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Mobile location services over the next generation IP core network

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Abstract: Mobile communication networks are evolving towards smaller cells, higher throughput, better security and provision of better services. Wireless short-range technologies such as the WLAN 802.11 standards family and Bluetooth are expected to play a major role for the future networks. The mobile core network is changing from circuit-switched to package-switched technology and evolving to an IP core network based on IPv6. The IP core network will allow all IP devices to be connected seamlessly. Due to the movement detection mechanism of mobile IPv6, the mobile terminals will periodically update their current point of attachment to the network and hence provide the current location of the mobile user automatically. The convergence of wireless short-range networks, mobile networks and Internet technology will provide the mobile user's location without any add-in equipment for location measurement. In this paper the concept of mobile location services over the next generation IP networks will be described. We will also discuss the effectiveness of short-range wireless network regarding a mobile user's position inside buildings and hotspot areas.

I. Introduction

The demand of Internet access via mobile terminals has been increasing dramatically, and we are seeing a trend of merging the Internet and the telecommunication networks into a unified multimedia infrastructure. Tomorrow's users of telecommunication networks expect to be able to access all their communication services easily from anywhere at any time and using any terminal. This means that the position of users will be changed frequently, and mobile location services become essential for the end-users in their daily life.

Mobile location services¹ and personal navigation represent a huge potential and challenge for the business players in the mobile service arena [1]. The number of users of location services is estimated to reach one hundred million over the next few years and the estimated revenue worldwide by the year 2007 is more than 5 billion dollars [2]. These services will be crucial for providing mobile end-users with the right service at the right time in the right

location. Users will be able to find out where they are, and they will be able to track their friends or family members. Many more applications based on location will become available. Actually, mobile location services based on both circuit-switched and package-switched platforms are already available today, but the accuracy is rather low. Location services based on GPS (Global Positioning System) satellites can support a high accuracy, but this technology is very expensive and not widely used. Also, information about users located inside buildings cannot be provided. Therefore, mobile location services have not, until now, shown any significant impact on the mobile service market.

In order to enable successful mobile location services with rich multimedia content, user-friendly interfaces and accurate means of determining the position of mobile users inside buildings must be provided. The reason is that most users spend a significant part of their time inside buildings such as homes and offices. The convergence of mobile technology, wireless short-range technologies and IPv6 [3] core network might be the right key for this kind of services.

In this paper we will describe not only the concept of mobile location services over the next generation IP core network, but also the advantage of wireless short-range technologies [4,5], which can provide the accurate location of mobile users in hotspots and enclosed areas like buildings.

In section II the concept of next generation mobile communication, where all heterogeneous networks can be connected seamlessly, will be discussed. The characteristics of wireless short-range technologies, the driving force behind mobile location service in hotspots and inside buildings, will then be described in section III. In section IV the movement detection mechanism of IPv6 will be illustrated. After that, the concept of mobile location services over an IP core network, including some service scenarios, will be discussed in section V. In section VI we present the idea of how to obtain the user's position in an in-door environment, which is not possible with existing technologies. Finally, the conclusion and suggestions for future work will be given in section VII.

¹ Note, that the term "location service" includes both location-based and location-dependent services as explained in Ref. 1.

II. Next generation mobile communication

Next generation mobile communications will be based on functional integration of advanced cellular systems and high-speed wireless access systems. Wireless end-to-end IP connectivity with high bandwidth will be provided. The combined network should be able to handle a large volume of multimedia data, and it should allow seamless connectivity to hosts and between networks. The future service platform has to be open, so that users can freely choose terminals, networks, protocols and applications. Application service providers and content providers must be able to provide their services and content independently from the operators. Location and charging information must be transferred among networks and applications. The users can access networks directly, at all times, connecting as long as the mobile terminals are on. In principle, users will be able to access any service with a single terminal. The enhancement of 3G and 4G will provide high-speed communication in the cellular environment with high mobility. Wireless short-range technologies like the 802.11 WLAN standards family [4] and Bluetooth [5], and digital broadcasting like DAB and DVB (especially DVB-T), are expected to play a major role in the next generation IP core network, see Fig. 1.

