Investigation of an intelligent personalised service recommendation system in an IMS based cellular mobile network

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INVESTIGATION OF AN INTELLIGENT PERSONALISED SERVICE RECOMMENDATION SYSTEM IN AN IMS BASED CELLULAR MOBILE NETWORK

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Abstract

Success or failure of future information and communication services in general and mobile communications in particular is greatly dependent on the level of personalisations they can offer. While the provision of anytime, anywhere, anyhow services has been the focus of wireless telecommunications in recent years, personalisation however has gained more and more attention as the unique selling point of mobile devices. Smart phones should be intelligent enough to match user's unique needs and preferences to provide a truly personalised service tailored for the individual user.

In the first part of this thesis, the importance and role of personalisation in future mobile networks is studied. This is followed, by an agent based futuristic user scenario that addresses the provision of rich data services independent of location. Scenario analysis identifies the requirements and challenges to be solved for the realisation of a personalised service. An architecture based on IP Multimedia Subsystem is proposed for mobility and to provide service continuity whilst roaming between two different access standards. Another aspect of personalisation, which is user preference modelling, is investigated in the context of service selection in a multi 3rd party service provider environment. A model is proposed for the automatic acquisition of user preferences to assist in service selection decision-making. User preferences are modelled based on a two-level Bayesian Metanetwork. Personal agents incorporating the proposed model provide answers to preference related queries such as cost, QoS and service provider reputation. This allows users to have their preferences considered automatically.

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List of Abbreviations

ACK	Acknowledgement
ACL	Agent Communications Language
AS	Application Server
BS	Base Station
BU	Binding Update
CBQ	Class Based Queuing
CDMA	Code Division Multiple Access
CN	Corresponding Node
Diffserv	Differentiated Services
FER	Frame Error Rate
FIPA	Foundation for Intelligent Physical Agents
GGSN	Gateway GPRS Support node
GoS	Grade of Service
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
HA	Home Agent
I-CSCF	Interrogating-Call/Session Control Function
IETF	Internet Engineering Task Force
IM	Instant Messaging
IMS	IP Multimedia Subsystem
IP	Internet Protocol
MIME	Multipurpose Internet Mail Extension
MIP	Mobile IP
MIDP	Mobile Information Device Profile
MMD	Multimedia Domain
MN	Mobile Node
MSRP	Message Session Relay Protocol
MTU	Maximum Transmit Unit
NAT	Network Address Translator
OMA	Open Mobile Alliance
PA	Presence Agent
P-CSCF	Proxy-Call Session Control Function
PDP	Policy Decision Point
PoC	Push-to-Talk over Cellular
PRACK	Provisional Acknowledgement
PS	Presence Server
PTT	Push-to-Talk
PUA	Presence User Agent
QoS	Quality of Service
RAN	Radio Access Network
RLS	Resource List Server
RPID	Rich Presence Information Data Format
S-CSCF	Serving- Call/Session Control Function
SCTP	Stream Control Transmission Protocol
SDP	Session Description Protocol
SGSN	Serving GPRS Support node

SIP	Session Initiation Protocol
SMS	Short Messaging Service
TCP	Transmission Control Protocol
TRU	Transmit/Receive Unit
UA	User Agent
UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunications System
URI	Uniform Resource Identifier
UTRAN	Umts Terrestrial Radio Access Network
VoIP	Voice over IP
WLMSI	Wireless LAN Mobile Subscriber Identity

CHAPTER 1

INTRODUCTION

1.1 Research Overview

The monolithic business model of Cellular Mobile Networks has changed from a Closed Walled business model to a Semi Wall Gardened business model to accommodate the convergence of wireless networks with Internet and take advantage of better, faster, more innovative and easily deployable services. At the heart of this concept lies the IP Multimedia Subsystem (IMS), which allows different access technologies to connect to the same IP core. The IMS is an emerging reference architecture which is evolving through several standard groups, research labs, vendors and carriers with the basic purpose to provide horizontal functional layers which would allow efficient and cost effective service deployment on an open IP-based infrastructure that supports both wireline and wireless networks on a common platform and to multiple access networks [1]. Success or failure of future information and communication services in general and mobile communication in particular is greatly dependent on the level of personalisation they provide [2]. One of the disadvantages of the converged networks form the mobile operators point of view is for them to become a mere bit pipe and in order to avoid such a situation they have to tap into historical data and behavioral pattern of their subscribers.

Personalisation is “the ability to customise each individual user’s experience of electronic content” [3] by tailoring the information and services to the context, which consists of parameters such as user location, user preferences and network and terminal capabilities. Web personalisation is the most mature form of personalisation, which stemmed from the need to overcome information overload. The emergence of converged mobile networks and the consequent availability of tens of thousands of services provided by third party service providers globally has lead to introduction of many new value-added services as we are already witnessing the emergence of new application stores by various mobile operators, therefore we can safely claim that service personalisation is a necessity to overcome service overload for users of Next Generation Networks (NGN).

Another strong reason is the strong link between personalisation and mobile communications that has its roots in the nature of mobile device which is truly personal. The importance of personalisation has been referred to in the activities of many standardisation groups such as World Wide Web Consortium (W3C), 3rd Generation Partnership Project (3GPP) [4]. The age of personalisation in telecommunications started with the customisation of ring tones. The variety of applications of personalisation in telecommunications however is far more complex than simple customisation of ring tones. Realisation of personalised services for mobile users spans over several major fields such as mobile communications, computer science, mobile and wireless networks, user modeling, artificial intelligence, machine learning, intelligent agents, trust and privacy issues, data and web mining are some of the research areas related to personalisation of mobile services as depicted in figure 1.1.

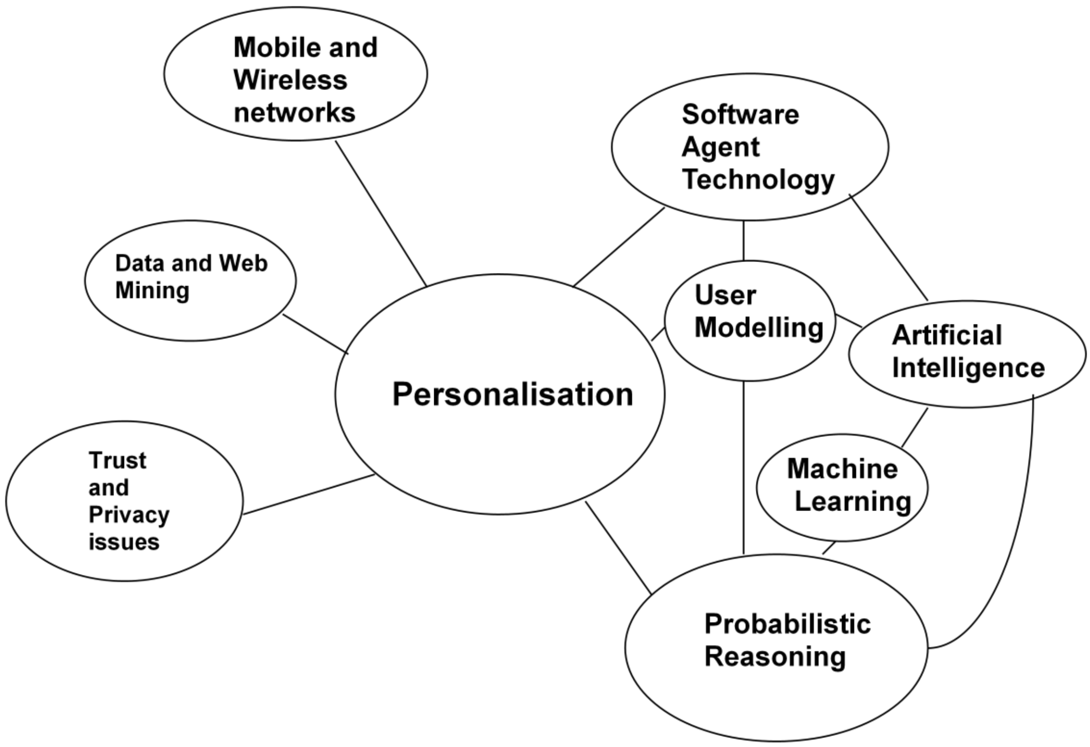

Figure 1-1: Personalisation interdisciplinary area of research

Personalised systems require user-profiling technologies such as machine learning techniques, intelligent agents and probabilistic reasoning in addition to context modelling technologies such as presence and location technologies. Software agents have been applied in many personalisation systems as the enabling technology for user modelling. Machine learning techniques are also applied in the personalisation domain for acquisition and modelling of user's interest and preferences.

Because of uncertain nature of user’s behaviour, probabilistic techniques such as Bayesian networks have been used in personalisation research projects. Privacy issues play an important role in the design and development of any personalised system including personalised mobile services. Privacy issues can be considered as the major obstacle on the way towards any personalisation system including personalised mobile services.

Different applications of personalisation can be classified in the four generations of web personalisation, e-commerce, mobile services and personalisation of home environment in assistive living. In the first generation of personalisation applications the main focus is the filtering of information to obtain a more relevant result. The second generation is personalisation (customisation) of e-commerce web sites. The third generation of applications are personalisation systems for mobile users in wireless environments. The fourth generation is personalisation of inhabitant-environment interactions. While other personalisation applications enhance the way people obtain information in the virtual world, fourth generation applications customise aspects of the physical world.

- Concept

The third generation of personalisation applications is the focus of study in this thesis. Personalisation applications that adapt the wireless services to mobile user’s preferences and needs can be classified into two categories. One category that consists of most of the personalisation applications in wireless environment, which attempt to adapt first and second generations of applications to the special requirements and limitations of mobile devices in wireless environment. Very few personalised mobile applications, on the other hand, tackle new personalised challenges raised specifically in wireless environment and for mobile users. Personalisation of mobile web applications is an example of the first category, where as personalisation of service selection in multiple service environment is an example of the second group of personalisations. In this study the issue related to the second group of applications, which is user preference modeling in service selection is studied. In the following sections this issue is explained in more detail after explaining a futuristic scenario as the motivation of this research.

- Challenges

Personalisation challenges can be categorised into two main categories:

- User and context modelling
- Content adaptation

The personalisation process consists of modelling the user and context and then adapting the electronic content to the user and context. Modelling context and user involves information gathering and modelling techniques. In order to customise services to individuals, a description of user's preferences is required. This information, namely the user profile, is used to adapt the performance of a system appropriately to user needs by predicting the future choices of the user. Adaptation has been as "change in the system to accommodate change in the environment". The personalisations challenges main categories are depicted in the figure 1.2 below.

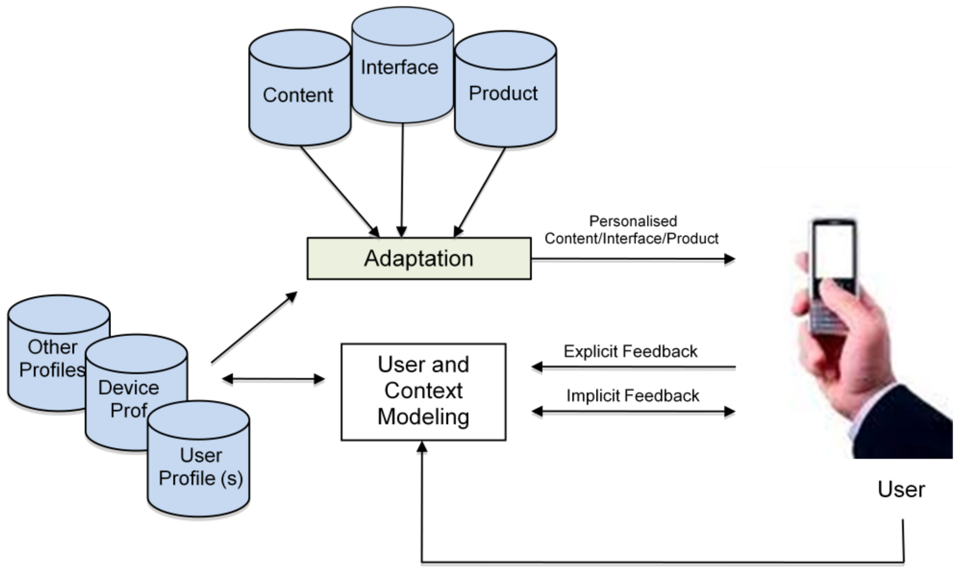

Figure 1-2: Challenges in Personalisation

1.1.1 Problem Statement and State-of-the-Art

In the converging world of mobile communications, broadcasting and computing, which promise the provision of information at any time, any place and in any form, the end-user and improvement of his/her experience is of great importance particularly in a user centric approach. Use case scenarios help to determine and specify issues related to possible future user needs and wishes independently of present technical or economical constraints. They can identify the elements and players involved and the issues to be solved. In this top-down approach we start from user requirements and end up with detailed technical requirements and flows of services and money [5].

This thesis is based on Mobile Multimedia scenario as the motivation and starting point of the research. The scenario involves a businessman who receives assistance from a number of personal agents in order to perform his business tasks and to achieve his leisure interests. The scenario starts from the user's home. The user asks his Residential Personal Assistant (RPA) to deliver world top news. While he moves from one room to another in the house, the RPA detects his movements and transfers the data to devices in the new location. The scenario continues in the user's car where he exchanges data with his friend. The user's Personal Mobile Assistant (PMA) is responsible for personalized assistance after he has left home to go to his office. The third part of the scenario is in user's office where his personal Office Assistant (OA) assists him in performing his work related tasks such as collecting information about a meeting in advance. Analysis of the above scenario resulted in identification of research issues related to the research reported in this report. Agent technology has gained momentum in telecommunications as it is seen as an important enhancement of distributed object technology, a software agent is a self-contained program capable of controlling its own decision-making and acting based on its perception of its environment in pursuit of one or more objectives. Software agents are a particular case in a more comprehensive area of Distributed Artificial Intelligence (DAI). Both technologies offer advantages in different aspects, which only collectively provide the necessary flexibility for the development of applications within an emerging open telecommunications service environment. Some of the benefits that can be derived from the distributed computing nature of agent technology and future telecommunications systems include system modularity, speed, which is a natural outcome of the parallelism and distributed nature Personal assistant agents, which play the main role in the Mobile Multimedia scenario, are discussed in the next section.

1.1.2 Enabling Technologies

In 1994 Pattie Maes introduced the idea of agents that reduce work and information overload [6]. This suggested, personal assistants that collaborate with the user in different ways and in virtually unlimited tasks and applications by hiding the complexity of difficult tasks, performing tasks on behalf of the user, teaching the user and/or monitoring events and procedures. Personal assistant agents have the potential to provide assistance for users in acquiring information, analysing and displaying results, deciding on an action or sequence and also implementing actions decided [7].

Since the introduction of personal agents they have been applied in applications such as email and call management, negotiations for e-commerce, information filtering, personal travel assistance and meeting scheduling. In the first generation of personal assistants the dominant applications, however have been for information retrieval and filtering in the web.

In recent years another generation of applications for personal assistants has emerged as the consequence of the increased number of mobile applications and services. Personal agents specifically designed to assist mobile users, have the potential to fulfil the huge demand of personalised mobile services. This generation of personal assistants are capable of providing new type of service requested in wireless environments. Electric Elves [8], My Campus [9], AbIMa [10], Cool Agent [11] and EasiShop [12] are some examples of personal agents providing assistance for mobile users.

Software agent technology is the enabling technology for the realisation of personal assistants. In the context of this thesis, software agents are viewed as "anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators" as defined by Russel and Norvig in [13]. Personal assistant agents are one of the three main applications of agent-based systems but application of software agents in personalisation is not limited to personal assistants. They have been applied as the enabling technology in a variety of personalisation applications such as information filtering [14], recommender systems [15] and personal service environment [16].

1.1.3 Research Objectives

In this thesis the service selection problem has been studied from an end user point of view. User preferences for services vary from one individual to another. Users, depending on their circumstances have different preferences for the service provider, cost and QoS. They have different cost affordability and might prefer one operator to another based on their past experiences. More importantly each user has a different preference in different contexts. For a user on a business trip cost is not an important factor in comparison to the quality of service but in leisure context the opposite might be true. Therefore user preferences can change according to the time of the day or situation or location they are in and for a non-technical user to decide on an optimal service is a difficult decision to make however, a personal software agent located at the user terminal can manage this task. The agent assists the user in making a decision when selecting a service according to the user's preferences and experiences. In this work, the objectives include design and development of a model for automatic acquisition of user preferences, proposing an IMS based network architecture for a personalised seamless service delivery and service continuation. Furthermore the preference differences between different contexts must be considered in this model.

1.2 Research Contributions

As discussed earlier this project is an attempt in the direction of providing a solution to overcome the problem of service overload of future mobile communications networks.

The main contributions of this work can be summarised as the following:

- Proposing a novel system level architecture providing seamless mobility between WLAN and 3G networks, by introducing WLMSI (Wireless LAN Mobile Subscriber Identity)
- Proposing a novel approach for modelling user preferences for choosing a service from a service provider in terms of acceptable level of quality of service, affordable cost and service provider's reputation.

In order to optimise the performance and accuracy of the system an emulator has been developed and the following steps have been performed:

- Analysis of a futuristic user scenario, Mobile Multimedia Scenario, in order to identify requirements and key technical challenges for the realisation of the scenario.
- Quantitative performance analysis of the user scenario for evaluation accuracy of the proposed model by a simulator specifically designed and implemented to test the proposed model.

1.2 Thesis Outline

This thesis is organised in six chapters. The personalisation problem in general and in mobile telecommunications in particular is studied in chapter two. In this chapter personalisation origins definition and categorisation through personal assistant agent technology and research issues associated with it such as user modeling and software agent technology are also discussed in this chapter.

A futuristic telecommunication scenario, in which personal assistant agents assist a businessman, Mobile Multimedia scenario, has been studied in chapter three to identify the requirements of such system for further research. The analysis and design of the scenario based on an agent oriented software engineering methodology, Gaia, are described. Scenario implementation in form of an emulator in an agent oriented framework, JADE-LEAP, is also described in this chapter. Scenario analysis and design result in identification of the main technical requirements to be met for the realisation of the Mobile Multimedia scenario.

In chapter four, the performance of the personal agent in Mobile Multimedia scenario is studied. Analytical results as well as experimental results are presented when applying the agent emulator described in chapter three.

In chapter five, the service selection problem in the future multiple service environment is investigated from a new perspective that of the users. The service selection problem and the criteria to be considered in are explored in this chapter. A novel model is proposed for automatic acquisition of user preferences. Features and structures of the model, which is based on a Bayesian Metanetwork, are discussed in detail. The algorithm of the simulator to evaluate the accuracy of the proposed model is also described in chapter 5. Furthermore, the results of the evaluation including the learning curve, evolution of network parameters during the learning process and the impact of preference change on the network are reported in this chapter. Finally in chapter six, a summary of the research carried out is provided and scope for future work is discussed.

CHAPTER 2

PERSONALISATION IN TELECOMMUNICATIONS

2.1 Introduction

The concept of personalisation may still be seen by most as tied to mobile services, the understanding is being developed, that within the context of Next Generation Networks (NGN) a renewed approach to fixed-mobile convergence is being proposed and this is ever more true for services. Seamlessness is a concept that starts from the user perception of services. “Being able to use services while roaming over different networks, taking advantage of the specific network capabilities, while perceiving continuity with respect to service fruition, naturally embeds the concept of service personalisation” [17]. In this chapter the origins, definition and categorisation of personalisation, as well as challenges faced, are studied.

2.2 Personalisation Definitions and Categorisation

Personalisation can be defined as “the ability to customise each user’s experience of electronic content” [18]. Kim defines personalisation as “delivering to a group of individuals relevant information that is retrieved, transformed and deduced from information sources” [19]. In personalisation, information about a user is applied in order to design products and services better by tailoring them to the user [20]. A user by this definition could be a customer, a website visitor, an individual, or a group. Information related to a user could be in any information context such as user preferences, user location, device capabilities and the network.

Personalisation can be achieved from two different aspects one is from the user point of view where the purpose is to provide the user with more relevant information tailored for that specific user. The second one is in the business context of supporting one to one marketing, both in conventional and electronic commerce, where marketing is tailored to a group of individual customers among the entire population of customers. In the majority of studies related to personalisation, when personalisation is referred to, they implicitly mean personalisation in information filtering or e-commerce as described above, “Who personalises” and “what is personalised” are two other important factors of personalisation. “Who personalises” defines the degree of autonomy offered to the end user. In explicit personalisation the user is actively and knowingly involved in personalisation, where as in implicit personalisation the user is not aware of the underlying profiling activities taking place. Another perspective in which personalisation can be studied is based on “What is personalised”? namely content or interface [18]. In content personalisation, information or links to the information are personalised, where as in interface personalisation the appearance of the content on the screen is personalised. Figure 2-1 summarises this categorisation.

Implicit	Interface configured by Computer	Content configured by Computer
Explicit	Interface configured by User	User configured content Customisation
	Interface	Content

Figure 2-1 A framework for personalised information system [18]

In some studies such as [4], the distinction between implicit and explicit personalisation is considered as the difference between personalisation and customisation respectively. According to [20], personalisation and customisation notions have differences in an aspect which is who performs the personalisation, either the system or the user. The user does customisation manually and the system is almost passive. The user enters his/her preferences and requirements to configure a website a product or a service. My yahoo is an example of customisation.

The user selects which modules (portfolios, news, weather, etc) are to be shown on the screen. The personalisation notion as opposed to customisation is applied according to [4], when the system automatically personalises a service or product based on the history of previous interactions with the user. Amazon is an example in which the system recommends items to a user and personalises the content of web page based on the user’s past history of purchases and navigations. Most studies however appear to use personalisation and customisation interchangeably, without considering the above distinction. We also use the personalisation term in the broader context, either the user has the control or the system.

2.2.1 Four Generations of Personalisations

Due to a huge success of mobile telecommunications in supporting a variety of devices in a multi access networks, personalisation has been used in a broader context, including mobile applications. Having studied a variety of personalisations applications, four different generations of personalisation applications are observed.

- Web personalisation
- E-commerce
- Mobile services
- Personalisation in physical space

In the first generation, the main focus was to filter irrelevant information, mainly web information. The CiteSeer digital library system [21] is an example of this type of application. CiteSeer filters scientific publications on the web according to a user's research interest and keeps users up to date on relevant research. The second generation is mainly personalisation of e-commerce websites such as Amazon.com. Personalisation of e-commerce website varies from a simple greeting message incorporating the end user's name, to more specialised interactions such as complex catalogue navigation and product customisation applying deeply complicated models. The personalisation consortium [22], which is an international advocacy group formed to promote the development and use of personalisation technology on the web, defines personalisation as follows, "Personalisation is the combined use of technology and customer information to tailor electronic commerce interactions between a business and each individual customer". This definition apparently defines the second generation of personalisation applications in our categorisation. Recommendation systems in which relevant products or services are recommended to the end user based on some user characteristics or past behaviour are in this category of personalisation applications. Amazon.com and Travelcity.com are examples of second-generation applications.

The third generation attempts to adapt first and second generations of applications to the special requirements and limitations of mobile devices in wireless environment. There is also some new personalisation challenges raised specifically in wireless environments and for mobile users. For instance personalisation of radio access selection is a new personalisation challenge specific to mobile users.

Fourth generation as, as McCarthy [23] defines, is personalisation of inhabitant environment interactions. While other personalisation applications enhance the way people obtain information in the virtual world, he suggests customisation aspects of the physical world. MusicFx is an example of such applications. MusicFx is an intelligent system installed in a fitness system that chooses music based on the preferences of the people currently in the fitness centre. This categorisation is not necessarily chronological and there might be overlaps between each generation and others. The third generation of personalisation applications is the focus of study in this thesis, and is introduced in more details in the next section.

2.2.2 Different Approaches to Web Personalisation

There are different ways to personalise internet websites, namely content, control link, screen design and anthropomorphic personalisation [18].

- Content personalisation

Content personalisation is the most common form of personalisation [18]. Cognitive and collaborative filtering are two approaches for content personalisation for websites [21]. In cognitive filtering systems or content–based filtering documents are filtered based on their content. In collaborative filtering or social systems, documents are filtered based on recommendation and annotations of the users. Both approaches, however, provide content personalisation.

- Control personalisation

Control personalisation is a meta-level form of personalisation and is about how much control is given to the user. Wu et.al.[18] define control, in this context, as "the ability to interrupt, modify, continue and/or terminate a process once it has been started".

- Link personalisation

Link personalisation selects additional relevant links, and reduces or improves the paths to the related web pages. For instance "favourites" in Internet Explorer are explicit link personalisation. Automatic link generation techniques such as Dynamic Hyper Link Engine [6] are examples of link personalisations, which are implicit.

- Customised screen design personalisation

Customised screen design personalisation is about personalising the user interface of the websites. Some websites provide the facilities for the users to customise both the look and the feel of the website. For example users of the Travelcity.com have the option to see a fare watcher for their favourite cities on the screen.

- Anthropomorphic personalisation

In anthropomorphic personalisation, the system is created in a way that acts like a human. Simple greeting messages, which are shown to the user at logins is an example of anthropomorphic personalisation.

2.2.3 Existing Web Personalisation Technologies

Since web personalisation is the most mature form of personalisation, we list existing technologies for web personalisation [18].

- Cookies

Cookies are small piece of information that web servers store on a client's local machine. Cookies are created and stored on the first visit of a web site and can be used for the purpose of personalisation in follow-up visits. Cookies can be considered as the most basic technology for web personalisation.

- Profile-based personalisation

The simplest way of profile-based personalisation is to save the information a user fills in forms to avoid re-entering them every time user visits the web site. User profiles stored by websites can also be applied to adapt services to users' preferences.

- Personal tool

Users of some websites, such as E*TRADE (etrade.com), can configure their own personal tools in order to access the pages they are interested in. users of E*TRADE can configure a personal tool to trace the stock market prices they are interested in. unlike the profile-based personalisation, personal tools are created by the user and not by the system.

- Opportunistic links

Opportunistic links personalise a user's experience of a website by observing the user's online activities and automatically offering related links. For example purchasing a flight ticket may results in links to hotels and car hire websites, which use an opportunistic, links method to advertise links related to user's purchase history.

- Recommender systems

"Recommender systems provide personalised recommendations based on user's preferences [18]". Collaborative and content filtering are the two-personalisation technologies for realisation of web recommender systems. Collaborative filtering techniques are based on the assumption that people with similar interests have similar purchase behaviour. Therefore the profiles of the current users are matched with the profiles of past users with similar interests in order to provide similar recommendations. In content filtering, on the other hand, recommendations are based on the relevance of the content to a user's interest. [24] studied different recommender systems in e-commerce such as Moviefinder, Amazon and Levis. GroupMark is an example of a recommender system that combines collaborative and information filtering for recommending websites [25]. Although the above distinction is specifically for the websites personalisations, it can be considered as the basis for any other personalisation applications.

2.3 Personalisation in Telecommunications

As mobile telecommunications applications grow in diversity and quality, research issues such as personalisation, which were already known in a desktop computing context, gain more importance and also face new challenges in the mobile environment. Personalisation has a special importance in the mobile telecommunications business because mobile devices are truly personal devices unlike desktop computers. The importance of personalisation has been referred to in the activities of many standardisation groups such as W3C [26], 3GPP [27] OMA, OSGi, OSA/Parlay and Liberty Alliance. Technologies in the Multimedia Scenario Work area are depicted in figure 2.2

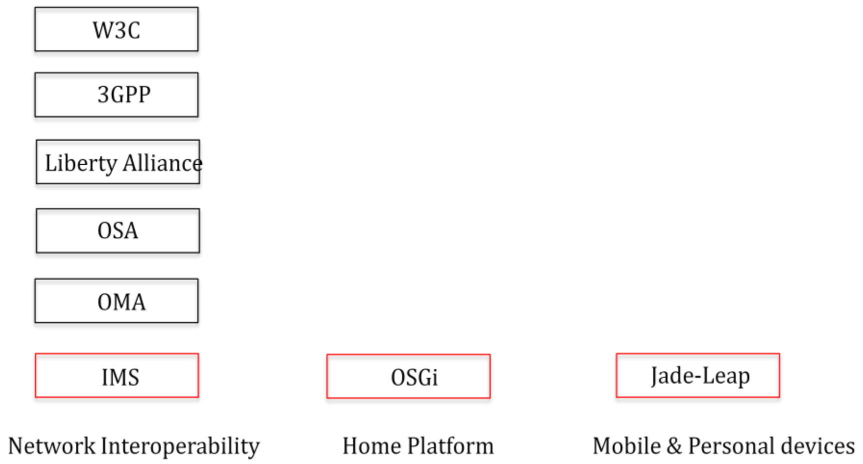

Figure 2.2: Multimedia Scenario, related technologies

2.3.1 W3C and OMA

The W3C [26] seems to be the oldest standardisation effort for the personalisation. It has developed a protocol standard called the Composite Capability/Preference Profile (CC/PP). This protocol is used by Open Mobile Alliance (OMA) [28], formerly known as the WAP Forum, to make a User Agent Profile (UAProf) to describe and transmit Capability and Preference Information (CPI) about the client, user and network to solve the personalisation problem in a changing environment W3C started a activity called the Device Independence Activity Working Group (DIWG) that replaced the CC/PP working group and the work of this group was later taken over by the Ubiquitous Web Applications Activity. A CC/PP profile consists of number of components such as hardware and software platforms. Each component is described as a sub tree and consists of CC/PP attributes, which describes client capabilities and preferences. The main goal of designing CC/PP and UAProf was to improve communications between user devices and web servers by providing device independent access to web resources. These standards however, can be considered as enablers for personal user profiling at the service level [26].

In direct relation to personalisation is the work of the Browsing and Content working group and the Mobile Web Services of Open Mobile Alliance (OMA). OMA offers the possibility of accessing network resources for easy use both internally and to third parties. The Mobile Instant Messaging and Presence Services (IMPS) specification of OMA-Wireless Village enables exchanging messages and presence information between mobile devices, mobile services and internet-based instant messaging services. This specification provides a solution for the interoperability problem and also exchange of personalised information such as online status and user id.

2.3.2 3GPP/Virtual Home Environment

The 3rd Generation Partnership Project (3GPP) view about service personalisation is based on two main concepts of Personal Service Environment (PSE) and Virtual Home Environment (VHE) central to this concept is the concept of Generic User Profile (GUP) which is presented as a solution to the problem of defining a flexible and extensible user profile. The 3GPP GUP is the collection of User-related data, which affects the way in which an individual user experiences services where a community of entities shares this data. GUP provides a generic mechanism to access and manipulate user related data.

3GPP's Virtual Home Environment (VHE) is an example of a personalisation-enabling infrastructure and seems to be among the first efforts towards personalisation of mobile services. 3GPP defines VHE as "a concept for Persona Service Environment (PSE) portability across network boundaries and between terminals [27]". The goal of VHE is to present users with the same personalised features, user interface customisation and services in any network, in all kind of terminals and wherever the user is located. Personal Service Environment in this definition contains personalised information in the form of one or more user profiles in order to personalise provision and personalisation of subscribed services towards the user. User communications preferences, terminal interface preferences and other important parameters of the user are stored as user profiles in either the mobile terminal or the core network to be used to tailor services and interface to user's location, network and terminal type. The user's PSE is provided and controlled by Home environment (HE). Home environment ensures user's access in the PSE. In addition to that, when the user moves from one network domain to another, Home Environment is responsible for providing identical services provided by HE-VASps (Home Environment – Value Added Service Providers). Home Environment manages one or more user profiles.

Presence and Availability Management (PAM) API of the Open Services Access (OSA) group in participation with 3GPP (Third Generation Partnership) and Parlay group provides the following types of information for service personalisation, Identities, Agent information for providing communication capabilities, Agent provisioning, Presence information, Availability information which consists of preferences associated with identities and Notification of changes to the above information and Security issues. The OSA/Parlay APIs allow third party applications to be hosted within a telecom operator's own network and allow applications running on external application servers to offer their services to the operator's subscriber via a secure gateway.

2.3.3 Liberty Alliance

Liberty Alliance is another open standard organisation for federated network identity management and identity based services with its main objective being single sign on that includes decentralised authentication and authorisation from multiple providers. Liberty Alliance defines identity as the distinguishing character or personality of an individual consisting of traits, attributes and preferences upon which one may receive personalised services. The relationship of the individual with an entity determines, which elements of the identity is shared and hence the concept of federated networks. The advantage of single sign on across all the applications enables users to manage the sharing of their personal information across identity and service providers as well as the use of personalised services in order to allow access to convergent services.

2.3.4 IP Multimedia Subsystem (IMS)

Fixed Telecommunications networks are evolving from their Public Switched Telephone Network (PSTN) roots to Next Generation Network based on an all Internet Protocol (IP) structure. Similarly, the foundations have already being laid for a similar transformation in the mobile space with the IP Multimedia Subsystem (IMS). IMS architecture separates the service layer from the network layer, facilitating interoperability between 3G/4G mobile networks and fixed networks such as PSTN and the Internet, the separation of control plane and bearer plane with an IP core network makes it easy to interwork with different access networks such as UTRAN, WLAN 3GPP, 3G LTE Evolved RAN, Femtocells and non-3GPP IP Access (WiMAX). IMS is radically different from earlier communications systems in that it allows multiple services to be carried on a single bearer channel. Session Initiation Protocol (SIP) is used within the 3GPP defined IMS system for multimedia call control and it has also been adopted by 3GPP2, allowing harmonisation of SIP at the services level. Users and their preferences become central and not the individual service networks, applications become the services users invoke.

2.3.5 Open Services Gateway Initiative (OSGi)

The OSGi specification framework can be used in many ways but it is mainly intended to serve as a federating gateway in a heterogeneous network environment, with a bundle for each different network interface, which can interconnect the various networks of the modern home (Ethernet, WiFi, Bluetooth, ADSL...), this software specification can be embedded and run on a services gateway, which could be a Set Top Box, a Cable/DSL modem, PC or a dedicated residential gateway. OSGi is well suited for operator controlled home based systems (entertainment or health monitoring systems) to support personalisation.

A comparison of the available technologies are summarised in table 2-1:

Technologies	Multimedia/Content adaptation	Location Services	Virtual Home Environment	CC/PP & UAProfile	XML/Web Services	3rd party Services Integration	Not sharing User Profile	Implementation
3GPP			X			X		No commercial implementation of Generic User Profile
W3C				X	X			Apache Foundation for parsing of CC/PP
OSGI	X					X		Limited capability implemented by china telecom
Liberty Alliance		X			X			AOL, HP, NTT, Ericson, Nokia Vodafone,
OMA/ Wireless Village		X		X	X			MessageVine, Nokia, Motorola, Insignia & others
OSA/Parlay X		X				X		Commercial platforms available
IMS	X	X		X	X	X	X	Commercial platforms available

Table 2-1: Comparison of different technologies in relation to personalisation

As we can observe from the comparison table above there has been many attempts in providing personalised services by developing software APIs to be Operating System and programming language independent and to hide complex often proprietary communication network's protocols but the answer seems to come from IMS platform which is an all IP protocol and integrates deep in the core network of Telecom operators.

