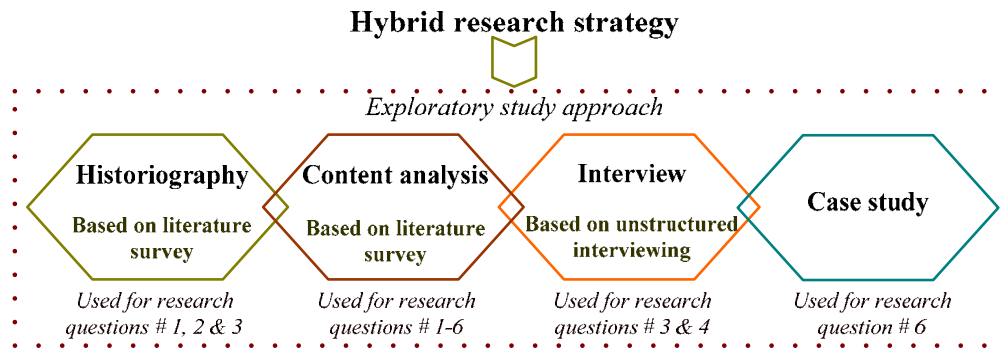
Figure 1-3: Conceptual model of the methodology used in this thesis. Different methods are appropriate to be used for answering different research questions indicated in the figure.

According to O'Connor *(O'Connor 2006)*, historiography is the method of doing historical research or gathering and analyzing historical evidence and presenting them rationally. The historiography method is conducted by considering currents and the countercurrents of present and past events, with the hope of discerning patterns that tie them together and make them a meaning piece of information

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[26] Qualitative data can be much more than just words or text. Photographs, videos, sound recordings and so on, can be considered qualitative data *(Trochim & Donnelly 2006)*. Qualitative data sources include interviews, documents and texts, and the researcher's impressions and reactions *(Myers 1997)*.

[27] Quantitative data is the data that is rendered into numerical form *(Trochim & Donnelly 2006)*.

[28] Ibid.

[29] As noted by Cavana et al. *(Cavana et al. 2001)*, "In exploratory studies, the researcher is basically interested in exploring the situational factors so as to understand the characteristics of the phenomena of interest". Additionally, Cavana et al. have highlighted that "exploratory studies are important for obtaining a good grasp of the phenomena of interest and for advancing knowledge through good theory building".

(Leedy & Ormrod 2001). In this thesis, the historiography has been conducted based on the literature survey. This method has been used for discerning patterns of knowledge on the evolution of mobile and wireless technologies, the development and deployment of mobile location technologies and services as well as trends in the next generation wireless network.

Content analysis is a technique for gathering and analyzing the content of text *(O'Connor 2006)*. The content can be words, phrases, sentences, paragraphs, pictures, symbols, or ideas[30]. In this thesis, content analysis has been used in different parts, mainly to discover the factors influencing the adoption of mobile location technologies of the network operators in Asia and Western Europe and the factors influencing the adoption of mobile location services of the users in both of the regions. A better understanding of the importance of user experience and context of use to the success of the service has also been contributed by the content analysis research method. Importantly, this method was also used while discovering the new method for determining the location of the user applying the mobility management protocols on the next generation wireless network. The concept behind the conceptual service architecture for adaptive mobile location services designed in this thesis has also been extracted from the content analysis.

Interview is a method used for gathering information, which begins with the assumption that the interviewees' perspectives are meaningful, knowable, and able to be made explicit, and that their perspectives affect the success of the research *(Mahoney 1997)*. The purpose of the interview is to probe the ideas of the interviewees about the phenomenon of interest. The information provided by different people participating in the interviews has been used to support the ideas and concepts of the new conceptual location method utilizing the features of the next generation wireless network and of the conceptual service architecture[31]. The information acquired from the experts in the research field has also been used to support the arguments and discussions through out the thesis.

Case study is a method for learning about a complex instance, based on a comprehensive understanding of that instance obtained by extensive description and analysis of that instance taken as a whole and in its context *(GAO 1990; Lynn 1991)*. There are six different types of case study: Illustrative, exploratory, critical instance, program implementation, program effects and cumulative *(Morra & Friedlander 1996)*. Each of the types is suitable for answering different kinds of research questions. In this thesis, the illustrative case study has been chosen to explore the conceptual service architecture and demonstrate its applicability in different contexts of use, as the illustrative case study is descriptive in character and

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[30] Ibid.
[31] The ideas and concepts behind the conceptual location method and the conceptual service architecture have been discovered from the content analysis research method.

it has been designed to be used for describing the domain by utilizing one or more instances[32].

In the next sections, the processes of information collection and information analysis used in this thesis are described.

1.4.1 Information collection

The data used in the process of qualitative research can be anything that is not quantitative or rendered into numerical form *(Thorne 2000; Trochim & Donnelly 2006)*. Qualitative data can be much more than just words or text. Photographs, videos, sound recordings and so on, can be considered qualitative data *(Trochim & Donnelly 2006)*. Qualitative data sources include interviews, documents and texts, and the researcher's impressions and reactions *(Myers 1997)*. Different methods used for collecting the qualitative data in this thesis are presented in the following sub-sections.

1.4.1.1. Interviews and discussions

The interviews and discussions related to this thesis were conducted with people who are associated with mobile technologies and services both in Asia and Western Europe (e.g. experts, researchers, engineers and academic professionals). The interviews and discussions give insight to the status and trends in the development and deployment of mobile technologies, mobile location technologies and mobile location services in Asia and Western Europe which is free from media hype.

The interviews have been conducted during the external research stay at Waseda University, Tokyo, Japan as well as with experts in Western Europe (i.e. Denmark and Finland). In Japan, the qualitative data based on interviews has been collected during the visits at mobile network operator companies (KDDI and NTT DoCoMo) and through the internal group discussions at the Global Information and Telecommunication Institute (GITI), Waseda University as well as during a seminar at the Yokosuka Research Park (YRP) and during a visit at Tokyo University. The knowledge of trends in next generation wireless network has been obtained through the discussions with researchers at KDDI, NTT DoCoMo and YRP. Through the discussion with researchers at KDDI, the ideas and concepts of determining the location of mobile users applying the movement detection of Mobile IPv6 has been confirmed to be possible, and this has played a significant part in the conceptual mechanism developed throughout this thesis for detecting the location of a user on the next generation wireless network. The concepts and ideas of indoor location detection utilizing the characteristics of Bluetooth and WLAN have been confirmed to be realistic from the discussions with professors and Ph.D. students at Tokyo

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[32] Ibid.

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University. Through the group discussions at Waseda University, and the discussion with engineers at KDDI, the information of what is going on with mobile location services in Japan has been obtained.

In Western Europe, the interview was conducted with a technical director at Motorola A/S, Denmark and the online interviews were conducted with a CTO from Terma A/S, Denmark and with a professor who is an expert in the area of mobile location services and E-commerce from the University of Jyväskylä, Finland. The purpose of these interviews is to acquire feedback (i.e. criticisms, comments and suggestions) on the concepts and ideas behind the conceptual service architecture developed in this thesis. The qualitative data obtained from these experts has been used for validating the conceptual service architecture developed in this thesis, to support the discussions and arguments made in the thesis, and to provide directions for the further research.

The list of people participating in the interviews and discussions can be found in appendix B.

1.4.1.2. Literature survey

This thesis covers a wide range of topics ranging from examination and analysis of the existing mobile location technologies and services to developing a new conceptual location method and service architecture. To cover the complete range of topics of this thesis, a large amount of texts and documents are needed to be reviewed and analyzed. The following areas of literature were studied:

- Evolution of mobile technologies.
- Mobile location technologies.
- Existing mobile location services.
- Next generation wireless technologies.
- Mobile IPv6 and mobility management protocols.
- Short-range wireless networks.
- User experience theory and context model.

The feasibility of providing mobile location services depends directly on the features provided by the mobile technologies (network and terminal). To understand the characteristics, capabilities and limitations of mobile technologies that can facilitate the development of mobile location services, the latest engineering and scientific developments in mobile technologies needed to be studied. The literature sources for this are relevant text books, journal and conference papers, technical specifications and online literature from different websites such as International Communication Union (ITU), 3rd Generation Partnership Project (3GPP), Universal Mobile Telecommunications System (UMTS) Forum, GSM Association (GSMA) and CDMA Development Group (CDG).

Analyses of mobile location technologies and existing mobile location services require a large amount of literature sources, since a wide range of technologies and services available in different parts of the world needed to be examined. Relevant text books, conference and journal papers, consultant reports[33] as well as articles from the websites of the location technology venders and mobile location service providers are chosen as the literature sources for these analyses. The text books together with conference and journal papers provide the technical knowledge behind different location technologies. The consultant reports and online articles provided by the venders and service providers give up-to-date information regarding the current status and the development of location technologies and services.

An understanding of the trends in the next generation wireless network, together with Mobile IPv6 and different mobility management protocols has been important in developing the conceptual location method. For determining the location of the user in indoor environments, the characteristics of wireless short- and medium-range networks, e.g. Bluetooth and WLAN, needed to be studied. To understand the trends in next generation wireless network, industrial related developments as well as new standardizations needed to be followed. Literature sources published by the leading companies in the mobile industry and consultant reports have been reviewed and analyzed. These sources of literature provide up to date information of what is going on in the mobile industry and what is going to be developed in the near future. Online technical specifications obtained from trust organizations, e.g. ITU, IETF, 3GPP UMTS forum and Bluetooth SIG have been studied. These online sources provided key knowledge when the conceptual location method was developed defining what is possible and not possible. The reports, white papers, articles and related activities presented on the websites of developers and service providers such as CDG, Qualcomm, SK Telecom, NTT DoCoMo, KDDI and 3gtoday were also chosen to provide useful sources of literature in this area.

User experience theory and the context model are important in several parts of the thesis. The books "Professional mobile user experience" from IT Press *(Hiltunen et al. 2002)* and "The Invisible Computer" and "Emotional design" by Norman *(Norman 1999; Norman 2004)* have provided systematic, practical and useful information on this topic. The utilization of user experience theory for real products and services have also been studied through online articles from different companies who practically deal with user experience design such as Apple, Frontend, NN/g 2006 and Semantic Studios. Relevant journal and conference papers have also been used as literature source for this area.

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[33] Consultant reports can be industrial reports, strategy analysis reports, market reports, etc.

1.4.1.3. Other information collection

The knowledge of mobile technologies and services has also been obtained through Ph.D. courses (material provided as part of the courses and presentations of Ph.D. students participating in the courses), conferences and peer review papers. The chosen Ph.D. courses have provided extensive understanding of the fundamentals behind the research topic. The list of courses can be found in appendix C. The trends in the next generation wireless network have also been followed by attending talks and presentations at the conferences by people who are involved with mobile technologies and services.

1.4.2 Information analysis

In qualitative analysis, the researcher decides which information are to be singled out for description according to principles of selectivity and this usually involves some combination of inductive and deductive analysis *(Berkowitz 1997)*. Generally, inductive reasoning uses the collected information to generate ideas, concepts or general conclusions, whereas deductive reasoning begins with the ideas or concepts and uses the collected information to confirm or negate these ideas or concepts *(Trochim & Donnelly 2006; Thorne 2000; Holloway 1997)*. The process of inductive and deductive reasoning is illustrated in figure 1-4.
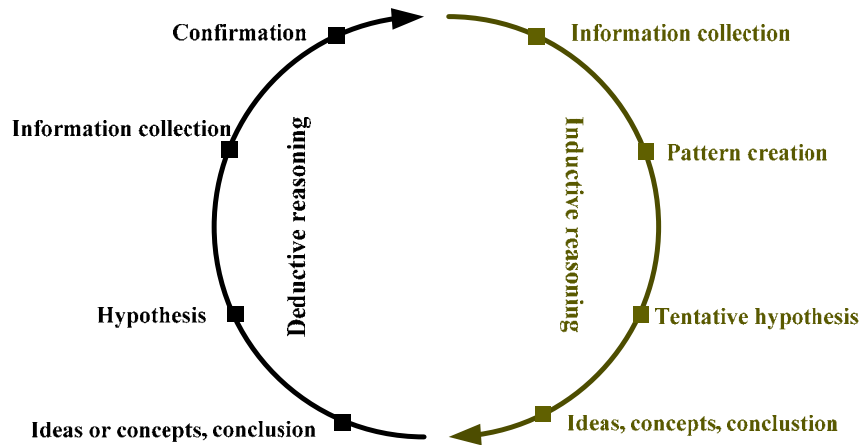
Figure 1-4: The process of inductive and deductive reasoning based on *(Trochim & Donnelly 2006)*.

In this thesis, both inductive and deductive reasoning were used to sustain the information analyses in different parts of the thesis. As this thesis is based on an exploratory study approach, inductive reasoning has been used as an analysis tool to generate some tentative hypotheses that can be explored and finally end up developing general conclusions, ideas or concepts. According to the research

objectives presented in section 1.3, inductive reasoning has been used to explore the capabilities and limitations of standard mobile location technologies and mobile location services commercially available in Asia and Western Europe. The factors influencing an adoption of these methods and services of network operators and users in Asia and Western Europe have also been discovered using inductive reasoning.

In the conceptual design part of the thesis (the second part of the thesis presented in section 1.3), inductive reasoning has been used to discover the features of the next generation wireless network and the possibilities of applying these features to facilitate the development and deployment of mobile location services. The ideas and concepts of determining the location of the mobile user applying the mobility management protocols used in Mobile IP6 were generated based on inductive reasoning. These ideas and concepts have been tested and confirmed to be possible using deductive reasoning (see figure 1-4). The ideas and concepts have then been used to develop a conceptual location method. A similar approach has also been applied in the development of the conceptual service architecture for providing adaptive mobile location services on the next generation wireless network.

1.5   Thesis structure

The remainder of the thesis is structured as follows:

Chapter 2   presents different kinds of mobile network standards and their evolution path followed by a description of the development of mobile terminals. At the end of the chapter, the relationship between technology life cycle, user behavior and the influence of user experience is discussed.

Chapter 3   presents the theories, concepts and ideas in the areas of user-centered design. The principles behind the mobile user experience, user expectation, user mental model and user experience formation are presented and discussed followed by the context of use and the importance of context of use to the user experience formation.

Chapter 4   presents accuracy and response time requirements for different kinds of mobile location services. Different types of standardized mobile location methods are then introduced together with the accuracies and response times provided by these methods. An analysis of the strengths and weaknesses of each method is then made. The network operators' adoption of mobile location technologies in Asia and Western Europe is finally presented together with a discussion of the factors influencing their decision.

Chapter 5   presents different categories of mobile location services, followed by an examination and analysis of mobile location services commercially available in Asia (i.e. Japan and South Korea) and Western Europe. A discussion of strong points and shortcomings of the services offered in both of the regions is given at the end of the chapter

Chapter 6   proposes a new conceptual mechanism for determining the location of all mobile users on the next generation wireless network applying the movement detection mechanisms of the mobility management protocols in the inter- and intra-domain level. The concept of detecting the location of a mobile user applying the characteristics of wireless short-range technologies is proposed followed by examples of future services utilizing the proposed method.

Chapter 7   discusses the importance of managing the mobile user experience followed by strategies for managing the user experience towards mobile location services. The adaptation possibilities of mobile location service will then be presented, and the descriptions of individual components which will later be combined to form a new conceptual service architecture for adaptive mobile location services will be provided. Illustrative case studies of new-concept services assumed to be deployed on the architecture will then be made as a means of exploring the developed architecture and demonstrating its applicability. Through the case studies, the interactions between the user and different components are demonstrated and the usefulness of the new conceptual service architecture is examined by comparing the possibilities, capabilities and shortcomings of the new-concept services with similar services offered on the current network. Finally, factors that may limit or sustain the practical implementation of the conceptual service architecture and of the new-concept mobile location services presented in the scenarios will be discussed.

Chapter 8   concludes the main findings of the thesis, and points to future research directions.

Figure 1-5 illustrates how the chapters are linked to each other.
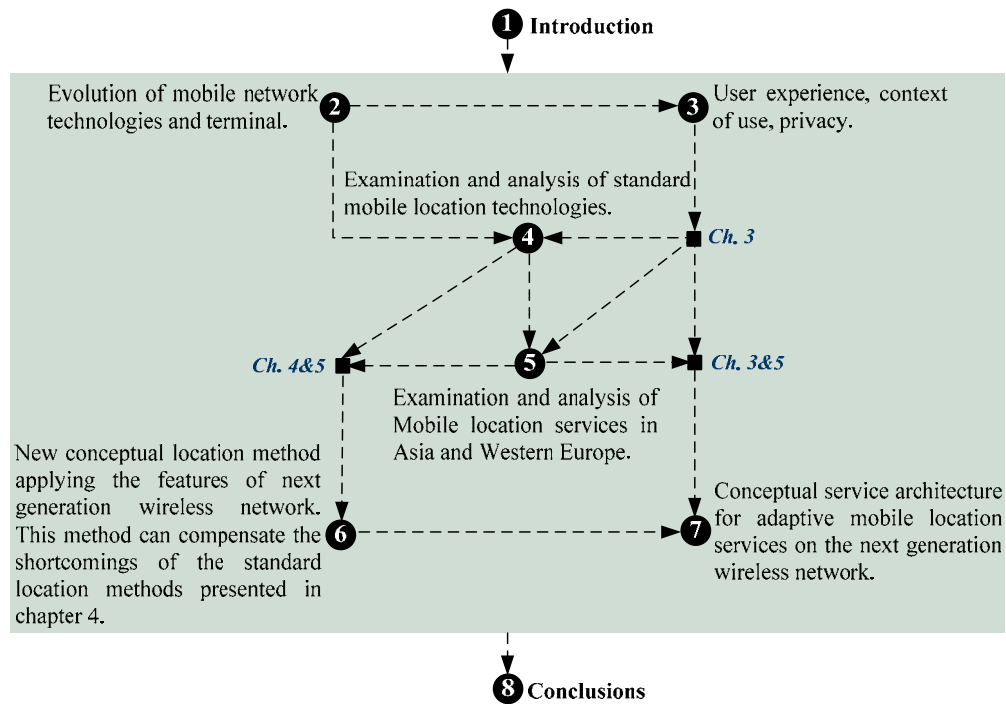
Figure 1-5: Thesis structure illustrating the relationship between the individual chapters.

The examination of the evolution of mobile network technologies and terminals in chapter 2 indicates that user experience (chapter 3) is the key determining the success of the services on 3G and beyond. The background information regarding mobile network technologies, user experience, context of use and privacy are used in chapter 4 to support discussions, arguments and conclusions regarding the examination and analysis of the standard mobile location technologies. The knowledge gained in chapter 3 and 4 is used to support the discussions, arguments and conclusions when examining and analyzing the mobile location services in Asia and Western Europe in chapter 5. Chapter 6 proposes a new conceptual location method that compensates the shortcomings of existing mobile location technologies (described in chapter 4) and facilitates the development and deployment of mobile location services in the future (chapter 7). The conceptual service architecture for adaptive mobile location services on the next generation wireless network is developed based on the conceptual location method developed in chapter 6 and the concepts of user experience, context of use presented in chapter 3. The knowledge gained in chapter 5 regarding the existing mobile location services is used as guidance when designing the new service architecture in chapter 7. Chapter 8 summarizes the main findings presented in the previous chapters and points to directions for further research.

2 Evolution of mobile technologies

Mobile location services are delivered to the users via mobile networks and the availability of the services depends on whether or not the network operator will be willing to add infrastructure for mobile location services on their network. Adding infrastructure on different network standards requires different levels of complication and investment, and the network operators will only do this if they are convinced that they can benefit from doing so. In order to understand the complications and technical and economical requirements for adding infrastructure for mobile location services in different network standards[34], the characteristics, limitations and capabilities of these network standards need to be examined. One important characteristic is the data rate achieved by the different network standards, since the data rate affects the quality of the user experience towards a mobile location service. For a service such as graphic-based real-time navigation, high data rate is required, and this kind of service will only be realized if the mobile networks can provide high data rate.

The mobile network operators are in the transition phase of mobile technology, where the network technologies are changing from 2G to 3G. Upgrading from 2G networks to 3G networks on GSM family[35] and CDMA family[36] networks require different levels of complications and resources. As the operators have to spend many resources on upgrading their networks, resource development of, e.g., mobile location services may be limited in terms of both human capital and infrastructure spending. In order to understand the factors affecting and possibly limiting the deployment of mobile location services in specific regions, the upgrade requirements from one network generation to the next need to be studied.

This chapter looks at the evolution paths of mobile network technologies in the GSM and CDMA family from 2G to 3G. The GSM family is the most dominant network family used in Western Europe and the CDMA network family is widely used in Asia (Japan and South Korea). The examination of the evolution of mobile technologies provides a historical understanding of the development of mobile technologies and the requirements for upgrading from one network generation to

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[34] See chapter 4 for different location methods and their requirements in relation to the characteristics of mobile networks.

[35] GSM family includes GSM, GPRS, EDGE and UMTS *(GSMA 2007a).*

[36] CDMA family include IS-95A and IS-95B revisions, CDMA2000 1X and CDMA2000 1xEV-DO technologies *(DCG 2007a; CDG 2007b).*

the next. The important characteristics of different network standards that influence the complication in deploying mobile location technologies (e.g. whether the network is synchronous or asynchronous) are emphasized and the results of this examination will later on be used to support the discussion, arguments and conclusions regarding the factors influencing the adoption of mobile location technologies of different mobile network operators in different parts of the world[37]. The development of the mobile terminal, which is the device the user uses to access the mobile location services, will also be looked at. At the end of the chapter, the relationship between the life cycle of mobile technologies, user behaviors and the dominance of user experience will be discussed. The background information regarding the evolution of mobile network technologies and the development of mobile terminals has been important in supporting this discussion.

As this thesis deals with utilizing the features of the mobile and wireless technologies for providing mobile location services rather than with the technical aspects of the mobile networks itself, only general perspectives of mobile and wireless technologies and capabilities of the mobile networks that may influence the development and deployment of mobile location services will be looked at.

2.1   Mobile technologies and their evolutions

The mobile technology has evolved from the first generation (1G) mobile technologies in 1980 *(ITU 2005)* to the advanced third generation mobile technologies of today. The first generation mobile technologies, Nordic Mobile Telephone (NMT) systems, Advanced Mobile Phone Services (AMPS) and Total Access Communication System (TACS) *(Schiller 2003, ITU 2005)*, were developed with the purpose of providing only voice call service on the move. Providing a mobile data service is not possible on the first generation technologies.

This section presents the evolution of mobile technologies from the second generation (2G) to the third generation (3G) mobile network[38]. The migration path from 2G to 3G depends heavily on the 2G network infrastructures originally deployed, and the presentation of the technology evolution is therefore divided into different technology families according to the network standards adopted in Western Europe and by the majority of the operators in Asia (Japan and South Korea), i.e. the GSM and CDMA families. The upgrade requirements of the mobile network from one generation to the next will be studied and this will enable the

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[37] The discussion of factors influencing the adoption of mobile location technologies of different mobile network operators in Asia and Western Europe can be found in section 4.3.
[38] Please note that the ITU does not officially recognize terms such as "2.5G," "3.5G" and "4G," as they are not well-defined terms within the body. Instead, various organizations use these terms as marketing tools when trying to segregate various advancements for a given technology. Examples include GPRS ("2.5G"), HSDPA ("3.5G") and WiMAX ("4G") *(Thelander 2005).*

discovery of the factors influencing the adoption of mobile location services of different network operators in Asia and Western Europe[39].

2.1.1 Evolution of mobile technologies in the GSM family

The GSM standard family is the dominant standard used in Western Europe. In the GSM family, the operators often improve the data rate by using General Package Radio Services (GPRS[40]). When the GPRS has been implemented, the typical 3G migration path is to add Wide Band Code Division Multiple Access (WCDMA) radio access network for providing 3G services. The latest technology on the GSM migration path after WCDMA is High Speed Downlink Package Access (HSDPA).

The following sub-sections present different mobile standards in the GSM family, which include GSM, GPRS, EDGE, UMTS and HSDPA *(GSMA 2007a)*. Also, the upgrade requirements from 2G to 3G GSM is presented.

2.1.1.1. GSM

GSM is the first commercially operated digital mobile technology and it is the most dominant standard used in the 2G era *(ITU 2005)*. The GSM has become the world's leading and fastest growing mobile standard, spanning over 200 countries *(GSMA 2007a)*. Today, GSM technology is in use by more than 20% of the world's population - by August 2007 there were over 2.5 billion GSM subscribers, representing approximately 80% of the world's cellular market *(GSA 2007; WCIS 2007)*. The GSM was developed by European commission telecommunication operators and equipment manufacturers, and it has become the unified standard in Western Europe *(ITU 2005)*. It is possible to use the same GSM phone throughout Western Europe *(Schiller 2003)* with roaming[41] agreements between the network operators, and this is the major benefit of GSM. GSM satellite roaming has also extended service access to areas where terrestrial coverage is not available *(GSMA 2007b)*.

The GSM network is asynchronous by design (*Duffett-Smith & Pratt 2006; Tian et al. 2005)*, and the transmitted signals have no pre-determined relationship with each other or with GPS time *(Duffett-Smith & Pratt 2006)*. The GSM operates in the 900 MHz and 1.8GHz bands in Europe and the 1.9 GHz and 850 MHz bands in the US *(GSMA 2007b)*. GSM uses digital technology and time division multiple access (TDMA) to share the radio channels *(ITU 2005)*, and it supports data transfer speeds of up to 9.6 kbps *(ITU 2005; GSMA 2007b)*. With the data rate achieved by

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[39] Asia and Western Europe are the focus areas of this thesis as mentioned in section 1.3.
[40] GPRS is commercially called 2.5G.
[41] Roaming refers to the ability of the users to automatically make and receive voice calls, send and receive data, or access other services via a base station or access point of other network operators rather than their subscribed network *(ITU-T 2005, GSMA 2007e; CDG 2007c)*.

GSM, the transmission of basic data services such as SMS (Short Message Service), IM (Instant Messaging) and mobile email is possible *(GSMA 2007c)*. SMS is the most successful data service offered on the GSM network, with an estimated one trillion messages sent globally in 2005[42].

2.1.1.2. GPRS

GPRS (General Packet Radio Service) is the enhancement of GSM, available now with almost every GSM network *(GSMA 2007f)*. The main advantage of GPRS is the "always on" characteristic meaning that no connection has to be set up prior to data transfer. Upgrading from GSM to GPRS requires additional network elements such as base transceiver station, base station controller and operation and maintenance centre and software *(Schiller 2003)*. GPRS represents a big step forwards towards UMTS as the main internal infrastructure needed for UMTS is exactly GPRS uses[43]. The data rate provided by GPRS varies depending on the current load of the cell and capabilities of the terminal, as not all terminals are able to send and receive at the same time. GPRS provides a theoretical data rate of 171.2 kbps, and this would require a single user taking over all eight timeslots without any error protection *(GSMA 2007j; Schiller 2003)*. In reality, the achieved data is approximately 40-50 kbps *(GSMA 2007j)*, which can support different kinds of data services e.g. email, color Internet browsing, multimedia messaging and location based services *(GSMA 2007f)*.

Similar to GSM, the GPRS has no concept of "network time"; it also works in asynchronous mode (*Duffett-Smith & Pratt 2006)*.

2.1.1.3. EDGE

Further enhancements to GSM networks are provided by the Enhanced Data rates for GSM Evolution (EDGE) technology. EDGE provides up to three times the data capacity of GPRS, and this can support advanced mobile services such as the downloading of video and music clips, full multimedia messaging, high-speed color Internet access and e-mail on the move *(GSMA 2007g)*. EDGE uses the same TDMA (Time Division Multiple Access) frame structure, logic channel and 200 kHz carrier bandwidth as today's GSM networks, which allows it to be overlaid directly onto an existing GSM network. For many existing GSM/GPRS networks, EDGE is a simple software upgrade[44].

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[42] Ibid.
[43] Ibid.
[44] Ibid.

2.1.1.4. UMTS

UMTS[45] is based on GSM network enhanced with a Wideband CDMA (WCDMA) air interface *(GSMA 2007h)*. As UMTS uses a WCDMA air interface, this lead some to refer to the technology as simply WCDMA. The WCDMA standard is the 3G standard chosen by most GSM/GPRS wireless network operators wanting to evolve their systems to 3G network technology *(3gtoday 2007a)*, and WCDMA is the most common standard used in Western Europe. UMTS offers enhanced voice and data capacity and peak data rates faster than most dial-up services and average data rates consistently greater than GSM/GPRS and EDGE[46]. UMTS enables the global provision of mobile multimedia services such as music, TV and video, rich entertainment content and Internet access. As of April 2007, there are over 196 commercial UMTS operators worldwide, almost 120 million subscriptions and over 235 WCDMA (UMTS) devices on the market *(3gtoday 2007)*.

UMTS can operate in both synchronous and asynchronous modes *(Korhonen 2001)*. In synchronous mode, the GPS timing is not used in the UMTS network *(Tektronix 2005; Holma & Toskala 2002)*. Instead, a sync signal is transmitted along with the downlink signal *(Holma & Toskala 2002)*.

Deploying UMTS requires a new frequency spectrum, which the operators need to pay for. European operators spent in aggregate more than $130 billion during the "3G Bubble" in order to acquire spectrum to deploy 3G services *(Thelander 2005; Hillebrand 2002)*. Due to the 3G license requirement, a number of UMTS operators invested billion of dollars before a single base station was ever deployed and this resulted in the delay of 3G deployment of many 3G operators worldwide *(Betti 2005)*.

In Japan, the PDC[47] operators have also chosen UMTS as their 3G technology. The Japanese operator, NTT DoCoMo, was the first operator tolaunch 3G services under the brand name "FOMA" or Freedom of Mobile Multimedia Access. Unlike the operators in Western Europe, the Japanese operators did not have to go through a financially debilitating auction process to secure 3G licenses, the 3G licenses were issued at no cost to three operators in Japan: NTT DoCoMo, Vodafone and KDDI *(Mitsuyama 2005; Srivastana 2001)*.

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[45] UMTS is also known as W-CDMA and 3GSM *(GSMA 2007h)*.
[46] Ibid.
[47] PDC (Personal Digital Cellular system) is a 2G mobile technology developed by NTT DoCoMo based on TDMA (Time Division Multiple Access) technology. PDC has been adopted only by the following Japanese operators: NTT DoCoMo and Softbank Mobile Corp. The PDC operates in the 800 MHz frequency band and 1.5 GHz with a data transfer capacity of 9.6 kbps *(Srivastana 2001)*.

2.1.1.5. HSDPA

HSDPA (High Speed Downlink Packet Access) is a 3G technology upgrade for the UMTS network. HSDPA improves the downlink package data speed achieved with the WCDMA air interface. HSDPA can theoretically provide data rates of up to 14.4Mb/s, which will enabling high-speed Internet access and rapid download of emails with attachments, as well as access to mobile audio and full-motion video services *(3gtoday 2007a; GSMA 2007i)*. As of November 2007, 141 operators have lunched HSDPA worldwide *(3gtoday 2007)*.

2.1.1.6. Upgrading from GSM/GPRS to UMTS and HSDPA

To maintain backward compatibility with GSM and GPRS, UMTS retains the network infrastructure for GSM and GPRS. However, UMTS has been implemented using Wideband CDMA technique and it requires a minimum spectrum allocation of 5 MHz per radio channel. This channel spacing is much wider than that in GSM and CDMA2000[48]. For 3G upgrade, the WCDMA standard requires the deployment of new base stations *(Srivastava 2004)*. However, because GSM phones use TDMA technique *(ITU 2005)* they cannot communicate with WCDMA base stations *(GSMA 2007d)*. Therefore, to serve the GSM users, 2G operators must keep their existing GSM networks while deploying new UMTS networks for serving 3G users *(CDG 2004)*.

To upgrade from GSM/GPRS to UMTS/WCDMA, the operators need to deploy additional radio access networks to support the new UMTS air interface. This includes new radio network controllers, new base stations (node Bs[49]), new terminals to use the UMTS access network or multi-mode terminals to use both GSM and UMTS *(Thelander 2005; CDG 2004)*. Finally the core network needs to be upgraded with software for the GSM mobile switch centers and GPRS support nodes *(CDG 2004)*.

To upgrade from UMTS to HSDPA, no new network elements are required, but it does require some hardware and software changes in the radio access networks *(CDG 2004)*. First the operators need to change the radio network controller software to support the signaling messages used to configure support and manage HSDPA channels[50]. Then they need to change the node Bs software and hardware to support the new HSDPA radio channel. Finally HSDPA channel card needs to be added to the node B[51].

Beginning in 2005 and continuing into 2006, "in-band" WCDMA infrastructure and devices became available. In "in-band" WCDMA, the 3G operators are allowed to

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[48] See section 2.1.2.2 for CDMA2000.
[49] Node B is a term used for a base station in UMTS networks.
[50] Ibid.
[51] Ibid.

deploy 3G in "2G spectrum *(Thelander 2005)*. The 3G WCDMA operators will eventually be able to recognize similar advantages that CDMA operators have been experiencing since the inception of 3G[52]. These WCDMA operators, however, will still require an entirely new Radio Access Network (RAN) infrastructure since legacy GSM base stations cannot be retrofitted for WCDMA[53].

2.1.2 Evolution of mobile technologies in the CDMA family

The CDMA air interface is used in both 2G and 3G networks and it is widely used in North America as well as in Asia *(Thelander 2005)*. 2G CDMA standard is branded cdmaOne and describes a complete wireless system based on the TIA/EIA IS-95 CDMA standard, including IS-95A and IS-95B revisions *(DCG 2007a)*. 3G CDMA standard is referred to as CDMA2000. The CDMA2000 represents a family of 3G standards based on CDMA, which includes CDMA2000 1X and CDMA2000 1xEV-DO technologies *(CDG 2007b)*.

Unlike mobile technologies in the GSM family, the CDMA standard requires that the forward link transmission timing of all CDMA base stations worldwide is synchronized within a few microseconds *(Wheatley 1999; CDG 2007d; Duffett-Smith & Pratt 2006)*. To meet this requirement, Global Positioning System (GPS) timing receivers are located at each CDMA base station *(Wheatley 1999)*. One of the advantages of having networks synchronized using GPS timing is that the common network time reference allows implementation of very efficient location techniques[54] *(CDG 2007d)*.

Different CDMA technologies and upgrade requirements from 2G CDMA to 3G CDMA are presented in the following sub-sections.

2.1.2.1. cdmaOne

cdmaOne is the family of IS-95 CDMA Technologies, and South Korea is the largest CDMA IS-95 market in the world *(ITU 2005)*. CDMA allows many users to share the bandwidth at the same time without interference by transmitting random spread frequencies all at once and a unique code is used to distinguish each different call *(CDG 2004)*. Because CDMA puts all the users on the same frequency spectrum at the same time, separating the users with code, this can result in increased capacity because of frequency reuse[55]. The cdmaOne standard includes IS-95A which is categorized as the standard for 2G CDMA, and IS-95B which is an enhancement of IS-95A *(CDG 2007a)*. In addition to voice services, IS-95A provides circuit-switched data connections at 14.4 kbps and IS-95B provides the

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[52] See section 2.1.2.
[53] Ibid.
[54] See chapter 4 for different mobile location techniques.
[55] Ibid.

data rate of 64 kbps packet-switched data[56]. IS-95A was first deployed in 1996 by the largest mobile operator in South Korea, SK telecom[57] *(Reynolds & Jin-Kyu 2004)* followed by the second largest mobile operator in Japan, KDDI in 1998 *(Srivastava 2001)*. cdmaOne IS-95B was first deployed in September 1999 also in South Korea and has since been adopted by operators in Japan and Peru *(Thelander 2005)*.

2.1.2.2. CDMA2000

CDMA2000 represents a family of 3G CDMA standards and includes:
- CDMA2000 1X
- CDMA2000 1xEV-DO Technologies
  - CDMA2000 1xEV-DO Rel 0
  - CDMA2000 1xEV-DO Rev A
  - CDMA2000 1xEV-DO Rev B

CDMA2000 is flexible in its spectrum requirement; it can work on all existing allocated frequency bands for wireless communication *(CDG 2007)*. The CDMA2000 networks have already been deployed in the 450, 800, 1700, 1900 and 2100 MHz bands *(CDG 2007d; CDG 2006)*, making it a viable option for operators with current operations in any of these bands to reuse their existing spectrum, which was likely being used to deliver 2G services, without having to invest in a new spectrum like the UMTS case. Instead the operators can focus their resources on upgrading their network more rapidly to provide advanced services to the users (*Thelander 2005)*.

Three different sub-standards under CDMA2000 standard are described in the following.

CDMA2000 1X

CDMA2000 1X (IS-2000) was recognized by the International Telecommunications Union (ITU) as an IMT-2000 standard in November 1999 *(CDG 2007e)*. It was the first IMT-2000 technology deployed worldwide, in October 2000 by operators in South Korea *(CDG 2007e; Reynolds & Jin-Kyu 2004)*.

CDMA2000 1X supports circuit-switched voice communications and packet data speeds of up to 307 kbps in a single 1.25 MHz channel *(CDG 2007e)*. CDMA2000 1X is fully backward and forward compatible with cdmaOne, meaning that 2G handsets are fully functional in a CDMA2000 1X network, and CDMA2000 1X handsets are fully functional in an IS-95 network, albeit without the 3G-enabled

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[56] Ibid.
[57] SK telecom was previously called "Sinsegi Telecom" *(Reynolds & Jin-Kyu 2004)*

features *(CDG 2007d; Thelander 2005)*. This is very advantageous for the CDMA operators as well as the users when the CDMA networks are migrated from a 2G to a 3G technology, as backward compatibility assures service transparency for the end user and smooth integration of 2G and 3G networks for the operator.

CDMA2000 1xEV-DO Technologies

CDMA2000 1xEV-DO (Evolution-Data Optimized) introduces new high-speed packet-switched transmission techniques that can deliver peak data rates beyond 2 Mbps in a mobile environment *(CDG 2007f)*. CDMA2000 1xEv-DO includes three revisions, Rev. 0, Rev. A and Rev. B. CDMA2000 1xEV-DO is backward compatible with both CDMA2000 1X and cdmaOne through multi-mode devices and CDMA2000 1X EV-D0 Rev. 0, Rev. A and Rev. B are fully compatible with each other *(CDG 2007d; Thelander 2005)*.

The first CDMA2000 1x EV-DO Rev. 0 was commercially launched in January 2002 by SK Telecom, South Korea (*Reynolds & Jin-Kyu 2004; CDG 2007f*). In commercial networks, Rev. 0 delivers average throughput of 300-700 kbps in the forward link and 70-90 kbps in the reverse link *(CDG 2007f)*.

CDMA2000 1x EV-DO Rev. A is an evolution of CDMA2000 1xEV-DO Rev. 0. The Rev. A provides a peak data rate of 3.1 Mbps in the forward link and 1.8 Mbps in the reverse link in a 1.25 MHz FDD carrier, and it achieves average throughput of 450-800 kbps in the forward link and 300-400 kbps in the reverse link in commercial networks *(CDG 2007f)*. The data rate achieved by Rev. A allows users to send large files, email with attachments, high resolution photographs and personal videos from their mobile devices. CDMA2000 1x EV-DO Rev. A was launched in October 2006, and it is the only all-IP network using advanced broadband technology commercially deployed today *(CDG 2007f)*.

CDMA2000 1x EV-DO Rev. B logically follows Rev. A, with indications that this revision will be commercially available in 2008[58].

2.1.2.3. Upgrading from cdmaOne to CDMA2000 1X, CDMA2000 1x EV-DO

CDMA2000 is the natural 3G evolution for cdmaOne operators. Upgrading from 2G to 3G of mobile technology in the CDMA family requires only minor upgrades to the network and small capital investment, which is much simpler and more cost effective than what is required for upgrading in the GSM family. For each step on the migration path from cdmaOne (2G) to CDMA2000 (3G), there is a large amount of hardware reuse in the Radio Access Network (RAN), with only modest hardware additions (largely channel cards) and/or new software. As CDMA2000 operates in

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[58] Ibid.

the same frequency as IS-95 the existing IS-95 base stations can be used to deploy CDMA2000 *(CDG 2007; Holma & Toskala 2002).*

CDMA2000 1X was the first 3G standard in the CDMA family. The transition from cdmaOne to CDMA2000 1X requires only channel card and software upgrades to the existing cdmaOne base stations, to the base stations controller and to mobile switch centers *(CDG 2007g*; *Thelander 2005; CDG 2004).* With the CDMA2000 architectures, an IS-95 mobile phone can still access package data networks using the existing functionality of the mobile switch center *(CDG 2007d; Thelander 2005).*

Upgrading from CDMA2000 1X to CDMA2000 1xEV-DO Rev. 0, requires only the addition of a new EV-DO channel card, responsible for processing the EV-DO signal, to the existing CDMA2000 1X base station *(Thelander 2005).* It is conceivable that cdmaOne, CDMA2000 1X and CDMA2000 1xEV-DO channel cards could sit adjacent to one another within the same base station and simultaneously share many elements within the base station *(Thelander 2005; CDG 2004).*

2.2   Development of mobile terminals

A mobile terminal is a terminal, e.g. a mobile phone or a PDA, which can connect to a mobile network, and for mobile location services the user applies it for accessing information services based on the location information provided by a location technology or defined by the user, as mentioned in section 1.1.2. The development of the mobile terminal is moving towards the smart terminal that can handle advanced mobile services such as moving or interactive maps, multimedia presentation (3D voice and graphic), and other PC-like operations, which allow the user to manage the use of data services more efficiently. Already today, the latest generation of web-enabled mobile terminals has most of the functions needed by business people and other demanding users, such as Bluetooth, infrared port, big screen with high resolution, built-in camera, support for 3D pictures and realistic sound, internet access, calendars, alarms, games, calculator, phone directories and even electronic wallet *(3gtoday 2007).* The semiconductor industry is already building entire systems on a single chip. These multimedia-enabled systems will be made small enough to be used in mobile terminals. They will offer full flexibility to be used in any way required *(Detken 2006).* This means that for mobile applications and services, a large variety of mobile terminals targeted at various market segments and user groups will emerge, with voice being only one of many features.

In Asia, especially Japan and South Korea, many smart mobile terminals are equipped for the provision of mobile location services. The mobile terminals now come with a Global Positioning System (GPS) as well as memory card slot, an embedded-camera with more than two mega pixel, (two-dimensional) bar code

reader, contact less IC chip, DMB, FM radio tuner, and music player function *(Mitsuyama 2005; Srivastava & Kodate 2004)*. There are also many smart terminals which can be used with GPS boxes. Some of the mobile navigation solutions are based on a combination of a smart terminal and a separate GPS device connected by Bluetooth *(3gtoday 2007)*. Many new services can be brought to the market with these smart terminals. It is likely that more advanced mobile terminals make users experiment with mobile data services more frequently.

2.3 The technology life cycle and the dominance of technology and user experience

This section describes the technology life cycle with relation to the needs and behaviors of different groups of users. Based on the technology life cycle, it can be explained why the development of the next generation mobile location services should no longer have the main focus on the technological aspect but rather on the user aspect.

A new technology tends to follow a predetermined life cycle: It starts with being very immature providing very limited technological features, with time it becomes more and more mature and reaches the phase where the technological features meet the basic requirements of average users. It provides more and more features and it finally reaches the peak of its life cycle and then slowly fades out. Different groups of users adopt technology at different phases of the technology life cycle and they have different requirements and behaviors. Figure 2-2 shows the life cycle of technology in relation to the user's requirements and behaviors *(Norman 1999; Christensen 1997)*.

The mobile technologies are also likely to follow the life cycle illustrated in figure 2-2. In the early days, mobile technologies were immature and could not meet all the needs and expectations of the users. The early adopters need the technology and they are willing to suffer from any inconveniences of the technology as well as its high cost. Meanwhile, the users keep demanding better technology with higher performance (see figure 2-2). At this stage, the limitations and capabilities of the technology are what differentiate different products and services. Products and services are advertised and sold on the basis of their feature lists and technological claims. User experience[59] is, at this stage, not the most critical factor when it comes to gaining an initial user base for a product or service based on a novel and incomplete technology *(Hiltunen et al. 2002)*. With time and continuous development, the technology becomes more mature, and it offers better performance, lower price and higher reliability. When the technology reaches the basic needs of the majority of the users, it comes to the transition point. From this

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[59] See chapter 3 for the detailed description of mobile user experience.

point, there is a major change in user's requirements and behaviors *(Norman 1999, Hiltunen et al. 2002)*.
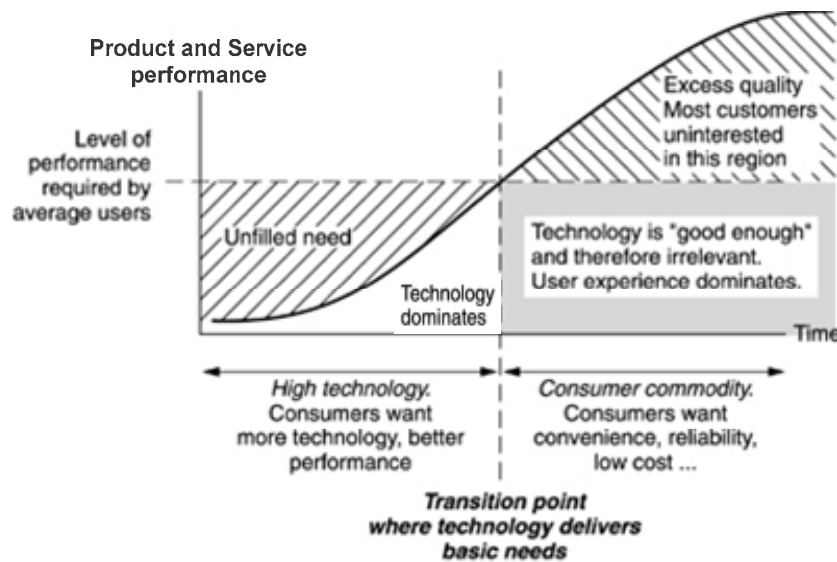
Figure 2-2: The life cycle of a technology – change from technology dominance to user experience dominance *(Norman 1999)*. New technologies start out at the bottom left of the curve, delivering less than the users require. As a result, users demand better technology and more features. The technology reaches a transition point when it can fulfill the basic requirements of average users. From this point, the majority of users start to demand a better user experience instead of more technological features.

When the technology exceeds the point where the technology can fulfill the basic requirements of the general users (the transition point), the improvements in technology are no longer the most important factor driving the market. At this stage, users seek a better user experience rather than new technological features *(Norman 1999; Pfeiffer 2006)*. Different groups of users enter the market at different phases of the technology life cycle and they have different requirements and behaviors, which are described in the following sub-section.

2.3.1 Different groups of users and their behaviors

A new product or service has a different user base in the different phases of its life cycle. Moore *(Moore 1995)* identifies five different user groups for a certain product and service: Innovators, early adopters, early majority, late majority, and laggards. The names of the groups describe the attitudes of each user group towards a new product and service. Figure 2-3 shows the different phases where these groups of users enter the market.

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The different groups of users illustrated in figure 2-3 play different roles in the development of technology and service. The innovators and early adopters drive the technology market and the pragmatic and conservative users wait until it is safe to jump in. The early adopters are people who are in love with technology. They want technological superiority, and they are willing to pay a high price for a limited set of features. Early adopters are important, as they help establishing the market. However, they are only a small percentage of the market (see figure 2-3).
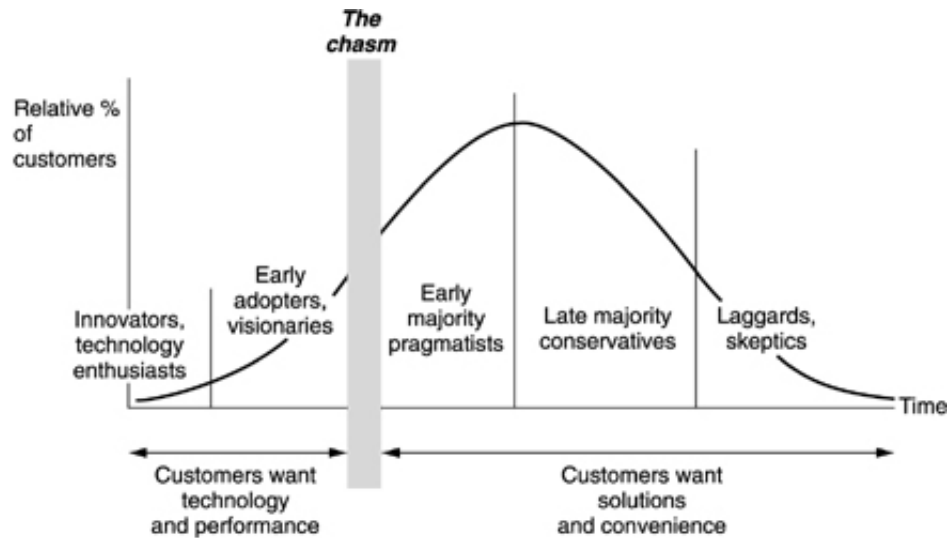
Figure **2-3:** The change in users as a technology matures *(Norman 1999)*. The chasm is the transition point of the life cycle of the technology. In the early days, the innovators and early adopters drive the market; they demand technology. In the later days, the pragmatists and conservatives dominate the market; they want solutions and convenience.

Norman states in his book *(Norman 1999)* that it is the late adopters (pragmatics and conservatives) that dominate how the product and service should be developed, as they are the majority in the market. These groups of users will not buy new products or services, they prefer to watch and learn from the experiences of the early adopters. They wait until things have settled down, the prices have dropped, and the technology has stabilized. They wait until the product and service is truly capable of meeting their needs. These groups of users do not demand technology features that complicate their life; rather they need a solution for their everyday problems *(Hiltunen et al. 2002)*. They need a product and service that conforms to their environment, with a low cost and which provides a good user experience[60].

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[60] Ibid.

2.3.2 Discussion: In which phase of the mobile technology life cycle are we now?

Due to the arrival of 3G technologies, it is, in this thesis, believed that we are currently in the phase where the mobile and wireless technologies are sufficiently mature (i.e. having reached the performance level required by average users). 3G networks achieve data rates comparable to the fixed internet services (e.g. ADSL), and currently more than 1000 different models of 3G-terminals worldwide provide features which support the basic requirements of the average users (e.g. graphic user interface, voice interface, high resolution terminal, built-in camera, organizer, etc.) *(3gtoday 2007)*.

Based on the model describing the relationship between the technology life cycle and the user requirements and behavior presented in figure 2-2 and 2-3, at the phase where the technology can fulfill the basic requirements of the general users, the users will look for a better user experience provided by the services, and user experience will play a key role in the service adoption decisions. The user experience is expected to become even more dominant in the future mobile service market, especially when the next generation wireless network has emerged. The next generation mobile location technologies presented by, e.g., Schou & Olesen *(Schou & Olesen 2005)[61]*, Mamei & Zambonelli *(Mamei & Zambonelli 2006)* and in Guo & Imai *(Guo & Imai 2007)* will provide better technological features, and this will increase the attractiveness of the mobile location services even further. More and more people will become more familiar with mobile data services and different groups of people (early majority and late majority) will enter the mobile service market, when they realize that the technology is mature enough to fulfill their requirements. These people are the majority in the market and it is these groups that will dominate the direction of the new mobile services and market. These people do not want a technological solution that complicates their life, instead they need a solution for their everyday problems, they need a service that conforms to their current contexts, with low cost and which provides a good user experience *(Norman 1999, Hiltunen 2002)*. The compelling user experience is therefore the critical determinant of the success of any mobile service in the 3G era and beyond.

2.4 Summary

This chapter presents evolution paths of mobile technologies in GSM and CDMA families and the upgrade requirements of the technology from one generation to the next. In the GSM family, upgrading from 2G to 3G technology requires new frequency spectrum, new base stations, hardware and software. In the CDMA family, the frequency used for 2G can also be used for deploying 3G CDMA and

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[61] See also section 6.2 and 6.3.

the base stations can be reused. Only minimum hardware and software upgrade is required. The upgrade requirements for 2G to 3G in terms of implementation and cost requirements may be one of the factors influencing the willingness and the eagerness of the network operators to add infrastructure to support the deployment of mobile location services.

One important characteristic of CDMA networks that sustains the development of mobile location services is that the networks are synchronized using GPS timing and this allows the implementation of very efficient location techniques. In GSM family networks, synchronization is not available and this makes it more complicated to deploy the high accurate location methods which require precise timing in the system[62].

The development of the mobile terminal is moving towards the smart terminal that can handle advanced services such as mobile location services. Support for, e.g., interactive maps and multimedia presentation (3D voice and graphic) are embedded features of some of the mobile terminals available today.

According to the technology life cycle and the capabilities of the existing mobile technologies, we are in the transition phase where the technology can fulfill the basic requirements of average users. At this stage the success of any mobile service will depend on whether or not the user gets a good experience from using the service.

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[62] See chapter 4 for a detailed description of mobile location technologies.

3 Mobile user experience

Good user experience is one of the key factors in providing successful mobile services *(Norman 1999; Usability Hub 2007)*, as the users' willingness to pay for a service depends on whether or not they get a good experience from using it. The users' expectation is the key behind the user experience, and how good an experience the users get varies depending on how well the service matches their expectations, which the users have built in their mental model before they start using the services *(Hiltunen et al. 2002; Schrammel & Tscheligi 2006)*. The user experience towards the service is often influenced by the context of use in which the service is used. In the case of a mobile location service, different users use a service at different places and times and in different situations. They access the service using different mobile and location technologies, which provide different levels of data rate and different levels of accuracy. They want to accomplish different tasks using different terminals with different user interfaces. They use the service in different roles[63] and with different social aspects. Using the same service in different contexts of use can result in significantly different levels of user experience *(Arhippainen 2003; Forlizzi & Ford 2000)*. For example the service may appear funny or annoying depending on how busy the user is. The context of use therefore becomes a very important parameter when designing mobile location services, and the user experience of using the service will typically be improved if the attributes of the current contexts of use are considered.

This chapter presents the goals of user experience, followed by a description of the relationship of the user's mental model, the user expectation constitution and user experience formation. The elements forming the user experience towards a mobile location service are then presented and discussed together with the factors influencing the quality of a mobile user experience. The context model is presented together with the discussion of the influence of the context of use to the mobile user experience formation.

The theories, concepts, ideas and knowledge presented in this chapter will be used as background information for examining and analyzing the mobile location services offered in Asia and Western Europe, and for analyzing the factors

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[63] Roles can be derived from the user context, time, location, and other factors to help understand if someone is using a service as an employee, mother, or one of many other potential roles *(Jagoe 2003)*.

influencing the service adoption of the users in both of the regions (see chapter 5). This knowledge will also be important for the development of a conceptual service architecture for adaptive mobile location services on the next generation wireless network in chapter 7.

3.1   The goals of user experience

In the book "Mobile user experience" *(Hiltunen et al. 2002)*, the term user experience refers to everything the user experiences while using any product or service. Similar definition is given by the Nielsen Norman Group: User experience encompasses all aspects of the end-user's interaction with the company, its services, and its products *(NN/g 2006)*. As a mobile user typically uses a mobile service in different use contexts, the term user experience can also refer to: The experience that the user gets when using a service in particular contexts of use *(Arhippainen & Tähti 2003)*. A good user experience is a very important factor in providing successful mobile services *(Usability Hub 2007; Hiltunen et al. 2002)*, as the user experience affects the willingness of the user to pay for a service, and since the user experience is the key defining whether or not the user will ultimately integrate the service into their lifestyle *(Adobe 2007)*. The fundamental concept behind the user experience formation is the user expectations, and a good user experience therefore depends on the service matching these expectations. This means that a good user experience towards a service does not come coincidently, but it requires considerable focus and attention to the needs, goals, and thought processes of the users[64].

The term "user experience" is used more and more in discussions and articles instead of the term "usability", as it is believed that context, emotions, expectations, and overall service processes are becoming more important than ever with regards to mobile services *(Arhippainen 2003; Hiltunen et al. 2002)*. Usability, on the other hand, has been interpreted too narrowly, excluding or not paying enough attention to things outside the screen *(Hiltunen et al. 2002)*. User experience means much more than just usability of a product or service, even if the usability is an important aspect as well *(Arhippainen 2003; Schrammel & Tscheligi 2006)*. The goals of usability and user experience are illustrated in figure 3-1.

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[64] See section 3.2.
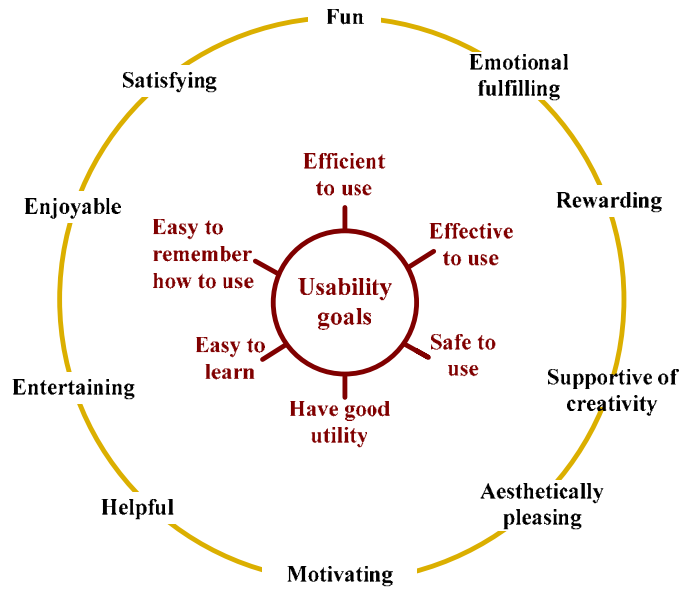
Figure **3-1:** Usability goals (inner circle) and user experience goals (outer circle) based on *(Preece et al. 2002)*.

Usability focuses mostly on how the service works and how to make the service perform efficiently in an easy and effective way, as it can be seen from the usability goals in figure 3-1. The scope of user experience is beyond the scope of usability. The user experience focuses more on emotions and feelings of the users as a result from using a service as it is also seen in the figure. From the mobile user experience point of view, usability is only one of several elements influencing how the user will experience the service *(Hilltunen 2002; Arhippainen 2003; Schrammel & Tscheligi 2006)*. Usable services are not necessary enjoyable to use (e.g. usable but ugly to look at) and attractive services are not necessarily the most efficient *(Norman 2004)*. The lack of usability can create either a negative or positive user experience[65]. A service that is difficult to use will normally result in a negative emotion (e.g. anger, frustration and annoyance) and a bad user experience is formed in this case. Such a service may, however, have some reflective appeal: The user may feel that "only a true expert, such as himself, can accomplish his tasks using the service"[66]. In such a case, the user may feel proud of himself and may get a good user experience from being able to use a service that is almost impossible to use. However, it is most likely that this will not happen very often.

If the service does what the user needs, if it is fun to use, and if the service makes it easy to satisfy the user's goals, it is most likely that a good user experience will be

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[65] Ibid.
[66] Ibid.

generated[67]. Everything depends on how the users will experience the service no matter how excellent features it has *(Usability Hub 2007)*. From the users' perspective, the offered services, their mobile terminals, the screen size of their mobile terminals and its interface, their surrounding environments, their situations, their moods, time and their life in general all interact and feedback on one another *(Hiltunen et al. 2002; Kuniavsky 2007)*. The mobile user experience influences not only what the users can accomplish, but it also affects what attracts them to the service. In addition, what attracts them to the service affects how willing they are to learn and use the service. If the users get a positive experience during their initial use, they will be motivated to use the service more often and thereby improve the chance of generating revenues for the service provider[68] *(Hiltunen et al. 2002)*.

The fundamental concept behind the user experience formation is the user expectations which the user has in the user's mental model *(Norman 2004; Arhippainen 2003; Hiltunen et al. 2002)*. Users have high expectations of the services they trust, they expect the services to perform precisely according to their expectations, which imply that they have built up particular expectations *(Norman 2004)*. These expectations come from multiple sources: Indirect experiences (e.g. advertisements and recommendations), direct experiences (e.g. the reliability with which the service has performed since the users started using the service), and the conceptual model of the service the users may have in their mind *(Lei et al. 2006; Norman 2004; Hiltunen et al. 2002)*. Additionally, people use a lot of indirect clues when trying to gauge what to expect from a service. One major factor is price: If the users pay more, as a rule they expect to get a better service *(Hiltunen et al. 2002)*. If the service fails to live up to the user expectation the trust towards the service is violated and this will typically form a negative user experience *(Norman 2004; Schrammel & Tscheligi 2006)*. In order to provide a mobile location service with a good user experience, the service must be designed in a way that matches the user's mental model and meets the user expectation.

3.2   Understanding the user's mental model, user expectation and the user experience formation

As mentioned previously, the user expectation is the key behind the user experience formation. Before the users use a service, they have some kind of expectation, in their mental model, of how they will be served by the service. This section describes the user's mental model, how the expectation is established and how the user experience is formed.

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[67] Ibid.
[68] Based on figure 1-2, the service will reach the re-purchase phase of its life cycle if it provides a positive user experience during the usage phase of its life cycle.

The user's mental model is a model of the service that the user builds in his or her mind *(Borgman 1986)* or the way that the user perceives how the service works *(Davidson et al. 1999; Norman 2004)*. This model arises from a combination of the user's previous knowledge, real-world experiences, experience with the same or similar services, and experience with other technologies in general *(Lei et al. 2006; Norman 2004; Hiltunen et al. 2002)*. The users use their mental models to predict the service behavior and to guide their actions while using the service. The user's mental model can be illustrated as in figure 3-2.

Needs or desires + **Goals** + **Procedures** = **Expectations**

Things that the user wants to get or fulfill. | *The concrete goals of the user's needs or desires.* | *The chain of tasks that the users think will bring them close to their needs.* | *The results that the users think will follow from their procedures.*
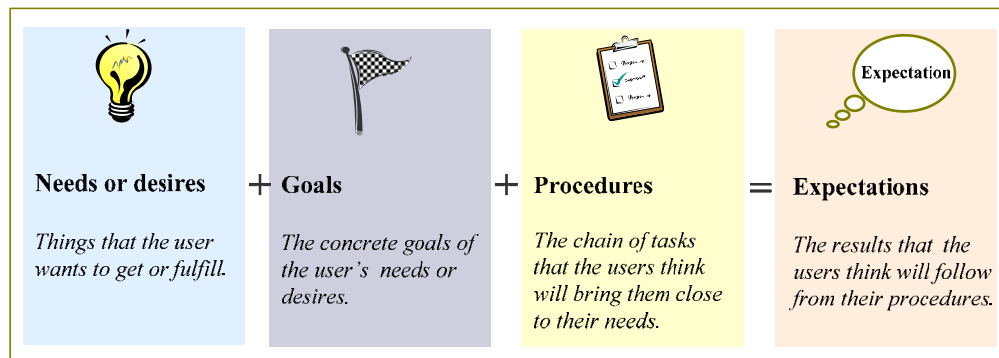
Figure **3-2:** The user's mental model comprises needs or desires, goals, procedures and expectations. The user expectation is constituted by the needs, goals and procedures (the figure is created based on the mental model described in the books of Borgman *(Borgman 1985)* and Hiltunen *(Hiltunen et al. 2002)*).

In figure 3-2, before using any service, the users already have, in their mental model, an idea of something they need or want, the concrete goals based on their needs or desires, the actual tasks they are going to perform in order to reach the goals and what they expect to happen from the concrete set of actions *(Borgman 1986*; *Hiltunen et al. 2002)*. The user's needs, goals and procedures constitute the user expectation.

The user's mental model is an important aspect of user experience design. A service that ignores the user's mental model and does not meet at least some of the user expectations will be difficult or even unpleasant to use *(Apple 2006)* and it is likely that such a service will fail. This is because such a service imposes an unfamiliar conceptual model on the users instead of building on the knowledge and experiences these users already have[69]. The relationship of the user's mental model, user expectation and user experience formation can be illustrated through the following scenario.

> *'Tim would like to donate some money to a child organization in Thailand. He has written to them and promised that he will transfer the money to them*

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[69] Ibid.

today and they will have it in the bank account tomorrow. Today is his busy day, since he needs to deliver the final software product to a customer. He manages to finish his job at 4:30 pm. The bank is already closed and he wants to keep his promise about transferring money to the child organization today. Fortunately, he has subscribed for a mobile banking service last month and he has a good reason to use it today. He takes his mobile terminal from his pocket and accesses the mobile banking service. He manages to access the service and fills out all required information and finally submits the money transferring request. Suddenly, his mobile terminal disconnects and the service request stops. He is not sure whether the money is already transferred. He tries to connect to the mobile banking service again and finds that the service is temporarily unavailable due to a technical problem. Tim is very angry, annoyed and frustrated'.

In every situation people have, in their mental model, some kinds of expectation of what the rules of the situation are. What is likely to happen and what will probably not happen. Sometimes these expectations are more accurate than at other times, but they have a tendency to match reality better and better as more experience with similar situations (or services) is gained. A very interesting aspect of expectations from the user experience point of view is that expectations have powerful influence on how people feel about things. Deviation from what people expect can cause a variety of emotions, for example frustration, anger and fear *(Norman 2004; Hiltunen et al. 2002).*

Based on the mobile banking service scenario presented above, figure 3-3 shows an example of the mental model of the mobile banking service Tim may have in his mind, and it illustrates how his expectation is established and how his experience is formed.