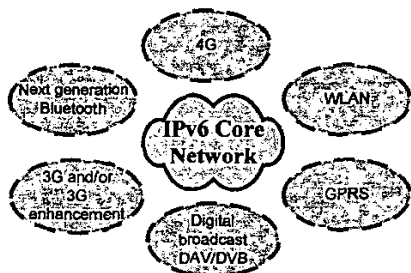


Fig. 1. Concept of the next generation mobile network, consisting of heterogeneous networks, that will provide wireless end-to-end IP seamless connectivity.

The characteristics of short-range technologies will provide user locations within the small coverage area of the wireless network without any add-in location measurement. When the mobile core network is changed to an IPv6 core network, the current location of IP terminals will be identified by the movement detection mechanism of mobile IPv6 [6], as will be described in section IV.

III. Short-range wireless technology

Both WLAN and Bluetooth technologies have their advantages and disadvantages in the service scenarios. When the mobile core networks change to be IPv6 core networks, it will not matter which of these technologies is used by the terminal. Both of them can take advantage of the user's position when the mobile terminal is connected to the IP network. Table 1 shows the characteristics of different versions of WLAN and Bluetooth technologies.

There are three types of wireless connectivity: wire replacement, ad hoc [8] and infrastructure mode [9] networks. Bluetooth includes all three capabilities, while WLAN can be configured in two ways, ad hoc and infrastructure mode.

The Bluetooth standard contains a set of profiles. An interesting profile is the LAN Access profile [10]. This profile allows Bluetooth-enabled devices to access the service of a LAN. In this way, Bluetooth devices are able to carry IP addresses and communicate with other IP devices through the Internet access. This will be very interesting, when the mobile core network changes to an IPv6 core network. Bluetooth devices will have a unique global IP address to identify themselves in both local and global networks. They will be able to communicate with any IP devices in the global network and other Bluetooth devices in an ad-hoc mode within the piconet. The piconet is then a part of the IP network. IP-enabled Bluetooth devices can be connected to the IP core network via Bluetooth access points, i.e. Bluetooth devices that provide access to the IP core network.

This mechanism is very useful to enable mobile location services inside buildings and in hotspot areas. When Bluetooth devices are connected to an IP core network via Bluetooth access points, this will automatically identify their position within a 10-meter cell radius.

The coverage area of a WLAN access point is larger than that of a Bluetooth access point. To get the precise position of a user, additional techniques have to be implemented. One possible technique could be to determine the user's position by measuring the signal strength sent from the mobile terminal.

	IEEE 802.11b	IEEE 802.11a	IEEE 802.11g	Bluetooth 1	Bluetooth 2
Frequency band	2.4 GHz	5.2 GHz	2.4 GHz	2.4 GHz	2.4 GHz
Transmission power	100 mW (EU)	200 mW (EU)	100 mW	1 mW	1 mW
Cell radius	50 m	30-50 m	30-50 m	< 10 m	< 10 m
Data rate	< 11 Mbps	< 54 Mbps	< 54 Mbps	< 1 Mbps	< 10 Mbps

Table 1. Characteristics of wireless short-range technologies [7].

Due to the evolution of wireless technology, we note that many mobile terminals and other electronic devices will soon be WLAN and Bluetooth enabled with built-in IP carrying capability. Consequently, it will be possible to pinpoint the position of mobile devices automatically with high accuracy.

IV. Movement detection mechanism of mobile IPv6

An IP address generally consists of two parts: a subnet identifier and an interface identifier. The interface identifier identifies a single interface within an IP subnet and does not take part in the routing procedure. While the subnet identifier identifies an individual subnet within the overall network and controls the routing between different subnets, the routing mechanism of IPv4 is designed for a fixed network infrastructure. But in the future many hosts will make wireless or mobile connections to the Internet. Therefore, the Internet Engineering Task Force (IETF) standardizes the Internet Protocol version 6 (IPv6) [3] to support mobile Internet devices.

In Mobile IPv6, the mobile terminal identifies itself with a unique static home address² regardless of its point of attachment. When the mobile terminal moves from its home network³ to a foreign network⁴, a new temporary address belonging to the foreign network will be allocated, in addition to the static home address. This address is called the care-of-address⁵. The current location of mobile users will be recognized by this temporary address. Mobile IPv6 terminals periodically send updates of their current point of attachment on the IPv6 core network to their home network, thus the current position of mobile users will be provided automatically. The movement detection mechanism of Mobile IPv6 is shown in Fig. 2.