2.3.6 Dimensions of Personalisation in Telecommunications

MacCarthy [23] argues that personalisation can be realised in several dimensions as follows:

- Different sources of content
- Arrangement of content on the screen
- Delivery mechanism
- Delivery vehicle

The first and second dimensions, content sources and arrangements are not specific to mobile applications but must be adapted from desktop computing systems to the specific requirements of mobile wireless devices. The delivery mechanism of McCarthy's categorisation, refers to "push" and "pull" delivery mechanisms. Similar to the first and second dimensions, this aspect of personalisation is not new to telecommunications and must also be adapted from fixed line to devices to mobile terminals. However, because of the important role of context-aware services in mobile telecommunications such as location based services, this dimension of personalisation has a special importance in mobile communications. The fourth dimension of personalisation in McCarthy's classification is delivery vehicles. This dimension of personalisation is specifically important in the telecommunications domain because of the variety of mobile devices.

In addition to the above dimensions, we envisage other dimensions of personalisation in telecommunications domain, especially in an all IP network where there is an abundant number of services. Some of these new dimensions are listed below,

- Variety of devices
- Variety of Users (individuals)
- Variety of access standards
- Variety of services
- Variety of service providers

As the mobile device supports more and more functions in addition to voice such as, camera, TV, video, email, picture messaging and web browsing there is a strong demand to make the human-device interactions more concise, useful and acceptable in terms of reducing user interventions.

Nowadays common devices are capable and are expected to support several access technologies such as, GSM, WLAN, Wi-Fi, 3G, UMTS, WCDMA, GPRS and HSDPA. There are thousands of service providers competing to provide services more intelligently and taking into account user's preferences and applications context. Users as different individuals have different needs, interests, preferences and behaviour, which service providers have to cater for to attract subscribers. Another characteristic of wireless networks is that they are supposed to support a variety of contexts for mobile users. As life is getting more and more complex, people play different roles in their daily activities. A businessman at work, a parent or sports person or, a musician at home while, they carry the same communication device, all the time, their mobile phones. User preferences and expected services in each of these "roles" or "contexts" are different and the services in next generation networks are characterised by the provision of the user preferences in each context. Different definitions of context have been given but in a broader term context information is any piece of information that characterises the situation of an entity in a system. The context of the user, in this definition might consist of their preferences, history and location. Context is a very fluid subject and can be interpreted and applied in a variety of meanings. In this thesis we use this term in the broader meaning as explained above.

2.4 Requirements of Personalisation

In web filtering applications, which can be considered as the first examples of personalised services, four requirements must be met:

- A representation of a web page
- A representation of the user's interest
- A function to determine the pertinence of a web page given a user's interests
- A function returning an updated user profile given the user's feedback on a page

These are the requirements of any cognitive or content-based filtering systems, as opposed to social filtering systems [29]. Personalisation in telecommunications, however, is a much more complex problem. Many technical and non-technical challenges exist for personalisation in wireless environments and for mobile users. Some of them are, user profiling, device profiling, personalised service discovery, distributed profile management, context-awareness, location awareness, service adaptation to device capabilities, preference elicitation and access selection personalisation. Some of these issues have already been addressed in research projects and some are either new research challenges or have new requirements in the telecommunications domain.

Personalisation challenges can be categorised into two main categories:

1. User and context modelling
2. Content adaptation

The personalisation process consists of modelling the user and context and then adapting the electronic content to the user and context. Modelling context and user involves information gathering and modelling techniques. In order to customise services to individuals, a description of user's preferences is required. This information, namely the user profile, is used to adapt the performance of a system appropriately to user needs by predicting the future choices of the user. Fouial et al. [30] defined adaptation as "change in the system to accommodate change in the environment". According to this definition a system S is adaptable to the environment, if it changes to S´ as the environment changes from E to E´. In this way S becomes S´ and it meets the needs of the new environment E´. Adaptation can be summarised as a function as below:

$$E \times E' \times S \rightarrow S' \text{ where meet } (S', \text{need } (E')) \qquad 2.1$$

2.5 User Modelling

User model is an explicit representation of the properties of an individual or group of users. Sometimes, user modelling "involves inferring unobservable information about a user from observable information about him/her such as his/her actions or utterances [31]". The first user modelling studies can be traced back to 1978 in [32]. Early user modelling systems had been applying hand-crafted knowledge bases to obtain inferences, but more recent ones are based on machine learning methods such as statistical modelling [33]. User modelling is an interdisciplinary area of research and spans a number of fields including artificial intelligence, education, psychology, linguistics, human-computer interaction and information science. User models are constructed and then applied by a system to adapt performance of the system.

In user profiling the assumption is that user behaviour is not completely unpredictable and in the long term is somehow correlated to the user's performance in the past. User profiles are not static and can be changed in many dimensions. For example user preferences may change for different budget limitations, or a mobile user's resources may change when roaming from one cell to another in a cellular network. Gathering these kind of information and more importantly keeping them up-to-date with the changing needs and context of the user is a crucial issue.

The user profile may consist of several pieces of personal information such as user needs, preferences, history, and behaviour as well as location, technical specifications and ambient conditions, or even business rules that apply the information is stored without adding further description. This includes types and preferable settings of services used daily, which are more steady, as well as those that are more temporary such as preferable settings and requirements of occasionally used services, or even more abstract information such as user personality and behaviours. Generally speaking, any information that characterises the user, the device, the infrastructure the context, and the content involved in a service request, in order to help to receive a more relevant response to a request, is called a user profile. However, information that is stored in a user profile is usually application dependent and varies from one application to the other [34]. The information needed to make a user profile is usually distributed and different entities manage distinct parts of the user profile, while some entities need to access the whole user profile. For instance, the network operator provides user location and personal data by the user [35]. Producing a user profile capable of predicting the user's future actions require a very large time corresponding to a very large training set. Besides, user wishes are usually incomplete, inaccurate and even contradictory, and it is difficult to interpret them into a set of precise rules suitable to be used in personalisation.

Depending on the content and the amount of information that is stored in the user profile, user can be modelled, user profile is used to retrieve the necessary information to construct a model of the user in another word a user model is the representation of the system's belief about the user. User models can be constructed by machine learning techniques. User behaviour is observed to form training samples, which subsequently are learned by the system [36]. Three types of machine learning techniques are usually distinguished, supervised, unsupervised and reinforcement learning. In a Supervised learning a function is learnt based on a number of inputs and outputs. Unsupervised learning problems deal with learning patterns in the input while no specific output values are provided. Reinforcement learning systems learn from reinforcement or rewards, without being told what to do by a teacher. As, can be seen in the above distinction, the nature of the learning problem is defined by the type of feedback provided to the system [37]. However in many real world problems, prevalence of uncertainty affects the learning and reasoning procedure and demands different types of learning and reasoning algorithms. In the area of user modelling, we are facing an uncertain domain, therefore user modelling falls within this category of learning problems. Eric Horvitz, the user-modeling expert in Microsoft, stated, "uncertainty is ubiquitous in attempts to recognise an agent's goals from observations of behaviour" [38]. The main statistical learning methods are explained below.

2.5.1 Different Approaches of Machine Learning Techniques

There are different methods that can be applied for constructing a user model, a learner model utilises machine learning methods by means of increasing accuracy and increasing efficiency. This section describes some of the main machine learning methods such as rule/tree learning method and probabilistic learning methods.

- Neural networks

A neural network is a network consisting of neurons or nodes connected by directed links that can be used to perform nonlinear statistical modelling. Each node is capable of a simple calculation that is a function of activations of connecting nodes. The complex processing capability of neural networks comes from the structure of the network, non-linear thresholds and inter-node connection strengths, or weights. Weights are obtained by a process of adaptation to, or learning from, a set of training patterns. Neural networks are used in [39] to model user preferences for news articles.

Neural Networks offer a number of advantages, including requiring less formal statistical training, ability to implicitly detect complex nonlinear relationships between dependent variables, ability to detect all possible interactions between predictor variables, and the availability of multiple training algorithms. Disadvantages include greater computational burden, empirical nature of model development, difficult to understand, may suffer from over fitting.

- Rule induction/Trees

Rule induction predicts the class of an observation by learning a set of rules, rule induction is a supervised learning technique and needs the class of each observation in the training set as well as its attributes.[28] creates rules that predict a user’s next action. In rule induction, a rule quality measure can be used as a criterion in the rule specification and/or generalisation process. Decision trees form the core of the learning and classifying process in most rule induction algorithms.

Classification methods such as Decision Trees classify a set of objects into distinctive classes based on the characteristics of the objects in other word maps data into predefined groups or classes. Since there is no a priori assignment between objects and classes, classification is considered as a supervised learning method. Each node in a decision tree represents a feature in an instance to be classified and each branch represents a value that the node can assume. Instances are classified starting at the root node and sorted based on their featured values. Advantages of decision trees include, transparency, as the mathematical structure of the trees is quite straightforward and the result could easily be deciphered by following the rules. And they are simple to relate to graphically. Disadvantage of rule induction is when using unordered rule sets, conflicts can arise between the rules i.e. two or more rules cover the same example but predict different classes. Decision trees can be significantly more complex representation for some concepts due to the replication problem.

- Bayesian networks

Bayesian networks “have steadily gained popularity in Artificial Intelligence (AI) community [40]. Russell and Norvig [41] consider the Bayesian view of learning as “extremely powerful”. A Bayesian network consists of a directed acyclic graph (DAG) with a set of variables and conditional probability tables associated with each variable [42]. Bayesian networks have several advantages over other approaches, they are able to predict more than variable, they represent causal relationships and they are the only approach in which “persistence of interest” is not a working assumption. Persistence of interest means that behaviour and interest of the user do not change over time. Bayesian networks have been applied in many user modelling applications such as Microsoft’s Lumiere project [43] and Sto(ry)chastics [44].

Advantages of Bayesian Networks are handling incomplete data, observed knowledge can be used to determine the validity of the acyclic graph that represents the Bayesian network they facilitate use of prior knowledge. The main disadvantage of Bayesian networks is the requirement of an expert to provide domain information for creation of the network. A summary of the performance comparison of these classifiers is presented in figure 2-2, the best performance is rated as four stars and the least performance as one star.

Classifiers	Neural Network	Decision Tree	Rule Induction	Bayesian Network
Accuracy in general	***	**	**	**
Speed of learning with respect to attributes and number of instances	*	***	**	****
Speed of classification	****	****	****	****
Tolerance of missing values	*	***	**	****
Tolerance of irrelevant attributes	*	***	**	***
Tolerance to redundant attributes	**	**	**	**
Dealing with discreet/binary/continuous attributes	***(not discreet)	****	***(not directly continuous)	***(not continuous)
Tolerance to noise	**	**	*	***
Dealing with danger of overfitting	*	**	**	***
Attempts for incremental learning	***	**	*	***
Explanation ability/transparency of knowledge/calssification	*	****	****	****
Model parameter handling	*	***	***	****

Table 2-2; comparison of Learning Algorithms

Regardless of the modelling technique applied for machine learning, there are some challenges specifically related with machine learning for user modelling. Some of these challenges were pointed out by Webb et.al. [45] as follows:

- The need for large data set

Most learning algorithms cannot reach a level of acceptable accuracy, unless they have a large number of training samples. Some learning algorithms start from an initial model as the basis for their modeling. Some learning algorithms can be fairly accurate if new examples are similar to the training samples. In some systems the structure of the task itself is re-organised in a way that predictions are not expected to be very accurate. In this way a less accurate model can be built by a smaller number of training samples.

- The need for labelled data

Supervised machine learning approaches need labelled data or training data, in a classification/regression problem, a sample from the data source with the correct classification/regression results (class labels) already assigned is called training data, but it is not always easy to assign a label to data. For instance assigning labels of "interesting" and "not interesting" to web pages from user behaviour is not a trivial task. Many machine learning approaches solve this problem by requiring explicit feedback from the end users.

- Concept drift

Concept drift refers to the problem of dynamicity of user interests. One way to tackle this problem is to place less weight on older observations. Another way is to have dual models of users. The first model is a short-term model, based on more recent observations and if this model is not capable of answering queries the second model which incorporates a long term view is applied.

- Computational complexity

Computational complexity refers to personalisation problems. For instance automatically acquired user model for millions of users visiting internet website every day, show the computational complexity faced in web personalisation.

2.6 Software Agents as an Enabling Technology for Personalisation

Software agent technology has been applied as enabling technology in a number of personalisation applications. Some of these applications are, information filtering [46], recommender systems [47], shopping assistants [48] and Personal service environments [49]. Implementation of personalisation requires intelligent software technology that enables representation of the personal needs and preferences of the user. In the following sections first we define what an agent is and then the role of software agents as personal assistants is studied.

2.6.1 Agent Characteristics

The definition of software agent varies in different key papers and books. Russell and Norvig [27] provide a basic definition of an agent as “anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators”, as shown in Figure 2-6.

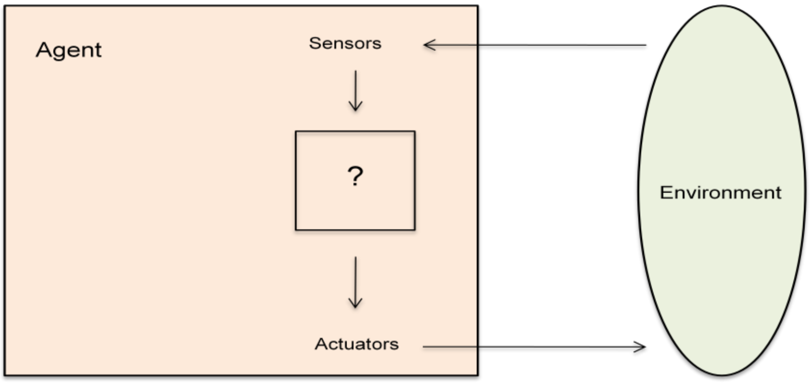

Figure 2-6: Agents interact with environment through sensors and actuators [40]

Russell and Norvig, then define rational agents based on the general definition of agents, as agents that act in a way “to achieve the best outcome or, when there is uncertainty, the best expected outcome [50]”. Rational agents select an action in each step that maximises the performance measure of the agent based on the agent’s built-in knowledge and the evidence provided by the percept sequence. A percept sequence is comprised of the complete history of everything an agent has perceived so far. Some agents select actions based only on the current percept, ignoring the percept history. These agents are called simple reflex agents. Another type of agent is called a model-based reflex agent, because it uses an internal model of the world to solve the partial observability of the environment. Goal based agents aim to fulfil a goal. Utility based agents use utility functions in order to choose a better sequence of actions to achieve the defined goal [51].

Wooldridge et.al [52], on the other hand, defines agents as “a computer system capable of flexible, autonomous action in some environment”, in which flexible means reactive, pro-active and social. An agent is considered reactive, if it interacts with the environment and shows responses to the changes in the environment in reasonable response times. Pro-activity means that the agent is capable of taking initiatives in order to achieve goals in addition to reacting to events. A social agent can communicate with other agents by an agent communication language in order to cooperate in performing a task [53]. The level of independence of the initial knowledge determines autonomy of an agent. An autonomous agent "learns as much as it can to compensate for partial or incorrect prior knowledge. Although agents need some initial knowledge for practicality reasons, autonomous agents can learn from experiences and after a sufficient number of experiences the agent becomes effectively independent of the prior knowledge" [53]. There are some other characteristics of agents, which are not intrinsic to their definition and are discussed in some applications. Mobility, which is the ability of the agent to move from one host to another, is one of these characteristics.

2.6.2 Personal Assistant Agents

The idea of agents that reduce work and information overload was first introduced in 1994 by Pattie Maes [49]. It was suggested that the personal assistant metaphor to replace the dominant interaction metaphor, which was called direct manipulation. In the direct manipulation metaphor the user initiates all tasks explicitly and monitors all events. On the other hand, in the personal assistant metaphor, an assistant agent collaborates with the user in different ways and in virtually unlimited tasks and applications by hiding the complexity of difficult tasks, performing tasks on behalf of the user, teaching the user and/or monitoring events and procedures. Email/call management, negotiation for e-commerce, information filtering and personal travel assistance are among the many potential applications of personal assistant agents. Maes suggested developing assistance agents that "watch over the shoulder of the user" and collaborate with the user at the interface level of a work environment such as spreadsheets or operating systems. Nwana [54] calls Mae's suggestion the strong hypothesis of personal agents. He argues that, in reality however, the strong hypothesis has been gradually replaced by the weak hypothesis. In the weak hypothesis, personal assistant agents have initial profiles of the users instead of "watching over the shoulder of the user" and their work environment is restricted to the web.

Since Maes's publication, personal assistant agents have been applied in many applications and for a variety of purposes. They can provide assistance in acquiring information, analysing and displaying results, deciding on an action or sequence of actions and also implementing actions decided. The dominant application of personal assistants, however, has been information retrieval and filtering in the web. Web agents, recommender agents and interface agents, as named in different articles, would all fall within this category of personal assistant agents.

Syskill and Webert [55], personal WebWacher [56], Recommender Agent [57], Letizia [58], and IntelliShopper [59] are some examples of these types of agents. There have also been other applications such as email prioritising, news filtering [60] and calendar management [61]. Syskill and Webert [55] assists users in distinguishing interesting web pages on a particular topic from uninteresting ones. Users provide feedback regarding their interests on a web page, and then the system learns user's interests and can suggest further web pages that might interest the user. The learning algorithm in Syskill and Webert is a supervised learning algorithm, therefore it needs positive as well as negative training samples. The prediction of interestingness of a web page is shown in the form of the probability that the user would like the page. This probability is calculated based on a naïve Bayesian classifier. Personal WebWatcher [56] is a personal browsing assistant that suggests interesting hyperlinks on the requested web documents. Personal WebWatcher models user's interests by machine learning techniques. Remembrance Agent is a program that assists users by unobtrusively showing relevant documents to the user's current context. The main aim of Remembrance Agent is to augment human memory. The user has the choice to ignore or follow the RA's suggestions. Letizia is a user interface agent that provides web browsing assistance for Internet users. Letizia's agent observes user's web browsing behaviour to infer user's interests. IntelliShopper [54] observes user's shopping habits, learns and models user's shopping preferences and then monitors vendors' websites to find items matching user's preferences.

In recent years, with the success of mobile telecommunications, another generation of applications for personal agents has emerged. Personal assistant agents specifically designed to assist mobile users have the potential to fulfil the huge demand of personalised mobile services. Electric Elves, MyCampus, AbIMa, CoolAgent, and EasiShop are examples of personal agents providing assistance for mobile users. Electric Elves is a system that provides assistance for users within an organisation in tasks such as rescheduling meetings, selecting presenters for meetings, tracking people's locations and organising lunch meetings. MyCampus is a semantic web environment for context-aware mobile services. Agents in MyCampus can access user's personal resources such as user's calendar and food preferences. AbIMa is an assistant agent that provides assistance for mobile users prior to and after execution of their tasks. This project studies challenges related to the use of cognitive agent architecture for intelligent mobile user support. EasiShop is a system for delivering cross merchant product comparison shopping for the mobile user. CoolAgent is to implement personal assistance for mobile professionals.

CoolAgent defines personal assistants as “the nexus of context-based, personalised me-centric computing”. The personal assistant in CoolAgent is a set of agents working together and they can run on different devices including mobile terminals.

Third generation of personal assistant agents, which serve mobile users are the subject of this study. Research issues related to this generation of personal assistant agents can be classified in to subcategories. The first category deals with the services and applications that have already been assigned to assistant agents in fixed networks such as information retrieval and filtering. These types of services and applications may need to be adapted to specific characteristics of mobile devices. The second category identifies and addresses new issues raised for personal assistants of mobile users in wireless environments. Most of the research projects reported in the literature are covered by the first subcategory of research issues. They attempt to adapt first and second generations of personal assistant agents, namely filtering and e-commerce agents, to the special characteristic of mobile devices. But very few research projects have actually studied issues specifically related to assistance of mobile users in wireless domain.

2.7 Chapter Summary

In this chapter a review of different aspects of personalisation was studied and Web personalisation as the most mature form of personalisation was examined in more details. In particular different approaches to web personalisation as well as existing personalisation web techniques were explored. Based on different personalisation applications developed to date Four generations of personalisation applications were identified. Mobile communications service personalisations requirements and related challenges were presented and the role of software agents’ technology as the most commonly used paradigm in telecommunications as a whole and as a solution in Multimedia scenario was discussed.

CHAPTER 3

SOFTWARE ARCHITECTURE AND SCENARIO ANALYSIS

3.1 Introduction

A scenario is a vehicle for developing alternative views of the future. Scenarios have been applied as the starting point of many research projects in the telecommunications industry recently. The research reported in this thesis is inspired by the Mobile Multimedia scenario as defined in the Mobile VCE and the views adopted by ePerSpace research project as a picture of potential future. Analysis of futuristic scenarios provides an insight into the requirements and technical challenges that lie on the path of realisation of future scenarios. Scenario analysis is also a powerful tool to identify possible future research areas and consequently research projects, which ultimately result in progress in the telecommunications industry as can be seen in the last few years.

In this chapter, the role of scenarios in telecom research is defined. Then the futuristic scenario, Mobile Multimedia scenario is explained. Then we analyse this scenario by applying an agent-oriented software engineering methodology in order to identify the requirements of the scenario. Then we study an IMS (IP Multimedia Subsystem) system level architecture (SLA) which supports the Multi Media scenario infrastructure and in particular proposing the provision of seamless mobility by introduction of WLMSI (Wireless LAN Mobile Subscriber Identity).

3.2 Scenario Based Research Strategy

Scenarios have been recognised as a tool for strategic planning by Herman Kahn since 1960s [62]. A scenario is "a thinking tool for helping us to take a long view in the world of uncertainty" [63]. Futuristic scenarios, which are about freedom and choices for both future and present, have been playing a particularly important role in the progress of the telecommunications industry in recent years. Many European research projects such as Brain, Scout and ePerSpace are based on futuristic scenarios. The Mobile Multimedia scenario is about the provision of rich data services independent of location. This scenario is fully presented in the next section.

3.3 The Mobile Multimedia Scenario

In this section the Mobile Multimedia scenario is introduced as an example of a futuristic telecommunications scenario:

"Wednesday, September 1st 2020, 6.15 am, wake-up call from the Residential Personal Assistant (RPA). Before John gets up, he asks the RPA to display the latest technology figures from the Tokyo stock market highlighting M'tech industry value and also to deliver world and top news (both political and main economical indicators) via the audio system and on a small part of the screen. Whilst walking to the bathroom the RPA detects John's movement and transfers both video and audio display through the hall to the display in the bathroom. Having the news update and the latest developments about technology stocks (share prices, movements, tendencies etc), John starts having breakfast and requests (using the voice recognition in the RPA) a video call to the hotel room of his fiancée. After finishing his breakfast he makes his way to meet Paul. Since the call has not yet finished the call is transferred to his personal mobile assistant (PMA), the PMA then assumes the best quality mode for the transferred voice and video call and resizes the image to fit the 4 inch screen. When John reaches his work and enters his office his PMA registers him and invokes his workspace {Personalised Workspace (PW) to start up and to update business related data between office workspace and PMA}.

3.4 Scenario Analysis and Design

In this section, in order to identify the key requirements and main issues involved in the Mobile Multimedia scenario, the scenario, definition has been extended, by applying an agent oriented software engineering methodology. Agent-oriented software engineering methodologies are designed specifically for analysis and design of multi-agent systems in an engineered approach [64]. Some software engineering methodologies for Multi Agent Systems (MAS) are based on an extension of object oriented methodologies and techniques. Agent modelling technique for systems of BDI (Belief, Desire, Intention) agents, MASB (Multi-Agent Scenario-Based) method [65] and MaSE (Multi Agent System Engineering) [66], are examples of such methodologies. The similarity of agents and objects in many aspects and the popularity of object-oriented methodologies, are among the reasons that justify the extension of object-oriented methodologies as an agent oriented methodology. However, there are dissimilarities between agents and objects. Agents are more complicated than objects, social dimension of agents are not modelled in object-oriented methodologies. Another example is that message passing between agents consists of complex negotiation of protocols rather than simple message passing between objects. Therefore object oriented methodologies fail to model all aspects required in agent-oriented software.

Another category of agent oriented software engineering methodologies is an extension of knowledge engineering methodologies. These methodologies can provide a good basis for modelling knowledge of the agents, however their disadvantages are that they cannot model the distributed or social aspects of the agents in addition to their reflective and goal oriented attitudes. CoMoMAS and MAS-CommonKADS are examples of these methodologies [66]. Some agent-oriented methodologies make use of formal languages for multi agent specifications such as DESIRE. The other main category of agent oriented software engineering methodologies model multi agent systems based on an organisation-oriented point of view. In this view multi-agents systems are conceived as organisations or societies. Gaia [67] and Mase extension [68] are among the methodologies that adopt an organisation-oriented point of view.

In this study the Gaia methodology has been chosen for the analysis and design phase. Gaia has been specifically tailored to the analysis and design of agent-based systems. Gaia allows for a systematic design from statement of requirements that is detailed enough for direct implementation. Gaia is both general and comprehensive. It is general because it can be applied to a wide range of applications and it is comprehensive because both macro level (societal) and micro level (agent) aspects of the system are considered in Gaia [67].

The Gaia analysis phase intends to identify roles and protocols in the system in order to develop an understanding of the system and its structure. Roles and protocols construct role model and interaction model respectively. The role model defines the roles to be played in the system. Protocols in the interaction model define the interaction between the roles. Analysis steps in Gaia are defined as follows:

1. Create the role model. The role model is a list of the key roles in the system. Describe each role in an informal descriptive language. A role could be an individual within an organisation department or an organisation itself.
2. Create the interaction model. The interaction model is a list of all potential interactions, protocols that could occur between roles.
3. Elaborate the complete role model and interaction model and repeat steps one and two if required.

The Gaia analysis phase provides fully elaborated role and interaction models as input to the design phase. The design phase attempts to associate roles to classes of agents and protocols to services provided by agents. Gaia suggests the following steps in the design phase:

1. Create the agent model. This defines agent types and numbers of their instances at run-time. Each agent type consists of one or more agent roles.
2. Create the service model. This is a list of services that agents provide. Services defined for each agent fulfil roles assigned to the agent by protocols and activities.
3. Create the acquaintance model. This identifies communication links between agent types. Repeat step 1, 2 and 3 if required.

The output of the design phase is the actual organisation of an agent system that can be implemented by traditional object oriented programming. In the next sections, Gaia analysis and design phases in relation to Multi Media scenario will be explained in more details. In section 3.4.1 and 3.4.2, the role model and the interaction model of the scenario can be found. Sections 3.4.3, 3.4.4 and 3.4.5 describe the agent model, service model and acquaintance model respectively.

3.4.1 The Role Model

In Gaia each role is composed of four attributes: responsibilities, permissions, activities and protocols. The key attribute of each role is Responsibilities which, defines functionalities, of a role in two forms, liveness and safety responsibilities. Wooldridge [8] describes liveliness as responsibilities that ensure “something good happens” and safety as responsibilities that ensure “nothing bad happens”. A role also needs a set of permissions in order to realise its responsibilities. Permissions define the resources available to the role and the rights for accessing those resources. Protocols define the interaction between the role and other roles. Activities on the other hand define the computations a role performs without any interactions with other roles [68]. Four roles are identified in the application layer of the Mobile Multimedia scenario: User, User Handler, Personalised Information Retriever and Location Detector. This is the minimum number of roles but other roles can be added. Roles schemas are as follows:

Role Schema: **User**
Description: Individual requiring a service
Protocols and Activities: Give query, GivePersonalInformation, GiveFeedback
Permissions: generates UserDetails //owner of user information UserQuery // owner of user query
Responsibilities Liveness: User = (GivQuery.GivePersonalInformation | GiveFeedback) Safety: True

Figure 3-1 User role

User role represents the user in the scenario. User handler on the other hand deals with all interactions with the user.

Role Schema: **User Handler (UH)**
Description: Receives request from the user and oversees process to ensure appropriate service is delivered. Adapts multimedia content to the user terminal.
Protocols and Activities: RecievePersonalInformation, PassUserDetails, RecieveQuery, RequestService,DeliverService, PrepareInformation, CollectUserFeedback,
Permissions reads supplied UserQuery //what user wants supplied UserDetails //user personal information filteredInformation generates FinalService
Responsibilities Liveness: UserHandler = AwaitPersonalInfo | (AwaitQuery.PassUserDetails.RequestService. PrepareInformation.DeliverService. AskorCollectUserFeedback). Safety: True

Figure 3-2: User Handler role

Personalised information retriever is responsible to gather and filter information and also to perform user profile-related tasks. Role schema associated with this role is depicted in figure 3-3:

Role Schema: **Personalised Information Retriever (PIR)**
Description: Responsible for information gathering, document scoring, information filtering, user profile construction and adaptation.
Protocols and Activities: ProduceUserProfile, AdaptUserProfile, SearchQuery, FilterandReturnInformation. RecieveUserFeedback
Permissions: read supplied UserQuery supplied UserDetails generate UserProfile PrimaryService FilteredInformation read UserFeedback change UserProfile
Responsibilities Liveness: PIR = ProduceUserProfile. (SearchQuery.FilterandReturnInformation.GetUserFeedback. AdaptUserProfile.AwaitUserFeedback) Safety: True

Figure 3-3: Personal Information retriever role

Location detector role deals with the user's location.

Role Schema: **Location Detector (LD)**
Description: Detects user location.
Protocols and Activities: ReportUserLocation
Permissions: Read userlocation
Responsibilities Liveness: LD = ReportUserLocation) Safety: True

Figure 3-4: Location Detector role

3.4.2 Interaction Model

The interaction model in Gaia represents the interplay and dependencies between roles in a multi-agent organisation. The interaction model is central capture how the system functions. The interaction model is composed of a list of protocol definitions. Each protocol is defined by six attributes: purpose, initiator, responder, inputs, outputs and processing. Figure 3-5 represents a template for protocol definition.

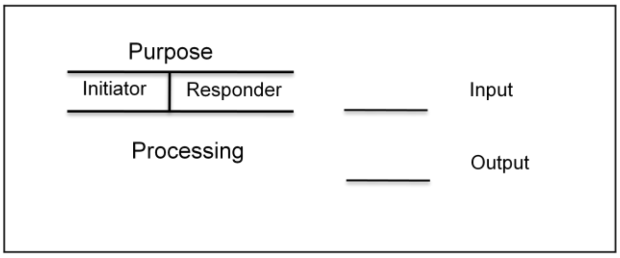

Figure 3-5: Protocol definition template

Protocol definition for each role in the Mobile Multimedia scenario is presented based on the protocol template depicted in 3-5. Protocols associated with User Role are depicted in figure 3-6.