In figure 3-3, the user's need is to help a child organization in Thailand economically. The concrete goal based on his need is to donate money to the organization and the procedure for achieving this goal is to transfer money using a mobile banking service. This procedure may contain several tasks and sub-tasks (e.g. accessing the service, fill out the form, push send button, etc.). The user expects that the service will work fine and that he can accomplish his tasks and can reach his goals. The information about needs, goals, and procedures form the user expectation of the mobile banking service, and this information is stored in the user's mental model. In reality, the user cannot accomplish his tasks and reach his goals as he expected, due to the technical problems of the service provider. The user evaluates his expectations of the service he has in his mental model with his realization of the service and the user experience is formed and an emotion is generated.
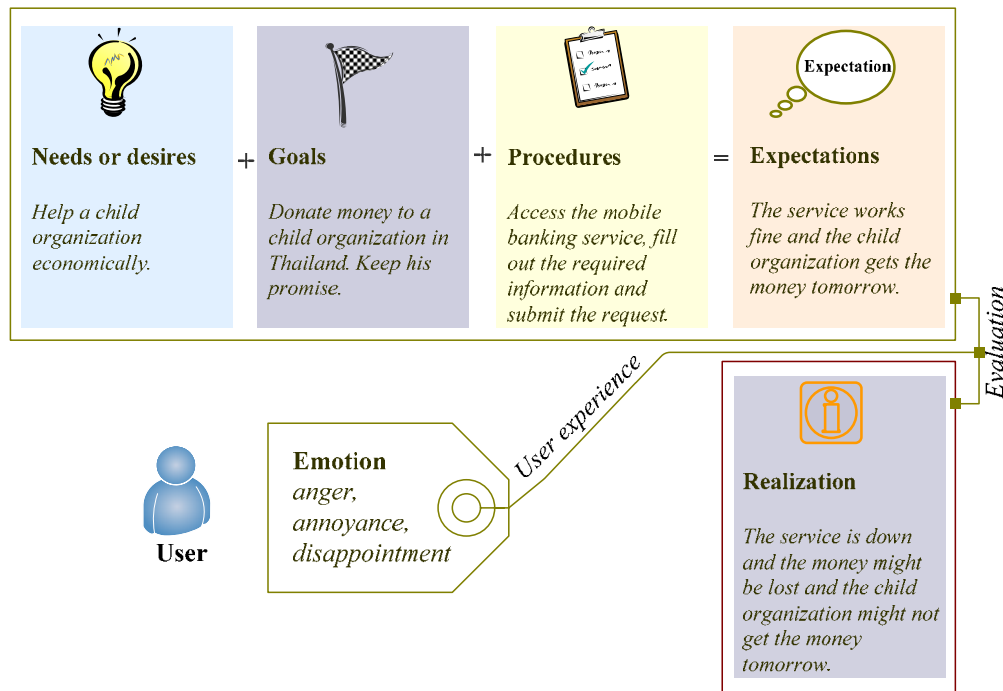
Figure **3-3:** Mental model of the mobile banking service Tim may have in his mind. The user establishes his expectations from his needs, goals and procedure. The user evaluates his expectations of the service he has in his mental model with his realization of the service. The user experience is then formed and an emotion is generated.

If this scenario actually happens with a mobile service the user will probably complain to the service provider and then never use the service again. He may also tell his peers of the bad experience he got from the service. In this way, his peers get indirect experience and will avoid using the service.

3.3   Major elements forming the mobile user experience

The elements forming a user experience of one particular kind of service or product are not necessarily the same as for other services, as the users have different expectations about different kinds of products or services. For example, the elements primarily forming a mobile user experience are not needed to be the same as the elements forming a web user experience. The web users access the web service using a desktop device while the mobile users access the mobile service using a small mobile terminal. The user experience of the web service is more related to the design of the website and internet speed, while the user experience of the mobile service also involves the mobile terminal (input/output channels, screen size), use contexts (location, light, noise) and the network reliability and capability (network connection and data speed). Mobile users and web users have different

behaviors and different requirements. By nature, the mobile users are generally very busy and most likely busier than the web users. The mobile users are normally having other things to do besides using a mobile service such as walking or waiting for the bus. The mobile users have to pay attention not only to the screen but also to other things surrounding them. The mobile users do not tend to surf around to the same extent as the users of desktop devices *(McQueen & Burk 2006)*. The information the mobile users are looking for is normally the information that is useful for them in their current context. A mobile service is more "transaction oriented" than a service for fixed access[70]. For example, mobile users do not want to receive a complete bus timetable. Instead, they want a service to respond to a direct request such as "When the next bus is coming".

This thesis deals with the user experience of one particular kind of service: The mobile location service[71]. There are many elements which can make or ruin a good mobile user experience. The list of all possible factors is endless, but they can roughly be grouped into five main categories based on the elements forming a mobile user experience presented in the book "Professional mobile user experience" (*Hiltunen et al. 2002*): Availability, usability, utility, aesthetics, and offline issues, as shown in figure 3-4.
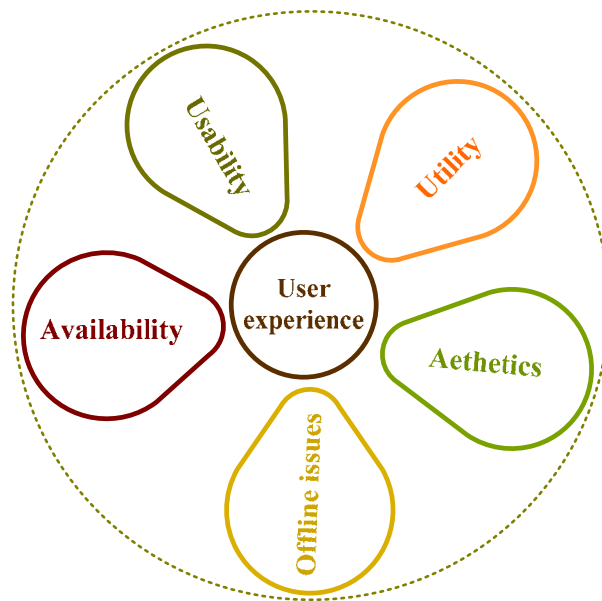
Figure **3-4:** Five main elements forming the mobile user experience. The mobile user will theoretically get a good user experience if these elements are as the user has expected.

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[70] Ibid.

[71] See chapter 5 for categories of mobile location services and different mobile location services commercially offered in Asia and Western Europe.

The five elements in figure 3-4 are the elements forming the mobile user experience and the users have expectations about all these five elements when using a mobile service. These elements can be used to estimate the extent to which a service provides a good mobile user experience in a particular context of use and the elements are described in the following.

3.3.1 Availability

There is nothing more frustrating in the mobile world than a mobile terminal that keeps disconnecting *(Hiltunen 2002)*. Availability is an important element forming the mobile user experience in the mobile environment. Availability of the service means that the service is available, accessible and reliable. Availability of mobile location services depends directly on the mobile network and location technologies[72] being used. Ideally, the service should be available, accessible and reliable regardless of time, place, terminal, network and operator. Roaming and interoperability should be possible across different networks, technologies and operators. In practice, it is almost impossible to make a service available anywhere and any time with the existing mobile and location technologies. There will always be some dead spots in some areas where the mobile networks do not cover or where the location technology is degraded or unavailable (e.g. deep inside buildings or unpopulated areas). Therefore, any service must take into account unsatisfactory network connections and location technology degradation.

However, as mentioned earlier, how the users experience a service depends on what they expect from the service (what they think they can achieve). It is therefore essential to be able to manage expectations about using a service. For example, if the user experiences unavailable mobile location services when traveling in sparsely populated areas, he may not be very disappointed. On the other hand, the user will be very disappointed if he is walking in the city of Tokyo and wants to use 3D navigation service[73] provided by KDDI, but the service is not available as the user expected it to be. Therefore, it is very important that any unavailability, inaccessibility and unreliability of the service which might occur should be clearly communicated to the user and this occurrence should be as predictable as possible.

3.3.2 Usability and utility

The usefulness of a product or service can be analyzed from a combination of utility and usability: *Usefulness = utility × usability (Nielsen 2000)*.

- Utility answers the question: What does the service do for the user; how closely does it match user's needs *(Nielsen 2000)*.

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[72] See chapter 4 for examinations and discussions of different standard mobile location technologies.
[73] See section 5.2.3.2 for detailed description of the 3D navigation service.

- Usability means how easily, efficiently and effectively the users can learn to use the functionality of the service in a specific context of use *(ISO 1998)*. Usability also deals with the potential of a system to accomplish the goals of the user *(Rosson & Carroll 2002)*.

Both usability and utility are necessary for any service: If a system has no utility, it does not matter how easy it is to learn or how efficient it is to use. But even the highest utility is useless if users cannot figure out how to use it *(Nielsen 2000)*.

The usefulness of mobile location services relies mainly on the location technology (e.g. accuracy and response time), mobile network (e.g. data rate), display capability of the mobile terminal, user interface for the mobile terminal (e.g. short key and graphic user interface) and the designed service (e.g. service task flow). For example, the SMS-based tracking service with the accuracy of 15 km is close to useless. Graphic-based location tracking that takes 10 minutes to download the map is not very useful either.

3.3.3 Aesthetics

Different people like or dislike certain things e.g. different colors, different shapes, etc. Aesthetics of the service concerns not only the visualization of the service, but it also concerns how the service behaves and how the user feels about the terminal (e.g. voice quality, display quality, user interface, brand, etc.). The aesthetics and behavior of the service direct the user's attention and have an effect on the way the user experiences the service. How the service looks and behaves can produce different emotional feelings (e.g. like, dislike, enjoyment, annoyance, etc.). This emotional feeling plays a critical role in daily lives, helping to assess situations as good or bad *(Norman 2004)* and emotion is a very important element affecting the user experience formation.

3.3.4 Offline issues

Based on Hiltunen et al. *(Hiltunen et al. 2002)*, the offline issues such as company brand, back-end processes and trustworthiness are also important elements forming the user experience towards the service. Other factors e.g. service charge, privacy handling, billing management, and error handling also influence the user experience formation.

- The company brand is a key part of a company's offline image, it perceives how the company might be seen, e.g. cool, uncool, young, innovative, etc., and this influences the user's attitude towards the service.

- Back-end processes are invisible to the user, but they are still perceivable in the form of their outcomes. For example, if a user hears about billing mistakes made by the ABC Company, his experience to the service provided by this company is likely to be negative.

- Trustworthiness is a user's subjective opinion about the company which is associated with user's emotion towards the service. For example, the user could have a negative emotion towards mobile location services provided by ABC Company if he experiences an inaccessible website when he wants to look for further information of the advertised services.

- The service charge is the obvious factor influencing the user expectation and the user experience toward the service; if the users pay more they generally expect to get more from the service. For some services[74], the users need to have a specific terminal model defined by the service provider in order to be able to access the service. The cost of the terminal required for accessing the service is also one of the factors affecting the user experience formation.

3.4 The influence of context of use to the mobile user experience

The term "context of use" or "use context" refers to: Users, tasks, technologies, and the physical and social environments in which a service is used *(ISO 1998; Hiltunen et al. 2002; ETSI 2005, p.24)*. As mentioned in the beginning of the chapter, the users of mobile location services access the service using different mobile and location technologies, wanting to accomplish different tasks using different terminals with different user interfaces. This can result in very different levels of user experience *(Arhippainen 2003; Forlizzi & Ford 2000)*, and it is therefore crucial to take the characteristics of the use context into account when designing a service. Taking the context of use into account helps the service designer to understand what the individual user is trying to accomplish and which services they might be interested in, and thereby ensuring that the outcome of the designed services come as closely as possible to the "best possible" solution. The quality of the user experience is likely to be improved if the service can be adapted to match the user' requirements and preferences in particular context of use *(Schou 2008a)*.

Figure 3-5 illustrates the relationship of the five perspectives of the context of use (users, tasks, technologies, physical environments and social environments), where the physical environment plays an important role in the context model of mobile location services.

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[74] See section 5.2.2.1, 5.2.2.2, 5.2.2.3, and 5.2.2.4 for the mentioned services.
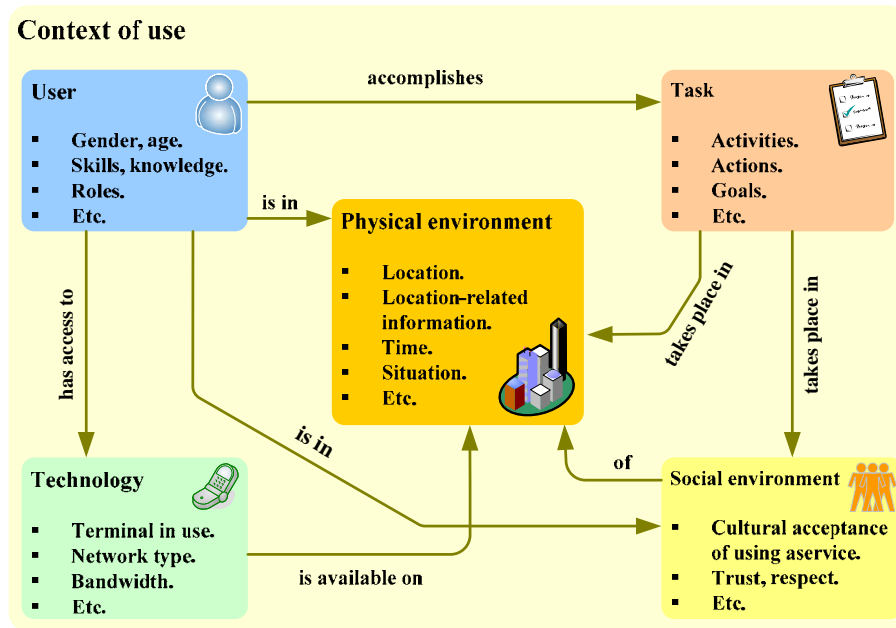
Figure 3-5: Generic context model of mobile location services. The user accomplishes his task by interacting with a service. User-service interactions take place in a particular physical environment (location) with particular social and cultural patterns (social environment), which may influence the user's behaviors and requirements. The interactions between the user and the service are made through the technology context, e.g. mobile terminal and network, available in the user's current location.

The five perspectives of the context of use presented in figure 3-5 are described in the following sections.

3.4.1   Users

User refers to people or groups of people who interact with the product or service *(ISO 1998)*. The relevant characteristics of these target users need to be studied when designing a service. The purpose of designing the service is to fulfill the users' needs and help them finish their tasks and reach their goals. It is therefore very important to know the users' needs, tasks and goals when designing a mobile location service. An example of the need, goal and task of the users is shown below.

Scenario:	**Mobile yellow pages**
Need:	Find a place to eat.
Goal:	Check the list of restaurants nearby.
Task:	Search for the restaurants using a mobile yellow pages service.

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It is also very important to know the users' attributes (e.g. knowledge, skill, experience, education, job type, training, physical attributes, present mood, etc.). It may be necessary to define the characteristics of different types of users, for example users having different levels of experience or users performing different roles.

3.4.2 Tasks

Tasks are the activities undertaken to achieve a goal *(ISO 1998)*. To achieve the goal, the user might need to accomplish several tasks. The tasks are bound together forming chains of tasks or procedures[75]. This gives the service designer the opportunity to predict the next task of a user *(Hiltunen et al. 2002)*. For example, the user needs to push the "i" button before he can access the i-menu and select the i-mode service he wants. A study of the characteristics of tasks provides both opportunities for and places limitations on a service. The ability to see the fundamental goals behind the current task opens many opportunities to design a successful service; coming up with new tempting tasks, reducing the number of annoying tasks, or making the completion of a task easier *(Hiltunen et al. 2002)* can make the service become a success.

Figure 3-6 shows an example of a task flow for the i-area service[76]. The task flow is a chain of tasks the user needs to complete in order to fulfill his tasks and reach his goal.
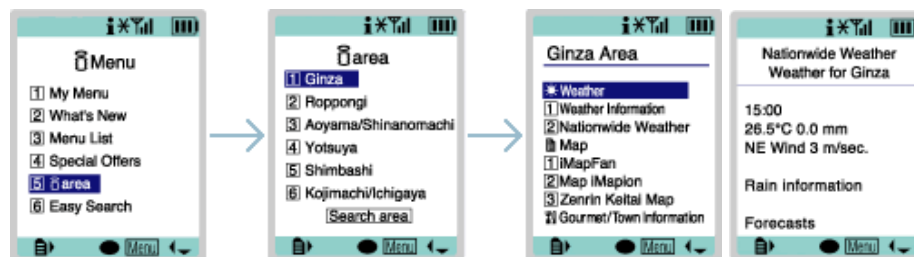
Figure 3-6: Example of task hierarchy of i-area service, where the user wants to check the weather forecast of the Ginza area.

From the figure, the user wants to check the weather forecast in the Ginza area; he needs to finish four tasks in order to reach his goal:

- Push the "i" button (access to i-menu).
- Select i-area from the i-menu (a menu of nearby areas will be displayed).
- Select the user's current area or desired area (Ginza).

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[75] In some articles the terms tasks or chain of tasks is referred to as "use case".
[76] See section 5.2.1.1 for detailed description of the i-area service.

- Accomplish the task by selecting weather forecast (reach the goal: Check weather forecast).

The design of the task flow depends on the availability and capabilities (e.g. data rate) of the technology. The task flow described above will be completely different if the service is provided on a GSM network and based on an SMS service. The task flow of this service on a GSM network could be:

- Push menu button.
- Scroll up or down for finding the SMS function.
- Select SMS function.
- Type "G", "i", "n", "z", "a", "&", "w", "e", "a", "t", "h", "e", "r".
- Select send.
- Select number "9", "9", "9", "9".
- Push send.
- Wait…
- Receive SMS of weather forecast for the Ginza area.
- Select read SMS.

The task flow for the i-area service using an i-mode terminal requires only 4 strokes to accomplish the tasks and reach the goal, while it requires at least 20 strokes to complete the tasks if the i-area service is deployed based on SMS service on a GSM network. Studying the task flow, the service designer can potentially come up with a more effective flow of tasks.

3.4.3 Technology

Technology context means the technologies involved in providing mobile location services. The technological context is one of the most important parts with regards to how the service will be experienced. Knowing the technology context gives an opportunity to a service developer to know how the service should be designed. The technology context of mobile location services can be divided into three components: The mobile terminal, the mobile network and the location technology.

- **Mobile terminal**

A user experiences a mobile location service using a mobile terminal. The characteristics of the terminal (whether the terminal has a big screen, short key menu, GPS functionality, large memory storage, processor, camera, Bluetooth or WLAN built-in, etc.) have direct impact on the mobile user experience and how the service should be designed. A mobile terminal has varying input/output possibility (textual input, voice input, graphic user interface, big display, color display, graphic support display, etc.). It is useful to know what is available and what is not available for the designed service. For example, knowing the input

channels can determine if the service can be operated without using hand at all or if it needs one hand (e.g. a mobile phone) or both hands (e.g. a PDA) to be operated.

"The function of the handsets will improve for sure, but the important part is how to use them. The main feature of 3G phones is the high-speed data communication and video transmission. The question is how to utilize this feature". - Keiji Tachikawa, President, NTT DoCoMo Inc., October 2002 (Sidel & Mayhew 2003).

- ▪ **Mobile network**

A mobile user accesses a service using a mobile terminal through a mobile network. It is necessary to know whether the characteristics of the mobile network (data rate, availability, accessibility, reliability, etc.) can support the service being developed.

- ▪ **Location method**

A mobile location service relies on a mobile location technology[77] being used. The applied location method and its performance (accuracy, response time, availability, compatibility, etc.) affects what the service can offer and how the user will experience the service. Knowing the features of the location methods gives the service developer ideas about how the service should be designed.

3.4.4 Physical environment

The physical environment is the obvious factor which directly affects how the user will experience a mobile location service. Such environment factors are, for example, the amount of light, the level of noise, temperature, humidity, trembling, the number of people, objects or buildings around, the physical attributes of the buildings (tall, deep, big, under the ground), etc. The physical environment sometimes changes according to the time of use (e.g. the amount of light, the level of noise, temperature, humidity). The time of use can refer to the instantaneous time of day or longer intervals such as morning, afternoon or evening, day of the week, month, season of the year, etc. The changes of the physical environment can affect the input/output of the user interface. For example, noise can make a voice output system inoperative. This also applies to voice input, as it is difficult for the system to distinguish between the user's voice and background noise. Furthermore, the lack of light also affects the quality of the user experience, since the users might have difficulties using buttons and seeing the screen.

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[77] See chapter 4.

For mobile location services, the ability to pinpoint the location of the user varies depending on the physical environment. The location might not be available when the user is deep inside buildings or the accuracy might be degraded when the user is in rural areas. Designing a mobile location service should take these context attributes into account and the service should provide alternative ways for the users to complete their task, when the quality of the service is degraded because of the physical environments (e.g. an option of determining the user's location manually).

3.4.5   Social environment

Social acceptance, the way people think about other people, has a profound effect on the ways people behave and think *(Hiltunen et al. 2002)*. Social environment has a significant influence on the service adoption of the user *(Hwang et al. 2007)*. The social acceptance of technology and its applications and services determine how and when it is used. Therefore, it is essential to know how certain technologies and services are perceived in the culture where they are supposed to be used, and what social rules apply in connection to the technology use. For example, Asia has a wider cultural acceptance of limitative control within the family. Asian culture traditionally places a premium on loyalty towards all members of the extended family, caring for children and the elderly and having a deep respect of senior members of society. Technologies can be used to care for an elderly and children. Therefore tracking the location of children and elderly is believed to be more acceptable in Asia compared to Western Europe, where the rights of the children and elderly to control their own privacy seem to be higher[78].

3.5   Summary

A user experience is the overall experience that the user gets while using a service. The user experience is one of the critical keys that define whether or not a service will reach the re-purchase phase of its life cycle, as presented in figure 1-2. The re-purchase phase can only be reached if the service provides a positive user experience at the current context of use (i.e. environment where the service is used). The user expectation is the secret behind the user experience, and a positive user experience will only be provided if the service works (e.g. behave, present, deliver) according to what the user expected before he starts using the service. The expectation is formed from the experience the user gets from the same or similar mobile services, web services or with computers in general. The user may also get indirect user experience from advertisements or from e.g. reviews, comments or criticisms of friends or family who have previous experiences with the service. The elements forming the user experience are different from service to service or from product to product. This thesis deals with a user experience towards a mobile service, i.e. a mobile user experience. There are many elements that potentially

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[78] See the discussion of this issue in section 5.4.1.5.

influence how the mobile user experience will turn out, and these elements represent what the general users expect while using a mobile service. The five main elements forming a mobile user experience are availability, usability, utility, aesthetics, and offline issues (e.g. pricing, privacy policy, back office management, etc.). For a mobile location service, the performance of, e.g., mobile and location technologies affect the service availability, and the level of accuracy and response time provided by the location technologies can extend or limit the service usefulness.

A mobile service is naturally used in different contexts of use, meaning that the service may be used by different users for accomplishing different tasks through different networks on different terminals at different physical environments with different social aspects. Using the same service in different contexts of use can potentially result in different levels of user experience. Therefore, it is very important to take into account the characteristics of the context of use when designing a service. These context attributes help the service developer to predict what the users want and how the service should be designed or adapted to match the user expectation[79].

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[79] See section 7.2 and 7.6 for service adaptation.

4 Mobile location technologies

Mobile location services exploit location technologies for determining where the user is geographically located. Different types of mobile location services require different levels of accuracy and response time. Providing a useful mobile location service, the right location method that can fulfill the accuracy and response time requirements of the service must be chosen. The mobile location technologies available today provide different levels of location accuracy and response time, and they are appropriate to be applied for different types of mobile location services. Adding mobile location technologies to different mobile network standards require different amounts of hardware and software investments, involves different levels of complication and cost, and this affects the willingness of the network operators for doing so. One of the characteristics of mobile network standards that have significant impact on the deployment of mobile location services is synchronization[80] or asynchronization of each network standard[81]. In comparison to asynchronous networks, it is cheaper to add the infrastructure for providing high accuracy location information on synchronous networks. Advanced location methods based on triangulation techniques, e.g. A-GPS[82], require that the components on the network must be synchronized. In the case of A-GPS, the system must be synchronized with GPS satellites. For the network standards that are asynchronous, e.g. PDC, GSM, and UMTS, additional timing units are required in order to be able to use the triangulation location methods for providing high accuracy location information. For synchronous network standards, e.g. CDMA, additional timing units are not required on the network, as the CDMA network is synchronized using GPS timing *(Endrun technology 2006)*. Adding synchronization on asynchronous networks is complicated and expensive, and the network operators will only do this if they are convinced that they will benefit from doing so.

This chapter presents accuracy and response time requirements for different kinds of mobile location services. Different types of standardized mobile location methods are then introduced together with the accuracies and response times provided by these methods followed by an analysis of the strengths and weaknesses

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[80] Type of transmission in which the transmission and reception of all data is synchronized by a common clock.
[81] Detailed description of synchronization and non-synchronization of different kinds of mobile network standards can be found in section 2.1.
[82] A-GPS location method is presented in section 4.2.5.

of each method. The network operators' adoption of mobile location technologies in Asia and Western Europe is then presented together with a discussion of the factors influencing their decision.

4.1 Accuracy and response time requirements for MLS

The ideal mobile location service (MLS) should meet specific accuracy and response time requirements. Different services require different levels of accuracy and response time. For some services accuracy is more important than response time and vice versa. For example, for tracking services high accuracy is more important than short response time. It is more useful to use 10 seconds to search for the exact location of a child when he is in danger than knowing at which base station he is connected within 1 second.

4.1.1 Accuracy

The location accuracy for a mobile location service can be expressed in terms of a range of values reflecting the general accuracy level needed for the specific service. The location accuracy includes horizontal and vertical accuracy *(3GPP 2005)*. Some services may not require both, others may do, but with different degree of accuracy.

- **Horizontal accuracy** can be expressed in terms of how closely the user is located to the base station. It can also be measured in meters, or the relative accuracy of the latitude and longitude coordinates *(3GPP 2005)*.

- **Vertical accuracy** can be expressed in terms of either absolute or relative height/depth to local ground level. This may range from about ten meters to hundreds of meters. The vertical accuracy can be used, for example, to indicate on which floor the user is[83].

The location accuracy could be one of the factors influencing the willingness of the user to disclose their location information. From the privacy point of view, it is likely that users become very concerned if the location method can pinpoint their exact location. For example, knowing which base station the user is connected to is more acceptable than knowing on which street corner the user is *(Beeson et al. 2002)*.

4.1.2 Response time

The response time of a mobile location service can be expressed in terms of how quickly the information can be delivered to the user *(3GPP 2005)*. Different

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[83] Ibid.

services require different levels of response time. For emergency services, the user should get a response as quickly as possible, while advertising location based services can be delivered with delay.

4.1.3 Comparison of accuracy and response time requirements for different mobile location services

A technical specification written by 3GPP *(3GPP 2005)* states, that the majority of attractive value-added mobile location services are enabled when location accuracies of between 25m and 200m is provided. Table 4-1 shows examples of mobile location services with different accuracy and response time requirements.

Table 4-1: Comparing the accuracy and response time requirements of different mobile location services[84] *(3GPP 2005; Mennecke & Troy 2003; Strategy analytics 2003)*.

Services	Accuracy requirements	Response time requirements	Service environment[85]
▪ Weather reports ▪ Localized weather warnings ▪ Traffic information (pre-trip)	Up to 200 km	Low	Outdoor
▪ Local news, traffic reports	Up to 20 km	Low	Outdoor
▪ Vehicle asset management	Up to 1 km	Medium to high	Outdoor
▪ Rural and suburban emergency services ▪ Man power planning ▪ Information services (where are?)	500 to 1000m	Low to medium	Indoor/Outdoor
▪ Emergency alert	100-300 m	High	Indoor/Outdoor
▪ Localized advertising ▪ Zone-based charging ▪ Asset tracking ▪ Buddy finder/Dating ▪ Information services (where is the nearest?)	75-125 m	Low to medium	Indoor/Outdoor
▪ Emergency call	50-150 m	High	Indoor/Outdoor
▪ Tracking ▪ Route guidance ▪ Pedestrian navigation ▪ Road tolling ▪ Car park guidance	10-50 m	Medium to high	Indoor/Outdoor
▪ Car navigation service	Up to 5 m	High	Outdoor

Most of the services listed in table 4-1 only require horizontal accuracy. Some services such as tracking and emergency services will be more valuable if the

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[84] See section 5.1 for a list of different mobile location service groups.
[85] Service environment is the environment where the service is mostly used.

vertical accuracy (e.g. floor number) can also be provided. As it can be expected, services which need high accuracy and low response time generally entail high cost solutions[86].

4.2   Existing location technologies and their capabilities

A variety of mobile location solutions have been proposed by various developers and venders. Some of the solutions have been used commercially while others have not. This section discusses, however, only the standardized location methods *(3GPP 2006a)* listed below.

- Cell coverage based (Cell-ID)
- Enhanced Observed Time Difference (E-OTD)
- Observed Time Difference of Arrival (OTDOA)
- Advanced Forward Link Trilateration (AFLT)
- Assisted-Global Positioning System (A-GPS)
- Hybrid location solution

This section introduces and discusses the accuracy, response time, availability, accessibility, and reliability of the above mentioned standard location methods, as these characteristics influence how the mobile user experience will turn out[87]. A comparison of all these location methods is provided at the end of the section.

4.2.1   Cell-Identification (Cell-ID)

Because the mobile terminals are personal devices, they travel with the owners anywhere and any time. By default, the location of these terminals can be determined by mobile networks and therefore the location of the owners can also be tracked. Location information of a mobile user can be collected whenever the user connects to the mobile network. To use the mobile network, the mobile terminals have to register to a base station, and as the users roam around they move from base station to base station *(Ralph & Searby 2004)*. The mobile operators record the location information of the terminals for billing and mobility management *(Katsaros et al. 2005)*. The mobility management function of a mobile network constantly keeps track of mobile terminals that are turned on *(Golding 2004)*. In fact, mobile terminals are in regular contact with the nearest base station in order to keep connected with the mobile network and to periodically tell the network which of the reachable base stations seems best for making or receiving calls or exchanging data. It is imperative that the network knows the location of a mobile terminal, so that any calls can be routed to the appropriate base station. Hence, if it is known at which base station a mobile terminal is currently connected, then the

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[86] See table 4-5 in section 4.2.7.
[87] See section 3.3

rough location of a mobile terminal with respect to its proximity to the serving cell site is known (see figure 4-1). This is the basis of the Cell-ID approach to mobile location services.
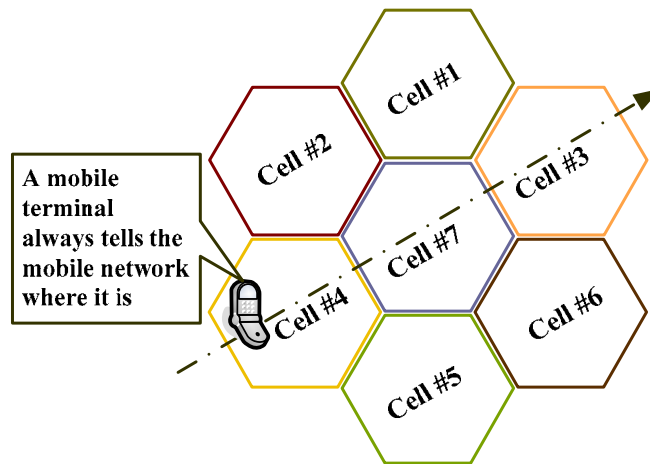
Figure 4-1: By default, a mobile network always knows the users' whereabouts because mobile terminals need to periodically tell the network which of the reachable base stations seems best for making or receiving calls or exchanging data.

Cell-ID is a terminal-assisted location method[88] which works with all mobile network standards: GSM, GPRS, UMTS and CDMA[89] *(3GPP 2006a; Openwave 2004)*. This method has been available since mobile networks were first deployed and it is the simplest method used to determine the location of mobile terminals. When a mobile terminal is connected to a base station, it is known to be located geographically within the area served by that base station. This method requires no modifications to the mobile terminals or networks *(Lim & Siau 2003)*. To provide reliable location, accurate maps of the coverage areas of the base stations are required.

The accuracy of Cell-ID depends on the cellular network density; smaller cells provide higher accuracy. For GSM networks, the accuracy provided by this method varies from 100 to 400 meters in urban areas, 400 meters to 2 kilometers in suburban areas and from 1 to 20 kilometers in rural areas *(Openwave 2004)*. The accuracy does not change in indoor environment unless the pico cell[90] is used *(Lim & Siau 2003)*. The response time of Cell-ID is typically around three seconds[91].

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[88] See section 1.1.3 for the description of terminal-assisted location method.
[89] See section 2.1 for different mobile network standards.
[90] A pico cell is a coverage area of a small mobile base station. The pico cell covers the area from tens to hundreds of meters in size and is normally used inside buildings.
[91] Ibid.

The accuracy of Cell-ID can be improved using enhanced techniques, such as cell sector. Some of the cells are divided into sections, thereby reducing the total area of the possible location (see figure 4-2 (b)), and the location accuracy can therefore be improved. To get an even more accurate location, Timing Advance (TA) *(Halonen et al. 2002)* and Round Trip Time (RTT) *(3GPP 2006b)* can be applied. TA is used in GSM and GPRS networks and it provides a way to find out how far away a user is from the base station, thereby dramatically reducing the possible locations for the user as shown in figure 4-2 (c) *(Mallick 2003)*. The combination of cell sector and Timing Advance can improve the location accuracy even further (see figure 4-2 (d)) to around 100 to 200 meters *(Mallick 2003)*. To improve the accuracy of the Cell-ID method in the UMTS networks, RTT is applied *(3GPP 2006b)*. This enhanced technique can measure how far away from the base station the mobile user is located.
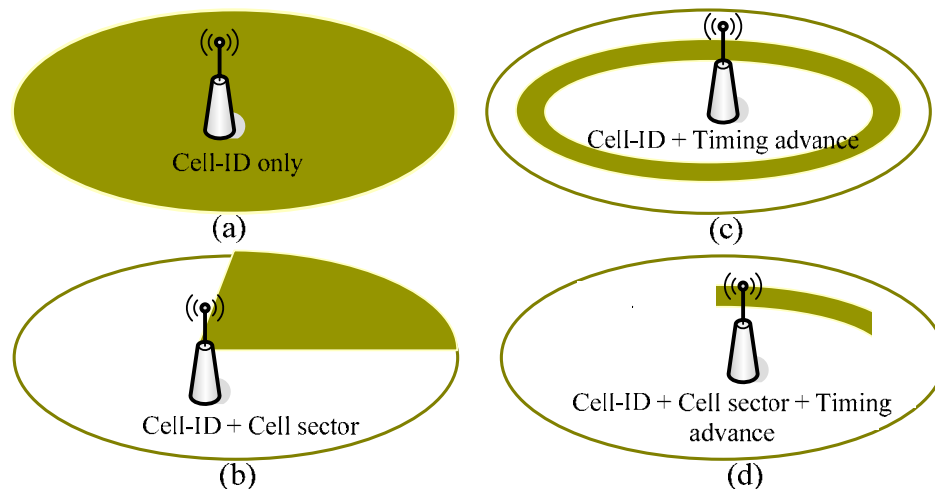
Figure 4-2: Cell-ID location methods based on *(Mallick 2003)*.

Discussion

The Cell-ID method is the cheapest and simplest location solution. Only one base station is needed to determine the location of the user. Generally, the response time is very good when applying Cell-ID, but the accuracy is poor and the consistency of the solution varies depending on cell site density. It is particularly poor in rural areas where base stations are located far from each other. In terms of implementation, it technically supports roaming to other networks without major modifications[92], it is easy to maintain, and it requires no major cost expenditure to

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[92] Roaming support in this context is looked at from the technology perspective. In practice, the agreement between the operators has to be made in order to roam to the networks of different operators.

expand the network. The Cell-ID method detects the users' location at the network, and therefore modifications are not required at the terminal. This also means that the option of controlling the user privacy by turning on and off location cannot be done on the mobile terminal.

Location errors often occur when using the Cell-ID method. Typically the extent of error in urban areas is around 500 m, but in rural locations this can increase up to 15 km *(Ralph & Searby 2004)*. Figure 4-3 shows some typical problems of the Cell-ID method. Both M#1 and M#2 are connected to the base station #2. With Cell-ID, the same location is found for M#1 and M#2, which is not true in real life. Another error happens when the mobile user is in the overlap area between two or more base stations. It is not certain that the user is connected to the closest base station; it depends on the signal strength of those base stations. In figure 4-3, the user M#1 is connected to the base station #2, even though he is located closer to the base stations #1 and #3.
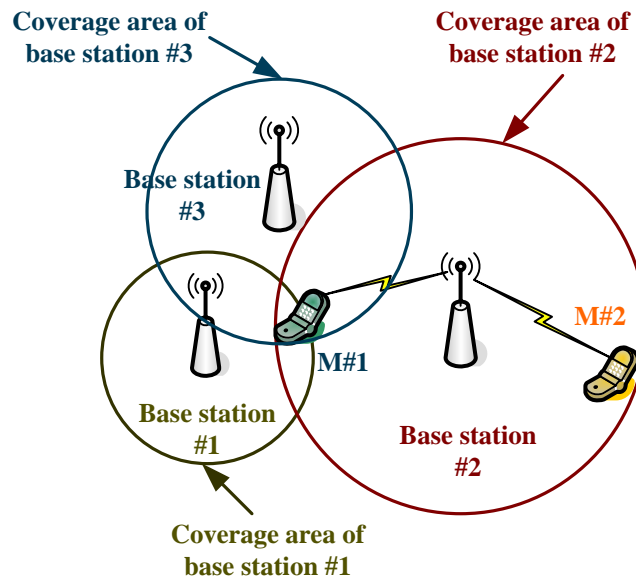
Figure 4-3: Typical problems of Cell-ID occur when the user is in the overlap area of three base stations and the signal strength of the nearest base station is weaker than the one located further away.

Even though Cell-ID is very inconsistent with regard to the accuracy of the determined location, it has many strong points. Strengths and weaknesses of the Cell-ID method are shown in table 4-2.

Table 4-2: Strengths and weaknesses of the Cell-ID location method.

Strengths	Weaknesses
▪ Short response time.	▪ Poor accuracy.
▪ Inexpensive.	▪ Unreliable (inconsistent).
▪ No modification requirements for the mobile terminals or networks.	▪ No option of controlling user privacy on the terminal.
▪ Need only one base station to detect the user's location.	
▪ Available in both indoor and outdoor environments in the areas covered by any mobile network.	
▪ Compatible with all mobile networks and terminals.	

Table 4-2 shows that Cell-ID has many strong points; the services using the Cell-ID method are always available both indoor and outdoor with short response time. The user can always access the service regardless of terminal and network, as this method is compatible with all mobile standards. However the Cell-ID provides only rough location information and therefore only supports less value services. According to the response time and accuracy requirements presented in table 4-1, Cell-ID can theoretically capture almost 50% of the services as listed below.

- Weather reports – requires the accuracy of up to 200 km.
- Localized weather warnings – requires the accuracy of up to 200 km.
- Traffic information (pre-trip) – requires the accuracy of up to 200 km.
- Local news, traffic reports – requires the accuracy of 20 km.
- Vehicle asset management – requires the accuracy of up to 1 km.
- Rural and suburban emergency services – requires the accuracy of 500 m to 1 km.
- Man power planning – requires the accuracy of 500 m to 1 km.
- Information services – requires the accuracy of 500 m to 1 km.
- Emergency calls using network based location methods – requires the accuracy of 100-300 m.

In practice, the usefulness of a service utilizing Cell-ID as a location method depends on the physical environment in which the service is used. Some services work properly only in urban areas where the Cell-ID can obtain high accuracy. For example, the emergency service using Cell-ID will only be useful if the accuracy of 100-300 m can be provided and this will only be possible if the user is in dense urban areas.

4.2.2 Enhanced Observed Time Difference (E-OTD)

E-OTD can operate in two modes: Terminal-assisted and terminal-based *(Halonen et al. 2002)*. This method only works on GSM and GPRS networks *(3GPP 2006a)*. E-OTD provides two-dimensional location information (altitude is not provided). To obtain the location of the user, the system requires a user to be in range of at least three base stations. A triangulation method is used to calculate the user's location. A mobile terminal with E-OTD enabled notes the time difference between the signals from the nearest surrounding base stations. The distance between each of the base stations can then be calculated from the time differences and the location of the mobile terminal can be found using triangulation *(Andersson 2001)* as shown in figure 4-4.
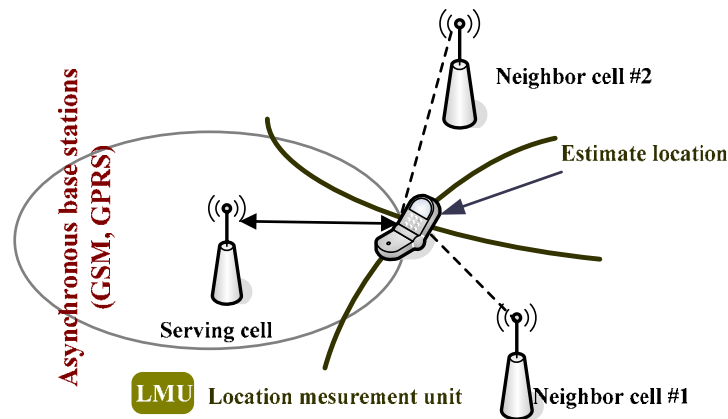
Figure 4-4: Enhanced Observed Time Difference (E-OTD) location method.

For this method, the coordinates of the base stations must be known in order to provide an accurate location, and the signals sent from the different base stations must be synchronized[93] *(Lenihan & McGrath 2003; Andersson 2001; Mallick 2003)*. Since GSM and GPRS networks are asynchronous[94] by design *(Duffett-Smith & Pratt 2006; Tian et al. 2005)*, E-OTD method requires additional location measurement units (LMUs) in the network in order to provide an accurate timing source for the measurements *(Andersson 2001; Mallick 2003)*. Therefore, to provide location services based on E-OTD, the system needs at least two LMUs for every three base stations *(Qualcomm 2003)*. This increases the complexity and cost effect for planning, installing, testing and maintaining the network of LMUs. Furthermore,

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[93] Synchronization is a type of transmission in which the transmission and reception of all data is synchronized by a common clock.
[94] In asynchronous network, each base station has an independent time reference. The mobile terminal has no knowledge of the relative time difference between base stations *(Qualcomm 2001)*. Also see section 2.1.1.1 and 2.1.1.2 for the description of GSM and GPRS.

special software is needed in the mobile terminal to support E-OTD and this software cannot be downloaded over the air[95].

For the E-OTD method, location calculation is made by the location calculation and control unit on the network. Making the calculations on the network normally makes the process less power consuming for the terminal, but E-OTD still adds new requirements to the terminal. In order to use the E-OTD method, the terminal needs to have additional memory, processing power, and battery power (compared to other terminals) *(Andersson 2001)*. E-OTD is typically accurate within approximately 50 to 125 meters, with a response time of around 5 seconds and the accuracy will drop in rural areas *(Lim & Siau 2003; Halonen et al. 2002)*.

Discussion

The E-OTD method has many similarities with the Observed Time Difference of Arrival (OTDOA) method, and therefore the discussion of E-OTD is made together with the discussion of OTDOA in the next section.

4.2.3   Observed Time Difference of Arrival (OTDOA)

OTDOA only works on UMTS networks; it is not compatible with GSM and GPRS *(3GPP 2006b)*. Similar to E-OTD, OTDOA can be operated in two modes: Terminal-assisted OTDOA and terminal-based OTDOA methods *(Korhonen 2001)*.

The OTDOA method is considered as a UMTS version of E-OTD, since there are some weaknesses similar to those of E-OTD (time dependency drives the need for location measurement units (LMUs), it does not work well in areas where there are too few base station/Node Bs[96], poor accuracy along linear networks[97], multi-path degradation, compatibility with only one network, etc.) *(Qualcomm 2003)*. Location calculation is performed by measuring the time of arrival differences of downlink signals received from at least three base stations. These measurements are then sent to the location server together with the identity of the base stations. The location server will then obtain the surveyed geographic locations of the base stations that have been measured from the database.

The OTDOA method does not work well when the mobile terminal is located very close to one of the base stations. This is because the mobile terminal might be swamped by the strong local signal and therefore might not be able to receive signals from other base stations. This problem is known as the "hearability" problem *(3GPP 2006b; Yap et al. 2002; Kim et al. 2005)*. Hearability is a basic

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[95] Ibid.
[96] Node B is a 3G name for base station.
[97] A linear network is a mobile network where the base stations are placed in a line such as the base stations along the road.

consequence of a WCDMA radio system where the terminal is located very close to its serving Node B and it cannot hear other Node Bs in the same frequency band. Therefore, the hearability problem makes the location calculation fail. This problem can be solved by using IPDL-OTDOA[98]. This standard has been proposed by 3GPP *(3GPP 2006b)*. Figure 4-5 illustrates the OTDOA method.

The accuracy of OTDOA varies from area to area within an operator's territory due to the effect of multi-path propagation, which is similar to E-OTD. It is possible for an operator to add more Node Bs in some areas to increase the accuracy of the location information. The operator might choose to have fewer Node Bs in areas where location information is not needed. In general, the accuracy of OTDOA can be better than 100 meter *(Ralph & Searby 2004)* and the response time is very high (around 10 seconds) *(Lim & Siau 2003)*.
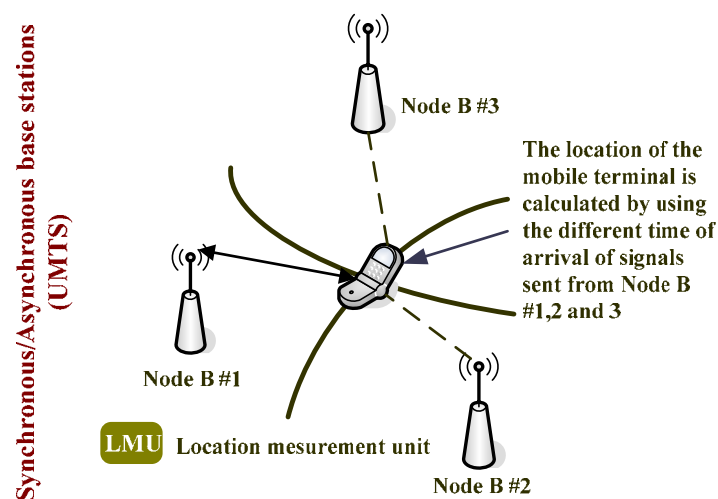
Figure 4-5: Location determination using OTDOA.

For the OTDOA method, the precise time is needed throughout the network even if the UMTS network is synchronized, because the synchronization required for mobile management on the UMTS system has a resolution in the order of ten microseconds, which is not high enough for OTDOA *(Qualcomm 2003)*. Therefore, the operators need to add LMUs in the network if they want to deploy the OTDOA location method.

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[98] Idle Period Downlink. The period when the mobile terminal is switched on but does not have any established Radio Resource Control (RRC) connection. This method is used in the OTDOA location method to mitigate the hearability problem in UMTS system.

Discussion

E-OTD and OTDOA methods provide the user location at a higher accuracy compared to Cell-ID. However, both methods detect the users' location by measuring the time difference between the signals sent from at least three base stations and this requires precise timing information. Unfortunately, GSM and GPRS networks are asynchronous networks and precise timing information is not provided, therefore LMUs are required throughout the networks to provide precise timing information. LMUs are also needed in the UMTS network, although UMTS can operate in both synchronous and asynchronous modes *(Korhonen 2001)*.

Since the mobile terminal location can only be obtained by measuring the signals from at least three base stations, these methods do not function well in rural areas where base station density is low. Also, because E-OTD and OTDOA obtain location information by measuring the signals from at least three base stations, the accuracy depends on the radio signal path. The radio signal path is not always equal to the geographic distance. The effects of multi-path and obstructions often make the radio path longer than the geographic path *(Schiller 2003)*. The accuracy of E-OTD therefore varies from area to area within an operator's territory due to the effect of multi-path propagation.

LMUs make the systems become more complicated and more expensive. The response time of E-OTD and OTDOA is longer than for Cell-ID because signals from three base stations are needed to be measured and calculated. E-OTD and OTDOA detect the users' location on the network side, and turning on and off location information can therefore not be done on the terminal.

E-OTD and OTDOA can work both in indoor and outdoor environments but the service is only available according to the availability of LMUs, and a special terminal with additional software is required. E-OTD works only with GSM and GPRS, while OTDOA is only compatible with UMTS. Therefore there is a problem with roaming support, as the location will only be available if the user roams between the same network standards which have additional location infrastructure for E-OTD or OTDOA. Since it is rather complicated and expensive to add E-OTD and OTDOA to the mobile networks, it is likely that the operators will have a hard time adopting these methods as their location technology choice. The strengths and weaknesses of E-OTD and OTDOA are summarized in table 4-3.

Table 4-3: Strengths and weaknesses of E-OTD and OTDOA.

Strengths	Weaknesses
- Medium-high accuracy. - Available both indoor and outdoor.	- Expensive (need LMUs, high maintenance cost). - Complicated (need three base stations to determine the users' location, need LMUs). - Accuracy is degraded in rural areas (unreliable). - Only accessible with terminals that have additional software. - Only available in networks with additional LMUs. - Roaming supports only networks with LMUs. - The reliability of E-OTD and OTDOA relies on the number and locations of the base stations as well as geographical environments. - High response time (approximately 5 seconds for E-OTD and 10 seconds for OTDOA). - E-OTD is only compatible with GSM and GPRS and OTDOA is only compatible with UMTS. - Location cannot be enabled and disabled at the terminal (no option of controlling the user privacy).

According to the accuracy and response time requirements for mobile location services shown in table 4-1, E-OTD and OTDOA can be used as mobile location technologies for most of the services as listed below.

- Weather reports – requires the accuracy of up to 200 km.
- Localized weather warnings – requires the accuracy of up to 200 km.
- Traffic information (pre-trip) – requires the accuracy of up to 200 km.
- Local news, traffic reports – requires the accuracy of 20 km.
- Vehicle asset management – requires the accuracy of up to 1 km.
- Targeted congestion avoidance advice – requires the accuracy of up to 1 km.
- Rural and suburban emergency services – requires the accuracy of 500 m to 1 km.
- Man power planning – requires the accuracy of 500 m to 1 km.
- Information services – requires the accuracy of 500 m to 1 km.
- Emergency calls - require the accuracy of 100-300 m.
- Localized advertising – requires the accuracy of 75-125 m.
- Home zone pricing – requires the accuracy of 75-125 m.
- Network demand monitoring – requires the accuracy of 75-125 m.
- Asset tracking – requires the accuracy of 75-125 m.
- Information services – requires the accuracy of 75-125 m.
- Emergency using terminal-based location methods – requires the accuracy of 75-125 m.

4.2.4 Advanced Forward Link Trilateration (AFLT)

AFLT is a terminal-assisted location technology used only in CDMA networks. Similar to E-OTD and OTDOA, this method determines the location of the mobile users by measuring the signals from three surrounding base stations. The measurements are sent back to a location processor in the network which calculates the approximate location of the mobile terminal using triangulation *(Ralph & Searby 2004)*. This method requires terminals with precise timing capabilities. As the CDMA base stations are GPS synchronized *(CDG 2007d; Halonen et al. 2002; Duffett-Smith & Pratt 2006)*, their locations are known and the location of the mobile terminal can be derived from time differences of arrival of the downlink signals. AFLT provides the mobile users' location with the accuracy of 50-200 meter *(Openwave 2002)* with altitude readings generally not available. AFLT is a form of downlink triangulation utilizing the fact that a CDMA terminal normally communicates with more than one base station at all times through the soft handoff mechanism[99] *(Tse & Viswanath 2005)*. Location measurement units are not needed but modifications are required in the mobile terminal *(Openwave 2002)*. Figure 4-6 illustrates the AFLT location method.
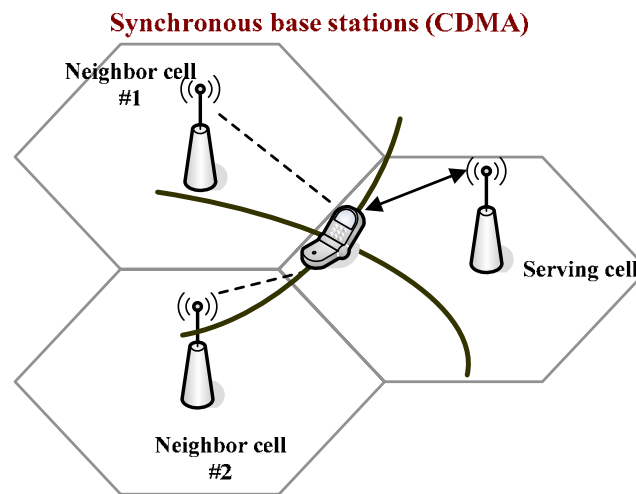
Figure 4-6: The AFLT location method on CDMA networks needs signals from three base stations to calculate the location of the mobile user. LMUs are not needed, as CDMA networks are synchronous.

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[99] As a user moves between base stations, a CDMA terminal picks up the same coded signal on the same frequency from both base stations. When the original base station stops transmitting, the terminal is already receiving the signal from the new base station causing a smooth transition with less chance of a dropped signal. This feature is called the soft handoff mechanism.

Discussion

This method gives approximately the same level of accuracy as the E-OTD method, but AFLT is less expensive and less complicated to deploy because LMUs are not needed. The location is calculated on the network side; hence the option of turning off the location function cannot be done at the terminal. AFLT captures the same services as E-OTD.

4.2.5 Assisted-Global Positioning System (A-GPS)

A-GPS is compatible with all mobile standards: GSM, GPRS, UMTS and CDMA *(3GPP 2006a)*. This method provides three-dimensional location information (latitude, longitude and altitude[100]). It works in two modes: Terminal-based and terminal-assisted *(3GPP 2005)*. For the terminal-based mode, the mobile terminal maintains a full GPS receiver functionality in the terminal and location calculation is performed by the mobile terminal itself, resulting in a short time to first fix (less than 2 seconds) *(Miyazono 2005)*[101]. This requires an extended set of assistance data from the network and GPS satellites. This assistance data contains information of visible satellites, and the terminal then knows from which GPS satellites it should receive the signals without having to spend time searching for the visible satellites *(Jagoe 2003)*.

For the terminal-assisted mode, the mobile terminal has reduced GPS receiver functionality. The A-GPS receiver in the mobile terminal obtains only a small set of aiding data from the A-GPS Location Server (A-GPS LS), which the terminal uses for calculating the pseudo ranges[102] from the satellite signals. The terminal sends this information back to the A-GPS LS, which finally calculates the location of the mobile terminal *(3GPP 2006b)*. For the terminal-assisted mode, it takes longer time to detect the user location compared to the terminal-based mode, because the signals from the satellites have to be sent and processed at the location server. Time to first fix for the A-GPS terminal-assisted mode is around 5-10 seconds *(Miyazono 2005; Golding 2004)*. The accuracy provided by A-GPS is around 10-20 meters outside buildings and the accuracy is reduced in certain environments, e.g. inside buildings or "urban canyons", because of signal degradation[103] *(Lim & Siau 2003)*.

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[100] For 3D location (latitude, longitude and altitude), signals from four satellites are needed. If the location is detected measuring signals from three satellites, only 2D location is achieved *(Halonen et al. 2002)*.

[101] The time to first fix in a standard GPS can take as long as 10 minutes, as a GPS receiver that does not know where it is has to search for the visible satellites *(Jagoe 2003)*.

[102] Pseudo ranges are distance measurements to the satellites in view.

[103] The indoor reception rate of GPS data is only 20% *(Kim 2006)*.
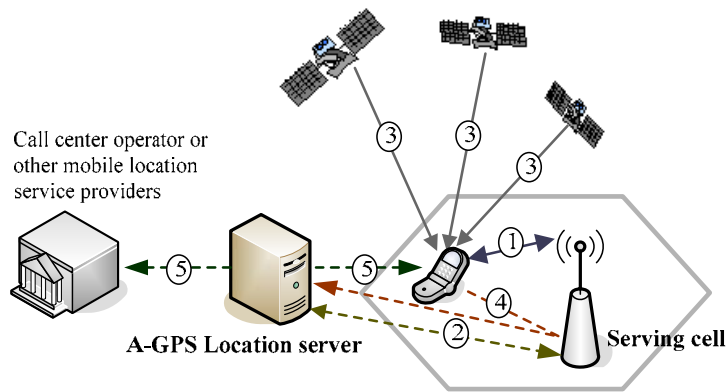
Figure 4-7: Terminal-assisted Global Positioning System (A-GPS) (adapted and developed from *(3GPP 2006b)*).

Figure 4-7 illustrates interactions between different components in a terminal-assisted global positioning system. The location request procedure in the figure is described in the following order list.

1. The mobile terminal asks the mobile base station for location information.
2. The mobile base station sends information to the location server to ask for assisted information, and the location server sends assisted information back to the mobile terminal saying which GPS satellites the terminal should collect signals from.
3. The mobile terminal collects information from the suggested GPS satellites and calculates its distance from the satellites in view.
4. The mobile terminal sends the collected information through the base station to the location server, which performs sophisticated error correction and calculates the current location of the mobile terminal in the form of latitude, longitude and (possibly) altitude.
5. This location information can then be sent to the service providers or mobile internet.

For the terminal-based A-GPS, in the process number 3 shown in figure 4-7, the location calculation will also be made by the mobile terminal and sent to the location server. The calculated location may then be sent to the service providers.

Discussion

A-GPS provides the best accuracy among all the location methods, and it operates on both synchronous (e.g. CDMA) and asynchronous (GSM and GPRS) networks

71

without the need for Location Measurement Units (LMUs). However, LMU information can be used to enhance accuracy in asynchronous networks if it is available *(Qualcomm 2003)*.

The terminal-based A-GPS implementation has minimum impact on the infrastructure and can easily support roaming, but A-GPS circuitry is required inside the mobile terminal. Therefore, terminals without modifications cannot support A-GPS.

A-GPS uses GPS satellites as reference points to determine the location of the mobile users. The location is calculated by measuring the time required for the signals to travel from the satellites to the receiver. This requires precise time information to perform the GPS satellite signal processing. CDMA networks are fortunately synchronized using GPS as a timing source. Each CDMA base station has at least one GPS receiver because its transmissions must be precisely synchronized within ten microseconds *(Wheatley 1999; CDG 2007d, Endrun technology 2006)*. Relative to the signals received by GPS receivers on the earth, signals from the CDMA base stations are much stronger (*Endrun technology 2006*). This means that the CDMA signals are easily received inside buildings[104]. For this reason the A-GPS method is very suitable for CDMA networks, since the location of a user can be detected utilizing the combination of synchronized signals from CDMA base stations and GPS satellites. This combination improves sensitivity and availability, and the location detection can be performed even when the mobile terminal can receive signals from only one GPS satellite *(Qualcomm 2002)*, as shown in figure 4-8.
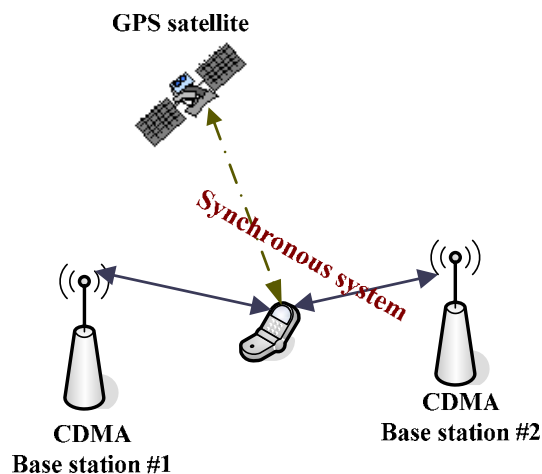
Figure **4-8:** Location calculation using the A-GPS method can be performed when receiving signals from only one GPS satellite, due to the GPS timing used in CDMA networks.

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[104] Ibid.

For GSM and GPRS, the networks are asynchronous. The A-GPS method will only work if the mobile terminal can receive signals from at least three GPS satellites, or if LMUs are installed throughout the networks. UMTS networks can also operate in synchronous mode, but GPS timing is not used in the UMTS networks *(Holma & Toskala 2002)*. Instead, a sync signal is transmitted along with the downlink signal *(Tektronix 2005; Holma & Toskala 2002)*. Therefore, using the A-GPS method on UMTS networks has the same problem as on the GSM and GPRS networks that LMUs are required to improve the service availability.

Additional software and hardware is needed at the terminal when using the A-GPS method, and therefore the location functionality can be disabled at the terminal[105]. Table 4-4 shows the strengths and weaknesses of the A-GPS method.

Table 4-4: Strengths and weaknesses of the A-GPS method.

Strengths	Weaknesses
▪ High accuracy. ▪ Low response time (terminal-based mode). ▪ Compatible with all network standards. ▪ Location functionality can be turned on and off at the terminal.	▪ Accuracy is degraded (sometimes does not work) in indoor environments, especially in asynchronous networks, unless LMUs are added. ▪ High response time (terminal-assisted mode). ▪ Need modifications in both network and mobile terminal.

Based on table 4-1, A-GPS can be used as a location method for all standard mobile location services defined by 3GPP. However, the availability of A-GPS relies on the physical environments, and the capability of determining the location is different in synchronous and asynchronous networks depending on the physical environments.

4.2.6   Hybrid location solution

For a hybrid solution, the system combines at least two location methods to enhance the accuracy, availability and acquisition time. Hybrid solutions work with all mobile standards: GSM, GPRS, UMTS and CDMA (assuming that at least one of the applied methods works with the standard). Hybrid solutions allow the strengths of one location method to compensate for the weaknesses of the others to provide a more reliable and robust location solution.

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[105] Please note that the location of a mobile terminal can still be known by the network as long as it is turned on (see section 4.2.1 for detailed description of this issue).

The most common hybrid solution is a combination of Cell-ID and A-GPS *(Qualcomm 2003)*. In rural areas where the base station density is low, Cell-ID provides poor location information, while A-GPS provides high accuracy and normally has a higher chance of successfully calculating the location in these areas. On the other hand, A-GPS has a lower chance of successfully calculating the location in dense urban areas and deep inside buildings, whereas Cell-ID can provide medium accuracy in urban areas and works well inside buildings. This solution enables an always-available location solution, since Cell-ID always works in all areas having mobile network coverage.

gpsOne is a hybrid solution that uses a combination of the A-GPS and Cell-ID method. gpsOne is widely used in Asia and North America, including KDDI in Japan, SK Telecom and KTF in South Korea, Verizon Wireless and Sprint-Nextel in the US and Bell Mobility in Canada *(3gtoday 2007)*. gpsOne is a terminal-based solution, in which the ability to make location measurements is embedded directly into the mobile terminal, thus eliminating the need for costly and time-consuming network cell-site upgrades.

Besides the hybrid solution consisting of Cell-ID and A-GPS, A-GPS can also be combined with AFLT, E-OTD or OTDOA *(Qualcomm 2003)*. All these combinations provide higher accuracy and shorter response time compared to using only one of the methods[106].

Discussion

Hybrid location solutions achieve better location accuracy compared to a single method, but naturally the system requires more investments and efforts from the service operators. For GSM/GPRS and UMTS networks, it is more complicated and more expensive compared to CDMA networks to adopt any location method except Cell-ID.

4.2.7 Location technologies – Summary

Different location methods have different strengths and weaknesses, as discussed in the previous sections. A mobile user expects to receive anywhere-anytime services. To provide anywhere-anytime mobile location services, there must be ways to overcome the weaknesses of the location methods. Triangulation methods such as E-OTD, OTDOA and AFLT have low accuracy in rural areas where there are few base stations. GPS based methods generally suffer where the user is in indoor environments or shielded from the clear view of the sky by buildings, terrain, or foliage, all of which are frequent occurrences. Cell-ID may be used to provide anywhere-anytime mobile location services, but it is very inconsistent and provides

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[106] Ibid.

relatively poor accuracy, especially in rural areas. A summary of the location technologies described in section 4.2.1 to 4.2.6 is shown in table 4-5.

Table 4-5: Summary of location technologies presented in section 4.2.1 to 4.2.6.

	Cell-ID	E-OTD/ OTDOA	AFLT	A-GPS
Performance	▪ The accuracy varies depending on the coverage area of base stations, often very low (especially in rural areas). ▪ Low response time. ▪ Available both indoor and outdoor. ▪ Compatible with all mobile standards. ▪ Unreliable.	▪ The accuracy declines in rural areas if there are not sufficient cell sites available. ▪ Medium response time. ▪ Available both indoors and outdoors in the areas where LMUs are added. ▪ E-OTD is only compatible with GSM and GPRS standards. ▪ OTDOA is only compatible with UMTS standard.	▪ Provides similar performance as E-OTD and OTDOA. ▪ Only compatible with CDMA.	▪ Provides the best accuracy compared to other location methods. ▪ Accuracy is degraded (or unavailable) in indoor environments, especially for asynchronous networks. ▪ Low response time in terminal-based mode and high response time in terminal-assisted mode. ▪ Compatible with all mobile standards.
Modification requirements	▪ No modification requirements at the terminal. ▪ Additional software is required at the network.	▪ LMUs are required throughout the system. ▪ Additional software is required at the terminal (cannot be downloaded over the air).	Additional software is required for both the network and the terminal.	▪ Additional software and hardware is required in the terminal. ▪ LMUs may be needed in GSM, GPRS and UMTS networks to enhance the performance.
Cost	Low.	High.	Lower than E-OTD and OTDOA, and higher than Cell-ID.	▪ Low in CDMA networks. ▪ High in GSM, GPRS and UMTS networks if LMUs are needed.
Option of turning on and off the location information	Turning on and off location function cannot be done at the terminal.	Turning on and off location function cannot be done at the terminal.	Turning on and off location function cannot be done at the terminal.	The A-GPS functionality can be disabled at the terminal.

At present, no single location method can provide the user location in a wide area without availability, accessibility and/or reliability problems. The lack of high accuracy location information in indoor environment is one of the main problems of the existing mobile location technologies, and roaming support between different

location technologies is still not possible. The most effective location solutions available at this time are the hybrid solutions, combining A-GPS and triangulation methods based on mobile networks (E-OTD, OTDOA, and ALFT) to enhance the performance. However, the system is more complicated with hybrid solutions and even though the hybrid solution is used, providing consistent mobile location services cannot be guaranteed with the location technologies available today.