Actually, there are two variations of Mobile IP, Mobile IPv4 and Mobile IPv6, but IPv6 offers a more enhanced support for future networks. The huge address space of IPv6 makes it possible to allocate a globally unique address for all terminals, and hence makes the deployment of Mobile IPv6 more straightforward. This has an extremely positive implication on mobility since the care-of-address can be obtained more easily compared to IPv4, which supports only a limited address space.

² Home address is an IP address assigned to a mobile IP terminal within its home network.

³ Home network is the network to which a mobile IPv6 device registers. It then gets a static home address with subnet prefix belonging to this network.

⁴ Foreign network is any network other than the home network.

⁵ Care-of-address is a temporary address with subnet prefix belonging to the foreign network, to which mobile terminal is currently attached.

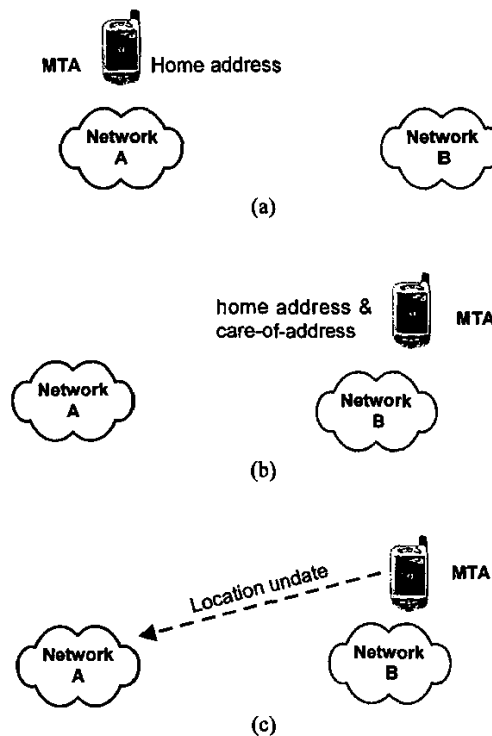


Fig. 2. Movement detection mechanism of Mobile IPv6. (a) Mobile terminal A (MTA) registers with network A. It gets a static home address with network prefix belonging to network A. (b) MTA moves to network B. It will get a new temporary address (care-of-address) with network prefix belonging to network B. (c) MTA informs its current location to the home network (network A). Then network A updates the current location of MTA.

V. Mobile location service over IPv6 core network

Future mobile location services will be implemented over heterogeneous networks as shown in Fig. 3. Issues like privacy and quality-of-service are important for this kind of service. Although the current position of a mobile user can be known by the mechanism of IPv6, this information should not be distributed freely to everybody. The users should have the right to control their privacy. They might either give or not give permission to the person, who wants to track their position. They can also check, who wants to track them, and when or how often their position has been tracked.

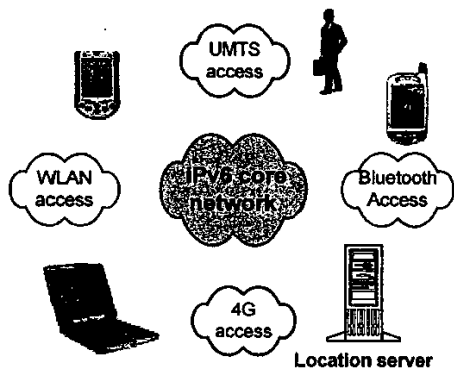


Fig. 3. Infrastructure of mobile location service over an IPv6 core network.

The scenario of position tracking is shown in Fig. 4.