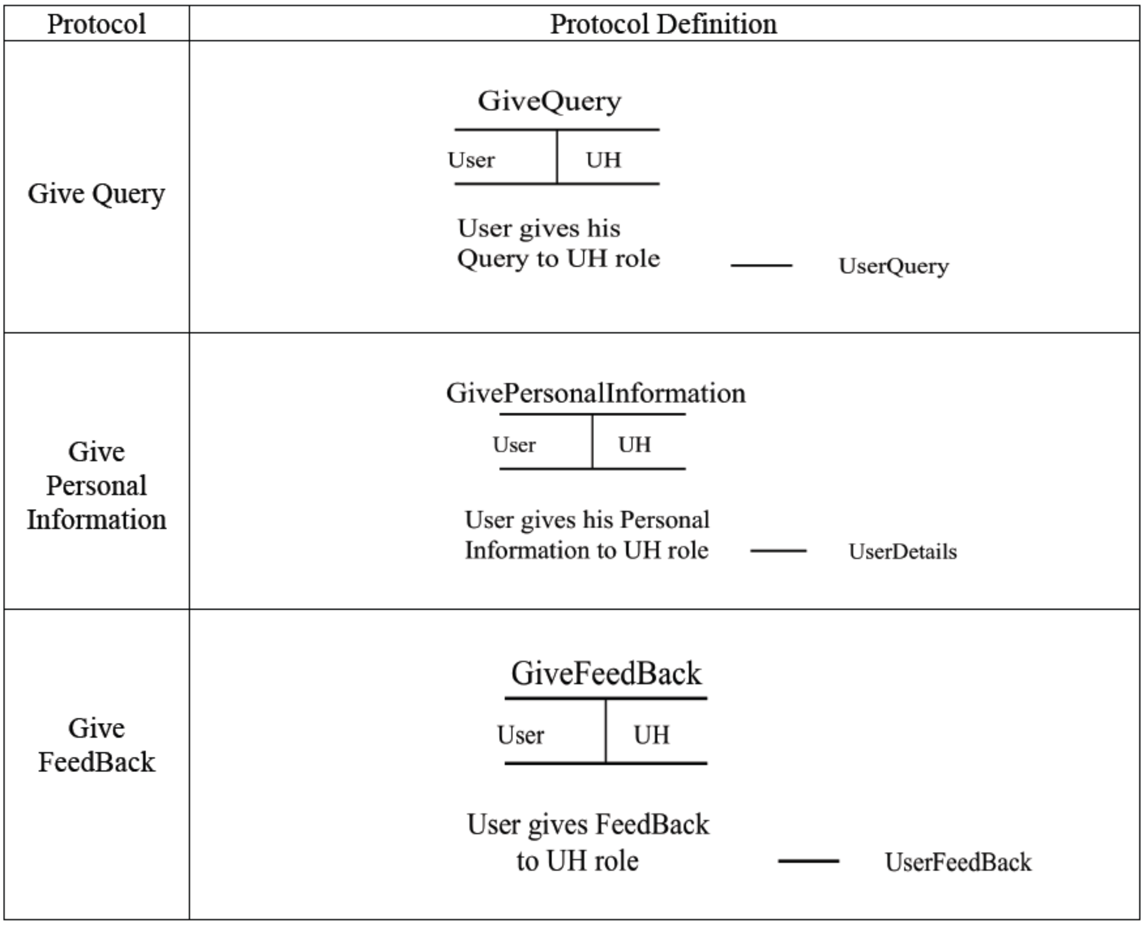

Figure 3-6: protocols associated with User Role

Protocol	Protocol Definition
Receive Personal Information	ReceivePersonalInfo User | UH Receive Personal information from the User — UserDetails
Receive Query	ReceiveQuery User | UH Receive User Query — UserQuery
Request Service	RequestService UH | PIR — UserQuery Send User Query to PIR — FilteredInformation
Pass User Details	PassUserDetails UH | PIR — UserDetails Pass User Details to PIR For User Profile Construction — UserProfile
Deliver Service	DeliverServive UH | User — FinalService Deliver final Service to the User
Prepare Information	DeliverServive UH | User — FinalService Deliver final Service to the User
Collect User Feedback	DeliverServive UH | User — FinalService Deliver final Service to the User

Figure 3-7: Protocols associated with user Handler role

Protocols associated with Personal Information Retriever role are depicted in figure below:

Protocol	Protocol Definition
Produce User Profile	ProduceUserProfile PIR | UH — UserDetails Produce User Profile according to User Details — UserProfile
Adapt User Profile	AdaptUserProfile PIR | UH — UserFeedback, UserProfile Adapts UserProfile to user Feedback — UserProfile
Search Query	SearchQuery UH | PIR — UserQuery Search for User Query — PrimaryResult
Filter and Return Information	FilterandReturnInformation PIR | UH — PrimaryResult, UserProfile Filter search result according to user profile — FinalResult
Receive User Feedback from UH	ReceiveUserFeedbackfromUH UH | PIR Receive user feedback from UH — UserFeedback

Figure 3-8: Protocols associated with Personal Information Retriever role

Finally protocols related to the Location Detector role are presented in Figure 3-9

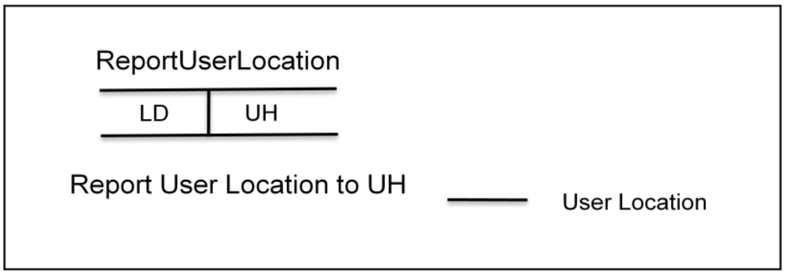

Figure 3-9: Protocols associated with Location Detector role

3.4.3 Agent Model

The Gaia agent model defines agent types in the multi-agent system and their hierarchy. It assigns one or more agent roles to an agent type. The agent model also defines the number of instances when each agent type is realised during the run time [68]. The agent model of the Mobile multimedia scenario is shown in figure 3-10

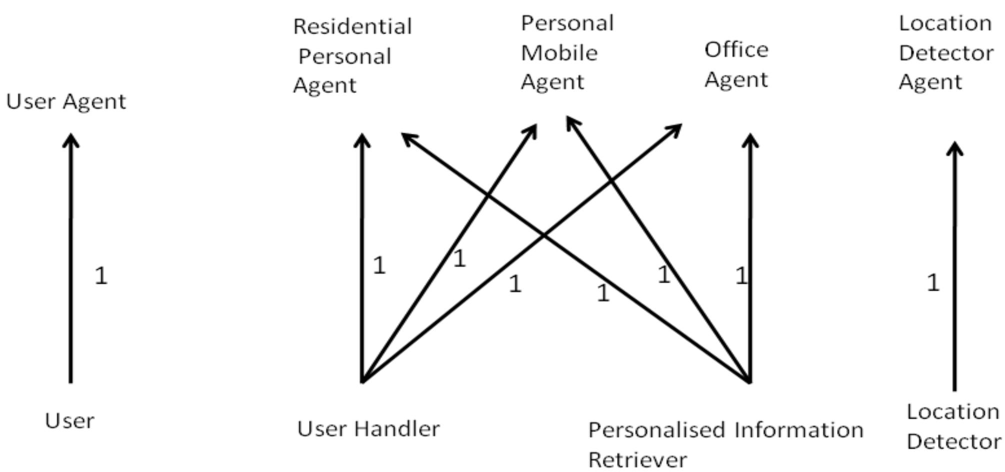

Figure 3-10 Agent Model

3.4.4 Service Model

A user entity requests services by using different physical devices and service selection and delivery to this entity is the main goal of the system. In the Multimedia scenario five entities have been identified. A residential Personal Assistant (RPA) manages all input/output devices in the user's home. An office assistant (OA) manages user's requests when the user is in the office. A Personal Mobile Assistant (PMA) serves the user when he is outdoors. Each user has a unique Personal Mobile Assistant. Each PMA manages its user request according to user's preferences. A Location Detector (LD) detects user location.

The service model identifies services each role needs in order to satisfy its responsibilities. It also identifies the main properties of each service. Each service defines a function of the agent. Input, output, pre-conditions and post-conditions specifically need to be identified for each service [68]. Table 3-1 describes the service model of the Mobile Multimedia scenario.

Service	Inputs	Outputs	Pre-conditions	Post-conditions
GiveQuery	---	user query	------	query<> nil
GivePersonalInfo	---	user details	------	user details <> nil
GiveFeedback	---	user feedback	------	user feedback <> nil
ReceiveQuery	---	user query	user query <> nil	user query <> nil
ReceivePersonalInfo	---	user details	user detail <> nil	user details <> nil
PassUserDetails.....		user details	user detail<> nil	user details <> nil
RequestService	user query	final service	user query <> nil	final service <> nil
DeliverService	final service	---	final service <> nil	---
PrepareInformation	filtered information	final service	filtered info <> nil	final service <> nil
ReceiveUserFeedback	---	user feedback	---	userfeedback<>nil
ProduceUserProfile	user details	user profile	user detail <> nil	user profile <> nil
AdaptUserProfile	user profile,	user profile	user profile <> nil	user profile <> nil
CollectUserFeedback	user feedback	final service	user feedback <> nil	primary service<>nil
SearchQuery	user query	primary results	user query <> nil	primary service <> nil
FilterandReturnInfo	primary result	filtered information	primary result <> nil	filtered info <> nil
ReceiveUserFeedbackformUH	---	user feedback	---	user feedback <> nil
ReportUserLocation	user location	---	user location<> nil	---

Table 3-1: service Model

3.4.5 Acquaintance Model

The acquaintance model is the final stage of design in Gaia. It models the communication links between agent types. The aim of drawing an acquaintance model is not to address what messages and when they are sent between agent types. It just represents that a communication link exists between two agent types [68]. Figure 3-11 shows the communication links between the agents in the Mobile multimedia scenario.

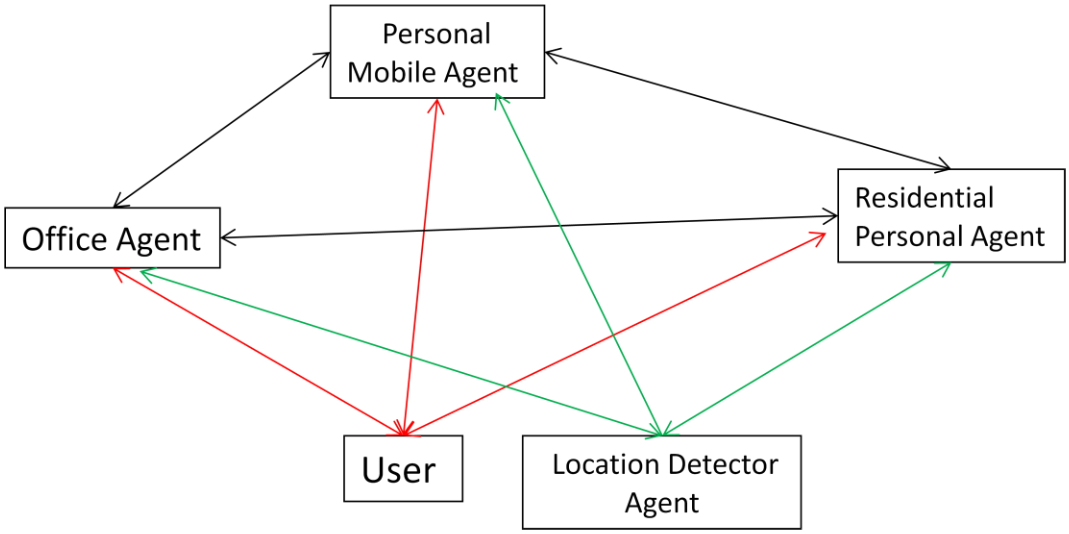

Figure 3-11: Acquaintance Model

3.5 Scenario Mapping to System Level Architecture

Based on the definition and detailed analysis of the scenario a novel system level architecture is proposed to portray overall purpose, responsibilities and relationships between the main entities and their interactions. In this architecture we present a solution for the vertical handover between WLAN and 3G networks based on the analysis of the Multimedia scenario. In the following sections the proposed SLA is explained and then the interaction between scenario entities and SLA entities are discussed.

3.5.1 System Level Architecture

In the recent past, however, technological progress has taken a new turn and the telecommunications industry is moving in a new direction which boasts not only of higher speeds, but there are also grand plans of convergence of different networks having a common IP backbone in a unified Next Generation Core Network with the IP Multimedia Subsystem (IMS) at its very heart [69]. According to [70], this convergence can be viewed from three angles

- User Service Convergence
- Device Convergence
- Network Convergence

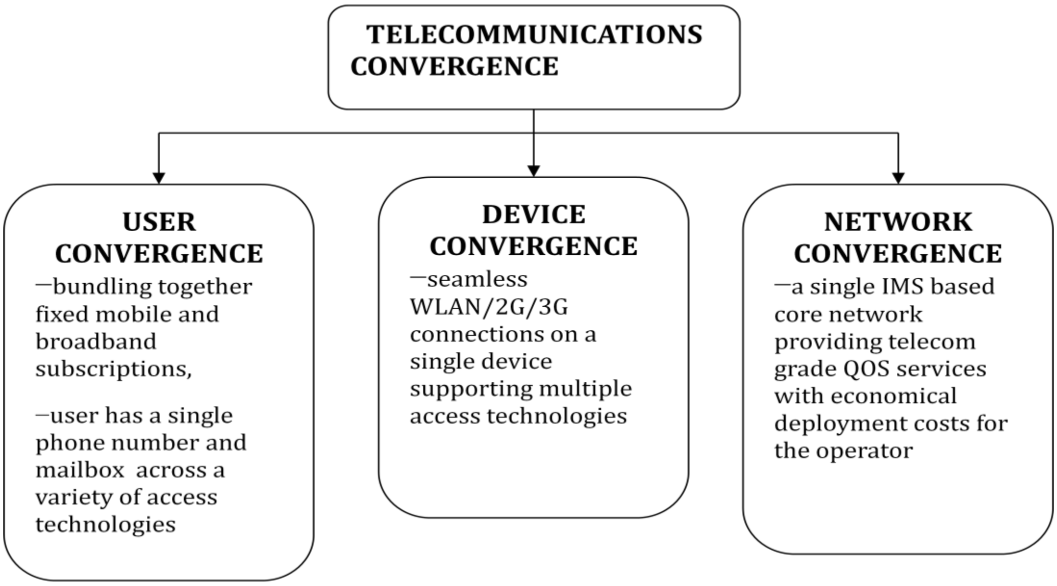

Figure 3-12: The telecommunications convergence.

In the converged network, the terms 2.5G, 3G and 4G will only be reduced to mere access technologies, and in essence, 3G and beyond will be just a high bandwidth radio modulation technologies, enabling high bandwidth subscriber applications and services by providing greater throughput in terms of bits per Hz [71]. Not only does the IMS provide a platform for converging the core networks for various access technologies, it also allows network operators to reduce the investment required for new service introduction by providing a horizontally layered service architecture and shared platform for faster and easier deployment of customized end user services [71].

TISPAN (Telecommunications and Internet converged Services and Protocols for Advanced Networking) launched NGN (Next Generation Networks) Release 1 in December 2005, providing robust and reliable open standards for the development and implementation of the first generation of NGN systems. Release 2, focuses on enhancement of mobility, new services, improved security and network management [72].

TISPAN is building upon the work already carried out by 3GPP in creating the SIP-based IMS (IP Multimedia Subsystem), TISPAN and 3GPP are working together to define a harmonized IMS-centric core for both wireless and wire line networks. IMS specifies IP-based transport for real time as well as non real time services, separation of control and bearer functionalities in an IP core network makes it easy to interwork with alternative access networks. This harmonized ALL IP network has the potential to provide a completely new telecom business model for both fixed and mobile network operators. Access independent IMS will be a key enabler for fixed/mobile convergence, reducing network installation and maintenance costs, and allowing new services to be rapidly developed and deployed to satisfy new market demand [73]. The figure below depicts the relationship between the IMS and the different Access technologies.

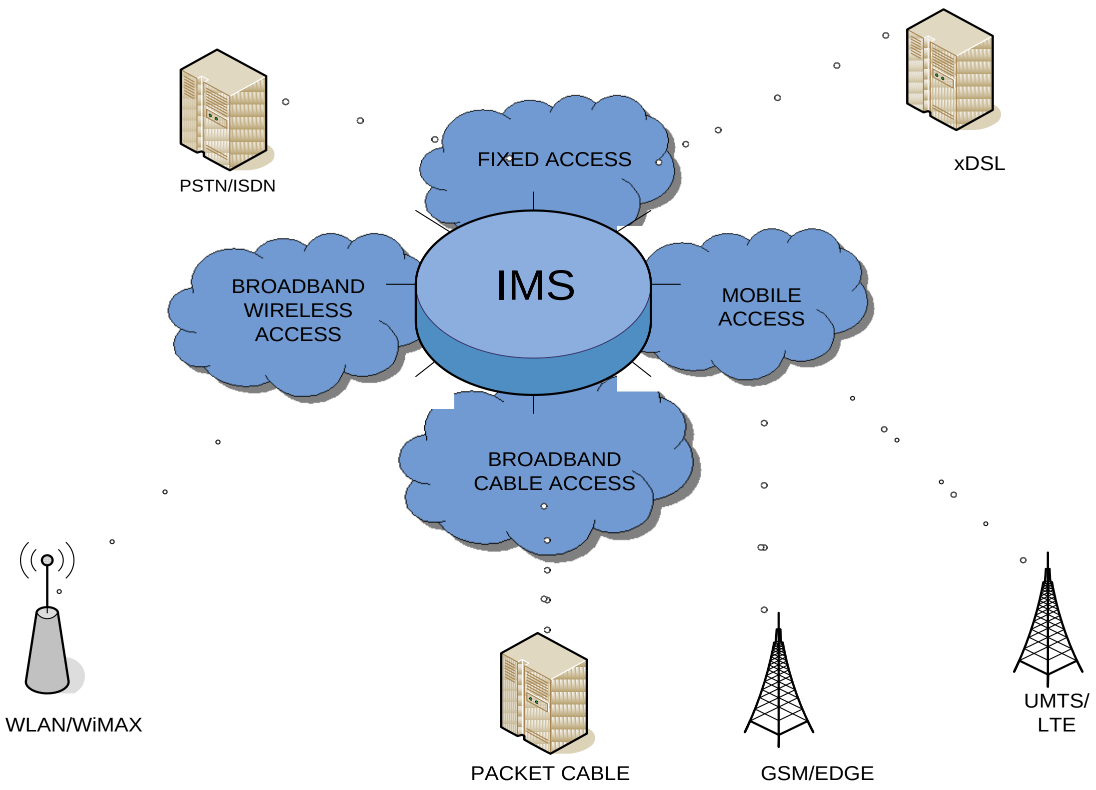

Figure 3-13:Vision of convergence

Some of the access technologies available in future IMS based converged networks are given in the table 3-2, however overview of each of these Access Technologies is presented, but only the WLAN and UMTS architectures are explained in more depth, as they are directly related to this study.

FIXED ACCESS	PSTN/ISDN , xDSL
BROADBAND CABLE ACCESS	PACKET CABLE
BROADBAND WIRELESS ACCESS	WLAN/ WiMAX
MOBILE ACCESS	GSM/EDGE , UMTS, LTE

Table 3-2: Different types of access technologies

3.5.1.1 PSTN/ISDN

The Public Switched Telephone Network (PSTN) is the forerunner of modern long distance wired telecommunication technologies and even today many communication technologies are based on those used in the PSTN regardless of whether it is data, voice or networking. In many countries the leased lines from the PSTN still provide the backbone of cellular communications and Internet Service providers.

The Integrated Services Digital Network ISDN, which goes hand in hand with the PSTN is a circuit-switched telephone network system that also provides access to packet switched networks. The key feature of the ISDN is that it integrates speech and data on the same lines, adding features that were not available in the classic telephone system [74]. This would allow IMS services to be able to interact with equivalent PSTN/CS services e.g. forwarding an IMS call to a PSTN phone.

The IMS is based on the IP and the SIP protocol while the PSTN/CS is based on the ISDN user part (ISUP) protocol. The protocol H238 and MEGACO is used for the Media Gateway (MGW) which will serve as an interface between the IMS and the PSTN [75].

3.5.1.2 xDSL and PACKET CABLE

The xDSL refers to a family of DSL technologies which use the traditional PSTN lines to provide broadband Internet Access to end users while at the same time providing the traditional voice services on the same lines. Hence its the way old telephone lines are used and not the telephone lines themselves which are changed [76].

DSL is also one of the broadband access technologies, which can be integrated with the IMS to provide a seamless user service experience. PacketCable networks use Internet Protocol (IP) to enable a wide range of multimedia services, such as IP telephony, multimedia conferencing, interactive gaming, and general multimedia applications [77] packet cable has the capability to interconnect t with PSTN, TCP/IP based networks and the Hybrid Fibre Coaxial (HFC) packet network [78] because of these technologies IMS services can be received on IP enabled TV in addition to other fixed broadband access devices.

3.5.1.3 WiMAX

WiMAX stands for Worldwide Interoperability for Microwave Access. This technology is based on the IEEE 802.16 standard also known as Wireless MAN. According to the WiMAX Forum, "WiMAX is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL". WiMAX comes in two flavours "Fixed WiMAX" IEEE 802.16d without support for mobility and Mobile WiMAX IEEE 802.16e which has also been included in the IMT 2000 by ITU [79]. WiMAX is not another type of fast Wifi. It is a separate radio modulation technology working in different frequency ranges which has a promise of quick and efficient deployment of higher speed pack data access to both areas with and without a prior telecommunications infrastructure. WiMAX can be installed as Point to Point High speed links or in a mesh configuration providing high speed internet access over a radius of more than 30 miles [79].

3.5.1.4 GSM/EDGE

GSM and EDGE refer to the 2G and 2.5G cellular mobile technologies, which are in use in many parts of the world. There are many similarities in the GSM and the UMTS Core Network. UMTS is basically an enhancement of GSM particularly in terms of the Radio technology where the GERAN (GSM Edge Radio Access Network) has been replaced by the UTRAN (UMTS Radio Access network), which promises higher speeds and bandwidth. We shall be concentrating on the UMTS cellular mobile network for the purposes of this thesis and will propose an IMS inter working solution between UMTS and WLAN however it must be noted that many of these suggestions are also applicable in the 2.5G, GSM, GPRS, EDGE Network with slight or no modifications.

3.5.1.5 WLAN TECHNOLOGIES

Wireless Local Area Network (WLAN) refers to a group of technologies ,which enable mobile internet connectivity for mobile computers within a small radius where the user can roam freely [80]. The table below gives an overview of the various WLAN technologies to date. Although WLANs also include the ETSI BRAN HiperLAN 1 and 2 technologies WLAN generally refers to the IEEE802.11 family of protocols which provide wireless network bearer capability for providing mobile connectivity in computers. Bluetooth and WiMAX often confused with WLAN, belong to WPAN (Wireless Personal Area Network) and WMAN (Wireless Metropolitan Area Network) respectively. UWB often mentioned along with WLAN is also a technology similar to Bluetooth [8] and hence we shall not treat it as a part of WLAN.

Wireless Technology	Frequency band	Speed	Modulation Type	Notes
IEEE 802.11	2.4 GHz	1,2 Mbits/s	FHSS,DHSS	
IEEE 802.11a	5 GHz	Upto 54 Mbits/s	OFDM	
IEEE 802.11b	5 GHz	5.5 - 11 Mbit/s	DSSS	802.11 equipment. known as WiFi
IEEE 802.11 g	2.4 GHz 2.5	Upto 54 Mbps		
IEEE 802.11n	2.4GHz	Upto 600 Mbps		
HiperLan 2	5GHz	Upto 54Mbits/sec		Developed by ETSI BRAN

Table 3-3: Summary of Notable WLAN technologies [82, 83, 84]

Wifi, more popularly known as the IEEE 802.11b is the most popular WLAN technology to date. Since the introduction of the IEEE802.11b wireless local area networking standards which offer performance comparable to the internet, the market for wireless communications has grown rapidly. WLANs are becoming ubiquitous and increasingly reliable and in the year 2000 the sale of WLAN 802.11b adapters rose dramatically from 5000 to 70,000 units per month. By 2002 the sale of IEEE 802.11 adapters rose to a million per month and nowadays all laptops come integrated with IEEE 802.11b network adapters. Despite the different radio technologies it is important to realize that the specific WLAN technology used in each wireless IP network is not very visible for the layers above IP. [85]

3.5.1.6 GENERAL WLAN ARCHITECTURE

802.11 Networks generally consist of four major physical components, Distribution system, Access point, RF channel and the WLAN station as summarized in the figure below.

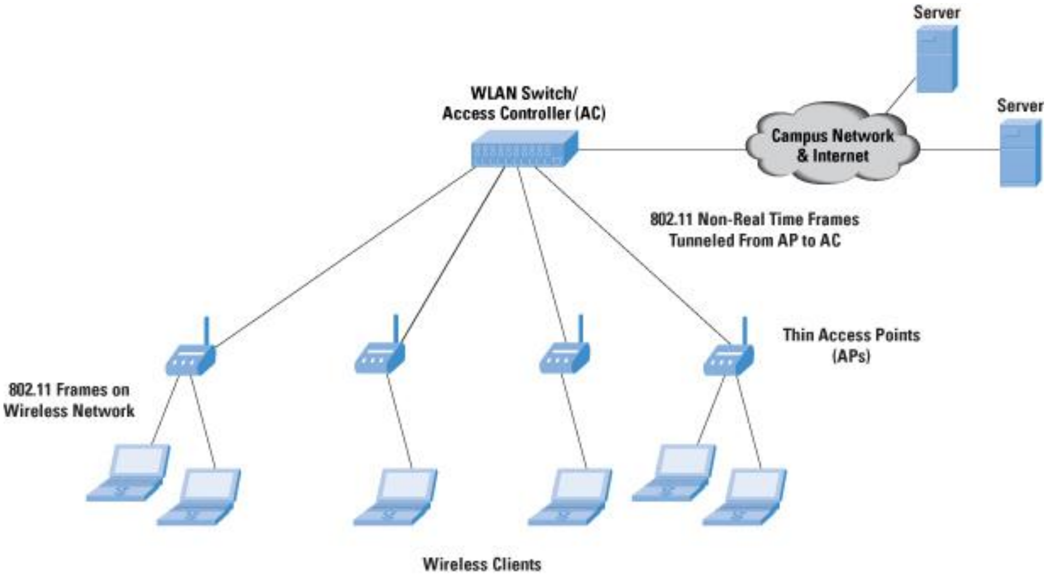

Figure 3-14: Components of a WLAN system [82]

A detailed description of the major components of a general WLAN architecture is summarized in the table below:

WLAN Element	DESCRIPTION
STATIONS	Stations are computing devices equipped with wireless network interface cards which will communicate over the wireless network
ACCESS POINT	Access points (APs) are base stations for the wireless network. They transmit and receive radio frequencies for wireless enabled devices to communicate. The most important function of Access points is bridging i.e. frame conversion from and to 802.11 air interface for delivery to the rest of the world
WIRELESS MEDIUM	Frames are propagated between stations using a wireless medium. Several different physical layers including Infrared and RF are defined but RF are the most popular.
DISTRBUTION SYSTEM	A distribution system (DS) connects access points in an extended service set. The concept of a DS can be to increase network coverage through roaming between cells. It is basically the backbone network technology connecting the APs and might be e.g Ethernet.

Table 3-4: Main components of the WLAN architecture [82]

3.5.1.7 UMTS ARCHITECTURE

The UMTS system consists of two independent subsystems connected over a standard interface. These are

- The UMTS Terrestrial Radio Access Network (UTRAN) consisting of the Node B and the RNC.
- UMTS Core Network which is similar to the GSM/GPRS NSS.[79]

Below is a simplified model of the UMTS network architecture

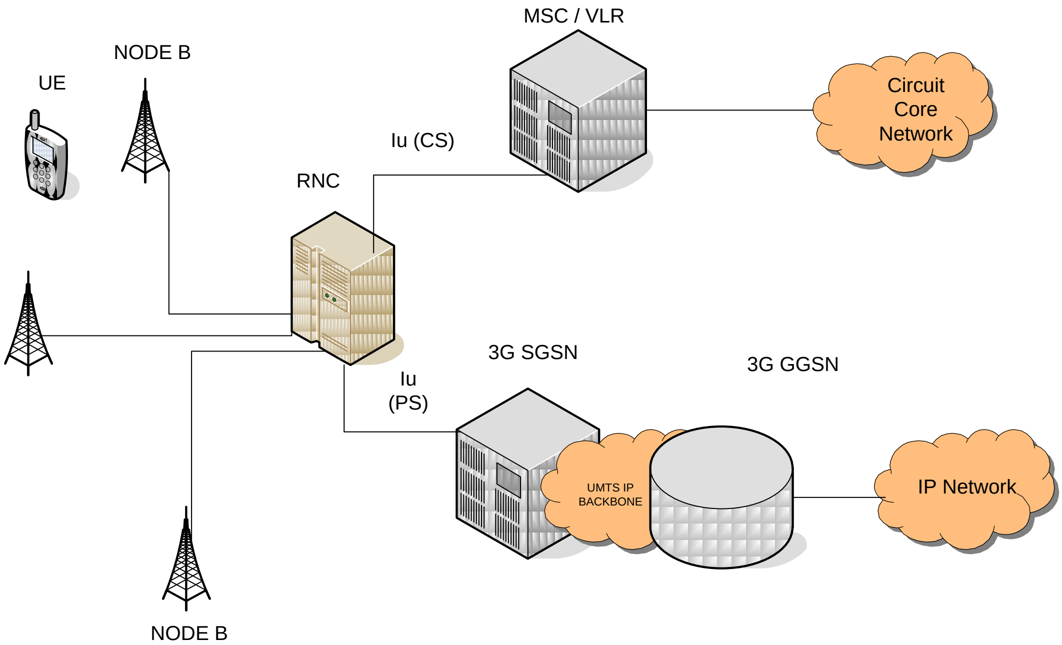

Figure 3-15 Simplified UMTS architecture [83]

Node B: equivalent of Base Transceiver Station in GSM
RNC: Radio Network Controller
MSC: Mobile Switching Centre
VLR: Visitor Location Register
SGSN: Serving GPRS Support Node
GGSN: Gateway GPRS Support Node

3.5.2 IMS ARCHITECTURE

The IMS architecture is evolving across multiple releases of 3GPP. [84] 3GPP has standardized the functions, which shall be performed by the IP multimedia subsystem and not the nodes themselves. It is up to the vendor whether they want to create a solution with multiple functions in a single node or a single function implemented as separate nodes [85].

The figure below is a detailed but non-exhaustive architecture for the IP Multimedia subsystem as specified by 3GPP.

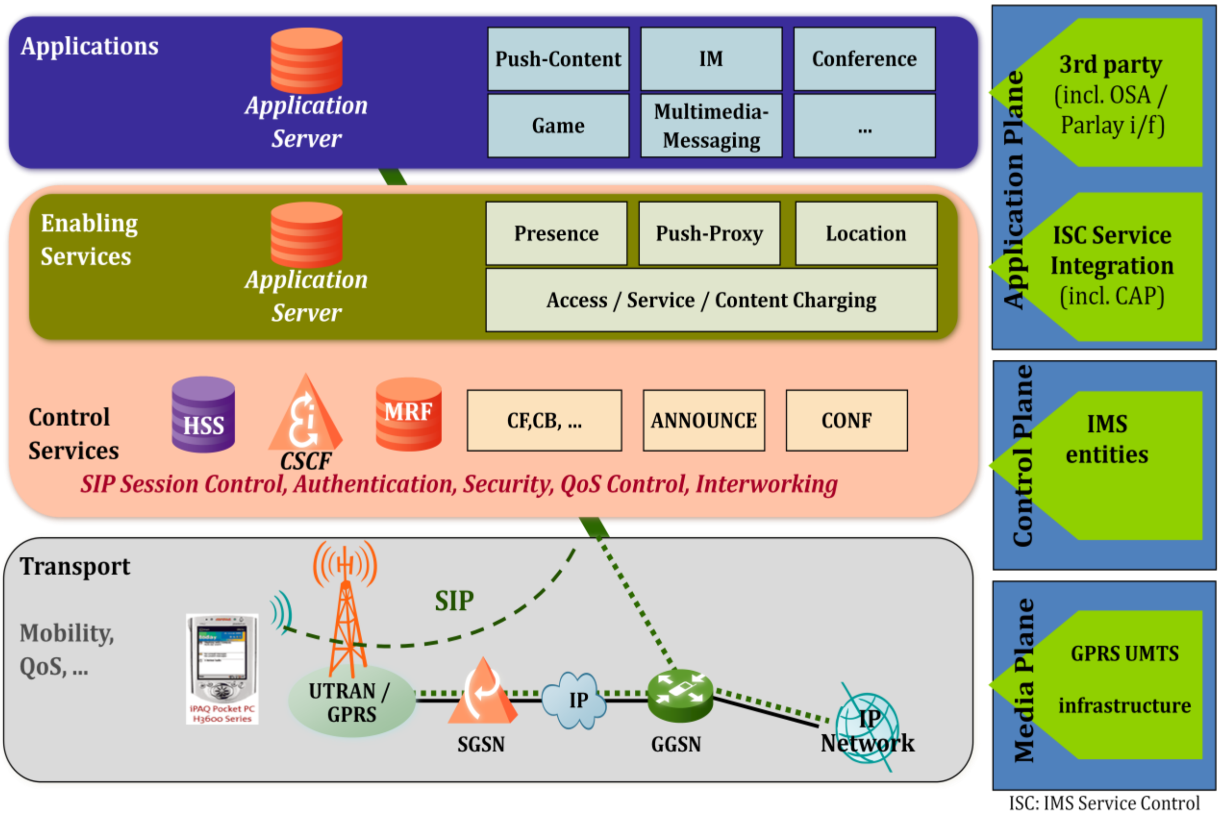

Figure 3-16: Architecture of the IP Multimedia subsystem

As can be seen in the figure above, the IP multimedia subsystem can be classified into three distinct operational planes, which are the application plane, the control plane and the user plane/Media plane respectively.

1. APPLICATION PLANE

The IMS application plane consists of a number of SIP Application Servers (AS) which can operate as SIP UA (SIP User Agents), terminating function, SIP B2BUA (SIP Back to back User agents) or as a SIP proxy server.[81]

2. CONTROL PLANE

The control plane deal with session signaling and consists of three different kinds of Call Session Control Functions (CSCF), Proxy-CSCF (P-CSCF), Serving-CSCF (s-CSCF) and Interrogating-CSCF (I-CSCF). Home Subscriber Server (HSS), Media Gateway Control Function (MGCF) and Breakout Gateway Control Function (BGCF) and are based on protocols such as SIP, Diameter and H.248 MEGACO [81].

3. **MEDIA PLANE (Transport layer)**

The media plane transports the media streams directly between subscribers; and between subscribers and IMS media generating functions [81] it contains Media Resource Function (MRF), Signaling Gateway (SGW) and Media Gateway (MGW).

The table 3-5 gives a brief description of the different IMS entities and their functions.

IMS ENTITY	FUNCTION
P-CSCF	The initial point of contact for signalling traffic in the IMS.A user is allocated a P-CSCF as a part of the registration process and provides a two way IPSEC association. All signalling traverses the P-CSCF for the duration of the session
S-CSCF	S-CSCF provides the coordination logic to invoke the AS needed to deliver the requested service. It downloads the User profile from the HSS to determine user service eligibility. S-CSCF is allocated for the duration of registration only
I-CSCF	A SIP proxy that serves as a gateway to other domains.
HSS/SLR	The HSS is a centralized database, which stores the subscriber profile information, which is accessed by the S-CSCF using the Diameter protocol for validation of the subscriber. I-CSCF SCIM and the AS also have access to HSS
AS	An AS hosts and executes services and can run in different SIP modes. They are attached to the S-CSCF to serve IMS services.
MRF	The MRF comprises two nodes: the controller and the processer. The MRFC is a SIP UA and is located in the signalling plane. The MRFP is situated in the media plane and provides media related functions such as voice announcements etc
BGCF	Identifies if a session should terminate on a PSTN and determines the appropriate MGCF to handle it, is basically a SIP proxy processing requests for routing.
SGW	Provides interworking with the legacy PSTN, provides SIP to PSTN signalling traffic interworking
MGCF	It controls the media flow over H.248 Media interface
MGW	Provides CS to RTP based packet media flow

Table 3-5: Main components of IP Multimedia Subsystem

3.5.3 Interworking Between WLAN and UMTS

3GPP has put forward many documents on convergence. Later releases of UMTS have included the IMS in the architecture. We shall now compare several of the different interworking scenarios available for interworking of WLAN and UMTS and the various levels of interworking, which have been defined by the 3GPP.

3.5.3.1 Interworking Scenarios

"Several interworking scenarios might exist between the WLAN and the cellular mobile network. These scenarios are broadly classified into one of three categories

- Tight coupling

Tight coupling refers to the network elements that are completely dependent on each other's interaction. Tight coupling offers the same level of security as UMTS. It requires standardization of a simplified Iu interface (Iu is the interface between the UMTS Radio Access network and the Core Network). The ETSI project called Broadband Radio Access Network (BRAN) is working on this specification for HiperLAN2.Tight coupling requires specific access network equipment and a wireless LAN terminal with an embedded Security Identity Module (SIM) card [86].

- Loose Coupling

Loose coupling refers to the integration and interaction of network elements that allow a degree of independence (e.g. Reconfiguration). Loose coupling offers the same security benefits as tight coupling while requiring less standardization effort. The link between a wireless LAN and the mobile network is performed between the Authentication, Authorization and Accounting (AAA) server and the Home Location Register (HLR). The HLR stores the current location of mobile subscribers and the list of services to which they have access rights. The ETSI BRAN committee is also working on the specification this interface for HiperLAN2. Unlike tight coupling; loose coupling does not require specific access network equipment. The wireless LAN terminal could include a SIM card [86].