In this thesis, the indoor location method applying Bluetooth and WLAN networks has been proposed to improve the availability and accuracy of mobile location services in indoor environments. This method is a non-standard location method, based on the same principle as Cell-ID, where the location of the user is referred to the location of an access point. The accuracy of this indoor location method is very high compared to the location accuracy of the location methods used on mobile networks presented previously. However, the indoor location method applying Bluetooth and WLAN networks requires a large number of access points in order to cover a large service area. The indoor location method applying characteristics of Bluetooth and WLAN can in principle be applied to compensate the lack of high accurate location capability provided by the location methods used on mobile networks, if the mechanisms for handling the location roaming and location update between different kinds of wireless access networks are emerged. This thesis takes advantage of mobility management protocols in inter- and intra-domains to identify the location of a user on the next generation wireless network. For this method, it does not matter which wireless access network is used, the user location can be determined by applying the mobility management and location update mechanisms used for the mobile environment on the next generation network, and this solution is presented in more details in chapter 6.

4.3 Discussion: Adoption of mobile location technologies of network operators in Asia and Western Europe

This section presents the location technology adoption of the network operators in Asia and Western Europe and discusses technological and economical factors influencing their decisions

Various location methods are available today, but the network operators cannot freely adopt the methods, as not all the methods are compatible with all mobile network standards. Also, deploying mobile location services on different mobile network technologies involves different levels of complication and cost, and this affects the willingness of the network operators for doing so. One of the characteristics of mobile network technologies that have significant impact on the deployment of mobile location services is synchronization or asynchronization of

each network standard[107]. In comparison to asynchronous networks (GSM family presented in section 2.1.1), it is cheaper and less complicated to add the infrastructure for providing high accuracy location information on synchronous networks (CDMA family presented in section 2.1.2). High accurate location methods based on triangulation techniques (e.g. E-OTD and OTDOA) require that the components on the network must be synchronized. For the network standards that are asynchronous, additional location measurement units are required in order to be able to use the triangulation location methods for providing high accuracy location information. For synchronous network standards, additional location measurement units are not required on the network. Adding synchronization on asynchronous networks is complicated and expensive, and the network operators will only do this if they are convinced that they will benefit from doing so.

CDMA networks, such as those used primarily in Japan[108] and South Korea[109], already have a high degree of synchronization, making it much easier to apply the location method that can provide the highest location accuracy like A-GPS.

In Western Europe where the GSM, GPRS and UMTS networks are used, the operators have possibilities of adopting Cell-ID, E-OTD, OTDOA and A-GPS location methods. However, so far we have not seen many operators using sophisticated location technology for precise user location detection. Because the mobile standards used in Western Europe do not require synchronization, it is expensive and complicated to add infrastructure for triangulation based location methods. The operators in Western Europe are more likely to choose a location method that is inexpensive and uncomplicated like the Cell-ID method.

For the PDC networks adopted by NTT DoCoMo, Japan, the systems do not require synchronization either, and Cell-ID is also chosen as the main location method, thereby enabling only less value services. On the other hand, various services can be offered with the hybrid location solution (a combination of A-GPS and Cell-ID) adopted by KDDI, Japan and operators in South Korea. Table 4-6 shows the location technologies adopted by the operators in Asia and Western Europe.

It is not only the technology compatibility that influences the adoption of mobile location technologies in each region. The upgrading requirements from 2G to 3G[110] also have a significant impact on the deployment of the location infrastructure. The operators in Western Europe have many issues to deal with when it comes to upgrading from 2G to 3G, as huge amounts of software and hardware needs to be

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[107] See section 2.1 for the descriptions of different mobile network standards, their characteristics, capabilities, etc.

[108] There are three main operators in Japan and one of them (KDDI) uses CDMA while the others (NTT DoCoMo and Softbank Mobile Corp) use PDC and UMTS.

[109] All three operators in South Korea use CDMA although at different frequencies *(Reynolds & Jin-Kyu 2004)*.

[110] See section 2.1.1.6 and 2.1.2.3.

added[111]. For 3G upgrade, the WCDMA standard requires the deployment of new base stations since the GSM standard is based on TDMA technique and operates at different frequency band than WCDMA *(Srivastava 2004)*. Therefore the operators must maintain the existing GSM networks to serve the GSM users while deploying new UMTS networks for 3G users. The CDMA2000 standard, on the other hand, can work on the existing frequencies (e.g. 800, 900, 1800 and 1900 MHz band) used for the 2G CDMA *(CDG 2007d; Holma & Toskala 2002)*, thus the existing CDMA base stations can be used with small upgrade requirements[112]. Besides the upgrading requirements, the operators in Western Europe have already spent billions of dollars on 3G licenses[113] *(Hillebrand 2002)*.

Table 4-6: Location technologies adopted by operators in Asia and Western Europe.

Networks	Region	Location method	Suitable Services (**refer to table 4-1**)
CDMA	Japan (KDDI).	Hybrid (Cell-ID+A-GPS).	All standard services.
	South Korea (all operators).	Hybrid (Cell-ID+A-GPS). In-vehicle GPS based.	
PDC	Japan (NTT DoCoMo/ Softbank Mobile Corp.).	Cell-ID. In-vehicle GPS based. Terminal-based A-GPS.	All standard services can be offered using in-vehicle GPS-based method.
GSM/GPRS	Western Europe.	Cell-ID.	See suitable services for Cell-ID in section 4.2.1.
UMTS	Western Europe.	Cell-ID.	See suitable services for Cell-ID in section 4.2.1.
	Japan (NTT DoCoMo).	Cell-ID.	

The upgrading requirements from 2G to 3G could be one of the reasons that the operators in Western Europe are not interested in adding advanced location technologies (e.g. A-GPS, E-OTD) to facilitate the deployment of mobile location services into their networks, since the operators have already spent large amount of money on spectrum licenses and network upgrades. As a result, many network operators are undertaking cost cutting, which can take many forms, but tends to focus on reducing resources spent on the development of new applications and services *(Betti 2005)*. Also, there are technical issues (e.g. network is asynchronous and LMUs are required) to be overcome if location infrastructure for high accuracy location information should be added on the mobile networks originally deployed in

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[111] See section 2.1.1.6 and 2.1.2.3
[112] See section 2.1.2.3.
[113] For the Japanese operators, they did not have to go through a financially debilitating auction process to secure 3G licenses, as previously presented in section 2.1.1.6.

Western Europe. It seems like the mobile operators in Western Europe are still looking at mobile location services as a distance class of services, and not a priority in their list of services, whereas the situation is significantly different in Asia[114].

4.4   Summary

This chapter presents different standard mobile location methods. E-OTD, OTDOA, AFLT and A-GPS can operate in both terminal-based and terminal-assisted modes, while Cell-ID can only operate in terminal-assisted mode.

Cell-ID offers the lowest implementation cost amongst all location methods and it can be used with all mobile standards. The E-OTD method is only compatible with GSM and GPRS networks and OTDOA is only compatible with UMTS networks. The accuracy of E-OTD and OTDOA is higher than the accuracy of Cell-ID but adding E-OTD and OTDOA to the network is expensive and complicated. AFLT is a location method compatible with CDMA networks only. This method provides the same level of accuracy as the E-OTD method but it is less complicated than E-OTD due to the synchronization provided in the CDMA networks. The A-GPS method provides the highest location accuracy amongst the existing location methods. This method is more suitable for CDMA networks than GSM, GPRS and UMTS networks, since all components in the CDMA networks are synchronized using GPS timing. This enables the location detection even when only one GPS satellite can be detected. A-GPS does not work well with the GSM, GPRS and UMTS network, when the user is in urban areas or inside buildings, because signals from at least three satellites are required. It is cheaper to add A-GPS technology on CDMA networks compared to GSM, GPRS and UMTS networks. Hybrid solutions combine at least two location methods, which allow the strengths of one method to compensate for the weaknesses of others. This provides a more reliable and robust location solution. The most common hybrid solution is the combination of Cell-ID and A-GPS.

Various location methods are available today, but the service operators can not freely choose amongst all the methods. The possible methods depend very much on the mobile network originally deployed in that area. The operators with CDMA networks have an obvious advantage, as the triangulation-based location methods can be deployed more easily compared to what is required on the GSM, GPRS and UMTS networks. Due to technical issues, most of the service operators in Western Europe choose to stick with the Cell-ID method, while the hybrid solution (a combination of A-GPS and Cell-ID) is adopted in Asia where the CDMA networks are widely deployed. Even when using hybrid solutions, the consistent location service cannot be guaranteed with the location technologies available today.

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[114] See chapter 5 for mobile location services commercially available in Asia (Japan and South Korea) and Western Europe.

5 Mobile location services in Asia and Western Europe

Mobile location services are the services that make use of location information. Location information is a set of data describing an individual's location at a specific time, and the location accuracy and response time varies depending on the technology used to collect the location information. Location information has limited value without context to the surrounding environment *(Gum & Burroughs 2006)*; it is difficult to sell user location information on its own. Mobile users not only want to know where they are in the context of surroundings and the intended destination, but they also want to have access to additional real time information. For example, most users do not want to know how to get to work along the same route taken each day. It is, however, useful and time-saving to utilize additional real time information regarding, e.g., traffic and accidents along the way or to compensate for inclement weather. Location should be used as a filter for content, a way to improve user input or to contextualize a user and provide better service and experience *(Betti 2005)*. Other services such as messaging, information delivering and navigation can be enriched using location information, and games can include location data to improve their functionality.

Mobile location services are based on the underlying location technologies[115] that enable the identification of the location of a mobile terminal, thus making the provision of different kinds of mobile location services possible. Different mobile location services require different levels of location accuracy and response time[116]. Providing an attractive and useful service, an appropriate location method has to be applied. Besides applying an appropriate location technology, the service behavior and content should match the user expectation or match the general mental model of the target users in specific contexts of use. As described in section 3.2, the user adopts the service based on his perception and he has expectations about the service before he starts using it. This expectation has a big influence on how the user will experience a service. It is very important to manage the user expectation of the service, which is the way to prevent the user from having too high expectations, which the service might not be able to live up to.

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[115] See chapter 4 for different mobile location technologies.
[116] See section 4.1 for accuracy and response time requirements of different kinds of mobile location services.

Mobile location services can be delivered to the user in two different ways, according to whether or not the user needs to interact with the system in order to receive the information: Push and pull. Push services deliver information to the user without any request from the user. Such push services can be activated by, for example, an event, which could be triggered if a specific area is entered. The push service can also be triggered by certain conditions of context of use (e.g. location or time) or other criteria defined in the user profile[117]. In a pull service the information is desired and expected by the user and the information will only be delivered to the user upon request. Since the push services are not activated by the user interacting with the service, they are generally more complex to establish compared to the pull type services. The background information such as context of use, user needs and preferences has to be sensed by the push system. Examples of push services are imadoco and i-kid services presented in section 5.2.2.1 and 5.2.2.3. i-area and A to B services presented in section 5.2.1.1 and 5.3.2.1 are examples of available pull services.

Mobile location services have been deployed in many parts of the world on both 2G and 3G networks. Asia is the area having the greatest attention from mobile service providers, especially Japan and South Korea. This thesis chooses to look at the services offered in Asia (Japan and South Korea) and Western Europe. Asia and Western Europe are chosen as the focus areas because these two regions are different both in terms of the mobile network standards being adopted by the network operators and in terms of social and cultural aspects (i.e. use context) of these two regions. Mobile location services in Asia and Western Europe became available at approximately the same time, but the services in Asia have expanded faster and obviously become more successful compared to Western Europe. This chapter examines the factors differentiating the successful levels of mobile location services in Asia and Western Europe and the strong points and shortcomings of the services offered in both of the regions. The knowledge gained from the examination and analysis of the factors influencing the adoption of mobile location services in Asia and Western Europe will be taken into account (what should be improved, emphasized and avoided) when developing a conceptual location method and conceptual service architecture presented in chapter 6 and 7.

This chapter starts by presenting different categories of mobile location services, followed by an examination and analysis of mobile location services commercially available in Asia (i.e. Japan and South Korea) and Western Europe. A discussion of strong points and shortcomings of the services offered in both of the regions is given at the end of the chapter.

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[117] See section 7.3 and 7.4 for the deailted description of the user profile.

5.1 Categorization of mobile location services

Mobile location services can be divided into location-based services and location-dependent services *(3GPP 2006a)*. Location-based services are provided utilizing the available location information of the mobile terminal[118]. These services are actual services that are visible to the user, e.g. find-a-friend, navigation, yellow pages, etc. The location-based services can be delivered to the user either as a pull type or push type service according to whether or not the user needs to interact with the system in order to receive the information. Location dependent services are available depending on the user's actual position. The service is available or is activated when the user enters a certain area[119]. Location sensitive charging[120] is an example of this kind of service. According to the technical specification written by 3GPP *(3GPP 2005)*, the services utilizing the location of a mobile user may be categorized into the following groups.

Group 1: Navigation services
Navigation services provide guidance to mobile users of how to get to their destination. In order to use the service, the users have to input the destination information on the mobile terminal. The system detects the current location of the user and then returns guidance of how to reach the destination from the current point. The guidance information can be delivered in various formats such as text, symbols with text information (e.g. turning point and distance) or symbols on a map display. The instructions may also be given verbally to the users using voice format. 3D Navi[121] provided by KDDI, Japan is an example of navigation services for pedestrians with 3D navigation map and voice guidance.

Group 2: Location based information services
Location based information services allow users to access information that has been filtered and tailored based on the users' current location and perhaps preference information stored in the users' profile. The services can be delivered to the users upon request, or delivered automatically to the user when triggering conditions set in the user profile are met. Examples of possible location based information services are i-area provided by NTT DoCoMo and mobile yellow page service provided by Telia, Sweden[122].

Group 3: Tracking services
Tracking services allow the tracking of location and status of a specific object (e.g. an animal, car or bus), user or group of users. For example, a delivery service company can use this service to track the location and status of employees or

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[118] Ibid.
[119] Ibid.
[120] See section 5.3.4.
[121] See sect 5.2.3.2.
[122] See section 5.2.1.1 and 5.3.1.1.

parents can monitor their kids' whereabouts. Tracking services are available in Asia and Western Europe. Examples are imadoco services provided by NTT DoCoMo, Japan, i-kids service offered by SK Telecom and ChildLocate available in the UK[123].

Group 4: Public safety services

This group of mobile location services is offered by service providers for safety reasons. They are available without subscription requirements. Examples of services in this group are emergency services and emergency alert services. These services can be delivered to the user upon request (e.g. an emergency call) or without any request from the user (e.g. an announcement of train accidence).

Group 5: Location dependent content broadcast

These services broadcast information to mobile terminals in a certain geographical area without any request from users. The information may be broadcasted to all terminals in the area or only to members of a specific group or organization. Examples of such services are mobile advertising services based on the current location of the user. The advertisement may be broadcasted to a specific user or group of users as personalized services based on their interests, behavior, preference time, or preference location.

Group 6: Location sensitive charging

Location sensitive charging allows service providers to charge subscribers/users at different rates depending on the geographic location or zone of the subscriber. The zone may vary in size and shape of a cell (or sector) coverage. In addition, different rates may be applied in different zones at specific periods of time (e.g. a period during the day, a specific day during the week or a specific month in a year). Examples of available location sensitive charging are ZonePlan[124] provided by Sonofon Denmark and Genion[125] provided by O2 Germany.

Group 7: Community services

This group of services provides entertainment services within the community based on the user location. Possible services in this group are: Buddy finder, instant message and dating services.

5.2   Services in Asia – Japan and South Korea

Mobile location services have been launched commercially in many countries in Asia such as Japan, South Korea, China, Hong Kong, Taiwan, Singapore, Malaysia, Philippines and Thailand. However, Japan and South Korea are the most advanced

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[123] See section.5.2.2.1, 5.2.2.3 and 5.3.3.2.
[124] See section 5.3.4.1
[125] See section 5.3.4.2.

mobile location services markets in Asia, with almost all categories of MLS available today. Therefore in this section, only services in Japan and South Korea will be discussed.

The key component that makes mobile location services popular in Japan and South Korea is the Global Positioning System (GPS). The majority of the mobile location services offered in Asia are based on gpsOne location technology[126] on CDMA networks *(Reynolds & Jin-Kyu 2004)*. Telematics related services[127] are also widely deployed using in-vehicle GPS-based systems, which can communicate with the mobile networks and receive information based on the current location of the vehicle. Users can find directions using voice commands or by moving through a set of menus on the terminal[128]. Commercially available mobile location services in Japan and South Korea are presented, analyzed and discussed in the following sub-sections.

5.2.1   Location based information services

A location based information service delivers relevant information based on the users' location. These services do not require high precision location information[129] and are considered as less value services.

5.2.1.1. Area information delivery (i-area)

i-area is a mobile location service for i-mode[130] users launched by NTT DoCoMo on July 2, 2001 *(NTT DoCoMo 2007)*. The service delivers a broad range of location specific i-mode content to the user. The system pinpoints the location of the user according to their nearest base station using Cell-ID[131] and provides them with a content menu specific for that area, including weather forecasts and maps, traffic information, restaurants and sales at local stores. The i-area service itself is free, but some providers may charge a fee for certain information. An example of the i-area service task flow is shown in figure 5-1.

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[126] See section 4.2.6.
[127] See section 5.2.4.
[128] Ibid.
[129] See table 4-1 in section 4.1.
[130] i-mode stands for "Internet mode". i-mode is developed by NTT DoCoMo for its mobile terminals and is based on a compact version of HTML. i-mode is not compatible with WAP.
[131] See section 4.2.1.
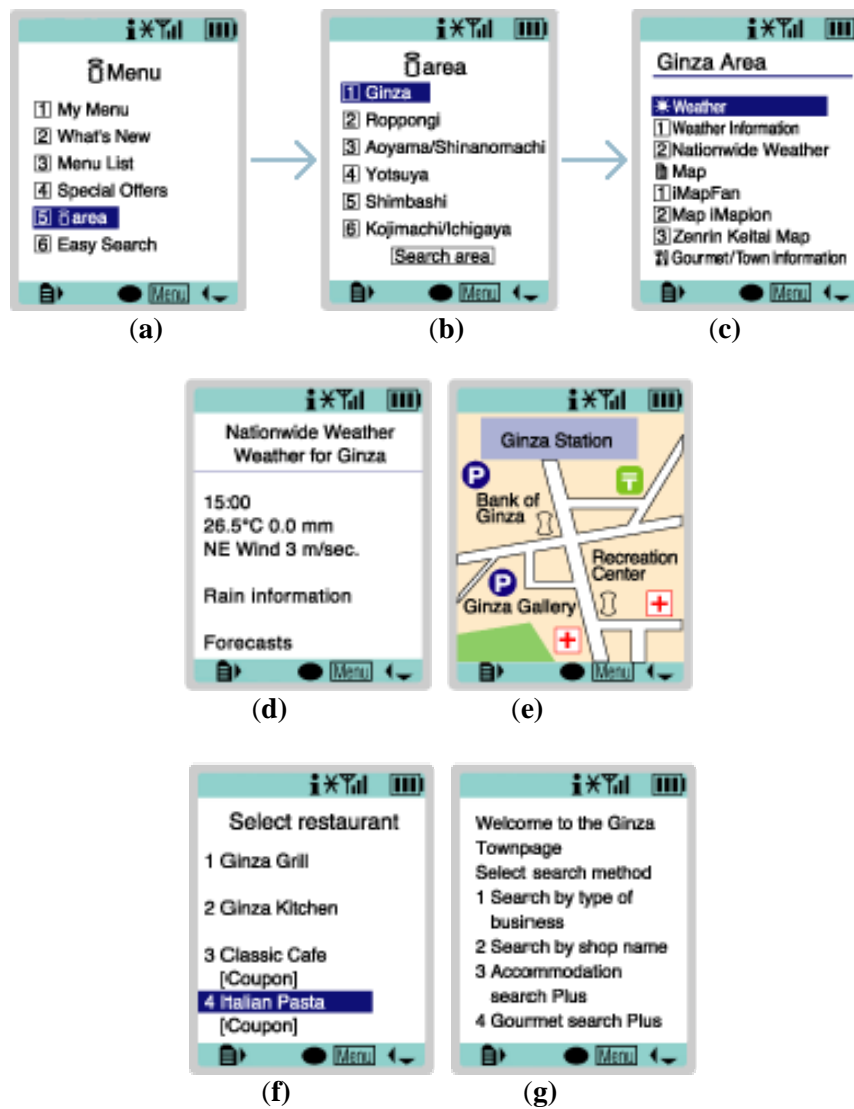
Figure 5-1: Example of the i-area service task flow. The user selects i-area from the i-menu (a); a menu of nearby areas will be displayed (b); the user selects the i-area content he needs (c). From i-menu, the user can access local weather reports (d), download maps (e), view information about nearby restaurants (f), look for hotels, shops or search by business name or type (g).

Discussion

Based on the accuracy and response time requirements for specific services presented in table 4-1 in section 4.1, accurate location is not required when providing location-based information services. The location based information service can be enabled with the accuracy of 500-1000 meters and the accuracy of

75-125 meters is required for "where is the nearest?" service[132]. According to the accuracy requirement mentioned above, i-area is deployed using the appropriate location method (Cell-ID). However, if the user wants to find information regarding nearby places, higher accuracy is needed.

The i-area service is generally available in both indoor and outdoor environments, the i-area service is however unreliable due to the inconsistency of the Cell-ID method. The usefulness[133] of the i-area service therefore varies depending on the physical environment. As discussed in section 4.2.1, the accuracy of the Cell-ID method varies from 100-400 meters in urban areas, from 400-2000 meters in suburban areas and from 1-20 kilometers in rural areas. The service therefore functions well in dense urban areas. An error can occur in suburban and rural areas and the service sometimes provides the information of the wrong areas to a user. The user then has to input the desired area on the mobile terminal manually. The correct location is sent to the service provider and the relevant information of that area is returned to the user *(NTT DoCoMo 2003)*.

Even though i-area has a shortcoming of sometimes providing wrong information to the user, it seems to be acceptable for the users, as NTT DoCoMo claimed to have 500,000 accesses to the i-area service per day in 2004 *(NTT DoCoMo 2004a)*. The user acceptance of the i-area service is related to the user experience aspect, how the user experience the service depends on the user expectation, as discussed in chapter 3. Regarding the shortcomings of i-area, the service provider has announced clearly in the i-mode user's manual *(NTT DoCoMo 2003)* that the user might need to input the right location information manually in order to get the relevant information. From this announcement, the users are always aware of the possibility of inaccurate location detection provided by the i-area service, and therefore the user may not be very disappointed when an error occurs.

i-area is accessible using an i-mode terminal with short key 'i' and the user can accomplish his tasks using a graphical user interface which is likely to be easy to use. The option of controlling the user privacy by turning on and off the location function at the terminal is not available because Cell-ID is used, as discussed in section 4.2.1. Although this function is not available, it is likely that privacy concern is not very high, as the user's location cannot be pinpointed precisely due to the use of Cell-ID method[134].

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[132] The user might be able to find the nearest service points if he is in urban areas, as the Cell-ID achieves the accuracy of 100-400 m. in these areas.

[133] See section 3.3.2.

[134] As mentioned previously in section 4.1.1, the level of privacy concern varies depending to the location accuracy. Knowing which base station the user is connected to is more acceptable than knowing on which street corner the user is *(Beeson et al. 2002)*.

5.2.2 Tracking and emergency services

Tracking services is one of the mobile location services that can potentially provide a good user experience if it is used amongst trust parties such as family members and friends, and the members in the group are willing to be tracked by others. Knowing that the loving person is there can generate positive emotions (e.g. safe, warmth, enjoyment, entertainment, satisfaction, etc.). On the other hand, a tracking service can also provide a bad user experience and negative emotions (e.g. fear, untrustworthy) if the person is not willing to be tracked and if the service is used amongst mistrusts. Various tracking and safety services are offered in Japan and South Korea. The services are provided in a similar way and five different tracking and emergency services available in Japan and South Korea are presented in the following sub-sections.

5.2.2.1. imadoco search™

imadoco search is a kid monitoring service launched by NTT DoCoMo in March 2006 *(NTT DoCoMo 2005a)*. This service allows parents to check the location of their children's mobile terminal or receive regular emails detailing its current location. This requires the kids to have a 3G FOMA[135] terminal (with or without A-GPS) and the parents to have a mobile terminal that supports i-mode services *(NTT DoCoMo 2005a, NTT DoCoMo 2007a)*. Parents can also use a computer to track the locations of their kids. In addition, parents can receive alerts if their children go outside of designated areas.

For this service, NTT DoCoMo has introduced a child friendly 3G terminal (SA800i) *(NTT DoCoMo 2005b)*. This terminal features a built-in location tracking function using gpsOne *(Kim 2006)* and it has been designed in a way so that children cannot disable the tracking feature *(NTT DoCoMo 2005b; NTT DoCoMo 2007b)*. It can be set to a mode where it can automatically switch itself on and send location information if the kid turns off the terminal. There is also a battery lock preventing anyone from trying to disable communications by removing the battery, as shown in figure 5-2.

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[135] FOMA, official abbreviation for Freedom of Mobile Multimedia Access, is the brand name for the 3G services being offered by Japanese mobile phone operator NTT DoCoMo. FOMA is based on the WCDMA standard.

Figure 5-2: Battery lock of the child friendly terminal designed for imadoco search service *(NTT DoCoMo 2007b).*

This terminal also includes a panic alarm feature, which the kids can activate if they feel that they are in danger. When the panic alarm is on, the kid is allowed to have conversations with up to 4 pre-registered people simultaneously and when the child calls the parent's phone, the location of the child is automatically displayed. The parent can also choose to track the location of the child periodically with 15, 30 or 60 minutes intervals. The service outlook of imadoco is shown in figure 5-3.

Figure 5-3: An example of the imadoco search service (*NTT DoCoMo 2007c).* The parents can track the location of the child at specific points of time using a mobile terminal or via the internet. The child's location is shown in the form of a graphic map.

Discussion

The usefulness of a tracking service depends on the location accuracy; higher accuracy provides a higher level of usefulness. As presented in table 4-1 in section 4.1, tracking and emergency services can be enabled at the accuracy of 50-300 meters. The service usefulness of imadoco can be degraded in indoor environments if the GPS signal cannot be received or in suburban and rural areas if the child carries a terminal without GPS functionality. In the case that the GPS functionality is not available, the Cell-ID method will be used to detect the user's location.

To use the imadoco service, it requires that the child carries a FOMA terminal (with or without GPS) and that the parents have i-mode terminals. From a user experience point of view, this obligation limits the service availability and affects the user experience towards the services[136].

For imadoco search service, the children have no option of controlling their own privacy even when they turn the mobile terminal off. Technically, the children's location can always be tracked by the network operator[137], unless the child turns off the terminal. But for this service, there is an option where the parents can set the terminal to a mode where it can turn itself on (in a very short period) and send location information to the parents through the service provider, even when the child turns off the terminal. This means that the location of the child will be tracked periodically by the operator. From the privacy point of view, the child's privacy is violated. However the target users of the imadoco service are the parents (who pay for the service) and not the child. The option of periodically sending out the location of the child without the child's notification, gives a positive meaning in the user experience point of view, as the parents' requirement can be fulfilled.

A positive feature provided by the imadoco search service in the user experience aspect is that the parents can have control of the service with regards to e.g. safe areas selection, choose when and how often to receive the child's location update, etc. The operator has also developed a child-friendly terminal (SA800i) for this service. This terminal is compatible with kids' i-mode, a service for FOMA i-mode subscribers. The service will restrict access to unofficial i-mode sites to prevent children from viewing adult content. The kids' i-menu will only list content suitable for children *(NTT DoCoMo 2005b)*.

5.2.2.2. Safety Navi

Safety Navi allows users to easily check the location of family members or other people they are concerned about *(KDDI 2005)*. The safety Navi is based on gpsOne

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[136] As discussed in section 3.3, the service should preferably be available, accessible and reliable regardless of time, place, terminal, standard, network and operator.
[137] See section 4.2.1.

technology (i.e. the combination of Cell-ID and A-GPS)[138]. The Safety Navi includes "Safety Navi area notification" and "Safety Navi location checking".

- **Safety Navi area notification**

This service provides automatic notification to family members (or others) when the user enters (or leaves) pre-registered areas. The notification can include a pre-registered message.

The service can be used to automate the sending of day-to-day messages to family members' mobile terminals such as when leaving school, arriving at the nearest train station, or sending notification when a child goes out of the desired area while playing at the park.

- **Safety Navi location checking**

This service has two sub-services: 'Location check mail' and 'always-on location check'. The 'location check mail' allows the user to check the location of someone in their address book without prior registration by sending an email. Then, with the receiver's permission, location information is sent back.

The 'always-on location check' allows automatic location checking of pre-registered parties. The service allows up to three registered partners (who's location can be searched), and up to five permitted users (who can search for the location of the terminal).

The Safety Navi has similar options as the imadoco search service provided by NTT DoCoMo presented in section 5.2.2.1. The service provider has rolled out a special terminal (A5520SA) designed for children *(KDDI au 2007)*. This terminal includes a security buzzer[139] key which the kid can activate when he is in danger. When this key is activated, the child's location will be sent to 5 pre-registered persons set by the parents. The buzzer volume is approximately 98 dB at a distance of about 10 cm from the terminal's speaker and approximately 80 dB at a distance of about 100 cm from the terminal's speaker (80 dB corresponds to the noise level of roads with heavy traffic and inside subway trains)[140]. Some surrounding environments may make the buzzer difficult to hear. Also, the volume of the buzzer cannot be adjusted[141]. An example of the service outlook is shown in figure 5-4.

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[138] See section 4.2.6.
[139] The security buzzer works the same way as the panic alarm available on the 3G terminal (SA800i) used for the imadoco service.
[140] Ibid.
[141] Ibid.

Figure 5-4: An example of Safety Navi service display *(KDDI au 2007)*. On the side of the child (left), he can see who he is talking to and on the side of the parent (right), the location of the child is displayed in a 2D map together with the route guidance from the current location of the parents to the child's whereabouts.

Discussion

Safety Navi is very similar to imadoco service from the user experience point of view. The service usefulness varies depending on the physical environment and the availability of the location technology. The Safety Navi theoretically provides less accurate location if the child is inside buildings and the signal from GPS satellites cannot be received. Although the same technology (Cell-ID) will be used in both imadoco and Safety Navi if the GPS signal cannot be received, the imadoco service might provide a better accuracy when the child is in indoor environments. This is due to the fact that the imadoco service is based on UMTS networks and Safety Navi is based on CDMA networks, and the coverage of the UMTS base station is generally smaller than the CDMA base station.

For both imadoco and Safety Navi, a special terminal is designed for the service. The terminal is easy to use, as the children can activate the emergency key at the terminal, and then the location is automatically sent to the parents and a conversation between the child and the parents is started.

From a personalization point of view, Safety Navi is more personalized than imadoco, as the child can see the picture of his parent while using the service. The service also shows the route from the location of the parents to the location of the child, which increases the service usefulness. With the terminal designed for Safety Navi service, the colorful user interface is designed specially for children (see figure 5-5).

Figure 5-5: Child-friendly user interface designed for the terminal used for the Safety Navi service *(KDDI au 2007)*. The main menu screen has explanations for each function that a child can easily understand. It has many fun features, including flash screen that displays a different message every time the terminal is turned on.

From the privacy aspect, the child has no option of controlling his privacy. However, similar to the imadoco service, the child is not a target user who is going to pay for the service but the parents are. This lack of privacy therefore gives a positive meaning in the user experience perspective.

5.2.2.3. i-kids

i-kids service is a child tracking service provided by SK Telecom, South Korea *(SK Telecom 2007)*. The child location is tracked using A-GPS location technology. The child's location can also be searched through base stations using Cell-ID, but an error can occur in the case that Cell-ID is used. This service is adaptable according to information defined by the users. The user can define how the service should behave in specific use contexts. For example, the parents can designate up to three safe zones each of which is an area having an approximately 2 km radius, so that an alarm is automatically triggered when the child leaves the safe zones *(Kim 2006)*. The parents can choose to receive the "automatic location report" and/or the "moving path display service". The "automatic location report" automatically reports the location of the child 8 times a day and the "moving path display service" traces and displays a child's traveled path for the past 24 hours as well as the 8-hour path from the time set by the parent[142]. This service allows the child to have simultaneous conversations with designated people by pressing the emergency button on the mobile terminal when an emergency situation occurs. In addition, the parents can receive the child's current location information in a text message (the parents need to assign and register the terminal number previously).

If a person besides the parents wants to track the location of the child, he needs to submit a document that can prove his relationship with the child. The permission

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[142] Ibid, p 43.

agreement has to be signed by the child and the parents or the legal representative of the child *(SK Telecom 2007)*.

Discussion

It is likely that the i-kids service has a lower level of usefulness compared to imadoco and Safety Navi services, as the child location is sent in the form of text message only *(SK Telecom 2007)*. Similar to the first two child tracking services, the availability and usefulness of the i-kids service depends on the physical environment and the availability of the location technology. However, the operator manages the user expectation by announcing clearly that an accidental error can occur in finding the location of the child if GPS is not available[143]. This announcement is positive in the user experience perspective[144].

The i-kids service allows the children to control their own privacy by choosing with whom they want their location information to be shared. However, the parents still have full control over the privacy of their children.

5.2.2.4. Phone bodyguard service

This is a GPS emergency calling service provided by SK Telecom and launched in April 2004 *(SK Telecom 2004a)*. This service allows a user to communicate with up to four people at the same time, by pressing the GPS emergency button (e.g. keypad number 9) when an emergency situation occurs. This will contact close friends, relatives, or response personnel who are registered to his or her mobile terminal. Moreover, the user is allowed to send his/her current location information in a text message with a map to the pre-registered four people in any emergency situation. In addition to the callers' current location information, this service allows the other parties to identify the callers' location for 48 hours after the receipt of an emergency call. For instance, if children or senior parents lose their way while on the move, their current location can be determined if their mobile terminal is turned on. An example of the Phone bodyguard service is shown in figure 5-6.

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[143] Ibid.

[144] How the user experiences a service depends on his expectation towards the service, as discussed in chapter 3.

Figure 5-6: Example of Phone bodyguard service *(NATE 2006)*. Only a terminal with GPS functionality is allowed to use the service. The user presses key number 9, if an emergency situation occurs, then the location of the user will be shown on the terminal of the four pre-registered persons.

The Phone bodyguard service can only be used with a dedicated GPS terminal *(SK Telecom 2004a)*. The service use is free of charge, but when users download a map or re-identify the current location of callers, SK Telecom charges 80 won (0.5 DKK) per one time information use. The company also charges for emergency calls[145].

Discussion

The Phone body guard service is an emergency service and the user will be located mainly in the case of an emergency. This service is different from imadoco, Safety Navi and i-kids services in the way that the service is activated by a person who wants to be tracked and not the person who wants to track. The target user of this service is therefore not a tracker.

This service can be accessed only if the user carries a GPS terminal and this limits the service availability in the user experience perspective. The service can be accessed using a short key, which is very user-friendly. The user who is in an emergency situation naturally expects getting help as quickly as possible and using the shortcut key it is likely that the users' expectation is fulfilled.

Similar to the previously described services, the usefulness and availability of the phone body guard varies depending on the physical environment.

5.2.2.5. Bus tracking service

The bus tracking service is offered both in Japan and South Korea. In Japan, the service called "Marunouchi Shuttle" was launched by NTT DoCoMo on November

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[145] Ibid.

20, 2003 *(NTT DoCoMo 2005)*. It provides the location information of the Marunouchi shuttle bus[146] using in-vehicle GPS technology. The user can get the present location and arriving time of the bus at certain bus stops in real-time. To access this service, the users do not need a mobile terminal with GPS functionality, but the GPS receiver is located in the bus.

In South Korea, a similar service is provided by KTF *(Kim 2006)* called "Bus Arrival Notification" and it has currently been one of the popular mobile location services available in South Korea[147]. This service displays the scheduled bus arrival time and current location of the bus, which can be searched by their line numbers. The users can choose between three different search methods[148]:

- **Search for bus line number in the vicinity**. This allows the user to search the bus line numbers within a 500m radius of the user's location and then display their destinations and scheduled arrival time.
- **Searching by first digit**. This allows the user to search for a bus line by the first digit of the bus line numbers.
- **Search by bus line number.** This allows the user to check the scheduled arrival time of a particular numbered bus.

Discussion

The quality of the user experience towards the bus tracking services depends on the precision of the time prediction of the bus arrival and how quickly the user can accomplish their tasks.

5.2.3 Navigation services for pedestrians

Three navigation services for pedestrians are found in Japan and South Korea. 3D Navi offers 3D navigation and others offer 2D navigation maps. All services presented in the following sub-sections utilize gpsOne solution[149] for detecting the location of the user.

5.2.3.1. EZ Navi walk

EZ Navi walk *(KDDI 2003)* is a set of navigation services for pedestrians provided by KDDI on CDMA networks. These services have been launched commercially in October 2003 *(KDDI 2003a)* using gpsOne solution. This set of navigation services

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[146] Marunouchi Shuttle is a city-type free public bus.
http://www.tourism.metro.tokyo.jp/english/webmaga/2004spring/bus/index.html.
[147] Ibid.
[148] Ibid.
[149] See section 4.2.6.

provides real-time location of the user and this location information can be updated continuously *(KDDI 2003)*. As the user walks, the map displayed on the terminal scrolls automatically keeping the current location in the center. The right direction is indicated by an arrow and the route information is also given in text and voice, such as "go straight 20 m and turn to the right".

A similar service was offered by SK Telecom, South Korea in September 2004 *(SK telecom 2004)*. This service is called "NATE pedestrian road guide service". It has similar functions as EZ Navi walk using the same technology – gpsOne.

Discussion

EZ Navi walk, NATE pedestrian road guide service and 3D Navi only differs in how the navigation map is shown (2D or 3D). The discussion of these three services is made in the next section.

5.2.3.2. 3D Navi

3D Navi is the 3D version of EZ Navi walk offered by KDDI. The 3D Navi service became available in April, 2006 *(KDDI 2006)* and it is the world's first mobile navigation service using high resolution three-dimension digital mapping to guide the direction for a mobile user.

3D Navi navigates pedestrians to their destination using voice, 3D map and text. The pedestrians will pass through various intersections or locations, and at each of these 3D Navi displays images of the surrounding scenery, such as buildings and landmarks. The difference between EZ Navi with 2D navigation and 3D Navi with 3D navigation is shown in figure 5-7.

Figure 5-7: Examples of 2D and 3D navigations provided by EZ Navi walk (left) and 3D Navi (right) *(KDDI au 2007)*. For 3D Navi, the user can first get an overview of the route in 2D format and then switch to a 3D map which can give a more detailed and clear guidance.

Discussion

The navigation service for pedestrians is mostly used in outdoor environments. Both EZ Navi walk and 3D Navi work based on gpsOne technology which is likely to function well in outdoor environments[150]. The EZ Navi service navigates the user by using 2D map while 3D Navi offers 3D navigation map. Text and voice navigational assistance are also available for both of the services. Providing navigation support in various formats improves the possibility of fulfilling the user expectation and probably gives a positive user experience since the users can choose the preferred navigation format.

From the user experience perspective, a 2D map may be more user-friendly compared to a 3D map. The 2D map has been used to represent navigation information for thousands of years and the user is more likely to be familiar with the 2D map than the 3D map. Using 3D navigation could generate positive emotions (cool, modern, innovation). However, the possibility of utilizing 3D navigation relies on the technology context, as 3D navigation is likely to demand a lot of processor, large bandwidth and power consumption. For some users and for some tasks a 3D navigation could be more useful than 2D maps and for others not. It might not be easy to find the direction to the users' destination by looking at a 3D model of the visited city on a small display of a mobile terminal, especially if the users do not know the city and do not know where they are. They might be lost both in the real and virtual world. If the users do not know where they are, 2D maps are most likely better, as they are good at describing a large area in a small space.

The Navi users have an option of switching between 2D and 3D maps, which is positive in the user experience perspective. As maps in three dimensions are displayed, users can enjoy a more comprehensible service, particularly at complex intersections or locations, which might be difficult to understand with a standard 2D map.

A 3D map is not available for the NATE pedestrian road guide service. However, this may be acceptable in the user experience point of view, because the user is more familiar with 2D map compared to 3D map as previously discussed and the lack of 3D map does therefore not decrease the service usefulness.

Verbal and text navigation formats are also offered by all three services. Navigation directions provided in a verbal format is a good feature to use on vehicular navigation systems, as the driver is occupied with driving. For pedestrian navigation services, noise from the use contexts or environments where the service is used (e.g. traffic areas) can make the voice navigation difficult or almost impossible to hear. The voice navigation might also affect the user's privacy, as the user might not

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[150] See section 4.2.6.

want the people around him to know if he is going to turn left or right on the next street corner. The voice navigation is obviously useful for a user who is blind.

5.2.4   Telematics-related services

One category of mobile location services that has increasingly gained attention from the users in Asia is telematics-related services, which is confined to vehicles and uses GPS navigation in the car for location determination. The car connects to the mobile network using a built-in communication unit in the car. Telematics-related services can provide up-to-date traffic information, transmit information on specific businesses in the car's area, and conduct remote diagnosis of car troubles and report accidents. While other types of mobile location services are designed for personal use for both indoor and outdoor, telematics-related services are designed to be used outdoors. Available telematics-related services are presented in the following sub-sections.

5.2.4.1.   NATE Drive Service

NATE Drive service was launched by SK Telecom in February 2002 *(SK Telecom 2002)*. This service is an interactive communication service that mainly guides drivers to the safest and most convenient roads through voice, text and graphics. Information is provided on a real time basis utilizing GPS technology and mobile networks. Besides navigation service, various location-based information services, entertainment services and safety services are offered to the Nate Drive users as shown in figure 5-8.

Figure 5-8: Different services offered under the NATE Drive services *(Lim 2005)*.

Using the NATE Drive service, drivers are assisted when their cars run low on fuel and they are in unfamiliar areas. Instead of choosing the nearest gas station, the users will be able to request a list of prices of gas stations within a 1.5 kilometers radius of their exact location. Once a low price is selected, the mobile phone displays exact driving directions to the chosen gas station *(Reynolds & Jin-Kyu 2004)*. For the emergency rescue service, the user just presses the "E" button to request assistance if they have a car accident. The user location will be detected automatically using GPS technology and a person will be sent to repair the car *(SK Telecom 2002)*. The user can access the NATE drive service using either a mobile terminal or an embedded terminal in the car *(Lim 2005)* as shown in figure 5-9.
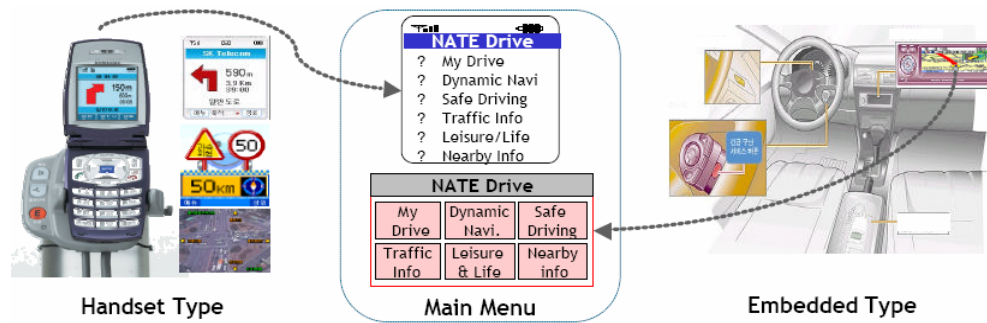
Figure 5-9: The user can access the NATE Drive service using a mobile terminal or an embedded terminal in the car *(Lim 2005)*. For the embedded terminal, the user interacts with the terminal using a touch-screen.

5.2.4.2. Other telematic-related services in south Korea

K-ways is a telematics-related service similar to NATE Drive provided by KT Freetel *(Kim 2006)*. Several sub-services are provided under the K-ways service package. The "search by telephone number" service finds the optimum route to the destination specified by the telephone number and can be linked to information regarding public transportation such as the subway and bus as well as pedestrian routes. The "come home safe" service transmits a friend's travel path using GPS, and the "mobile dispatch" service dispatches company security personnel when a hotkey is pressed during emergencies. The "Current Weather" service displays the weather of the users' current location.

LG Telecom also offers telematics-related services such as the route guide service which is available on 3-dimensional images of intersections, bridges and underground roads *(Kim 2006)*. Unlike the other services, which require the mobile

phone to be connected to a GPS kit, this one has the telematics kit in the vehicle without the mobile phone[151].

Discussion

The NATE Drive, K-ways and LG Telecom Telematics services are designed for specific target users (drivers) in specific physical environments (in the car/outdoor/on the road) and in a specific situation (while driving). NATE drive service offers three different kinds of navigation, voice, text and graphic map. Voice navigation is likely to provide a better usability and user experience, as the user is occupied by driving. Text and graphic navigations are useful in the traffic environment, where the voice navigation is difficult to hear. It is positive in a user experience perspective that the service provides different kinds of navigation, as the user can choose his preferred format.

5.2.4.3. Okutto-Keitai

The Okutto-Keitai service was launched by NTT DoCoMo, Japan, in October 2004 *(NTT DoCoMo 2004)*. It is an integration of a GPS navigation system in the car and a mobile communication system (car multimedia). The service allows drivers to receive i-mode digital maps and restaurant information corresponding to the area in which their car is located or destined. The driver can request the information from CARWINGS's live operator or select the desired information manually on the navigation system. Within a few minutes, the CARWINGS data center will send an e-mail to the driver's i-mode compatible mobile terminal with a URL link to the information he or she requested. By clicking on the URL, the driver will be able to view the i-mode site containing the information. The Okutto-Keitai service platform is shown in figure 5-10.
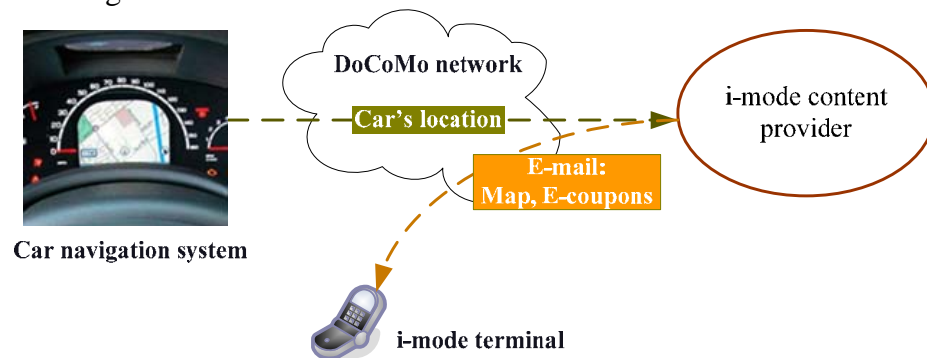
Figure 5-10: Okutto-Keitai service platform based on the presentation given by NTT DoCoMo (*Kitagawa 2005*). The car's location is sent to the i-mode content provider via the NTT DoCoMo network and the information is sent back to the user via the operator's network, in the form of an i-mode e-mail with links to the i-mode website of the restaurants nearby.

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[151] Ibid.

Discussion

Okutto-Keitai is a Japanese limited version of telematics-related services launched in South Korea. The Okutto-Keitai has been designed without taking the context of use into account and this service potentially provides a much lower level of user experience compared to the services offered in South Korea due to the following reasons.

- The user cannot get real time information, as the operator reveals that the requested information will be sent in the form of i-mode mail with a link to the requested information within a few minutes after the user requests it.
- The way the information is delivered does not seem to fulfill the user expectation in the context of use. The driver is driving a car and he needs to pay attention to driving; receiving an e-mail, opening and reading the e-mail and linking to the i-mode website is unpractical to do while driving.
- The content offered by Okutto-Keitai is very limited (only a digital map and the location of nearby restaurants are available). It is likely that the location of other service points (e.g. gas stations, stop points) are more relevant for a driver than the location of the restaurants but that information is unavailable.

5.3   Services in Western Europe

Mobile location services have been commercially available in Western Europe for several years. The services such as location-based information services, tracking and location-based sensitive charging are currently available in Western Europe. Most of the services are offered on GSM networks based on SMS and WAP, and Cell-ID is the dominant location method used in Western Europe. Since the Cell-ID method[152] is the main location technology used in Western Europe, high accuracy location information cannot be provided and this limits the capability of the mobile location services. Different services require different location accuracy and Cell-ID can only capture 50% of the standard mobile location services presented in table 4-1 in section 4.1. The mobile location services in Western Europe are not as widely used as the services in Japan and South Korea. The following sub-sections present and discuss different kinds of mobile location services offered in Western Europe.

5.3.1   Location based information services

Various location-based information services are available in Western Europe. This section presents a number of these services.

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[152] See section 4.2.1.

5.3.1.1. Mobile yellow pages

The world's first mobile yellow page service was launched by Telia, Sweden in June 2000 *(Walmsley 2002)*. This service allows users to find the nearest service points such as restaurant, dry cleaner or subway station, or whatever business or service they might be looking for. The users can also check the weather forecast in their current areas. Users can access the service using either WAP or SMS and the user location is detected using the Cell-ID method.

5.3.1.2. Quick map

The Quick map service *(Hutchison 3G UK 2006b)* is a location based information service using the Cell-ID method provided by 3, UK. It allows the users to download a map of their current area or any other desired area. The users can zoom in and out for a better view. An example of the quick map display is shown in figure 5-11.
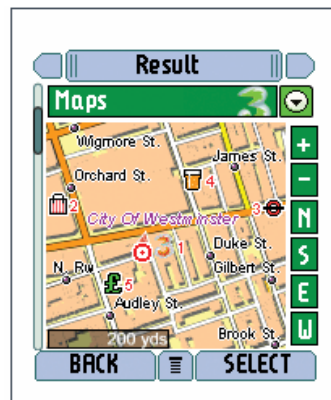
Figure 5-11: An example of the map display offered by the Quick map service *(Hutchison 3G UK 2006b)*.

5.3.1.3. Find

The Find service *(Hutchison 3G UK 2006e)* is a kind of mobile yellow pages service available for 3G users in the UK provided by 3 using the Cell-ID location method. It has similar functionalities as the i-area service presented in section 5.2.1.1. The service task flow of the Find service is shown in figure 5-12.

Figure 5-12: Task flow of Find service provided by 3, UK *(Hutchison 3G UK 2006e)*. First the user chooses Find service (a); and chooses My Nearest menu (b); then chooses to search for the locations of the restaurants nearby (c). The user selects the preferred restaurant (d), then the system displays the user's current location, here the user have an option to input the correct location in the case that the system displays the wrong location or the user prefers to find the location of the restaurant in another areas (e); the service then displays the location of the nearest French restaurants on a 2D map (f).

5.3.1.4. Discussion

The location-based information services available in Western Europe can be divided into second and third generation services on 2G and 3G networks. The services on 2G are not very attractive because they are offered based on SMS, and the mobile location services using SMS provide very low usability *(Nielsen 2000)* generally resulting in a negative user experience. The location-based information services provided by 3, UK are similar to the i-area service offered in Japan and they are generally more attractive than the services based on SMS.

5.3.2 Navigation services

A real time navigation service such as those offered in Japan and South Korea[153] requires an advanced location method that can provide highly accurate location information with short response time. As an advanced location method is not adopted in Western Europe[154], only simple navigation services in the form of static map is offered.

5.3.2.1. A to B

The A to B service is a simple navigation service for pedestrians provided by Hutchison 3G UK *(Hutchison 3G UK 2006c)*. It allows the user to find the route from one point to another. The service does not depend on the location method, as the user is required to manually input their starting point and destination point. The static navigation map is shown in figure 5-13.

Figure 5-13: An example of the navigation map provided by A to B service *(Hutchison 3G UK 2006c)*.

5.3.2.2. Discussion

Some kinds of mobile location services can be offered without using any location method. The A to B service is an example of a service in this group. It is similar to route guidance services provided on the internet (e.g. by krak[155] and map24[156]). The user can manually input his starting point and destination. This service will only be useful if the user knows where he is. The factor affecting the user experience in the technical point of view in this case is therefore not the location accuracy and response time provided by the location method but the data rate achieved by the

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[153] See section 5.2.3.
[154] See section 4.3.
[155] www.krak.dk
[156] www.map24.com

mobile network. The user may get a good experience from using the "A to B" service if he can download a navigation map at a data speed comparable to the fixed internet.

5.3.3 Tracking services

Several tracking services are found in Western Europe and examples of these services are presented in the following sub-sections.

5.3.3.1. FriendFinder

The FriendFinder service *(Finney 2002)* is offered by Telia, Sweden. It allows mobile users to find the real-time location of friends in the vicinity using SMS, WAP or the Web. The Cell-ID method is used to detect the mobile users' location. If the service is used through the web, users must manually input their own location. With SMS, users send a message to FriendFinder's mobile terminal number and information on other users' locations are sent back. Web-based users receive a street level map detailing the location of the friends. Once the locations are known, the users can communicate with their friends either individually or in predefined groups.

The users need to opt in to use the service, but they remain in control when it is activated. They can choose to switch off the service[157] at any time or they can refuse a request from a friend to be located.

5.3.3.2. ChildLocate

This service allows parents to track the location of their children carrying GSM mobile terminals. This service is not offered on 3G networks *(ChildLocate 2007)*. The location can be tracked via a website provided by the service provider or by sending an SMS from a mobile terminal. The ChildLocate service is available for all existing mobile terminals on the networks of Vodafone, T-Mobile, O2 and Orange[158]. ChildLocate uses location information from the GSM operators in the UK and the Cell-ID method is used. The expected accuracy of the service offered by different operators is shown in table 5-1.

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[157] The user can switch off the service, but the user's location is still tracked by the mobile operator as discussed in section 4.2.1.
[158] Ibid.

Table 5-1: Expected service accuracy of the ChildLocate service offered by different operators[159].

	Vodafone (900 MHz)	T-Mobile (1800 MHz)	Orange (1800 MHz)	O2 (BT Cellnet) (900 MHz)
Urban	50-350 meters	400-600 meters	400-600 meters	600-900 meters
Suburban	350-550 meters	600-2000 meters	600-2000 meters	900-2500 meters

As shown in table 5-1, the service provided on Vodafone networks provides better location accuracy than the others, since Timing Advance[160] is used *(ChildLocate 2007)*. An example of ChildLocate is shown in figure 5-14.

To locate a child, the user needs to send a simple SMS **Find <child name>** to **60066** and the location of the child will be sent back to the user in the form of a text message.

Example:

Send "Find Alan" to 60066

The user will receive the text message showing the location of his/her child as shown in the right figure.

Figure 5-14: Tasks needed to accomplish when using the ChildLocate service *(ChildLocate 2007)*.

The annual service charge of the ChildLocate service is 765 DKK and up to five mobile terminals are allowed to be searched[161]. Beside the annual service charge, the users have to pay a per time basis charge each time they try to locate the child and also for sending SMS. The service charge is free for the first two unsuccessful location attempts but for further unsuccessful location attempts the user will be charged[162].

A similar tracking service called Traceamobile is offered using the same location method as the ChildLocate service *(Traceamobile 2007)*. The Traceamobile service is only available for the GSM users on Vodafone, T-Mobile, O2 and Orange

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[159] Ibid, http://www.childlocate.co.uk/faq.html.
[160] See section 4.2.1.
[161] Ibid, http://www.childlocate.co.uk/prices.html
[162] Ibid, http://www.childlocate.co.uk/faq.html

networks and it is expected to be offered on 3G networks early 2008[163]. For this service, the users have to pay even when the tracking fails[164].

5.3.3.3. Discussion

According to table 4-1 in section 4.1, a tracking service will be attractive if the location accuracy of 10-50 meters can be provided. The tracking services presented above work based on the Cell-ID method which does not meet the accuracy requirement of the service and this affects the service usefulness and can potentially affect the quality of the user experience. With the charging strategy used by the service providers, the users have to pay for the service request even when the tracking is not successful. This gives a double negative user experience, since the user can neither accomplish his tasks nor reach his goal but he still has to pay for the service[165]. This might scare the user away from using the service. For Vodafone services, the operator adds Timing Advance into the network and this enhances the location accuracy and improves the service usefulness.

The tracking services available in Western Europe are based on WAP and SMS, which provides very low usability and may result in a negative user experience. One positive thing about the mobile location services in Western Europe is that the user does not need an expensive terminal with additional software and hardware in order to access the services.

5.3.4 Location sensitive charging

Location sensitive charging uses the potential of location techniques not for providing location-based services but for offering pricing for all kinds of mobile services depending on the location of the users. Location sensitive charging is currently offered by many operators in Western Europe. This service is attractive for mobile operators who want to capture wire-line minutes by offering less-expensive rates via mobile networks based on the user's current area or zone. Location sensitive charging offers an additional form of price differentiation. Examples of location sensitive charging services offered in Western Europe are presented in the following sub-sections.

5.3.4.1. ZonePlan

Sonofon, Denmark, has offered a location sensitive charging service called ZonePlan for the business segment since 1999 *(Sonofon 2004)*. This service intends

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[163] Ibid, FAQ.
[164] Ibid, FAQ.
[165] As presented in section 3.3.4, price is one of the offline issues that affect the user experience formation. The users normally expect to get what they pay for and if the users pay more, as a rule they expect to get a better service *(Hiltunen et al. 2002)*.

to shift traffic from the fixed network to the mobile network. The ZonePlan service allows users to use their mobile terminal in a predefined geographical zone with a call rate comparable to those for fixed telephony. Companies can configure designated geographical areas across Denmark and benefit from mobile call charges that are close to fixed line rates. The zone is set up by specifying the network cells bordering. Users can choose between three ZonePlan options:

- **CompanyZone** covers the business premises, and may also cover the surrounding area depending on the position of the network transmitters. It can consist of multiple zones to support companies with multiple sites.

- **TemporaryZone** provides coverage for a temporary location outside the company's premises. This option can be activated for a maximum period of six months, after which it can be converted to a companyZone. A typical example would be a construction site, where employees operate for a limited time period.

- **HomeZone** is defined by the employee's home address. This option allows employees to work from home and still benefit from CompanyZone rates.

5.3.4.2. Genion

Genion is a location sensitive charging service provided by O2, Germany *(O2 2006)*. This service allows mobile users to pay fixed network rates for calls initiated from their home area. The service was launched in 1999 on GSM networks and it was re-launched in June 2005 with a streamlined pricing structure and a new tariff option and package. Here customers benefit from cheaper calls to friends on the O2 network by using a new call option, inside O2.

Genion, in combination with O2 Germany's mobile broadband product surf@home, also allows the consumer to surf the internet and talk at home without the need for a fixed line, using the UMTS network. Pioneered by O2 Germany, surf@home is the first product of its kind in Europe to integrate 3G and wireless LAN technologies into a single, compact box for use in the home or office. Customers simply use their PC, PDA or notebook across a wireless LAN via the box and out over the 3G network to access the Internet at speeds of up to six times greater than ISDN[166]. The same service is offered by O2 UK called O2 Home.

5.3.4.3. Discussion

For a location sensitive charging service, revenue is not directly generated using a user location, but the location makes other services become more attractive to the user by offering the attractive tariff based on the zones in which the user accesses

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[166] Ibid.

the service. The location sensitive charging is invisible to the user and how accurate the location can be determined does not affect the user experience towards the service, but it will affect the user experience towards the billing management of other services.

5.4 Discussion: Strong points and shortcomings of mobile location services offered in Asia and Western Europe

In the last sections the mobile location services commercially available in Asia and Western Europe have been examined and discussed. This section provides an overall perspective of these services including the strong points and the shortcomings of the services.

5.4.1 Services in Asia – Japan and South Korea

Mobile location services in Asia are maturing quickly and almost all kinds of standard mobile location services listed in section 5.1 are offered. Some of the available services are more popular and useful than others. For example, navigation services for vehicles and pedestrians are very useful in Japan due to the labyrinthine nature of Japanese cities with confusing addressing systems. Tracking services are very popular in South Korea and used between friends, couples and family members. The number of subscribers of tracking and safety services provided by SK Telecom in South Korea alone is already 24 millions[167] and the number is growing steadily *(Kim 2006)*. Continued growth of the mobile location service industry has been confirmed in a report published by the Korea LBS Industry Council. According to the report, its domestic market size was 565.5 billion won (3.55 billion DKK) in 2005 and is estimated to be 850.3 billion won (5.32 billion DKK) in 2006. It will then surpass 1 trillion won and reach 1.7 trillion won (10.64 billion DKK) in 2008 *(Kim 2006)*. The characteristics of the mobile location services industry in Japan and South Korea are summarized in the following sub-sections.

5.4.1.1. The right location technologies are chosen

The right location technology does not only fulfill the service requirements but also meets the implementation cost of a service provider. With the mobile standard used by some of the operators in Asia (CDMA), the operators have an option of choosing the most effective location solution like gpsOne for their infrastructure[168]. The

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[167] As of July 2006 the number of South Korean population is 48,846,823 *(CIA 2006)* and the number of subscribers for tracking services provided by SK Telecom alone is 50% of the size of population.
[168] See table 4-6 in section 4.3 for the location technology options of the operators and section 4.2.6 for gpsOne solution.

location detection using gpsOne enables a broader range of mobile location services in Asia, especially Japan and South Korea, compared to other markets. Based on the accuracy and response time requirements presented in table 4-1 in section 4.1 and the services offered in Japan and South Korea presented in section 5.2, it can be seen that all the services available in both countries are offered using the right location technologies.

5.4.1.2. Advanced terminals with MLS support are in the market

As of January 2007, 65 models of 3G terminals with GPS build-in are available in the Japanese market, and 74 models are available in the South Korean market *(3gtoday 2007)*[169]. Most of the models are CDMA terminals and only 14 models are UMTS terminals. There are also many smart terminals which can be used with GPS boxes. Some of the mobile navigation solutions are based on a combination of a smart terminal and a separate GPS device connected by Bluetooth. There are also mobile terminals that have been specially designed for mobile location services, for example SA800i which is designed for imadoco search service in Japan and the i-kids terminal which is designed for the i-kids service in South Korea[170] as shown in figure 5-15.

SA800i, for imadoco service   **i-kids mobile terminals**

Figure 5-15: Mobile terminals designed specially for child tracking services in Japan (left) and South Korea (right).

It is likely that more advanced mobile terminals make users experiment with mobile data services more frequently. The mobile users in Japan and South Korea are very demanding, and this has pressured the manufacturers into producing smart mobile terminals that are small, lightweight and capable of longer talk time *(Mitsuyama 2005; Reynolds & Jin-Kyu 2004)*. Many smart mobile terminals available in the Japanese and South Korean market are equipped for the provision of MLS. The latest mobile terminals now come with a GPS as well as memory card slot, an

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[169] The reference is available under the devices search function.
[170] See section 5.2.2.

embedded-camera with more than two mega pixel, (two-dimensional) bar code reader, contact less IC chip, DMB, FM radio tuner, and music player function *(Mitsuyama 2005; Reynolds & Jin-Kyu 2004)*. Many new services can be brought to the market with these smart terminals.

5.4.1.3. Good user experience management

By the nature of mobile and location technologies available today, providing always consistent and always available mobile location services is still not possible[171]. To prevent the user from generating too high expectations about the service, it is required that the service provider informs the user about unexpected errors that might occur due to the nature of mobile and location technologies. This is one of the key strategies to manage the user experience. Managing user experience[172] is one of the keys driving the success of mobile location services in Japan and South Korea. The result of successful user experience management can be seen in the case of i-area service[173].

5.4.1.4. Flat rate service charging is attractive

Unlike operators in Western Europe, which have normally chosen to discount the service charge for voice services and maintain a premium on data[174], Japanese and South Korean operators have changed from the per packet data charge strategy to flat rate pricing strategy. This strategy allows the user to use the data service as much as they want with a fixed price. Table 5-2 illustrates flat rate pricing in the Japanese market.

Table 5-2: List of flat rate pricing offered by different network providers in Japan *(Anderson 2006)*. The users pay a fixed monthly charge and are allowed to download and upload an unlimited amount of data.

Operator	Launch Date	Tariff name	Cost (¥)	Cost (DKK)	Description
KDDI	October 2003	EZ Flat – level 2	4200	192	Unlimited
NTT DoCoMo	June 2004	Pake-Houdai	3900	179	Unlimited
Softbank Mobile Corp	November 2004	Packet Free	3900	179	Unlimited

In South Korea, there are several flat rate options for multimedia services like video on demand and music download, including a full-scale flat rate tariff that allows

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[171] See section 4.2.7.
[172] See section 7.1 for the user experience management.
[173] See section 5.2.1.1.
[174] See section 5.4.2.5 for a detailed discussion of service charges in Western Europe.

unlimited data traffic for a monthly payment of between 24,000 won and 26,000 Won (154-176 DKK) *(Seong 2006)*. SK Telecom's Nate Drive offers an unlimited service for 18,000 Won (117 DKK) per month.

The flat rate charging is easy to understand, simple to communicate, simple to bill, and makes it simple to make a financial planning for the user. This flat rate strategy has kick-started the usage of data service in Japan and South Korea *(Anderson 2006)*.

5.4.1.5. The mobile information society is exciting

The Japanese and South Korean are known as highly technophile people, who are regularly seen sporting the latest technological gadgets *(Srivastava & Kodate 2004; Reynolds & Jin-Kyu 2004)*. They find the mobile information society exciting, as they can find efficient use of the technologies. It is perceived, that the Japanese and South Koreans are more ready to adopt the mobile technologies and services than users in other developed economies *(Reynolds & Jin-Kyu 2004)*. The Japanese and South Korean may be more trusting about how their data is used than users in countries in e.g. Western European[175]. The services such as m-commerce, m-banking, m-wallet and tracking services are already well adopted in Japan and South Korea. Several mobile services, e.g. those dealing with personal information such as m-commerce and mobile location services have been slow to deploy outside of Asia for many reasons, but privacy concerns of users have been one of the biggest concerns. Many Western users will not adopt a technology until their fears have been assuaged[176]. Asians, on the other hand, appear to have a stronger sense of community trust in their institutions to protect their data. This allows the Asian countries such as Japan and South Korea to become a leader in general mobile commerce and services.

The trend in Japan and South Korea is the use of the mobile terminal as a fashion accessory[177]. The South Korean users upgrade their mobile terminal approximately every eight or nine months *(Samsung 2002)* and 63 per cent of the Japanese users replace their mobile devices within two years *(Srivastava & Kodate 2004)*. Young students have an even shorter replacement cycle. This is because they want to have the latest model or service, or the fact that the design or function was "out of date". Most of the new versions of mobile terminals come with GPS built-in and it is likely that adding GPS functionality into a mobile terminal will become mandatory in South Korea *(Jae-Kwon 2006)*. This means that in the near future all the mobile users in South Korea will have a possibility of accessing highly accurate location services and the operators will have a chance to offer almost all kinds of standard

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[175] Ibid.
[176] Ibid, p 55.
[177] Ibid, p 46.

mobile location services listed in section 5.1, since the location method utilizing GPS can capture all standard mobile location services as discussed in section 4.2.5.

5.4.1.6. The MLS development is going on

Although the mobile location services are already widely used in Japan and South Korea, the service providers continuously develop new services to attract the mobile users. Service operators in South Korea are currently focusing on offering point of interest information services (POI) by providing more attractions, restaurants and entertainment spots that will interest mobile users, and by adding more information that will provide practical assistance to the users *(Kim 2006)*. The service providers plan to develop new services such as a mobile coupon service in connection with mobile location service, and to introduce these to the market as soon as possible[178].

Accuracy, availability, accessibility and reliability are the major problems of mobile location services offered in Japan and South Korea even though GPS solutions are mostly used. The inaccuracy is mostly due to the fact that the indoor reception rate of GPS data is only 20% *(Kim 2006)*[179]. As most of the mobile location service requests are made inside buildings *(Sidel & Mayhew 2003; De La Vergne et al. 2006)*, a location solution for indoor environments is required. The operators in South Korea are developing an indoor location solution and this solution will enhance the location accuracy by measuring the delay or signal strength between the base stations. Using this solution, indoor location information is expected to be available with the accuracy of 100~200m *(Kim 2006)*. The expected accuracy is however not appropriate to provide some of the services listed in table 4-1 in section 4.1 such as tracking and indoor navigation services. To cover a wide range of mobile location service, a new indoor location solution is required.

5.4.1.7. The services provide higher level of usefulness compared to the services offered in Western Europe

The services in Japan and South Korea generally provide a higher level of usefulness (utility $\times$ usability)[180] compared to the services in Western Europe[181]. As discussed in section 5.4.1.1 and 5.4.2.2, the appropriate location methods are chosen in Japan and South Korea while the accuracy provided by the location technologies adopted in Western Europe do not fulfill the requirements for many of the services[182]. In addition, the majority of mobile location services offered in Western

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[178] Ibid.
[179] SK Telecom recommends that the users should move to a window when they use a mobile location service indoors utilizing GPS technology *(SK Telecom 2002a)*.
[180] See section 3.3.2.
[181] See section 5.4.3.
[182] See table 4-1 in section 4.1 for different accuracy levels required by different mobile location services.

Europe are based on GSM networks which achieve low data rate[183], and the services are therefore mostly suitable for text based location information. The text based location services offered in Western Europe provide lower usefulness compared to the multimedia location services offered in Japan and South Korea. The usability of the mobile location service depends on the user interface of the mobile terminal and how the service is designed. The mobile terminals available in Japan and South Korea[184] have been designed to support mobile location services. Some of the terminals have shortcut key and the user can easily access the service by pushing the shortcut key, without having to put an effort into sending SMS or browsing for the service like the way it works in Western Europe.

An example case of two different tracking services providing different levels of usefulness can be seen in the case of ChildLocate offered in the UK and imadoco services available in Japan as illustrated in figure 5-16.

Figure 5-16: Two different child tracking services with different levels of utility and usability: ChildLocate service offered in the UK (left) and imadoco service offered in Japan (right).

Figure 5-16 shows examples of child tracking services available in the UK (ChildLocate[185]) and Japan (imadoco)[186]. These services determine the location of

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[183] See section 2.1.1.1.
[184] See section 5.4.1.2.
[185] See section 5.3.3.2.

the child at approximately the same level of accuracy and response time. As shown in figure 5-16, the ChildLocate service provides the location of the child with the accuracy of 396 meters and the imadoco service provides the location with the accuracy of 350 meters. For the ChildLocate service, the user needs to send an SMS with the name of the child to a specific number and the approximate location of the child is sent back in the form of text (see figure 5-16 (left)). The imadoco service can be accessed by pushing "i" menu on the i-mode terminal and the parents can finish their tasks using graphic user interface and the location of the child is shown in the form of graphic map including date and time (see figure 5-16 (right)). With these two services, the parent can accomplish the same thing – locating their child at a specific time. However, it is obvious that the imadoco service provides higher level of usability and utility than the ChildLocate service. The imadoco service can be accessed using graphic user interface, which is likely to be easy to process and consumes less time and effort. In addition the child's location is displayed in the form of a graphic map and this gives a clearer picture of where the child is.

In the case of the ChildLocate service, the utility and usability of the service is limited by the mobile technology and the mobile terminal and its user interface, since the ChildLocate service only works on GSM networks which provide low data rate. With the data rate provided by GSM networks, it is very difficult to handle a multimedia service. imadoco service, on the other hand, works on PDC and UMTS networks. These networks have enough capability to support multimedia data.

5.4.1.8. Lack of availability, accessibility and reliability

Even though the most advanced mobile networks and location technologies are adopted in Japan and South Korea, the mobile location services offered in both of the countries still lack of availability[187] (availability, accessibility and reliability). Most of the mobile location services offered in Japan and South Korea are available and accessible depending on the specific mobile network standard and specific terminal defined by the operators. For some services, the service providers even define that one party needs one specific terminal and others need another kind of terminal, an example is imadoco search service presented in section 5.2.2.1. This limits not only the quality of the user experience but also the willingness of new users to try the service, as the users need to fulfill the requirements of the service providers in order to be able to access the service. Table 5-3 shows the availability of different mobile location services in Japan and South Korea.

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[186] See section 5.2.2.1.
[187] See section 3.3.1.

Table 5-3: An analysis of service availability for some existing mobile location services in Japan and South Korea. The green smiling face represents the strong points; the red sad face represents weak points of the service availability, and the orange face represents something in between.

Service	Service availability
i-area	☹ Available and accessible only for the NTT DoCoMo subscribers. ☹ Available and accessible only on PDC, UMTS. ☹ Available and accessible only with i-mode terminal. ☺ Available and accessible in both indoor and outdoor environments. ☹ Unreliable (due to the Cell-ID location method being used).
imadoco	☹ Available and accessible only for the NTT DoCoMo subscribers. ☹ Available and accessible only on PDC, UMTS. ☹ Available and accessible only if the child carries a FOMA terminal and the parents carry i-mode terminal *(NTT DoCoMo 2005a; NTT DoCoMo 2007a)*. 😐 Accurate location services might not be available in indoor environments. ☹ Unreliable, especially in indoor environments (varies depending on the penetration of the signals received from the mobile networks and GPS satellites).
Safety Navi	☹ Available and accessible only for the KDDI subscribers. ☹ Available and accessible only on CDMA networks. ☹ Available and accessible only with specified terminal models (W32SA, W31T, and A5512CA) *(KDDI 2005a)*. 😐 Accurate location services might not be available in indoor environments. ☹ Unreliable, especially in indoor environments (varies depending on the penetration of the signals received from the mobile networks and GPS satellites).
i-kids	☹ Available and accessible only for the SK Telecom subscribers. ☹ Available and accessible only on CDMA networks. ☹ Available and accessible only if the child carries i-kids terminal. 😐 Accurate location services might not be available in indoor environments. ☹ Unreliable, especially in indoor environments (varies depending on the penetration of the signals received from the mobile networks and GPS satellites).
Phone body guard	☹ Available and accessible only for the SK Telecom subscribers. ☹ Available and accessible only on CDMA networks. ☹ Available and accessible only if user carries the terminal with GPS built-in. 😐 Accurate location services might not be available in indoor environments. ☹ Unreliable, especially in indoor environments (varies depending on the penetration of the signals received from the mobile networks and GPS satellites).

As can be seen in table 5-3, the availability and accessibility of mobile location services in Japan and South Korea depends very much on the specific technology, network, terminal and operator. The lack of availability and accessibility of mobile location services in Japan and South Korea is also due to the lack of open standards and open environments that allow interoperations between different networks, terminals and services provided by different venders and providers. To allow interoperations of different technologies, networks, terminals and services, different business players (e.g. network operators, terminal manufacturers, service providers, etc) will need to cooperate in developing an open standard for mobile location services.

5.4.1.9. Lack of adaptability

As presented in section 3.4, the context of use has a big influence on how the user will experience the service. It is most likely that the services will have a better chance of providing a positive user experience if it is adaptable according to different contexts of use or environment where the services are used. Some of the mobile location services offered in Japan and South Korea are adaptable. Those services are imadoco, Safety Navi and i-kids services, for which the user can specify how the services should behave. For example, the user can define that the service should deliver the location notification of their kids every half an hour or send the notification when the kids leave the pre-defined areas. However, adaptation of the service can be made to match many other elements of use contexts, such as to match the user's terminal, to match the social rules, to match the user's physical condition, etc.[188], and these adaptation capabilities are not available in the services offered in Japan and South Korea. The lack of adaptability and the lack of offerings tailored to different users' requirements are some of the main barriers limiting the success of the mobile location services in Asia *(Shen et al. 2007; De La Vergne et al. 2006)*.

5.4.2   Services in Western Europe

Most of the mobile location services that have been launched in Western Europe are based on the Cell-ID technique on the GSM networks, and so far the services have not shown any significant impact on the mobile service market across Western Europe. The lack of commitment from network operators is the main reason mobile location services have not taken off in Western Europe. Due to technical and cost issues, most operators will rather stay with a network-based location strategy (Cell-ID), rather than a terminal-based strategy (e.g. A-GPS)[189]. However, over the past two years Europeans have shown interest in a form of mobile location service that

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[188] See section 7.2 for the adaptation possibilities for mobile location services.
[189] The discussion regarding the factors influencing the adoption of the mobile location technologies of the mobile network operators in Asia and Western Europe can be found in section 4.3.

does not necessarily involve mobile network operators *(De La Vergne et al. 2006)*. Their interest has been spurred by the availability of GPS-enabled terminals.

Nokia is the dominant mobile handset manufacturer in Western Europe, and Nokia has therefore the potential to increase the mobile location service market penetration in the region. Nokia recently launched the N95, a smart phone with embedded GPS and world map *(Nokia 2007)*. The mobile service providers may start to deploy high-accuracy location capabilities when they are supported by handset manufacturers putting GPS in new mobile terminals. However, the lack of high accurate location capability in dense urban areas, underground and in indoor environments will not be solved with the new terminal alone. The characteristics of the mobile location services industry in Western Europe are discussed in the following sub-sections.

5.4.2.1. Location infrastructure is not a priority

How the mobile location services are implemented and offered in Western Europe is highly influenced by the mobile network standards used in the region[190]. As discussed in section 4.3, it is more complicated and expensive to add high accurate location infrastructure to the mobile networks originally deployed in Western Europe compared to the networks originally deployed in Asia. The operators in Western Europe have many issues (e.g. 3G license, 3G network upgrade, etc.)[191] to deal with and adding infrastructure to support the deployment of mobile location services is not a priority for them *(Betti 2005; De La Vergne et al. 2006)*. Other services such as video and music are more important for revenue generation. It is easier to excite users with video or music services than to explain the potential of generic mobile location services *(Betti 2005)*. The mobile location services in Western Europe suffer from being at the bottom of a long list of new services that operators are still trying to develop and market for 3G network. It might take some years before the technologies are ready to offer attractive mobile location services in Western Europe *(Strategy Analytics 2005)*. This strategy for the mobile operators in Western Europe is different from the Asian countries where the operators are making heavy investment in mobile location services, for example operators in South Korea have spent 50 to 100 billion won (approximately 313 to 626 million krones) to upgrade their location infrastructure *(Kim 2006)*.

5.4.2.2. Cell-ID is the dominant location technology

Mobile location services offered in Western Europe are ranging from location based information services to tracking services, but they are provided using the same location technology – Cell-ID. The mobile location services are not widely adopted

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[190] See section 2.1.1 for detailed description of mobile network standards used in Western Europe.
[191] See section 2.1.1.4, 2.1.1.6 and 4.3.

in Western Europe, and one of the reasons could be that the location technologies used in Western Europe do not fulfill the accuracy requirements of the services presented in table 4-1 in section 4.1. For example, a tracking service using Cell-ID is close to useless, especially in the rural areas where a location accuracy of 10 or 20 km is provided.

Vodafone UK enhanced location accuracy by installing Timing Advance[192] in their networks in December 2004 *(Traceamobile 2007)*, which can achieve the accuracy of 50-350 meters in urban areas and 350-550 meters in suburban areas. With this accuracy, most of the service can be captured but not navigation services[193].

Cell-ID has, however, been a successful key for simple services like location sensitive charging services such as zoneplan, genion and O2 Home services offered in Denmark, Germany and the UK[194]. In this case, the user location does not really generate revenue, but help in reinforcing a competitive advantage and a more generic strategy.

5.4.2.3. The number of advanced terminals with MLS support is limited

The location infrastructure for supporting advanced mobile location services is not deployed in Western Europe, and therefore only few models of advanced terminals with MLS support are in the market. New mobile terminals in Western Europe are mostly designed to support other kinds of entertainment such as music and video, rather than mobile location services. As of January 2007, 99 models of 3G terminals are available in Western Europe, 70 models have built-in MP3 player, 58 models have video player, 71 models have Bluetooth built-in and only 5 models have GPS built-in *(3gtoday 2007)* . One of the leading terminal manufacturers, Nokia, has launched a new mobile terminal (N95) with GPS built-in and world map *(Nokia 2007)*, and this may boost the mobile location service market in Western Europe.

5.4.2.4. Poor service discovery and usability

Mobile location services available in Western Europe have not been sufficiently user friendly to encourage repeated use as most of the services are based on SMS and WAP. By the time users have finished typing an SMS to request for the location-based information service, the user can probably accomplish their tasks faster by asking local people for the information they want. For example if the users want to find the location of the nearest ATM machine, using location services based on SMS might take ten times longer than asking a local shopkeeper for the direction to the nearest ATM machine. To enhance the utility and usability of mobile location services, a good user interface and short key access, such as those available in Japan

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[192] See section 4.2.1.
[193] See table 4-1 in section 4.1.
[194] See section 5.3.4.

and South Korea, is very important, and this feature is still missing in Western Europe.

5.4.2.5. Data services are more expensive than voice service

It is less appealing to use mobile data services in Western Europe compared to Japan and South Korea. The mobile data services in Western Europe are generally more expensive than the flat rate strategy used for data services in Japan and South Korea. An example is the service charge of mobile data services provided by 3 in the UK; the monthly charge varies from 270 DKK to 1078 DKK depending on the number of minutes used *(Hutchison 3G UK 2006d)*. Besides the monthly charge the user has to pay additional charge for data service. The data service charges differ from service to service. The service charge for a simple location based information service provided by Hutchison 3G UK Ltd varies from 2.7 to 6.5 DKK per one time request in addition to the monthly charge *(Hutchison 3G UK 2006a)*.

For 3 mobile in Denmark, data charge is much more expensive than voice *(3 mobile DK 2006)* and data charge per packet strategy is still used, which is rather confusing for the user. The user can also choose flat rate tariff at 3 Denmark, it costs 624 DKK per month, with an obligatory 6 months contract. Although the user can choose flat rate tariff (e.g. unlimited data package provided by 3 Denmark), the charge rate is approximately three times more expensive than the flat rate tariff in Japan and South Korea[195].

5.4.2.6. The services in Western Europe provide higher level of availability compared to the services offered in Asia.

In Western Europe, the services are more available compared to Japan and South Korea, as most of the services are based on Cell-ID and no special terminal is needed in order to utilize the Cell-ID method. The users can, for example, use a single GSM terminal to access different services. The services are available regardless of operators. Table 5-4 shows examples of the availability of different mobile location services in Western Europe.

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[195] See section 5.4.1.4 for more details.

Table 5-4: An analysis of service availability for some existing mobile location services in Western Europe. The green smiling face represents the strong points and the red sad face represents weak points of the service availability.

Service	Service availability
▪ **FriendFinder** ▪ **ChildLocate**	☺ Available and accessible for all GSM subscribers of all GSM operators (Vodafone, T-mobile, O2 and Orange). ☺ Available and accessible for all GSM terminals. ☺ Available and accessible in both indoor and outdoor environments. ☹ Unavailable for 3G subscribers. ☹ Unreliable (due to the Cell-ID location method being used).
▪ **Quick map** ▪ **Find** ▪ **A to B service**	☹ Available and accessible only for 3G subscribers of Hutchison 3G UK Ltd. ☺ Available and accessible for all 3G terminals. ☺ Available and accessible in both indoor and outdoor environments. ☹ Unreliable (due to the Cell-ID location method being used).
▪ **ZonePlan** ▪ **Genion**	☺ Available and accessible for all mobile subscribers with all kinds of mobile terminals. ☺ Available and accessible in all environments covered by a mobile network. ☹ Unreliable (due to the Cell-ID location method being used).

5.4.3 Summary: Strong points and shortcomings of mobile location services in Asia and Western Europe.

Based on the discussions made in the previous sections, strong points and shortcomings of mobile location services in Asia and Western Europe are summarized in table 5-5.

From the table it is seen that the mobile location services in Japan and South Korea are less available compared to the services in Western Europe. It is also clear from the table that the services in Japan and South Korea have a higher level of usefulness compared to Western Europe. Since the mobile location services are more widely used in Japan and South Korea than in Western Europe, this strongly suggests that the fundamental element affecting the quality of the user experience and making the services become a success is actually the usefulness (utility and usability) of the services, which is corresponding to the research on factors affecting continued intention to use mobile services in South Korea *(Hwang et al. 2007)*.

Table 5-5: Summary of the strong points and shortcomings of the mobile location services in Asia (Japan and South Korea) and Western Europe.

	Asia (Japan and South Korea)	Western Europe
Strong points	**1. Medium to high level of usefulness** ▪ The chosen location methods match the accuracy requirements of the offered services. ▪ The service is easy to use with short-cut key and graphic user interface. **2. The services are compelling** ▪ Cheap, flat rate pricing strategy. ▪ Graphic user interface, multimedia services. ▪ Provides some levels of adaptability. **3. Social acceptance** ▪ People generally like to discover new services. ▪ Seniority makes tracking services acceptable. ▪ Confusing address system in Japan makes the navigation services very useful.	**1. High availability** ▪ Available anywhere and any time, using any terminal within the same mobile network standard. ▪ Available anywhere and any time regardless of network operators.
Shortcomings	**1. Low availability** ▪ Available depending on the network standard, terminal, operator and physical environment. ▪ The high accurate location services are often degraded or unavailable in indoor environments. ▪ Lack of interoperability and location information sharing between different network operators.	**1. Low level of usefulness** ▪ Location accuracy provided by the adopted location technology does not match the accuracy requirements of the services. ▪ Several services are provided using text-based services. **2. The services are generally less compelling compared to the services in Asia** ▪ Expensive. ▪ Mostly text based location information. ▪ Inadaptability.

The user will not pay for the service if the service does not match his needs and does not meet his expectations, even if it is always available[196]. With the mobile and location technologies available today[197], it is not possible to develop a mobile location service that is always available due to the lack of indoor location methods that can provide high accuracy location information. The service providers in Japan and South Korea, however, manage the user experience by announcing clearly to the user about the errors that might occur and the obligation of having the right terminal in order to access the service, thereby reducing the user expectations towards the service to a realistic level.

Other offline issues[198] such as pricing also play an important role in defining the success of the services in Japan and South Korea. Also some of the services in Japan and South Korea are adaptable based on the user requirements and preferences, this makes the services attractive for the users, as they can control the services to behave as they like.

Use contexts[199] have obviously influenced the adoption of mobile location services. The difference of social and cultural aspects[200] as well as physical environments[201] of each country is one of the reasons for the different deployment rates of mobile location services in Asia and Western Europe. Western European are generally more concerned about their privacy than Asian *(Beeson et al. 2002)* and they will therefore be less willing to adopt mobile location services compared to Asian. In Asian societies (e.g. Japan and South Korea) people are excited about new technology and they are more ready to discover new services. Social aspect, e.g. social hierarchy, also influences the successful implementation and take-up of mobile location services (e.g. tracking services). For example, children in Asia are brought up to respect this hierarchy, thus if parents wish to track their location they would allow it. Children in Western Europe on the other hand, might be less willing to let their parents know about their whereabouts. Sense of community and trust also strongly affect the adoption of mobile location services. For mobile location services, users have to consent to being tracked before such services can apply to each user. In many countries (e.g. in Western Europe), there are personal privacy laws that prohibit the mobile operator from distributing or making information of their subscribers available to any other party, whereas privacy does not seem to be a

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[196] This is related to the user mental model, user expectation and user experience formation explained in section 3.2. The user will get a positive experience if the service functions and behaves as he has expected and if it matches his needs in a specific context of use.

[197] See section 2.1 for more details of mobile network technologies and section 4.2 for mobile location technologies.

[198] See section 3.3.4 for examples of offline issues that influence the mobile user experience formation.

[199] The influence of use context or context of use to the user experience has been described previously in section 3.4.

[200] See section 3.4.5 for the description of social environment.

[201] More detailed description of physical environment can be found in section 3.4.4.

big issue in some of the Asian countries (e.g. Japan and South Korea) *(Beeson et al. 2002)*. In terms of the physical environment, mobile location services will be useful for locating certain places in areas where roads are poorly marked or in areas where nonsystematic addresses are used, such as Japan. The mobile location service may, on the other hand, be a less valuable tool in areas where roads are clearly marked and systematic addresses are used, thereby making it simple for people to find a certain place.

As the current context of use has a big influence on how the mobile user experience will turn out as discussed in section 3.4, the mobile location services have a bigger chance to provide a positive user experience if the service is adaptable based on the current context of use. The lack of service adaptability is one of the main barriers of mobile location services both in Asia and Western Europe[202].

5.5   Summary

In this chapter, the mobile location services in Asia (Japan and South Korea) and Western Europe have been examined and analyzed. The services available in Asia generally provide a better user experience compared to the services in Western Europe. Almost all kinds of standard mobile location services are available in Japan and South Korea, since the location method utilizing GPS technology (gpsOne solution) is widely adopted in Asia. The operators in Western Europe, on the other hand, choose to stay with the simple and cheap method (Cell-ID) and this can only capture approximately 50% of the standard mobile location services. The service providers in Western Europe, however, offer services such as tracking services even though the accuracy requirements of the services are not fulfilled, resulting in a low level of service usefulness which may potentially lead to a negative user experience.

The main reason for the services in Asia being more popular than the services offered in Western Europe is because the service providers choose the right location method for the right service. The terminals with MLS support are in the market and the flat rate strategy used in Japan and South Korea is also more appealing than the service charge strategy adopted in Western Europe. Physical environments, social and cultural aspects are also important factors that have direct affect on how the mobile location services are adopted in Asia and Western Europe.

Even though the location methods utilizing GPS technology (e.g. gpsOne) is adopted in Japan and South Korea, the offered services are still suffering from the limitations of accuracy and availability, as the quality of the service is degraded when the user is in indoor environments. However, the operators are aware of these problems and they are developing a solution that can complement or extend the service capability. This new solution will be able to provide an indoor location

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[202] See sections 5.4.1.9 and 5.4.3.

accuracy of 100-200 meter, which is still not enough for some of the services such as indoor navigation or indoor tracking services.

The different levels of success of mobile location services in Asia and Western Europe demonstrates that the fundamental element affecting the quality of the user experience and the willingness of paying for the service is the service usefulness. It is therefore necessary to emphasize the service usefulness (what the service does for the user, how it fulfills his needs and how easy it is to use) when designing a mobile location service. The service must also be compatible with the context of use, and finally the service provider should manage the user expectation by communicating errors that might occur while the user is using the service.

6   New conceptual mechanism for detecting the location of a mobile user on the next generation wireless network

Recent developments in mobile and wireless technologies indicate that the next generation wireless network will be based on IPv6. Big organizations such as ITU and IETF are working actively on establishing standardizations to support the use of IPv6 in both wired and wireless environments. The IPv6 forum is developing IPv6 deployment guides to foster the operational use of IPv6[203] and Regional Internet Registries (RIRs) have already allocated and registered IPv6 addresses within a particular region of the world *(RIPE NCC 2007)*. Also, major business players in the mobile and network market such as Nokia, Ericsson, Cisco and KDDI are already developing the next generation wireless technologies and terminals based on IPv6 *(Nokia 2002; Ericsson 2003; Cisco 2007[204]; KDDI 2002)*. Since September 2004, KDDI R&D laboratory has switched to IPv6 networking for most of their internal operations at the laboratory *(KDDI R&D Laboratories 2005)*. In addition, a big organization like UMTS forum also has a vision of an IP core network *(UMTS Forum 2006)*. 3GPP mandates IPv6 for its IMS (IP-based Multimedia Subsystem). All IMS elements are IPv6-only, and both the protocol signaling and media-flow are carried only over IPv6 *(Usai et al. 2006)*.

Due to the wide spread of IPv6, it is desirable to investigate the possibility of determining the location of a mobile user applying the features of the next generation wireless network based on IPv6, and to develop a system architecture to provide mobile location services for mobile users on this future network. The main objective of this chapter is to propose a new conceptual mechanism for determining the location of all mobile users on the next generation wireless network, and the chapter is partly based on publication papers written during the period of this study *(Schou & Olesen 2005; Thongthammachart & Olesen 2003a, Thongthammachart & Olesen 2003b and Thongthammachart et al. 2003)*. The chapter starts by presenting the technical backgrounds for the proposed conceptual location determination solution including trends in the next generation wireless network, IPv6, and global and local mobility management protocols. The mechanism for detecting and sharing

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[203] See www.ipv6forum.org
[204] Cisco has taken a leading role in the definition and implementation of the IPv6 architecture within the IETF and continues to lead the industry in standardization *(Cisco 2007)*.

the location of all mobile users on the next generation wireless network applying the mobility management protocols in both global and local levels, is then proposed. This location detection mechanism is, in this thesis, referred to as the conceptual IPv6-based location method. The concept of detecting the location of a mobile user applying the characteristics of wireless short- and medium-range technologies together with the developed conceptual IPv6-based location method is presented. This location solution can provide accurate location information of mobile users in dense urban areas and closed areas such as buildings or undergrounds. The usefulness of the developed conceptual location method is then demonstrated through two service cases. Finally, problems involved with the proposed IPv6-based location detection and system architecture for providing mobile location services on the next generation wireless network are discussed.

As indicated in the title of this chapter, the mechanism for detecting the mobile user location proposed in this chapter is a conceptual design based on theories, concepts and knowledge in the area of information communication technology and it has not been implemented in practice.

6.1 Technical background

The underlying technologies behind the new conceptual mechanism for detecting the location of a mobile user on the next generation wireless network proposed in this chapter include IPv6, Mobile IPv6, the movement detection mechanism of Mobile IPv6 and the Intra-Domain Mobility Management Protocol (IDMP). This section presents trends in the next generation wireless network and the aforementioned technologies applied for the new detection mechanism.

6.1.1 Trends in next generation wireless network[205]

The next generation wireless network is based on functional integration and convergence of heterogeneous wireless access networks *(Reynolds & Jin-Kyu 2004; Srivastava & Kodate 2005; ITU-T 2005; Uusitalo et al. 2006)*. The next generation wireless network includes not only cellular networks but also emerging wireless access networks such as WMAN, WLAN, WPAN, high speed portable internet, and digital broadcasting networks and other forthcoming wireless technologies *(Srivastava 2004, p13; Uusitalo et al. 2006)*. These wireless access networks will coexist to provide a variety of multimedia services via a common IPv6-based network *(Chen et al. 2007; Kappler et al. 2007; Uusitalo et al. 2006; Srivastava & Kodate 2005; Reynolds & Jin-Kyu 2004)*.

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[205] This section is mainly based on the publication papers written during this study *(Thongthammachart & Olesen 2003b; Schou & Olesen 2005)*.

"In future, the telecommunication industry will be joined by information technology, consumer electronics, broadcasting and media and entertainment industries to form a common digital industry" (Uusitalo et al. 2006).

A generic view of the next generation network is shown in figure 6-1. All elements used in the next generation wireless system will be digital. Such a multi-access system will be able to handle a large volume of multimedia data (up to 100 Mbps or even higher in some areas) *(Reynolds & Jin-Kyu 2004; Srivastava & Kodate 2005; Uusitalo et al. 2006)*. The future service platform is expected to be open, allowing users to freely choose terminals, networks, protocols, applications and services *(Reynolds & Jin-Kyu 2004; ITU-2005; Uusitalo et al. 2006)*. Service providers and content providers will be able to provide their services and content, independently from the operators[206]. Location and charging information can be transferred among networks and applications *(Reynolds & Jin-Kyu 2004)*.
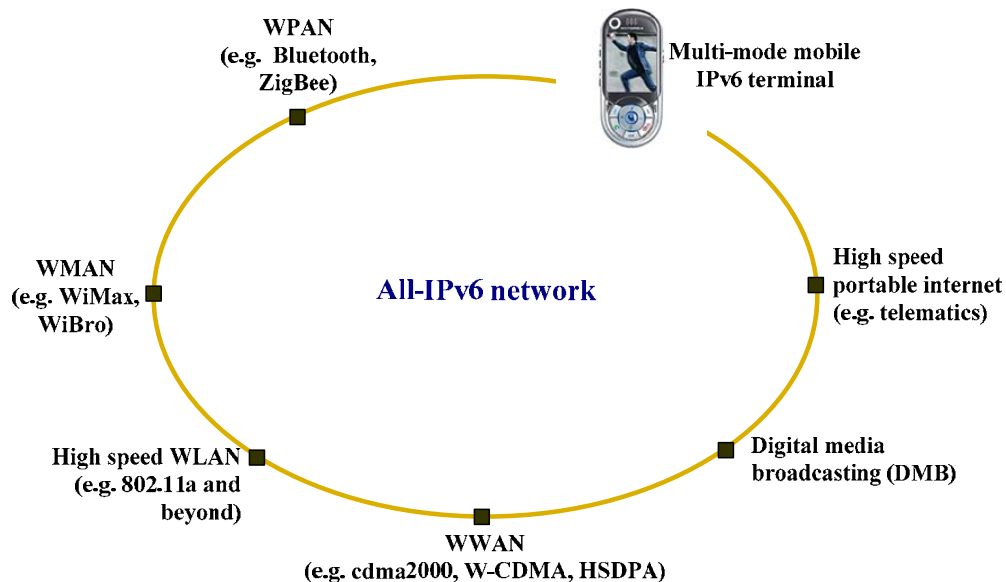
Figure 6-1: A generic view of the next generation wireless network, consisting of heterogeneous networks that will provide wireless end-to-end IP seamless connectivity. Users are allowed to connect to the all-IPv6 network using a single multi-mode mobile terminal (the figure is made based on the information presented in Kappler et al. *(Kappler et al. 2007)*, Makaya & Pierre *(Makaya & Pierre 2007)*, Chen et al. *(Chen et al. 2007)* and ITU *(ITU-T 2005))*.

Figure 6-2 shows the vision of the single broadband converged network for many services and operators based on *(Uusitalo 2006; Uusitalo et al. 2006; ITU-T 2005; Reynolds & Jin-Kyu 2004)*. On the left side of the figure is the current situation,

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[206] Ibid.

where different services are each provided by different service providers on specific networks. The next generation network will change this and combine all networks into one large IP network. Then, the same services will be available to all users over a common IP network, regardless of which part of the network they connect from (right). As an example, users can configure their Internet enabled refrigerator via broadband, their mobile terminal, a PDA, or any other connected terminal

The move towards one network, many services
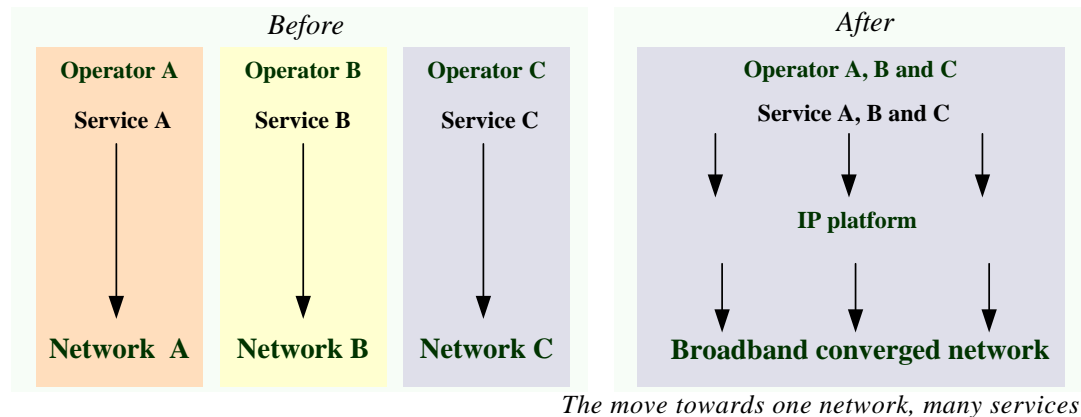
Figure 6-2: An evolution of wireless networks and services based on Uusitalo *(Uusitalo 2006)*, WWRF *(WWRF 2006)*, ITU *(ITU-T 2005)* and Reynolds & Jin-Kyu *(Reynolds & Jin-Kyu 2004)*. The situation can be broken down into "before and after" network services.

Both seamless roaming and universal access is expected to be achieved in the next generation system, and users may have an option of connecting to different kinds of access networks and accessing different kinds of services using a single mobile terminal *(Chen & Yang 2007; Uusitalo et al. 2006; Reynolds & Jin-Kyu 2004; Kim 2006a)*. Mobile terminals and networks will be multi-mode, operating at different frequencies and using a variety of wireless access technologies[207]. Already today, KT Corporation in South Korea is offering a convergence of CDMA, WLAN, Bluetooth, WiBro and fixed broadband networks *(Kim 2006a)*. The user is allowed to connect to the Bluetooth or WLAN while he is in indoor environments and switch to CDMA or WiBro outdoors[208]. The next generation terminal with an integration of a variety of technologies such as CDMA, WiBro, wireless LAN, Bluetooth, RFID, DMB and GPS is also under development in South Korea and it is expected to be available around the year 2009-2010 *(Sang-don 2006)*. UMA (Unlicensed Mobile Access) technology also allows users to access different kinds of wireless access technologies such as GSM, GPRS, UMTS, Bluetooth, WLAN and WiMax. The concept is that the users connect to the unlicensed networks such

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[207] Ibid.
[208] Ibid.

as Bluetooth or WLAN when they are inside a building and automatically switch to a mobile network outdoors. The concept of UMA is shown in figure 6-3.
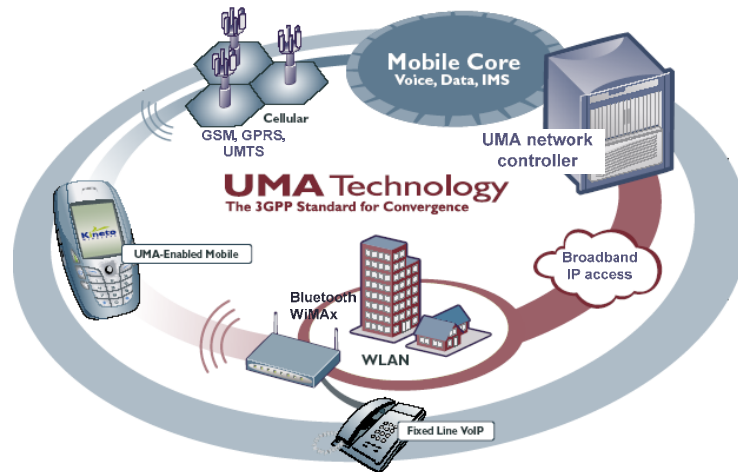
Figure 6-3: The concept of UMA where the users are allowed to use one terminal to access different kinds of mobile and wireless networks *(Kineto wireless 2005)*.

With the advanced features that are expected to be offered by the next generation mobile network and next generation mobile terminals, a lot more interesting services will be enabled. Especially, mobile location services are highly expected to gain more attention in the next generation wireless networks *(UMTS Forum 2003; Kim 2006)*.

6.1.2   Internet protocol version 6 (IPv6)

The Internet protocol (IP) is becoming the end-to-end protocol of the future delivery of most services in both wired and wireless networks. However, the vast majority of communication devices are expected to be mobile within a few years[209]. Most network traffic will originate from IP-based applications *(Wisely et al. 2002)* and voice calls will be handled as voice over IP (VoIP) along with data services *(Srivastava 2004, p.18; Reynolds & Jin-Kyu 2004)*. Based on the global visions for the future wireless world from the WWRF, 7 trillion wireless devices will be used by 7 billion people by 2017 *(Uusitalo 2006)*. However, it is predicted that the IPv4 unallocated address pool will be exhausted around 2009-2012 *(Huston 2005)*. The shortage of IPv4 addresses will create a number of problems for migration and interoperability. Private IPv4 addressing and NAT (Network Address Translation)[210] do not preserve the end-to-end transparency paradigm of IP *(Loshin*

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[209] Confirmation can be seen in Japan where the number of mobile subscribers has outnumbered the number of fixed-line subscribers since 2000 *(Srivastava & Kodate 2004)*.
[210] NAT involves re-writing the source and/or destination addresses of IP packets as they pass through a router or firewall. Most systems using NAT do so in order to enable multiple hosts on a

1999; Kabata 2006a). That makes many applications and services fail, and support of mobile terminal VoIP calls becomes difficult to achieve. Another alternative way of handling the limitation of IPv4 address is to use dynamic IPv4 address assignment that only assigns an IP address to terminals that are connected. However, there is no guarantee even then, that the number of IPv4 addresses will be sufficient to sustain a large number of simultaneous users[211]. Moreover, the support of mobile terminal applications which are based on an "always on" functionality becomes more difficult.

Due to the limited number of IP addresses offered by IPv4, which is not enough to support a huge number of mobile terminals, Internet protocol version 6 (IPv6) (the latest version of Internet protocol) is expected to be used in the next generation networks *(Nokia 2002; Srivastava 2004, p.18; Uusitalo et al. 2006).* IPv6 will play a role in overcoming problems relating to addressing, end-to-end security as well as numbering, naming and Quality-of-Service (QoS) for real-time applications and services. Mobility support is a common embedded feature in the IPv6 specification but not in IPv4 *(Deering 1998; Johnson et al. 2002).* Besides providing a larger number of IP addresses and support of mobility, IPv6 has many other advantages over IPv4 *(IPv6 summit 2006).* One of the advantages is that IPv6 allows for many new possibilities, including a new geo-location system that lines up IPv6 addresses with squares or hexagons across the earth's surface, in a novel latitude and longitude system[212].

Currently, IPv6 has been actively adopted in Asia and Europe where there is a relatively critical shortage of IPv4 addresses, whereas North America has not yet widely adopted IPv6 as a large amount of IPv4 addresses has been allocated to North America *(Srivastava 2004, p.18)* (more than 60% of all IPv4 addresses are allocated to North America *(JPNIC 2006)).* Official IPv6 addresses are already allocated and the largest number of IPv6 addresses is allocated to Europe and Asia *(RIPE NCC 2007),* which shows that IPv6 deployment is in fact fairly close at hand.

Even though IPv6 has more advanced features than IPv4, it is expected that IPv4 and IPv6 will have to co-exist for a long time. To preserve the existing investments in infrastructure and services, the Internet Engineering Task Force (IETF) has standardized different transition mechanisms to support internetworking between IPv4 and IPv6. The three types of transition mechanisms are tunneling, dual stack and translation *(Nordmark & Gilligan 2005).* With the tunneling mechanism, IPv6

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private network to access the Internet using a single public IP address, due to the limitation of the IPv4 addresses.

[211] IPv4 supports 4,294,967,296 addresses (2^{32}), which are inadequate for giving even one address to every living person (approximately 6.7 billion people alive today *(ibiblio.org 2006)).* IPv6 supports 340,282,366,920,938,463,463,374,607,431,768,211,456 addresses (2^{128}) which are more than enough to allocate addresses to every electronic object in the world.
[212] Ibid.

packets are encapsulated within IPv4 packets and routed through the IPv4 network. In the dual stack mechanism, hosts and routers can support both IPv4 and IPv6 traffic and applications on the same network interfaces. Conversion of IPv6 headers to IPv4 and vice versa and address conversion from a 128-bit IPv6 address to a 32-bit IPv4 address will be performed by the translation mechanism.

6.1.3   Mobile IPv6 – global mobility management

Mobile IP is an IETF standard communications protocol that is designed to allow mobile devices to move from one network to another while maintaining their permanent IP addresses *(Perkins 2002)*. Mobile IP was originally designed for IP version 4 *(Solomon 1998)*. However, with the increased need of IP addresses, Mobile IPv6 (MIPv6) is well suited for mobile networks because it does not require the mobile node[213] to use dynamic address allocation like it does in Mobile IPv4. With 128 bits IPv6, there are more than enough addresses to identify every electronic device in the world with IPv6 addresses. In the mobile IP environment, every mobile terminal in the world can identify itself with at least two IP addresses. One address will be used as a globally unique identifier of the mobile terminal (home address). This address is unique and static regardless of the current point of attachment of the mobile terminal. The other address (care-of address) will be used to identify the temporary location of the mobile terminal in the global network. However, it is feasible to assign many more IPv6 addresses to terminals, depending on the specific applications *(Kabata 2006; Kabata 2006a)*.

Mobile IPv6 places all the mobility management functionality at the network (IPv6) layer *(Loshin 1999; Johnson et al. 2004)*. It enables mobile devices to be constantly addressed by their static home address, regardless of their current point of attachment on the global IP network *(Johnson et al. 2004)*. Mobile IPv6 is therefore an enabler for true user and service mobility in a multi-access environment. It provides connectivity over any wireless access type and enables seamless hand-over through various wireless technologies. Mobile IPv6 is the only realistic mechanism for handling host mobility in the multi-access environment of the mobile internet *(Dunmore & Edwards 2002)*.

Compared to existing cellular-based mobility management methods, a major advantage of Mobile IPv6 is that it is completely independent of access network technologies and the media over which it runs. This will allow simple and efficient global roaming management in networks that include different kinds of wireless access technologies *(Chen & Yang 2007)*. IPv6 has the ability to link together multiple access technologies within a single architecture *(Chen & Yang 2007; Reynolds & Jin-Kyu 2004)*. The envisioned solution is to replace the complexity of

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[213] A node is any object that carries IPv6 addresses and connects to the IPv6 network. A node can both be a fixed and a mobile device (e.g. mobile terminal, server, access point, etc.).

the current mobile network architecture with the pure IPv6 backbone *(Srivastava 2004)*. This will ease the integration of heterogeneous access within the network. Therefore, a multi-mode Mobile-IPv6 terminal will be able to roam transparently among different kinds of networks and operators, being reachable at its static and unique IPv6 home address.

6.1.3.1. Mobile IPv6 architecture

In the Mobile IPv6 environment, different networks are distinguished by different network prefixes[214]. Each network has a router or node called the agent. The agent allocates IPv6 addresses to all the mobile nodes on the network[215]. When a mobile node (MN) wants access to the IPv6 network, it has to register with an agent of the network. The network where the mobile node registers for the first time is known as the home network[216] and the agent at the network is called the home agent *(Johnson et al. 2004)*. The home network is the network that administrates the mobile node, and it is typically the network to which the mobile node is normally attached *(HP 2004)*.

After the mobile node has registered with its home network, it gets a unique and static IPv6 address called a home address (HA)[217]. The home address of the mobile node is known as the "identifier" and it is reachable by the rest of the IPv6 nodes on the IPv6 network regardless of the current point of attachment. All the nodes that have been registered with the same home agent carry a home address with the same network prefix *(HP 2004)*. Mobile nodes and home agents are expected to be subject to the network administration of the home domain[218] *(Johnson et al. 2004)* and different domains are managed and administrated by different management entities *(ITU-T 2005, p. 158)*.

When a mobile node is attached to another network called the visited network than its home network, it gets a temporary address called the care-of address (CoA). The care-of address is an IPv6 unicast global address with the network prefix of the visited network. The mobile node can get this address using IPv6 stateless auto-

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[214] A prefix is a bit string that consists of some number of initial bits of an IP address.

[215] The agent also maintains the mapping between the home address and care-of address for purposes of rendezvous and possibly traffic forwarding.

[216] Home network is the network associated with the operator/service provider that owns the subscription of the user *(ITU-T 2005)*.

[217] Home address is a unicast routable address assigned to a mobile node, used as the permanent address of the mobile node.

[218] Domains are defined by an IP address and all devices sharing a common part of the IP address (prefix) are said to be in the same domain *(Pitkow & Nielsen 1998)*. The home domain is the domain where the home network and home agent are located *(Fogelstroem et al. 2007)*. A mobility domain is essentially identified as a collection of IP subnets and networks that are aggregated together based on factors such as geographic proximity or administrative control *(Misra et al. 2000)*.

configuration[219], or by using a stateful configuration method such as DHCPv6 *(HP 2004)*. All the visiting nodes on the visited network carry the care-of address with the same network prefix.

In the Mobile IPv6 architecture, a node that communicates or corresponds with the mobile node is referred to as a correspondent node (CN). The correspondent node is any device or node carrying IPv6 addresses, such as a portable computer, mobile terminal, PDA, Bluetooth access point, Base station, etc. Any IPv6 node may at any time be a correspondent node of a mobile node, either sending a packet to a mobile node or receiving a packet from a mobile node.

6.1.3.2. Basic operation of Mobile IPv6 and route optimization

In the basic operation of the Mobile IPv6, the correspondent node sends data-packets to the mobile node using the mobile node's home address. The home address contains the network prefix of the mobile node's home agent. A home agent, a node or router on the mobile node's home network, intercepts these data-packets and forwards them to the mobile node's current care-of address *(HP 2004)*, as show in figure 6-4 (route 1).
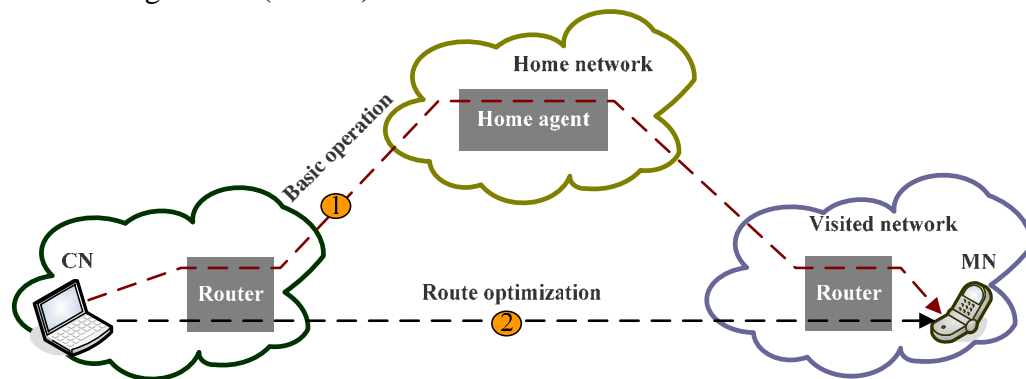
Figure 6-4: The correspondent node (CN) communicates with the mobile node (MN) in (1) basic operation and (2) route optimization *(HP 2004).*

In addition to the basic operation, Mobile IPv6 can operate using route optimization (route 2 in figure 6-4). The route optimization improves data transmission rates between the correspondent node and mobile node. With route optimization, the mobile node and correspondent node communicate directly with each other and bypass the home agent. It is expected that Mobile IPv6 route optimization will be used on a global basis between nodes belonging to different administrative domains

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[219] The stateless auto-configuration allows a mobile node to generate its own IPv6 addresses using a combination of locally available information and information advertised by routers *(Thomson et al. 2005)*.

(Johnson et al. 2004). Route optimization can only be operated in the case that the correspondent node has the care-of address of a mobile node and this can be obtained during a movement detection mechanism presented in section 6.1.3.3.

In most cases, the mobile node and correspondent node communicate using route optimization *(HP 2004)*. The Mobile IPv6 basic operation is used in initial communication, when the correspondent node does not have information about the mobile node's care-of address and in cases where the correspondent node does not support Mobile IPv6 route optimization.

6.1.3.3. Movement detection mechanism of Mobile IPv6

Mobile IPv6 is designed for managing mobility between two domains. It is also known as the inter-domain mobility management protocol or macro-mobility management protocol *(Chen et al. 2007; Das et al. 2002)*. Mobile IPv6 allows nodes to move within the all-IPv6 network while maintaining reachability and on-going connections to correspondent node. This can be realized by the movement detection mechanism of Mobile IPv6. Mobile nodes use IPv6 router advertisement and neighbor discovery methods to detect when they have moved to or attached to a new network *(HP 2004)*. For example, if a mobile node receives a router advertisement with a different network prefix than its current prefix, the mobile node can assume it has moved to a new network. Figure 6-5 shows the movement detection mechanism of Mobile IPv6, and the numbers in the circles describe the events in the movement detection mechanism.

In figure 6-5 the mobile node is moving away from its home network to a visited network (step 1). The mobile node sends a router solicitation message to the agent on the visited network to check whether it has moved into a new network (step 2). A router on the visited network responds with a router advertisement which includes the network prefix of the visited network (step 3). The mobile node recognizes from the router advertisement message that it is away from its home network. The mobile node generates a care-of address from the router advertisement message and sends a binding update message to its home agent (step 4). The binding update message contains the mobile node's care-of address and home address. When the home agent receives the binding update message, the IPSec[220] module on the home agent authenticates the message *(Johnson et al. 2004)*. The home agent then sends a binding acknowledgement to the mobile node (step 5). The binding acknowledgement indicates whether the binding update was accepted or rejected.

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[220] IP Security (IPSec) is a set of protocols developed by the IETF to support secure exchange of packets at the IP layer.
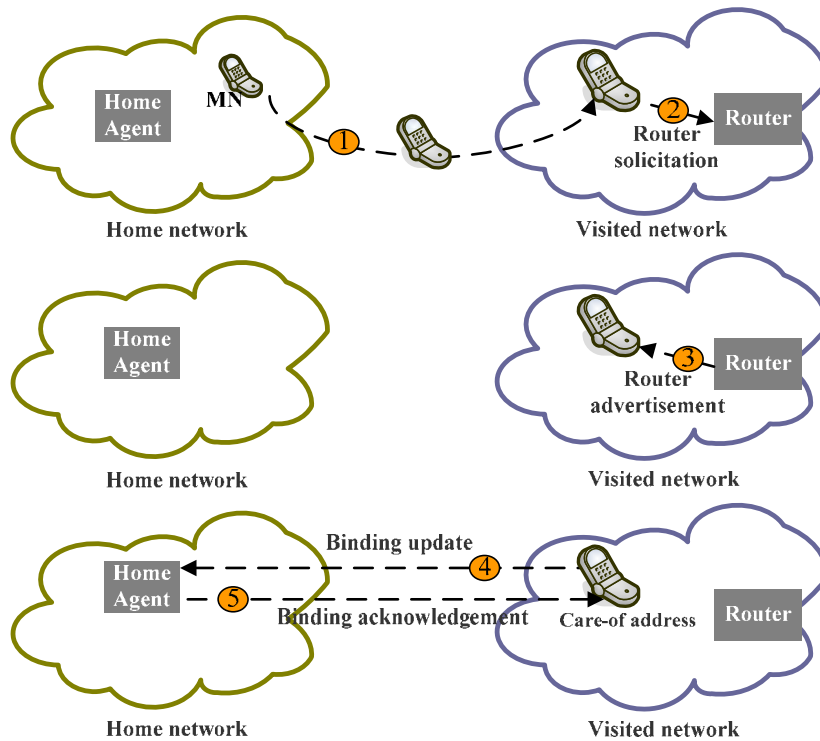
Figure 6-5: Movement detection mechanism of Mobile IPv6 at inter-domain level based on *(HP 2004)*.

To establish route optimization, the mobile node also sends a binding update to the correspondent node (see figure 6-6) and this allows direct communication between the mobile node and the correspondent node as already described in section 6.1.3.2.
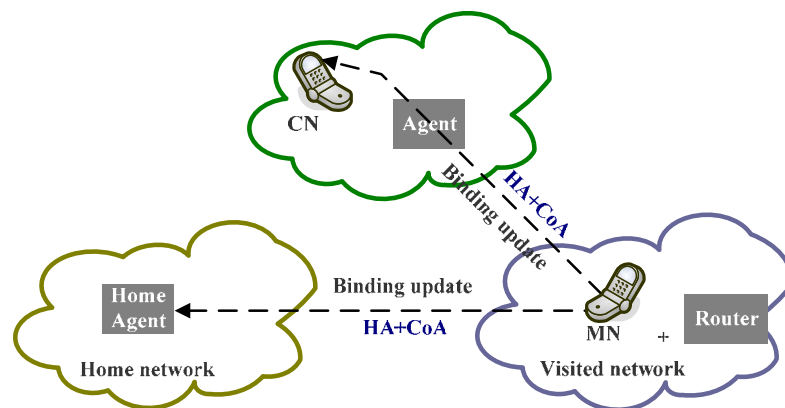
Figure 6-6: A mobile node sends a binding update to both its home agent and correspondent node and this allows the mobile node to communicate directly with the correspondent node and bypass the home agent *(HP 2004)*.

This thesis takes advantage of the movement detection mechanism to determine the location of a mobile terminal (node) on the next generation wireless network. With the movement detection mechanism of Mobile IPv6 together with the knowledge of the location and size of a given domain, the current location of mobile entities on the IPv6 network can be roughly determined, as the care-of-address of the mobile node identifies in which network (or domain) the mobile node is *(Jaksa et al. 2007; Schou & Olesen 2005; Yegin & Williams 2003)*. In order to determine the exact location of a Mobile IPv6 terminal, the movement detection mechanism of Mobile IPv6 must be supplemented with other mechanisms to handle local mobility and location update at the subnet or intra-domain level.

6.1.4   Local mobility management protocol

The Mobile IPv6 protocol presented in the previous section is for managing mobility between different domains or global mobility management. Mobility management protocols for local mobility management have also been proposed by IETF. A local mobility management protocol handles mobility between two subnets[221] within the same domain. The local mobility management protocols are also known as the micro-mobility management protocol or intra-domain mobility management protocol. The main purpose of the local mobility management protocol is to reduce the global signaling load and handoff latency. Examples of local mobility management protocols are Mobile IP regional registration (MIP-RR) *(Fogelstroem et al. 2007)*, Cellular IP (CIP) *(Campbell et al. 2000)*, Handoff Aware Wireless Access Internet Infrastructure (HAWAII) *(Ramjee et al. 2000)*, Hierarchical Mobile IPv6 Mobility Management (HMIPv6) *(Thomson et al. 2005)* and Intra-Domain Mobility Management Protocol (IDMP) *(Das et al. 2002; Misra et al. 2000)*.

In the mobile location service environment, the system needs information of who the user is (identifier) and where he is (locator). The local mobility management protocol can only be applied to determine the location of the user if two IP addresses are allocated to the mobile node in the local domain; one for the identifier and one for defining the current point of attachment of the mobile node. Among the above mentioned local mobility management protocols, it is only MIP-RR, HMIPv6 and IDMP that allocate two IP addresses to a mobile node. However, the MIP-RR is designed for Mobile IPv4 and only HMIPv6 and IDMP support IPv6.

This section describes two different local mobility management protocols: The Intra-Domain Mobility Management Protocol (IDMP) and the hierarchical Mobile

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[221] Subnet (short for "subnetwork") is a part of a domain which can be distinguished by subnet prefix. Typically, a subnet may represent all the nodes at one geographic location e.g. in one building or in the same local area. Network designers employ subnets as a way to partition networks into logical segments for greater ease of administration. The size of the subnet varies depending on the network design of a network provider or an operator.

IPv6 Mobility Management (HMIPv6). As the focus of this chapter is on how to determine the location of a mobile terminal, the detailed descriptions of the mobility management protocols presented in this chapter are based on how the location update is made rather than on how the data packets are routed.

6.1.4.1. Intra-Domain Mobility Management Protocol (IDMP)

IDMP is a protocol designed for managing mobility of mobile nodes inside a mobility domain[222]. IDMP specifies two types of agents, subnet agents and mobility agents, to support two-layer mobility hierarchy in the subnet level and domain level. IDMP uses two care-of addresses to manage mobility. The local care-of address identifies in which subnet the mobile node is and changes every time the mobile node changes subnet. The global care-of address identifies the mobile node's current domain and remains unchanged as long as the mobile does not change domains. The global care-of address is a publicly reachable address that enables packets to be globally routed to the mobile node through the home agent[223]. The local care-of address is recognized only in the local domain.

In the IDMP environment, each domain has a mobility agent (MA), and each subnet has a subnet agent[224] (SA). The mobility agent provides topologically correct, globally reachable care-of addresses (GCoA) to all mobile nodes within the local domain. All mobile nodes associated with an MA share the same global care-of address *(Das et al. 2002; Misra et al. 2000)*. The SA provides subnet specific mobility services and allocates unique and topologically correct local care-of addresses (LCoA) to all mobile nodes within the subnet. All mobile nodes associated with an individual subnet agent carry a unique local care-of address with the same subnet prefix. The LCoA identifies the attachment of the mobile node to the subnet and the scope of the LCoA is only within the subnet. When the mobile node changes subnet, the LCoA will change corresponding to the new subnet. The GCoA resolves the current location of the mobile node only at domain level granularity and hence remains unchanged as long as the mobile node stays within a single domain *(Misra et al. 2000; Das et al. 2002)*. The movement detection mechanism of IDMP is illustrated in figure 6-7.

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[222] A mobility domain is essentially identified as a collection of IP subnets and networks that are aggregated together based on factors such as geographic proximity or administrative control *(Misra et al. 2000)*.

[223] The global care-of address in IDMP is the same as care-of address in Mobile IPv6 presented in section 6.1.3.

[224] The subnet agent is a router on a specific local subnet which provides the local Care-of Address to the mobile node *(Misra et al. 2000)*.

Figure 6-7: Location update with IDMP based on (*Misra et al. 2000; Das et al. 2002*).

In figure 6-7, when a mobile node first moves into a subnet in a new domain (subnet A in domain C), it performs subnet specific mobility registration using IDMP (step 1). Subnet agent A allocates a unique LCoA to the mobile node (step 2). This address contains the subnet prefix belonging to subnet A. The mobile node then performs an intra-domain location update by communicating its current LCoA together with the GCoA (IP address of MA assigned by the SA) and its static home address (HA) to the designated MA via the binding update message (step 3). The MA includes its static IPv6 address in the intra-domain location update acknowledgement and sends this acknowledgement back to the mobile node (step 4). The static IPv6 address contained in the binding acknowledgement is used as a GCoA by all nodes in the same domain *(Misra et al. 2000)*. After the initial intra-domain registration process, the mobile terminal retains its GCoA as long as it stays within the same domain. Subsequently, the mobile node is responsible for

generating a global location update to the necessary remote nodes (e.g. home agent or correspondent node) (step 5). The global location update is beyond the responsibility of IDMP. If Mobile IPv6 is used for global mobility management, the global binding update binds a mobile nodes' home address with the GCoA allocated by IDMP.

Whenever the mobile node changes subnet within the domain, it performs a new subnet specific registration with the new subnet agent. The mobile node then performs a new intra-domain location update and informs its new LCoA to the MA. There is no global message in this case, since the GCoA does not change.

6.1.4.2. Hierarchical Mobile IPv6 Mobility Management (HMIPv6)

Hierarchical Mobile IPv6 Mobility Management (HMIPv6) is published by IETF as an extension of Mobile IPv6 to manage mobility management within the domain *(Soliman et al. 2005)*. The HMIPv6 introduces the Mobility Anchor Point (MAP) to handle the mobility management in the domain level (similar to MA in IDMP) and the access router (AR) which is similar to SA in IDMP. A mobile node also carries two care-of addresses: Regional care-of address (RCoA) and on-link care-of address (LCoA). The movement detection mechanism of HMIPv6 is shown in figure 6-8.

In figure 6-8, when a mobile node (MN) first moves into a visited domain (domain C), it obtains the global address of the MAP (Regional care-of address (RCoA)). This address is stored in the Access Router and communicated to the mobile node via router advertisement *(Soliman et al. 2005)*. The mobile node uses the RCoA address as its home address while it is in a local domain. The mobile node also gets an additional on-link care-of address (LCoA) from the access router. The mobile node then sends a local binding update message to the MAP (via route 1). The binding update message binds the RCoA and LCoA and there is no home address of the mobile node in the binding update message. Therefore, the MAP has no knowledge of the mobile node's home address (identifier), as the RCoA is used as a home address in HMIPv6 *(Soliman et al. 2005)*. The MAP sends binding acknowledgement back to the MN (via route 2). The MN then sends global binding update to its home network and correspondent node (via route 3). The global binding update binds the mobile node's home address with the RCoA and not the LCoA. Similar to the IDMP, the MN retains the same RCoA as long as it stays in the same domain. When the MN moves to the new Access Router, it gets a new LCoA and performs a local binding update to the MAP. Similar to the IDMP, global binding update is not needed in this case.
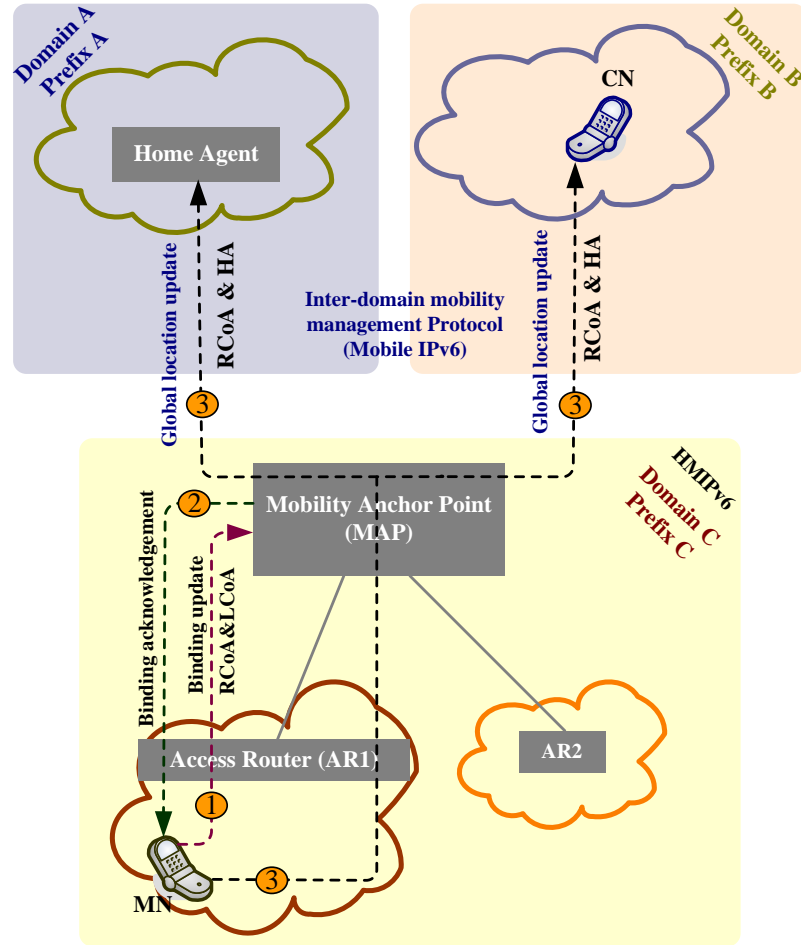
Figure 6-8: Movement detection mechanism of HMIPv6.

6.1.4.3. Discussion

Both IDMP and HMIPv6 use two-layer mobility hierarchy in the subnet and domain levels and two care-of addresses are allocated to a mobile node, one is recognized in the domain level and another one is for the subnet level. RCoA used by HMIPv6 is similar to the GCoA used in IDMP and on-link care-of address used by HMIPv6 is similar to local care-of address used in IDMP. The difference between IDMP and HMIPv6 is the local binding update message. The local binding update used in IDMP contains the mobile node's global identifier (home address), global point of attachment (GCoA) and local point of attachment (LCoA). The local binding update of HMIPv6 contains only RCoA and LCoA and not the home address of the mobile node, which is the mobile node's identifier. As mentioned previously, the identifier (who the user is) and the locator (where he is) are both needed in the mobile location service environment, and therefore it is not suitable to apply HMIPv6 as a

mechanism for determining the location of a mobile node, as the information of the mobile node's identifier is not revealed.

From a privacy point of view, HMIPv6 preserves higher location privacy compared to IDMP, as the identifier is hidden. IDMP is however more suitable to apply for mobile location services, as the information of the identifier and locator is included in the local binding update as discussed above.

This thesis takes advantage of the movement detection mechanism of global and local mobility management to determine the location of a user at different levels of accuracy. Standard Mobile IPv6 is adopted as a mechanism to determine the location of a user at the domain level and the intra-domain mobility management protocol (IDMP) is adopted as a mechanism to determine the location of a user at the subnet level. The IPv6-based location detection taking advantage of the movement detection mechanism of Mobile IPv6 and IDMP is proposed in the next section.

6.2   Proposed IPv6-based location detection

The idea of determining the location of a mobile user by applying the movement detection mechanism of Mobile IPv6 has been mentioned in the work in progress article published by the Internet Engineering Task Force (IETF) as a use case scenario *(Jaksa et al. 2007)* and a similar idea is recognized by an IPv6 special interest group in Japan *(Kabata 2006; Kabata 2006a)*. However, the concrete proposal of how to realize the idea has not been proposed, but it is believed to be possible.