- Open coupling

Open coupling is a simple solution that does not require standardization. The link between the wireless LAN and the mobile network is performed at Customer Care and Billing System (CC&BS) levels. The AAA server sends information related to the usage of the wireless LAN network to the mobile network CC&BS. This solution does not employ the mobile network security mechanisms .All access equipment and wireless LAN interface cards are standard commercial products [86].

Tight and loose coupling offer security but require specific equipment meaning higher investment for operators and end users. New interfaces also need to be standardized. Open coupling requires no specific equipment, needs a limited investment and can be deployed today. To test the market, open coupling seems more adapted because of its readiness and its cost. In the long term the evolution of the network towards loose coupling is linked to the availability of terminals with wireless LAN capabilities and embedded SIM card."[87]

3.5.4 Mobility Solution Between WLAN and 3G

This section discusses the novel proposal for the service continuity and seamless mobility between heterogeneous access networks connected to the IMS, in particular, in relation to the Multimedia scenario between Home and Elsewhere WLAN and 3rd Generation (UMTS). While Service continuity refers to the capability to maintain an active session while moving from one access network to another without the need to consider transport level related continuity issues such as bandwidth or packet loss, seamless mobility refers to the ability to have a handoff between different access technologies which is almost imperceptible to the user with no noticeable service interruption greater than that perceived in intra-3GPP handovers [88].

An important feature of seamless mobility is the capability of vertical handoff which means that if two users are engaged in a voice conversation and one of the UE roams into a coverage area where UMTS coverage is not available, the UE should gracefully locate other access methods available and make the "switch over" without breaking the continuity of the call. Seamless mobility aims to make this transition as smooth as possible so that it is imperceptible to the user.

This solution is based on the following propositions

1. According to 3GPP TS23.327 [89] the handoff process must not compromise the security required for any of the access technologies hence authentication is an essential part of the handoff process and cannot be overlooked. This call flow is access technology independent and the authentication over the access technology is not shown for purposes of clarity. The authentication process is composed of two steps,

- Authentication with the IP multimedia subsystem core Network.
- Authentication for the air interface for access technology Proposed architecture aims to reduce the time required for both of above authentication stages.

2. During the handoff, authentication process within, IMS core network is optimised, by reducing the redundant signaling. This can be achieved y reducing re-registering with IMS network, therefore the proposed architecture introduces a new mechanism that avoids re-registration and reducing redundant signaling thereby making the call flow as simple as possible.

- This proposal relies on the introduction of a WLMSI (Wireless LAN Mobile Subscriber Identity) similar to the concept of IMSI and TMSI. This WLMSI will be a secure UE identity, which will be generated and stored in the IMS Core Network (in the AAA or HSS server) at the time of registration of the UE into the IMS network regardless of the access mechanism used at the time of initial registration.

- This WLMSI can be used at the time of handover from WLAN to the UMTS (possible in a manner the TMSI is used by the MSC) in order to authenticate the UE requesting the handover procedure and will serve to replace the cumbersome re-authentication procedure, which is needed by the UE while accessing the system again via WLAN. Although in the WLAN mode the UE will have to pass through the security mechanisms of the WLAN in order to connect to the IMS, the process of re registration and authentication within the IMS can be made simpler by such an arrangement and the only change required at the end of this authentication will be a simple change in the profile of the user from UMTS to WLAN mode in the concerned IMS node and a redirection message to be sent to the media stream to use the new access method for further data delivery.

- This will significantly reduce the overhead time to setup the new data stream thereby reducing the duplication which might occur in data which is a problem in other solutions as is illustrated in [90]

3. Authentication mechanism utilised in UMTS is more complex as compared to the authentication procedure in a WLAN network although there are many schemes to make the WLAN more secure including the use of an IPsec tunnel for data transfer. Hence in the event there is a handover from WLAN to UMTS a re-authentication is necessary to bring the security profile to the UMTS standard which might again add to the handover time.

- In order to overcome this, we propose that the standard UMTS method is also used in conjunction with authentication in the WLAN while performing the initial registration. In this way while initiating the handover procedure, it shall be easier to perform a faster transition from WLAN to UMTS or vice versa as the subscriber would already exist in the UMTS database which generally requires a more exhaustive authentication process as compared to WLAN. This is known as double authentication while registering.

- Provided the UE (User Equipment) has handover capability and both UMTS and WLAN networks are supported the UE might stay connected to both WLAN and UMTS networks and remain an active or "stand-by" subscriber in the respective databases. WLAN does not have any paging like UMTS and the IP messaging overhead to keep the user connected might be considered negligible. UMTS on the other, hand pages the subscribers even in the idle mode and the, duration between these paging requests is controlled by the operator according to set policy. Keeping the user's profile active in the UMTS VLR database as an active subscriber is a very small price to pay. As far as the SGSN and GGSN are concerned the user might stay in the "Attach State" although no PDP context is activated until the actual data transfer has to take place after the handover.

The constant paging of the UE by the UMTS network might be a drain on the UE battery and hence this issue needs to be addressed. One approach to solving this issue can be taken from the analogy that when a subscriber moves out of the GERAN coverage area the subscriber information remains in the VLR for a fixed time until the same user is picked up by another VLR or the information is purged. However since the last roamed VLR of the subscriber is stored in the UMTS network, with the HLR containing the last VLR accessed and the VLR containing the subscriber records, locating the subscriber is much easier and much faster than a fresh LU and Attach procedure. Similar approach can be adopted by 3GPP in future releases in establishing a separate node containing a pool of subscribers which have performed the LU and the Attach procedure over GPRS but are nevertheless paged over a different channel at a lesser frequency than normal paging. Until then the user might have to seek a trade-off between shorter battery life and increased seamlessness in the Handover.

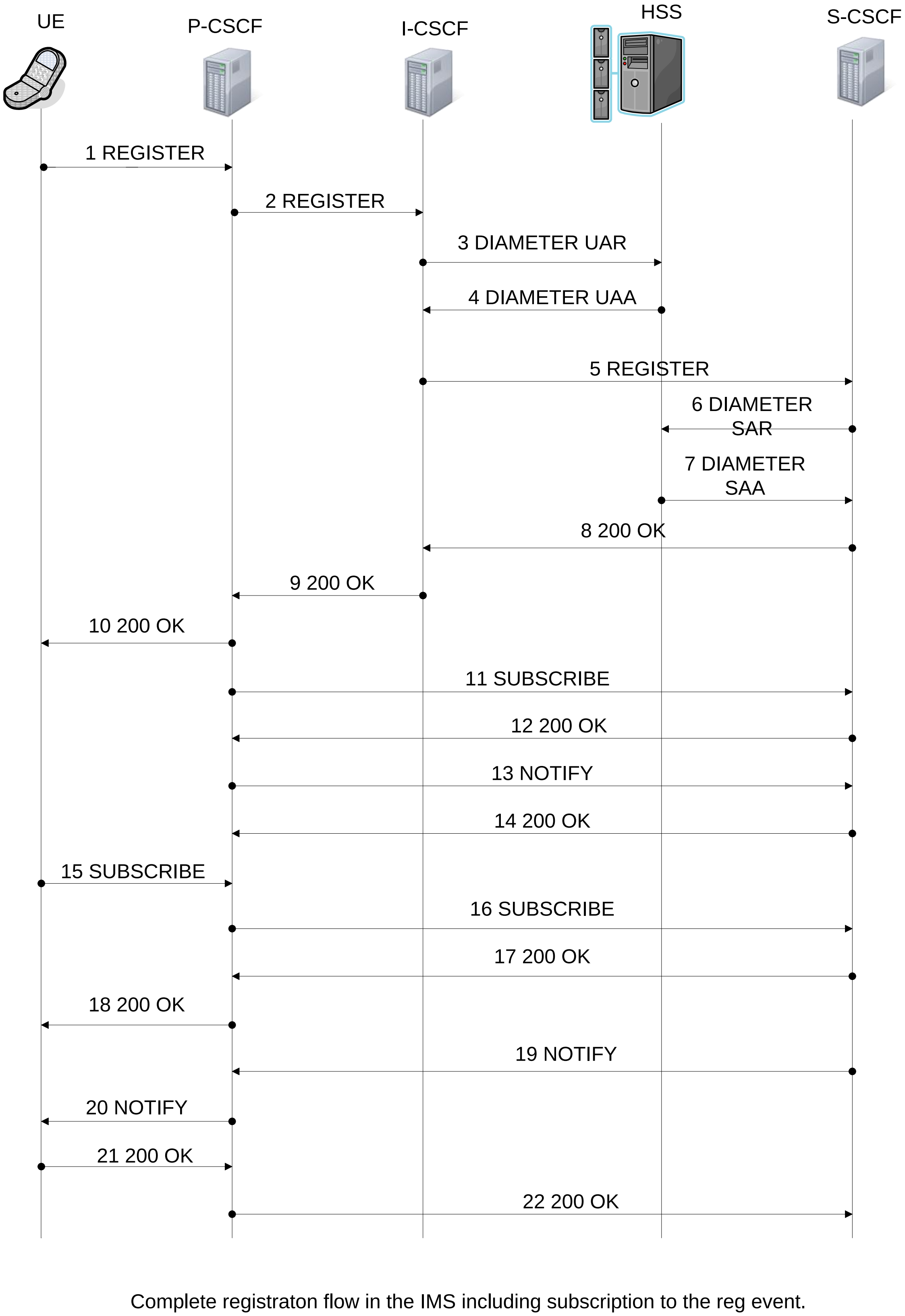

Figure 3-17: IMS internal core network standard registration procedure. This call flow assumes that the access network authentication is already in place [62]

3.5.5 The Interworking Architecture

While choosing the interworking architecture for the implementation of the proposed solution the following guidelines must be adhered.

- " 3GPP does not standardize nodes but functions. This means that the IMS architecture is a collection of functions linked by standardized interfaces. Implementers are free to combine two functions into a single node e.g. into a single physical box. Similarly implementers can split a single function into two or more nodes." [91]

- Although it is possible to combine multiple functions into a single node, this comes at a cost of increasingly complex machinery, which requires better memory, storage and processor capability. While on the other hand the benefit of implementing multiple functions in a single node also means that there are lesser time delays as communication on internal interfaces is much faster than inter node communication over the network and should definitely lead to better efficiency and network performance as can be seen in the case of VLR and EIR which although were two separate functions, are most incorporated with the MSC as a single node by most vendors.

The IMS integration architecture, for the implementation of this approach, is shown in figure 3-18.

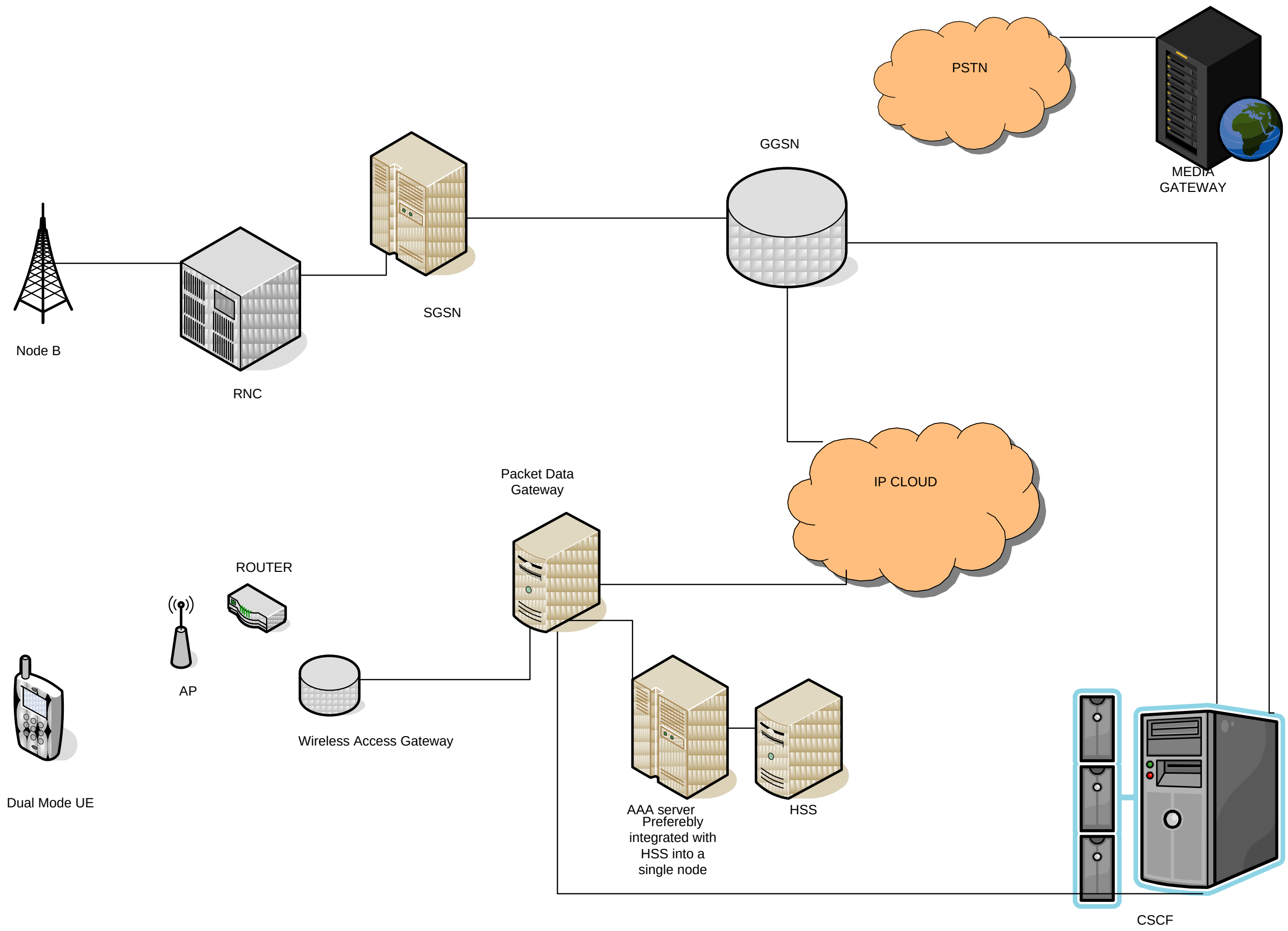

Figure 3-18: Proposed Architecture based on Loose Coupling

Legend:

AP: Access Point RNC: Radio Network Controller
SGSN: Serving GPRS Support Node GGSN: Gateway GPRS Support Node
UE: User Equipment HSS: Home Subscriber Services
AAA: Authentication, Authorisation, and Accounting GPRS: General Packet Radio Service

The above architecture shows that UMTS access standard and WLAN access standard as two independent access technologies can provide seamless mobility through IMS. The seamless handover of Multi media session between the two access standards can be performed by introducing the concept of WLMSI and Loose coupling and further optimised by implementing HSS functionalities with that of AAA server in the same node.

3.5.6 Cost Benefits of the Proposed Architecture

The cost benefits of the proposed architecture are discussed in the next sections discussing different scenarios, these analyses are for the user in the home network only, but can easily be adapted to the case of user roaming in a foreign network with roaming agreement.

3.5.6.1 Access Network Authentication Cost Benefit

The call flow for the 3G/GPRS attach procedure in accordance with the proposed architecture, is shown in figure 3-19, which will be compared with the handover mechanism specified by 3GPP [30] in figure 3-20.

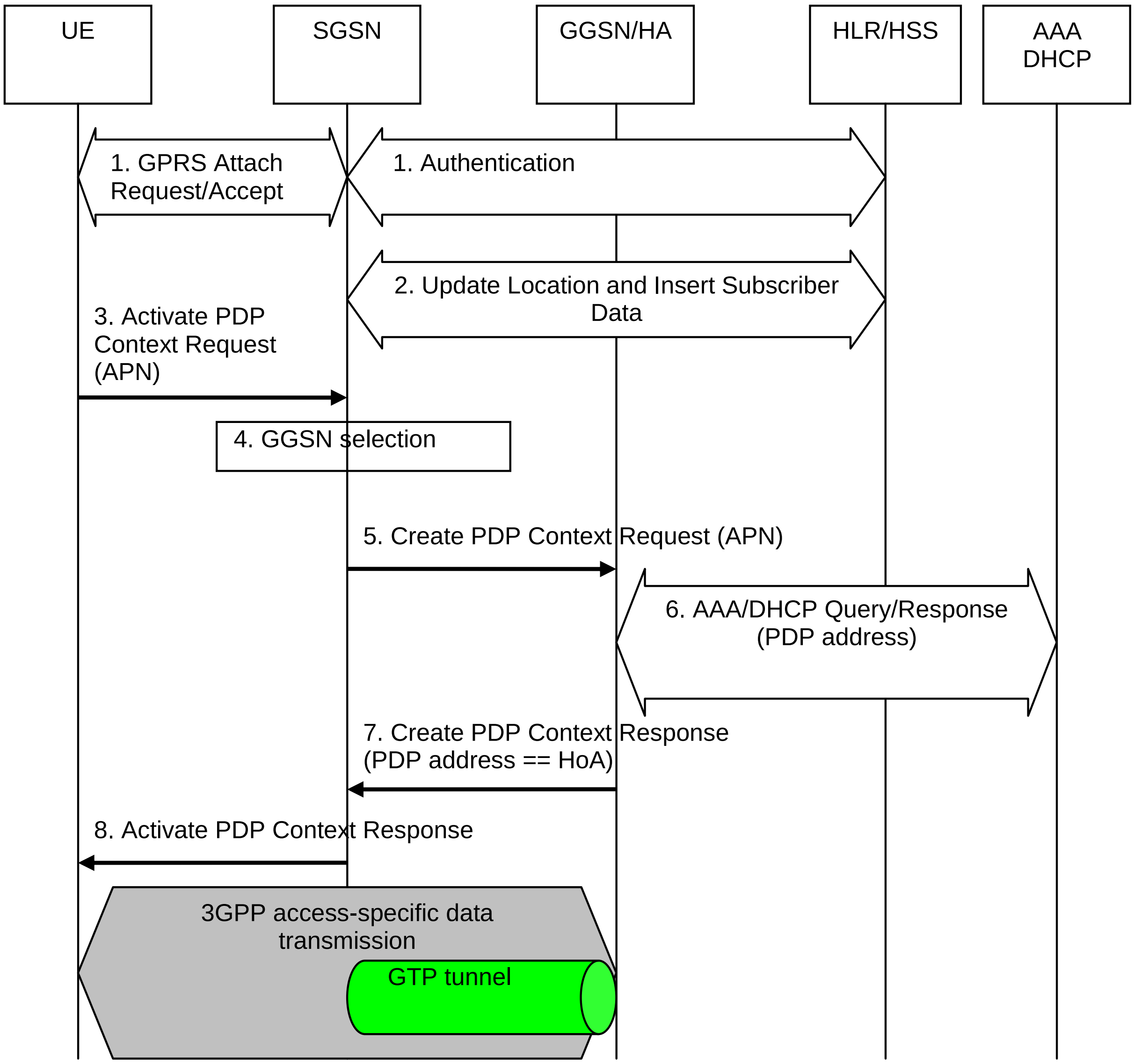

Figure 3-19: UMTS to WLAN Interworking procedure

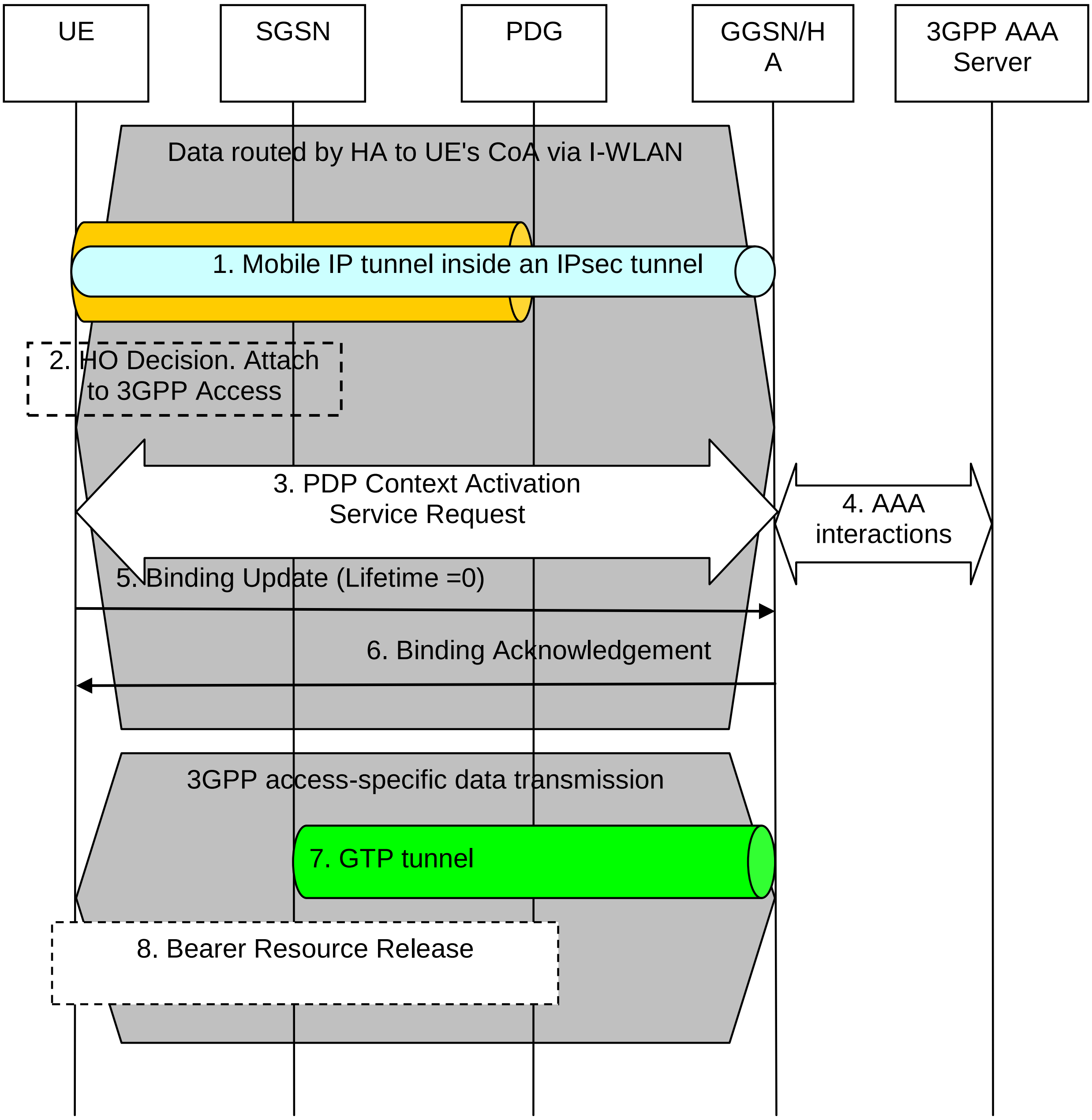

Figure 3-20: Interworking call flow attach procedure as specified by 3GPP [80]

As it can be seen proposed approach in figure 3-19 of keeping the UE in the "attached" state prior to handover reduces the need for the first two stages in the handover. This translates to a reduction in the time required to perform the following actions.

- GPRS Attach Request and GPRS attach accept
- Authentication form the HLR
- Update Location and insert subscriber data.

To further explore cost benefits of the proposed mechanism the call flow attached state procedures from WLAN Access Point to UMTS access nodes are compared, which are depicted in figures 3-21 and 3-22. The WLAN establishes an IPSec tunnel for secure data transfer as shown in figure 3-21.

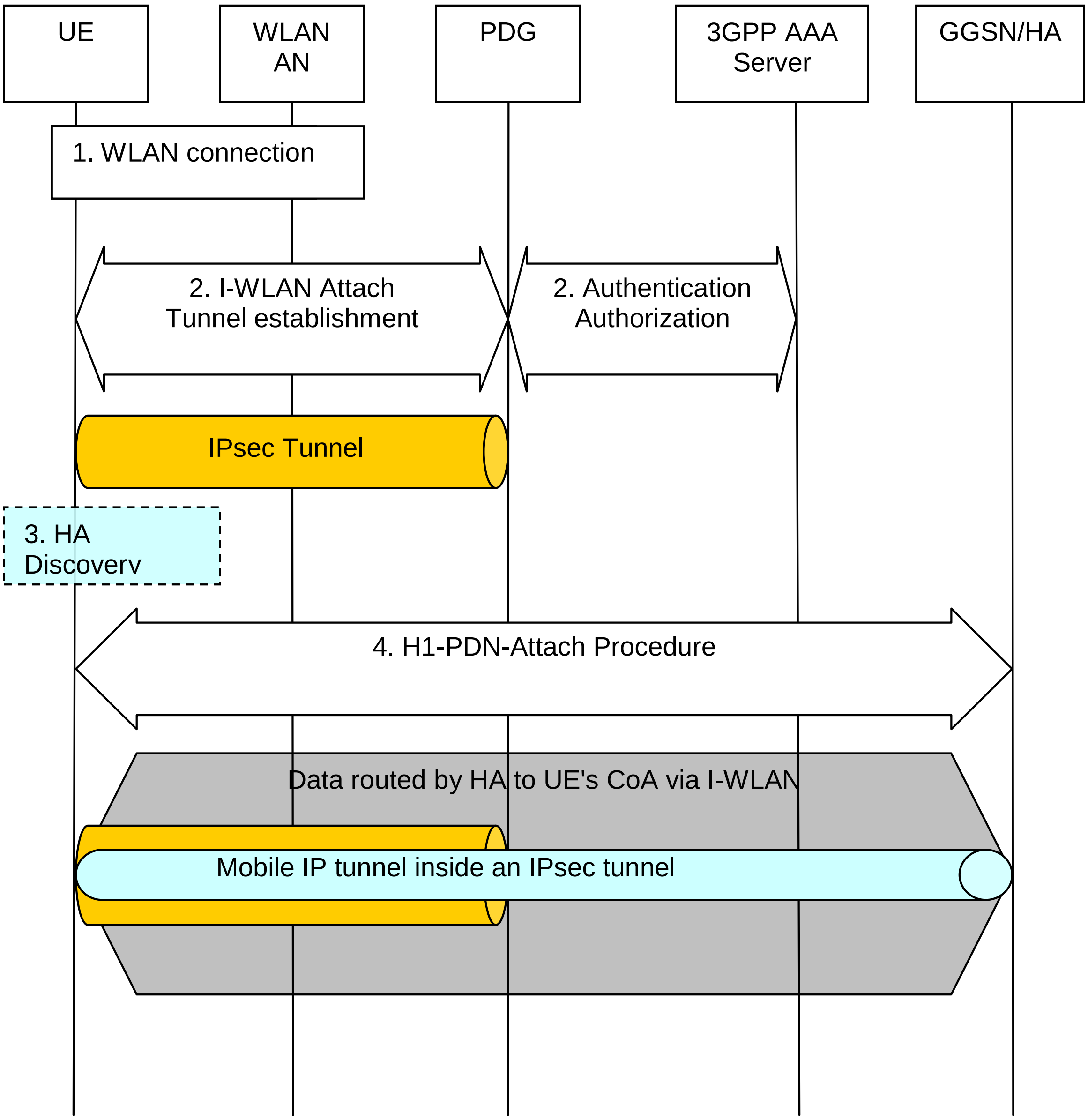

Figure 3-21: Interworking WLAN attach procedure as specified in 3GPP release 8[80]

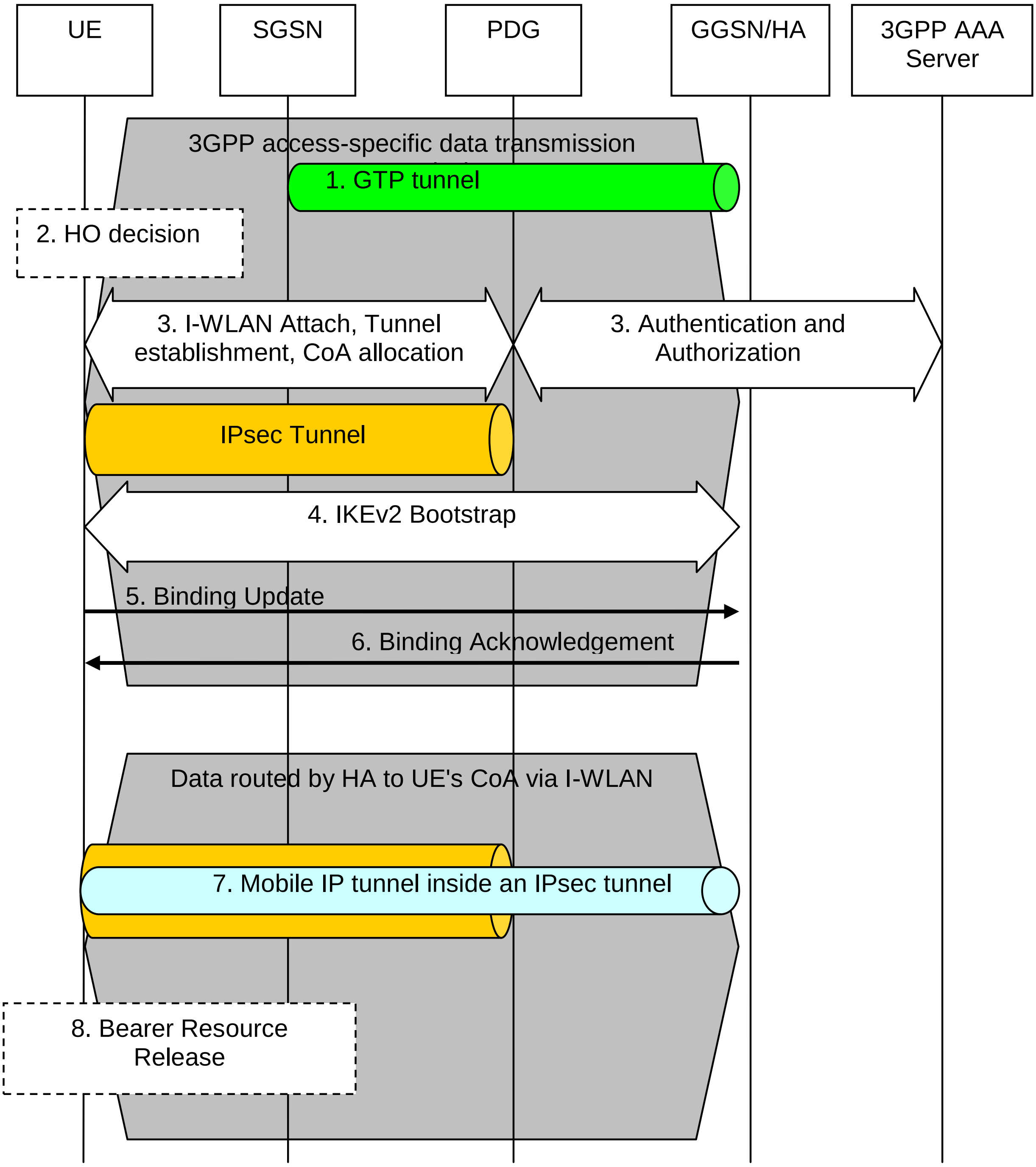

Figure 3-22 Handover from 3GPP access to I-WLAN [80]

As it can be seen from the call flows in figures 3-21 and 3-22 it can be concluded that the time required for WLAN Attach tunnel establishment and Authorization can be saved although the benefit might be more marked in the reverse scenario, this is also not without its benefits as the Authentication has to be done once only with the Access Network. IPSec tunnel establishment at the time of initial network discovery may also be considered provided that it doesn't have power limiting constraints however it is beyond the scope of this thesis and further work on IPSec tunnel and mobility can be found in [92].

3.5.6.2 Core IMS Network Authentication Cost Benefit

The benefits of using a single IMS node is demonstrated in the IMS registration session of figure 3-17 which can be further reduced to the call flow shown in figure 3-23, thereby causing lesser network messaging however this is for the case where the P-CSCF and the S-CSCF are located in the same network. Where the user has roamed into another network the S-CSCF of the roamed network will come into play and hence network interfaces will be used.

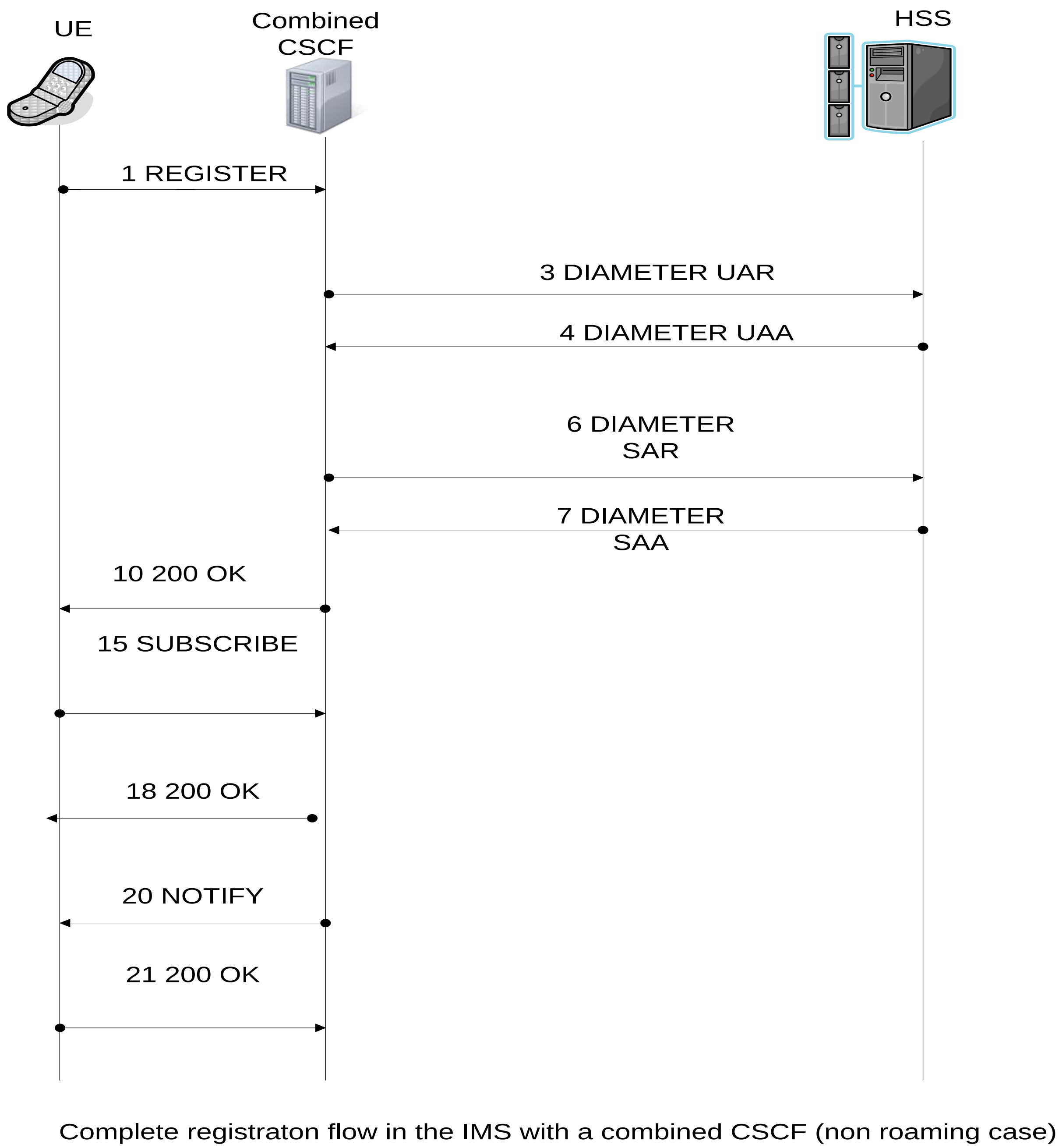

Figure 3-23: Call flow of the proposed architecture

In this approach by keeping the UE in the “attached” state prior to the handover, reduces the need for the first two stages in the handover. This translates to a reduction in the time required to perform the following actions.