In Schou & Olesen *(Schou & Olesen 2005)*, we have proposed a new location method designed to be used in the all-IPv6 network, which is called the IPv6-based location method. The IPv6-based location method applies the movement detection mechanism of the standard Mobile IPv6 protocol and of the IDMP to determine the location of all mobile users on the all-IPv6 network by mapping the IP addresses[225] of the mobile nodes with an approximate geo-location. Assessing the geographical location based on IP addresses is similar to assessing the geographical location based on the area-code of a telephone number. The granularity of the physical area corresponding to an IP address varies depending on the coverage area of the networks administrated by the network operators. Applying the movement detection mechanism of Mobile IPv6[226] alone to determine the location of the user can only reveal in which domain the user is. In this case, the domain will be administrated by a wireless network operator and the size of the domain depends on the service area of each network operator. Applying IDMP to determine the location of the user can

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[225] The IP address of a mobile node contains a network prefix determining in which network the node is connected. If the approximate area of the network is known, the location of the mobile node is also known.

[226] See section 6.1.3.3.

reveal in which subnet the user is. Similarly, the size of the subnet also depends on the administration by the network operator. The possibility of determining the location of a user by mapping the network prefix and geographical location is considered as a disadvantage of mobile IP with respect to privacy concern *(Koodli 2007)*, but it turns out to be an advantage for providing mobile location services.

As mentioned above, the combination of Mobile IPv6 and IDMP can reveal in which domain and in which subnet the user is. This thesis takes a step further to improve the location accuracy by adding the information of the access point at which the mobile node is connected in the local binding update message. As described in section 6.1.4.1, a binding update message of IDMP includes the IPv6 permanent home address, GCoA and LCoA *(Misra et al. 2000; Das et al. 2002)*. In this thesis, it is proposed that an additional static and unique IPv6 address of an access point is added in the binding update message (step 3 in figure 6-7) to identify at which access point the user is connected and this can provide more accurate location information of the user on the all-IPv6 network. The information in the new binding update (including the IPv6 unique address of the access point) will be forwarded to the location server[227]. The location server is an element maintaining the location information of all mobile users carrying an IPv6 terminal on the local domain and it also handles the transformation of the location information to a form that can be used by the service providers and users.

The proposed IPv6-based location method is based on the same principle as the Cell-ID method *(Schou & Olesen 2005)*, where the location of the user is known to be in the coverage area of the base station, and each base station carries a unique identification. In the case of the IPv6-based location method, the user's location is known to be in the coverage area of the connected access point or base station which carries a unique IPv6 address. In order to know the user location geographically, an accurate geographical map of the coverage areas of different access points, base stations, subnets and domains is needed[228].

The advantage of the IPv6-based location method developed in this thesis in comparison with Cell-ID is that all kinds of wireless access points that can support functionalities of IPv6 can be used to identify the location of a mobile user. The location of the user can be updated continuously when the terminal of the user changes its point of attachment from one kind of wireless access network to the next by applying the location update mechanism of Mobile IPv6 and IDMP *(Schou & Olesen 2005)*. Furthermore, the location of all the users on the unified IPv6 network can be detected using a single location method. The IPv6-based location method

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[227] The location server is one of the components forming the suggested service architecture for providing mobile location services presented in section 7.8.
[228] Possible methods used for obtaining the location of the access points on the all-IPv6 network are presented in section 6.5.

provides different levels of accuracy depending on the access technology being connected to by the user, as shown in figure 6-9.

Bluetooth/WLAN access points, Subnet of Bluetooth access points

WiMax/WiBro base stations, Subnet of WLAN

Mobile base stations, Subnet of WLAN

Domain

Country
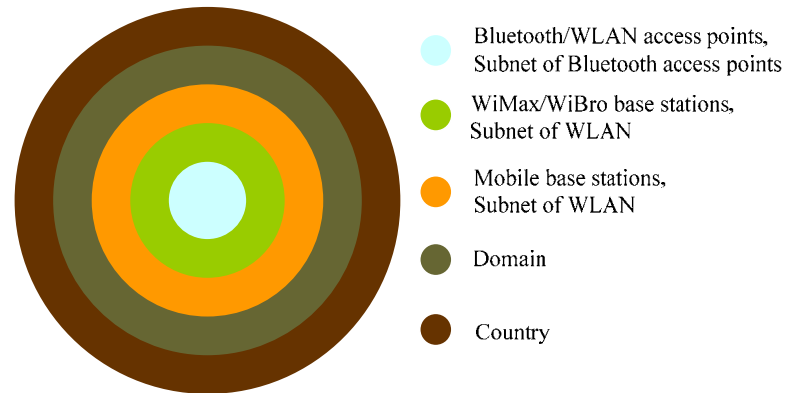
Figure 6-9: The IPv6-based location method provides different levels of accuracy corresponding to the coverage of the access point, the size of the subnet and the size of the domain to which the user is connected.

If an access point with a wireless technology such as Bluetooth or WLAN is used as a reference point to identify where the user is, the accuracy of the service will be determined by the coverage area of that access point[229] *(Thongthammchart & Olesen 2003)* and this can be applied to determine the location of the user in dense urban areas and in indoor environments. The indoor location solution applying the IPv6-based location method on the Bluetooth and WLAN networks has been proposed in this thesis and is presented in the following sub-sections.

6.2.1   Location solution for indoor environments and dense urban areas

As discussed in chapter 3 and 4, the availability and usefulness of a mobile location service depend amongst other things on the penetration of the mobile signal and the location method being used. In an indoor environment the signal tends to be degraded because line-of-sight barriers affect the quality of the radio connections, and the radio signals in outdoor environments are easily deflected by buildings, trees, etc. These are the reasons why the A-GPS is often degraded or unavailable in indoor environments and dense urban areas, and this has a direct affect on the quality of the mobile user experience towards the mobile location services as discussed in section 3.3. The lack of indoor location information is one of the main problems limiting the success of mobile location services in Asia as well as Western Europe as discussed in section 5.4.1.6 and 5.4.3. To improve the service availability in closed environments and urban areas, the IPv6-based location method together with the characteristics of Bluetooth and WLAN can be applied to detect the

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[229] See section 6.2.1.

location of a mobile user in indoor environments and urban areas with the accuracy of 10 to 50 meters. The proposed solution is to use access points of Bluetooth and WLAN as reference points to determine the point of attachment of a mobile terminal on the network[230]. When the mobile networks change to be all-IPv6 networks, it will not matter which of these wireless technologies is used by the terminal. Both technologies can be used to determine the user's location when the mobile terminal is connected to the IPv6 network via Bluetooth or WLAN access points.

6.2.1.1. Location determination applying Bluetooth

To take advantage of the user's location, Bluetooth networks must be configured in infrastructure-mode in multi-user mode *(Bluetooth SIG Inc. 2001)*. In the infrastructure-mode network, the mobile terminal communicates with other terminals via the base station or access point. This implies that the Bluetooth access point must always perform the role of master in the piconet[231] and participating devices must operate as slaves. All communication must be made through the master, and a direct transmission between slaves is not possible. If mobile terminals refuse to allow the Bluetooth access point to become master then the mobile terminals cannot gain access to the network[232]. If the wireless network is configured as an infrastructure-mode network, the location of the mobile user can be known by referring to the location of the base station or access point[233]. The accuracy of the provided location varies depending on the coverage area of the base station or wireless access point being applied.
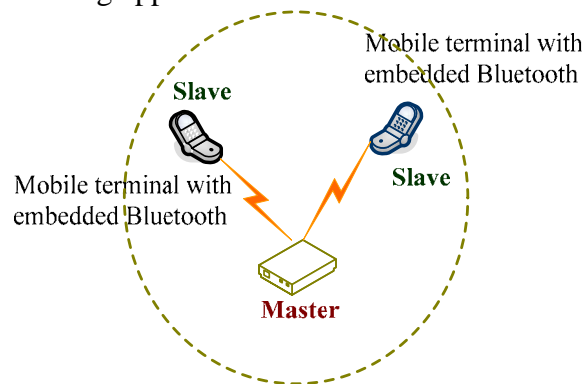
Figure 6-10: Bluetooth network configured in infrastructure-mode. The Bluetooth access point acts as a master and the connected devices are slaves.

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[230] This section is based on the publications written during this study *(Thongthammachart & Olesen 2003a, Thongthammachart & Olesen 2003b and Thongthammachart et al. 2003).*
[231] Piconet is a set of Bluetooth devices sharing the same physical channel defined by the master parameters *(Bluetooth SIG, Inc. 2001).*
[232] Ibid.
[233] The mobile networks are also configured in the infrastructure mode and the location of the user is known to be in the coverage of the base station which is the principle behind the Cell-ID method described in section 4.2.1.

In figure 6-10, a Bluetooth access point[234] can be used as a reference point to identify where the user is by correlating the exact location of the access point with an accurate map of the indoor environments (e.g. a building plan or a floor plan) *(Thongthammachart & Olesen 2003a)*. In the case of location detection using Bluetooth, the accuracy of the service is about 10 meters with class 3, 20 meters with class 2, and around 100 meters with class 1 standard *(Weissman 2006)*. Only class 3 of the Bluetooth standard is adopted for the location solution proposed in this thesis. The Bluetooth class 3 standard provides high accuracy location information with low power consumption (specified power consumption of a Bluetooth terminal is only 1 mW with class 3 standard; a Bluetooth device consumes more power in class 1 and 2 standards having bigger serving areas).

The location information provided by Bluetooth access points cannot, however, be updated continuously, when the mobile terminal moves between access points, since the mechanism for handover is missing in the Bluetooth standard *(Weissman 2006)*. With the compensation of the movement detection mechanism of IDMP, the location information of mobile end-users can be detected and updated seamlessly, when mobile terminals change their point of attachment.

The Bluetooth specification contains a set of profiles specified by the Bluetooth SIG. One of the interesting profiles is the LAN access profile *(Bluetooth SIG, Inc. 2001)*, which allows Bluetooth-enabled devices to access the services of a LAN. In this way, Bluetooth devices are able to carry IPv6 addresses and communicate with other IPv6 devices on the all-IPv6 network, when the mobile network changes to an all-IPv6 network. Bluetooth devices will have a unique global IPv6 address to identify themselves in both local and global networks[235]. IPv6-enabled Bluetooth devices can be connected to the all-IPv6 network via Bluetooth access points and the location of a Bluetooth device can possibly be tracked by any IPv6 node on the all-IPv6 network using the IPv6-based location.

Due to the small coverage area of Bluetooth networks, many access points are required. To cover large buildings (e.g. airport, shopping centers, museums, convention halls, etc.), an infrastructure with a large number of Bluetooth access points must be deployed. This infrastructure could support a large variety of new mobile location services, which cannot be offered today due to the lack of accurate location information indoors and in urban areas (e.g. indoor navigation and tracking services).

For the mobile terminal, the Bluetooth interface is simply an embedded chip or a plug-in module. The cost of adding Bluetooth to a mobile terminal is approximately 22 DKK in 2005 and it is expected to be less than 12 DKK by 2009 *(Milanesi et al.*

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[234] A Bluetooth access point is a Bluetooth device that provides access to the all-IPv6 network.
[235] See section 6.1.3.

2005). Sales of Bluetooth terminals are highest in Western Europe and it is predicted that nine out of ten mobile terminals in Western Europe will have Bluetooth embedded in 2009[236].

6.2.1.2. Location determination applying WLAN

Similar to Bluetooth, the WLAN networks have to be configured in infrastructure-mode in order to take advantage of the user's location. When users move from one access point to another access point, the location of the user will be known by the IPv6-based location detection method. In the case of location detection using WLAN, the coverage area of a WLAN access point[237] is larger than that of a Bluetooth access point resulting in a higher power consumption and lower location accuracy compared to Bluetooth. On the other hand, fewer WLAN access points are needed to cover the same service area compared to Bluetooth.

It is more suitable to apply WLAN access points to identify the location of a user in dense urban areas than in indoor environments, as the signals sent from a wireless access point are severely attenuated and reflected by objects (e.g. walls, furniture) *(Weissman 2006)*. This problem is more severe in a large cell (e.g. WLAN) than in a small cell (e.g. Bluetooth), as a large cell contains more objects and uses a single transmitter (a serving access point) to cover it, resulting in a highly non-uniform coverage area[238]. In a small cell (e.g. Bluetooth cell), the attenuation is much more uniform and predictable. Bluetooth is therefore more suitable to use as a location solution in indoor environments while WLAN is more suitable for dense urban areas.

6.2.2 Case example of indoor mobile location services applying Bluetooth and WLAN

Figure 6-11 shows the concept of indoor mobile location services applying Bluetooth and WLAN together with the proposed IPv6-based location detection mechanism.

In figure 6-11, Bluetooth access points are installed on the ceiling along the walk way and WLAN access points are located in the hot spot areas and in the gates, where the passengers sit and wait for departure. The main purpose of having WLAN access points at the airport is to serve the passenger with an access to the internet, as WLAN provides higher data rate compared to Bluetooth. WLAN access points also provide the user location but the location accuracy is not as accurate as when applying Bluetooth as discussed in section 6.2.1.2.

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[236] Ibid.
[237] 50 m for IEEE 802.11b, 30-50 m for 802.11a and 802.11g *(Hannikainen et al. 2002)*.
[238] Ibid.
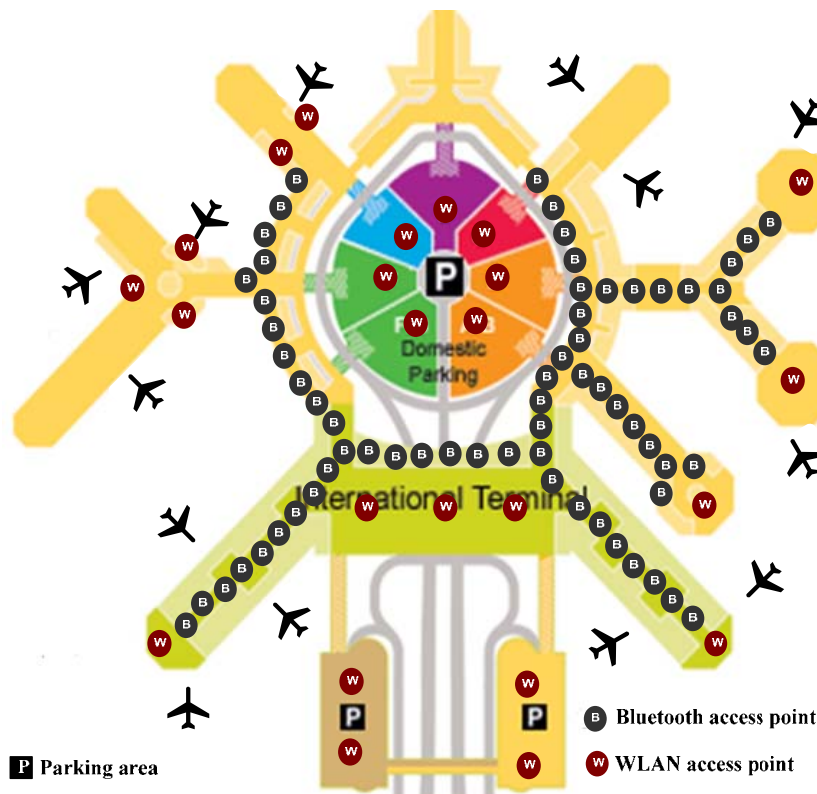
Figure 6-11: The concept of indoor mobile location infrastructure in the airport.

With the infrastructure presented in figure 6-11, a variety of new indoor mobile location services can be offered[239]. Services such as tracking, navigation services and indoor location-based games are examples of services that become possible. These above mentioned services are not possible today, because the high accuracy location information in indoor environments cannot be provided with the location technologies available today (as presented in table 4-1in section 4.1, tracking and navigation services will be useful if the accuracy of 10-50 meters is provided). Indoor tracking and navigation services are likely to be useful at the airport, as international passengers are normally not familiar with the airport. The tracking service is also useful, as the user can track the location of an arriving passenger, who is going to be picked up.

With the concept of one network having many services and many operators, as discussed in section 6.1.1, mobile users are allowed to access the all-IPv6 network seamlessly regardless of terminal, network, operator, etc. Therefore, it does not matter if the users are from Japan, Korea or Denmark, they will all be able to access the available network and access the services, such as navigation and tracking

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[239] See scenarios in section 7.9 for examples of mobile location services in the future.

148

services, at any airport on the all-IPv6 network (assuming that the agreements between network and service providers have been made). The location of international passengers can conceptually be tracked by their family or friends in their home countries, as the location of all mobile users on the all-IPv6 network is made available with the proposed IPv6-based location method. The service such as arriving alert could probably be interesting for the passengers' friends and family, as they can be sure that the passengers are arriving safely[240].

Applying IPv6-based location determination together with Bluetooth and WLAN access technologies, local location dependent services[241] can also be provided based on the location of a wireless access point. Services like local advertising/announcement and e-coupon services are examples of local location dependent services. The user will only receive the local information service when they pass by a shop or restaurant, where local location information is provided. The local location information can also be applied to provide services such as local television zone, local music zone, game zone, etc. For example, if the user enters the music zone, they can listen to music broadcasting content with or without payment through the local access point. The local location information can also be applied for promoting products such as software and games. For example, if a user enters the zone of a mobile game company, they are allowed to try mobile games developed by the company for free.

6.2.3 Privacy issue

Determining the location of the user applying the new IPv6-based location method on the Bluetooth and WLAN networks is made at the network side, and the user's location can always be tracked as long as the user enables the Bluetooth and WLAN connectivity on the terminal. As the level of the privacy concern varies corresponding to the accuracy of the location information *(Beeson et al. 2002)*, and as the accuracy provided by Bluetooth and WLAN is quite high, the users may be highly concerned about their privacy. With the IPv6-based location method, it is technically possible for the user to define the level of location accuracy that should be shown to other users on the all-IPv6 network. As presented in section 6.1.4.1, the location update in IDMP contains the unique IPv6 home address of the terminal; it contains the GCoA identifying the current domain of the connected terminal and the LCoA identifying the local subnet of the terminal. This thesis proposes that the unique IPv6 address of the access point to which the user is connected should be added in the location update mechanism in order to improve the accuracy of the user's location information as presented in section 6.2. This means that using the IPv6-based location method, the location of the user can be determined at three different levels of accuracy, i.e. access point level, subnet level and domain level.

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[240] See section 7.9.1 for an example of arriving alert service.
[241] Location dependent services are services that are available depending on the user's actual position. The service is available or is activated when the user enters a certain area *(3GPP 2006a)*.

Instead of showing at which access point the user is connected, the user may define that the system should show his location accuracy at the subnet level or at the domain level to other users. With this option, the user will feel more in control of the use of mobile location services, and this will soften the privacy concern and enhance the user comfort.

6.3   IPv6-based location solution service cases

This section demonstrates the usefulness of the proposed conceptual IPv6-based location method through two service cases: Tracking service and location-based advertising service as presented in section 6.3.1 and 6.3.2.

To facilitate the usage demonstration of the IPv6-based location method, different basic components required for providing mobile location services are introduced and these components form a system architecture for mobile location services. These components are the location server, the application and content server, and the third party content server, as shown in figure 6-12.
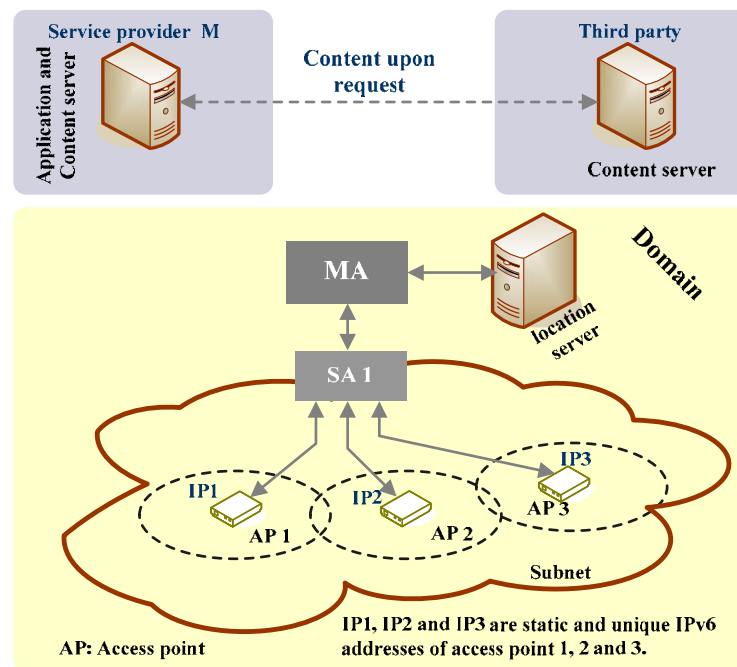
Figure 6-12: System architecture for mobile location services applying the proposed IPv6-based location method.

The purpose of introducing the system architecture in this section is to demonstrate how the location of the user can be determined and shared between different users and different components in the system architecture. The system architecture

150

presented in this section will later be combined with others components to form an advanced service architecture[242] for adaptive mobile location services, which is presented in chapter 7.

The idea of the system architecture is that the location server is placed in every domain and the location server and the domain are owned and administrated by a network operator. The role of the location server is to maintain the location information and user location profiles of all registered Mobile IPv6 nodes on the local domain, and to manage authentication and privacy control. The privacy control is made based on the information stored in the user location profile.

The user location profile contains not only location information of a user but also the rules of using and sharing the location information related to a specific IPv6 node. The user location profile is established by the user and the IPv6-based location detection. The user has the right to modify the part of the profile he has established (e.g. privacy rules) but not the location information which is specified by the IPv6 based location detection. In this thesis, it is suggested that the users should have full control over the use of their location information and the rules of sharing information is defined in the user location profile, which is maintained and managed by the location server as mentioned above.

Information such as user identity, age, gender, education background, job type, etc., will not be maintained in the user location profile but it will be stored in the user profile. The user profile may be used by a service provider for adapting the behavior and content of a service to the user and/or current context of use. The service adaptation based on the user profile will enhance the user experience towards a service[243]. A detailed description of the user profile and service adaptation for the conceptual service architecture is given in section 7.3, 7.4 and 7.6.

The other components required in the system architecture are the application and content server and third party content server. These two components belong to a service provider and third party content providers. Some service providers might establish their own content and some might provide services based on content from different content providers. The role of the application and content providers is to

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[242] The difference between the system architecture and the service architecture, as seen in this thesis, is that the system architecture identifies basic components required to realize a mobile location service and describes the way these components interact from a technical point of view, while the service architecture identifies the components required to build a commercial mobile location service that requires the involvements of different stakeholders and allow the billing and charging management. The service architecture describes the interactions between the components in a more service-oriented way, and it also has a higher focus on the user aspects (e.g. user experience, context of use and privacy) compared to the system architecture.

[243] See section 3.1, 3.2 and 3.3 for the principles of user experience.

provide a service and content to the users. The application and content servers can be placed anywhere on the all-IPv6 network.

In this thesis, it is suggested that the additional components mentioned above carry a static and unique IPv6 address and a mobile node will see these components as IPv6 nodes on the all-IPv6 network. It does not matter where the application and content servers are placed, only their static and unique IPv6 addresses are needed and the router will handle the data routing to the destination. The user can request for any mobile location service regardless of network operator and terminal type and model, from anywhere on the all-IPv6 network, assuming that the roaming agreement[244] between network operators is made and open standards for mobile location services are applied.

In the following sub-sections, the usefulness of the conceptual IPv6-based location method is demonstrated through two different service cases: Tracking and location-based advertising services. Through the demonstration of these two service cases, the usage of the IPv6-based location method can be explored.

6.3.1 Search by identifier – tracking service case

The IPv6-based location detection and the system architecture for mobile location services proposed in the previous sections can be applied to search for the user location by looking at the static and unique home address of a mobile terminal (node) which is the identifier of the mobile terminal. "Search by identifier" can be used to search for the current location of other Mobile IPv6 nodes on the all-IPv6 network and it can be applied for services such as tracking services. This section presents three different searching mechanisms in the cases that the mobile node and correspondent node are in the same subnet, in different subnets and in different domains. The searching processes are shown in the form of the protocol sequences illustrated in figure 6-13, 6-14 and 6-15 where the numbers in the circles indicate the sequence of events in each case.

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[244] Roaming agreement is a business arrangement between a pair of operators in which it is agreed that one operator will provide services to the customers of the other operator. Among other issues, a roaming agreement may address the level or type of service to be provided to the roaming customers as well as arrangements for compensation for the use of the roamed-to operators resources *(ITU-T 2005)*.
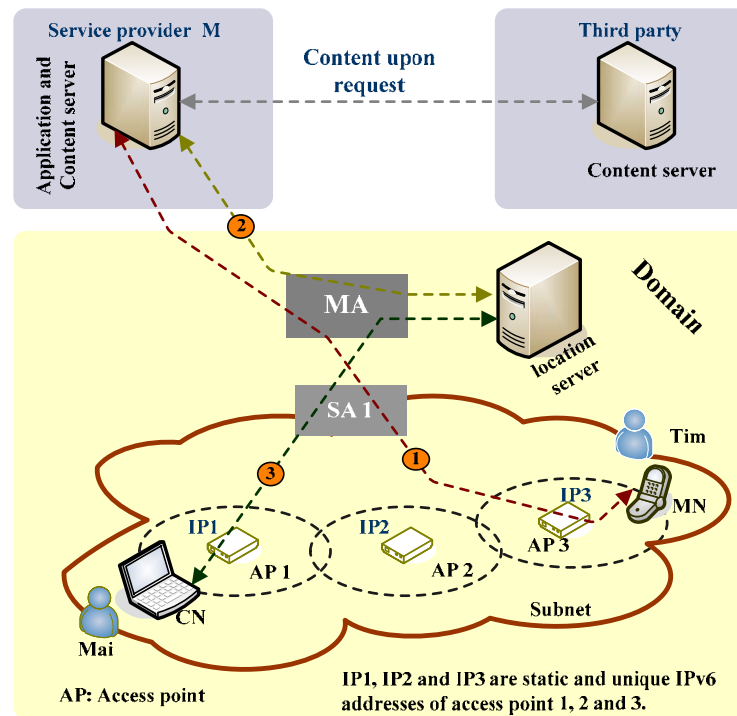
Figure 6-13: "Search by identifier" in the case where the mobile node (MN) and correspondent node (CN) are in the same subnet *(Schou & Olesen 2005)*. The location servers are placed in every domain. The location server maintains location information of all the nodes in the domain and manages authentication and control of the privacy of the users. The application and content servers can be placed anywhere on the all-IPv6 network.

In figure 6-13, Tim and his sister (Mai) have registered to use a tracking service of service provider M. Tim carries MN and Mai carries CN and both of them share location information, meaning that they can check the current location of each other any time they desire (they are in a permission list of each other)[245]. Now Tim wants to know where Mai is. He sends a location request to the service provider M (via route 1). The service provider M has neither the current location of Tim nor Mai but the location information can be requested from a location server (via route 2), which is placed in every domain. The service provider knows in which domain Tim is and which location server the location request should be sent to, by looking at the GCoA of MN (Tim's terminal)[246].

The location server looks in the user database to find out whether Mai is in the local domain. If Mai is in the local domain, the location server looks for the user location

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[245] Sharing location information with other users is one of the privacy rules defined by the user and stored in the user location profile in the location server.
[246] All mobile terminals on the particular domain share the same GCoA, and this address is the same as the address used by MA *(Misra et al. 2000)*, as described in section 6.1.4.1.

profiles of Tim and Mai to find out whether Tim is in Mai's permission list[247]. If Tim is in Mai's permission list, Tim is allowed to know the location of Mai without an instant permission request. Then the location server maps the current point of attachment of Mai (i.e. the access point at which she is connected) combined with geographical information and sends the result back to the service provider M (via route 2). In this case, the current point of attachment of the CN can be determined from its current LCoA, which is allocated by the current subnet, and the static IPv6 address of the access point, to which the CN is connecting. The current location of Mai is then delivered to Tim via route 1.

If Tim is not in the permission list of Mai, the location server will send an instant permission request to Mai via SA 1 and SA 1 forwards the request to the current access point where Mai's terminal is connected (via route 3 in figure 6-13). The permission acknowledgement is sent via the same route.
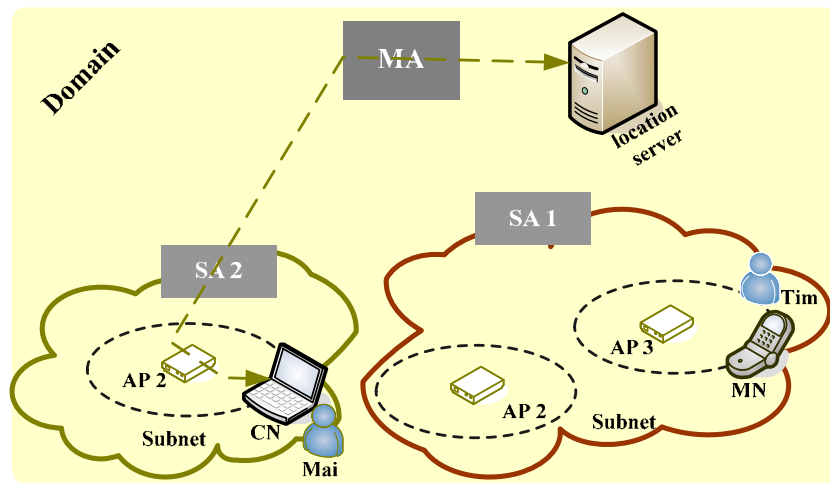
Figure 6-14: When MN and CN are in different subnets, the location server sends the permission request to CN via SA 2 and the permission response is sent back to the location server via the same route.

In the case that Tim and Mai are in different subnets, the location server will forward the permission request to the current subnet where Mai is connected. The location server knows in which subnet Mai is, by looking at the LCoA carried by Mai's terminal (SA 2 in figure 6-14), which has the same prefix as the IPv6 address carried by SA 2[248].

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[247] This process is the location privacy check process, which corresponds to the privacy check control process presented in the "work in progress" document of Open Mobile Alliance *(OMA 2006)*.

[248] See section 6.1.4.1 for more details.

If permission is granted, the permission acknowledgement will be sent and stored in both the user location profiles of Mai and Tim at the location server. This permission could be either permanent or temporary, depending on the users. Otherwise, the request will be turned down.

In the third case Tim and Mai are in different domains and Mai is not in her home domain. Perhaps they subscribe for different wireless network operators, or roam to the network of different local operators or are in different countries. The application and content server of service provider M can request location information of Mai by forwarding the location request to the home agent of Mai's terminal (CN)[249]. The home agent of CN then forwards this request to the current domain of CN (via route 1 in figure 6-15) [250]. The current domain of CN is known by looking at the GCoA which the CN sent to its home agent during the global binding update process presented in step 5 in figure 6-7 in section 6.1.4.1. The location server in domain B then sends location information to the service provider in domain A via the same route (see figure 6-15). The service provider uses this information to further process the mobile location service for the users. If the permission request is required, it will be done via route 2.
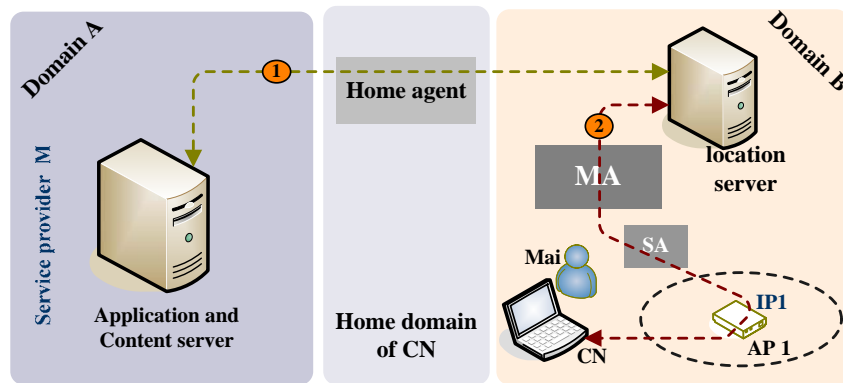
Figure 6-15: "Search by identifier" in the case, where the mobile node (MN) and the corresponding node (CN) are in different domains.

Applying the proposed IPv6-based location detection, the location of all mobile users on the global network (all-IPv6 network) can be determined and shared among users and service providers. This will bring new unimagined services to the market. Examples of future services applying the proposed IPv6-based location detection are given in section 7.9.

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[249] Please note that the process of requesting the location information of a user when he is in a local domain or other domains will not be visible to the user in the location request process, the routers on the network will handle the data routing to the destination.
[250] See section 6.1.3 for detailed description of the binding update of the standard Mobile IPv6 protocol.

6.3.2 Search by area – location based advertising service case

Mobile location services which target mobile end-users in a certain area also need a mechanism for finding the users in a specific area. A "search by area" can be achieved by mapping geographical data of that area with the network prefix of the domain or subnet covering a specific area and the user location profile of the registered users. With this feature several services can be enabled. For example, a restaurant can send advertising information to mobile end-users in a specific area or city. The protocol sequence of "search by area" is illustrated in figure 6-16.

In figure 6-16, the advertising portal[251] provides location-based advertising services (push) to mobile users. The advertising portal may acquire content from a content aggregator or several content owners.
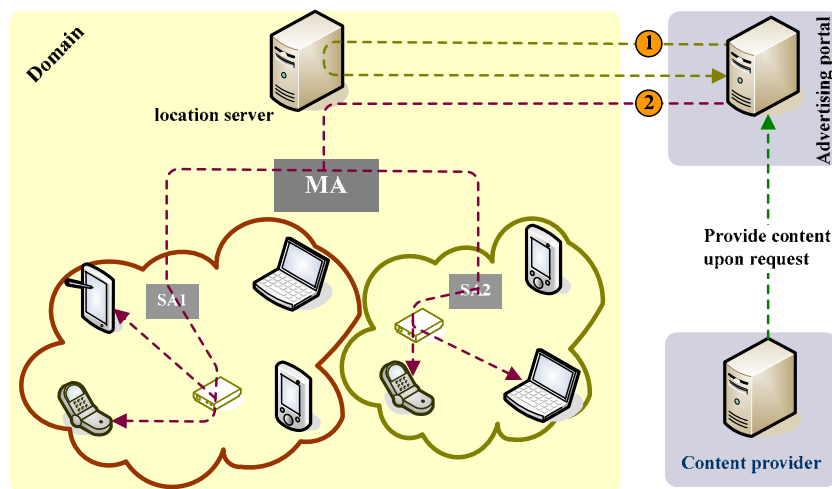
Figure 6-16: "Search by area" protocol sequence.

Assuming that an advertisement agency wants to send advertising information to the mobile terminals in a specific area (e.g. business target area), the advertising portal first sends a request to the location server to ask for information about the registered mobile users in that area (route 1). The location server searches and processes privacy control and returns the list of registered mobile terminals to the advertising portal via route 1. The advertising portal can then deliver data services to all mobile terminals that are registered to receive this kind of service in the area via the MA and SA (route 2). It is obvious, that the functionality of the location

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[251] The advertising portal acts as an application and content server providing location-based advertising services to the user. See section 1.1.4 for the description of the application and content server.

server becomes vital for the network, as the control over the use of location information of the user is made by the location server.

6.4   IPv6-based location solution in comparison with other methods

Many of the existing mobile location services lose some of their value due to the lack of service availability and the lack of high accuracy location information in dense urban areas and in closed environments[252]. The IPv6-based location solution together with the indoor location infrastructure applying short- and medium-range wireless access networks, e.g. Bluetooth and WLAN, enables high accuracy location information in indoor environments and dense urban areas as presented in section 6.2.1, and thus increases the value of the services.

Unlike the currently available location methods[253] which are only compatible with some of the mobile network standards, the IPv6-based location solution can be used as a single solution to determine the location of all users on the all-IPv6 network regardless of the access networks that the users are connected to. As demonstrated in section 6.3, the IPv6-based location solution enables the location roaming between different kinds of wireless access networks and makes the location sharing between different stakeholders on the all-IPv6 network become possible. Figure 6.17 shows the differences between the IPv6-based location solution and some of the existing location methods in terms of compatibility, availability and accuracy.

As shown in figure 6-17, the A-GPS method and the hybrid location solution are compatible with mobile networks only. A-GPS (see figure 6-17 (a)) provides high accuracy location information outdoors but is unavailable in indoor environments. The hybrid location solution (see figure 6-17 (b)) is available in both indoor and outdoor environments; it provides high accuracy location information outdoors and low location accuracy in closed environments. The IPv6-based location solution (see figure 6-17 (c)) is compatible with all kinds of wireless access networks, and it provides superior location availability and generally also superior accuracy compared to compared to A-GPS and the hybrid location solution, especially in indoor environments and dense urban areas.

The IPv6-based location solution determines the user's location by applying the movement detection mechanism of Mobile IPv6 and the Intra-Domain Mobility management protocol (IDMP) together with the unique IPv6 address of the access point or base station to which the user is connected[254]. This location solution requires neither hardware nor software to be added to the terminal, as the location

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[252] See chapter 5 for the examination and analysis of existing mobile location services.
[253] See chapter 4 for a description of the location technologies currently available.
[254] See section 6.2 and 6.3 for the description of the IPv6-based location solution.

157

determination is made on the network side. Since the user location is determined on the network side, similar to all terminal-assisted (or network-based location) methods on the existing network presented in chapter 4, turning off the location detection at the terminal is not possible. Applying the IPv6-based location method for mobile location services therefore requires another mechanism that provides the user a possibility to control their location privacy and this can be done in the service architecture, as presented in chapter 7.
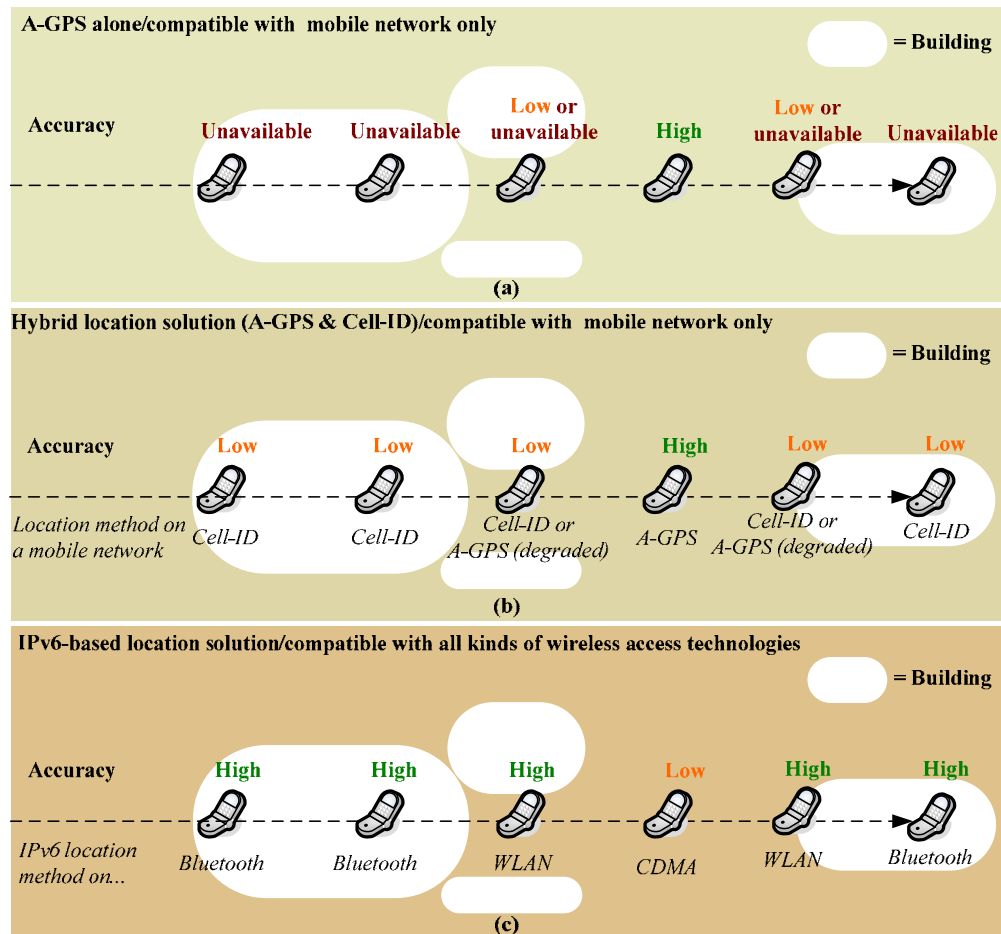
Figure 6-17: Compatibility, availability and accuracy of the IPv6-based location solution in comparison with two of the existing location methods, A-GPS and hybrid location solution that combines the Cell-ID and A-GPS methods.

As the IPv6-based location solution is based on the same principle as Cell-ID, where the user's location is known to be in the coverage area of the access point or base station at which the user is connected, this solution provides high accurate location only in the areas where a short- or medium-range wireless network (e.g. Bluetooth or WLAN) is available (mostly in indoor environments and urban areas). The accuracy of the IPv6-based location solution will be lower in outdoor

environments, where the wide area networks (e.g. CDMA, UMTS, WiMax, and WiBro) are more suitable to be used compared to the short- and medium-range wireless access networks. The accuracy will be even lower in the rural areas, where the number of base stations is limited and each base station covers a large serving area.

To improve the location accuracy in outdoor environments, the terminal-based GPS may optionally be used in combination with the IPv6-based location solution. In the terminal-based GPS method, the user location is determined at the terminal without any assisted signals from the mobile or wireless networks, and this location information will be sent to the location server together with the unique address of the terminal. The terminal-based GPS is suggested to be used instead of the A-GPS location method because the A-GPS method requires the assisted signals from the mobile terminal[255], and the A-GPS method is compatible with mobile networks only and not other kinds of wireless networks.

The advantage of having the GPS in the IPv6 terminal on the all-IPv6 network is that the user location can be determined using GPS in the case that the accessed mobile location service requires high accuracy location information and the IPv6-based location method cannot provide the location accuracy that matches the accuracy requirement of the service. An example of a service that requires high accuracy location information in outdoor environment is a navigation service for pedestrians. For other kinds of mobile location services where high accuracy location information is not required outdoors (e.g. location-based information services, location-based dating services), the IPv6-based location solution alone can be used for serving the mobile location service anywhere and any time regardless of the access technology and the terminal model being used by the users. Having the GSP in the IPv6 terminal allows the provision of high accuracy location information in both closed and open environments (see figure 6-18).
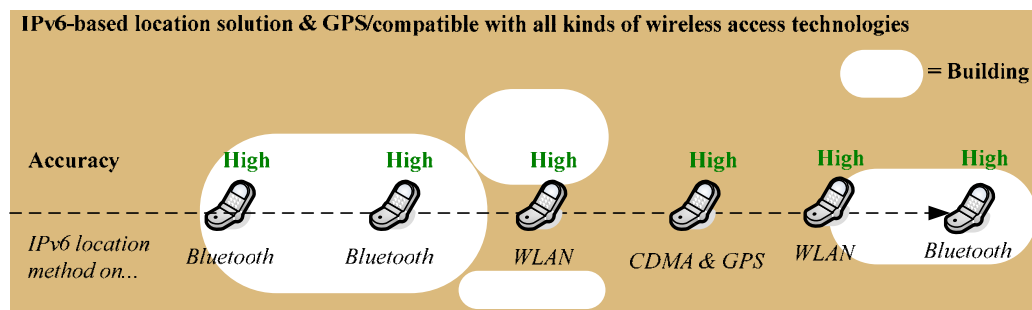
Figure 6-18: The IPv6 terminal with GPS built-in can be used to determine the location of the user in both indoor and outdoor environments. The location accuracy will be high in the outdoor environments in the case that the user has IPv6 terminal with GPS.

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[255] See section 4.2.5 for the description of A-GPS.

Even though the IPv6-based location solution alone can only provide high accuracy location information in indoor environments and urban areas (see figure 6-17 (c)), it significantly increases the service value, as approximately 70% of the service requests are made in indoor environments *(De La Vergne et al. 2006)*.

In order to utilize the location of the access points and base stations for providing mobile location services, the database that maps the unique addresses of the access points and base stations to their geographic coordinates is required. Different methods used for collecting the physical locations of the access points and base stations for constructing the database of their unique addresses and their geographical coordinates is presented in the following section.

6.5 Construction of database of geographical coordinates of the access points and base stations

One of the core challenges of applying the proposed IPv6-based location method for facilitating the deployment of mobile location services is how to create and maintain the database of the unique addresses of the access points and base stations and their references to the geographical coordinates. Various approaches for determining the location of the access points and base stations are available today. These solutions take advantage of the signal strength sent from the access points or base stations. Each access point and base station broadcasts a radio signal to announce its presence to the terminals located in its serving area. This signal incorporates a unique address that identifies the access point or base station, which is transmitted whenever the access point or base station is on *(Mexens 2007)*. The terminal does not need to connect to the access point and base station in order to receive these broadcast signals. Using high level mathematics, the location of the access points and base stations can be calculated by using the location of the location collector as a reference point (see figure 6-19).

Currently, there are different solutions that have been used for collecting the unique addresses of the access points or base stations, map these addresses with the geographical map and maintain them in the database. Examples are the method used for creating the Navizon Network Database (NND) used for the Navizon service *(Mexens 2007)* and the method used for finding the location of the WLAN access points used in WiFiFoFum *(Aspecto Software 2007)*.
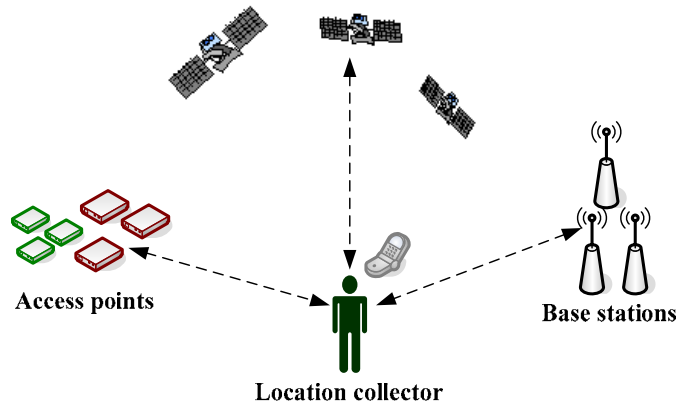
Figure 6-19: Method used for detecting the location of the access points and base stations. The location of the location collector is determined by using GPS satellites. This location is used as a reference point to determine the location of the access points or base stations by measuring the signal strength of the signals broadcasted by different access points and base stations. The signals sent out from the access points and base stations contain their unique addresses which can be used for constructing the database of their unique addresses (identifier) in connection to their geographic coordinates.

The concept of Navizon *(Mexens 2007)* is that there is a mapping application installed in a mobile terminal with GPS. When the GPS signals are available to the terminal, this application will automatically map the local wireless landscape by calculating specific, physical and geographic locations of all access points and base stations in the vicinity. Naturally there is complex mathematics involved for conducting the process of mapping the wireless landscape, which has not been further examined in this thesis. The mapping application used by the Navizon service is able to get the information of where the signal is coming from and record the location of the access points or base stations and construct a map of the wireless landscape composed of access points and base stations in the database.

Another similar application that can possibly be used for finding the locations of the WLAN access points for constructing the database of their unique addresses and their geographical locations is the WiFiFoFum *(Aspecto Software 2007)*. The concept of WiFiFoFum is that user carries a terminal with the WiFiFoFum application and GPS, and by using the user's location obtained from the GPS as a reference point, the location of different access points in the vicinity can be calculated based on the signal strength received by the terminal using complex mathematics (see figure 6-19). This way, the location of the access points can be collected and sent to the server for constructing the database of the WLAN access points and their geographical coordinates.

Figure 6-19: Screen shot of WLAN access point location detection using WiFiFoFum *(Aspecto Software 2007)*.

The database of access points and base stations in different regions in the world can be built by people who live in the neighborhoods. Constructing the database of the unique addresses of the access points and base stations and their reference to geographical coordinates requires a new business model that attracts people (i.e. location collectors) to participate in mapping the location of the access points and base stations for constructing the database that can be used for providing mobile location services. This can e.g. be done in a way that the people who map the location of the access points or base stations can use the mobile location services for free and they can earn some points according to the number of the access points they have mapped. The points they earn can later be converted to money, similar to how the database for the Navizon service is constructed.

One of the shortcomings of the mapping methods used in Navizon and WiFiFoFum is that the location of the access points is determined using the location of the location collector as a reference point. As the location of the location collector is determined by GPS and as the GPS is often degraded indoors, the automatic mapping methods used in Navizon and WiFiFoFum can mostly be used to map the access points and base stations in outdoor environments. Some of the access points in dense urban areas and inside building can possibly be mapped but not the access points located deep inside building.

The location of the access points in indoor environments may be built based on the information provided manually by the owners of the individual access points. In this case, the owners of the access points may earn some revenue sharing if their access point is used for mobile location services, similar to the revenue sharing model used in FON *(Fon 2007)*. The location of the access points in the department stores, airports, libraries, exhibition centers may also be provided manually by the organizations or companies responsible for these places. The companies or

162

organizations can benefit in different ways from making the location of the access points available for the users. For example, making the mobile location services available in department stores, location-based advertising services can be made available to the users and this can attract more customers to the shops. E-coupons based on the user's location can also be provided if the location of the access points are available and the user can access the mobile location services while they are in the department stores. Navigation services in the department store can guide the user to different shops. Providing the location of the access points may be done online, by letting the owners of the individual access points, the responsible companies and organizations interact with an online map through a mobile or web browser.

Figure 6-20 shows the concept that may be used for collecting the location of the access points for constructing the database of access points and base stations and their geographical coordinates.
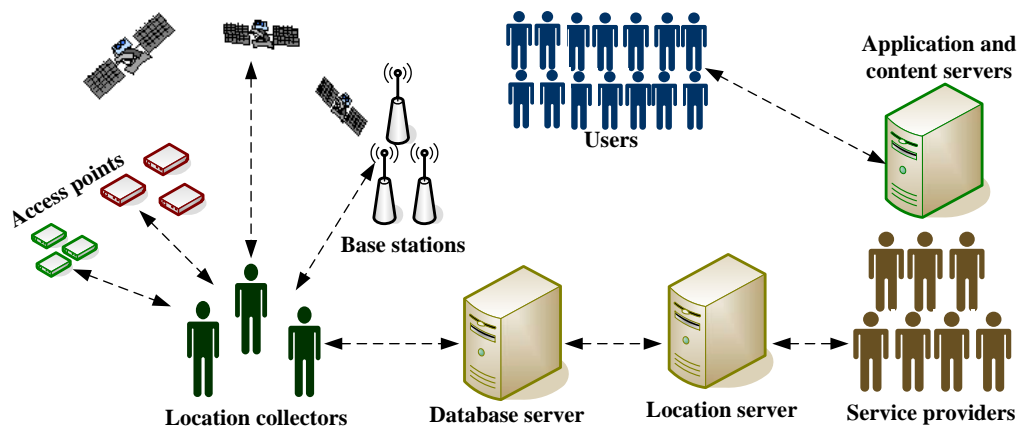
Figure 6-20: The concept of constructing the database of the access points and base stations and their geographical coordinates.

In figure 6-20, the database of the geographical coordinates of the access points and base stations in different areas can be constructed from the location of the access points or base stations collected and provided by the people in the community. The location collectors can be people who carry a mobile terminal with GPS and mapping application or the owners of individual access points who provide the location of their access points manually. The database server constructs and maintains the database of the access points and base stations using the information collected by the location collectors and provided manually by the owners of the access points. The database will be used by the location server to transform the unique address of the access point to which the user is connected to the geographical map that can be used by the service providers for providing the mobile location services to the users. Only the access points and base stations that have

already been mapped can be used for providing mobile location services. The availability of the mobile location services depends directly on the number of access points and base stations being mapped and maintained in the database. The more access points and base stations contained in the database the higher the service availability will be.

6.6   Summary

This chapter has proposed a new IPv6-based location determination solution applying the movement detection of standard Mobile IPv6 together with the Intra-Domain Mobility management protocol (IDMP). Location determination applying standard Mobile IPv6 can reveal in which domain the user is and the location of a mobile user can be revealed at the subnet level applying IDMP. The domain is administrated by the network operator and the size of the domain and subnet vary depending on the network management made by the network operator. To provide more precise location information of a mobile user, the static and unique IPv6 address of a wireless access point is suggested to be added in the local binding update message. This will make it possible to reveal at which access point the user is connected. If a Bluetooth or WLAN access point is used as a reference point, a location accuracy of 10 to 50 meters can be provided when the user is in indoor environments or in dense urban areas, where the GPS functionality is often degraded and thereby limiting the location technologies applying GPS (e.g. A-GPS).

For the proposed method, the location of the user can be detected regardless of the access technologies being used. The user location will be determined at different levels of accuracy depending on the coverage areas of different kinds of available wireless access technologies. A-GPS or other location technologies may still be used in outdoor environments, especially in rural areas. The user will possibly have an option of utilizing the best location technology available in each area. The mechanism of switching between different location methods will be done seamlessly and invisibly to the user. This will improve the availability and usefulness of mobile location services in the future and the quality of the user experience is thereby improved.

In this thesis, three elements are needed to be added in order to form the system architecture for providing mobile location services: Location server, application and content server and third party content server. The location server maintains location information and the user location profile. The location server also authenticates the service requests and controls the user privacy based on the privacy rules defined by the user. The application and content server provides mobile location services to the user. In this thesis, it is suggested that the location servers are placed and managed by the network operators, as the network operator owns the network domain and has information of who the users are. The application and content servers can be placed

anywhere on the network and they will be seen as IPv6 nodes on the all-IPv6 network. The third party content server provides content to the application and content server and it can also be placed anywhere on the all-IPv6 network.

With the proposed IPv6-based location detection method, the location of all mobile users on the global network will be available. This will open up opportunities for the mobile service providers to generate revenue based on the user location at the global level. The user will experience new unimaginable mobile location services. The mobile location services will possibly be offered in the same way as web services are offered today, where the user can access any web service regardless of location, computer model, operating system, protocol, ISP, etc.

Applying the IPv6-based location method for mobile location services requires the database of the access points and base stations and their geographic coordinates. The database can be constructed based on the location information of the access points and base stations collected automatically by people in the neighborhood using a mapping application installed in the mobile terminal with GPS. The mapping of the access points to their geographic coordinates can also be made manually by the owners of individual access points or by the companies or organizations who manage the buildings or places where the access points are located.

7 Conceptual service architecture for adaptive mobile location services on the next generation wireless network

The existing mobile location services presented in chapter 5 are typically available locally within the networks of specific operators or available on different networks of different operators in the same country, since the services are designed for specific end systems (e.g. specific networks or mobile terminals). Most of the services are fully controlled by the service providers. The services have their own style of presentation, user interface, and behavior. The services are not aware of what the user wants, how and in which context. The sharing of network resources (e.g. bandwidth, base stations, and access points) and information resources (e.g. location information and user profile) between different stakeholders (e.g. network operators, service providers, and users) is very limited or not possible. The way mobile location services are offered today is not compatible with the service environment of the next generation wireless network, which is likely to be open *(ITU-T 2005; Uusitalo et al. 2006)*.

In the open service environment, the users will be able to access a mobile service from anywhere, at anytime, using any terminal model, via any available access network of any operator *(Uusitalo et al. 2006; Chen et al. 2007; Kappler et al. 2007)*. Service providers and content providers will be able to provide their services and content independently from the types of network and the operators, and location, billing and charging information will be transferable between different administrative domains *(Reynolds & Jin-Kyu 2004; ITU-T 2005, p. 158)*. Both seamless roaming and universal access is one of the features of the next generation wireless network *(Chen & Yang 2007; Uusitalo et al. 2006; Uusitalo 2006)*.

Based on the global vision for the future wireless world from the Wireless World Research Forum (WWRF), the next generation wireless network is expected to emerge around the year 2017, and it is expected that 7 trillion wireless devices will serve 7 billion people by then *(Uusitalo 2006)*. Towards 2017, the technology will become increasingly more complex and more mature. As the technology gets more mature, the user will demand a better and better user experience from a service that is enabled by the technology *(Norman 1999; Hiltunen et al. 2002)*, and the success

of any service in the future wireless world will therefore be highly dominated by the quality of the mobile user experience[256].

Providing mobile location services on the next generation wireless network requires a new service architecture that fits in an open service environment and which allows the coexistence of a number of stakeholders performing various roles. The new service architecture must support universal service access and allow the end-users to access services independently of the physical location, type of access network and terminal model being used by the user. As the user experience is the key success of the future mobile location services, it is essential to take into account the principles behind the user experience[257] when developing a new service architecture for providing mobile location services on the future network. As a means of providing the best possible user experience to different users in different use contexts, the future mobile location services need to be adaptable to a vast range of user profiles and needs along with seamless connectivity anywhere-anytime *(Uusitalo 2006)*.

This chapter presents a new conceptual service architecture for adaptive mobile location services[258], which is designed to be used in the open service environment of the next generation wireless network. The service architecture consists of a set of concepts, rules and guidelines for constructing, deploying, and operating the services *(Abarca et al. 1997)*. The service architecture identifies components required to build the services, and describes how they interact[259]. The conceptual service architecture presented in this chapter is developed based on a combination of the system architecture presented in section 6.3 and some extra components that are added to the architecture in order to realize the provision of commercial mobile location services in the real market context. The conceptual IPv6-based location method proposed in Schou & Olesen *(Schou & Olesen 2005)* and presented in chapter 6 may be used within the architecture as a method to determine the location of a user on the next generation wireless network. The existing location methods (e.g. GPS-based methods) and the forthcoming location methods, e.g. sensor network *(Mamei & Zambonelli 2006; Guo & Imai 2007)*, may also be used. The conceptual service architecture developed in this thesis allows the adaptation of a service to best fit with the user requirements/preferences in different contexts of use. The new conceptual architecture provides a mechanism for sharing information resources (i.e. user profile and location information) between different stakeholders, thus it supports the deployment of new-concept services which have not been possible to provide using the existing service architecture on the current network.

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[256] Please refer to figure 2-2.

[257] The principles behind the mobile user experience have previously been presented in chapter 3.

[258] An adaptive mobile location service, in this thesis, refers to a mobile location service that is able to adapt itself according to the changes of use contexts and according to the user's definitions.

[259] Ibid.

As the quality of the mobile user experience is a key factor towards the success of any service on the future network as described above, the chapter starts by discussing the importance of managing the mobile user experience followed by strategies for managing the user experience towards mobile location services. Two strategies have been suggested to manage the user experience: To adapt the user to the service and to adapt the service to the user. The possibilities for adapting a mobile location service to match the requirements/preferences of different users in different contexts of use will then be described. A description is then provided of the different components (i.e. user profile, profiling management agent, service and content profile, context-based service adaptation platform and user expectation management platform and service portal) which will later be combined with the components in the system architecture previously presented in section 6.3 (i.e. location server and application and content server) to form a new conceptual service architecture for adaptive mobile location services. After the new conceptual service architecture has been presented, two scenarios representing new-concept mobile location services assumed to be deployed on the developed conceptual service architecture are then provided. Illustrative case studies of the services presented in the scenarios will then be made as a means of exploring and demonstrating the applicability of the developed architecture. Through the case studies, the interactions between the user and different components are demonstrated and the usefulness of the developed conceptual service architecture is examined by comparing the possibilities, capabilities and limitations of the new-concept services with similar services offered on the current network. At the end of the chapter, the factors that may limit or sustain the practical implementation of the conceptual service architecture and of the new-concept mobile location service presented in the scenarios will be discussed. The discussion is based on the feedback (criticism, comments and suggestions) obtained from the experts in the research area[260].

7.1 Managing the user experience towards mobile location services

The user experience is formed from the comparison of the expectations the users have in their mental model with the realization of the service, as previously described in section 3.2. Several mobile services have failed, often because the users of a service are unsatisfied with the service, as it does not meet their expectations. However, the users sometimes have unrealistic expectations due to the lack of understanding of what is going on, why and what to expect from the services *(Schrammel & Tscheligi 2006)*. To prevent unrealistic expectations and to enable users to interact in a positive way with the service, the service provider needs to manage the user expectation by communicating with the user about what is going on, why and what they can expect, and this is one way of managing the user experience.

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[260] See appendix D.

In the ACM ubiquity article "Why features don't matter anymore", Pfeiffer states that managing the user expectations and user experience is much more important for the success of a product and service than its technological features *(Pfeiffer 2006)*. A similar statement is also given by Usability Hub "No matter how excellent features the service has - everything depends on how the users will experience it" *(Usability Hub 2007)*. These statements have been proved to be true by WAP and i-area services.

WAP has demonstrated the importance of managing user expectations. The first version of WAP has been accused of failing to meet user expectations *(Danielyan 2003)*, which were inflated by marketing campaigns claiming that the experience of surfing the Internet from a mobile terminal using WAP service would be similar to browsing the web on a PC. As the users heard about WAP, they built high expectations of the WAP service in their mental model and it was not possible for the WAP service to meet these expectations.

The i-area service, on the other hand, has shown how a service can benefit from good user expectations management. As discussed in section 5.2.1.1, the i-area service does not always function as it is supposed to, but it is acceptable for the users[261] because the service provider manages the user expectation by informing the user of possible errors that might occur due to the inconsistence of the location technology being used (Cell-ID) *(NTT DoCoMo 2003)*. In this case, NTT DoCoMo provides an option for the user to manually input their actual location information. Therefore, the users can still accomplish their tasks and reach their goals, even when a location detection error occurs. This strategy keeps the user expectation of the service at a certain level and prevents the users from establishing too high expectations in their mental model[262]. Establishing realistic expectations in the user mental model is most likely one of the key factors to the success of i-area service.

As discussed previously, it is essential to manage the user expectation and the user experience towards a service. This thesis suggests two different approaches for managing the user experience towards mobile location services. The approaches are to adapt the user to the service and to adapt the service to the user, as presented in the following sub-sections.

7.1.1. Adapt the user to the service

Adapting the user to the service does not mean to change the characteristics of the user to match the designed service, but rather to adapt the users' expectations to the

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[261] NTT DoCoMo claimed to have 500,000 accesses to the i-area service per day in 2004 *(NTT DoCoMo 2004)*

[262] See section 3.2 for the explanations of the mental model, user expectation and user experience formation.

realization of the service. As we have learned from the WAP case discussed previously, the users had unrealistic expectations about the WAP service because the service developers and service providers positioned a WAP service as a mobile internet solution and claimed that the experience of surfing the Internet using WAP would be similar to the fixed Internet. As the users have experienced surfing the Internet using a PC, they built their expectations towards a WAP service based on the experiences they previously had with the fixed Internet, and they expected that surfing the Internet using WAP would give them the same feeling as they had with the fixed internet on the PC. After having tried the WAP service, the users realized a big difference between the WAP service model they had in their mind and their realization and this formed a bad user experience and negative emotion (e.g. disappointment). Adapting the user expectation to the realization of the service prevents the user from having unrealistic expectations and this can be done by giving the user the right and enough information regarding the service.

The process of adapting the user to the service takes place after the service is completely designed and ready for the market and before the user starts using the service. This is the process of providing the user the right perception about the service and this can be done by marketing[263]. The user expectation and user experience can also be continuously managed after the user has already adopted the service, and this thesis focuses on this stage of the user experience management. This thesis proposes, in section 7.7, the user expectation management platform to manage the user expectation after the user starts using the service.

7.1.2. Adapt the service to the user

The approach of adapting the service to the user is much more complicated than adapting the user to the service but both approaches are important. The process of adapting the service to the user takes place during the service design and after the service has been deployed. This section describes only the adaptation of the service to the user during the service development process, and real-time service adaptation will be described in section 7.6. During the service development, the concept of user experience and context of use is needed to be taken into account. Please note that the five elements forming the user experience (availability, usability, utility, aesthetics and offline issues) and the five perspectives of context of use (user, task, technology, physical environment and social aspect) have been presented in section 3.3 and 3.4, respectively.

Based on the analysis of the quality of the user experience generally provided by the mobile location services commercially available in Asia and Western Europe

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[263] A marketing strategy used for adapting the user to the mobile location service has not been studied in this thesis. However, a brief description of the importance of marketing to the success of a service is provided in section 1.2.1.

presented in section 5.4.3, it shows that the usefulness[264] (usability and utility) of the service is the most fundamental element influencing the user experience formation. The service usefulness (what the service does for the users and how it fulfills their needs and how easy it is to use) should therefore be emphasized when designing a mobile location service. The service will only succeed if it matches the user expectation better than the services that are currently in the market *(Hiltunen 2002)*.

Besides emphasizing the service's usefulness, the service must also comply with the use context and achieve the best fit with the mental model of the user *(Apple 2006; Schneider-Hufschmidt et al. 2001)*. Please note that the term "mental model of the user" is not the mental model of a single user, as it is not possible to know precisely what the users have in their mental model. The term mental model here refers to a generic mental model of the situation and service the users may have in their mind. Before developing the service it should be known who the target users are, what kinds of people they are, where and when the designed services are supposed to be used and why. In order to understand the target users and their generic mental model, researchers should go to the users and collect data to be processed to provide information to help the service designers hit the target users. The generic mental model of the target users and the context attributes of the contexts where the target users are expected to be, need to be researched and established qualitatively *(Hiltunen 2002)*. Since the service does not exist at the point when the researchers collect data, the use context knowledge and generic mental model of the user is based on assumptions and predictions (e.g. what the use context might be in the future, when the service would be used, etc.). However, the focus of this thesis is on how to apply the information that has already been analyzed rather than on how to collect and analyze the information from the target users.

Several services have been designed without taking the use contexts and the user's mental model into account. An example of a mobile location service that has ignored the use context and the user's mental model is the Okutto-Keitai service presented in section 5.2.4.3. This service has been designed to be used in the car by a driver. Okutto-Keitai delivers location-based information service to the user in the form of e-mail. The user (driver) needs to access the e-mail and the location-based information is contained in the e-mail in the form of a list of links to nearby restaurants. The user needs to click the links and access the websites of those restaurants. The way the service allows the user to interact with the service does not fit with the use context, where the driver needs to interact with the car and not only with the Okutto-Keitai service. Also, it is likely that the content provided by the service does not best match with the user's needs or expectations (in the mental model), as only a location-based map and a list of nearby restaurants is available,

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[264] See section 3.3.2.

and not a list of gas stations or stop points which is likely to better match with the driver's needs and expectations.

The service adaptation presented in this section is based on the predicted target users and predicted context of use. In reality, the target users and the context of use might turn out to be someone and something else, and the service may be experienced in different ways than the service designer intended. To ensure that the service matches the actual users' requirements and preferences in their current context of use, a real-time adaptation may be required. The process of real-time service adaptation based on the current context of use takes place while the user is using the service, and it can be handled by the context-based service adaptation platform presented in section 7.6.

7.2   Adaptation possibilities for mobile location services

A mobile location service is naturally adaptive by itself, since the information delivered to the user is adapted according to the location of the user. However, there are many more aspects of use contexts (user, task, technology, and physical environment and social environment) that mobile location services can be adapted to. For mobile location services, the adaptation can take place at five different levels: Technology, service behavior, user interface, presentation and content (*Reichenbacher 2003*). The five different levels of service adaptation are described below.

- **Technology level:** In this level, the service is adapted to the technology context. For example information is encoded for specific mobile terminals with different characteristics (e.g. display size and resolution, memory, CPU power, etc.) (*Zhang 2007)*, or for specific network conditions by e.g. reducing image resolution and color depth, and lowering video frame rate to match the network bandwidth *(Brewer et al. 1998)*.

- **Service behavior level:** The service behavior may be adapted to the user's location or task. An example of the service behavior adaptation based on the user's location is the zone alert feature of a tracking service, where the alert message is sent to specific persons when the tracking target leaves or enters a pre-defined zone[265]. The service behavior may also be adapted to the user's tasks *(Sousa et al. 2006)*. For example, a taxi driver may define that he wants text information to be translated to voice while driving *(ETSI 2005, p. 12)*.

- **User interface level:** The user interface may be adapted to the user's tasks, the system in use (e.g. terminal and network), and the user's physical

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[265] See section 5.2.2.1, 5.2.2.2 and 5.2.2.3 for examples of adaptive mobile location services based on task related information and location predefined by the user.

conditions *(Nilsson et al. 2006; Bisignano et al. 2005)*. For example, the user interface is changed from graphic user interface to voice interface when a blind user is accessing the service or when a user is driving. The user interface may also be adapted to a child-friendly version when the child is accessing the service[266]. The service adaptation in the user interface level requires that the terminal can support different kinds of user interfaces; otherwise adaptation in the user interface level is limited or not possible.

- **Presentation level:** The visualization of the service may be adapted to user's tasks, social aspect, and physical condition of the user. For example, the visualization of the service is changed based on social aspects (e.g. mature look for European users and cartoon version for Japanese users), or text information is presented with "large text" when elderly people are accessing the service. The visualization of the service may also be adapted according to the user's age, example can be found in the GiMoDig project *(Nivala & Sarjakoski 2004)*.

- **Content level:** In this level the content of the service is adapted to the current location, situation and user (e.g. age groups, gender, preferences) *(Yang & Williams 2007; Lech & Wienhofen 2005)*. For example, the system detects that the user is a child, and the service then adapts the content to an "easy to understand and child-friendly" version.
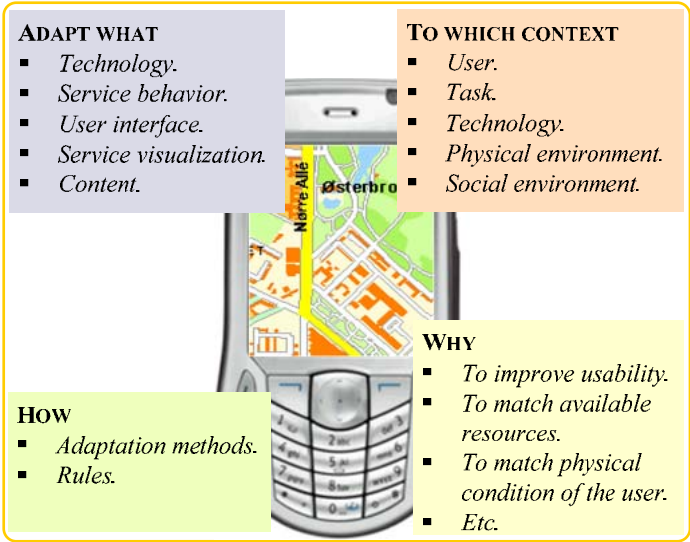
Figure 7-1: Perspective of the context-based service adaptation for mobile location services.

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[266] See figure 5-4 in section 5.2.2.2 for an example of a child-friendly user interface.

Figure 7-1 gives an overview of service adaptation illustrating why the service should be adapted, how and to which context. The service adaptation may be activated when both the context is changed and the user's requirements/preferences changed according to the new context. The change of context can be the change of one or more perspectives of use contexts (e.g. change of user, terminal, location, etc.). The context-based service adaptation platform proposed in this thesis will minimize the need of interactions between the user and the service without taking the overall control of the system from the user. To facilitate the context-based service adaptation, the user profile is required. The details of the user profile is described in the next section and the platform for context-based adaptation applying the context attributes and service and content related information is presented in section 7.6.

7.3　　User profile

When the users want the service to be adapted according to their requirements or preferences in specific contexts of use, a user profile is required. The term "user profile" can be referred to as a set of stored information related to a user *(ITU-T 2005, p. 173)* or a total set of user related information, preferences, rules and settings which affects the way in which a user experiences terminals and services *(ETSI 2005, p.10)*. The user profile represents a unique lifestyle and current context surrounding and situation of a user *(ETSI 2005, p.11)*.

The set of information required in the user profile depends on the purpose of using the profile. For example, the user profile in Devlic & Jezic *(Devlic & Jezic 2005)* is used to adapt and disseminate the content to the user terminal, and the user profile consists of attributes concerning characteristics of the user's terminal, the user's location and presence information, and preferences. The user profile in Bartolomeo et al. *(Bartolomeo et al. 2007)* contains information describing the user's physical being (e.g. identity, presence, preferences, history, group, society etc.) and its surroundings (user's location, available devices, networks etc.), and it is used to adapt services to the user, available network and terminal. The user profile in the Simplicity project *(Papanis et al. 2005)* is used to provide the user with the means to automatically personalize terminals and services according to his current context, and the Simplicity user profile contains information about the user himself, about the available services, the network connectivity options, the device capabilities and the terminal environment preferences.

In this thesis, the user profile is used by the context-based adaptation platform for adapting the services (e.g. visualization, user interface, behavior) to best fit with the user requirements and preferences in particular contexts of use. In order to support the adaptation, the user profile in this thesis contains the information related to the current context of use in which the service is used (i.e. information related to the user, task, technology, and physical and social environments) and the context-

dependent user requirements/preferences (e.g. task-dependent user requirements/preferences). The information related to the current context of use describes in which context and situation the service is used, and the context-dependent user requirements/preferences describe how the users want the service to, e.g., behave and present in particular contexts of use and situations. As the user profile in this thesis is used for context-based service adaptation, it is a context-dependent user profile. Figure 7-2 shows the groups of information required in the context-dependent user profile and used by the platform for context-based service adaptation proposed in section 7.6.

Information required in the context-dependent user profile

Information related to the current context of use

User	Task	Technology	Physical environment	Social environment

Context-dependent user requirements/preferences

User-dependent user requirements	Task-dependent user requirements	Technology-dependent user requirements	Physical environment-dependent user requirements	Social environment-dependent user requirements

Figure 7-2: Groups of information required in the context-dependent user profile. The profile contains the information related to the current context of use (user, task, technology, physical environment and social environment), and information related to the user's requirements/preferences in particular contexts of use and conditions, which is defined by the user.

In figure 7-2, the user is responsible for creating some parts of the user profile (e.g. user related information, task related information, and context-dependent user requirements/preferences). The terminal related information is provided by the terminal itself, and the physical environment related information is analyzed from the current location of the user, which is determined by a location technology or defined by the user. The information related to the physical environment may also be provided by a sensor embedded in, e.g., the mobile terminal or physical objects in the user's surrounding. The social environment related information (e.g. a social rule of using a specific service or a social rule of how people should behave and act in a specific society) can be derived from the user's location, type of location (e.g. class room, theater, meeting room) or defined by the user. The following sub-sections describe the individual parts of the user profile and how to obtain the required information for those parts.

7.3.1. User related information

User related information is a part of the user context shown in the context model presented in section 3.4.1. User related information is a set of stored information related to a user and his personal requirements or preferences in particular contexts of use. Information related to an individual user is obtained from the user's own input. The user is allowed to modify the information he has specified in the profile as he desires. Please note that the user related information presented in this section is for service adaptation and not for billing management[267]. For the service adaptation, the user can define attributes about himself as he desires and it does not have to be the user's real personal information. This will minimize the user's concern about privacy[268]. The user related information may include:

- User identity (e.g. uniquely assigned number or name). From the user experience point of view, a user should not feel uncomfortable from using a service. Some users might not be willing to reveal their real identities and attributes (e.g. real name, age, and gender) while using a service (e.g. location-based dating service). In this thesis, it is suggested that the user should be allowed to freely choose his identity and define his attributes as he desires.

- User's personal characteristics (e.g. physical condition of the user, etc.). The service might add some extra features to be used by users with limited perception capability, or by users who have difficulty using traditional input channels such as physical disabled persons (e.g. no hand, speech problem). The service may provide options to adapt the service to different users with different personal characteristics e.g. people with hearing difficulties may prefer to receive information and communications in a text format.

- User subscription information for services and applications, e.g. the name of a service and an application, and the address of the application server.

- Presence information of the user (e.g. in a meeting, busy, out of lunch) and present mood (e.g. sad, happy, angry, disappointed, etc.).

- Privacy rules defined by the user and these rules are applied for the service providers or other users who want to utilize the user profile. The users could specify in detail what information is shared and not shared, when, where, with whom, how and under what conditions. The privacy rules are applied not only

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[267] The billing management is handled by the service portal, as presented in section 7.8. For billing management, the real personal information of the user is required (e.g. the real name, address, credit card number, etc.) and this information will be maintained in the user billing profile.
[268] In this study, it is believed that the Internet chat programs (e.g. MSN, Skype, AIM, etc.) will not be as popular if the users are required to provide their real personal information.

for the user related information but also for all context related information stored in the user profile.

7.3.2. Task related information

Task related information is a part of the task context shown in the context model presented in section 3.4.2. Task related information is information related to the tasks the user wants to accomplish. This information is obtained by input from the user and it can be established and modified by the user anytime he desires. The task related information can be a service schedule set by the user (e.g. at 8 a.m., the user wants weather forecast information to be delivered and wants to know his child's whereabouts every one hour), the user's time schedule (e.g. meeting at 10 a.m., pick up customers from Japan at 2 p.m. at the airport) or the user's weekly or monthly plan (e.g. having dinner with the customer in Copenhagen on Friday next week). The task related information can be used to adapt the service behavior to match the task-dependent user requirement. Information about time schedule can be used to filter information that matches the user's need. For example, the user wrote in his time schedule that he is going to have dinner with a customer at 8 p.m. in Copenhagen. The service provider may use this information to filter the information of nearby restaurants to the user. The service provider may provide even more useful information to the user if the user gives detailed information about his customer (e.g. Japanese, 40 years old, likes to drink beer, etc.). The service provider may use this information to filter information of the restaurants where Japanese or Asian food is served or information of the restaurants where good beer is served.

Some of the tasks might interfere with each other in the mobile service environment. An example is illustrated by the scenario presented below.

'The user has registered for a child tracking service and location-based weather forecast. The user tried to call his child from 10 a.m. to 5 p.m., the terminal is on but there is no answer. He is very concerned about his child and uses a tracking service to check where the child is. Suddenly, the location-based weather forecast pop up on his terminal and the tracking process stops.'

The situation presented above could be very annoying for the user, as he is very worried about his child. To avoid bad experience from using a mobile location service, the user should be allowed to define different priorities for different tasks. The service should be adapted based on this information.

7.3.3. Technology related information

Technology related information is a set of information related to the terminal and network used by the user to access the service. The terminal related information can be stored in the terminal and uploaded to the user profile the first time the terminal

177

is contacting the profiling management agent[269]. Based on ITU-T *(ITU-T 2005, p. 129, 174)*, the terminal related information may be referred to as a device profile, and the information related to the terminal required for the service adaptation may include:

- Terminal identification, unique IPv6 address, name of the terminal.
- Static attributes such as supported protocols (WAP, MMS, etc.), input/output methods offered (text, voice, etc.), supported media (e.g. video, text, audio), display capability (screen size, colors in use, etc.), data storage and processor, browser support (Java support, frame support, Markup language versions support, etc.), transmission speed, bandwidth, and processing power.
- Dynamically changing attributes such as connection types (UMTS, WLAN, Bluetooth, WiBro, etc.), geographical location, and applications running on the terminal. The IP address, MAC address of the terminal and of the access point address to which the terminal is connected should also be included in the terminal related information *(ITU-T 2005, p. 175)*.
- Etc.

The terminal related information should maintain the latest available information of the terminal. It is expected that the terminal related information will be provided and updated by the terminal itself. However, there should be a mechanism that allows the user or agents of users to modify their terminal related information *(ITU-T 2005, p. 175)*. The information related to the network can, e.g., be the type of the network to which the user is connected and the data rate provided by the network.

7.3.4. Physical environment related information

The physical environment related information can be derived from the current location of the user, detected by sensor networks *(Uusitalo et al. 2006; Mamei & Zambonelli 2006; Guo & Imai 2007)* or defined by the user. The current location of the user may be obtained by applying the IPv6-based location method described in section 6.2 and 6.3 or by applying other existing and forthcoming location methods. The user location is stored in the user location profile in the location server as presented in section 6.3. Location information can also be stored in the user profile if the user desires or if real-time location information is required (e.g. for a service such as always-on location check[270]). When the user requests for location information, the current location information of the user will be sent and stored in the user profile. The user can define a period for which this location information is allowed to be retained in the user profile or the location information must be deleted from the user profile as soon as the location-based information is delivered to the user. In this thesis, the location information stored in the user location profile in the

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[269] See the roles of the profiling management agent in the introduction part of section 7.4 and 7.8.
[270] See section 5.2.2.2.

location server is the actual location of the user and this location is not allowed to be modified by the user, as this actual location may be used for billing management or some location dependent services such as location sensitive charging services[271]. However, it is suggested in this thesis that the location information stored in the user profile should be allowed to be modified by the user. This will provide an option for the user to fully control his location privacy and this will significantly reduce the user's privacy concern about using mobile location services.

The context attributes related to the user's location (physical environments context[272]) can be analyzed from the location information and probably from other local sensors as well (e.g. temperature, humidity). Based on the global visions for the future wireless world from WWRF *(Uusitalo et al. 2006; Uusitalo 2006)* and Guo & Imai *(Guo & Imai 2007)*, the sensors will be embedded in all physical objects in our living space, not only electronic devices but also e.g. vehicle, transport systems, weather systems and building infrastructure (furniture and lights for context sensitivity, doors and windows for security). Part of the role of the sensors is to provide context sensitivity. These sensors will connect to the all-IPv6 network and provide context information including location information, and this context information will be made available on a common IPv6 network[273]. The attributes of the current physical environment have an affect on the interaction between the user and the service. For example, the user might have problems seeing the content on the display if there is not enough light. If the context can be sensed, the system from the service provider side may communicate with the terminal and the terminal can then adapt itself to the context by adjusting the brightness of the display. This requires that the terminal is also an adaptive terminal; otherwise adaptation is in general not possible. Location related information such as weather and time could be used to predict what kind of information the user may want in a specific location. For example, the user might be interested in a list of nearby swimming suit shops during summer and winter jacket shops during winter.

7.3.5. Social environment related information

The social environment is important to take into account when trying to understand how and when the service is supposed to be used, and also to understand which social rules applies in connection to the use of the service. The social aspect has a strong effect on how users perceive the service *(Hiltunen et al. 2002)*. For example, it is more common to allow parents to track the location of their child in Asia compared to Europe[274]. Peer[275] pressure and comments are especially influential, as people usually pay a lot of attention to what people close to them say about certain

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[271] See section 5.3.4 for location sensitive charging services.
[272] See section 3.4.4 for physical environment with respect to the context of use.
[273] Ibid.
[274] See section 5.4.3.
[275] The word "peer" refers to friends, family, colleagues or anyone in the same society as the user.

things[276]. If people in the society do not accept the use of, or have a negative attitude towards, a certain type of service (e.g. child tracking service), people might not be willing to use the service in public and would also avoid displaying their enthusiasm for such services to their peers.

The social environment related information may be analyzed from the area (e.g. city or country) in which the service is used or from the type of location (e.g. theater, classroom, or airport). In this thesis, it is suggested that the social aspect of the use context should be taken seriously into account during the service design process. During the service usage, the service might be adapted to the social aspect of the use context in connection to the user's current location. For example, if the user is detected to be in the cinema or in a meeting room, the user's terminal may be triggered to be switched to the silent mode[277].

7.3.6. Context-dependent user's requirements/preferences

As the user profile in this thesis is used for adapting the service to best fit with the user's requirements/preferences in his current context of use, the information regarding the user's requirements/preferences according to a particular context of use is required. This part of the user profile will be defined by the user and may include:

- User-dependent user requirements/preferences, e.g. accepting only sport-related advertising content, applying tone B for child tracking alert service.
- Task-dependent user requirements/preferences, e.g. wanting all the text content to be translated to voice while driving.
- Technology-dependent user requirements/preferences, e.g. wanting 70% of the terminal resources to be reserved for a mobile location service. Please note that the change according to the technology-dependent user's requirement may not be visible to the user.
- Physical environment-dependent user requirements/preferences, e.g. navigation services must be provided in 3D format only when the user is in foreign countries, wanting the maximum volume for voice-based services in noisy environments.
- Social environment-dependent user requirements/preferences, e.g. wanting the service alert to be automatically changed from voice mode to vibrant mode in the class room, theater and on the bus.

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[276] Ibid.

[277] Switching a mobile terminal to a silent mode based on the user's location is a kind of "location-dependent service" (an explanation of location-dependent services can be found in section 5.1).

7.4　User profile management and user profile structure

In this thesis, the user profile is used for facilitating the context-based service adaptation performed by the platform for context-based service adaptation presented in section 7.6. This platform is one of the elements forming a new conceptual service architecture for adaptive mobile location services presented in section 7.8. The conceptual service architecture is designed to be used in the open service environment of the next generation wireless network. In the open service environment of the next generation network, reusability of the network resources and information resources should be possible *(ITU-T 2005, p. 170-172),* and the exchange of the user profile between administrative domains must be allowed in the next generation network *(ITU-T 2005, p. 158).* The user profile used in the service architecture in this thesis should therefore be reusable, meaning that the user should be able to reuse and share the same user profile or parts of the user profile with other users and with different services without having to re-create and update different profiles for different services.

The International Telecommunication Union has also defined that the user profile for the next generation network should be independent of any physical objects, such as terminal and access link, and it should be possible to identify and authenticate users independently of terminals/devices recognized by the network *(ITU-T 2005, p. 173).* Different approaches have been proposed in the literature to manage the user profile; some are more suitable to be used in the open service environment of the next generation wireless network than others. Examples are the user profile management in the Simplicity project *(Blefari-Melazzi et al. 2007)*, the user profile management in the MAGNET beyond project *(Kyriazanos et al. 2007)*, the user profile management proposed by ETSI *(ETSI 2005)* and the user profile management in the Mobilife project *(Sutterer et al. 2007).*

The Simplicity user profile (SUP) is maintained by a portable and robust device, and this device is called a Simplicity device (SD). The user can utilize the user profile by plugging the SD to a chosen device. The availability of the Simplicity user profile is fully depending on the SD, and the service adaptation and authorization is not possible without the SD. As the SUP depends fully on the Simplicity device, the user profile management in the Simplicity project does not fulfill the general requirements for the user profile management for the next generation network suggested by the International Telecommunication Union. In the MAGNET beyond project, the user profile is separated into several subcomponents and they are placed in different locations. Some are placed in the user's devices, whereas others are placed in an online repository of the service provider. As different subcomponents of the MAGNET user profile are placed in different locations, the reuse and sharing of the same user profile for different services or with other users in the open service environment becomes complicated. For the user profile management proposed by ETSI, it is suggested that the user

profile is maintained by a profile provider, which may be a network operator, service provider or profile vender. ETSI *(ETSI 2005, p. 77)* also suggests that the users should be able to share information in their user profiles with others, such as with a user's affinity group or buddy list, and it should also be possible for users to send the entire profiles or parts of profiles to other users. Furthermore, the information stored in the user profile may be distributed over different devices, networks and services and belong to different administrative domains. The concept of the user profile management suggested by ETSI is very suitable to be used in the open service environment of the next generation wireless network. However, the ETSI does not provide concrete proposals of how to realize the described concepts and suggestions. Another approach for managing the user profile that can fulfill the requirements for service support capabilities of the next generation network in terms of information resource reusability and physical object independency is the user profile management in the Mobilife project. The Mobilife user profile has been designed to support the context-based service adaptation and personalization in the ubiquitous network environment. The Mobilife user profile management system allows the sharing and reuse of a user profile or parts of the user profile between different services and different users.

In this thesis, the user profile is used for adapting the service (e.g. visualization, user interface, behavior) to best fit with the user's requirements/preferences in particular contexts of use, thus the user profile must be structured and managed in a way that can be used for facilitating the context-based service adaptation. Additionally, the user profile management has to be compatible with the general requirements for the user profile management on the next generation network suggested by ITU in terms of resource reusability and physical object independency, since the user profile is a part of the service architecture for adaptive mobile location service presented in section 7.8, and this architecture is designed to be used on the next generation network. Instead of reinventing a novel solution for managing and structuring the user profile, this thesis adopts parts of the approach and suggestion for structuring and managing the user profile from the Mobilife project, as it is compatible with the open service environment of the next generation network, as discussed previously. With small adjustments, the Mobilife user profile can be used for structuring and managing the user profile for the context-based service adaptation in this thesis.

7.4.1. User profile structure

As presented in section 7.3, the context-dependent user profile in this thesis contains the information related to the current context of use and the context-dependent user requirement/preferences. The entire set of information presented in

section 7.3 is, in this thesis, referred to as the central user profile[278]. However, only some parts of the information in the central user profile will be required for adapting a specific service to best fit with the user's requirements/preferences in a specific context of use and situation. In this thesis, the user profile is structured based on the approach proposed in the Mobilife project. Figure 7-3 illustrates the structure of the context-dependent user profile.
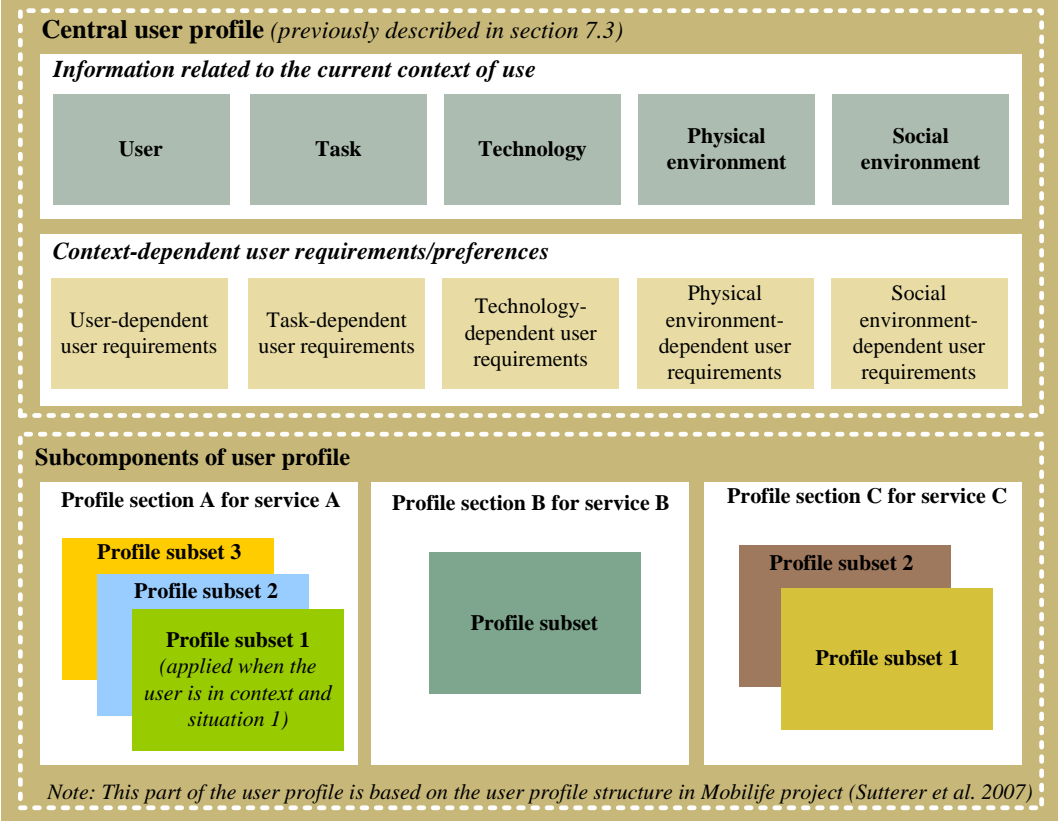
Figure 7-3: Structure of the context-dependent user profile. The central user profile refers to the profile that contains the entire information related to the current context of use and context-dependent user requirements/preferences (previously described in figure 7-2). The profile sections and profile subsets are derived from the central user profile (the structure and organization of this part of the user profile is based on the user profile management proposed in the Mobilife project *(Sutterer et al. 2007)*).

In figure 7-3, the profile section is created to be used for a specific service, and each profile section contains one or more profile subsets. One of the profile subsets in the

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[278] The central user profile may be created using a template provided by the profiling management agent as suggested in the guideline for user profile management of ETST *(ETSI 2005, p. 45-50)*. With the use of the template, the user will be asked to provide the relevant default information and values required for the context-based service adaptation.

profile section must be defined as a default profile subset and the remainders are context-dependent profile subsets (referred to as "profile subset" in the following). The default profile subset contains the default information such as user identity and service identity, and the profile subset contains both the default information and necessary additional information that is required for context-based service adaptation such as context information, context-dependent user requirements/preferences and adaptation conditions. Different profile subsets in the same profile section will be applied for the same service in different contexts of use or situations. For example, profile subset #1 is applied when the user is in a specific location with specific social rules (e.g. meeting room, theater), and profile subset #2 is applied when the user is busy with other tasks (e.g. driving). Examples of sets of information that may be contained in two different profile subsets used for adapting the same service to the user's requirements/preferences in different contexts of use and situations are presented in figure 7-4.

Service ID: Zone alert tracking service	Profile subset #1
User ID: John *Type of location: Theater* *Task: Watching a movie*	*Physical and social environment-dependent user requirements/preferences* *- Vibrant service alert* *- Text or graphic user interface* *- Text or graphic location notification*

Service ID: Zone alert tracking service	Profile subset #2
User ID: John *Type of location: In the car, on the road* *Task: Driving*	*Task-dependent user requirements/ preferences* *- Voice service alert* *- Voice user interface* *- Voice location notification*

Figure 7-4: Examples of two different profile subsets generated for a zone alert tracking service and applied for the service adaptation in two different contexts of use and situations *(Schou 2008a)*. The profile subset #1 will be applied when John is in the theater and profile #2 will be used when he is driving. The profile subset #1 is used to adapt the service to the physical and social environment in which the service is used. The profile subset #2 is used to adapt the service to best fit with the current task performed by the user.

The information required in each profile subset is derived and generated based on the information stored in the central user profile and this task is handled by the profiling management agent presented in the following.

7.4.2. User profile management

In this thesis, the user profile is maintained and managed by the profiling management agent[279]. The role of the profiling management agent is to maintain, generate and manage the user profile or parts of the user profile (i.e. the profile section and profile subset) of registered users as well as to handle authentication and authorization. This agent acts as a broker handling the usage and sharing of the information in the user profile according to the current context of use in which the service is used and according to the privacy rules defined by the users[280]. When a service provider wants a user profile of a specific user, the profiling management agent will search, match, and provide the profile subset that contains the necessary information required for the service adaptation process for a particular context of use.
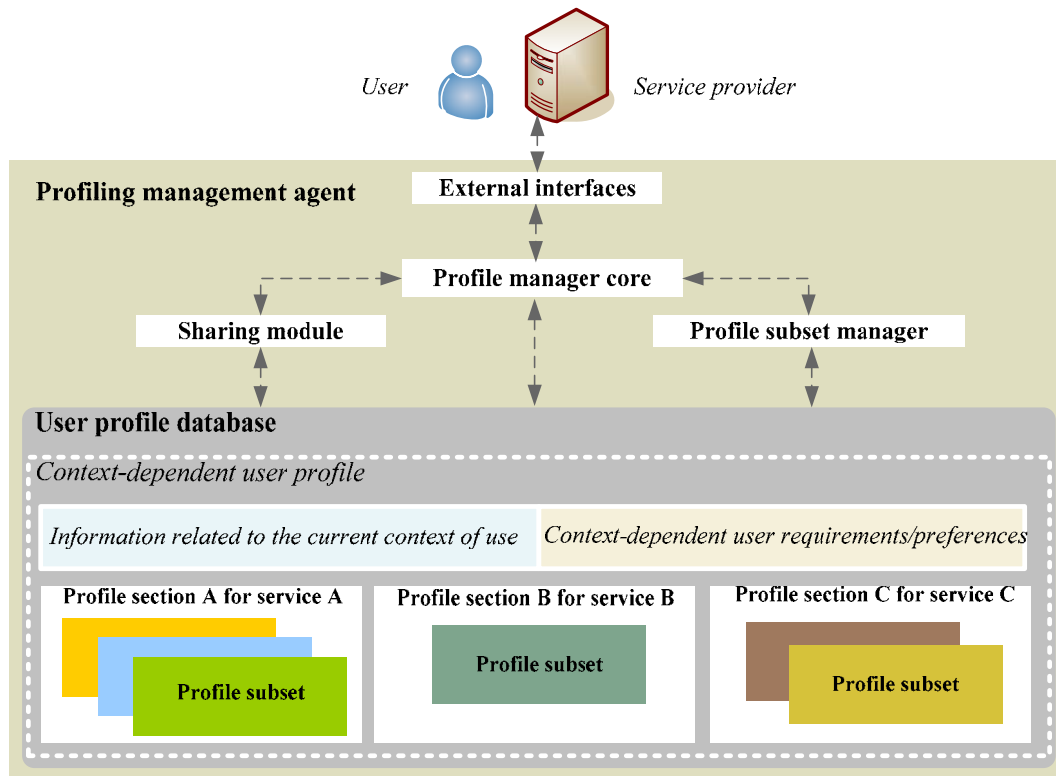
Figure 7-5: Profiling management agent partly based on the profile management approach proposed in the Mobilife project *(Sutterer et al. 2007).*

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[279] The profiling management agent is referred to as a "profile provider" or a" profile agent" in the ETSI guide to user profile management *(ETSI 2005).* In this thesis, the term "profiling management agent" is used, as the agent does not only store the user profile but also manage the usage and the sharing of the user profile.

[280] See section 7.3.1.

The profiling management agent in this thesis is adapted from the profile management approach proposed in the Mobilife project *(Sutterer et al. 2007)*. In the Mobilife project, the context information is maintained in a separate database than the user profile, the mobile management component has to externally request for the context information from the context management system in order to find the best matching profile subset for a specific service in a specific context of use and situation. The concrete proposal of how to manage the context information has not been provided in Sutterer et al. *(Sutterer et al. 2007)*. In this thesis, as presented in section 7.3, the information related to the current context of use of the user is maintained in the user profile together with the context-dependent user requirements/preferences, as this information is unique for each user. Since both the information related to the context of use and the context-dependent user requirements/preferences is maintained in the same database, finding the best matching profile subset for a specific service in a specific context of use in this thesis can be done within the profiling management agent. Figure 7-5 presents the subcomponents that form the profiling management agent and illustrates how these components should interact.

The profile manager core in figure 7-5 provides the external interface for the service provider or other users to request for a user profile and for the registered users to create, view, update, edit, and delete their user profile maintained in the user profile database. The profile manager core also interacts with different components in order to obtain the requested information. The profile subset manager is responsible for the management and retrieval of profile subsets from the user profile database. In the case that there are more than one profile subsets for an individual service, the profile subset manager is responsible for searching for the best matching profile subset, i.e. a set of information that best matches the user's current context of use and situation. The sharing module supports the reuse and sharing of the information in a user profile (e.g. user identity, physical condition of the user, preference language, privacy rules, etc.) for different services. For example, if the user registers for a new service, the sharing module can support the user in creating a new profile section and subset for the new service based on the existing information previously defined by the user. In this case, the user does not need to re-provide the entire set of information to different services.

The interactions between different components in the profiling management agent in the case that a service requests for a profile subset of a registered user are as follows.

1. A service provider requests for the context-dependent user profile of a specific user, by specifying the service identity and the user identity.
2. The profile manager core contacts the profile subset manager to ask for the profile subset for the requested service and user.

3. The profile subset manager contacts the user profile database to ask for the relevant profile subset and sends this profile subset to the profile manager core, which then forwards it to the requested service (assuming that there is only one profile subset for the requested service).
4. If the profile section of the requested service contains more than one profile subset, the profile subset manager searches for the profile subset that best matches with the current context of use of the user and situation.
5. In the case that there is no existing profile section and profile subset for the requested service, the profile manager core contacts the sharing module for creating a profile section and subset for the service by retrieving information from the central user profile maintained in the user profile database. The information such as user identity, physical condition, privacy rules, context-dependent user requirement (e.g. voice content when driving), etc. can be reused for a new profile subset for a new service. This feature makes it easy for the user, as they do not need to provide the same information more times than necessary. The user can later modify the information in the profile subset generated by the profiling management agent as he desires.
6. In the case that there is one or more profile subsets in the profile section but none of them match the current context of use and situation, the default profile subset will be provided and the context-based service adaptation will not be activated.

As the context-based service adaptation platform in this thesis is supposed to be used in the open service environment of the next generation wireless network, where the user can access the service anywhere and anytime, a user profile must be accessible and modifiable by the user from anywhere on the all-IPv6 network, which corresponds to the profile management policy proposed by ITU-T *(ITU-T 2005, p. 29, 173-174)* and the standardization regarding user profile management specified by ETSI *(ETSI 2005)*. Based on the user profile management suggested by ITU *(ITU-T 2005, p. 173-174),* the user should be allowed to have as many profiles or profile subsets with different identities and attribute information as he desires. The user should also be allowed to use a single profile or a single profile subset for different services provided by different providers. The user profile can be viewed and modified by the user and/or an agent of the user upon the user's permission.

7.5 Service and content profile

The service and content profile is a set of information related to a service and the content provided by the service. This profile is established and managed by the service and content providers[281]. The service and content profile is maintained in

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[281] See section 1.1.4 for the description of service and content providers.

the application and content server[282]. It contains information about what the service can and cannot provide to the user including the information of adaptation possibilities. Information that may be contained in the service and content profile is shown below.

Service related information may include:

- Service identity, IPv6 address of the server where the service is located.
- Terminal supports (e.g. browser requirements, connection type requirements, data storage and processor requirements, user interface requirements, etc.).
- Data rate requirements (e.g. 345 kbps or higher).
- Location accuracy requirements (e.g. 10 meters or higher).
- User interface supports (e.g. graphic user interface, voice interface, finger print, iris, etc.).
- Schedule delivery support (e.g. every one hour, only weekdays, when the criterion in the user profile is fulfilled).
- Etc.

Content related information may include:

- Provided information formats (e.g. text, picture (2D, 3D), voice, video).
- Color change support (e.g. color change according to the user's preferences).
- Supported languages.
- Different content related to the user's age (e.g. for children, adult, elderly).
- Different content related to the user groups (e.g. gender, age, etc.).
- Different forms of content related to the user's physical capability (e.g. text and picture for deaf-mute, voice for blind, etc.).
- Etc.

7.6   Conceptual platform for context-based service adaptation

It is often impossible to design a service that fulfills the requirements and matches the preferences of all its users, because people have different life styles, they perform different tasks in different context surroundings with different social rules. They access the service via different networks using different terminals with different capabilities. To satisfy different users in different use contexts, the service should be adaptable and customizable according to the change of the context of use. An adaptive service can automatically adjust e.g. user interface, visualization and behavior of the service based on e.g. the user's task, location, and physical condition. An adaptive service that provides what the user requires and prefers at

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[282] Description of application and content server is given in section 1.1.4.

his current contextual surrounding, can theoretically provide a positive user experience[283] *(Schou 2008a)*.

Based on the analyses made by De La Vergne et al. *(De La Vergne et al. 2006)* and Shen et al. *(Shen et al. 2007)*, and as discussed in section 5.4.1.9, the lack of adaptability and the lack of offerings tailored to different user requirements in specific contexts of use are some of the main factors inhibiting the take-off of the existing mobile location services both in Asia and Western Europe. Adaptability is envisioned by WWRF as one of the keys to the success of any service beyond year 2010 *(Uusitalo 2006)* and one of the service capabilities that should be made available on the next generation wireless network suggested by International Telecommunication Union (ITU) *(ITU-T 2005)*. Adding adaptability to the future mobile location services will therefore be one way of increasing the possibility of the service being a success *(Schou 2008b)*. To add adaptability to a mobile location service on the next generation wireless network, a platform for handling the service adaptation to match the users' requirements/preferences in specific contexts of use is added in the conceptual service architecture in this thesis.

7.6.1. Choice of the adaptation

Two types of adaptation can be applied for the context-based service adaptation for mobile location services: Self-adaptation and user-controlled self-adaptation *(Dietrich et al. 1993)*. In the self-adaptation process, such as the Rainbow framework *(Garlan et al. 2004)*, the system adapts itself without any interaction between the user and the system, while the user-controlled self-adaptation process, such as an adaptive icon toolbar presented in Debevc *(Debevc et al. 1996)*, is a sort of system in which the user makes the decision but the system automates the rest of the change. Meyer *(Meyer 1994)* concluded that adaptation performed entirely by the system (self-adaptation) can be effective primarily when the adaptation does not change the actions available to the user. To change service characteristics that are visible to the user (e.g. user interface, visualization, behavior), it is important to give the user the opportunity to decide about the adaptation[284].

An example of a mobile service adaptation that is based on self-adaptation is the adaptation approach proposed in the Simplicity project *(Blefari-Melazzi et al. 2004)*, where the service relies on the user profile containing information such as the user preferences and characteristics of terminal and network. Part of the profile proposed in the Simplicity project is automatically collected by the system and the adaptation is made automatically based on the information stored in the user profile. Another adaptation proposal based on self-adaptation is the AmbieSense project *(Lech & Wienhofen 2005)*. The AmbieSense adaptation platform has been designed

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[283] See chapter 3 for the principles behind the user experience, user expectation, and the influence of the context of use to the user experience formation.
[284] Ibid.

to be used by travelers at the airport. The system collects the attributes of the current context of use of the users by using sensor tags, and the context-based information service is automatically pushed to the user terminal based on the predicted users' requirements at their current contexts of use and situations. The obvious problems of the adaptation approach used in the Simplicity and AmbieSense projects are the lack of control by the user. Since self-adaptation is driven by the computer without the user's decision, the outcome of the adaptation cannot be guaranteed to match the user's requirements/preferences in the current context of use. If this is the case, the user will have to spend extra time changing the adaptation made by the system and he may leave the service permanently.

The services based on self-adaptation will only succeed in a few, limited cases that are characterized by being very simple to describe in machine-understandable ways and relatively unchanging *(Nielsen 1998)*. Even if a service can adapt itself perfectly to match the user expectations, it could be unacceptable for the user due to psychological reasons *(Reichenbacher 2004)*. The user may feel that the service is untrustworthy, due to the lack of power over the service and the lack of understanding from situations where they feel out of control, unaware of what has happened or why, and this can lead to a negative user experience *(Schrammel & Tscheligi 2006; Arhippainen 2006; Norman 2004)*. The WWRF has suggested that the user of the future mobile services should be able to control the service to the extend they want *(Uusitalo 2006)*. As the self-adaptation process lacks of the user control, it is not an appropriate approach to be used in the service architecture in this thesis, which is designed to be used on the future wireless network.

The service adaptation proposed in this thesis relies on the user-controlled self-adaptation, where the service adapts itself automatically based on the information defined by the user. While self-adaptation is driven by the computer (i.e. artificial intelligence), the user-controlled self-adaptation is based on the user definitions, selections and control (i.e. natural intelligence). The service based on natural intelligence only works if it is easy to understand and the user knows how to define and control the service adaptation *(Nielsen 1998)*.

7.6.2. Adaptation platform

This section describes the process of context-based service adaptation[285] based on the context-dependent user requirements/preferences defined in the user profile and managed by the profiling management agent[286]. The context-based service adaptation for mobile location services in this thesis is based on the principle that the user should always have full control of the service adaptation and the user

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[285] Mobile location services can be adapted to the use contexts in five different levels as presented in section 7.2.

[286] The detailed descriptions of user profile and profiling management agent have previously been provided in section 7.3 and 7.4 respectively.

should be able to decide whether he wants adaptation at all or at certain levels. In this thesis, the control of the service adaptation by the user is made in the user profile, where the user defines, in the context-dependent user requirements/preferences part, what he wants from the service, how he wants it and in which context surrounding and situation. Figure 7-6 shows the conceptual platform for context-based service adaptation. This platform is placed at the application and content server of the service provider[287].
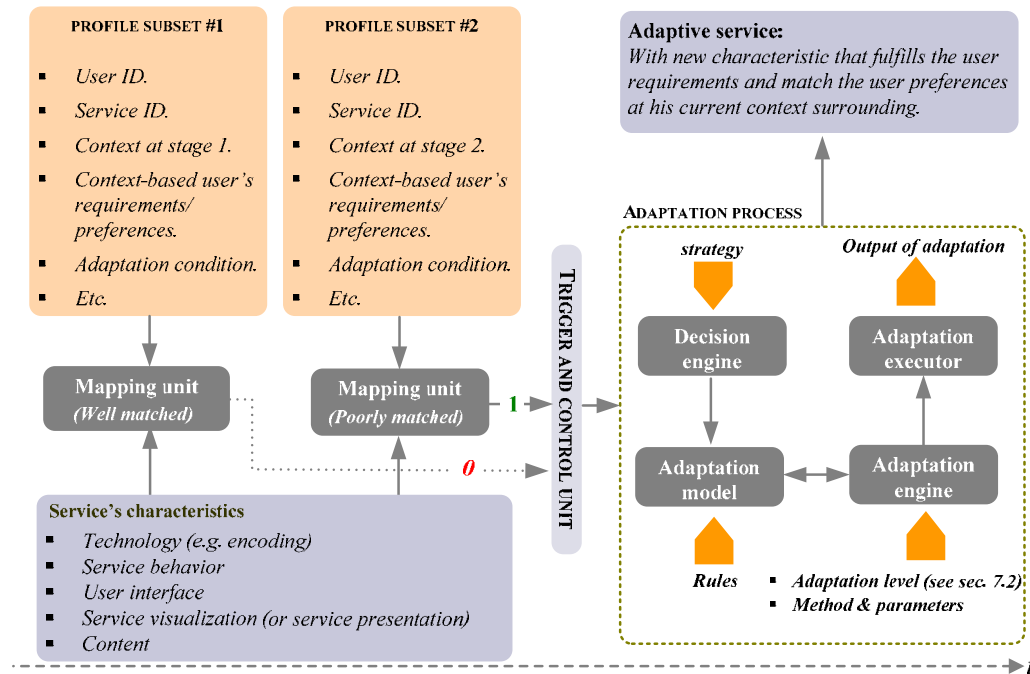
Figure 7-6: Conceptual platform for context-based service adaptation for mobile location services *(Schou 2008a)*. The profile subset #1 and #2 are sent from the profiling management agent to the application and content server at stage 1 and 2 respectively. At stage 1, the characteristics of the service match the user requirements/preferences in his current context and the adaptation function will not be activated. At stage 2, the service is used in another context and situation and the characteristics of the service do not match the user requirements/preferences in the new context, and the adaptation is triggered at this stage.

In figure 7-6, the mapping unit checks whether the characteristics of the service (e.g. user interface, visualization) match the user requirements and preferences at his current context (e.g. wanting voice-based user interface while driving) included in the profile subset, which is provided by the profiling management agent. In the case that the service's characteristics match with the requirements and preferences of the user in his current context, the service adaptation will not be activated. Also

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[287] The description of the application and content server is given in section 1.1.4.

in the case that the user has not defined his context-dependent user requirements/preferences in the user profile or the user has only a default profile subset in the profile section of the requested service; the service adaptation will not be activated. In the case that the service adaptation is not activated, the default version of the service will be delivered to the user.

If the context-dependent user requirements/preferences have been defined in the user profile and the characteristics of the service do not match what is defined in the user profile, the mapping unit will notify the trigger and control unit, which then starts the adaptation process *(Schou 2008a)*. When an adaptation is triggered, the new context-dependent user requirements and preferences are transferred to the decision engine. The decision engine checks whether the adaptation is possible (i.e. whether the service has a capability to adapt itself to fulfill the context-dependent user requirements/preferences defined in the profile subset) by looking at the possible features provided by the service in comparison to the user's requirements/preferences maintained in the profile subset. If an adaptation is possible, the decision engine selects an appropriate adaptation strategy. Then the rules for service adaptation are selected from the adaptation model. The adaptation engine chooses the adaptation levels of the service (i.e. technology, task, user interface, presentation, or content levels) that will be adapted and selects the appropriate methods and parameters. The adaptation executor finally adapts the mobile location service by applying the chosen methods, parameter values and rules. The details of the adaptation strategy, adaptation parameter and adaptation rules have not been examined in this thesis and this requires further research work.

If the service cannot be adapted based on the information stored in the user profile (e.g. the service does not support the function for people having physical disabilities such as no hand or speech problems), the user expectation needs to be managed by using the user expectation management platform presented in section 7.7.

7.6.3.   Discussion – problems involved with context-based service adaptation

Some of the problems that might be involved with the context-based service adaptation platform are discussed in the following.

7.6.3.1. Privacy

A general problem of adaptive services is the lack of data protection or privacy *(Browne et al. 1990, p. 208)*. Context-based service adaptation requires the collected information of the current context attributes and the context-dependent user requirements/preferences in the user profile. In this case, the user's personal information or related facts (e.g. age, physical condition, and current location) may be required. Many users, naturally, feel reluctant to give away such information. Especially if the users do not know and understand which information is stored

about them and where it is stored and who will have access to it. Even if the service can be adapted perfectly to the context-dependent user requirements/preferences, it would probably not be acceptable for the user due to psychological reasons as discussed in Reichenbacher *(Reichenbacher 2004)*, Schrammel & Tscheligi *(Schrammel & Tscheligi 2006)* and Norman *(Norman 2004)*. In this thesis, it is believed that the privacy concern has a stronger effect on the user experience towards mobile location services compared to other kinds of mobile services. For mobile location services, the acceptance of allowing other people to see the user location information can e.g. lead to physical harm if it is in the hands of a criminal *(Beeson et al. 2002)*. People are becoming increasingly aware of the privacy implications of disclosing their whereabouts and they generally perceive location as being very sensitive information *(Appelbe 2003; Gadzheva 2007)*. People are becoming more demanding with regards to the protection of their personal privacy, and there are a number of privacy concerns that keep bothering their minds *(Lam 2005)*. To minimize unpleasant experiences from using a mobile location service, appropriate means to minimize the risk of misuse have to be developed. If there are mechanisms to guarantee data privacy and if the user is convinced that the service provides a substantially improved utility through the adaptation, the privacy issue regarding the use of mobile location service can be softened *(Reichenbacher 2004)*.

In this thesis, it is suggested that collection of the context attributes should be transparent to the user. The user should know what information is collected and what the purpose of collecting such information is. The users should have the right to specify what information is collected, shared, when, with whom, how and under what conditions[288]. The users should also be able to define the period of visibility for their location. For the service adaptation process proposed in this thesis, the control of data privacy is made in two levels. The first level is the control of using the user's actual location information stored in the user location profile. The privacy control of using and sharing the actual location of the user is handled by the location server and the location server is maintained by the network operator as mentioned in section 6.3.

The second level of the privacy control is made in the profiling management agent. The user profile for the conceptual service architecture suggested in this thesis is not managed by the service provider alone as the way it works today, but it is handled by the profiling management agent who acts as an agent managing the usage and sharing of the information stored in the user profile as discussed in section 7.4 and 7.8.3. The service provider can only access the user profile when the user is accessing the service or according to the user's definitions. The user may

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[288] The study made by *(Consolvo et al 2005)* shows that the most important factors affecting whether or not the users are willing to disclose their location are: Who is requesting for their location and why the requester wants to know their location. The study also shows that the mobile users are willing to share their location with family and friends and less willing to share the location with their boss, colleagues and other people. Activity and mood also affect the willingness of the users to disclose their location information.

also modify every piece of information stored in the user profile as he desires. This will minimize the privacy concern of using a mobile location service in the future. However, the service adaptation will not be effective if the user changes all the actual attributes of the current context. The service adaptation is based on the principle that the more precise information available for the service provider, the better the service becomes for the user.

7.6.3.2. Adaptive services can be confusing

The context-based service adaptation proposed in this thesis is based on the user-controlled self-adaptation process described in the beginning of section 7.6.1, meaning that the users can define what, when, where, how, and under what conditions the service should and should not be adapted. The advantage of the user-controlled self-adaptation process is that the users have full control over the adaptation, and the adaptation is made based on the users' actual requirements and not based on the predictions by the system. On the other hand, this might not fit very well with the nature of mobile users, as they are typical busier than the web users, and they do not want to spend time setting up complex adaptation features *(Nielsen 1998)*. Additionally, the users are likely to be confused by the complicated setting up options and mess up the user interface and then leave the service *(Hiltunen et al. 2002)*. This thesis argues that the context-based service adaptation will only be successful if it is easy to use, easy to understand, easy to control and if it does not take too much time to define the service behavior.

Adding more adaptation features to the service does not always result in a better user experience. Instead the service may become more complicated and confusing for the user. Only the features that provide a good user experience will be used, others are useless and they will limit the service's ease of use, as the users have to spend extra time finding the feature they want amongst the huge set of available features which they do not want or even understand and this is obviously frustrating *(Pfeiffer 2006)*.

This thesis argues that the well-designed service does not require large amount of adaptation features, and it is easy to understand and easy to use. The well-designed service refers to the service that has, during the design process, taken into account the context of use presented in section 3.4, the elements forming the user experience presented in section 3.3, and the generic mental model of the user presented in section 3.2. As presented in section 7.1.2, adapting the service to the user during the service design process requires research about the users and the context of use. From the user research process, it can be predicted who the target users are, what they want, how they want it, where and in which situation they want it. Performing a user research also helps the service designer to understand the generic mental model of the user, and the outcome of the well-designed service based on the user research result will already be able to fulfill some of the expectations for most of

the target users without real-time adaptation requirements. If the service is expected to be used by different groups of people, the service may alternatively be designed in different versions, e.g. stockbroker version, bus driver version, etc. in order to make the service match the general expectations or generic mental model of different groups of users[289]. As the context of use and user mental model applied during the service design process is based on estimations and predictions, this information might not be completely correct, and slight adjustments of the service may be needed in reality. Real-time context-based service adaptation presented in figure 7-6 will adjust the characteristics of the service (e.g. user interface, behavior, visualization, content) to better fit with the user's requirements/preference in the current context of use and this requires only minimal setting of adaptation features, as parts of the expectations are already fulfilled according to the discussion given above.

The poorly designed service is the service that ignores the context of use, the user mental model and the elements forming the user experience. This kind of service is designed without doing user research, without understanding who the target users are, what they actually want, and where and in which situation they are supposed to use the service. The poorly designed service requires a huge set of adaptation features in order to allow the users to adjust the service functions and behaviors to match the user expectations and fit with the context of use. The service might end up providing a good user experience, but it requires a lot of setting effort from the user before a good user experience is available. It cannot be ensured that the users will be willing to spend time setting up these adaptation features, and they might end up leaving the service before they reach the point where the poorly-designed service starts to provide a good user experience.

7.7   User expectation management platform

The deployment of mobile location services depends on the availability of mobile networks and location technologies. Usually, the service provider cannot control the capabilities of the network and location technologies (e.g. the coverage area of the base station or access point and the data rate provided by the network). As summarized in section 6.6, the availability and usefulness of the next generation mobile location services is likely to be improved with the advance of the next generation wireless network. The mobile location service can ideally be made available both indoor and outdoor regardless of access technologies, terminal, network, protocol, and operator by applying the conceptual IPv6-based location method proposed in Schou & Olesen *(Schou & Olesen 2005)* and presented in section 6.2 or using sensor networks such as those proposed in Mamei & Zambonelli *(Mamei & Zambonelli 2006)* and Guo & Imai *(Guo & Imai 2007)*. The reliability of the services and networks, however, cannot be guaranteed, as a

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[289] See suggestion from Ring in question 11 in appendix D.

wireless network is naturally not as reliable as wired networks and often varies depending on the physical environments. In addition, the accuracy of the location information depends on the coverage area of the wireless network available in a specific area as well as the physical environment context (e.g. the coverage area of a WLAN access point is typical non-uniform depending on the physical environment as discussed in section 6.2.1.2). The service provider should therefore take these factors into account and manage the user expectation by communicating to the user the errors or inconsistencies that might occur while the user is using the service in a specific context of use, due to the nature of the mobile and wireless networks and the location technologies. For example, in the case that the location information does not match the accuracy requirements for the current service, the service provider should issue an informatory message to the users. The service should also provide an option to manually input the location information, e.g. city/street name, landmarks or special buildings and this process is handled by the user expectation management platform[290].

The user expectation management platform is a platform suggested to be added in the service architecture for providing mobile location services on the next generation wireless network. This platform manages the user expectation in the stage where the user has already subscribed to the service and while the user is using the service. The user expectation management platform in this thesis is suggested to be placed in the application and content server which is owned and administrated by a service provider.

The role of the user expectation management platform is not only sending informative messages to the user but also suggesting a better way of utilizing a service to the user. For example, the user is at the airport where he is downloading audio streaming from the internet and at the same time accessing a navigation service. The user sets the connection default to WLAN connection but the indoor navigation service works better with Bluetooth infrastructure[291]. The service may send a message to the user and suggest him to switch the connection from WLAN to the Bluetooth network. The user may either accept to switch to a higher accuracy location navigation service by pushing one stroke on the defined key pad or reject the suggestion. The user may set different priorities for different tasks and services in his user profile and may let the service adaptation be performed automatically based on the parameters predefined by the user (e.g. having either high data rate or high accurate location as the first priority).

Also when a service provider wants to upgrade the server or change something related to the service, the service provider should inform the user and make the user understand the situation (e.g. service upgrade, change of service visualization,

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[290] The i-area service presented in section 5.2.1.1 provides this option to the user.
[291] See section 6.2.1.

temporary service unavailability, etc.), and this is also handled by the user expectation management platform.

In relation to the context-based service adaptation platform presented in section 7.6, if the service cannot be adapted based on the information defined in the user profile, the service will inform the users of the reason for the inadaptability and may suggest them alternative ways for accomplishing their task. This is also one of the roles of the user expectation management platform.

This section provides ideas of how the user experience should be managed in the case that, e.g., the service does not behave as the user expected. However, the details of the user expectation management platform have not been studied in this thesis and this requires future work.

7.8 Conceptual service architecture for adaptive mobile location services

Several architectures have been proposed to support a provision of mobile location services such as the OpenLS architecture *(Bychowski et al. 2005),* the architecture proposed in Koutsiouris et al. *(Koutsiouris et al. 2007)* and in Mosmondor et al. *(Mosmondor et al. 2006).* However, none of these architectures are suitable to be used in the open service environment of the next generation wireless network, and none of them are compatible with the concept of one network many services[292], where the services offered by different providers are available for all users on a common network[293]. For the available architectures, the sharing of information resources, e.g. user profile and user location, across different networks and countries are not supported. This limits the availability of the mobile location services to specific networks of specific operators and specific geographical locations.

This section presents a conceptual service architecture for adaptive mobile location services, which is designed to be used in the open service environment of the next generation wireless network. The architecture supports provision of new-concept mobile location services that are not possible with the existing service architecture on the current mobile networks. The provision of mobile location services that allow users to access a service and content based on the location information of other users on the all-IPv6 network will be possible with the service architecture developed in this thesis. For example, location-based information services may be provided based on the location of other users at the global-level instead of based on the current location of the user himself like the services available today. The service architecture supports universal service access and the end-users are allowed to

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[292] See section 6.1.1 for the concept of one network many services.
[293] A common network here refers to the global network or a unified network.

access a service independently of the physical location, type of access network, network operator and terminal model being used by the users. One of the important features of the designed architecture is adaptability. Adding adaptability to the designed architecture, the service can be adapted to best fit with the user requirements and/or preferences in a particular context of use. This is an important approach to improve the quality of a mobile user experience and thereby also improve the possibility for mobile location services to be successful. Figure 7-7 illustrates the components that form the new service architecture[294].
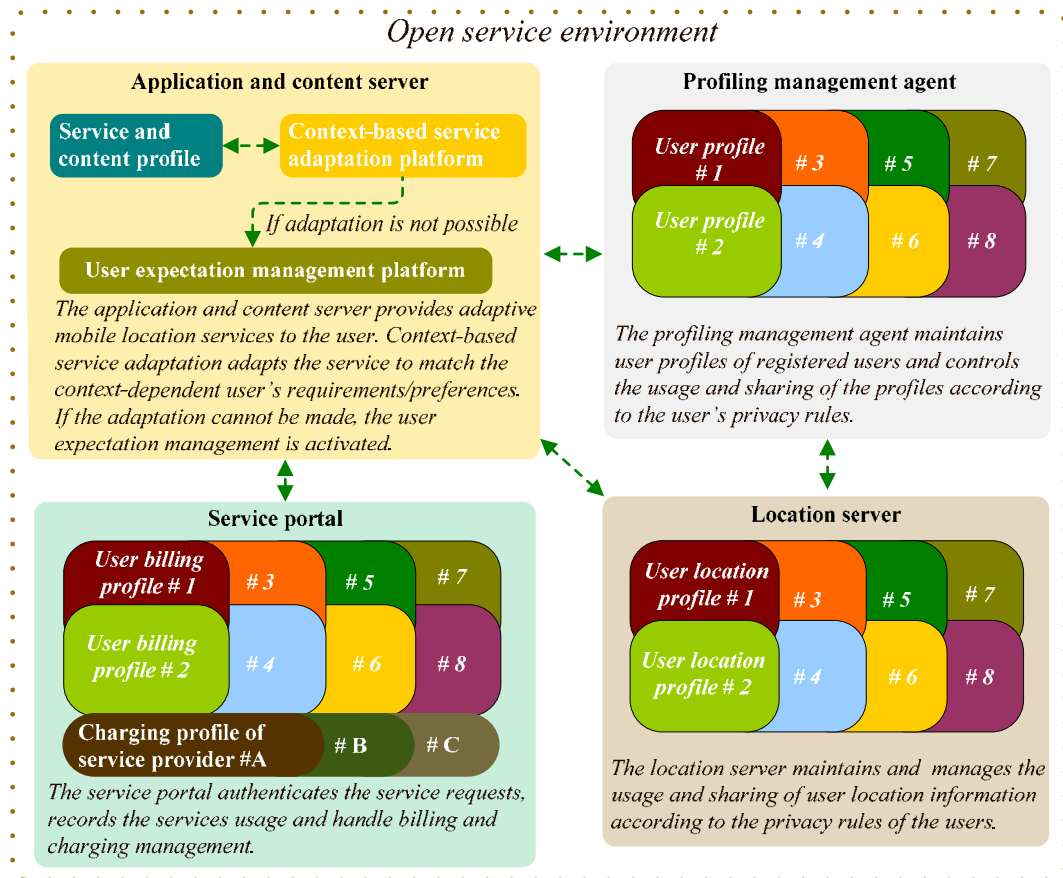
Figure 7-7: New conceptual service architecture for adaptive mobile location services on the next generation wireless network *(Schou 2008b)*. The conceptual IPv6-based location method proposed in Schou & Olesen *(Schou & Olesen 2005)* and presented in section 6.2 and 6.3 may be used for determining the location of all users on the unified IPv6 network, and the location information is maintained by the location server. For simplicity, the infrastructure needed for location determination is not shown in the figure.

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[294] As illustrated in figure 1-2, the service will only reach the re-purchase phase of its life cycle if it provides a positive user experience at the usage phase of its life cycle. Improving the quality of the user experience is therefore the way of improving the possibility of the service to be successful.

Two of the components (i.e. application and content server and location server) presented in figure 7-7 have previously been introduced as parts of the system architecture, presented in section 6.3. In that section, the system architecture was used to describe the mechanisms for detecting the user location on the all-IPv6 network and the mechanisms for sharing the user location between different components on the network. In this section, some extra components have been added to the system architecture to form a service architecture that facilitates the provision of commercial mobile location services in the real market context. As shown in figure 7-7, the service portal has been added to handle the billing and revenue sharing, the context-based service adaptation platform and the user expectation management platform have been added in order to improve the possibility of providing a service with compelling user experience, and the profiling management agent has been added to support the concepts of open service environment and one network many services of the next generation wireless network[295].

The ways the components that form the service architecture interact with each other vary depending on the types of service, adaptation conditions, privacy rules, and context[296]. However, the typical service requests and responses may be as follow. The user accesses the service via the service portal. The service portal authenticates the service request, records the service usage and updates the user billing profile and service provider charging profile. The service request is forwarded to the application and content server. The application and content server asks for the user profile (i.e. profile subset) from the profiling management agent. The location server may send the most up to date location information of the user to the profiling management agent depending upon the roles of using and sharing of location information defined in the user location profile. In the case that the service (e.g. navigation service) requires real-time location information, the application and content server may request the real-time location information directly from the location server. The application and content server then delivers the requested service back to the user. The descriptions of the different components forming the architecture and their roles are given in the following sub-sections.

7.8.1. Service portal

The concept of the service portal in this thesis is adapted from the concept of the service platform portal proposed in the OpenLS architecture. The service portal handles session management, requests handling, authentication of subscribers and

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[295] See section 6.1.1 for the description of the concept of one network many services of the next generation wireless network.
[296] More detailed description of the interactions between the different components for different kinds of mobile location services used in different situations, conditions and contexts are provided in section 7.9.
[296] See section 1.1.4 for the description of application and content server.

manages the billing system *(Bychowski et al. 2005, p. 44)*. The difference between the service platform portal in the OpenLS architecture and the service portal in this thesis is that the service platform portal in the OpenLS architecture is managed by the service provider and it is placed at the application and content server *(Bychowski et al. 2005, p. 7)*, while the service portal in this thesis is placed in every domain and it is owned and managed by the domain owner (i.e. the network operator) or the agent of the domain owner.

The advantage of the service portal in the service architecture developed in this thesis in comparison with the service platform portal of the OpenLS is that the users (or subscribers) of different network operators are allowed to access the services of different service providers from anywhere on the all-IPv6 network with the feasibility of managing the billing for the users and revenue sharing between the different stakeholders (e.g. network providers, service providers and content providers). The service portal makes it easy for the user and service providers, as the user can use different services without having to pay different bills for different service providers and the service providers do not have to handle the billing management of different users but instead let the network operator handle this task. The idea of the service portal in this thesis is also inspired by the charging and billing strategy used in Japan and South Korea, where the revenue sharing and billing management is managed by the network operators *(Seong 2006; NTT DoCoMo 2004a)*.

The service portal contains the "user billing profile" and "service provider charging profile". When the user accesses the service, the service usage will be recorded and the billing and charging reports will be updated in the user billing profile and service provider charging profile, respectively. The user and service provider can access and check their profiles but editing and deleting of the profiles is not allowed. The user billing profile contains the actual information of the user, which is required for billing management such as real name, real address, telephone number, credit card number and a list of subscribed services.

In order to realize the concept of one network many services, where the user can access any service regardless of location, access network and network operator, exchanging of charging and billing profiles or part of the profile between service portals of different administrative domains and different providers must be supported, and this is one of the interoperability requirements between next generation network domains defined by International Telecommunication Union *(ITU-T 2005, p. 158, 161)*.

7.8.2. Application and content server

The application and content server[297] handles different tasks from providing the service and content to the user and adapting the service to best fit with the user's requirements/preferences in a specific context of use to managing the user expectations towards the service. This server is owned and managed by the service provider, and one server may contain many applications and different kinds of content. The context-based service adaptation platform[298] plays an important role in adapting the service to best fit with the user's requirements/preferences in the current context of use[299]. Adapting the service to best fit with the user's requirements/preferences in the current context of use is the approach to manage the user experience in the usage stage of the service, as the context plays an important role in defining how the user will experience the service as previously described in section 3.4. The service adaptation is made based on the context-dependent user requirements/preferences and conditions defined in the user profile[300]. The service and content profile is created by the service provider and maintained in the application and content server. This service and content profile contains information about what the service provides and what can be adapted and cannot be adapted in different contexts and situations[301].

Another task of the application and content server is to manage the user expectation, and this task is handled by the user expectation management platform presented in section 7.7. The main task of this platform is to inform the user about the service (e.g. if the service is temporarily unavailable, new features, new service update, etc.) and to inform the user of the reason and further suggestions in the case that the service adaptation requested by the user cannot be made (e.g. 3D navigation is not possible because the user's terminal does not support 3D display). This is the platform that controls the user experience by providing an understanding of what the user can and cannot expect from the service. This approach prevents the user from generating unrealistic expectations that the service cannot live up to.

7.8.3. Profiling management agent

The profiling management agent previously introduced in section 7.4.2 has been added to the developed conceptual service architecture to support the idea of one network many services presented in section 6.1.1, and to realize the concept of open

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[297] See section 1.1.4 for the description of application and content server.
[298] Detailed description of the context-based service adaptation is provided in section 7.6
[299] Adaptation can be made in five different levels as presented in section 7.2.
[300] The user profiles in this conceptual service architecture are maintained by the profiling management agent and not by the service provider like the case today. A detailed description of the user profile is given in section 7.3 and 7.4.
[301] See section 7.3, 7.4 and section 7.5 for the detailed description of the user profile and service and content profile.

service environment of the next generation wireless network where the information resources (e.g. user profile, location information, etc.) should be reusable and sharable across networks. As different services may require similar or identical information related to the users and their current contexts of use, the profiling management agent provides a great benefit to the users by allowing them to share and reuse their profiles or parts of the profiles[302] with different service providers without having to create and update different user profiles for different service providers[303]. The service providers also benefit from the profiling management agent, as they do not have to implement a platform for handling the user profiles of different users, instead letting the profiling management agent handle this task.