- GPRS Attached Request and GPRS attached accept
- Authentication from the HLR
- Update location and insert subscriber data

Once the authentication has been done, there is no need to repeat the authentication within the IMS core network, this process could be replaced by a more efficient handover call flow in which the S-CSCF sets the HSS status of the user to the new network and directs the MRCF to re-route the data flow.

3.6 Scenario Mapping to System Level Architecture

Based on the definition and analysis of the scenario a system level architecture is proposed to portray overall purpose, responsibilities and relationships between the main entities and their interactions. In the following section the proposed SLA is explained and then mapping of the Mobile Multimedia scenario to the SLA is presented. Then the interaction between scenario entities and SLA entities is discussed.

3.6.1 System Level Architecture

The IMS based proposed architecture is shown in figure 3-24. Figure 3-25 shows the same architecture with the representation of agents. The architecture is organized in three layers of application, middleware and transport. The application layer consists of third party service providers. The middleware layer is comprised of core IMS functionalities in addition to the agent management entities. The transport layer consists of access networks.

For the purpose of clarifying functionality, a brief description of each element is provided. Management of services and service logic is provided by IMS service level functionalities. Service providers such as (network, 3rd party, virtual, ISP) provide the actual service. Virtual Home/Service Management provides portability of a user’s familiar service environment across network boundaries and between terminals. Directory services, Global Name Mapping and Location Enabler elements store data such as data base entries and corresponding access methods associated with the terminal, subscriber and service. The Authentication manager seeks proof of identity for each entity. The Accounting Manager records network resource usage for a particular user activity. The Mobility Manager provides roaming and handover functionalities. The Session Manager provides functionalities such as session/call state management. The QoS Manager monitors QoS and adapts QoS when required. The Agent management provides execution and operation environments for agents.

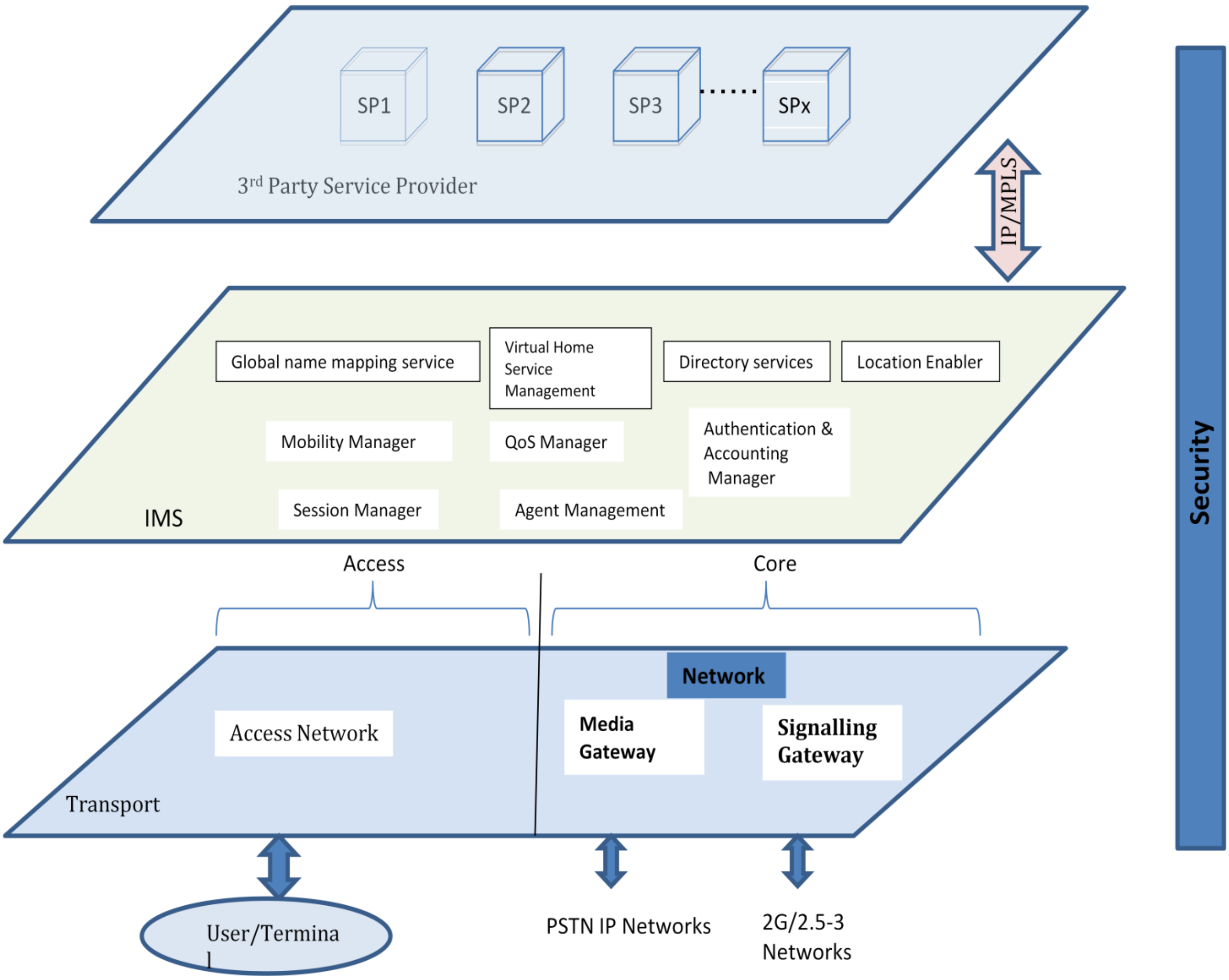

Figure 3-24: System Level Architecture

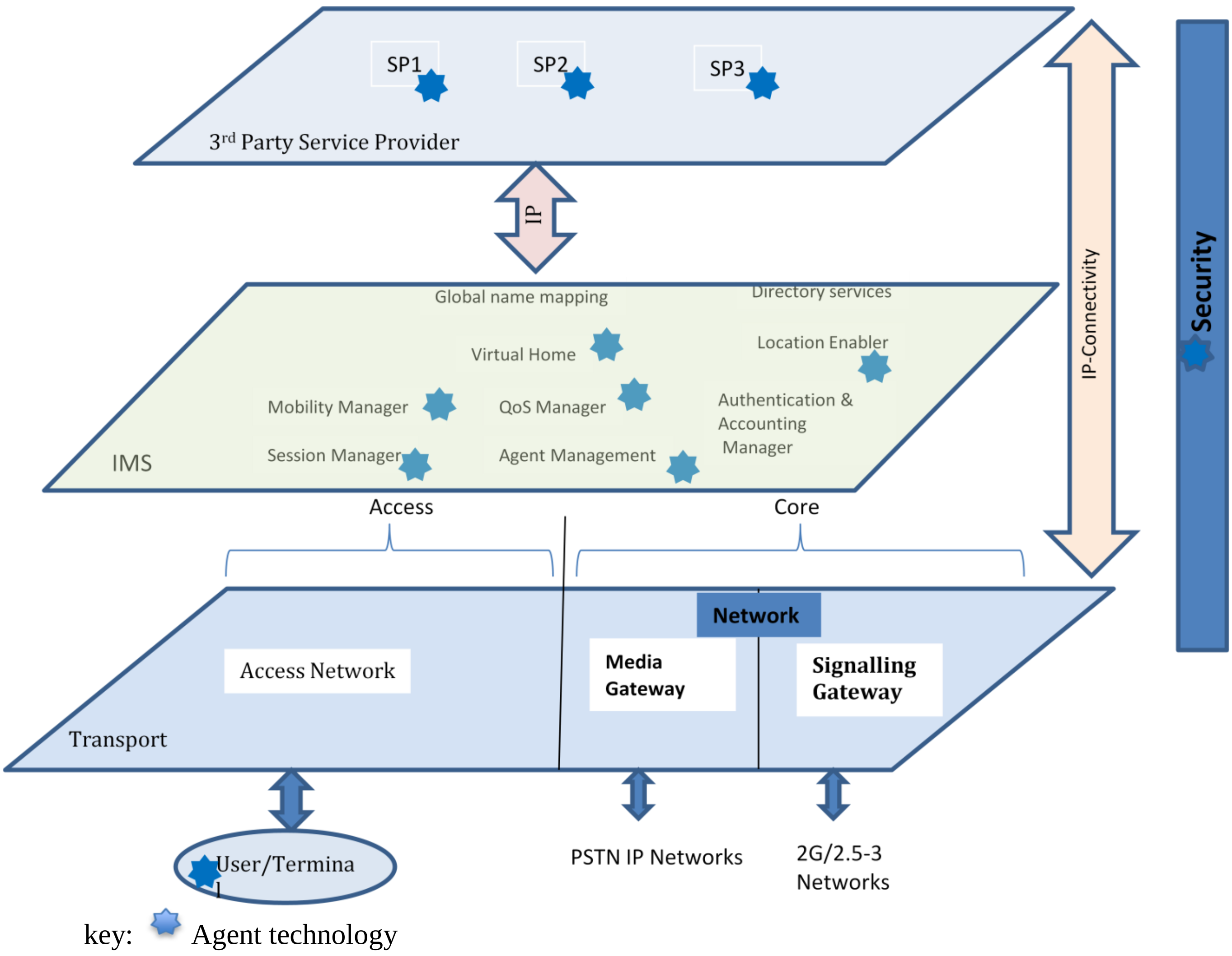

Figure 3-25: SLA with Agents representation

3.6.2 Scenario Entities

Five main entities are identified in the Mobile Multimedia scenario.

- User Agent which acts on behalf of the user
- A Residential Personal Assistant (RPA) manages all input/output devices in the user's home.
- An Office Assistant (OA) manages user's requests when the user is in the office.
- A Personal Mobile Assistant (PMA) serves the user when user is not at home. Each PMA manages its user's requests according to his/her priorities and preferences.
- A Location detector (LD) detects the user's location. A user entity requests services by using different physical devices and personalized service delivery to this entity is the main goal of the system.

3.6.3 Mapping to SLA Entities

In this section the mapping between the Mobile Multimedia Scenario entities and SLA entities is presented. In Table 3.2 key entities and services from the Mobile Multimedia scenario as well as the required SLA functionality to provide the services to the other entities, are shown. Each entity represented interacts with identified SLA functionalities to perform the services they provide. A simple one-to-one correspondence between SLA functionalities and agent types is shown in figure 3.24. In order to show high level interaction between scenario agents and the SLA agents, two sections of the Mobile Multimedia scenario have been chosen. The first part chosen is the first paragraph as follow:

"Wednesday, September 1st 2020, 6.15 am, wake-up call from the Residential Personal Assistant (RPA). Before John gets up, he asks the RPA to display the latest technology figures from the Tokyo stock market highlighting M'tech industry value and also to deliver world and top news (both political and main economical indicators) via the audio system and on a small part of the screen. Whilst walking to the bathroom the RPA detects John's movement and transfers both video and audio display through the hall to the display in the bathroom".

Second part chosen is the second paragraph of the scenario:

"Having the news update and the latest developments about technology stocks (share prices, movements, tendencies etc), John starts having breakfast and requests (using the voice recognition in the RPA) a video call to the hotel room of his fiancée. After finishing his breakfast he makes his way to meet Paul. Since the call has not yet finished the call is transferred to his personal mobile assistant (PMA), the PMA then assumes the best quality mode for the transferred voice and video call and resizes the image to fit the 4 inch screen.

When John reaches his work and enters his office his PMA registers him and invokes his workspace (Personalised Workspace (PW) to start up and to update business related data between office workspace and PMA)".

Entity	Location	Services	SLA Functionality
RPA/ OA	Home/Office	• Interaction with user (request gathering and service delivery) • Document management • Personal Information Retrieval (based on user preferences) • Content adaptation • Interaction with PMA • User Profile Construction	User Application Layer (VHS, QoS, LE, MM)
PMA	User's Terminal	• Interaction with user (request gathering and service delivery) • Interaction with User's other agents (OA, RPA) • User profile construction • Profile adaptation (according to user's feedback) • Personalised information retrieval • Content adaptation	User Application Layer (VHS, QoS, LE, MM)

Table 3-6: Mapping between scenario entities and SLA entities

Key
VHS Virtual Home Service management
MM Mobility Management
QoS Quality of Service
RPA Residential Personal Assistant
OA Office Assistant
LE Location Enabler
SM Session Management
PMA Personal mobile Agent

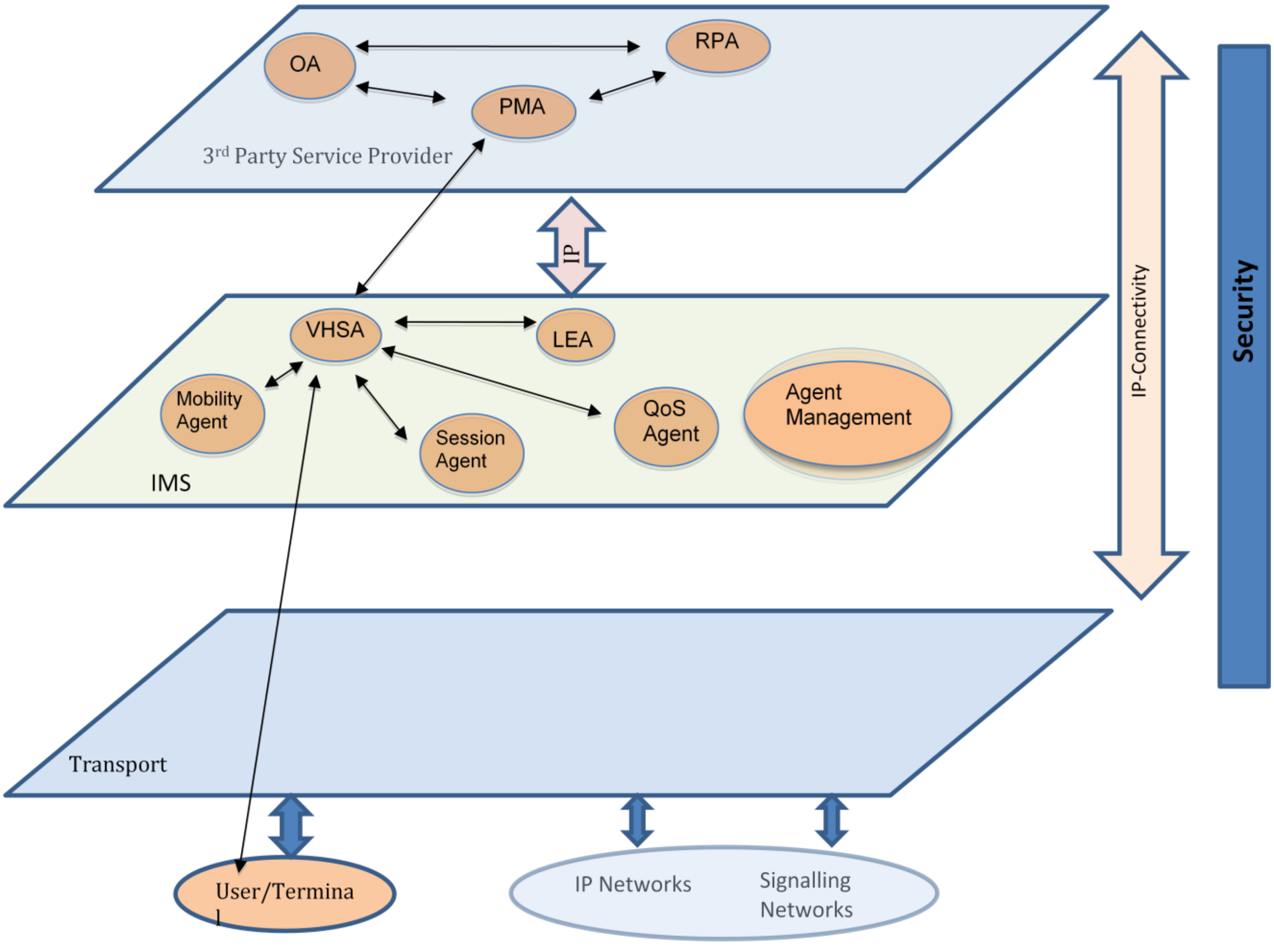

Figure 3-26: Mapping of Multimedia scenario onto SLA

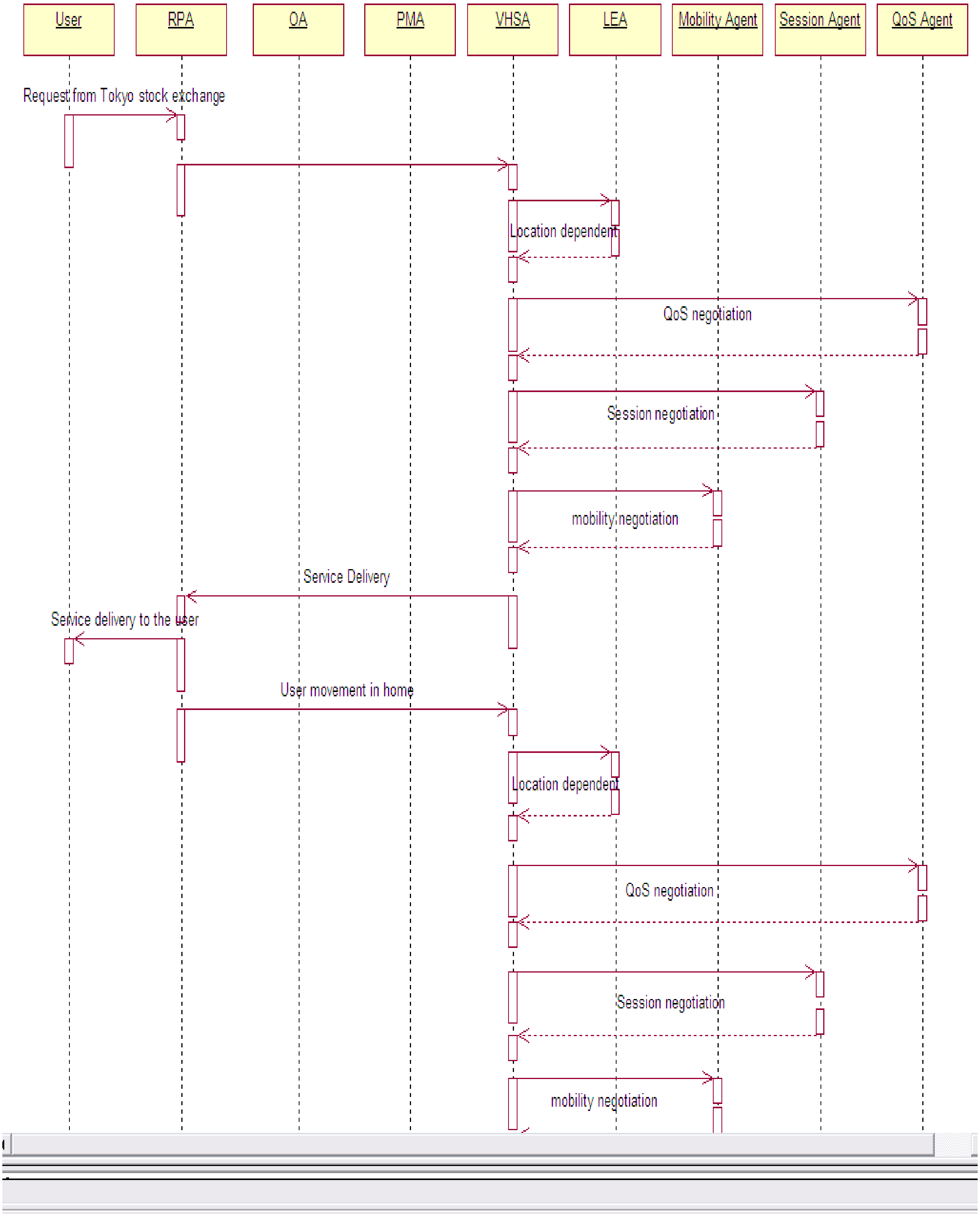

Figure 3-27 Part one (first paragraph) of the scenario

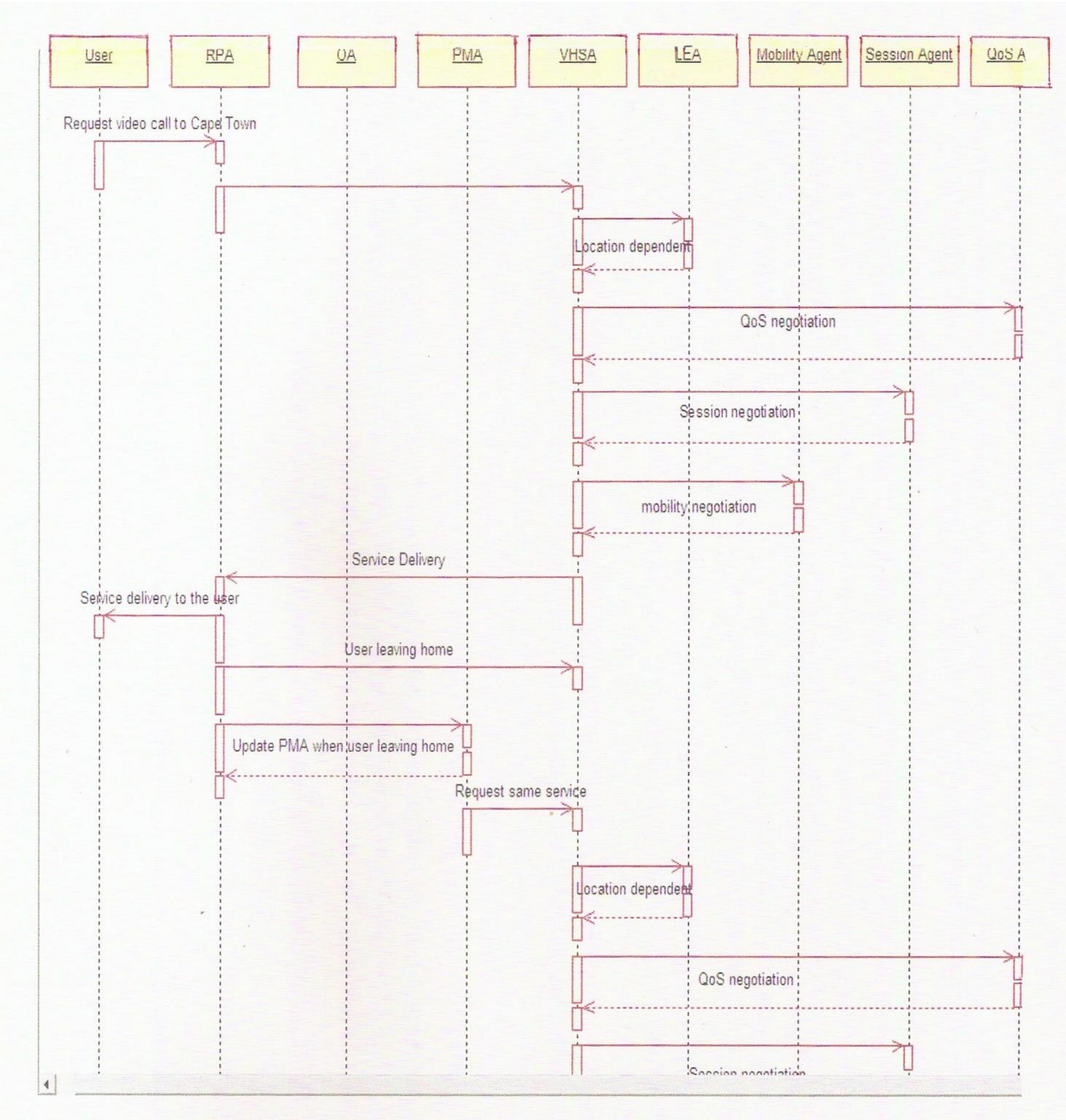

Figure 3-28 Part two (second paragraph) of the scenario

Analysis of Mobile Multimedia scenario results in identification of multitude of issues, such as terminal and personal mobility, multimedia content in mobile environment, profiling and personalization including user and device profiling. In this section we look at these technical challenges and requirements to enable partial realization of the scenario. Some of these issues such as personal mobility are the basis of research reported in this thesis.

3.7 Important Issues and Technical Challenges

Analysis of Mobile Multimedia scenario results in identification of multitude of issues, such as terminal and personal mobility, multimedia content in mobile environment, re-configurability of soft terminals and profiling and personalization including user and device profiling. In this section we look at these technical challenges and requirements to enable partial realization of the scenario. Some of these issues such as personal mobility are the basis of research reported in this thesis.

3.7.1 Terminal and Personal Mobility

Form the scenario we have identified three different states that the user requires assistance from the personal agents, at home, at elsewhere and office. The scenario begins with a call session at user's home that could be a wireless local loop. Then the user leaves home while and starts moving away from the home coverage, at this point a handover to a 3^{rd} or 4^{th} generation mobile access network is required. In the nest state the user reaches his office and another handover from 3G/4G to his work WLAN is required. Provision of a suitable handover mechanism from one wireless access standard to another is a key issue when dealing with personal and terminal mobility, a novel architecture for handover between WLAN and 3G was presented in 3.5.3.

3.7.2 Multimedia Content in Mobile Environment

Provision of multimedia content in a mobile environment necessitates satisfaction of some basic characteristics that multimedia applications require, some of these requirements are listed below:

- Processing of continuous stream of data
- Provision of QoS
- Provision of fine grained parallelism, in which the same basic rather small operations can be performed across sequences of data

- Provision of coarse-grained parallelism, in which pipe line of functions process a single stream of data
- High memory bandwidth for larger data sets
- High network bandwidth for streaming data such as video and images

In addition to the basic characteristics of multimedia systems, distributed multimedia applications running in a mobile environment have a number of special characteristics. For instance distributed multimedia applications need to be executed in a heterogeneous processing environment including mobile hosts. These applications also need mechanisms to handle rapid and massive fluctuations in the quality of service provided by the underlying communicating infrastructure. QoS control is a key requirement that needs to be addressed for the realisation of mobile multimedia systems [77].

3.8 Chapter summary

In this chapter a futuristic Mobile Multimedia Scenario, was presented and analysed to provide an insight into its potential future. The scenario describes the interaction between different assistive personal agents. This scenario covers a multitude of environments such as home, elsewhere and office. Elsewhere refers to any location when the user assumes connectivity through a mobile operator either in a metropolitan area network or when roaming. The novel contributions of this work in terms of identification of requirements and translating these requirements into system level architecture and mapping to an IMS model architecture has been explained. The challenges and mobility issues were explained and a novel new approach by introducing a new feature such as WLMSI to overcome handover constraints between two different access networks was studied.

CHAPTER 4

USER PREFERENCE MODELLING

4.1 Introduction

An agent emulator is implemented using JADE (Java Agent Development Framework) agent framework based on the analysis and design presented in 3.4. This emulator helps in requirement identification and also is used to produce experimental results, which will be presented in the next chapter. In this section first an overview of JADE is explained and finally the architecture of the implemented software is explained.

4.1.1 Overview of JADE

Constructions of agent-based systems require software tools specially designed for this purpose. JADE (Java Agent Development Framework) developed by telecom Italia, is a middleware for the development and runtime execution of peer-to-peer applications based on software agent technology, and provides this functionality for both wired and wireless environments. In JADE the distributed system topology affects how different components are linked together and the component architecture defines what the components must expect from each other. JADE allows a dynamic agent discovery each agent is identified by a unique name and the services that it provides. Agents communicate by exchanging messages based on FIPA (Foundation for Intelligent Physical Agents) specifications and ACL (Agent Communications Language). The agent platform is distributed on different machines and the configuration can be controlled via a remote GUI. The configuration can be changed at run-time by moving agents from one machine to another as and when required. A suite of graphical tools that allows administrating and monitoring the activity of running agents. Each running instance of the JADE runtime environment is called a Container as it can contain several agents. The set of active containers is called a Platform. For service discovery there is a Directory Facilitator (DF) that provides a yellow pages directory service to agents. Every agent should find an appropriate DF and request to register in order to publish its own services. For device discovery the Agent Management System (AMS) is responsible for managing the operation of an agent platform (AP) such as the creation, registration and agent mobility. The AMS maintains an index of all the agents that are registered with an agent platform. JADE architecture is shown in figure 4 below,

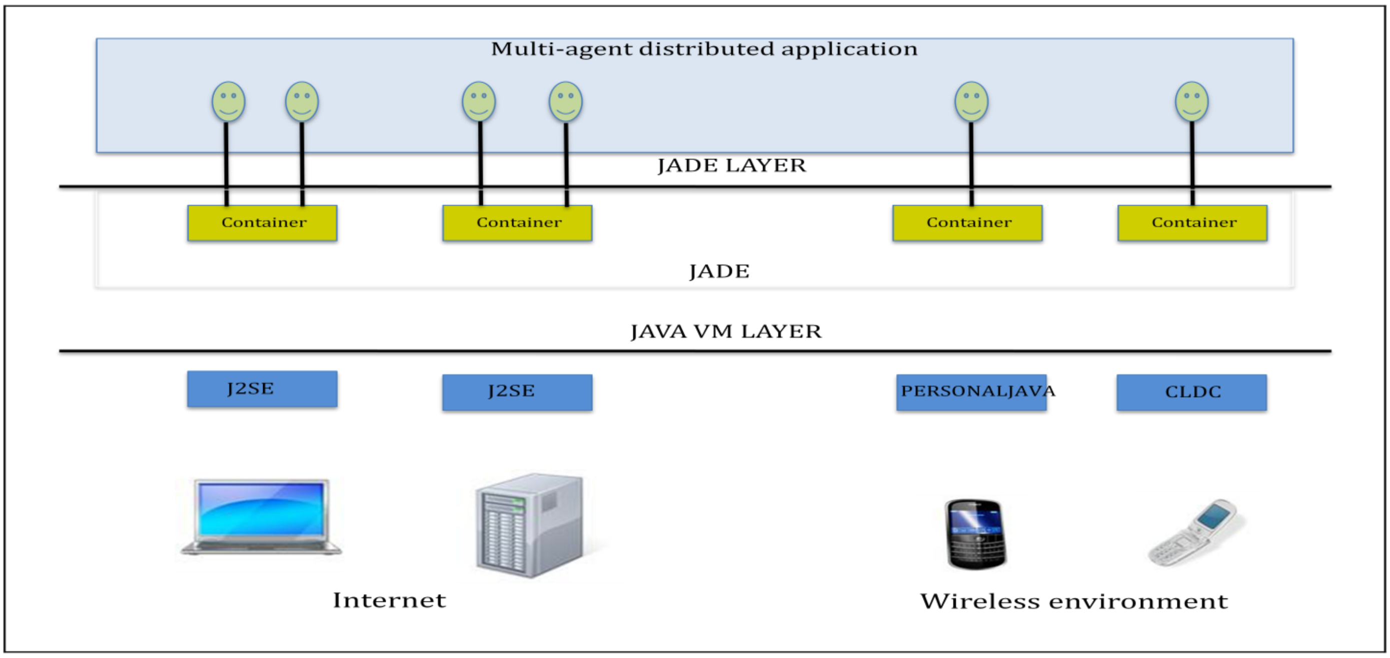

Figure 4-1: JADE Architecture

4.1.2 JADE in Mobile Environment

JADE supports a variety of lightweight devices and the only requirement is Java MIDP (Mobile Information Device Profile). In order to address the limitations of mobile devices such as processing power and memory and to take into account the characteristics of wireless networks in relation to bandwidth, latency and internet connectivity, a module called LEAP once activated "splits" a JADE container as it is shown in figure below into a front-end and a back-end part. Front-end runs on the mobile device and the back-end run in the fixed network. An element called mediator is in charge of instantiating and holding the back-ends. A mediator holds several back-ends and it is possible to activate more than one mediator according to the workload. A bi-directional connection connects each front-end to its corresponding back-end. The advantages of this technique are that part of the functionality of a container is transferred to the back-end hence reducing the required memory and processing power. If a front-end detects a loss of connection with the back-end it will re-establish the connection as soon as it becomes possible. A store-and-forward mechanism is implemented in both front-end and back-end for the messages that have not been transmitted due to a loss of connection.

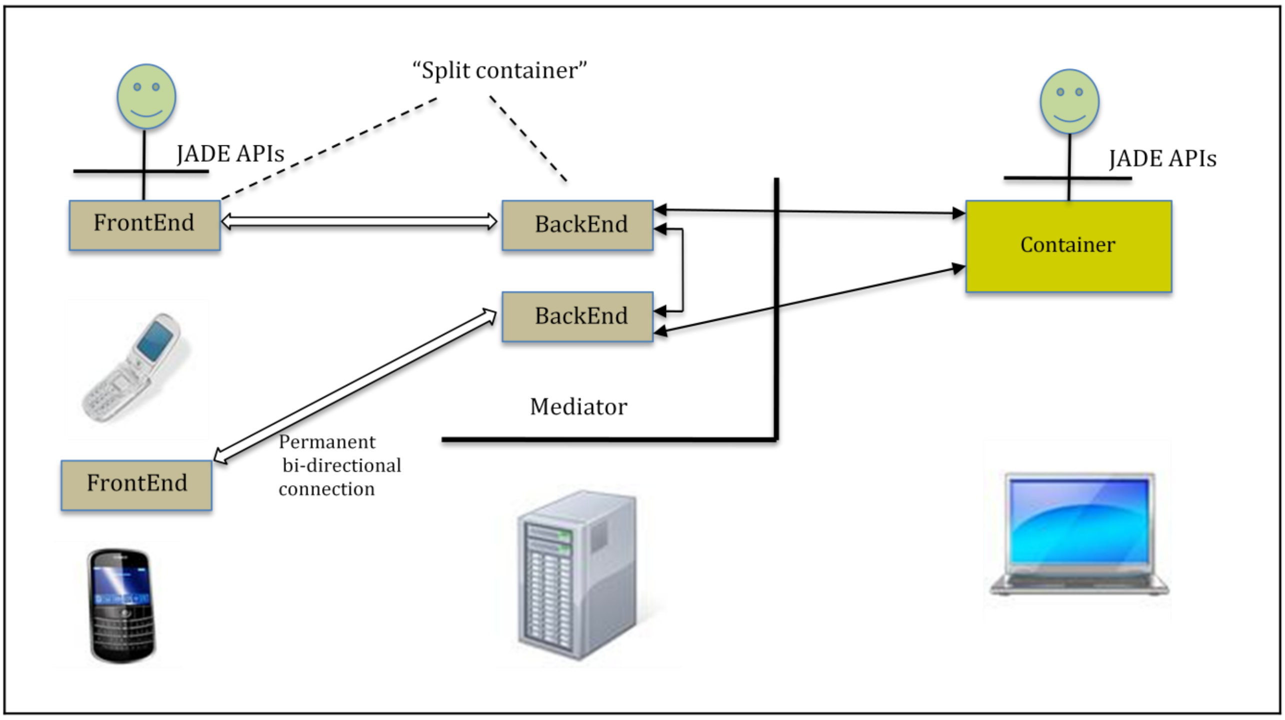

Figure 4-2: JADE Mobile environment

4.1.3 Software Architecture

Two different perspectives can be adopted when observing an agent in a multi-agent system, from inside and from outside the agent. This section is divided into two subsections according to the above view of the agents, Agents in the Agent society and Inside the Agents.

4.1.3.1 Agents in the Agent Society

The Multimedia scenario covers three different states. First, a call using audio and display facility is originated at Home. Secondly, when leaving home and travelling to work a handover to 3rd generation takes place (Elsewhere). Finally, when at the office there is another handover from 3G networks to wireless LAN of the office building and subsequently to the PW (Personal Workspace). Therefore three different states of Home, Elsewhere and Office can be distinguished in the scenario. According to the scenario, in each state a specific Personal Agent serves the user, at home the Residential Personal Agent, on the way to work Personal Mobile Agent is the active agent and at the office is the office Agent. As it can be seen each of these agents is responsible for a specific geographical area and has specific characteristic according to their tasks and resources. Despite the implementation differences, these agents have more or less the same responsibility. They are all responsible for the user's request handling, information gathering and suitable preparation of multimedia content. They are not exactly the same, because according to their resources, they are capable of different levels of service. For instance the PMA is relatively smaller software in comparison to the RPA or the OA, which are located in fixed locations.

Thus one of the technical challenges in the simulation of the multimedia scenario is the implementation of Personal Agents. Implementation of personal agents has been chosen as the main focus of the emulator. As mentioned above a user has more than one Personal Agent, so these agents must cooperate with each other to provide the user with a consistent experience. Personal agents in addition to other agents in the system form a Multi Agent system. Agent's cooperation is accomplished by negotiation between agents. In order to establish data connection between Personal agents, JADE Agent Management System has been deployed.

4.1.3.2 Inside the Agent

Three main approaches to agents architecture have been adopted, reactive, deliberative and hybrid. In reactive architectures agents make decisions based on simple situation-action rules in addition to sensory inputs. Very limited information for agents is another characteristic of reactive architectures. Fast response and robust behaviour rather than optimal behaviour is the aim of reactive architectures. In deliberative architecture, a symbolic model of the world is presented explicitly and decision-making is based on logical or pseudo-logical reasoning.

In hybrid architectures, as the name suggests, attempt to incorporate the advantages of both reactive and deliberative architectures. Hybrid agents are designed in a way that can respond rapidly to changes in the environment and also achieve long term goals. To this end, deliberative system, which is capable of directly reaching to events in the environment, are incorporated in hybrid architectures. In most hybrid architectures, sub-systems are arranged into a hierarchy. In this way, the architecture becomes a layered architecture in which different functionalities and goals are assigned to different levels. Levels are arranged in such a way that higher levels deal with information at a higher level of abstraction. Agents in this implementation are hybrid agents. The architecture in Figure 4-3 depicts a simple agent interaction with an environment. The agent senses the environment through its sensors then based on sensory input chooses an action to perform through its effectors. Messages received by the agent can make part of the sensory inputs and messages sent by the agent can perform chosen actions [93].

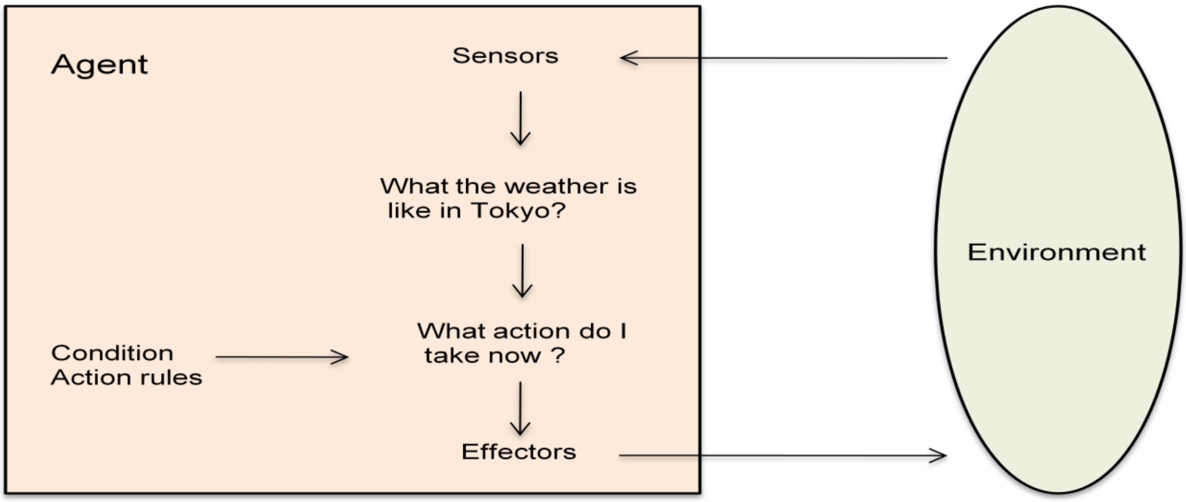

Figure 4-3: Simple agent interaction environment

Each agent has a deliberate or proactive part and a reactive part that reacts to messages. Agents respond to events that occur in the physical world and take actions when needed. There are three types of input for each agent, a piece of sensory information (1 in Figure 4-4), a message from another agent (2 in Figure 4-4), or an event defined by the agent (3 in Figure 4-4). Sensory inputs in this implementation are terminal and personal movements. User's requests can be considered as another input from the environment. Since there is no actual hardware as sensors in this emulator, all of these inputs are implemented as input files.

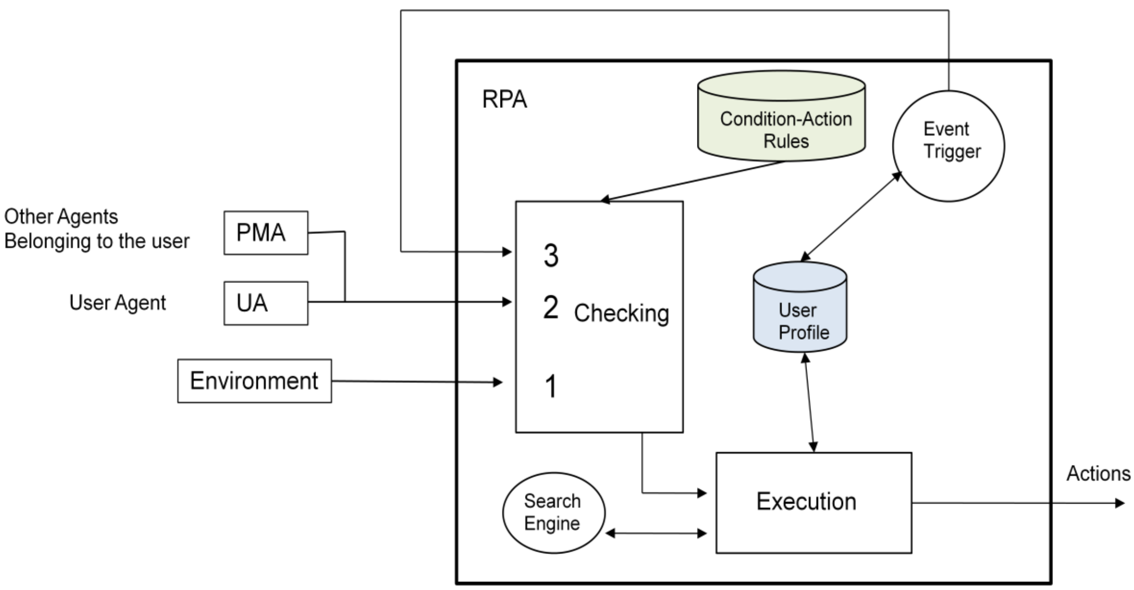

Figure 4-4: Inside Personal Agent

The checking block in the figure 4-4 compares a new input with the condition-action rules and chooses an action to be taken by the agents. The event trigger block is the proactive part of the agent. It triggers some event according to the user profile. Figure 4-5 shows inside the same agent from another point of view. There are three different interfaces with the outside world for this agent. All three interfaces are combined in one (User Agent) and implemented as the checking part in figure 4-5. The Personal Information Retriever (PIR) part uses the search engine to search for a query and then filters the information according to the user profile.

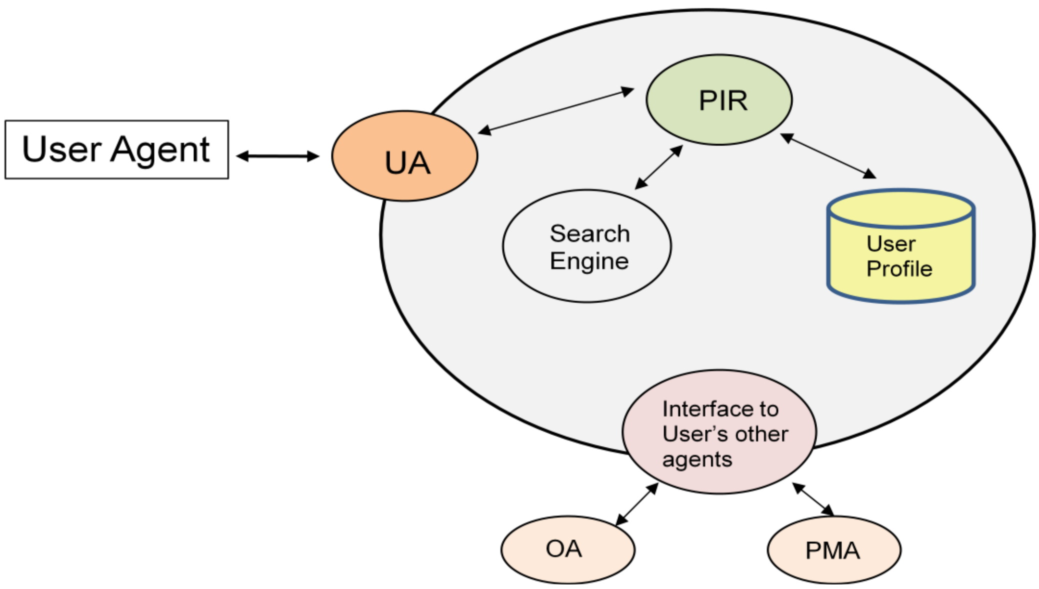

Figure 4-5: Inside Residential Personal Agent (design view)

4.2 Profiling and Personalisation

The converged and all IP networks means more and more application stores such as the Apple app store and Blackberry app store and the need for personalized services will be a real necessity. Personalized services involve issues of both terminal and service personalization. It can also be realised in aspects of both content and interface. Some of the issues to be addressed in personalization are as follows:

- User Modeling/Profiling
- Device Profiling
- User preference elicitation
- Information filtering
- Privacy

In the Mobile Multimedia scenario specifically, personalization is suggested to be realised by personal agent serving mobile user in different contexts. Personal agents and related issues, in addition to a detailed description of personalization in telecommunications and issues involved were presented in chapter 2.

4.3 User Preference Modeling

One of the valuable assets of the Telco's is the profile information and historical data that they have gathered on their individual subscribers. Many researchers are studying network and physical layer issues to maximize network performance, little work has been conducted at the opposite end of the spectrum in studying user preferences to maximize customer's satisfaction. Nevertheless many research projects have emphasized the importance of user preferences as a key criterion for the future growth of mobile communications. This chapter proposes an approach, based on a Bayesian Metanetwork, for automatic acquisition of user preferences to assist in decision making of a more suitable service based on user's preference and context.

4.3.1 Considering User Preferences in Personalised Service Selection

Many research projects have emphasised the importance of user preferences as a key criterion in service selection. Theses include the ABC concept introduced by Ericsson [94], adaptive user profiles for Software Defined Radio (SDR) introduced by IST – TRUST and consequently IST- SCOUT [95] and End-To-End (E2R) reconfiguration [96]. In a study described in [95] to identify the user requirements for SDR systems, potential users of future telecommunications services have acknowledged that consideration of user preferences in service selection, specially automatic elicitation, would improve user experience. More recently Allsop et al. [97], have introduced "adaptive user profiles" as a solution to manage the complexity of multiple network choices, location based information, varying quality of service and a range of software applications for users. Among the functionalities proposed for "adaptive user profiles" is the monitoring of user preferences. Case-based reasoning techniques are recommended in [97] to elicit and store user preferences in the adaptive user profile. Case-based reasoning is a machine learning tool technique for the automatic construction of user profiles. In machine learning techniques such as neural networks, case-based reasoning and Bayesian networks, a software agent can automatically "learn" user preferences from the user behaviour. The research reported in this thesis proposes a Bayesian approach for the automatic acquisition of user preferences to assist service selection decision-making. The Bayesian approach has been chosen because the technique has been extensively applied to preference modeling in other domains such as information retrieval and web-based applications. In addition the dynamic and uncertain nature of users' preferences suits probabilistic techniques and more specifically Bayesian networks.

4.3.2 Bayesian Networks

Making decisions under uncertainty is a problem that is a reality in many real world problems. "The Bayesian network formalism was invented to allow efficient representation of, and rigorous reasoning with, uncertain knowledge"[98]. Bayesian networks can be applied in virtually unlimited applications and domains such as diagnosis, forecasting, automated vision, sensor fusion and manufacturing control. They "Now dominate AI research on uncertain reasoning" [98]. A Bayesian network consists of a directed acyclic graph (DAG) with the set of variables and conditional probability tables (CPTs) of $P(A|B_1, ...B_n)$, associated with each variable.

Bi terms are parents of A and each variable has a finite set of mutually exclusive states [99]. The joint probability of the variables can be calculated by the chain rule for Bayesian networks as follows:

$$P(A_1, \ldots, A_n) = \prod_{i=1}^{n} P(B_1, B_2, ...B_n) \tag{4.1}$$

Each Bayesian network has two parts, qualitative and quantitative. Bayesian network structure including nodes and arcs construct the qualitative part of a Bayesian network where as conditional probability tables are the quantitative part of the Bayesian network. The structure of the Bayesian network itself can answer questions on dependence between variables. The most common task to be performed with Bayesian networks is probabilistic inference. This inference can be defined as follows:

$$P(X_i, \ldots, X_j) = \sum_{k \neq i,j} P(X_i, X_j, X_k) \tag{4.2}$$

X_j is a set of observed variables. They are also called information variables [100] or predictive attributes [101]. Xi represents a set of hidden variables for which we are interested in calculating probabilities. They are also called hypothesis variables [100] or target attributes [101]. Observation of hypothesis variables is either impossible or too costly. X_k are mediating variables. These variables are introduced for a special purpose. For instance they can be introduced to facilitate the acquisition of conditional probabilities.

In the Bayesian approach to statistics, the goal is to reduce the amount of uncertainty in an inferential or decision making problem by utilizing all available information. Inferential statistics, which address inferential problems, draw conclusions or make predictions on the basis of immediate data. Statistical decisions, in addition to making inferential statements, go one step further by using the available information to choose among a number of alternative actions. The formal way to combine new information as it is obtained with all previously known information is known as the Bayes' theorem [102]. Thomas Bayes British mathematician presented Bayes' theorem, which is mathematically expressed as follows:

$$P(H \mid E,C) = \frac{P(H \mid C)P(E \mid H,C)}{P(E \mid C)} \qquad (4.3)$$

Using the Bayes' theorem we can update our belief in hypothesis H given an additional evidence E and the background context C. P(H|E,C) represents the posterior probability of the hypothesis given the evidence P(E|H) is the likelihood of the evidence given the hypothesis. P(H) represents the prior probability of the hypothesis and P(E) is the normalizing constant.

Bayesian networks have several advantages for data analysis. First, Bayesian networks can handle situations where some data is missing. This is due to the fact that model encodes the dependencies among the variables. Secondly, Bayesian networks can be used to gain understanding of a problem domain. The reason for this is that Bayesian networks can be used to learn causal relationships. Thirdly, a Bayesian network is an ideal representation for combining prior knowledge and data. This is due to the fact that the model has both a causal and probabilistic semantic [103].

4.3.3 Bayesian Metanetwork

A Bayesian Metanetwork consists of a set of Bayesian networks, organized on levels one above the other in a way that conditional or unconditional probability distributions associated with nodes of the probabilistic network on one level depend on probability distributions associated with the nodes of the network on the next level [101]. The Bayesian Metanetwork can expressed mathematically as a triplet:

$$MBN = (BN, R, P), \qquad (4.4)$$

where BN = {BN_1, BN_2, ...BN_n) is a set of Bayesian networks,

R = {$R_{1,2}$, $R_{2,3}$, ...$R_{n-1, n}$) represents a set of sets of interlevel links and P is a joint probability distribution over the Metanetwork.

$R_{i,i+1}$ defines the interlevel links between level I and level i+1. Terzian et.al. propose two types of links [104]:

1- $R_{v,e}$ is a "vertex – edge" link in which stochastic values of vertex $v_{i,k}$ in the network BN_1 correspond to different conditional probability tables $P_k(V_{i-1,j} | V_{i-1,pj})$ in the network BN_{i-1}.

2- R_{v-v} is a "vertex-vertex" link in which stochastic values of vertex $v_{i,r}$ in the network BN_i correspond to the different relevance values of vertex $v_{i-1,r}$ in the network BN_{i-1}.

Two types of Bayesian Metanetworks can be defined based on the above distribution in interlevel links: C-Metanetwork and R-Metanetwork. A C–Metanetwork (Conditional dependencies Metanetwork) is a Bayesian Metanetwork for managing conditional dependencies and has interlevellinks of the R_{v-e} type, on the other hand an R-Metanetwork (Relevance Metanetwork) is a Bayesian Metanetwork for slecting a subset of the relevant features of the target concept and has interlevel links of the R_{v-v} type [105]. Figure 4.6 represents example of a c-Metanetwork projected on 2D space.

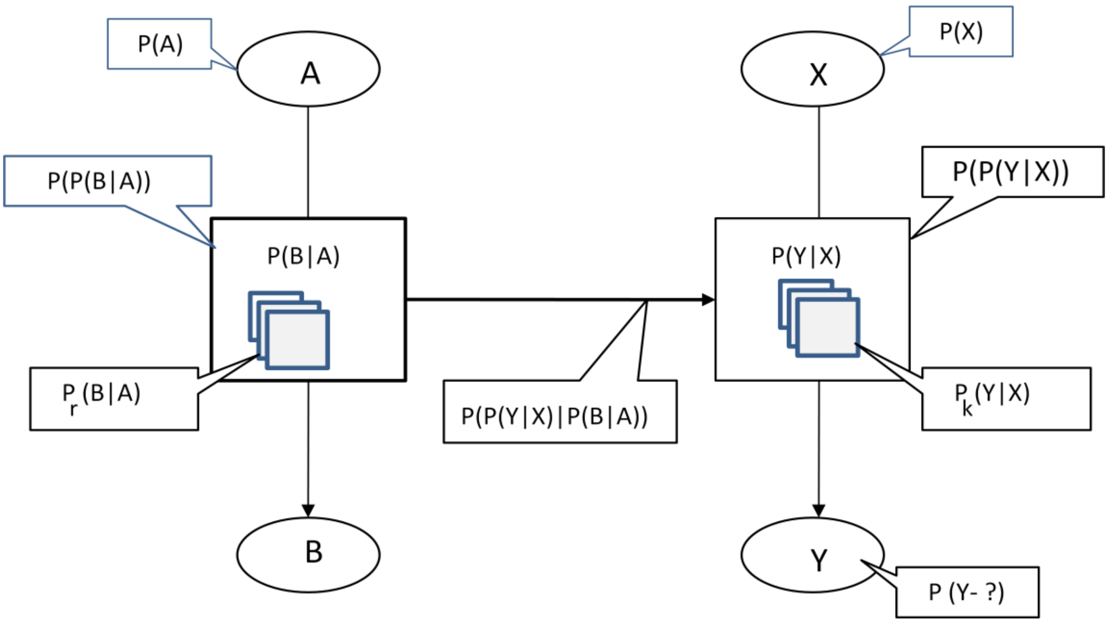

Figure 4-6: A C-Metanetwork projected on 2-D space [12]

A and B in figure 4-1 are contextual variables on the second (contextual) level to manage the conditional probabilities associated with X and Y on the first (predictive) level of the network.

4.4 Preference Model

When choosing the “best” service for the user a number of parameters such as the application, network and physical layer constraints, available access networks, accessibility, the capability of devices and security constraints as well as user preferences must be taken into account. On the other hand a non-technical person looks at this problem from a completely different perspective. They evaluate the service offerings subjectively in terms of parameters such as cost and quality. In a similar manner this chapter studies preferences for service selection from the user point of view. Consideration of technical limitations and any requirements imposed by the network, application, device or otherwise are not the subject of this study. It is assumed that more than one service provider is available to the user and the user can make a choice based solely on his/her preferences in terms of cost and quality of service that each service provider offers as well as the reputation of each service provider. The proposed model does not make the decision as to which service provider user should select rather it provides information on user preferences to decision units such as the service selector depicted in figure 4-7.

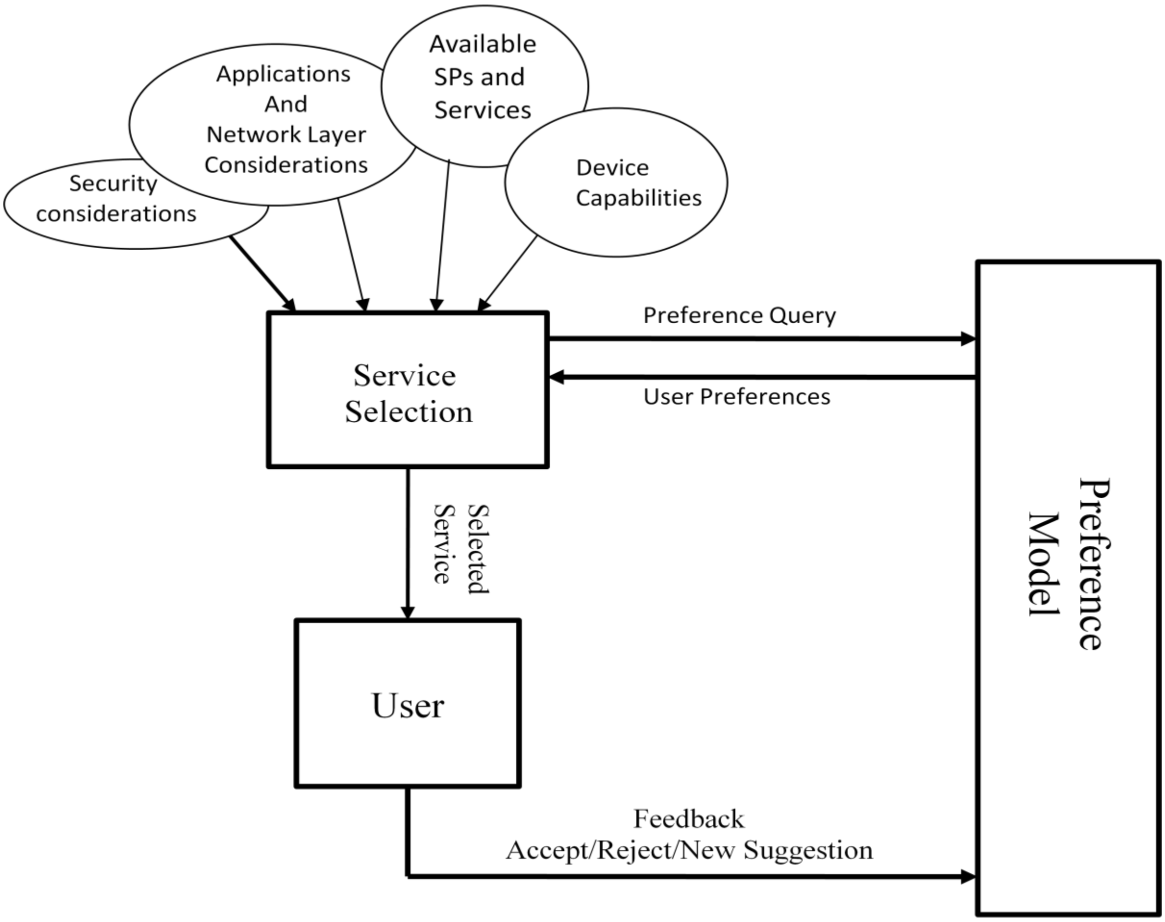

Figure 4-7: Interaction between Preference Model, Service selector and User

In this way the service selector can consider user preferences in addition to other decision parameters such as application and network layer considerations, security issues, device capabilities when making a decision. The service selector and preference model are proposed here as separate entities since the service selector might be located in the network, either centrally or as a distributed entity, whereas the preference model is located within the user's terminal. Furthermore, since the preference model is subject to change as user preferences change over time, it is easier to update the preference model as a separate entity rather than updating the decision making process in service selector. In this approach the preference model can be part of the user's Personal Agent, the software agent providing personalised assistant. The service selector interaction with the Personal Agent consists of the following sequence until a decision is reached:

1. Service selector consults Personal Agent about user preferences
2. Personal Agent provides priority list of user preferences
3. Service selector selects the "best" service considering the priority list

After the user has received the network service, he/she provides feedback for the Personal Agent from which it learns the user experiences satisfied and adapts the preference model to the new successful experience. In modeling user preferences the nature of these preferences must be considered. User preferences are user’s beliefs of what is better than the other. This interpretation suits the Bayesian view of the probability that interprets probabilities as the “degree of belief” about events in the world and data is used to strengthen, update or weaken these degrees of belief. Bayesian networks are used for decision making under uncertainty. The uncertainty in the service selection problem domain comes from four aspects. First, the users have individual preferences in terms of affordable cost, acceptable quality of service and other selection parameters. Secondly, preferences of a single user might change over time. Thirdly, users make different tradeoffs between service selection parameters. For instance, one user might value reputation statistics greatly and choose a high profile service provider even with a higher price, and another user might not trust reputation statistics and choose the less expensive offer regardless of the service provider’s rating. Finally, user preferences in terms of cost and quality of service vary depending on the current user context. As an example, a user might value quality of service regardless of cost in the business context, but the sane individual might want to minimize the cost without considering the quality of service in a leisure context.

4.5 A Two Level Bayesian C-Metanetwork

The proposed model is a two level Bayesian C-Metanetwork as depicted in the figure 4-8.

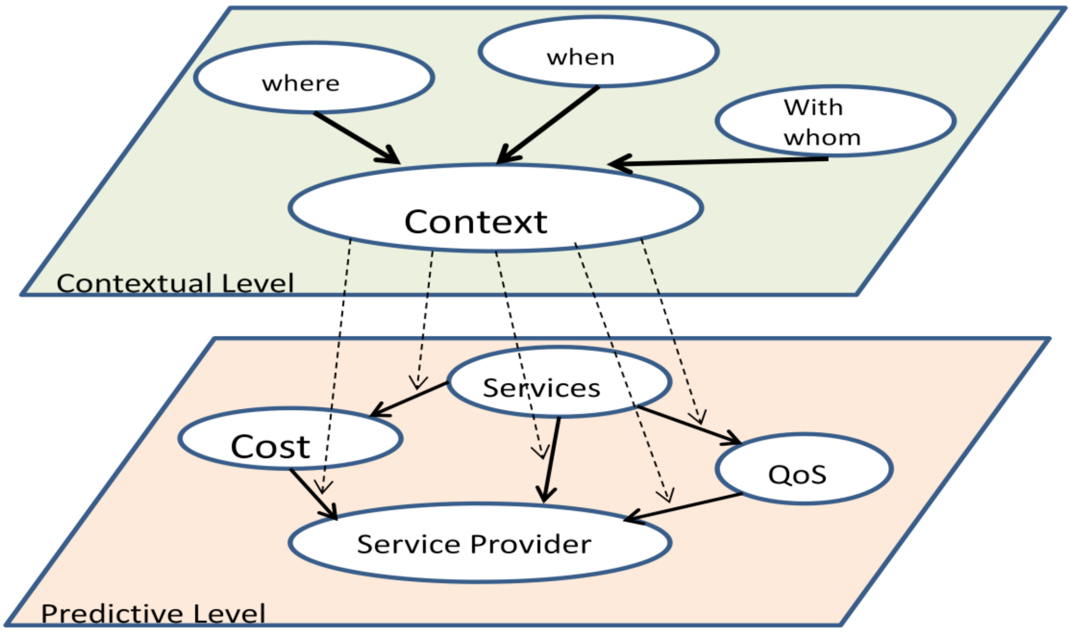

Figure 4-8: Bayesian C-Metanetwork for user preferences model

The Bayesian network on the first, predictive, level has four nodes: service, cost, QoS and one node for Service provider. Based on the causal relationship between these variables the Bayesian network on the first level is designed as shown in the figure above. A Personal Agent can use this BN to provide a real time estimate of user preferences in selecting a service provider, cost and QoS for given services. To model such a Bayesian network it is assumed that the, information available to the system is modeled by the observed nodes of service, cost and QoS.

One node has been assigned to the service provider, however, it is possible to split this node into separate nodes based on the way the relationship between entities such as the network operator and the service provider is defined in the business model. For instance, if the subscription model allows the user to subscribe to more than one network operator, then we can add network operator as a node.

Rather than having continuous values for nodes, which increases the complexity of the probability update techniques, discrete values such as “high” and “low” are chosen for each node’s state. For discrete variables of nodes, the conditional probability distribution can be written as a table, which includes the probability that the child node takes for each combination of values of all parent nodes. Prior probabilities of the parent nodes as well as the conditional probabilities of the child nodes are needed to fully introduce the Bayesian network. In other words, we need probability assessments of P(service), P(cost | service), P(QoS | service) and P(service provider | service, cost, QoS), which are conditional probability tables (CPT) for service, cost, QoS and service provider nodes respectively. The initial values for the CPTs of the Bayesian network can be assigned based on expert opinion or the statistics, which network operators, accumulate in their databases.
CPTs of Bayesian network on the predictive level are illustrated in figure 4-9.

Service Usage

video call	0.6
web browsing	0.15
file download	0.25

Cost Affordability

Service	video call	web browsing	file download
low	0.038933	0.355403	0.336835
high	0.253292	0.41349	0.474131
very high	0.707775	0.231107	0.089033

Acceptable QoS

Service	video call	web browsing	file download
Ok	0.017176	0.113631	0.075676
good	0.149089	0.434114	0.241017
Very good	0.833734	0.452255	0.683308

Service Provider Reputation

Service	video call									web brow
QoS	ok			good			very good			ok
Cost	low	high	very high	low	high	very high	low	high	very high	low
service provider1	0.531	0.172	0.61	0.633	0.128	0.089	0.154	0.036	0.58	0.694
service provider2	0.155	0.469	0.057	0.258	0.571	0..087	0.145	0.694	0.061	0.092
service provider3	0.16	0.172	0.719	0.054	0.123	0.735	0.551	0.253	0.097	0.107

Figure 4-9: Conditional probability tables of the Bayesian network on the predictive level

Table 4-1: P_1(QoS|service) acceptable QoS in leisure context

P_1(QoS|service)	Service 1	Service 2	Service 3
OK	80%	70%	35%
Good	20%	30%	65%

Table 4-2: P_2 (QoS|service) acceptable QoS in Business context

P_2(QoS|service)	Service 1	Service 2	Service 3
OK	10%	20%	10%
Good	90%	80%	90%

Therefore, the Bayesian network on the contextual level is designed to manage the complexity of different probability tables in each context. Bayesian Metanetworks has been proposed in [105] for modeling the link between contextual and predictive variables in mobile environments but for web filtering applications. Similarly, context variables on the second level of the proposed model, in this chapter, control the conditional probabilities on the predictive level. As an example, Figure 5-4 shows the context node on the contextual level of the model can control conditional probabilities of the QoS node on the predictive level.

Assume S= $\{S_1, S_2 .... S_n\}$ is the service node with n_s states, C = $\{C_1, C_1, ... C_n\}$ is the context node with n_c states and Q is QoS node. The conditional dependence attribute between S and Q can be written as:

$$P(Q \mid S) = \{P_1(Q \mid S), P_2(Q \mid S), ... P_r(Q \mid S)\} \quad (4.5)$$

$P(P(Q \mid S) \mid C)$ can be defined as conditional probability between context node and P(Q|S) which have been defined in (4.5).