Since the user profile contains very important information regarding the user[304], it is suggested in this thesis that the profiling management agent should be operated by governmental agencies and not a private enterprise, which can go bankrupt and/or sell this information to the highest bidder[305]. Also, if the operators/service providers become even more impacted by the anti-terror legislation in the future than they are today, it might be a requirement to segregate the user profiles and manage them inside a public body, completely separated from the private sector[306]. If the profiling management agent is trustworthy, the privacy concern regarding the collecting, storing, using and disclosing of the user profile would likely be minimized[307]. The profiling management agent can be placed anywhere on the all-IPv6 network and it is seen as one of the IPv6 nodes on the network and reachable from anywhere on the common IPv6 network through the IP routing mechanism. Based on the open service environment concept of the next generation wireless network, the users should be able to access the profiling management and edit or delete their profile from anywhere and at any time they desire *(ITU-T 2005)*.

7.8.4. Location server

The location of the user may be determined by the IPv6-based location method presented in section 6.2 and 6.3. Based on the IPv6-based location method by Schou & Olesen *(Schou & Olesen 2005)* the user location can be determined regardless of geographical location, terminal model, access network type and network operator, assuming that the business agreements for sharing the network resources is made between different operators. The location of the user may also be detected by the existing location methods such as GPS or the forthcomings location solutions such as sensor network presented in Mamei & Zambonelli *(Mamei & Zambonelli 2006)*

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[302] Part of a profile may be referred as a profile subset *(Sutterer et al. 2007)* or profile component *(ETSI 2005)*.
[303] The roles of the profiling management agent have previously been presented in section 7.4.2.
[304] See section 7.3 and 7.4 for the information contained in the user profile.
[305] See suggestion from Ring to question 9 in appendix D.
[306] Ibid.
[307] Ibid.

and Guo & Imai *(Guo & Imai 2007)*. The location information of all the users in the domain is maintained and managed by the location server. This server is owned and managed by the network operator. There should be at least one location server in every domain[308]. In the location server, the location of individual users is stored in a profile called the user location profile. This profile maintains the actual location of the user and the privacy rules of using and sharing this information is defined by the users as previously described in section 6.3. As the mobile user may travel into different domains administrated by different management entities or different network operators, it should be possible to exchange the user location profile between different domains or between different network operators according to the user mobility. For example, if the user moves from domain A to domain B, the transfer of user location profile from domain A to B should be possible. This requires new mechanisms for handling the user location profile transfer process and the agreements between network operators. The study of such mechanisms and agreement policies is out of the scope of the thesis.

Section 6.3.1 and 6.3.2 illustrate the interactions between the user and different components on the system architecture for two possible services (tracking and location-based advertising services). In those two scenarios the location requests were made directly from the application and content server to the location server, as the profiling management agent was not yet introduced. In this chapter, the conceptual platform for context-based service adaptation requires the user profile and this profile may also maintain the actual location information of the user as described in section 7.3. The location request may therefore be made through the profiling management agent which maintains the user profile instead of the user location profile in the location server. Whether the location request is made through the profiling management agent or the user location profile in the location server depends on the rules of using and sharing the location information, which are set in the user profile stored in the profiling management agent and in the user location profile in the location server. As mentioned in section 7.3, the users are allowed to modify their location information in their user profile maintained in the profiling management agent but not the actual location information stored in the user location profile maintained in the location server. The user may define that service providers cannot access his actual location in the location server but they can access the user location information in the user profile, which could be either the actual location of the user or the location information that the user has freely defined. The users can also define the rules regarding using and sharing location information in their user profile. As the location defined in the user profile can either be an actual location of the user or the location defined by the user, this will allow the users to have full control over their location privacy and the location privacy concern will be softened down.

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[308] A domain is a management concept, that is, one domain is managed or controlled by one management entity. Since one network operator may separate management of its network using various policies, one network operator may have multiple domains *(ITU-T 2005, p. 158)*.

7.9 New-concept mobile location services: Illustrative case studies

As a means of exploring the conceptual service architecture presented in the previous section and demonstrating its applicability, two scenarios representing new-concept mobile location services assumed to be deployed on the architecture have been developed and are presented in this section. Case studies of the services presented in the scenarios have then been carried out to demonstrate how the conceptual service architecture can be used for a provision of the new-concept mobile location services presented in the scenarios. Through the case studies, the service request and response processes are illustrated and the new possible service concepts and new possible service functions provided by the conceptual service architecture are examined in comparison with the existing mobile location services. The advantages and limitations of the services assumed to be deployed on the conceptual service architecture are discussed in comparison to the existing services deployed on the existing service architecture on the current network. The examinations and discussions indicate how the developed service architecture may improve the possibility of making mobile location services more successful compared to the existing services. The conceptual service architecture has been commented upon, evaluated and criticized by experts in the research area[309], and the concepts and ideas behind the developed architecture has been evaluated and reviewed by peer researchers through two peer-review conferences papers *(Schou 2008a; Schou 2008b)* and one peer-review journal paper *(Schou 2008)* written during the period of this Ph.D. study, and these are the means of validating the architecture.

Scenario 1: Help you out

The ability of sharing the information resources, e.g. user profile, is one of the requirements in the open service environment of the next generation wireless network[310], and the conceptual service architecture allows the user to share the same user profile or part of the profile with different service providers and users via the profiling management agent. The concept of "Help you out" is that the user shares her location information with other users and let them access any information related to her location. With this concept, the users can help each other managing life (e.g. parents can help their child finding relevant information). The service scenario based on the concept of "Help you out" is presented in the following scenario.

> *Sara is 12 years old and she is traveling alone to Tokyo for studying Japanese. Sara has not been in Tokyo before but her father was there last*

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[309] See appendix D.
[310] See section 7.4.

year. He wants to help Sara with practical things such as where to go and what to buy and which areas are safe and which areas should be avoided. Sara appreciates her father's help and she shares her location information with her father and remains open for his suggestions.

When Sara arrives at the Narita airport, her father gets an alert message that she has arrived safely[311] and now she needs to go through all the check out processes and then get her luggage. While Sara is managing the practical things at the airport, her father helps her finding a taxi by locating the location of the taxi at the vicinity of the airport and reserves one for Sara[312]. The service sends reservation information to Sara including the taxi number and real-time navigation map to the taxi's location[313]. Sara gets her luggage and the taxi is ready for her. Sara is getting into a taxi and her father is monitoring her location all the way to the hotel[314]. Sara is jet-lagged and she wants to rest. She asks her father to make a traveling plan to the school for her tomorrow. Sara's father accesses a navigation service and makes pre-navigation for her. He chooses that the navigation service should be alerted at Sara's terminal at 8 O'clock tomorrow morning[315]. Sara's father can access any information related to the location of Sara. Sara shares her location with her father and he can help her check all the conditions based on Sara's location (e.g. weather, traffic, safety/danger zones, etc). Sara's father is not concerned about Sara, as he can see that she is safe and managing her life fine in Tokyo.

The above scenario represents the usage concepts of three different kinds of mobile location services indicated in the footnotes: Tracking service, location-based information service, and navigation service. These three kinds of services are currently available on the current mobile networks. However, the services presented in the above scenario are assumed to be deployed on the developed conceptual service architecture and on the next generation wireless network, which allows the deployment of new-concept services with new possible functions. The discussion of new possible functions, advantages and limitations of the services presented in the scenario in comparison with the similar services deployed on the existing service architecture and presented in chapter 5 are made in section 7.9.1, 7.9.2 and 7.9.3.

Scenario 2: Come along with me

With the concept of "Come along with me", the user will experience a new way of communication. Instead of saying where she is, the user may share her real-time

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[311] Context-based tracking service.
[312] Location-based information service.
[313] Navigation service.
[314] Tracking service.
[315] Context-based navigation service.

location information in a form of map (2D or 3D) to her peer or even invite him to travel with her virtually. This will open up new ways of experiencing mobile location services for the future mobile users. The service scenario based on the concept of "come along with me" is presented in the following scenario.

> *Claus has an online friend in Thailand who he normally chats with everyday - Mai. Sunday morning, Mai is ready to go shopping at Chatuchak weekend market[316] and she wants to bring Claus along. She wants Claus to get a good impression of the largest weekend market in the world[317]. She will rather bring Claus along in the virtual world instead of explaining how the market is and how she is going to get there. She also wants Claus to get a clear picture of how people spend their weekend in Thailand - the country where all the shops are open everyday from early morning to late at night. She shares her location information with Claus and guides him on the way. Claus can see all the places where Mai has passed by. Claus can look at the real-time route map based on Mai's location and he can choose either a 2D or 3D map. When Mai passes important places, the information box explaining the places pops up on Claus' terminal so that he can get more information about the place and he can, at the same time, chat with Mai about the places he finds interesting and plans to visit together with Mai when he goes to Thailand next summer. Claus can also choose to disable the pop up box and only let Mai guide him on the way.*

> *Mai finally arrives at the Chatuchak market by skytrain, and now Claus is ready to virtually discover the weekend market together with Mai. Mai and Claus get the feeling of traveling together in the virtual world and they have common experiences to talk about. Claus gets a good user experience from traveling virtually with Mai at the weekend market and he cannot wait visiting Thailand until next summer. He decides to book the ticket and fly to Thailand next weekend and one of his destinations is Chatuchak.*

"Come along with me" is a new concept of a service utilizing real-time location information of other users on the all-IPv6 network. The service presented in the scenario cannot be made available with the current technologies and service environment, due to the lack of open standards and open environments, and the fact that the mechanisms for sharing location information, user profiles and revenues

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[316] Chatuchak market (Bangkok, Thailand) is one of the largest markets in the world. The market is only open at the weekends, Saturday and Sunday from 7 a.m. until late. It covers over 35 acres (142,000 m²) and contains upwards of 15,000 stalls. It is estimated that the market receives between 200,000 and 300,000 visitors each day. This amazing market has nearly everything you could ever wish to buy and many things that you would never want to. Chatuchak basically is shoppers' paradise and a MUST for anyone in Bangkok who has shopping on their agenda.
[317] http://en.wikipedia.org/wiki/Chatuchak_weekend_market

between the different involved parties have not been developed. The demonstration of the interactions between users and the components in the service architecture in the case of the "come along with me" service scenario is provided in section 7.9.4.

7.9.1. Tracking service

Based on the "help you out" scenario, the tracking service is triggered by the current use context of the target (i.e. Sara's current location). The service is activated when Sara arrives at Narita airport. In this case, Sara's father has defined the service behavior beforehand by specifying that the service must send notification of arrival to him when Sara arrives in Japan. The tracking service is continuously used by Sara's father until she arrives at the hotel. In this case, Sara's father is the tracker and Sara is the tracking target.

Figure 7-8 demonstrates the request/response sequences of the tracking service based on the "help you out" scenario.
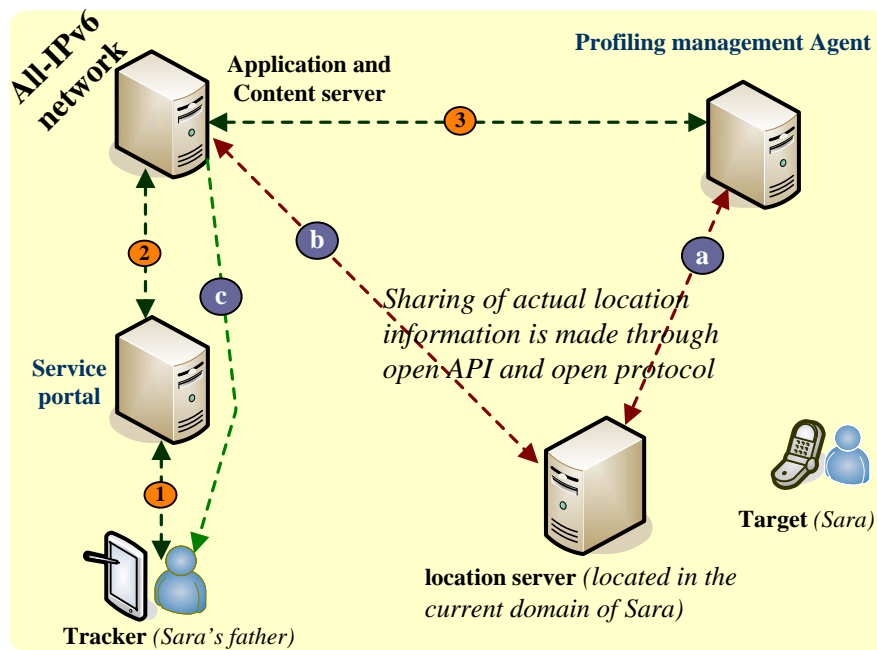
Figure 7-8: Interactions between different components in the conceptual service architecture previously presented in figure 7-7 in section 7.8 for the case of a global-level tracking service *(Schou 2008b)*. The user profiles are assumed to be maintained in the same profiling management agent. The tracker and the target are in different domains and different countries. Each domain has a location server which maintains the actual location of all users on the domain and the actual location of the tracker and the target in the scenario are maintained by different location servers.

207

The processes of service activation, request and response of the tracking service presented in the "help you out" scenario are as follow.

1. The tracker sends a service request to the application and content server via the service portal (Route 1). The service portal authenticates the request and records the service usage for billing and charging management.
2. The service portal forwards the service request to the application and content server (route 2). Based on the scenario, the tracker defines that he wants the service to be activated when the target enters a pre-defined context (i.e. the target has arrived in the pre-defined location (Narita Airport)).
3. The application and content server asks the profiling management agent for the user profiles of the tracker and the target (assuming that the user profile of the tracker and the target are maintained in the same profiling management agent[318]). The profiling management agent processes the privacy control and delivers the information required for the requested service to the application and content server (via route 3). The profile of the tracker will be used for adapting the service (e.g. service visualization, user interface, etc) to the tracker's requirements/preferences in his current use context, and the location information of the target in her user profile will be used for service triggering (i.e. service behavior adaptation).

After the tracker has requested the tracking service, the profiles of the tracker and the target are sent to the application and content server. Based on the scenario, the tracker defines the service behavior by setting that the tracking function should be triggered when the target has entered the pre-defined area. The period from this point to the point when the target is in the pre-defined area is, in this thesis, referred to as the "monitoring period" (i.e. the period where the service is waiting for activation depending on the conditions defined by the tracker). The service will remain in this period as long as the target is not in the pre-defined area. Figure 7-9 illustrates the interactions between the components in the service architecture from the start of the monitoring period to the point where the tracking function is activated and the target is tracked continuously by the tracker.

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[318] On the next generation network, the users should be able to freely choose their profiling management agent and the exchange of the user profile or parts of the user profile between administrative domains should be allowed *(ITU-T 2005, p. 158)*.
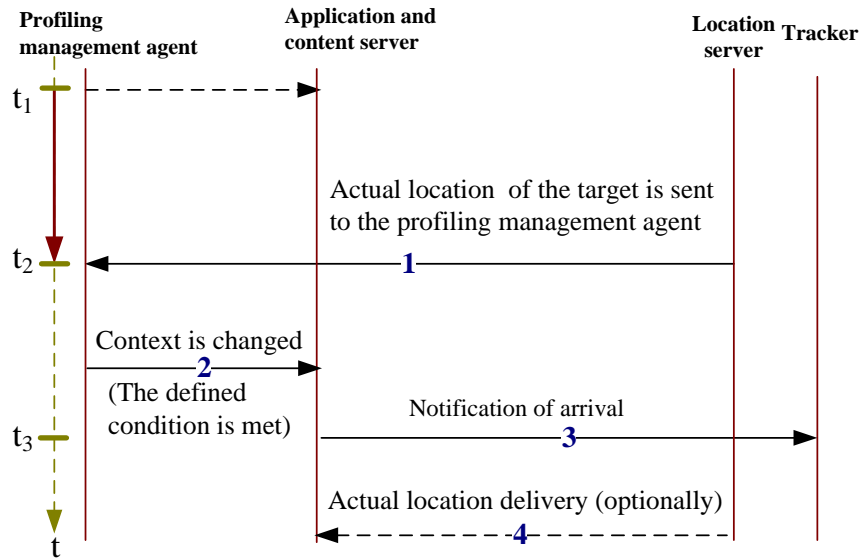
Figure 7-9: Interactions between the components in the service architecture from the start of the monitoring period (t_1) to the point where the arrival alert is sent out to the tracker (t_3). The period from t_1 to t_2 is the monitoring period. The target enters the pre-defined area at t_2 and notification of arrival is sent to the tracker at t_3 *(Schou 2008b)*.

The tracking function will be activated when the target is in the pre-defined area (i.e. arrived at Narita Airport). The service activation processes are as follow.

1. When the target is at the Narita airport and turns on her mobile terminal (t_2), one of the available indoor location methods (e.g. the method presented in Schou & Olesen *(Schou & Olsesen 2005))* determines her location and the location information is sent to the location server. The location server then sends information update to the profiling management agent where the target has registered (route a in figure 7-8 and process # 1 in figure 7-9). The sharing of location information between the location server and application and content server is made through open API and open protocol[319] (assuming that the open API and open protocol have already been developed to be used on the next generation wireless network).

2. The profiling management agent detects the change of current use context of the target (the target enters a new location). The profiling management agent then provides a new profile subset of the target including her new location information and a new profile subset of the tracker including his context-dependent requirements/preferences related to his current context of use to the context-based service adaptation platform located in the application and content server (process # 2 in figure 7-9). This information will be used for

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[319] An open protocol is an application-level protocol for querying the location of mobile terminals independent of underlying network technology. The open protocol serves as the interface between a location server and profiling management agent or application and content server *(OMA 2004)*.

service triggering (i.e. service behavior adaptation) and for adapting the service, e.g. visualization and user interface, to match the requirements/preferences of the tracker.

3. The adaptation condition set by the tracker (i.e. the target is entering the pre-defined area) is met, and the tracking function is activated. At this point (t_3), the notification of arrival is sent to the tracker and the global-level tracking service begins (process # 3 in figure 7-9).

4. Based on the scenario, from the point where the notification of arrival is sent, the target will be continuously tracked by the tracker (via route c in figure 7-8). As real-time location information is needed from this point, the location information of the target may optionally be sent directly to the application and content server (route b in figure 7-8 and process # 4 in figure 7-9).

Based on the scenario, the location of Sara will be tracked from the point where she arrives at the airport, during the check-out and luggage collection, and while taking a taxi to the hotel. The tracking service will be withdrawn when Sara arrives at the hotel.

Discussion

Based on the demonstration of the tracking service presented above, the conceptual service architecture can in principle provide several new functions for the new-concept tracking service compared to the functions of the existing tracking services presented in sections 5.2.2 and 5.3.3. Global-level is one of the main advantages of the conceptual service architecture, and global-level tracking is one of the new possible functions of the developed conceptual service architecture. This function is not possible with the existing mobile location services deployed based on the existing service architecture in the current service environment of the current network, due to the lack of location methods[320] that can handle the user location in the global-level, the lack of open standards and open service environment, and the fact that the mechanism for sharing the required information (e.g. location information and user profile) is not available.

The lack of open standards and open service environment is one of the shortcomings of the existing mobile location services[321]. The availability of the existing mobile location services is depending on the geographical location, service provider, network operator, and terminal. For some tracking services (e.g. imadoco search presented in section 5.2.2.1) the users are required to have a specific terminal in order to be able to access the service, and this service is only available locally

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[320] See chapter 4 for standard mobile location technologies.
[321] Section 5.4.1.8 discusses the affect of the lack of open service environment to the success of the existing mobile location services.

within a specific geographical area and a specific network, and the tracking is only possible if the tracker and the target are subscribers of the same network operator and service provider.

Adaptability is another useful capability of the conceptual service architecture[322]. Based on the "help you out" scenario, the context-based service adaptation will adapt the service behavior based on the task[323] defined by the tracker. In this case, the tracker has defined that he wants to be notified when the target is in the pre-defined area. The service will be activated and the notification will be sent to the tracker when the conditions set by the tracker are met. With this service function, the tracker does not have to manually track the location of the target, but rather let the tracking service monitor the location of the target and notify the tracker when the target is in a pre-defined area. This function is currently available in some of the tracking services (e.g. Safety Navi and i-kids presented in section 5.2.2.2 and 5.2.2.3) offered in Japan and South Korea but not for the services in Western Europe.

Another advantage of the tracking service based on the conceptual service architecture is that it is available in indoor environments (airport). This can be realized by the use of Bluetooth location infrastructure and the conceptual IPv6-based location method developed in this thesis and presented in section 6.2 and 6.3, or the use of other forthcoming location methods such as the sensor network presented in Mamei & Zambonelli *(Mamei & Zambonelli 2006)* and Guo & Imai *(Guo & Imai 2007)*. The lack of capability of providing high accurate location in indoor environments and dense urban areas is one of the main problems limiting the success of the tracking services offered today[324]. With the developed conceptual IPv6-based location method, and indoor location infrastructure applying short- and medium-range wireless networks, the lack of high accuracy location information in closed environments can be compensated.

In terms of improving the user experience, the tracking service utilizing the conceptual service architecture cannot be guaranteed to provide a better mobile user experience than the existing tracking service, as there are many offline issues that affect the user experience formation as presented in section 3.3, and these issues are out of the scope of the conceptual service architecture. However, the user experience concept has been taken into account during the development of the

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[322] Please refer to section 7.6 for the context-based service adaptation platform in the conceptual service architecture.

[323] Task has been discussed in section 3.4.2.

[324] As presented in section 5.4.1.6, the enhanced indoor location method measuring the delay or signal strength between different base stations is being developed in South Korea. This method is expected to provide the location accuracy of 100~200m *(Kim 2006)*. The expected accuracy is however not appropriate to provide some of the services listed in table 4-1 in section 4.1 such as tracking and indoor navigation services.

conceptual service architecture resulting in the context-based service adaptation platform and the user expectation management platform presented in section 7.6 and 7.7. These two platforms will handle the user experience management during the service usage and the possibility of providing a positive user experience will be improved.

Norman has stated in the book "Emotional design" *(Norman 2004)* that the service that almost always guarantees success is the service that provides social interaction and emotional connection between people. The global-level tracking service presented in the "help you out" scenario provides social interactions and emotional connections between father and his child. Naturally, the father is concerned about his child, especially when she is a girl and alone in a foreign country. The child is likely to be nervous when she is alone in an unfamiliar area, and she wants to feel safe *(Schou 2008b)*. The global-tracking service allows the father to see what is going on with his child and at the same time he can help his child handle some of her tasks remotely as presented in the scenario. This service has a high potential of being a success if it is used between trust parties. However, it involves a higher level of complexity to realize this service concept compared to the tracking service that is available locally. In order to realize the services presented in the scenario, exchanging of user profile, location information, and billing and charging information between administrative domains is required, and new business agreements and new business models are needed to be developed *(ITU-T 2005, p. 158, 161)*.

7.9.2. Location-based information service

The existing location-based information services (e.g. shopping guide, finding nearby restaurant, etc.) are typically provided based on the user's own location[325]. The new concept of location-based information services on the proposed conceptual service architecture is that the user may request for the information service based on the location of other users in the global-level. This new concept of global-level location-based information services was presented in the "help you out" scenario.

Based on the "help you out" scenario, Sara's father interacts with the location-based information using Sara's location information for requesting for the location of the taxi. The content is filtered and the service behaviors, visualization and user interface may be adapted based on the user profile of Sara's father. Figure 7-10 demonstrates the interactions between the components in the proposed conceptual service architecture in the case of the location-based information service presented in the scenario.

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[325] Examples of location-based information services are presented in sections 5.2.1 and 5.3.1.

In figure 7-10, the service portal is placed in the current domain of Sara' father (i.e. domain 1), while the application and content server can be placed anywhere on the all-IPv6 network[326]. The user profiles of Sara and her father are assumed to be maintained by the same profiling management agent (i.e. profiling management agent 1) and the user profiles containing the location information of the taxis and information related to the taxi drivers who are participating in the taxi-finder service are assumed to be maintained by profiling management agent 2. The actual location information of the taxis and Sara is stored in the location server in domain 2, which is the current domain of Sara and the taxis. The sharing of the required information between different stakeholders is assumed to be made through open standards in the open service environment (assuming that the open APIs and open protocols have already been developed to be used on the next generation wireless network).
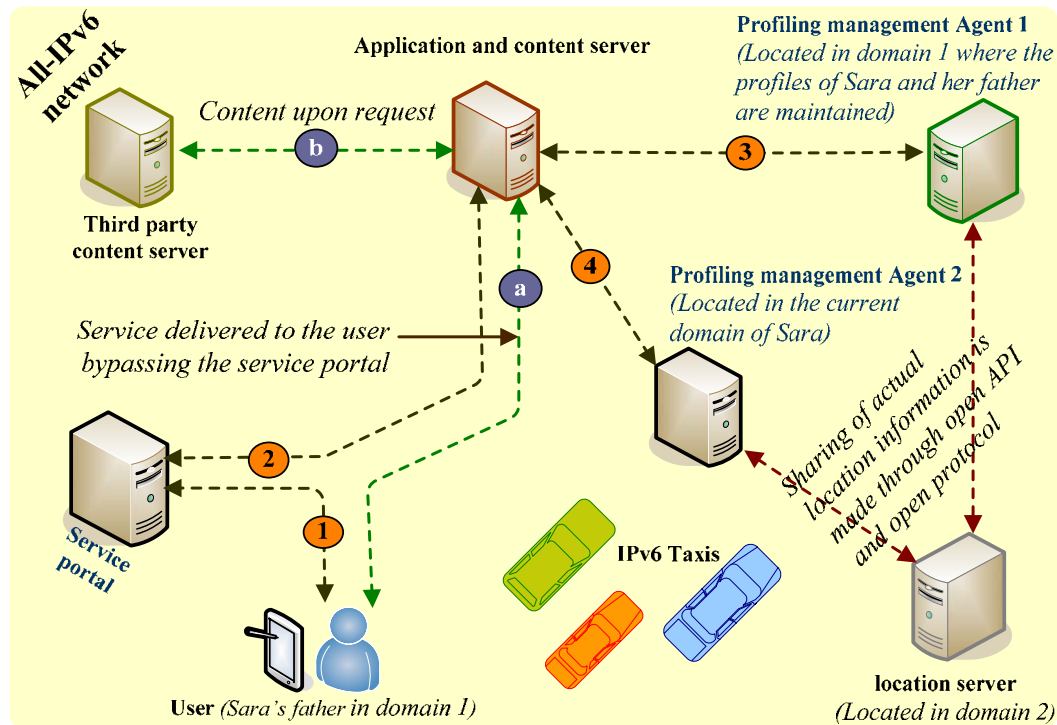
Figure 7-10: Interactions between the components in the proposed conceptual service architecture for location-based information services on the next generation wireless network.

The service request/response sequences illustrated in figure 7-10 are as follows:

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[326] See section 7.8 for descriptions of the components in the conceptual service architecture and their roles.

1. The user accesses the service portal via the wireless IPv6 network to request for the location-based information service (via route 1).

2. The service portal authenticates the user request, records the use of the service for billing and charging management, and forwards the service request to the application and content server (via route 2).

3. The application and content server requests the user profiles from the profiling management agent (via route 3). Based on the "help you out" scenario, two user profiles are required (Sara's and her father's). The user profile of Sara's father is used for filtering the content and adapting, e.g., the behaviors, visualization and user interface of the service to match his requirements and preferences in his current context of use, and only location information is required from Sara's profile. In this scenario, Sara's father is the one who uses the location-based information utilizing the current location information of Sara and not his own current location. The profiling management agent returns the information required for the location-based information service to the application and content server (via route 3).

Note: If the tracking service presented in the last section and the location-based information service presented in this section are provided by the same service provider, the process of user profile request may not be required for the location-based information service, as the service provider already has the necessary information from the user profiles used for the tracking service request.

4. Based on the scenario, the user wants to find the location of the taxis in the area of Narita airport. The user may also define the preferred characteristics of the driver and the car (e.g. non-smoking, have more than 5 years experience with driving a taxi, etc.). The application and content server requests, via route 4, the location information of the taxis that have registered for the taxi-finder service and which have their user profiles maintained by profiling management agent 2. The profiling management agent filters the relevant taxis and returns the locations of the taxis together with the information regarding the car model, condition and also the information of the taxi driver (e.g. age, gender, driving experience, picture, smoker/non-smoker, etc.) to the application and content server.

5. The application and content server filters the available taxis based on the conditions previously defined by the user. The list of the taxis displayed on the user's terminal may be adapted based on the adaptation conditions set by the

user and the current context of use where he is using the service[327]. The requested information is delivered to the user either via the service portal (via route 2 and 1) or directly to the user (via route a), depending on the charging strategy of the service provider. For example, if the flat-rate tariff is used, the service can be delivered directly to the user bypassing the service portal. If per-packet is used, the information will be delivered via the service portal. It is however likely that the flat-rate charging strategy will be widely used in the future, as it is easy to understand, simple to communicate, simple to bill, and makes it simple to make a financial planning for the user *(Anderson 2006)*. In some cases, the service provider may also request content provided by third parties content providers via route b.

Discussion

The location-based information service presented in the "help you out" scenario represents a new concept of information services that is provided using the location of other users rather than the current location of the user himself. The location-based information service in the "help you out" scenario provides a new way of helping each other to accomplish different tasks that may be difficult to handle at the same time. Based on the "help you out" scenario, Sara has many tasks that she has to accomplish (e.g. checking out, collecting her luggage and finding a taxi). With the new-concept service, her father can take over one of the tasks that can be accomplished remotely, which is finding a taxi. This assistance from her father will make it easier for Sara to manage her life alone in a foreign country. Allowing a person to accomplish a specific task utilizing the location information of other users rather than the user's own location is not possible with the location-based information services offered today, as the mechanism for sharing the user profile and location information between users, network providers and service providers in different administrative domains is not possible. For the service architecture in this thesis, the user profile can be shared through the profiling management agent.

Even though the new-concept location-based information service in this scenario provides the information based on the location of another user, the information can be presented on the terminal of the user in a way that match the user's requirements/preferences in his current context surrounding, which are defined in the user profile. Adaptability is not available with the location-based information services commercially available today.

In comparison with the location-based information services offered on the current networks presented in section 5.2.1 and 5.3.1, neither offering the service in a

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[327] This is a sort of content and visualization adaptation based on the user's requirements. See section 7.6 for more details about context-based service adaptation.

global level nor accessing the service based on the location of another user is possible on the current network. With the conceptual service architecture developed in this thesis, the user profiles are maintained by the profiling management agent and not by individual service providers like the way it is today. Letting the profile management be handled by the profiling management agent allows different users to share the user profiles or pieces of information stored in the user profile with each other or with different service providers. This makes it possible for the users to access a mobile location service based on the location of other users on the unified IPv6 network. As all the components on the unified IPv6 network have their unique IPv6 addresses, the profiling management agent will be seen as an IPv6 node on the unified IPv6 network. This makes it possible for the users or service providers to contact the profiling management agent from anywhere on the unified IPv6 network.

7.9.3. Navigation service

Navigation services may be categorized into two categories: Static and dynamic navigations. The static navigation service is a kind of map download with route guidance[328], while dynamic navigation services provides real time route guidance with turn directions in the form of voice, graphic or text[329]. The existing navigation services presented in section 5.2.3 and 5.3.2 are based on the user's own request, and the services do not allow options such as pre-navigation definition. The new-concept navigation service available with the new conceptual service architecture allows pre-navigation services that will be activated at the desired time or possibly desired location. For example, the user defines that the real-time navigation service will be triggered at 7 O'clock, when he is supposed to walk from home to the nearby train station, and the navigation service is activated (automatically by the current context of use of the user) again when he gets off at the destination station and has to walk from the train station to the conference center.

In the "help you out" scenario, the new concept of navigation service for pedestrian is presented. Based on the scenario, Sara's father knows Sara's current location and situation from the tracking service illustrated in section 7.9.1. Sara is busy with her current tasks (e.g. checking out, collecting her luggage), and her father wants to help her handle her remaining tasks (finding a taxi to the hotel). The taxi search process has been presented in the last section and the navigation service presented in this section is the step further after the taxi has been reserved. Sara's father requests for navigation service based on the current location of Sara to the location of the taxi he has reserved. The service sends the information regarding the reserved taxi with the pre-navigation service that Sara can just activate by pushing one stroke on the key pad on her mobile terminal. Based on this scenario, Sara's father is the

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[328] See section 5.3.2 for example of static navigation service.
[329] See section 5.2.3 for examples of dynamic navigation services.

service requester and Sara is the user of the service. Figure 7-11 illustrates the interactions between the different components in the service architecture in the case of the new-concept navigation service in the "help you out" scenario.
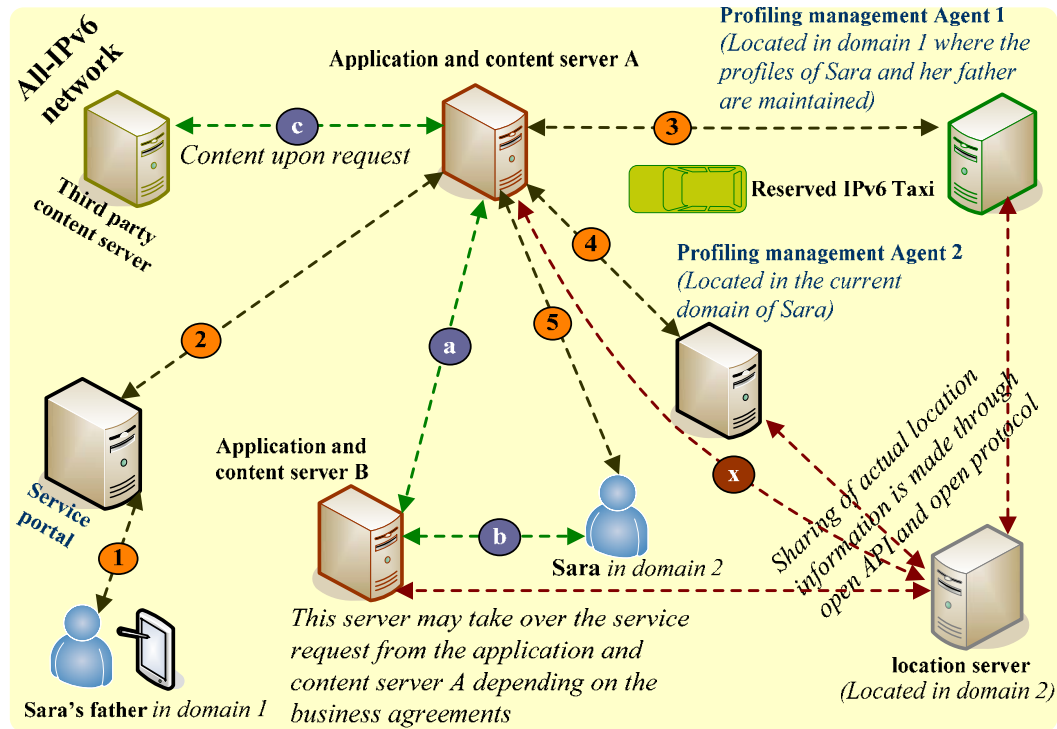
Figure 7-11: Interactions between different components in the conceptual service architecture in the case of the new-concept navigation service based on the "help you out" scenario. Based on the scenario, the service requester (Sara's father) is in domain 1 and the user of the service (Sara) is in domain 2.

The service request and response sequences are as follows.

1. Sara's father accesses, via the service portal (route 1), the application and content server requesting for the navigation service from the current location of Sara to the current location of the reserved taxi. Please note that both the location of Sara and the location of the reserved taxi may be dynamic (on the move). Real-time location update is required in this case. The sharing of the actual location of Sara and the reserved taxi between the location server and the profiling management agents is made through open API and open protocol.
2. The service portal authenticates the service request and records the service usage for billing and charging management and forwards, via route 2, the request to the application and content server A.

3. The application and content server requests for the user profiles of Sara and her father from the profiling management agent 1 (via route 3). The information in the profile of Sara's father may be used for adapting e.g. the user interface of the service to match his requirements at his current context, and the profile of Sara will be used for adapting the navigation service (e.g. visualization) to match her requirements/preferences at her current context, requirements or preferences. Real-time location information is needed in this case, and this information may be obtained directly from the location server (via route x). As presented in the last paragraph of section 7.8, whether the location will be obtained from the profiling management agent or location server depends on the privacy rules for using and sharing the actual location information which Sara has defined in her user location profile in the location server and user profile in the profiling management agent.

4. The application and content server requests (via route 4) for the user profile of the reserved taxi including the information regarding the driver. In this case, the taxi may be on the move and the real time location of the user (i.e. Sara) and the taxi is required, and this may be requested directly from the location server (via route x).

5. The context-based service adaptation platform[330] located in the application and content server may adapt the service to match the adaptation conditions that may be set in Sara's user profile, and then delivers the service to Sara via route 5. At this point, the navigation does not begin yet. The navigation will start when Sara activates the service manually.

Based on figure 7-11, the application and content server A may request, via route c, for necessary content (e.g. map of Narita airport) from a third party content server. Depending on the business agreement between service providers, the service provider A may forward, via route a, the service request and necessary information in the user profiles to its partner (i.e. service provider B who owns application and content server B) in the case that service provider A does not have capability to handle the service requested by the user[331]. For privacy reasons, the sharing of the user profiles including the actual location of the users between service providers A and B needs to be approved by the user profile owners. The application and content service B then delivers the service to the user via route b.

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[330] More detailed description of the context-based service adaptation can be found in section 7.6.

[331] The idea of forwarding the service request and necessary information from one service provider to another should be possible in the open service environment of the next generation network, as exchanging of information resources is one of the interoperability requirements suggested by ITU *(ITU-T 2005 p. 158, 161).*

Discussion

Two navigation services for pedestrians are currently available in Japan and these two services are unavailable in indoor environment[332]. In this thesis, the lack of indoor location information will be compensated using the IPv6-based location method on the location infrastructure applying Bluetooth and WLAN[333] or other forthcoming location methods such as the sensor network presented in Mamei & Zambonelli *(Mamei & Zambonelli 2006)* and Guo & Imai *(Guo & Imai 2007)*. This will enable the indoor location navigation in closed environments such as airports, department stores, exhibition centers, etc. The conceptual IPv6-based location method on the indoor location infrastructure allows Sara to use the navigation service when she is at the airport area.

Based on the "help you out" scenario, the service requester is Sara's father and the user of the service is Sara. This option is not available with the existing navigation services. For the available navigation services for pedestrians presented in section 5.2.3, only the user can request for navigation service based on his own location. The option of having other people to request pre-navigation service for oneself can be useful in the case that the user has many tasks to do and is currently busy with some other tasks, or in the case that the user does not have information about the destination.

In the "help you out" scenario, pre-navigation services were requested twice by Sara's father. The first navigation service usage can be activated manually by the user as presented above, and the second time the pre-navigation service is used, and it will be activated at the pre-defined time.

Based on the scenario, "Sara is jet-lagged and she wants to rest. She asks her father to make a traveling plan to the school for her tomorrow. Sara's father accesses a navigation service and makes pre-navigation for her. He chooses that the navigation service should be alerted at Sara's terminal at 8 O'clock tomorrow morning".

Pre-navigation service in the above case is triggered when the condition is met, similar to the pre-tracking service presented in section 7.9.1, where the tracking starts when the target enters the pre-defined area. This function can be realized with the use of the context-based service adaptation platform and the user profile presented in section 7.6 and 7.3 respectively.

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[332] See section 5.2.3 for navigation service offered in Japan.
[333] See section 6.2.1 for the indoor location solution.

7.9.4. Come along with me

The mobile location service presented in the "come along with me" scenario is a novel mobile location service that utilizes the location information of another user. This service is similar to the concept of the location-based information service presented in section 7.9.2, where Sara's father accesses the information based on the location information of Sara rather than on his own location. The difference of these two scenarios is that the service in the "come along with me" scenario is initiated by the location owner (Mai) and the information is continuously delivered to her peer (Claus) corresponding to Mai's mobility.

Based on the "come along with me" scenario, the interactions between the different components in the conceptual service architecture are demonstrated in figure 7-12.
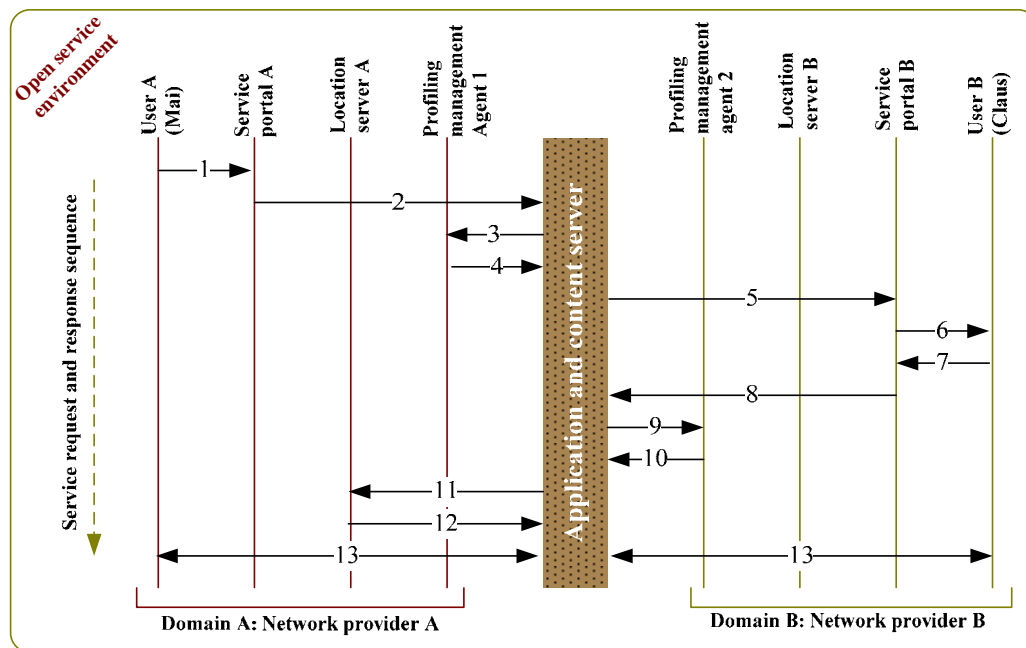
Figure 7-12: Service request and response sequences based on the "come along with me" scenario. The users are in different domains and different countries. The actual location and the user profiles of the users are maintained in different location servers and different profiling management agents. The exchange of the required information stored in different places owned by different stakeholders is assumed to be made through open standards in the open service environment based on the business agreements made between these stakeholders.

In figure 7-12, the service requests and response sequences of the "come along with me" scenario start from the point where Mai invites Claus to come along with her in the virtual world.

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1. Mai sends a service request to the application and content server via the service portal on her current domain via the wireless access network available at her current location.
2. The service portal authenticates Mai's request, records the use of the service for billing management, and forwards the service request to the application and content server.
3. The application and content server requests Mai's user profile from the profiling management agent 1.
4. The profiling management agent 1 searches for the profile subset containing a set of information required for adapting the service (e.g. user interface) to best fit with the user's requirements/preferences in her current context. The matched profile subset will then be sent to the application and content server. This information will be used by the platform for context-based service adaptation for adapting the service based on the adaptation condition set by Mai.
5. The application and content server forward Mai's request to the service portal of the domain where Claus is currently located (i.e. service portal B). The forward destination is known by looking at the global care-of address of Claus's terminal which is contained in the service request sent by Mai. This address reveals in which domain Claus is, as previously explained in section 6.2 and 6.3.
6. The service portal sends the acknowledgement to Claus to ask whether he will accept the invitation to come along with Mai in the virtual world.
7. Based on the scenario, Claus accepts the invitation sent by Mai to come along with her in the virtual world. After the invitation has been accepted, the acknowledgement is sent back to the service portal B. The service portal records the use of the service, which may be used for billing management depending on the business model.
8. The service portal forwards the acknowledgement to the application and content server.
9. The application and content server requests Claus's user profile from profiling management agent 2.
10. The profiling management agent searches for the profile subset that matches the current context of use in which the service is used by Claus and forwards it to the application and content server. This information will be used by the platform for context-based service adaptation to adapt the service (e.g. service visualization, content) to best fit with the requirements/preferences of Claus in his current context of use. From this stage, the profiling management agent may send a new profile subset of Claus to the application and content server if the context-dependent user requirements are changed due to e.g. Claus entering a new context and his context-dependent user requirements/preferences are changed according to the new context.

11. The application and content server asks for the actual location of Mai maintained in the user's location profile located in the location server in the current domain of Mai (i.e. domain A). The use of Mai's actual location is subject to the privacy rules defined in Mai's user location profile.
12. The real-time location information of Mai is sent to the application and content server.
13. The content based on Mai's location is delivered from the application and content server to Claus. This content may be adapted based on Claus's requirements and preferences pre-defined in his user's profile, as Claus is the one who receives information utilizing the location information of Mai. While Claus is enjoying the content based on Mai's current location, Mai has a possibility of controlling the service. She may give Claus permission for receiving information based on her location for one or two hours and this can be disabled anytime by Mai.

With the new concept of mobile location services, the mobile users can travel virtually to anywhere in the world utilizing the location of friends or family members. The service based on "come along with me" is not only an information service, but it is a kind of service that provides social interaction and emotional connection between users. The users can get the felling of being together and have a common topic to talk about. A service which provides social interaction and emotional connection people has a very good chance of being successful, as previously discussed in section 7.8.1 for the tracking service.

7.10   Discussion

The new-concept mobile location services presented in the last section are novel, and they are assumed to be deployed on the conceptual service architecture presented in section 7.8. The realization of these services relies on the availability of the conceptual service architecture. This section discusses the factors that may limit or sustain the practical implementation of the conceptual service architecture and of the services presented in the scenarios in the last section. The discussion is mainly based on the feedback (criticisms, comments and suggestions) obtained from the interview and discussions with the experts in the research area[334] and based on the feedback provided by the peer researchers through the peer review processes of two conference papers *(Schou 2008a, Schou 2008b)* and one peer-review journal paper *(Schou 2008)* written during the Ph.D. period.

To facilitate a provision of the new-concept mobile location services presented in the last section, the concept of the open service environment envisioned by ITU *(ITU-T 2005)* and WWRF *(Uusitalo et al. 2006)* has to be realized. Based on

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[334] See appendix D.

discussions with the experts in the research area, the open service environment can technically be realized without any major problems. The realization of the open service environment requires interoperability between components within a single administrative domain and between administrative domains[335] *(ITU-T 2005, p. 70)*, and this requires a global set of interconnectivity standards.

Besides the requirements for interoperability and global standardizations, the introduction of Cognitive Radio/Software Defined Radio (CR/SDR) will be required in order to make the concept of seamless roaming between different types of access technologies in the open service environment feasible. The CR/SDR will support the functionalities of seamless mobility by allowing the terminal to automatically switch among multiple wireless protocols or move to different frequencies, waveforms, protocols, or applications *(Rubenstein 2007)*. The CR/SDR will allow the terminal to automatically request new operational parameters when roaming across networks. The CR/SDR will make the mobile terminal become smart enough to analyze the radio environment and decide for itself the best spectral band and protocol to reach whatever base station or access point it needs to communicate with, at the lowest level of power consumption *(Rubenstein 2007)*. In fact CR/SDR will be a prerequisite for the effective realization of seamless service roaming, and the CR/SDR concepts have just been assigned to the agenda of the ITU-R World Radio Conference in 2011[336].

Based on the "help you out" and "come along with me" scenarios, the services can practically be done only if the sharing of the user profile (or parts of the profile) between different stakeholders (e.g. users, network providers, service providers, profiling management agent) within and between administrative domains is allowed. The ability of sharing of information resources (e.g. user profile, location information and billing and charging information) is one of the capability requirements in the open service environment of the next generation network suggested by ITU *(ITU-T 2005, p. 170-172)*. In order to enable such a profile sharing function, the business agreements for sharing of network resources and information resources between different stakeholders involved in realizing the new concepts of mobile location services have to be made *(ITU-T 2005, p. 349)*.

Besides the technical issues discussed above, the availability of the open service environment also depends on the policy of the big players in the mobile service market and also on business and regulation issues[337]. Different stakeholders have different interests. The open service environment is most likely favored by the users and service providers, but may not currently be favored by some of the terminal manufacturers or network operators. The users can obviously benefit from the open

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[335] Interoperability is the ability of two or more systems or applications to exchange information and to mutually use the information that has been exchanged *(ITU-T 2005, p. 70)*.
[336] See comment from Ring to question 1 in Appendix D.
[337] See comments from experts in appendix D.

service environment, as they can access the service from anywhere at any time using any terminal via any available network of any network operator. The service and content providers would also benefit from the open service environment, as their services and content would be available for all users on the common IP network regardless of which network provider the users are subscribed to *(Reynolds & Jin-Kyu 2004; ITU-2005; Uusitalo et al. 2006)*, and it would therefore be possible to generate revenue in the global level for the service and content providers. However, for the terminal manufacturers, some of them might want to control the compatibility and accessibility of the services and content on their terminals in order to make their products more competitive compared to the competitors'. For example, the terminal manufacturer like Nokia is entering the service and content business and they want to limit the service and content to be available only on their own terminals[338]. Similarly, the network operator may also want to be more competitive by controlling the service availability only on their network[339], since they would get revenue from data transmission.

From the experts' point of view presented above, whether or not the concept of the open service environment can practically be realized depends on whether or not the big players in the mobile service market such as the terminal manufacturers and network operators can benefit from this concept. However, it can also be argued based on the discussion in section 2.3 that the availability of the open service environment and the realization of any service architecture and new service in the future network will be driven by the requirements of the user. Based on the discussion in section 2.3, we are currently in the technology phase where the mobile technology can fulfill the basic requirements of general users, and the success of any mobile service will be defined by the quality of the mobile user experience. In the next generation wireless network, the mobile technologies will be even more mature and the forthcomings location technologies are expected to be mature enough to fulfill the requirements of general users. Based on figure 2-3, the late adopters will enter the mobile service market and these people are a group of people that will dominate how the mobile location services should be designed. Since the majority of the users demand a better user experience, this may change the strategies of the stakeholders, e.g. the service providers, terminal manufacturers and network operators. The availability, accessibility, price, visualization, behavior, etc., of the existing mobile location services are mostly controlled by the service providers, network operators, content providers and terminal manufacturers. Based on figure 2-2 and 2-3, all these characteristics of the future mobile location services will likely be controlled by the user. It is likely that the user will be able to define how the service should look and behave, when it should be available and accessible and what price they are willing to pay, similar to the statement given by the chair of

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[338] Nokia starts to provide mobile services and content that are available only on Nokia's terminals. See www.ovi.com for more details.
[339] See existing mobile location services in chapter 5, the availability of most of the services is controlled by the network provider.

WWRF "the users should be able to control the services to the extend they want" *(Uusitalo 2006)*. As the technology is mature, the future mobile location services may be provided in the same way as web services, where the web user can access any web service using any PC and any Internet Service Provider (ISP). At the mature phase of the technology's life cycle, the terminal manufacturers may need to design their terminals based on the factors that affect the quality of the user experience towards the use of mobile terminals, instead of trying to, e.g., limit the compatibility of the terminal to specific networks, services and content. The terminal manufacturers may compete with their competitors based on e.g. compatibility, processing speed, memory space, display quality, sound quality, user interface, aesthetics and price.

The conceptual service architecture in this thesis takes into account the user experience concept, and the users have an option to control e.g. the behavior, visualization, and user interface of the service. The architecture supports the profile sharing and this makes the provision of new-concept mobile location services feasible, as presented in the previous section. For the profile sharing, there will be some ethical/emotional and trust issues between users of such service scenarios[340]. To realize such scenarios, these issues have to be handled in the ways that are acceptable by the users. To handle ethical/emotional issues, it is suggested by Ring[341] that the party under surveillance should clearly get an indication, that surveillance is ongoing or has taken place. For the parent-child scenario presented in the "help you out" scenario, the indication may not be highly required[342]. To handle the trust issues, Veijalainen[343] has suggested that there should be a trust management in the user profile.

For mobile location services, privacy concern is one of the potential problems inhibiting the take-off of mobile location services[344], and the privacy issue must be handled in a way that is acceptable by the users. In the conceptual service architecture developed in this thesis, the users are allowed to define their own privacy rules[345]. However, there should also be a standard privacy policy that the users can adopt without having to spend time setting their own privacy rules. Different privacy laws are applied in different countries and the privacy rules of using mobile location services should be defined based on these privacy laws. It is clear that a service operating in a certain country must obey the local privacy laws *(Beeson et al. 2002)*. However, the concept of mobile location services on the future network is that the service will be offered in the global-level, meaning that they can

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[340] See appendix D.
[341] See response to question 2 in appendix D.
[342] Ibid.
[343] See response to question 6 in appendix D.
[344] See the introduction part of chapter 1, section 4.1.1 and 7.6.3.1 for the discussion of privacy issues.
[345] See section 7.3.

be used in many countries. One of the issues that the service providers have to deal with when providing the global-level service is to define privacy rules that can be acceptable by different users from different parts of the world. If the service is to be used in multiple countries without doing country specific versions, the service should then operate according to the most strict privacy regulation *(Beeson et al. 2002)*; otherwise the privacy policy is needed to be adapted according to the privacy laws of specific countries.

Regarding the privacy law, the EU privacy related directives are among the strictest ones in the world *(Beeson et al. 2002)*. If the service providers want to be on the safe side, the privacy rule of using mobile location services could be defined according to the EU directives (Directive 2002/58/EC: Directive on privacy and electronic communications). The EU privacy related directives and the guidelines for defining the privacy rule can be found in the privacy guidelines provided by Location Inter-operability Forum (LIF)[346].

Jari Veijalainen, a professor in the area of mobile location services and E-commerce from University of Jyväskylä, Finland, stated that the realization of any service architecture is more a business related question than a technical question. A similar statement has also been given by Steffen Ring, a technical director from Motorola A/S, Denmark, "the service architecture will be realized if the healthy business case can be established". The global-level service may be realized if the business model is acceptable for the stakeholders in the ecosystem. The new business model will also affect how the billing management part of the architecture should be designed. In the conceptual service architecture developed in this thesis, the billing management and revenue sharing will be handled by the network operator similar to the business model used in Japan and South Korea *(NTT DoCoMo 2004a; Seong 2006)*, and this business model has proven to be effective in Japan and South Korea.

7.11   Summary

The service environment of the next generation wireless network is envisioned, by several researchers and big organizations such as ITU and WWRF, to be open. Providing mobile location services on the next generation wireless network requires a new service architecture that fits into the open service environment. This chapter presents a conceptual service architecture for adaptive mobile location services, which is designed to be used in the open service environment of the next generation wireless network, assuming that the next generation wireless network is emerged and the open service environment is realized. The conceptual service architecture has been developed based on a combination of different components and the service portal and profiling management agents play important roles in realizing the concept of one network many services, where different service providers can

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[346] Ibid.

provide their services to all users on a common IP network. The context-based service adaptation platform, user profile and service and content profile play important roles in adapting the service to best fit with the user's requirements and preferences in the current context of use. The architecture supports the sharing of the user profile, location information and billing and charging information within a single administrative domain and between administrative domains, and this facilitates the provision of new-concept mobile location services that are available in the global level. The global-level service such as the tracking service of the child when she is abroad is seen to be an interesting service in the future because of globalization[347].

One of the important features supported by the designed architecture is adaptability, which is envisioned by WWRF to be one of the keys to the success of the services in the future wireless world. In this thesis, adaptability relies on the user-controlled self-adaptation, and the service adaptation is made based on the changes of the context-dependent user requirements and preferences defined in the user profile. The user profile contains information related to the current context of use (i.e. user, task, technology, and physical and social environments) and the context-dependent user requirements/preferences. The user profile can be used to describe what the user requires and prefers in specific contexts of use, and the user profile is used for facilitating the context-dependent decision making made by the context-based service adaptation platform.

The users are allowed to modify every piece of information in their user profile, even the location information. However, the service adaptation will not be effective if the user changes all the actual attributes of the current context of use. The service adaptation is based on the principle that the more precise information available for the service provider, the better the service becomes for the user. The users may also set their profile to invisible mode in specific time periods, locations and situations. Modifying, updating and turning off the user profile should be easy to handle and can be done from anywhere on the all-IPv6 network. The strategy of allowing the users to modify every piece of information in the user profile and turning off their profiles can heavily soften the privacy concern of using mobile location services in the future. However, not all the users want to have full control over the service, but would rather like to leave much of the control to other parties. There should be standard privacy rules set by the service providers, which the user can choose.

The user profile in this thesis is maintained by the profiling management agent and not by the service provider like the case today. The service provider can only utilize the user profile when the user wants to use the service. It is obvious that the profiling management agent plays an important role in providing mobile services in the future. The profiling management agent must be trustworthy and the users

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[347] See comment from Ring to question 3 in appendix D.

should feel safe and comfortable allowing the agent to protect the use of their personal information as well as their location information. It is likely that if the users have a bad experience from profiling abuse, they might refuse to use any mobile service. They might also provide indirect experience to their peers by telling them about the bad experience they get from using a mobile service and this will definitely influence the adoption of mobile services in general. To resolve the ethical and emotional obstruction regarding the concern of the user profile abuse, the profiling management agent is suggested to be operated by a government agency and not by a private enterprise.

With the conceptual service architecture, the service developer can invent new kinds of mobile location services that have not been possible on the current network and the users will experience new ways of using mobile location services. The services such as global-level tracking service and location-based information service that allows the user to access the information utilizing the location information of other users on the all-IPv6 network will be possible. However, only the service that provides a good user experience will be successful. Providing a service on the conceptual service architecture developed in this thesis does not guarantee good user experience, as there are many issues beyond the scope of the service architecture that also affect how the user experience will turn out. However, the possibility of reaching a good user experience is likely to be improved with the context-based service adaptation platform and the user expectation management platform of the developed conceptual service architecture combined with the privacy handling of the architecture.
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8 Conclusion and directions for further research

Back in 2000 and the following two or three years, mobile location services gained a great deal of interest and they were considered as one of the few service categories where users would be willing to pay for the usage. Since 2000 countless mobile location services have been launched on 2G and 3G networks in different parts of the world, but mobile location service have not yet met the hyped expectation of mass-market adoption that was expressed in 2000. In this thesis, the examinations and analyses of the available mobile location technologies and of the existing mobile location services have been carried out as a means of finding the answers for the following research questions (research questions number 1 and 2 in section 1.3): Why have we not seen the breakthrough of mobile location services, and what are the barriers limiting the adoption by the users and how can these barriers be overcome? The answers to these research questions provide indications and ideas of how the mobile location technology and service for the next generation wireless network should be like in order to reach a more successful level compared to the existing technologies and services on the current network.

To find the answers to the research questions number 3 and 4 previously defined in section 1.3, trends in the next generation wireless network were studied in order to identify the characteristics of the next generation wireless network that the new mobile location technologies and services may be based on. At the time this Ph.D. study started (2002), the trend indicated that the networks would likely evolve towards the all-IPv6 network or unified IPv6 network, and the mobility of a mobile terminal between administrative domains and within a single administrative domain would likely be managed by applying the inter- and intra-domain mobility management protocols respectively[348]. Mobile IPv6 and IDMP were the best candidates for mobility management around the year 2002 and 2003 [349], and based

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[348] This trend is still ongoing, as can be seen from some of the current research works related to the all-IPv6 network *(Wang & Chuang 2007; Nam-Seok et al. 2007; Jordan et al. 2007)*, and from the roadmap and vision towards 2010 published by IPv6 Forum *(IPv6 forum 2006)*.

[349] Based on the current research works *(Wang & Chuang 2007; Nam-Seok et al. 2007; Jordan et al. 2007)*, Mobile IPv6 remains the best candidate for mobility management protocol for the next generation wireless network (i.e. all-IPv6 network). For IDMP, quite a number of conference and journal papers regarding the intra-domain mobility management based on IDMP were published

on this the new conceptual mobile location method called the IPv6-based location method has been proposed in this thesis based on the assumption that the Mobile IPv6 and IDMP have been adopted as the mobility management protocols on the next generation wireless network (i.e. all-IPv6 network). The IPv6-based location method takes advantage of the movement detection mechanism of Mobile IPv6 and IDMP to determine the location of the user without the requirements of additional hardware or software in the terminal. The IPv6-based location method can theoretically be used as a single method to determine the location of all users on the all-IPv6 network regardless of which part of the network the user is connected from and regardless of the type of access technology and terminal being used by a user.

The study of the trends in the next generation wireless network also indicates that the service environment of the next generation wireless network is expected to be open and the way the mobile location services would be provided on the future wireless network would be quite different from the way they are provided today. Based on the discussion in section 2.3, the user experience will be one of the critical keys in defining the success of the services on the next generation wireless network. The user would likely be able to access any service from anywhere at any time using any terminal model via any available access network, and the existing services that are available locally among users of the same network operator and service provider would be made available for all the users on a common IPv6 network. Providing a mobile location service on the next generation wireless network requires a new service architecture that fits to the open service environment and which focuses on providing a compelling user experience to the user *(Schou 2008a; Schou 2008b)*. In this thesis, the conceptual service architecture for adaptive mobile locations service has been designed based on the assumption that the network is all-IPv6 and the service environment is open, and the answer of research question number 5 regarding integration of the user experience concept has been taken into account when the conceptual service architecture was designed. To answer research question number 6, the scenarios representing new-concept mobile location services assumed to be deployed on the developed conceptual service architecture have been built and the illustrative case studies of the services presented in the scenarios have been carried out as a means of exploring the architecture and demonstrating its applicability.

This chapter concludes the main findings of the thesis derived from the objectives of the thesis and the answers to the research questions previously defined in section 1.3. The main findings based on research questions number 1 and 2 are concluded in section 8.1 where the mobile location services in Asia and Western are discussed. Section 8.2 discusses the conceptual IPv6-based location method based on research questions number 3 and 4, while section 8.3 describes the conceptual service

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during 2002-2005. Examples of the research works related to IDMP can be found in *(Misra et al. 2002; Das et al. 2002; Wei et al. 2003; Aljifri & Tyrewalla 2004; Schou & Olesen 2005).*

architecture according to research questions 5 and 6. Section 8.4 points towards further research directions.

8.1   Mobile location services in Asia and Western Europe

This thesis has examined and analyzed the factors limiting the success of mobile location services offered in Asia (Japan and South Korea) and Western Europe. These regions are different in terms of the mobile network standards being adopted by the network operators as well as in social and cultural aspects which makes them ideal focus areas. Mobile location services have been offered in Asia and Western Europe around the same time, but the services in Asia have obviously gained more attention from the network operators, service providers and mobile users compared to Western Europe. In comparison to Western Europe, mobile location services are more widely deployed in Asia. As discussed in chapter 4 and 5, the main factors differentiating the deployment stages of mobile location services in Asia and Western Europe are the complications and cost requirements for adding location infrastructure on synchronized and non-synchronized network standards. In Asia, CDMA networks are widely deployed whereas GSM and UMTS are the dominating technologies in Western Europe. The most accurate location method, A-GPS, can be deployed more easily and with lower cost on the CDMA networks compared to GSM and UMTS networks, due to the synchronization requirements of A-GPS. Adding A-GPS to a non-synchronized network requires the deployment of location measurement units and this requires both human capital and infrastructure spending. The requirements for upgrading the mobile network from 2G to 3G have also a significant impact on the deployment of the infrastructure for mobile location services. Upgrading from 2G to 3G networks in the CDMA family requires very low investment compared to the network upgrade in the GSM family, as the 2G CDMA base stations can be reused for 3G CDMA and 2G and 3G CDMA operate in the same frequency band. Upgrading from 2G to 3G for the network standards used in Western Europe (i.e. from GSM to UMTS) requires a big investment, since new UMTS base stations and huge amounts of software and hardware as well as new frequency spectrum for 3G is required. As a large amount of money have already been spent on 3G licenses and network upgrades, many network operators in Western Europe are undertaking cost cutting, which tends to focus on reducing resources spent on the development of new applications and services such as mobile location services. Most of the network operators in Western Europe choose to stick with the least expensive and least complicated methods like Cell-ID. The accuracy provided by Cell-ID can only capture approximately 50% of the standard mobile location services, while the A-GPS method widely used in Asia can capture almost all kinds of standard mobile location services. However, the services based on GPS technology are only functioning well in open areas while they are often degraded or unavailable in closed environments. To make mobile location services available in both indoor and outdoor environments, other location solutions for indoor environments are required.

Different kinds of mobile location services are available in Japan and South Korea ranging from simple location-based information services to advanced tracking and navigation services. Most of these services are deployed utilizing GPS-based location methods. Mobile location services have been taken up more enthusiastically by mobile users in Asia compared to Western Europe, but the usage of mobile location services is still not very high compared to other entertainment and messaging services. As discussed in chapter 5, the important reasons for this are the limitations of the applied location technologies and the fact that the service providers have not paid enough attention to the user experience and context of use. In terms of technology limitations, the usefulness of the mobile location services offered in Asia is often degraded in dense urban areas and in closed environments such as inside buildings and undergrounds, as high accuracy location information cannot be provided in these environments with the mobile location technologies (GPS-based) typically used in Asia. The lack of availability of mobile location services in Asia is also due to the lack of open standards and open service environments that allow interoperations between different terminal models from different venders and between different network standards of different network operators. The services in Asia are only available locally within the network of specific operators. Some of the services are only available if the users have specific terminals specified by the service providers. Besides the lack of service availability, the lack of adaptability and offerings tailored to different users' requirements is also one of the limitations of the mobile location services offered in Asia as well as Western Europe. Adding adaptability and interoperability to the services can potentially improve the service attractiveness and this will also improve the possibility of providing a positive user experience and the possibility of making the service become a success.