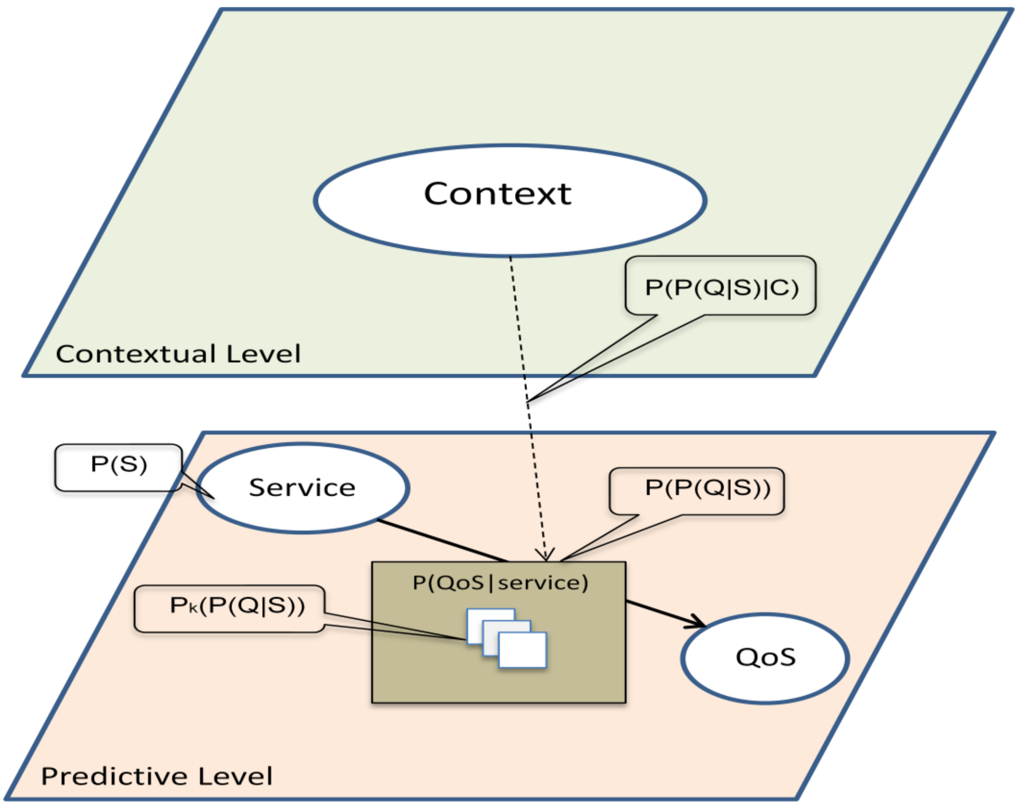

Figure 4-9: Context effect on conditional probability of QoS node

Table 4-3 illustrates an example of conditional dependence between context node and P(Q|S) where r $= n_c = 3$

P(P(Q|S)|C)	Context 1	Context 2	Context 3
$P_1(QoS)$	10%	4%	92%
$P_2(QoS)$	5%	90%	3%
$P_3(QoS)$	85%	6%	5%

Table 4-3: Conditional dependence between context nodes and conditional probability P(QoS|service).

In the next section features of the proposed model including the reasoning algorithm are explained.

4.6 Features of the Model and Reasoning Algorithm

A personal agent incorporating the proposed model applies a “causal” or “top-down” algorithm, which means having evidence from specific causes, which state is most likely to be chosen. This approach is first used on the contextual level of the proposed model to identify the context and then on the predictive level to find the most probable SP, cost and QoS. When a user requests a service, the location, time and communicating counterpart of the user can be identified through the network, the terminal clock and address book respectively. Then the Bayesian network on the contextual level has to find the most probable context based on the parameters identified as follows:

$$C_m = \underset{C}{\mathrm{ArgMax}}(P(C \mid WR = WR_i , WN = WN_j, WM = WM_k)) \qquad (4.6)$$

Where WR, WN and WM represent “where”, “when” and “with whom” node respectively, as shown in figure 4-8.

The user has the chance to specify the context explicitly. After selecting the context through the model or receiving it from the user, the CPTs related to this context are chosen on the predictive level. Having the evidence of a specific demand of service in the identified context, we can then find which service provider, cost and QoS are more likely to be chosen.
In addition to the query explained above, this model can provide answers to other preferred related queries, which may be summersied as follows:

- How much is the affordable cost for this service in this context?
- What is the acceptable level of quality of service for this service in this context?
- What are the acceptable QoS, affordable cost and most preferred SP for this service in this context?

- Which of the offered choices of cost, QoS and SP are most preferable for this user in this context?

The above queries can be classified in four groups of cost affordability queries, quality of service related queries, reputation related queries, a combination of the three and comparison queries. Each of them is discussed in the following sections.

4.6.1 Affordable Cost

Having the evidence of a particular demand of service, this model can find affordable cost for the given service in the context identified from the individual user point of view. Assuming that $T = \{T_1, T_2 \ldots\ldots\ldots\ldots T_n\}$ is a cost node with n states then, in order to find which price range (T_1) the user can afford in the identified context (C_m), to calculate

$\underset{T}{\text{ArgMax}} (P(T \mid S = S_n, C = C_m))$ by following these steps:

1. Find $\underset{P(T|S)}{\text{ArgMax}} (P (P(T \mid S) \mid C = C_m))$
2. Assuming that the result of step 1 is $P_q (T|S)$, refer to CPT of $P_q (T \mid S)$ to find $\underset{T}{\text{ArgMax}} (P(T \mid S = S_n))$

In the conditional probability table of cost nodes on the predictive level, if the probability of state T_2 is greater than the probability of state T_1 and assuming that $T_1 < T_2$, then this means that this user has had more satisfied experiences in the price range T_2 so the user can afford T_2. Since cost affordability might be dissimilar in different contexts, for each context a cost CPT has been defined. The context node on the contextual level indicates which CPT to choose as mentioned in step 1 and 2. This model can also adapt to the change of affordable cost. As an example the model can adapt to change of preferences for a user who is willing to pay more than before. I

4.6.2 Acceptable QoS

The model can answer queries related to the acceptable level of quality of service for each service from a user point of view by referring to the QoS CPT. Assuming that QoS node $Q = \{Q_1, Q_2 \ldots\ldots Q_{nq}\}$ has n_q states, we need to find:

$\text{ArgMax} (P(Q \mid S = S_n, C = C_m))$ by following these steps similar to those for the affordable cost queries above,

1. Find $\text{ArgMax} (P (P(Q \mid S) \mid C = C_m))$

$P(Q|S)$

2. Assuming that the result of step 1 is $P_u(Q|S)$, refer to CPT of $P_u(T | S)$ to find $\underset{Q}{\text{ArgMax}}\,(P(Q | S = S_n))$

4.6.3 Reputation of Service Provider

When a user requests a service, and provides a desired cost and QoS explicitly and more that one service provider can provide the requested service with the desired cost and QoS requirements, the decision to choose a service provider is based solely on the user's past experiences with each service provider, that is the reputation of the service provider from the individual user point of view. Therefore, service, cost and QoS will be considered as evidence and we calculate:

$$N_r = \underset{N}{\text{ArgMax}}\,(P(N|S=S_i, Q=Q_j, T=T_k, C=C_m))$$

Where N represents a service provider node. This can be calculated by the following steps:

1. Find $\underset{P(N|S,Q,T)}{\text{ArgMax}}\,(P(P(N | S,Q,T) | C = C_m))$
2. Assuming that the result of step 1 is $P_w(N|S,Q,T)$, refer to CPT of $P_w(N|S,Q,T)$, to find the $\text{ArgMax}(P(N|S=S_i,Q=Q_j,T=T_k))$

The service provider conditional probability table, shown in figure 4-3, stores the priority list of service providers. A higher value in this table shows that this has been chosen more frequently, so is more preferable. This table can be initialized based on statistics of service provider performance and then adapted according to the individual user's experience or, in case of no access to reputation statistics, the model can be initialized with equal values for all service providers and then adapted based on user experience.

4.7 Chapter Summary

In this chapter a test bed based on Java Agent Development Framework (JADE) and the related Agents and their construction in the system was discussed. A User Preference Model based on Bayesian Metanetwork was introduced and features of the model were described.

CHAPTER 5

SIMULATION AND RESULTS

5.1 Introduction

For the simulation the prior probabilities of the nodes on the contextual level are initialized based on a number of experiments in a user scenario. Prior probabilities of the service node in addition to conditional probabilities of cost and QoS nodes on the predictive level are initialized based on expert opinion. The interlevel link between contextual and predictive levels also needs to be defined. Then the model is trained and tested with different sets of data in order to evaluate performance of the model in terms of the proportion of correct predictions on test data. Test and training data are produced based on the decisions a sample user makes among a set of random choices. The performance of the model is evaluated in terms of the proportion of correct predictions on test data during the learning process. The learning technique applied in this simulation in addition to each step of the simulation process, is explained in detail in the following chapter.

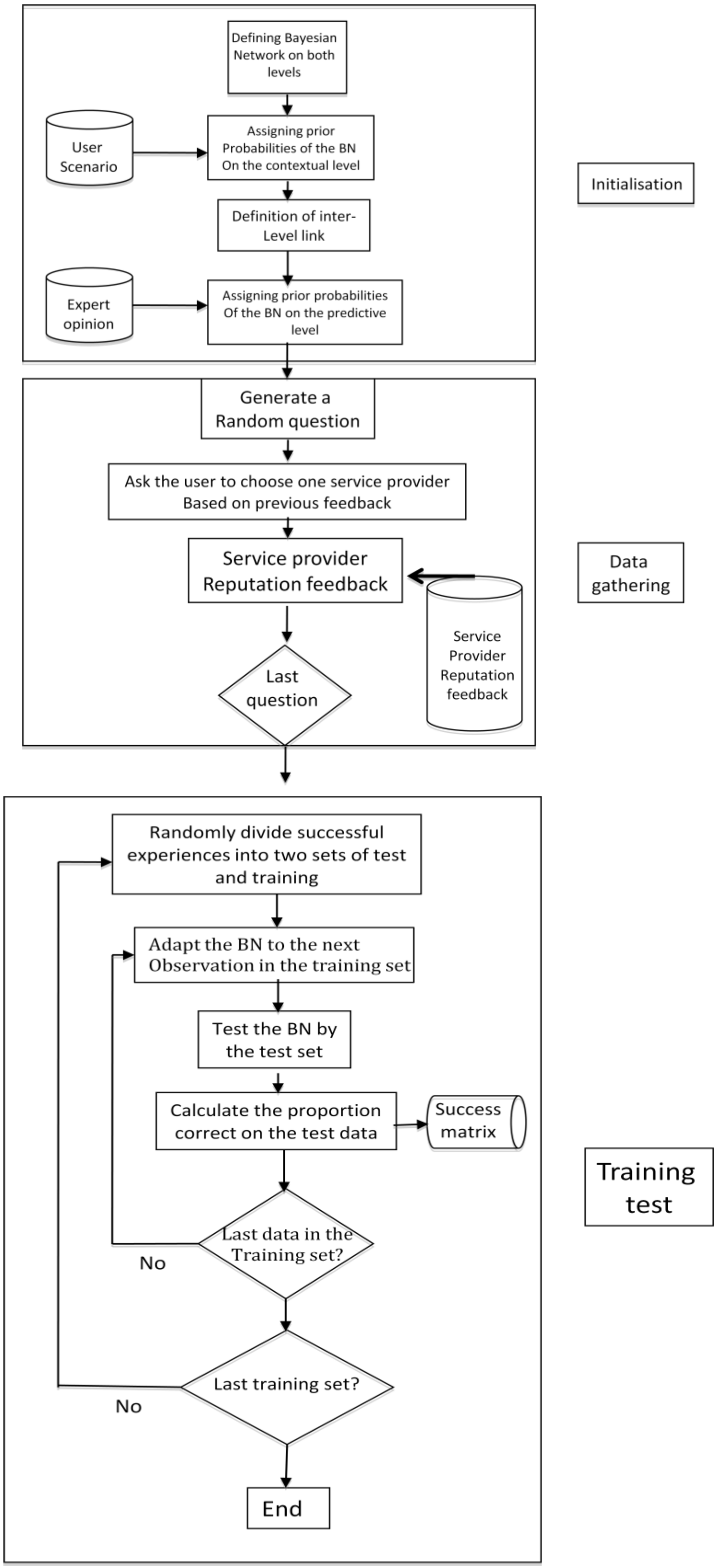

Figure 5-1: Simulation flowchart

5.2 Learning Technique

Learning for a Bayesian network includes learning the topology as well as parameters of the network. In this simulation we made the assumption that the structure of the network is known and training data were used to learn the parameters, which are the conditional probability tables CPTs of the Bayesian networks. Since we do not have access to the operator's statistics, sets of experiences have been assumed as training data for both predictive level and contextual level. Then based on the training data initial values of conditional probability tables associated with each node of the Bayesian networks on both levels are calculated. For instance, given sufficient statistics, the maximum Likelihood Estimate of the CPT for the "Context" node on Contextual level can be calculated as:

$$P(Context = C_i \mid where = wr_e, when = wn_e, with-whom = wm_e) \approx N(Context = C_b \; where = wr_e, when = wn_e, with-whom = wm_e) / N(where = wr_e, when = wn_e, with-whom = wm_e) \quad (5.1)$$

The values stored in all CPTs are always subject to change when the Bayesian network "learns" a new experience, after the initialisation of the CPTs. The adaptation process can also reduce the gap between the model and the real world, when the experts cannot agree upon the quantitative part of the Bayesian network, CPTs initialisation, or when the training data is not satisfactory.

5.2.1 Bayesian networks on the Contextual level

Prior probabilities of the nodes on the contextual level are initialized based on a number of experiments in a user scenario. For each telecommunications service in the scenario, a number of parameters are stored for application to the training of the Bayesian network on the contextual level. These parameters include location, time and the name of the communication counterpart as well as the context in which communications take place.

#	Scenario snapshot	When	Where	Whom	Context
1	Morning calling fiancé	Non-working hours	Home	Family	Leisure
2	Calling colleague	Non-working hours	Home	Colleague	Business
3	Continue the call	Non-working hours	Outdoor	Colleague	Business
4	Continue the call in the car	Non-working hours	Car	Colleague	Business
5	Business call in the car	Non-working hours	Car	Colleague	Business
6	Arriving at the office	Working hours	Office	Colleague	Business
7	Calling a family member	Working hours	Office	Family	Leisure
8	Business meeting	Working hours	Office	Colleague	Business
9	Calling a friend	Working hours	Office	Friend	Leisure
10	Calling a friend at lunch	Working hours	Outdoor	Friend	Leisure
11	Calling a family member at lunch	Working hours	Outdoor	Friend	Leisure
12	A call from a colleague at lunch	Working hours	Outdoor	Colleague	Business
13	Business call	Working hours	Office	Colleague	Business
15	Business call	Non working hours	Office	Colleague	Business
16	Business call	Non working hours	Office	Colleague	Business
17	Call from family member	Non working hours	Office	Family	Leisure
18	Going back home	Non working hours	Outdoor	Friend	Leisure
19	Going back home	Non working hours	Outdoor	Colleague	Business
20	Going back home	Non working hours	Car	Family	Leisure
21	Going back home	Non working hours	Car	Friend	Leisure
22	Business call at home	Non working hours	Home	Colleague	Business
23	Calling a family member at home	Non working hours	Home	Family	Leisure
24	Calling a friend	Non working hours	Home	Friend	Leisure

Table 5-1: First day of the user scenario, applied on the first set of training data on the Contextual level

The learning algorithm is a maximum likelihood method as explained in the previous section. As the result of the conditional probability table will show, when the user is at home in non working hours and calling a family member, she is in a leisure context with very high probability, or if she is in the office at working hours communicating with colleagues, she is in a business context with very high probability.

5.2.2 The Inter-Level Link

After the definition of the Bayesian network on the contextual level, we need to define the inter-level link between the contextual and predictive level. The inter-level link in this simulation is defined in 5-2, however it is possible to initialize it with other distributions.

$P(QoS \mid service)$

P(P(Q|S)|C)	Context 1	Context 2
$P_1(Q \mid S)$	100%	0%
$P_2(Q \mid S)$	0%	100%

Table 5-2a: Conditional dependence between context node and conditional probability

P(cost|service)

P(P(T|S)|C)	Context 1	Context 2
$P_1(T \mid S)$	100%	0%
$P_2(T \mid S)$	0%	100%

Table 5-2b: Conditional dependence between context node and conditional probability

P(servive provider|service,cost,QoS)

P(P(N|S,T,Q)|C)	Context 1	Context 2
$P_1(N \mid S,T,Q) \mid C)$	100%	0%
$P_2(Q \mid S,T,Q)$	0%	100%

Table 5-2c: Conditional dependence between context node and conditional probability

5.2.3 Bayesian networks on the Predictive level

In this section the simulation process and results related to the Bayesian networks on the predictive level are reported.

5.2. 3.1 Prior Probabilities

Prior probabilities of service nodes in addition to conditional probabilities of cost and QoS nodes on the predictive level are initialized by a sample user as shown in table 4-6, if these probabilities are not defined very accurately, they would be updated to more accurate probabilities in the process of learning. Conditional probabilities of the service provider node, based on the states of parent nodes, are initialized with equal values for all providers, because the user has not had any experience yet with any of the service providers. The prior values are shown in the tables below.

P_1(service)	
Service 1	0.4
Service 2	0.25
Service 3	0.35

Table 5-3: P_1(service) Prior probability of service node in Leisure context

P_2(service)	
Service 1	0.6
Service 2	0.2
Service	0.2

Table 5-4: P_2(service) prior probability of service node in Business context

P_1(QoS|service)	Service 1	Service 2	Service 3
OK	80%	70%	35%
Good	20%	30%	65%

Table 5-5: P_1(QoS|service) acceptable QoS in leisure context

P_2(QoS|service)	Service 1	Service 2	Service 3
OK	10%	20%	10%
Good	90%	80%	90%

Table 5-6: P_2 (QoS|service) acceptable QoS in Business context

P_1(cost|service)	Service 1	Service 2	Service 3
Low	85%	80%	40%
High	15%	20%	60%

Table 5-7: P_1 (cost|service) Affordable cost in Leisure context

P_2 (cost|service)	Service 1	Service 2	Service3
Low	20%	40%	10%
High	80%	60%	90%

Table 5-8: P_2 (cost|service) Affordable cost in Business context

5.3 Learning Curve

After assigning prior probabilities, the model must be trained by new experiences to become adapted to the preferences of the individual user. Then, in order to evaluate the performance of the proposed model, the number of correct predictions of unseen examples needs to be measured. To this end, the following algorithm is applied.

1. A large set of data is gathered
2. Data is divided into two sets: training and test data
3. Learning algorithm is applied to each experience in the training set
4. Proportion of correct predictions compared to test is measured
5. Steps 2-3 are repeated for all experiences in the training set
6. Step 2-5 are repeated for five different training and test sets

in order to simulate the performance of the chosen service provider for the provision of the requested service with its promised cost and quality, a random success rate is generated based on the probabilities in table 5-12 below.

Service	Service Provider 1	Service Provider 2
Service 1	80%	20%
Service 2	20%	90%
Service 3	60%	80%

Table 5-9: Service provider success rate

When answering the first few questions, the user chooses a service provider almost randomly but based on the performance he/she receives, user adapts the selection. The user might remember previous unsuccessful experiences and change the service provider based on that. Satisfied cases were gathered and stored.

The first few cases were discarded because user decisions were random. In order to achieve robustness the data were divided into a training group and a test group in five different ways. One of the training data sets and the corresponding test set is shown in table 4-8 part a and b. other data sets are included in the appendix A. The number of training data varies from 0-30 and the number of test data is 10 in all tests. A maximum-likelihood learning method has been applied in this simulator as the learning algorithm.

Services	QoS	Cost	Service Provider
Service 1	Good	Low	SP1
Service 1	Good	Low	SP1
Service 2	Ok	High	SP2
Service 3	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 1	Ok	High	SP1
Service 1	Good	High	SP1
Service 3	Good	Low	SP2
Service 3	Good	Low	SP2
Service 1	Ok	High	SP1
Service 3	Good	High	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2
Service 2	Ok	Low	SP2
Service 3	Good	Low	SP2
Service 2	Ok	Low	SP2
Service 2	Ok	Low	SP2
Service 3	Ok	Low	SP2
Service 3	Ok	Low	SP2
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 1	Ok	High	SP1
Service 2	Ok	High	SP2
Service 1	Good	High	SP1
Service 1	Good	High	SP1
Service 1	Good	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2

Table 5-10a; Training data set 1

Services	QoS	Cost	Service Provider
Service 1	Ok	Low	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 3	Ok	High	Sp2
Service 2	Ok	Low	SP2
Service 2	Ok	High	SP2
Service 1	Ok	Low	SP1

Table 5-10-b: Test data 1

The learning procedure was repeated with five data sets and the results obtained were compared as shown in figure 5-14:

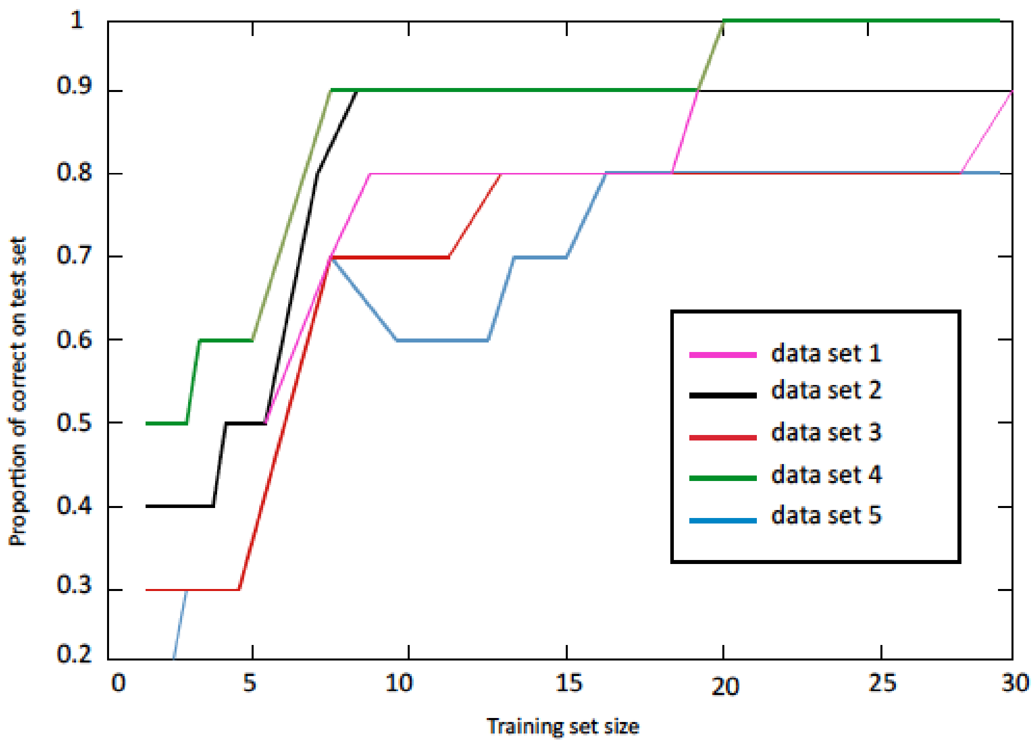

Figure 5-14: Comparison of five training data sets

The vertical axis in figure 12 shows the proportion of correct predictions when comparing test data with the prediction provided by the proposed model. This figure illustrates how the proportion of correct predictions on test data increases as the model sequentially absorbs each item in the training data. The learning curve in this figure indicates that proportion of correct preference prediction is 85% on average after just 15 training cases. These results are very promising because in modeling user preferences, the main challenge is to create as accurate a model as possible with as little information as possible.

5.4 Chapter Summary

In this chapter we have looked at the problem of 3rd party service selection from a user perspective. We have presented a model that can automatically elicit user preferences from user behaviour. User preferences are modeled based on a two level Bayesian C-Metanetwork. In our proposed model user preference for service selection are modeled in terms of Cost, QoS and service provider reputation.

CONCLUSION AND FUTURE WORK

In this thesis the service selection problem has been studied from an end user point of view. User preferences for services vary from one individual to another. Users, depending on their circumstances have different preferences for the service provider, cost and QoS. They have different cost affordability and might prefer one operator to another based on their past experiences. More importantly each user has a different preference in different contexts. A business trip context is very different to a holiday or leisure time context in pertaining the choice of services utilised. Therefore user preferences can change according to the time of the day or situation or location they are in and for a non-technical user to decide on an optimal service is a difficult decision to make however, a personal software agent located at the user terminal can manage this task. The agent assists the user in making a decision when selecting a service according to the user's preferences and experiences. In this work, the objectives included design and development of a model for automatic acquisition of user preferences, proposing an IMS based network architecture for a personalised seamless service delivery and service continuation. Furthermore the preference differences between different contexts must be considered in this model.

The personalisation problem in general and also in mobile telecommunications in particular is studied in this thesis. The definition and classification of personalisation problem are discussed. Personalisation applications have been classified into four generations namely web personalisation, e-commerce, mobile services and personalisation in physical space. This study is directed towards the third generation of personalisation applications. World Wide Web consortium (W3C) has been studied as the oldest standardisation body for personalisation. Virtual Home Environment (VHE), which is a personalisation-enabling infrastructure defined by 3rd Generation Partnership Project (3GPP), is discussed as the first efforts towards personalisation of mobile services. This thesis believes that the complexity of personalisation in telecommunications and its multi-dimensionality is the result of a variety of devices, access technologies, 3rd party service providers, user interests and preferences and finally variety of contexts. Therefore, personalisation efforts benefit by defining which dimension of personalisation they are addressing.

Since web personalisation is the most studied area of research in personalisation, different approaches to web personalisation, in addition to existing web personalisation techniques, have been studied as a guide through personalisation in telecommunications. User modeling is discussed as one of the main technical challenges. Some of the machine learning techniques applied in user modeling are discussed. Software agent technology is also discussed as an enabling technology. Personal assistant agents have been specifically studied as the main focus of this study.

Since the main aim of personalisation is improving, user's experience, user scenario gains special importance in personalisation projects. User scenarios are, however, the starting point of many research projects in the telecommunications domain because of the futuristic vision of most projects in this domain and in order to visualize the potential future. In this thesis the Mobile Multimedia scenario, was analysed in order to identify the technical requirements. Gaia, which is an agent oriented software methodology, has been applied for the analysis of the scenario. A system level architecture, that supports personal mobility when roaming between two different access networks is discussed and an innovative solution of WLMSI (Wireless LAN Mobile Subscriber Identity) based on an IMS architecture, which facilitates the vertical hand over between two access technologies of WLAN and 3G was analysed.

Assisting users in selecting the most suitable service is discussed in this thesis. The service selection problem has been defined and different criteria for making the selection decision have been studied. This thesis proposes an approach for automatic acquisition of user preferences to assist the user in service selection decision-making. In this approach user preferences are modeled in terms of cost, QoS and reputation of the service provider. The proposed model is based on the idea of the Bayesian Metanetwork. Applying a hierarchical structure of Bayesian networks can model the impact of the user's context on his/her preferences. The structure of the model in addition to the interactions between the proposed model incorporated in a personal agent. The proposed model can provide answers to the preference related queries to the service selection entity, which selects the "best" service. Queries that this model can provide answers to, are cost affordability, acceptable QoS queries and also queries related to the reputation of a service provider. Each of these features of the model as well as algorithms applied for calculations are fully elaborated in the thesis.

The proposed model can incorporate a fading factor as a parameter of how to forget old experiences. A proper value of fading factor can improve the learning ability of the model in the case of non-persistence in user preferences. Simulation results, in the form of a learning curve illustrates how the proportion of correct predictions on test data increases as the model sequentially learns each item in the training data. The learning curve indicates that proportion of correct preference predictions is 85% on average after 15 training cases. The proportion of correct predictions is calculated by comparing test data with the prediction provided by the proposed model. These results are very promising because in modeling user preferences, the main challenge is to create accurate a model as possible with as little information as possible. The literature on user perspectives of service selection is very limited, therefore this contribution maybe considered as an important step forward.

Future Work

The research reported in this thesis can be continued in three main directions namely personalisation and user scenarios, recommendation of personalised services and mobility management in terms of vertical and horizontal hand over in wireless networks.

- Definition of personalisation in mobile telecommunications as a multi-disciplinary field of research. Personalisation needs further work at the definition level. The literature lacks good review and introductory papers to lay the foundation of the research in this field. In addition to that, since this area of research is multi-disciplinary, the interaction between different disciplines would be enhanced, if high level review papers were provided these type of research would depict the bigger picture for researchers indifferent fields.

- Development of emulators or prototypes installed on the handsets for qualitative evaluation. Users can provide feedback on the level of their satisfaction regardless of the technical performance measurements.

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Appendix A

Training Data Sets

In this appendix five different training data sets used in chapter 5 are presented.

Services	QoS	Cost	Service Provider
Service 1	Good	Low	SP1
Service 1	Good	Low	SP1
Service 2	Ok	High	SP2
Service 3	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 1	Ok	High	SP1
Service 1	Good	High	SP1
Service 3	Good	Low	SP2
Service 3	Good	Low	SP2
Service 1	Ok	High	SP1
Service 3	Good	High	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2
Service 2	Ok	Low	SP2
Service 3	Good	Low	SP2
Service 2	Ok	Low	SP2
Service 2	Ok	Low	SP2
Service 3	Ok	Low	SP2
Service 3	Ok	Low	SP2
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 1	Ok	High	SP1
Service 2	Ok	High	SP2
Service 1	Good	High	SP1
Service 1	Good	High	SP1
Service 1	Good	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2

Training data – data set 1

Services	QoS	Cost	Service Provider
Service 1	Ok	Low	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 3	Ok	High	Sp2
Service 2	Ok	Low	SP2
Service 2	Ok	High	SP2
Service 1	Ok	Low	SP1

Test data 1

Services	QoS	Cost	Service Provider
Service 1	Good	Low	SP1
Service 1	Good	Low	SP1
Service 2	Ok	High	SP2
Service 3	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 1	Ok	High	SP1
Service 1	Good	High	SP1
Service 3	Good	Low	Sp2
Service 3	Good	Low	SP2
Service 3	Ok	Low	SP2
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 1	Ok	High	SP1
Service 2	Ok	High	SP2
Service 1	Ok	Low	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 3	Ok	High	SP2
Service 2	Ok	Low	SP2
Service 2	Ok	High	SP2
Service 1	Ok	Low	SP1
Service 1	Good	High	SP1
Service 1	Good	High	SP1
Service 1	Good	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2

Training data- data set 2

Services	QoS	Cost	Service Provider
Service 1	Ok	High	SP1
Service 3	Good	High	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2
Service 2	Ok	Low	SP2
Service 3	Good	Low	SP2
Service 2	Ok	Low	SP2
Service 2	Ok	Low	SP2
Service 3	Ok	Low	SP2

Test data 2

Services	QoS	Cost	Service Provider
Service 1	Good	Low	SP1
Service 1	Good	Low	SP1
Service 2	Ok	High	SP2
Service 3	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 1	Ok	High	SP1
Service 1	Good	High	SP1
Service 3	Good	Low	Sp2
Service 3	Good	Low	SP2
Service 1	Ok	High	SP1
Service 3	Good	High	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2
Service 2	Ok	Low	SP2
Service 3	Good	Low	SP2
Service 2	Ok	Low	SP2
Service 2	Ok	Low	SP2
Service 3	Ok	Low	SP2
Service 3	Good	High	SP2
Service 3	Ok	High	SP2
Service 2	Ok	Low	SP2
Service 2	Ok	High	SP2
Service 1	Ok	Low	SP1
Service 1	Good	High	SP1
Service 1	Good	High	SP1
Service 1	Good	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2

Training data – data set 3

Services	QoS	Cost	Service Provider
Service 3	Ok	Low	SP2
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 1	Ok	High	SP1
Service 2	Ok	High	SP2
Service 1	Ok	Low	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 2	Ok	Low	SP2

Test data 3

Services	QoS	Cost	Service Provider
Service 1	Good	Low	SP1
Service 1	Good	Low	SP1
Service 2	Ok	High	SP2
Service 3	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 1	Ok	High	SP1
Service 1	Good	High	SP1
Service 3	Good	Low	SP2
Service 3	Good	Low	SP2
Service 1	Ok	High	SP1
Service 3	Good	High	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2
Service 1	Ok	Low	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 3	Ok	High	SP2
Service 2	Ok	Low	SP2
Service 2	Ok	High	SP2
Service 1	Ok	Low	SP1
Service 1	Good	High	SP1
Service 1	Good	High	SP1
Service 1	Good	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2

Training data – data set 4

Services	QoS	Cost	Service Provider
Service 3	Good	High	SP2
Service 3	Ok	High	SP2
Service 1	Ok	Low	SP2
Service 1	Ok	High	SP2
Service 1	Ok	Low	SP1
Service 1	Good	High	SP1
Service 1	Good	High	SP1
Service 1	Good	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2

Test data 4

Services	QoS	Cost	Service Provider
Service 1	Good	Low	SP1
Service 1	Good	Low	SP1
Service 2	Ok	High	SP2
Service 3	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 1	Ok	High	SP1
Service 1	Good	High	SP1
Service 3	Good	Low	Sp2
Service 3	Good	Low	SP2
Service 3	Ok	Low	SP2
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 1	Ok	High	SP1
Service 2	Ok	High	SP2
Service 1	Ok	Low	SP1
Service 1	Ok	Low	SP1
Service 2	Ok	Low	SP2
Service 1	Ok	High	SP1
Service 2	Ok	Low	SP2
Service 3	Good	High	SP2
Service 3	Ok	High	SP2
Service 2	Ok	Low	SP2
Service 2	Ok	High	SP2
Service 1	Ok	Low	SP1
Service 1	Good	High	SP1
Service 1	Good	High	SP1
Service 1	Good	Low	SP1
Service 2	Ok	Low	SP2
Service 2	Good	High	SP2

Training data- data set 5

Services	QoS	Cost	Service Provider
Service 3	Ok	High	SP2
Service 3	Good	High	SP2
Service 1	OK	Low	SP2
Service 1	OK	Low	SP2
Service 1	OK	High	SP1
Service 1	OK	Low	SP1
Service 1	Good	High	SP1
Service 1	Good	Low	SP1
Service 2	Good	Low	SP2
Service 2	Ok	High	SP2

Test data 5

Appendix B

Simulation of the System Architecture

CHOICE OF SIMULATION SOFTWARE

We were faced with quite a few choices of simulation software for conducting traffic analysis and choosing the best fit for availability and efficiency was not an easy task. The first issue was that of emulation versus simulation. Roughly speaking, emulation involves one computer system behaving as another system in a network and in this way different subsystems might be interconnected in order to observe the behaviour pattern and traffic characteristics of the entire configuration. However keeping in view the diversity of the different types of the nodes which were to be employed, and the size of the network, this approach was discarded in favour of simulating the entire network traffic behaviour on a single platform device.

Another option was to simulate the application creation on IMS platform using Ericsson SDS Developer Studio, which is a Java based environment for creating customized applications for the IP Multimedia Subsystem. However this approach was dropped because the application would be made for the Ericsson customized solution and exposure to integration of the individual IMS components would not be obtained.

From among the different Network Simulators widely used, such as Netsim, NS2, OPENT IT Guru , OPNET Modeler and QuickSim, two softwares QuickSim and OPNET were shortlisted as they had the capability of modelling both UMTS and wireless networks. QuickSim was difficult to procure and the student academic version of IT Guru provide insufficient for simulating UMTS.

Consequently OPNET Modeler Wireless Suite v14.5 with an additional UMTS model licence was attained from the OPNET website using the University research Program.

SIMULATION SETUP

Our simulation in OPNET was planned out in three distinct stages. Stage one involved the successful implementation of a WLAN network topology in OPNET and getting the results for a successful simulation and was part of our primary goals. Stage two would involve WLAN IMS and UMTS connectivity in a single network and the next aim was to be able to model our innovative handover scheme and observe the cost benefits it would be able to bring in terms of improved seamlessness.

SCENARIO 1 SIMULATION OF VOIP CALL IN THE IMS NETWORK

For the purposes of the simulation we simulated a VOIP call in the WLAN using the IP Multimedia subsystem. We simulated the P-CSCF, I-CSCF and the S-CSCF functionality in the WLAN based on the SIP-IMS model defined in [33] in order to make a SIP call from the WLAN Workstation to a remote IP Phone. Below is the scenario for the IMS based call from the WLAN workstation to the IP phone using the SIP protocol.

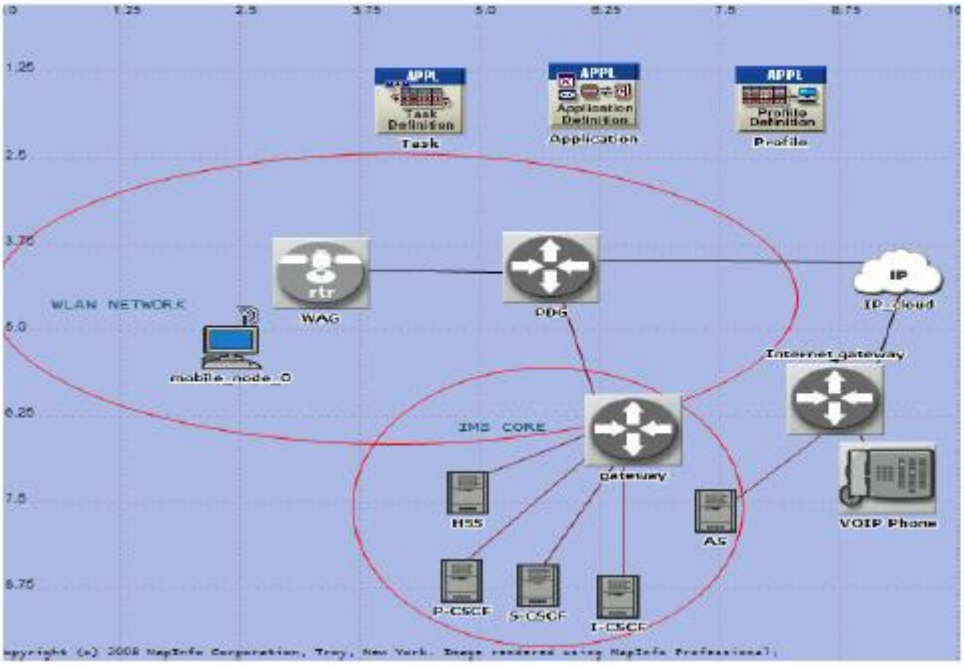


Figure 5.1 OPNET Simulation scenario for the implementation of a VOIP application over IMS WLAN

Figure 5.2 OPNET Simulation scenario for the implementation of a VOIP application over WLAN SIP

The Application profile was based on standard VOIP communications and was based on the parameters given in the following screenshot.

Attribute	Value
Silence Length (seconds)	(...)
Talk Spurt Length (seconds)	(...)
Symbolic Destination Name	Voice Destination
Encoder Scheme	G.729 A
Voice Frames per Packet	2
Type of Service	Interactive Voice (6)
RSVP Parameters	None
Traffic Mix (%)	All Discrete
Signaling	SIP
Compression Delay (seconds)	0.02
Decompression Delay (seconds)	0.02
Conversation Environment	(...)

VoIP application profile

The AP and the WAG are built into a single node for the purposes of the simulation only.

Since the OPNET modeler does not allow the back to back connection of SIP servers, the CSCF are connected to each other via a gateway to allow intercommunication. The control plane call flow for session establishment was implemented in the OPNET CSCF node models.

Attribute	Value
name	Profile
⊟ Profile Configuration	(...)
Number of Rows	1
⊟ profile1	
Profile Name	profile1
⊟ Applications	(...)
Number of Rows	1
⊟ VOIP call	
Name	VOIP call
Start Time Offset (seconds)	constant (5)
Duration (seconds)	exponential (120)
⊟ Repeatability	(...)
Inter-repetition Time (secon...	exponential (300)
Number of Repetitions	Unlimited
Repetition Pattern	Serial
Operation Mode	Simultaneous
Start Time (seconds)	constant (100)
Duration (seconds)	End of Last Application
⊟ Repeatability	(...)
Inter-repetition Time (seconds)	constant (300)
Number of Repetitions	Unlimited
Repetition Pattern	Serial

VoIP repeatability profile

RESULTS AND ANALYSIS

The simulation was conducted for one hour. For both of the simulation scenarios we collected the following network parameters

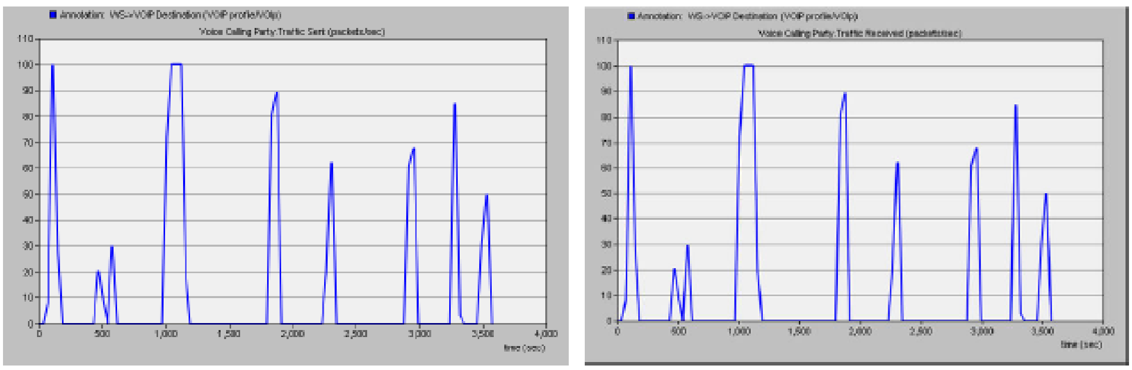
□□Traffic Sent and Received on the Calling Party

□ Traffic Sent and Received on the Called Party

□ Traffic Sent and Received on the Application Server

□ Overall network throughput and Delay

The results for the VOIP call simulation over OPENT are given below



Calling party sent traffic and calling party received traffic in the network without IMS

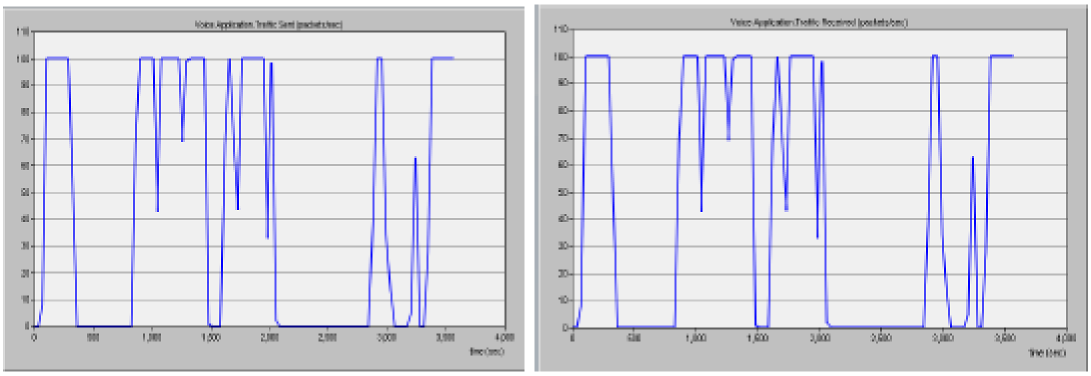


Figure Calling party sent traffic and calling party received traffic for network with IMS

The presence of sent and received traffic on the calling party indicates that the communication was successfully established. Multiple VOIP calls have been configured in
this model. As we can see the general trend is for longer durations of connectivity in the IMS case which is due to additional IMS signalling

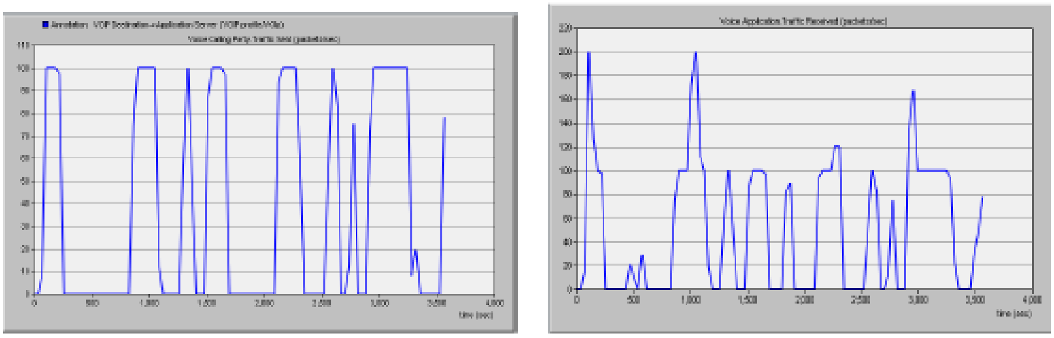


Figure Called party sent traffic and calling party received traffic for the network without IMS

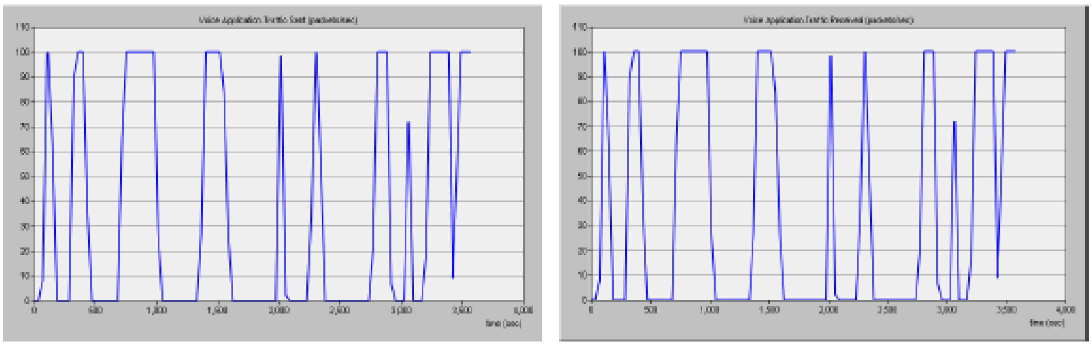


Figure Called party sent traffic and calling party received traffic for the network with IMS

The called party sent and received traffic is shown in the above figures. The called party in this case is a VOIP phone which Is connected to the internet and not under the influence of the IMS subsystems for session establishment. Received traffic has slightly become flatter although the sent traffic is the same , however this can not be attributed to the IMS.

Traffic sent and received at the Application Server

WLAN throughput and delay
WLAN throughput and delay

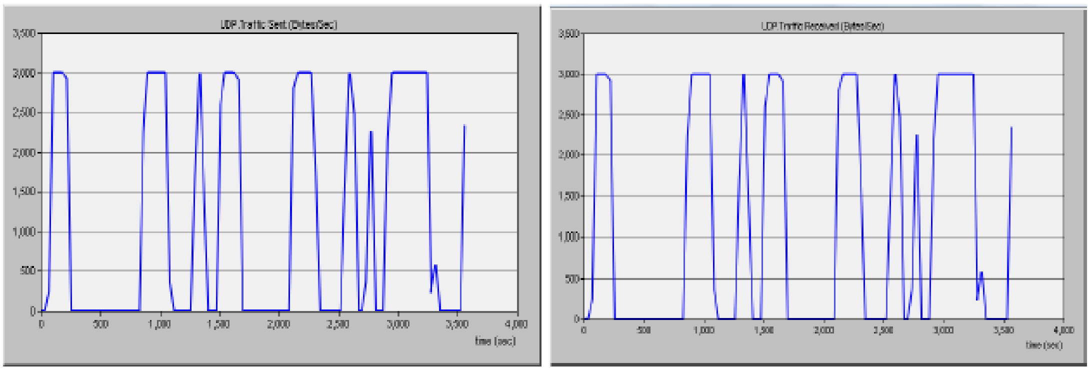


Figure SIP Application server sent and received traffic for the network without IMS

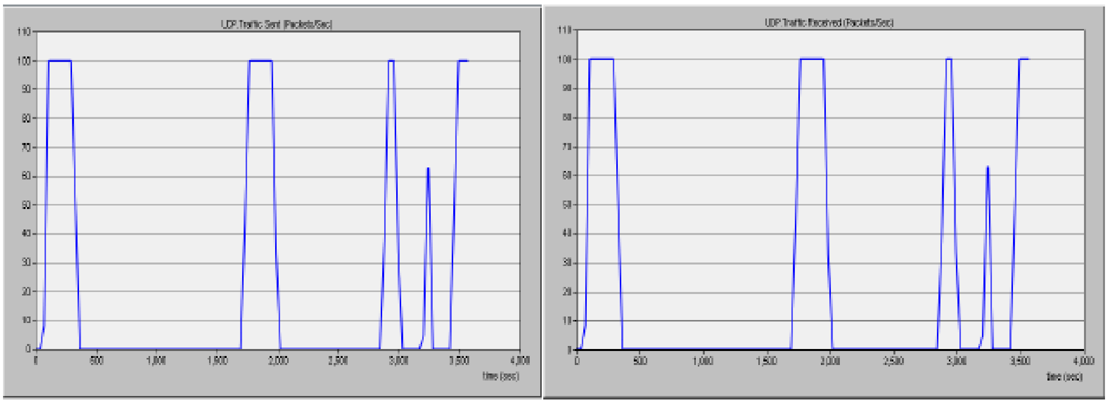


Figure SIP Application server sent and received traffic for the network with IMS

WLAN throughput and delay

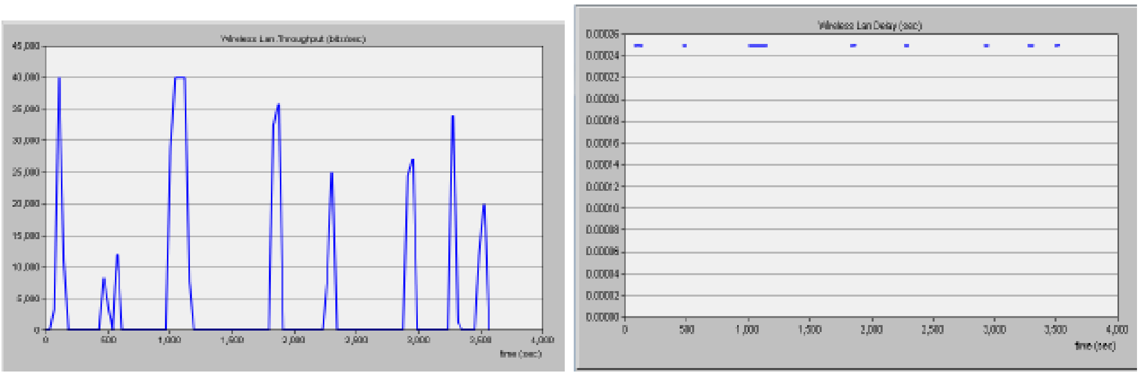


Figure WLAN throughput and delay for the network without IMS

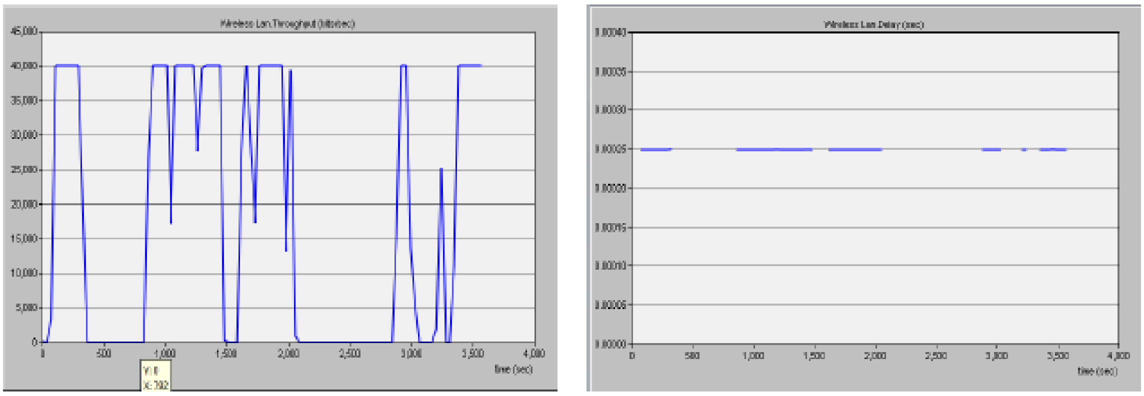


Figure WLAN throughput and delay for the network with IMS

From the above graphs it is clear that the IMS signalling does not have any extra load on the traffic to cause network congestion or delays. However it must be noted that only SIP functionality was implemented. The increase in the WLAN throughput duration is simply indicative of the extra IMS signalling which is going on in the network although the peak throughput has also remained the same which indicated that the IMS did not have any adverse effect on overall network performance.

Other Scenarios for the simulation

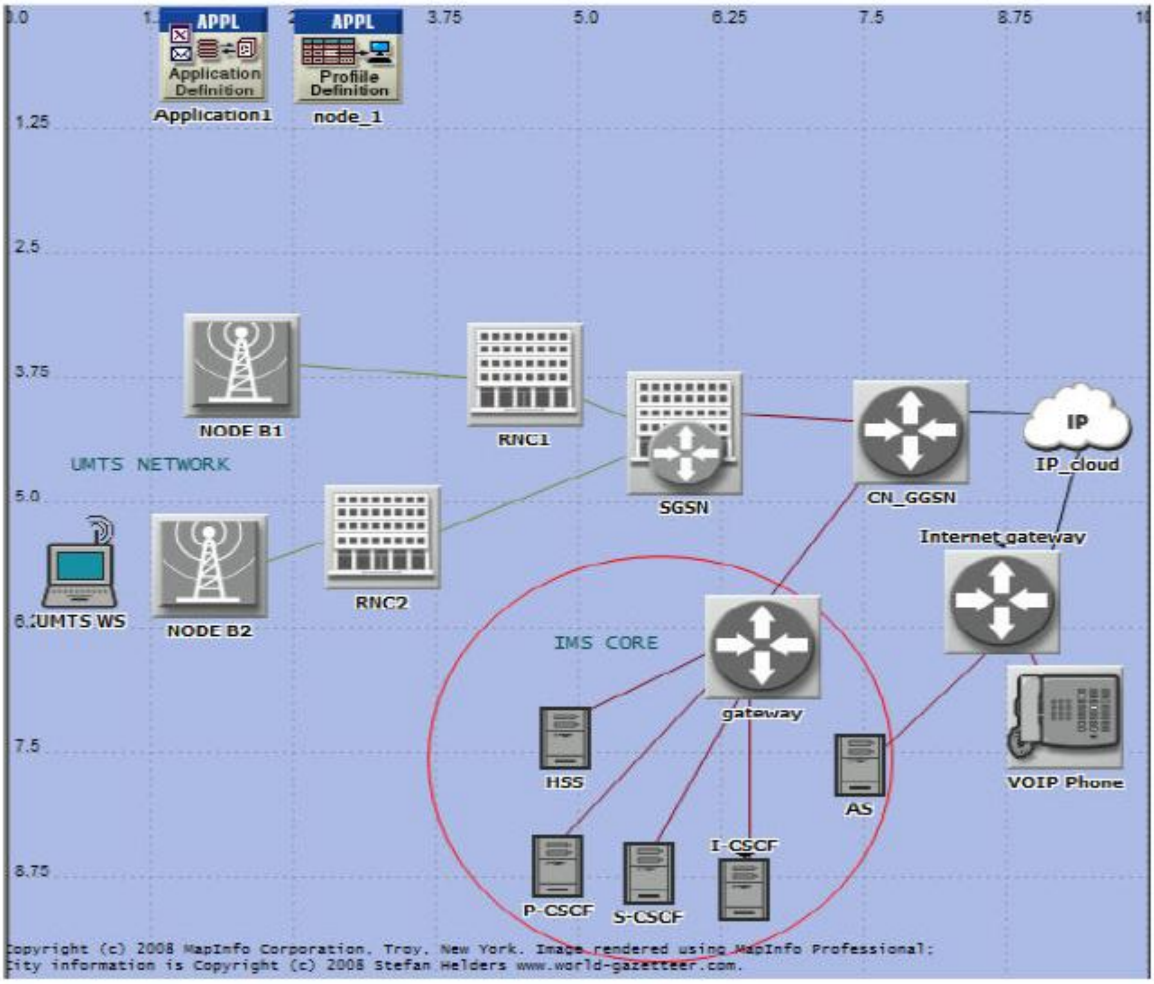


Figure: Proposed OPNET scenario for IMS integration with UMTS

The UMTS model had been implemented in OPNET and was also integrated with IMS WLAN however it was still in the process of being configured. UMTS configurations for RACH channel were not available and I was in the process of acquiring them.

The graphs obtained indicating RACH channel failure are also attached as reference and this work could be continued and much better executed if there was a little more time

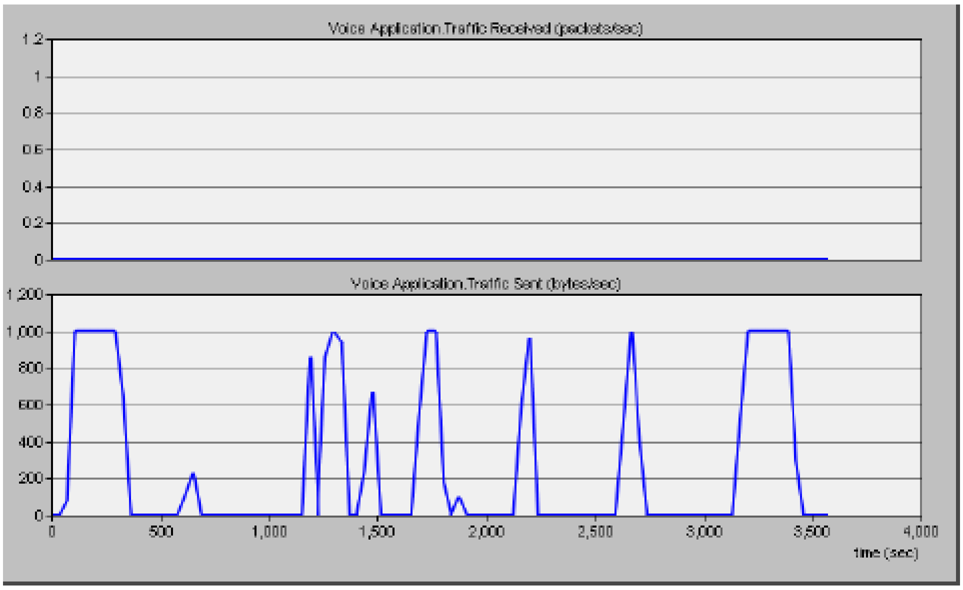


Figure: Graph of failing received traffc due to RACH congestion in UMTS

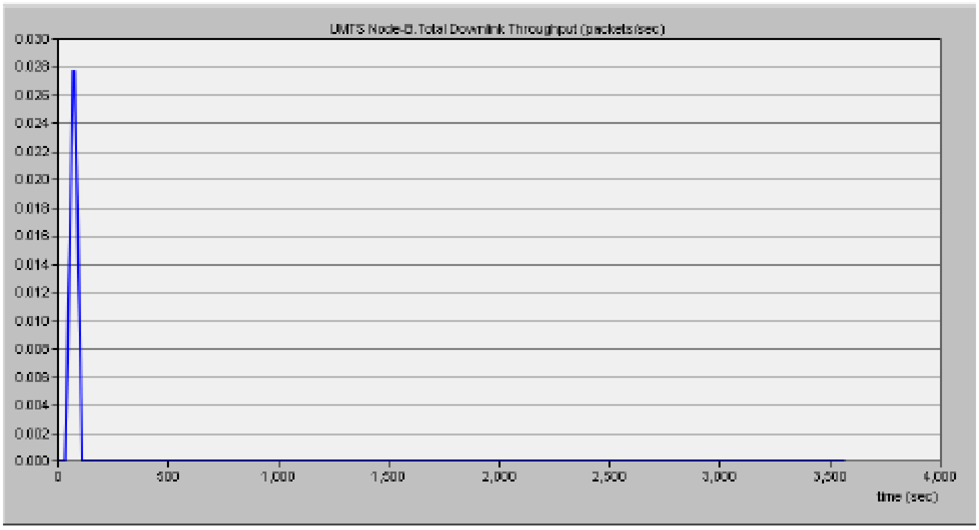


Figure : UMTS Node B traffic falls down due to RACH congestion

UMTS IMS WLAN Interworking model

The third stage involved combining these with IMS functionality to get an IMS to WLAN interworking model which would then be used for our experiments on simulating the UMTS-IMS –WLAN interworking and handover scenario.

The final WLAN to UMTS interworking scenario is shown in the screenshot below

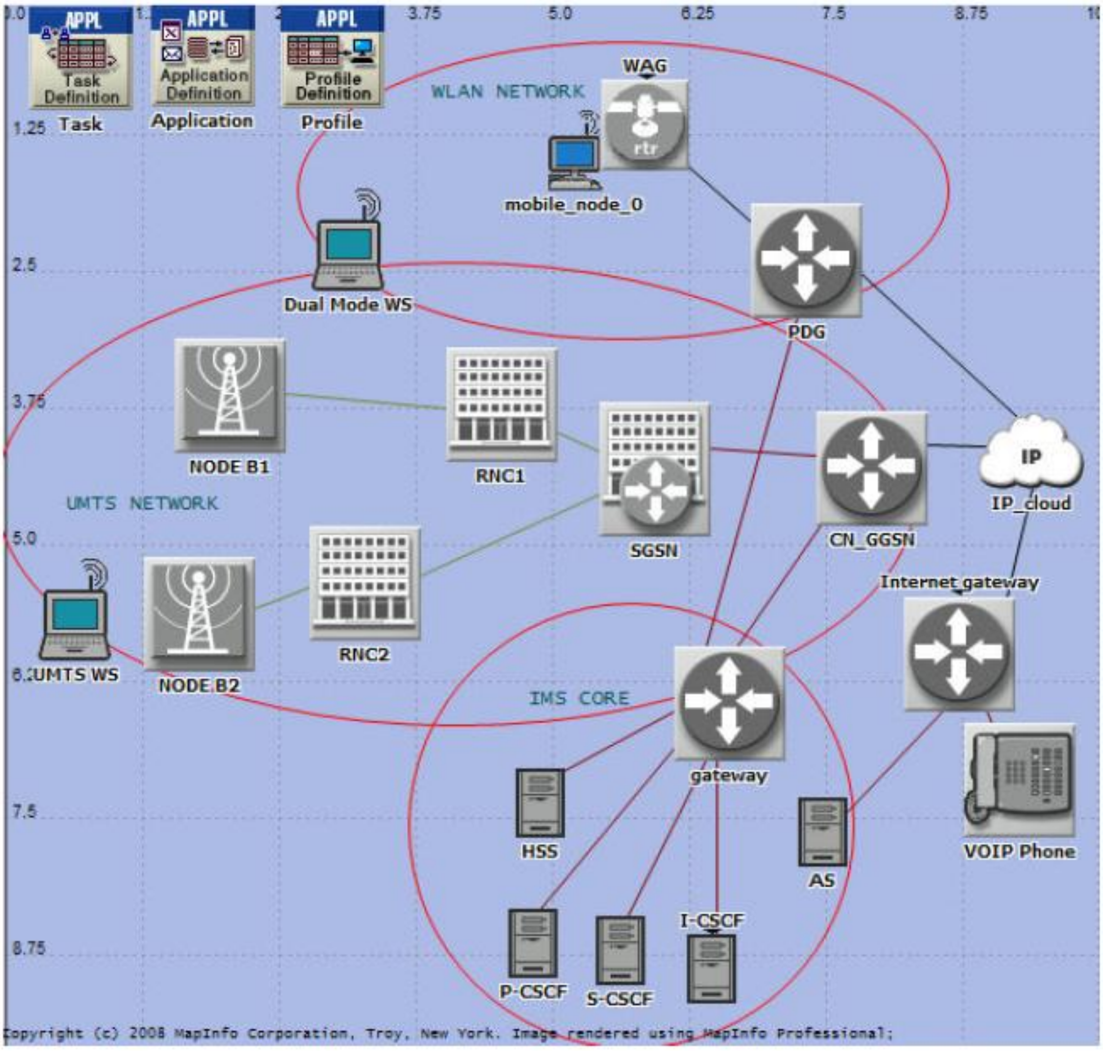


Figure 7.1 The final interworking scenario between WLAN and UMTS. The WLAN UMTS and the IMS domains are clearly marked.

EXPECTED RESULTS

According to the model presented by [] if the SGSN emulator is used to connect the WLAN to the UMTS IMS model then during soft handover the following traffic pattern is observed

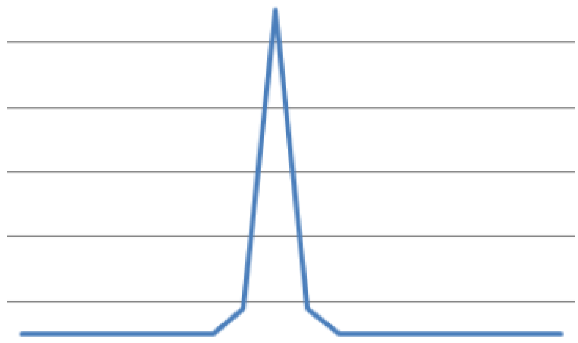


Figure Simple graph to show the trend of traffic upshoot during soft handover. This leads to a handover which is delayed and not smooth

Figure Expected outcome of our proposed handover solution.There will be two peakes in traffic, once during initial registration and once during handover , but the handover is expected to be smoother and requirimg lesser duration for the transition.

Appendix C

List of published conference papers

[1] K. Madani, A. Lohi, "Technological Challenges in Software Defined Radio", International Conference on Telecommunications (ICT'2000), Mexico, Acapulco, May 2000.

[2] A. Lohi, et al, "Configurable radio with Advanced Software Technology (CAST) Initial Concepts, IST Mobile Communications Summit 2000, Galway, Ireland, October 2000.

[3] M. Lohi, K. Madani, A. Lohi, “A Generic Handover Prioritisation Queuing Scheme (SPQS) for a Future Hierarchical Cellular System”, IST’2001, Tehran, Iran, September 2001.

[4] K. Madani, A. Lohi et al., “Enabling Technologies for the CAST Intelligent Reconfigurable Mobile Radio Network”, IST Mobile Summit 2001, Barcelona, Spain, September 2001.

[5] M. Lohi, K. Madani, A. Lohi, "Flexible Channel Allocation Schemes (FCAS) Using Handover Service Prioritisation for 3G Wireless Systems", International Conference on Internet Computing (IC'2001), Las Vegas, USA, 25-28 June 2001.

[6] K. Madani, A. Lohi, et al. “A Distributed Approach for Intelligent Reconfiguration of Wireless Mobile Networks”, IST Mobile Summit 2002, Thessalonica, Greece, June 2002.

[7] K.Madai, M. Lohi, “A Novel Architecture For Reconfiguration Of Next Generation Of Wireless Mobile Networks”, ICT' 2003, Tahiti, Papeete, French Polynesia, February 2003.

[8] K. Madani, M. Lohi, A. Lohi, “Technology and applications beyond the Third Generation”, Invited Paper, Wireless Broadband Research Forum (WBRF), London, October 2003.

[9] K. Madani, M. Lohi, G. Terstyansky, I. Mort, H. Mohammed, A. Lohi, T. Kiss “ Towards the era of personal services at home and everywhere”, PTC’05: 16–19 January 2005, Honolulu, Hawaii USA.

[10] K. Madani, A. Lohi, et al, “Service Management Architecture in ePerSpace”, Eurescom Summit 2005, Heidelberg – Germany, 27 April 2005.

[11] K. Madani, A. Lohi, et al, “ePerSpace: A Distributed Platform for Personalised Services at Home & Elsewhere”, Invited Paper, The International Council on Medical and Care Compunetics (ICMCC) Conference, The Hague- Netherlands, 1-3 June 2005.

[12] K. Madani, A. Lohi, et al, “A Semi-Autonomous Generic Network for Seamless Personalised Services at Home & Elsewhere”, IEE Forum on Autonomous Systems, Savoy Place, London, UK, November 2005.

[13] K. Madani, A. Lohi, G. Terstyanszky; “Applications of ePerSpace Service Management Platform in Health Care, The International Council on Medical and Care Compunetics (ICMCC) Conference, The Hague- Netherlands, 7-9 June 2006.

[14] K. Madani, M. Lohi, A. Lohi; “PERFORM: An Assisted Technology Platform for Neurodegenerative Disease Patients”; Invited Paper; Tenth International Symposium on Communication Theory and Applications (ISCTA ’09), Ambleside, Lake District, UK, 13th - 17th July, 2009.

[15] A. Lohi, M. Lohi, W. Imtiaz, “An Efficient Handoff Scheme for Seamless Transmission Between IMS Enabled UMTS & WLAN Networks”, WMSCI’09, July 10th-13th, Orlando, Florida, USA, 2009.

[16] K. Madani, M. Lohi, A. Lohi; “A Decision Support Service Platform for Neurodegenerative Disease Patients”; ICNS 2010-Cancun; March 7-13; 2010.