In Western Europe, different kinds of mobile location services have been offered. Most of the offered services are location-based information services, and these services are typically delivered to the users in the form of text. Advanced services such as tracking services are also available in Western Europe and these are also text-based services. These services are available in both indoor and outdoor environments, and the user can access some of the services regardless of the mobile terminal model and network operator. However, the services have not yet shown a major impact on the mobile service market. An important reason for this lack of success is the fact that the services are generally not very useful due to the lack of high accuracy location information and the way the services are delivered to the users (e.g. SMS-based tracking services). The usefulness of some of the mobile location services offered in Western Europe (e.g. tracking services) is limited both in indoor and outdoor environments by the location technologies (Cell-ID) being adopted by the network operators.

The adoption of mobile location services in Asia and Western Europe is partly driven by the social aspects as well as the physical environment (context of use) of

the country. Japanese and South Korean generally find the mobile location society exciting and they can find efficient use for the technologies. In comparison to Western European, Asian appear to have a stronger sense of community trust in their institutions to protect the use of their personal data (e.g. location information), and they are more ready to adopt new technologies and services. Western Europe, compared with Asia, has more issues regarding privacy concerns and laws and the population is more often suspicious of any service that has to do with tracking. Privacy is seen as one of the hurdles to the successful implementation and adoption of mobile location services in Western Europe but this does not seem to be a big issue in Asia. In comparison with Western Europe, parents in the Asian societies seem to have more control of the whereabouts of their children. Because of the social hierarchy in Asia, where elders or parents have seniority over their children, children are brought up to respect this hierarchy and thus if parents wish to track their location, they would allow it. In terms of the physical environment, most roads in Asia, e.g. Japan, are poorly marked and mobile location services are a useful tool for users to locate certain shops and businesses. In Western Europe, most roads are clearly marked and this means a similar service may not be highly required here.

The different levels of adoption of mobile location services in Asia and Western Europe show that the fundamental element affecting the willingness of the users to pay for the service is the service usefulness. The user will not pay for the service if it is not useful even if it is always available. The service should also be adaptable to the user's requirements and preferences in different contexts of use, and finally the service provider should manage the user expectation by communicating any errors that might occur while the user is using the service.

8.2 Conceptual mechanism for detecting the location of mobile users applying the features of the next generation wireless network

The past research and development of mobile and wireless networks indicate that the next generation wireless network is evolving towards a unified IPv6 network. The service environment is expected to be open, allowing a mobile user to use a single terminal to access different services, provided by different service providers, using different access technologies on a common IPv6 network. As a means to overcome or minimize the problems of the existing location technologies, a conceptual IPv6-based location method has been developed to determine the location of all users on the next generation wireless network. This method takes advantage of the movement detection mechanisms of Mobile IPv6 and IDMP to determine the location of all users on the all-IPv6 network. Location determination applying standard Mobile IPv6 can reveal in which domain the user is and the location of a mobile user can be revealed at the subnet level applying IDMP. The domain is administrated by a network operator and the size of the domain and subnet vary depending on the network management by the network operator. To

provide more precise location information of a mobile user, the static and unique IPv6 address of a wireless access point is suggested to be added in the local binding update message. This will make it possible to reveal at which access point the user is connected. Applying the proposed IPv6-based location method, the location of the user can be detected regardless of the access technologies being used. The user location will be determined at different levels of accuracy depending on the coverage areas of available wireless access technologies. With the IPv6-based location method, the location of all the users on the unified IPv6 network can be determined using a single location method, making the location roaming between different types of wireless access networks owned by different network operators possible.

Many existing mobile location services lose their value, as the users cannot use them in all environments or contexts. For example, this is the case with the services utilizing the GPS-based location methods in closed environments. To increase the service value, a method to detect the location of mobile users in indoor environments by applying the IPv6-based location detection method and the characteristics of Bluetooth and WLAN with the accuracy of 10 to 50 meters is suggested in this thesis. This will open up huge opportunities for service providers to provide new kinds of mobile location services that require high accuracy location information in indoor environments (e.g. indoor navigation, indoor tracking games, etc). The indoor location solution uses the access points of Bluetooth and WLAN as reference points to determine the point of attachment of a mobile terminal on the network. This can compensate for the shortcomings of GPS-based location methods which are normally degraded in closed environments. This will improve the availability and usefulness of mobile location services in the future and thereby potentially improve the service value and the quality of the user experience. Using a wireless access point as a reference point to determine the location of a mobile user requires that the location of the access point has to be fixed, and that an accurate map showing the geographical location of those access points is available. If the indoor location solution applying Bluetooth or WLAN is going to be used, it is likely that this solution may only be adopted in some buildings where the indoor mobile location services are required or highly desired by the users, e.g. at airports, exhibition centers or big department stores.

The realization of the proposed IPv6-based location method depends on how the next generation network will turn out, as the proposed method requires that the network is all-IPv6. It might take years to realize the all-IPv6 network, as the IPv4-networks are still currently widely used and network operators are not eager to transform their network from IPv4 to IPv6 due to the requirements of the new infrastructure. It is, however, in this thesis believed that the networks will slowly be evolved to the all-IPv6 network. Many countries in Asia, e.g. Japan, South Korea, China and Thailand, have already started using IPv6 in the networks. Large amounts of IPv6 addresses are allocated to different parts of the world and big

organizations such as ITU and IETF are working actively on establishing standardizations to support the use of IPv6 in both wired and wireless environments. In addition, several companies such as Nokia, Ericsson, Cisco and KDDI are already developing the next generation wireless technologies and terminals based on IPv6. Besides the realization of the all-IPv6 network, the proposed IPv6-based location method also requires that Mobile IPv6 and IDMP are adopted to manage mobility between the domains and within the domain respectively. Based on the current research works and the vision from IPv6 forum *(Wang & Chuang 2007; Nam-Seok et al. 2007; Jordan et al. 2007; IPv6 forum 2006)*, Mobile IPv6 seems to be the most qualified candidate available for inter-domains mobility management on the next generation wireless network or all-IPv6 network. However, there are a few candidates that can be used for intra-domain mobility management in all-IPv6 networks, e.g. HMIPv6[350] *(Thomson et al. 2005)* and IDMP[351] *(Misra et al. 2002)*. HMIPv6 is designed to be used dependently with the Mobile IPv6 protocol *(Soliman et al. 2005)*, while IDMP is independent from the inter-domain mobility management protocol *(Misra et al. 2002)*. The IDMP can be used with both Mobile IPv6 as an inter-domain mobility management protocol or with any other protocol.

8.3   Conceptual service architecture for adaptive mobile location services

Based on the future wireless world envisioned by WWRF, the next generation wireless network is expected to emerge around the year 2017. Towards 2017, the technologies will be more mature and more complex and the mobile users will demand a better user experience from the services enabled by the technology. The quality of mobile user experience will be one of the important keys in defining whether or not the service will be a success. To provide a positive user experience to different users, the service must be adaptable to the requirements and preferences of different users in different contexts of use. In this thesis, the conceptual service architecture for adaptive mobile location services has been designed to be used in the open service environment of the next generation wireless network. The main objectives of the architecture are to facilitate provisions of future mobile location services that are compatible with the concept of open service environments envisioned by WWRF and ITU, and to improve the possibility of the future mobile location services being successful.

As the user experience is envisioned to be one of the critical keys to the success of a service on the future network, the principles of user experience, context of use and privacy issues have been taken into account when the conceptual service architecture was designed. This resulted in the context-based service adaptation

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[350] Detailed description of HMIPv6 can be found in section 6.1.4.2.
[351] See section 6.1.4.1 for the detailed description of IDMP.

platform, user profile, profiling management agent, and the user expectation management platform within the service architecture. The context-based service adaptation platform adapts the service to best fit with the context-dependent user requirements and preferences defined in the user profile. If the service cannot be adapted as the user required, the user expectation management platform will inform the user of the reason for the inadaptability and may also suggest alternative ways the user can accomplish his tasks. The developed conceptual service architecture can support a wide range of new-concept mobile location services. The architecture supports universal access and the deployment of global-level services which have not been possible with the existing service architecture on the current networks.

As envisioned by WWRF, the users of the future mobile service should be able to control the service to the extend they want. The platform for context-based service adaptation allow the users to control the services (e.g. behavior, visualization, user interface) by setting their context-dependent user requirements/preferences in the context-dependent user profile. The service architecture also provides the mechanism allowing the users to have full control over their privacy. The user privacy is handled at two different levels, both at the location server and at the profiling management agent. The users are allowed to modify every piece of information in their user profiles, even the location information. The user profiles are maintained by the profiling management agent instead of the service providers like the way it is today. The profiling management agent acts as an agent managing the usage and sharing of the user profile, thus it is important that the profiling management agent is trustworthy, and it is therefore suggested that this agent should be operated by a governmental agency.

As the user profiles are maintained and managed by the profiling management agent and not by particular service providers, sharing the user profile or part of the information in the user profile between different service providers and different users on the common IP network is feasible. This enables the deployment of new-concept services that allow the user to access the service based on the location of other users. Based on the concept of sharing the user profile and location information between different users, the user can possibly help each other to accomplish some of their tasks remotely (e.g. the location-based information service presented in the "help you out" scenario). With the conceptual service architecture, the user will experience new ways of creating emotional connection with each other. The user will also be able to share and reuse the existing profile or part of the profile with different services without having to recreate and update the same information more times than necessary.

The conceptual service architecture supports the idea of one network many services by adding the service portal to the architecture, and this allows different users or subscribers of different network operators to access the services provided by

different service providers from anywhere and anytime with the feasibility of billing management and revenue sharing between different stakeholders.

To realize the practical implementation of the conceptual service architecture in the open service environment of the next generation wireless network, the interoperability between components within a single domain and administrative domains must be allowed and this requires a global set of standards for interconnectivity support. The agreements for sharing network resources (e.g. base stations, access points, frequency spectrum) and information resources (e.g. user profile, location information, billing and charging information) between different stakeholders involved in realizing the new-concept mobile location services available in the global level will also be needed. Importantly, a new business model that is acceptable for all these stakeholders will need to be developed.

Assuming that the developed conceptual service architecture is practically implemented, provisioning of several new-concept mobile location services that cannot be provided on the existing service architecture on the current network would be possible. As the architecture support the sharing of the user profile including location information between users, it is possible for the user to access any service based on the location of other users, and this makes it possible for the user to e.g., accomplish some of the tasks on behalf of other user. Finding a taxi based on the location information of the child is one example of a service that the developed service architecture can provide while the existing service architecture on the current network can not. A provision of global-level mobile location services such as tracking the location of a child when she is abroad or safely-arrival notification service would also be possible. Such new-concept services will potentially be required by the users in the future if the ethical/emotional issues can be resolved[352]. Since the realization of the new-concept mobile location services requires involvement of a large number of stakeholders, they are naturally more complicated to realize compared to the existing services that are available only on the local network.

8.4 Directions for further research

This thesis contributes with a better understanding of the factors limiting the success of the existing mobile location services, which gives indications and ideas of how the future mobile location service could be designed in order to reach the re-purchase phase of the service's life cycle[353] and to become more successful compared to the existing ones. The thesis also provides an idea of how the next

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[352] See comment from Ring to question 1 and 3 in appendix D.
[353] Based on figure 1-2, the service will be successful if the users keep paying for it (i.e. it can reach the re-purchase of its life cycle). In order to reach the re-purchase phase of its life cycle, the service has to provide a positive user experience which normally requires that appropriate technology is applied.

generation wireless network is expected to turn out and how the service architecture for mobile location services may be designed in order to be compatible with the service environment of the next generation wireless network. However, there are some related topics that have not been the main focuses of this thesis and which have therefore not been investigated in details. These related topics are presented in the following together with the directions for further research.

- Based on figure 1-2, marketing, technology and user experience influence different phases of the life cycle of the services. This thesis chooses to look at the influence of the technology and user experience to the usage and re-purchase phases of the service's life cycle. The effects of marketing in the pre-purchase and purchase phases of the life cycle of the existing mobile location services have not been looked at in this thesis. Further research work related to the business aspects, e.g. market analysis and business model that affect the adoption of the existing mobile location service in Asia and Western Europe may be required in order to provide an even better understanding of the elements affecting the success of mobile location services.

- As presented in section 6.2, the conceptual IPv6-based location method provides different levels of location accuracy depending on the coverage area of the access point or base station to which the user is connected. The consistency of this method cannot be guaranteed, and the accuracy tends to be high inside buildings and lower in outdoor environments, assuming that the location infrastructure applying short-range wireless access networks is available inside buildings. In section 6.4, it is suggested that a combination of the IPv6-based location method and GPS-based location method can provide high accuracy location information anywhere and any time. However, the details of how to combine these two location methods have not been studied in the thesis and further research regarding this topic would be interesting.

- For the conceptual service architecture developed in this thesis, a user on the next generation wireless network is expected to be able to access a service regardless of network type, terminal, and network and service providers. To make this a reality, the billing management system has to be well organized. The location information is very important information used for billing management in the all-IPv6 network environment, where all network operators and service providers are offering the network access and services on the common IPv6 network[354]. On the all-IPv6 network, different network operators use different network prefixes and this prefix is contained in the home address of all mobile terminals registered with the operators as described in section 6.1.3.1. Knowing the home address prefix and GCoA prefix can reveal that a user is a subscriber of a particular network operator and is using a network of a

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[354] See section 6.1.1 for the concept of one network having many operators and services.

particular network operator. This location information can be used for the billing management system. The issues of how to manage the billing and how revenues should be shared amongst different network operators and service providers as well as roaming agreements and policies between operators have not been looked at in this thesis and further research work is required.

- The context-based service adaptation platform presented in section 7.6 provides ideas, concepts and guidelines of how the service can be adapted to best fit with the user requirements/preferences in the current context of use, which is the way to manage the user experience during the usage stage of the life cycle of the service[355]. In the adaptation process, the details of the adaptation strategy, the rules specifying how the adaptation should be effected, and the methods and parameters used for the service adaptation has not been examined in this thesis. The future research of these topics could provide a better idea of how the adaptation can be made practically.

- In section 7.7, the concept of the user expectation management platform is proposed to control the user experience towards the services. A detailed description of this platform is not provided in the thesis and further research of how this platform should be managed, how it should be activated and how the information should be sent to the user, etc., is required.

- To realize the new-concept mobile location services presented in section 7.9, a large number of stakeholders around the world will have to be involved in sharing the network resources, the information resources, and the revenues. Naturally this raises many issues that have to be dealt with before this concept can be practically realized. One major issue that requires further research is how to share revenue between different stakeholders, as an interesting business model is of course a requirement for the realization of the new-concept services.

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[355] See figure 1-2 for the life cycle of a service.

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Appendix A: List of publications

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2. *Schou S.* (2008a), "Context-based Service Adaptation Platform: Improving the User Experience towards Mobile Location Services", In Proc. of the International Conference on Information Networking 2008, (ICOIN 2008), Busan, Korea.
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10. *Thongthammachart S.* and Olesen H. (2003), "Mobile location services over the next generation IP core network," In Proc. of 10th International Conference on Telecommunications (ICT'2003), Tahiti, Papeete – French Polynesia, Vol. 1, February, Pages: 324-329.

Appendix B: List of individuals interviewed

1. Hidetoshi Yokota and Takeshi Kubo, Mobile Network Laboratory, KDDI R&D Laboratories, Inc., Japan. Topic: Determining the user's location applying the mobility management protolcol in interdomain and intradomain levels, mobile location technologies used by KDDI and mobile location services provided by KDDI, 2003, 2004.
2. Prof. Akihisa Kodate and Prof. Mitsuji Matsumoto, GITI, Waseda University, Tokyo, Japan. Topic: Mobile location technology and mobile location services in general, 2003.
3. Takeshi Kato and Osama Takahashi, Mobile Internet laboratory, NTT DoCoMo, Kanagawa, Japan. Topic: Mobile technologies (4G) and services in the research and development stage, 2003.
4. Kunitake Kaneko, the University of Tokyo, Tokyo, Japan. Topic: Detection the location of a mobile user applying Blueooth, 2003.
5. Satoshi Hirachi and Junichi Shimizu, P's-in Co.Ltd. Tokyo, Japan. Topic: Location determination applying WLAN, 2003.
6. Jakob Grubjerg, Nokia, Copenhagen, Denmark. Topic: Location based technology and services in Denmark, 2005.
7. Prof. Jari Veijalainen, University of Jyväskylä, Jyväskylä, Finland. Topic: Evolution of the conceptual service architecture developed in the thesis, 2007.
8. Steffen Ring, Motorola A/S, Denmark. Topic: Evolution of the conceptual service architecture developed in the thesis, 2007.
9. Ole Mørk Lauridsen, Terma A/S, Denmark. Topic: Evolution of the conceptual service architecture developed in the thesis, 2007.

Appendix C: List of Ph.D. courses

1. Wireless and mobile network architectures, Kungliga Tekniska Högskolan (KTH), Stockholm, Sweden.
2. Writing and reviewing scientific papers, Aalborg University, Aalborg, Denmark.
3. Interface: from the desktop to interactive spaces – Challenging aesthetics, architecture and computer science, Nordic Interactive Research School, Aarhus, Denmark.
4. Professional Communications, Aalborg Univerisy, Aalborg, Denmark.
5. Internet Research Ethics: Foundations, Law and Guidelines and Cross-cultural Perspectives, the IT University of Copenhagen, Copenhagen, Denmark.
6. Design and management of information technology, Copenhagen business school, Copenhagen, Denmark.

Appendix D: Evaluation of the conceptual service architecture based on interviews

Interviews have been used as one of the means of evaluating the conceptual service architecture presented in chapter 7 in this thesis. This appendix provides a description of the planning, execution and data results from the interviews where the conceptual service architecture has been criticized, commented upon and evaluated by experts in the research area. The selections of experts are:

1. Jari Veijalainen, Professor from department of Computer Science and Information Systems, University of Jyväskylä, Finland.
2. Steffen Ring, Technical director from Motorola A/S, Denmark.
3. Ole Mørk Lauridsen, Chief Technology Officer from Terma A/S, Denmark.

In order to provide the experts a clear understanding of what they were asked to criticize, comment and evaluate, two conference papers *(Schou 2008; Schou 2008a)* have been written to present the conceptual service architecture and all the concepts and ideas behind it. The questionnaire related to the architecture has then been set up and sent out to the experts together with the papers. The responses to the questionnaire were provided in the form of written text[356], and this information has been used to support and contribute to the arguments and discussions made in the thesis.

In the following, the two conference papers *(Schou 2008; Schou 2008a)* are provided together with the questionnaire and the responses from the experts.

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[356] Face to face interview was also conducted at Motorola A/S with Steffen Ring.

Conceptual Service Architecture for Adaptive Mobile Location Services

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Abstract— **This paper presents a conceptual service architecture for adaptive mobile location services designed to be used on the next generation wireless network. The developed service architecture consists of a set of concepts, principles, rules and guidelines for constructing, deploying, and operating the mobile location services. The service architecture identifies the components required to build the mobile location services and describes how these components are combined and how they should interact. As a means of exploring the developed conceptual service architecture, an illustrative case study of a new-concept tracking service is chosen to demonstrate the applicability of the architecture. Through the case study, the service request and response processes will be illustrated. New possible service functions provided by the developed service architecture will be examined and discussed in comparison with the functions provided by the existing tracking services on the current network to show the usefulness and value of the developed service architecture.**

I. INTRODUCTION

The existing mobile location services are typically available locally within the network of a specific operator or available on different networks of different operators in the same country. The way mobile location services are offered today is not compatible with the service environment of the next generation wireless network which will be open [1][2]. In the open service environment, the users will be able to access a mobile service regardless of geographical location, terminal model, access network, network operator and service provider [1][2][3][4]. Different services will be provided by different service providers on a common IPv6 network, and these services will be available to all users on the network, regardless of which part of the network they connect from [3][4]. Location information, user profile, and billing and charging information can be transferred between administrative domains, operators and service providers [1][3]. Both seamless roaming and universal access is expected to be achieved in the next generation wireless network [2][5].

Providing mobile location services on the next generation wireless network requires a new service architecture that fits in an open service environment and which allows the coexistence of a number of stakeholders performing various roles. The new service architecture must support universal service access and allow the end-users to access services independently of the physical location, type of access network and terminal model being used by the user.

This paper presents a conceptual service architecture for adaptive mobile location services which is designed to be used in the open service environment of the next generation wireless network. The architecture supports a provision of new-concept services which have not been possible to provide using the existing service architecture on the current network, e.g. the services that allow users to access a service based on the location information of other users on the IPv6 network. For example, the location-based information service may be provided based on the location of other users at the global-level instead of based on the current location of the user or the location manually defined by the user like the services available today. The mobile location services that are currently only available in the local domain (e.g. tracking services) will possibly be made available globally (e.g. tracking the location of a child who is traveling abroad).

The "help you out" scenario presented in the following represents example usage cases of new-concept mobile location services based on the developed service architecture presented in this paper. The types of services are indicated in the footnotes.

Scenario: Help you out *"Sara is 12 years old and she is traveling alone to Tokyo for studying Japanese. Sara has not been in Tokyo before but her father was*

there last year. He wants to help Sara with practical things such as where to go and what to buy and which areas are safe and which areas should be avoided. Sara appreciates her father's help and she shares her location information with her father and remains open for his suggestions.

When Sara arrives at the Narita airport, her father gets an alert message that she has arrived safely[357] and now she needs to go through all the check out processes and then get her luggage. While Sara is managing the practical things at the airport, her father helps her finding a taxi by locating the location of the taxi in the vicinity of the airport and reserves one for Sara[358]. The service sends reservation information to Sara including the taxi number and real-time navigation map to the taxi's location[359]. Sara gets her luggage and the taxi is ready for her. Sara is getting into a taxi and her father is monitoring her location all the way to the hotel[360]. Sara is jet-lagged and she wants to rest. She asks her father to make a traveling plan to the school for her tomorrow. Sara's father accesses a navigation service and makes pre-navigation for her. He chooses that the navigation service should be alerted at Sara's terminal at 8 O'clock tomorrow morning[361]. Sara's father can access any information related to the location of Sara. Sara shares her location with her father and he can help her check all the conditions based on Sara's location (e.g. weather, traffic, safety/danger zones, etc). Sara's father is not concerned about Sara, as he can see that she is safe and managing her life fine in Tokyo".

The components required to build the conceptual service architecture for providing new-concept mobile location services are introduced in section II together with descriptions of how these components are combined and how they should interact. An illustrative case study of a new-concept tracking service is made in section III as a means of exploring and demonstrating the applicability of the developed conceptual service architecture. Section IV discusses the usefulness of the new-concept tracking service based on the developed service architecture in comparison with the existing tracking services on the current network. Concluding remarks are given in section V.

II. CONCEPTUAL SERVICE ARCHITECTURE FOR ADAPTIVE MOBILE LOCATION SERVICES

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[357] Pre-tracking service.
[358] Location-based information service.
[359] Navigation service.
[360] Tracking service.
[361] Pre-navigation service.

This section presents the conceptual service architecture for adaptive mobile location services which is designed to be used in the open service environment of the next generation wireless network. One of the important features of the designed architecture is adaptability. Adaptability is envisioned by WWRF as one of the keys to the success of any service beyond year 2010 [6] and one of the service capabilities that should be made available on the next generation wireless network suggested by ITU [1]. Adding adaptability to the future mobile location services will therefore be one way of increasing the possibility of the service being a success.
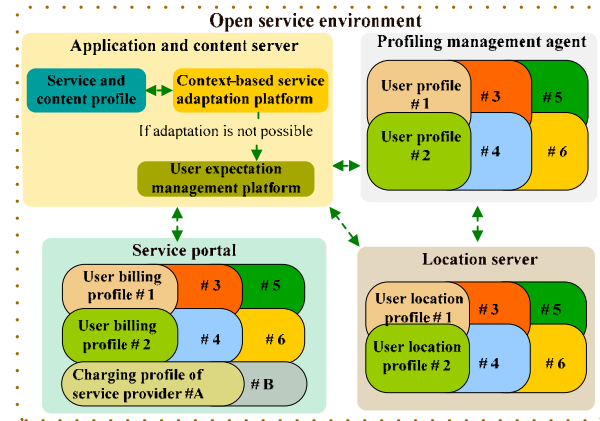

Figure 1: New conceptual service architecture for adaptive mobile location services on the next generation wireless network. The conceptual IPv6-based location method proposed in [9] may be used for determining the location of all users on the unified IPv6 network, and the location information is maintained by the location server. For simplicity, the infrastructure needed for location determination is not shown in the figure.

Figure 1 illustrates the components that form the service architecture, and the descriptions and roles of the individual components are given in the following.

The service portal handles session management, requests handling, authentication of subscribers, and manages the billing and charging. The service portal contains the "user billing profile" and "service provider charging profile". When the user accesses the service, the service usage will be recorded and the billing and charging reports will be updated in the user billing profile and service provider charging profile, respectively. The user and service provider can access and check their profiles but editing and deleting of the profiles is not allowed. The user billing profile contains the actual information of the user, which is required for

billing management such as the real name, real address, telephone number, credit card number and a list of subscribed services. The service portal allows users (or subscribers) of different network operators to access the services of different service providers from anywhere on the all-IPv6 network with the feasibility of managing the billing for the users and revenue sharing between different stakeholders. The service portal is placed in every domain and it is owned and managed by the network operator who administrates the domain. The service portal makes it easy for the user and service providers, as the user can use different services without having to pay different bills for different service providers and the service providers do not have to handle the billing management of different users but instead let the network operator handle this task.

The application and content server handles different tasks from providing the service and content to the user and adapting the service behaviors and content to best fit with the user's requirements/preferences in a specific context of use, to managing the user expectations towards the service. This server is owned and managed by the service provider. The context-based service adaptation platform plays an important role in managing the user experience in the usage stage of the service, as the context plays an important role in defining how the user will experience the service [7]. The service adaptation is made based on the context-dependent user's requirements and preferences and the conditions defined in the user profile[362] and the service and content profile. The service and content profile is created by the service provider and maintained in the application and content server, which is owned by the service provider. This service and content profile contains information about what the service provides and what can be adapted and cannot be adapted in different contexts and situations.

Another task of the application and content server is to manage the user expectation, and this task is handled by the user expectation management platform. The main task of this platform is to inform the user about the service (e.g. if the service is temporarily unavailable, new features, new

service update, etc.) and to inform the user of the reason and further suggestions in the case that the service adaptation requested by the user cannot be made (e.g. 3D navigation is not possible because the user's terminal does not support 3D display). This is the platform that controls the user experience by providing an understanding of what the user can and cannot expect from the service. This approach prevents the user from generating unrealistic expectations that the service cannot live up to.

The profiling management agent maintains, manages and updates the user profiles of registered users and also handles authentication and authorization. The profiling management agent has been added to facilitate the concept of open service environment of the next generation wireless network where the information resources (e.g. user profile and location information) should be reusable and sharable across networks [1]. As different services may require similar or identical information related to the users and their current contexts, the profiling management agent provides a great benefit to the users by allowing them to share and reuse their profiles or parts of the profiles with different service providers without having to create and update the same information many times than necessary. The service providers also benefit from the profiling management agent, as they do not have to implement a platform for handling the user profiles of different users, instead letting the profiling management agent handle this task. The profiling management agent can be placed anywhere on the all-IPv6 network and it is owned by a new stakeholder, which in this paper is called the "profiling broker". This agent acts as a broker handling the usage and sharing of the information in the user profile according to privacy rules defined by the users. Based on the open service environment concept of the next generation wireless network, the users should be able to access, edit or delete their user profiles anywhere and any time they desire [1].

The location server maintains the location information of all the users in the domain. This server is owned and managed by the domain owner (network operator). There should be at least one location server in every domain. In the location server, the location of individual users is stored in a profile called the user location profile. This profile maintains the actual location of the user and the privacy rules of using and sharing this information is defined by the users. As the mobile user may

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[362] The user profile is merely a conceptual entity representing a unique lifestyle and current context surrounding and situation of a user. The user profile contains details of the user and his personal requirements in a form that can be used by the system to deliver the service that match the user's requirements in particular contexts of use and situations [12].

travel into different domains administrated by different management entities or different network operators, it should be possible to exchange the user location profile between different network operators according to the user mobility. For example, if the user moves from domain A to domain B, the transfer of user location profile from domain A to B should be possible. This requires new mechanisms for handling the user location profile transfer process and the agreements between network operators.

The ways the components in the service architecture, presented in figure 1, interact with each other vary depending on the types of service, adaptation conditions, privacy rules, and context. However, the typical service requests and responses are as follow. The user accesses the service via the service portal. The service portal authenticates the service request, records the service usage and updates the user billing profile and provider charging profile. The service request is forwarded to the application and content server. The application and content server asks for the user profile from the profiling management agent. The location server may send the most up to date location information of the user to the profiling management agent depending upon the rules of using and sharing of location information defined in the user location profile. In the case that the service (e.g. navigation service) requires real-time location information, the application and content server may request the real-time location information directly from the location server. The application and content server then delivers the requested service back to the user.

III. NEW-CONCEPT TRACKING SERVICES

The tracking services based on the existing service architecture on the current mobile networks are typically available locally within the same kind of mobile network technology in the same domain or available for the subscribers of different operators in the same country. The concept of tracking services on the developed conceptual service architecture presented in this paper is compatible with the service environment of the next generation wireless network, where the service is available in the global-level and supports universal access, meaning that the user can access the same tracking service regardless of geographical location, terminal model, access technology, network operator and service provider. Figure 2 demonstrates the request/response sequences of the

tracking service based on the "help you out" scenario presented previously in the introduction section.
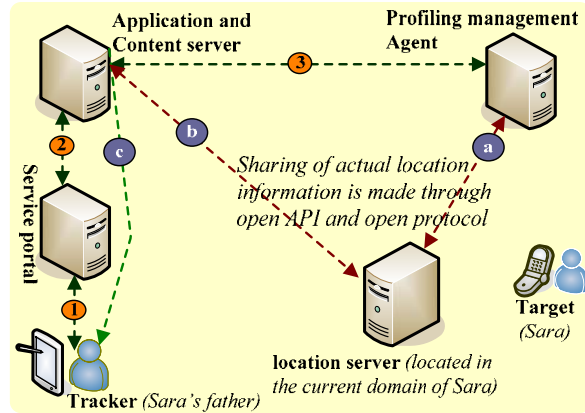

Figure 2: Interactions between different components in the conceptual service architecture in the case of a global-level tracking service. The user profiles of the tracker and the target are assumed to be maintained in the same profiling management agent. The tracker and the target are in different domains and different countries. Each domain has a location server which maintains the actual location of all users on the domain and the actual location of the tracker and the target in the scenario are maintained by different location servers.

Based on the "help you out" scenario, the tracking service is triggered by the current use context of the target (i.e. Sara's current location). The service is activated when Sara arrives at Narita airport. In this case, Sara's father has defined beforehand that the service must send notification of arrival to him when Sara arrives in Japan. The tracking service is continuously used by Sara's father until she arrives at the hotel. In this case, Sara's father is the tracker and Sara is the tracking target. The processes of service activation, requests and responses of the tracking service presented in the scenario are as follow.

1. The tracker sends a service request to the application and content server via the service portal (Route 1). The service portal authenticates the request and records the service usage for billing and charging management.

2. The service portal forwards the service request to the application and content server (route 2). Based on the scenario, the tracker defines that he wants the service to be activated when the target enters a pre-defined context (i.e. the target has arrived in the pre-defined location (Narita Airport)).

3. The application and content server asks the profiling management agent for the user profiles of the tracker and the target (assuming that the user

272

profile of the tracker and the target are maintained in the same profiling management agent). The profiling management agent processes the privacy control and delivers the information required for the requested service to the application and content server (via route 3). The profile of the tracker will be used for adapting the service (e.g. service visualization, user interface, etc) to the tracker's requirements/preferences in his current use context, and the location information of the target in her user profile will be used for service triggering (i.e. service behavior adaptation).
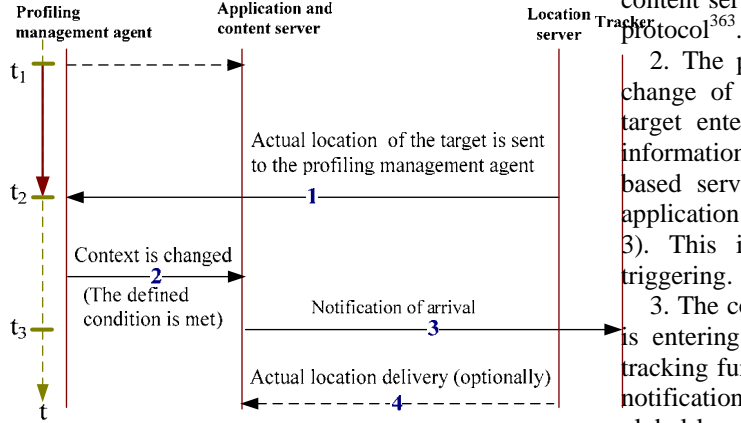

Figure 3: Interactions between the components in the service architecture from the start of the monitoring period (t1) to the point where the arrival alert is sent out to the tracker (t3). The period from t1 to t2 is the monitoring period. The target enters the pre-defined area at t2 and notification of arrival is sent to the tracker at t3.

After the tracker has requested the tracking service, the profiles of the tracker and the target are sent to the application and content server. Based on the scenario, the tracker defines the service behavior by setting that the tracking function should be triggered when the target has entered the pre-defined area. The period from this point to the point when the target is in the pre-defined area is, in this paper, referred to as the "monitoring period" (i.e. the period where the service is waiting for activation depending on the conditions defined by the tracker). The service will remain in this period as long as the target is not in the pre-defined area. Figure 3 illustrates the interactions between the components in the service architecture from the start of the monitoring period to the point where the tracking function is activated and the target is tracked continuously by the tracker. The tracking function will be activated when the target is in the

pre-defined area (i.e. arrived at Narita Airport). The service activation processes are as follows.

1. When the target is at the Narita airport and turns on her mobile terminal (t_2), one of the available indoor location methods (e.g. the method presented in [8]) determines her location and sends the location information to the location server. The location server then sends information update to the profiling management agent where the target has registered (route a in figure 2 and process # 1 in figure 3). The sharing of location information between the location server and application and content server is made through open API and open protocol[363].

2. The profiling management agent detects the change of current use context of the target (the target enters a new location). The new location information of the target is then sent to the context-based service adaptation platform located in the application and content server (process # 2 in figure 3). This information will be used for service triggering.

3. The condition set by the tracker (i.e. the target is entering the pre-defined area) is met, and the tracking function is activated. At this point (t_3), the notification of arrival is sent to the tracker and the global-level tracking service begins (process # 3 in figure 3).

4. Based on the "help you out" scenario, from the point where the notification of arrival is sent, the target will be continuously tracked by the tracker (via route c in figure 2). As real-time location information is needed from this point, the location information of the target may optionally be sent directly from the location server to the application and content server (route b in figure 2 and process # 4 in figure 3).

Based on the scenario, the location of Sara will be tracked from the point where she arrives at the airport, during the check-out and luggage collection, and while taking a taxi to the hotel. The tracking service will be withdrawn when Sara arrives at the hotel.

IV. USEFULNESS OF THE DESIGNED SERVICE ARCHITECTURE

Based on the demonstration of the tracking service presented above, the conceptual service

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[363] An open protocol is an application-level protocol for querying the location of mobile terminals independent of underlying network technology. The open protocol serves as the interface between a location server and profiling management agent or application and content server [13].

architecture can in principle provide several new functions for the new-concept tracking service compared to the functions for the existing tracking services. Global-level is one of the main advantages of the conceptual service architecture, and global-level tracking is one of the new possible functions of the developed conceptual service architecture. This function is not possible with the current service architecture in the current service environment and on the current network, due to the lack of open standards and open service environment, and the fact that the mechanism for sharing the required information (e.g. location and user profile) is not available.

The lack of open standards and open service environment is one of the shortcomings of the existing mobile location services. The availability of the existing mobile location services is depending on the geographical location, service provider, network operator, and terminal. For some tracking services the users are required to have a specific terminal in order to be able to access the service, and this service is only available locally within a specific geographical area and a specific network, and the tracking is only possible if the tracker and the target are subscribers of the same network operator and service provider.

Adaptability is another useful capability of the conceptual service architecture. Based on the "help you out" scenario, the context-based service adaptation will adapt the service behavior based on the task defined by the tracker. In this case, the tracker has defined that he wants to be notified when the target is in the pre-defined area. The service will be activated and the notification will be sent to the tracker when the conditions set by the tracker are met. With this service function, the tracker does not have to manually track the location of the target, but rather let the tracking service monitor the location of the target and notify the tracker when condition set by the tracker is met. This function is currently available in some of the tracking services offered in Japan and South Korea but not for the services in Western Europe.

Another advantage of the tracking service based on the conceptual service architecture is that it is available in indoor environments (e.g. airports). This can be realized by the use of Bluetooth location infrastructure [8] and the conceptual IPv6-based location method proposed in [9]. The lack of capability of providing high accurate location in indoor environments and dense urban areas is one of the main problems limiting the success of the

tracking services offered today [10]. With the conceptual IPv6-based location solution, and indoor location infrastructure applying short- and medium-range wireless networks [8][9], the lack of high accuracy location information in closed environments can be compensated.

Norman has stated in the book "Emotional design" [11] that the service that almost always guarantees success is the service that provides social interaction and emotional connection between people. The global-level tracking service presented in the "help you out" scenario provides social interactions and emotional connections between people (father and his child). Naturally, the father is concerned about his child, especially when she is a girl and alone in a foreign country. The child is likely to be nervous when she is alone in an unfamiliar area, and she wants to feel safe. The global-level tracking service allows the father to see what is going on with his child and at the same time he can help his child handle some of her tasks remotely as presented in the scenario. This service has a high potential of being a success if it is used between trust parties. However, it involves a higher level of complexity to realize this service concept compared to the tracking service that is available locally. In order to realize the services presented in the scenario, exchanging of user profile, location information, and billing and changing information between administrative domains is required, and new business agreements and new business models are needed to be developed.

V. Conclusion

This paper presents a conceptual service architecture for adaptive mobile location services to be used in the open service environment of the next generation wireless network. In the designed service architecture, the service portal and profiling management agents play important roles in realizing the concept of one network many services. The context-based service adaptation platform, user profile and service and content profile play important roles in adapting the service to best fit with the user requirements in a particular context of use. In the designed architecture, the user profile is handled by the profiling management agent and not by the service provider like the case today. The service provider can only utilize the user profile when the user wants to use the service. This will minimize the privacy concern towards the use of any mobile service. It is obvious that the profiling management agent plays an important role in

providing mobile services in the future. The profiling management agent must be trustworthy and the users should feel safe and comfortable allowing the agent to protect the use of their personal information as well as their location information. The developed service architecture supports the deployment of new kinds of mobile location services that have not been possible on the current network. The services such as global-level tracking service and location-based information service that allows the user to access the information utilizing the location information of other users on the all-IPv6 network will be possible.

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Context-based Service Adaptation Platform: Improving the User Experience towards Mobile Location Services

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Abstract— Back in 2000 and the following two or three years, mobile location services gained a great deal of interest and they were considered as one of the few service categories where users would be willing to pay for the usage. Since 2000 countless mobile location services have been launched in different parts of the world. However, the mobile location services have obviously not yet met the hyped expectation of mass-market adoption that was expressed in 2000. The lack of adaptability and offerings tailored to different user requirements in specific contexts of use is one of the factors inhibiting the take-off of the existing mobile location services both in Asia and Western Europe. Adaptability is envisioned by Wireless World Research Forum (WWRF) as one of the keys to the success of any service beyond year 2010 and one of the service capabilities that should be made available on the next generation wireless network suggested by International Telecommunication Union (ITU). This paper proposes a new conceptual platform for context-based service adaptation which is designed to be used in the open service environment of the next generation wireless network. The platform aims to add adaptability to the future mobile location services as a means of improving the possibility of the service being a success.

VI. INTRODUCTION

Mobile location services refer to mobile services that provide information based on the geographical location of people or objects. Mobile location services exploit location technologies for determining where the user is geographically located, thus making the provision of different services based on a given location possible. Since 2000 countless mobile location services have been launched in different parts of the world. The areas with the greatest attention to providing mobile location services are Asia, Western Europe and North America, each with very different technologies, business models and outcomes. Mobile location services have been taken up more enthusiastically by mobile users in Asia, especially in Japan and South Korea, compared to other parts of the world. However, the overall usage of mobile location services is still not very high compared to other entertainment and messaging services. One of the main inhibitors to the adoption of the existing mobile location services, besides the lack of location methods that can provide high accuracy location information in closed environments and urban areas, is the lack of adaptability and offerings tailored to different users' requirements [1][2].

In the case of a mobile location service, different users use a service through different mobile networks using different location technologies, which provide different levels of data rate and different levels of accuracy. They want to accomplish different tasks using different terminals with different user interfaces. They use the service in different roles and with different social aspects. Using the same service in different contexts of use[364] can result in significantly different levels of user experience[365] [3][4]. For example the service may appear funny or annoying depending on how busy the user is. The quality of the user experience is likely to be improved and the service has a high possibility of being a success if the service can be

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364 The term "context of use" or "use context" refers to: Users, tasks, technologies, and the physical and social environments in which a service is used [6][20][21].

365 The user experience is the experience that the user gets when using a service in particular contexts of use [3].

adapted to match the user requirements/preferences in particular contexts of use.

This paper proposes a conceptual platform for context-based service adaptation which will add adaptability and provide improvements and a foundation for more success for mobile location services in the future network compared to the existing services on the current network. The main task of the designed platform is to adapt the service to best fit with the user requirements and/or preferences in particular contexts of use, which is one of the possible approaches for improving the user experience towards mobile location services.

The adaptation possibilities for mobile location services are presented in section VII followed by, in section VIII, the description of the user profile which is a set of information required in the process of service adaptation. The conceptual platform for context-based service adaptation is then proposed in section IX, while the concluding remarks are given in section X.

VII.   ADAPTATION POSSIBILITIES FOR MOBILE LOCATION SERVICES

A mobile location service is naturally adaptive by itself, since the information delivered to the user is adapted according to the location of the user. However, there are many more aspects of use contexts (user, task, technology, and physical environment and social environment) that mobile location services can be adapted to. For mobile location services, the adaptation can take place at five different levels: Technology, service behavior, user interface, presentation and content [5]. The five different levels of service adaptation are described below.

Technology level: In this level, the service is adapted to the technology context. For example information is encoded for specific mobile terminals with different characteristics (e.g. display size and resolution, memory, CPU power, etc.), or for specific network conditions by e.g. reducing image resolution and color depth, and lowering video frame rate to match the network bandwidth.

Service behavior level: The service behavior may be adapted to the user's location or task. An example of the service behavior adaptation based on the user's location is the zone alert feature of a tracking service, where the alert message is sent to specific persons when the tracking target leaves or enters a pre-defined zone. The service behavior may also be adapted to the user's tasks. For example, a taxi driver may define that he wants text information to be translated to voice while driving [6].

User interface level: The user interface may be adapted to the user's tasks, the system in use (e.g. terminal and network), and the user's physical conditions. For example, the user interface is changed from graphic user interface to voice interface when a blind user is accessing the service or when a user is driving. The service adaptation in the user interface level requires that the terminal can support different kinds of user interfaces; otherwise adaptation in the user interface level is limited or not possible.

Presentation level: The visualization of the service may be adapted to the user's tasks, social aspect, and physical condition. For example, the visualization of the service may be adapted according to the user's age [7].

Content level: In this level the content of the service is adapted to the current location, situation and user (e.g. age groups, gender, and preferences).

Fig. 1 gives an overview of service adaptation illustrating why the service should be adapted, how and to which context.
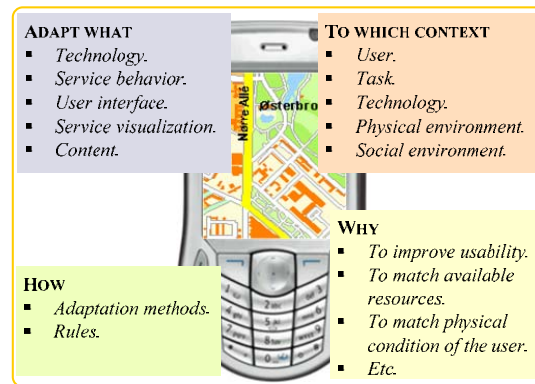

Fig. 1 Perspective of the context-based service adaptation for mobile location services.

The service adaptation may be activated when both the context is changed and the user's requirements and/or preferences changed according to the new context. The change of context can be the change of one or more perspectives of use contexts (e.g. change of terminal, location, social environment, etc.). The context-based service adaptation platform presented in section IX will minimize the need of interactions between the user and the service without taking the overall control of the system from the user. To facilitate the context-based service adaptation, the user profile is required.

When the users want the service to be adapted according to their requirements or preferences in specific contexts of use, a user profile is required. The user profile represents a unique lifestyle and current context surrounding and situation of a user [6]. The set of information required in the user profile depends on the purpose of using the profile. In this paper, the user profile is used by the context-based adaptation platform for adapting the services (e.g. visualization, user interface, behavior) to best fit with the user requirements and preferences in particular contexts of use. In order to support the adaptation, the user profile in this paper contains the information related to the current context of use in which the service is used (i.e. information related to the user, task, technology, and physical and social environments) and the context-dependent user requirements/preferences (e.g. task-dependent user requirements/preferences). The information related to the current context of use describes in which context and situation the service is used, and the context-dependent user requirements/preferences describe how the users want the service to, e.g., behave and present in particular contexts of use and situations.

Since the user profile in this paper is used for facilitating the context-based service adaptation, it must be structured and managed in a way that allows the context-dependent decision making for service adaptation. The user profile should also be reusable, sharable and transferable between administrative domains, operators, services providers and users, as this is one of the interoperability requirements in the open service environment of the next generation network defined by ITU [8].

A. User profile structure

As mentioned previously, the context-dependent user profile in this paper contains the information related to the current context of use and the context-dependent user requirement/preferences. The entire set of this information is, in this paper, referred to as the central user profile. However, only some parts of the information in the central user profile will be required for adapting a specific service to best fit with the user's requirements/preferences in a specific context of use and situation. Instead of reinventing a novel solution for managing and structuring the user profile, this paper adapts the approach for structuring and managing the user

profile from the Mobilife project [9] as it are compatible with the open service environment of the next generation network in terms of resource reusability, and as the Mobilife user profile structure allows the context-dependent adaptation decision making.

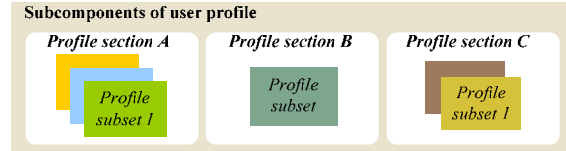Fig. 2 illustrates the structure of the context-dependent user profile.

Fig. 2 Structure of the context-dependent user profile adapted from the user profile management proposed in the Mobilife project [9]. The profile section A, B and C are created to be used by the service A, B and C respectively. The profile subsets maintained in the profile sections are derived from the central user profile.

In fig. 2, the profile section is created to be used for a specific service, and each profile section contains one or more profile subsets. One of the profile subsets in the profile section must be defined as a default profile subset and the remainders are context-dependent profile subsets (referred to as "profile subset" in the following). The default profile subset contains the default information such as user identity and service identity, and the profile subset contains both the default information and necessary information that is required for context-based service adaptation such as context information, context-dependent user's requirements/preferences and adaptation condition. Different profile subsets in the same profile section will be applied for the same service in different contexts of use or situations. For example, profile subset #1 is applied when the user is in a specific location with specific social rules (e.g. meeting room, theater), and profile subset #2 is applied when the user is busy with other tasks (e.g. driving).

Examples of sets of information that may be contained in two different profile subsets used for adapting the same service to the user's requirements/preferences in different contexts of use and situations are presented in fig. 3.

Service ID: Zone alert tracking service	Profile subset #1
User ID: John Type of location: Theater Task: Watching a movie	Physical and social environment-dependent user requirements/preferences - Vibrant service alert - Text or graphic user interface - Text or graphic location notification

Service ID: Zone alert tracking service	Profile subset #2
User ID: John Type of location: In the car, on the road Task: Driving	Task-dependent user requirements/preferences - Voice service alert - Voice user interface - Voice location notification

Fig. 3 Examples of two different profile subsets generated for a zone alert tracking service and applied for the service adaptation in two different contexts of use and situations. The profile subset #1 will be applied when John is in the theater and profile #2 will be used when he is driving. The profile subset #1 is used to adapt the service to the physical and social environment in which the service is used. The profile subset #2 is used to adapt the service to best fit with the current task performed by the user.

The information required in each profile subset is derived and generated based on the information stored in the central user profile and this task is handled by the profiling management agent presented in the following.

B. User profile management

In this paper, the user profile is maintained and managed by the profiling management agent. The role of the profiling management agent is to maintain, generate and manage the user profile of registered users as well as to handle authentication and authorization. This agent acts as a broker handling the usage and sharing of the information in the user profile according to current context of use in which the service is used and according to the privacy rules defined by the users. When a service provider wants a user profile of a specific user, the profiling management agent will search, match, and provide the profile subset that contains the necessary information required for the service adaptation process for a particular context of use. As the user profile in this paper is supposed to be used in the open service environment of the next generation wireless network, where the user can access the service anywhere and anytime, a user profile must be accessible and modifiable by the user from anywhere on the network, which corresponds to the profile management policy proposed by ITU [8] and the standardization regarding user profile management specified by ETSI [6]. Based on the user profile management suggested by ITU [8], the user should be allowed to have as many profiles or profile subsets with different identities and attribute information as he

desires. The user should also be allowed to use a single profile or a single profile subset for different services provided by different providers. The user profile can be viewed and modified by the user and/or an agent of the user upon the user's permission.

IX. CONCEPTUAL PLATFORM FOR CONTEXT-BASED SERVICE ADAPTATION

It is often impossible to design a service that fulfills the requirements and matches the preferences of all its users, because people have different life styles, they perform different tasks in different context surroundings with different social rules. They access the service via different networks using different terminals with different capabilities. To satisfy different users in different use contexts, the service should be adaptable and customizable according to the change of the context of use. An adaptive service can automatically adjust e.g. user interface, visualization and behavior of the service based on e.g. the user's task, location, and physical condition. An adaptive service that provides what the user requires and prefers at his current contextual surrounding, can theoretically provide a positive user experience.

A. Choice of the adaptation

Two types of adaptation can be applied for the context-based service adaptation for mobile location services: Self-adaptation and user-controlled self-adaptation [10]. In the self-adaptation process, the system adapts itself without any interaction between the user and the system, while the user-controlled self-adaptation process is a sort of system in which the user makes the decision but the system automates the rest of the change [11]. Meyer [12] concluded that adaptation performed entirely by the system (self-adaptation) can be effective primarily when the adaptation does not change the actions available to the user. To change service characteristics that are visible to the user (e.g. user interface, visualization, behavior), it is important to give the user the opportunity to decide about the adaptation.

An example of a mobile service adaptation that is based on self-adaptation is the adaptation approach proposed in the Simplicity project [13], where the service relies on the user profile containing information such as the user preferences and characteristics of terminal and network. Part of the profile proposed in the Simplicity project is automatically collected by the system and the

279

adaptation is made automatically based on the information stored in the user profile. Another adaptation proposal based on self-adaptation is the AmbieSense project [14]. The AmbieSense adaptation platform has been designed to be used by travelers at the airport. The system collects the attributes of the current context of use of the users by using sensor tags, and the context-based information service is automatically pushed to the user terminal based on the predicted users' requirements at their current contexts of use and situations. The obvious problems of the adaptation approach used in the Simplicity and AmbieSense projects are the lack of control by the user and the lack of data protection or privacy. Since self-adaptation is driven by the computer without the user's decision, the outcome of the adaptation cannot be guaranteed to match the user's requirements and preferences in the current context of use.

The services based on self-adaptation will only succeed in a few, limited cases that are characterized by being very simple to describe in machine-understandable ways and relatively unchanging [15]. Even if a service can adapt itself perfectly to match the user expectations, it could be unacceptable for the user due to psychological reasons [16]. The user may feel that the service is untrustworthy , due to the lack of power over the service and the lack of understanding from situations where they feel out of control, unaware of what has happened or why, and this can lead to a negative user experience [17][18]. The Wireless World Research Forum (WWRF) has suggested that the user of the future mobile services should be able to control the service to the extend they want [19]. As the self-adaptation process lacks of the user control, it is not an appropriate approach to be used with the adaptation platform in this paper, which is designed to be used on the future wireless network.

The service adaptation platform proposed in this paper is based on the user-controlled self-adaptation, where the service adapts itself automatically based on the information defined by the user. While the self-adaptation is driven by the computer (i.e. artificial intelligence), the user-controlled self-adaptation is based on the user definitions, selections and control (i.e. natural intelligence). The service based on natural intelligence only works if it is easy to understand and the user knows how to define and control the service adaptation [15].

B. *Adaptation platform*

The context-based service adaptation for mobile location services in this paper is based on the principle that the user should always have full control of the service adaptation and the user should be able to decide whether he wants adaptation at all or at certain levels. In this paper, the control of the service adaptation by the user is made in the user profile, where the user defines, in the context-dependent user's requirements/preferences part, what he wants from the service, how he wants it and in which context surrounding and situation. Fig. 4 shows the conceptual platform for context-based service adaptation. This platform is placed at the server, of the service provider.

In fig. 4, the mapping unit checks whether the characteristics of the service (e.g. user interface, visualization) match the user requirements and preferences at his current context (e.g. wanting voice-based user interface while driving) included in the user profile subset, which is provided by the profiling management agent. In the case that the service's characteristics match with the requirements and preferences of the user in his current context, the service adaptation will not be activated. Also in the case that the user has not defined his context-dependent user requirements/preferences in the user profile or the user has only a default profile subset in the profile section of the related service; the service adaptation will not be activated. In the case that the service adaptation is not activated, the default version of the service will be delivered to the user.
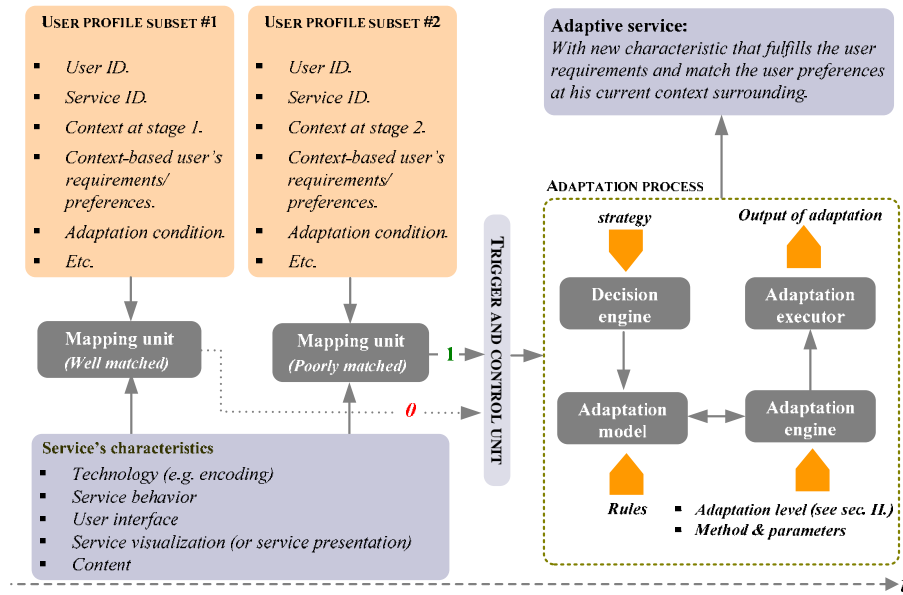
Fig. 4 Conceptual platform for context-based service adaptation for mobile location services. The user profile subset #1 and #2 are sent from the profiling management agent to the application and content server at stage 1 and 2 respectively. At stage 1, the characteristics of the service match the user's requirements/preferences in his current context and adaptation function will not be activated. At stage 2, the service is used in another context and situation and the characteristics of the service do not match the user requirements/preferences in the new context, and the adaptation is triggered at this stage.

If the context-dependent user requirements and preferences have been defined in the user profile and the characteristics of the service do not match what is defined in the user profile, the mapping unit will notify the trigger and control unit, which then starts the adaptation process. When an adaptation is triggered, the new context-dependent user requirements and preferences are transferred to the decision engine. The decision engine checks whether the adaptation is possible (i.e. whether the service has a capability to adapt itself to fulfill the context-dependent user requirements/preferences defined in the profile subset) by looking at the possible features provided by the service in comparison to the user's requirements/preferences maintained in the profile subset. If an adaptation is possible, the decision engine selects an appropriate adaptation strategy. Then the rules for service adaptation are selected from the adaptation model. The adaptation engine chooses the adaptation levels of the service (i.e. technology, task, user interface, presentation, or content levels) that will be adapted and selects the appropriate methods and parameters. The adaptation executor finally adapts the mobile location service by applying the chosen methods, parameter values and rules.

X. CONCLUSION

This paper presented a conceptual platform for context-based service adaptation which is designed to be used in the open service environment of the next generation wireless network. The main task of the platform is to adapt the characteristics (e.g. behavior, user interface, and visualization, content) to best fit with the user requirements and/or preferences in particular contexts of use. The adaptation platform applies user-controlled self-adaptation, in which the adaptation is made automatically by the system based on the user's definitions. The user controls the service adaptation by defining his context-dependent user requirements/preferences (e.g. task-dependent user requirements/preferences, social-dependent user requirements) and adaptation condition in the user's profile. Adapting the service to best fit with the user's requirements/preferences in his current context surrounding is one of the possible approaches for improving the user experience towards mobile location services.

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281

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Questionnaire

Section 1: Criticism, comments and suggestions for the concept of the service architecture presented in the paper entitled "Conceptual Service Architecture for Adaptive Mobile Location Services" (Questions 1-6).

1. The conceptual service architecture for adaptive mobile location services presented in the paper is designed based on the assumption that the next generation network is a unified IPv6 network and the service environment of the network is open. This assumption is made based on the global vision for the future wireless world from WWRF, the trend in next generation network provided by ITU, and based on relevant research works *(WWRF 2006; Chen et al. 2007; Kappler et al. 2007, Reynolds & Jin-Kyu 2004; ITU-T 2005; Chen & Yang 2007; WWRF 2006; Uusitalo 2006).* In the open service environment, the users will be able to access a mobile service from anywhere, at anytime, using any terminal model, via any available access network of any operator. Service providers and content providers will be able to provide their services and content independently from the types of network and the operators, and location information, user profile, billing and charging information will be transferable between different administrative domains, operators, and service providers. Both seamless roaming and universal access are important features of the next generation wireless network.

   Do you see any other trend in the next generation wireless network than the trends mentioned above? If yes, please mention these.

   Veijalainen: Different players have different interests. Openness is favored by terminal manufacturers and perhaps by customers, but not necessarily by the operators. The only revenue mobile operators would get if they are outside the service and contents business is fees for data and voice transmission.

   Ring: There will be a need to introduce CR/SDR (Cognitive Radio/Software Defined Radio in order to realize the functionalities of Seamless Mobility. These technologies will allow terminals automatically to request new operational parameters when roaming across networks. These parameters include operational frequencies as well as making it possible for the users to enjoy a maximum number of services and facilities as their home subscription contain. In fact CR/SDR will be a prerequisite for the effective realization of seamless service roaming. CR/SDR concepts have just been assigned to the agenda of the ITU-R World Radio Conference in 2011.

   Lauridsen: In some ways it is a dreams world with open architectures as every infrastructure vender will promote his own way of doing things. Also one

wireless operator does not want his competitors easily to be able to copy his services---so here we have a conflict!

2. Based on the service scenario presented in the paper, Sara shares her user profile (including her location information) with her father and her father is allowed to access any mobile location service using the information stored in Sara's user profile regardless of his own geographical location. What do you think the user will benefit from adding such a service option to mobile location services and what is required to realize such an idea?

   Veijalainen: Sharing this kind of information requires a lot of trust.

   Ring: There will be some ethical/emotional issues between adult users of such a sharing scenario. It will definitely be a requirement, that the party under surveillance clearly gets an indication, that surveillance is ongoing or has taken place. Of course the Farther-daughter scenario does not require such strict need.

3. The conceptual service architecture presented in the paper can support the provision of global-level mobile location services (e.g. tracking the location of a child when he is abroad, or safely-arrival notification when the child arrives at the airport, or accessing the information based on the location of other users on the network, e.g. finding a taxi using the location of a child presented in the scenario). Do you see the need for such services in the future mobile location services environment?

   Ring S: Because of globalization, there will surely be such a need in the future if the earlier mentioned ethical obstacles can be resolved together with standardization as earlier mentioned.

4. After having read the paper, have you seen any limitations or problems of the conceptual service architecture? If there are any limitations or problems please list them.

   No feedback from the experts.

5. Could you please provide any suggestions (if possible) of how to handle the abovementioned limitations and problems of the service architecture?

   No feedback from the experts.

6. Please provide other criticism, comments and suggestions regarding the conceptual service architecture presented in the paper.

Veijalainen: This is closely related with trust. You should have trust management in the profiling.

Lauridsen: I think the paper is very good. It gives a good argumentation for the need for open architectures. Then a personalized service can reuse personal profiles etc.

Section 2: Criticism, comments and suggestions for the concept of the adaptation platform presented in the paper entitled "Context-based service adaptation platform: Improving the user experience towards mobile location services" (Questions 7-13).

7. Several researchers are working on self-adaptation, where the service is adapted automatically based on the information (e.g. user's behavior, user preference, context history, location history) collected by the system. However, the adaptation platform presented in the paper relies on the user-controlled self-adaptation, in which the adaptation is made based on the user's definitions made in the user profile. Do you think if the self-adaptation or user-control self-adaptation will be more acceptable in the mobile world? And why?

   Ring: It is my observation in general, that the more straightforward it is to use/manipulate the functions/services, the more popular they will become amongst users. This is why Motorola has developed the concept of Seamless Mobility which requires ideally no specific interaction by the user, which moves seamlessly in and out of buildings, cars, trains, boats, aircrafts and across different network boundaries, both technology wise and ownership wise.

8. In the paper, the user profile is maintained by the profiling management agent and not by the service provider like today. Do you think if this way of handling the user profile will be acceptable by the service providers? And why?

   Veijalainen: This is business model issue. If the users are willing to pay, yes, other wise not.

   Ring: If in the future the operators/service providers become even more impacted by the anti-terror legislation than today, it might be a requirement to segregate the user profiles and manage them inside a public body, completely separate from the private sector.

9. Do you think if the user privacy concern will be minimized if the user profile is handled by a profiling management agent and not by a service provider?

   Veijalainen: I do not see a big difference in this. This is again a trust issue.

285

Ring: Yes, if this agent is operated by governmental agencies and not in a private enterprise, which can go bankrupt and/or sell this information to the highest bidder.

10. For the context-based service adaptation platform, the user will be able to define e.g. service behavior, user interface, visualization, language, etc. Do you think if the service providers will put an effort in to providing such adaptation options to the user? And why?

    Veijalainen: Depends on business model.

    Ring: Yes, but only if a healthy business case can be established.

    Lauridsen: All services are basically a question about sending specific billings to the users, the users real need normally happens to be the second or third choice.

11. To define the service adaptation, the user needs to define what they want, how and in which context. Do you think if the user will spend time setting these adaptation conditions or will the user rather choose the service that behaves as the user has expected without having to do any setting?

    Veijalainen: Only skilled users would do that. If the user does not see any immediate benefit in investing into these kinds of managerial activities, he/she does not want to invest the time needed. Even if the users were skilled enough to do it.

    Ring: An alternative will be to sell the user some preconfigured packages, like "the truck driver package", the "stockbroker package" etc, in order to make this much more easy.

12. Do you see any way of providing a service that match the user expectation without having definitions from the user?

    Veijalainen: Interesting question. Google tries this, based on the reactions of the user. Maybe, if the computers would be much faster, they could learn faster.

    Ring: Yes, see above.

13. Please provide other comments and suggestions to the conceptual platform for context-based service adaptation.

    Veijalainen: Good concept, no comment.

Lauridsen: This is a nice piece of introduction to database retrieval also based on context with adaptation on it. Basically it covers a little bit of artificial intelligence, which I think is needed as services else wise become too difficult to use!

Section 3: General opinion regarding the next generation wireless network (Question 14-20).

14. Recent developments in mobile and wireless technologies as well as standardizations indicate that the next generation wireless network is evolving towards the all-IPv6 network. Do you think the all-IPv6 network will ever be realized?

    Veijalainen: Maybe, maybe not. This is again a business issue, but also a deeper issue. The work on the next generation Internet has begun and it is evident that many basic principles should be changed. IPv4 and IPv6 are based on the same basic philosophy and it is not clear whether this philosophy will survive.

15. How long time do you think it will take to realize the all-IPv6 network?

    No feedback from the experts.

16. What requirements do you think are needed in order to realize the all-IPv6 network?

    No feedback from the experts.

17. Based on documents published by e.g. ITU-T and WWRF, the service environment of the next generation wireless network is envisioned to be open (as mentioned in question 1). Mobile terminals and networks will be multi-mode, operating at different frequencies and using a variety of wireless access technologies.

    Do you think the concept of open service environment can be realized?

    Veijalainen: This depends on the policies of the big players and also on the regulation issues. It seems now that big global manufacturers like Nokia are entering the service and contents business.

    Ring: Yes, but standardization within the CR/SDR area will have to take place.

18. What do you think are the requirements in order to realize the open service environment?

    Veijalainen: Primarily this is business, standardization, and regulatory issue. Technically I do not see big problems, except scalability.

19. Based on the concept of the open service environment, it will be possible for different stakeholders to share network resources and information resources (e.g. location information and user profile).

    What do you think is required in order to be able to share such resources and what are the benefits of doing so?

    Veijalainen: see above.

20. Please provide other comments regarding the next generation wireless network.

    Veijalainen: Wireless networks are certainly here to stay (unless they turn out to be too dangerous in some respects, cancer etc.). But they will always be only access networks; one also needs the heavy-duty global backbone. Who will pay for these and in which way is a big question.