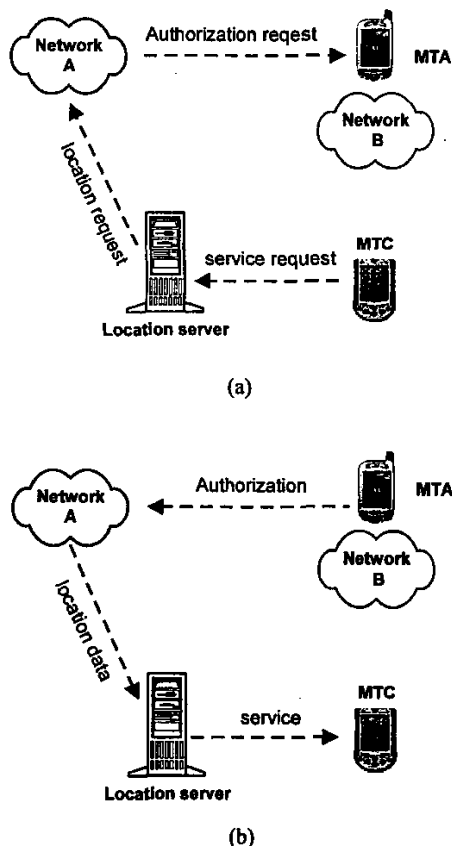


Fig. 4. Mobile user position tracking scenario. Details are explained in the text.

In Fig. 4(a) the mobile terminal C (MTC) wants to track the position of mobile terminal A (MTA). It sends a request to the location server to access the location service. Then the location server sends a request to the home network of MTA (Network A) to ask for the current point of attachment of MTA. Network A asks for authorization from MTA. If MTA allows MTC to know its current position, it sends an authorization to network A. Then network A sends the current position of MTA to the location server. The location server correlates the location data with geographical map information and then sends this result back to MTC, as shown in Fig. 4(b).

To reduce the network traffic, the MTC might ask for permanent authorization from the MTA, so that next time it can track the position of the MTA without an authorization request. The MTC will be added in the permission list of the MTA, which will be stored in the location server. This tracking scenario can apply for several services such as:

- Friends and family members tracking
- Next bus/train tracking
- Taxi service
- Mobile teleworking

Figure 5 shows an example of a user position identification scenario. This scenario could provide the services based on the user's location such as:

- Place finding
- Weather forecast
- Traffic checking
- More detailed guidance in certain areas

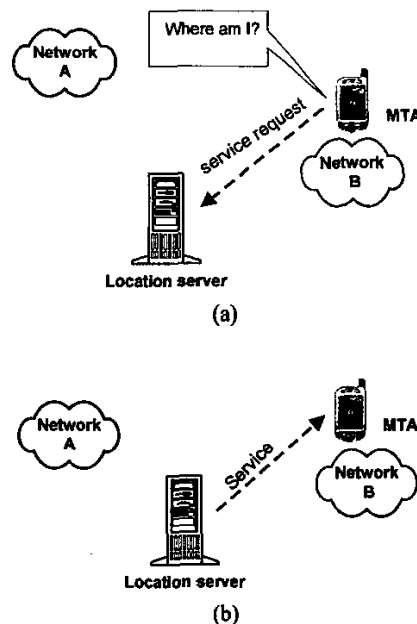


Fig. 5. "Where am I"-scenario. Details are explained in the text.

In Fig. 5(a) MTA asks for its current geographical position. It sends a request with its care-of-address to the location server. The location server uses the network prefix of the care-of-address (which contains the location of the current network, to which MTA is connected) to identify the geographical position. Then it sends the result to MTA as shown in Fig. 5(b).

The users might register for this kind of service as an “always-on” service. This service will be available as long as the mobile terminal is on. The current position of mobile users will be automatically updated while they are traveling.

VI. In-door location service

The quality-of-service properties of a mobile location service depend on the radio connection and the network infrastructure. In an in-door environment, the signal tends to be degraded, because line-of-sight barriers affect the quality of the radio connections, and outside, the radio signals are easily deflected by buildings, trees etc. This limits the usefulness and reliability of mobile location services, and these are the reasons why the most precise technology like A-GPS and other location techniques based on mobile network do not work in this environment. The problem with location services over mobile networks, such as poor in-door performance, provides a significant opportunity for wireless short-range networks. It is an ideal solution for hotspots and in-door environment, providing the user’s position with high accuracy.

To implement in-door mobile location services, short-range wireless access points have to be installed in the buildings as shown in Fig. 6. These access points determine the point of attachment of a mobile terminal on the network, and also identify the current position of mobile users.

- **Bluetooth solution**

Bluetooth has a tremendous advantage over other wireless networking approaches because it is much cheaper to implement and it covers only a small area (up to 10 meter with 1 mW signal power), which makes in-door mobile location services more accurate. To take advantage of the user position from a Bluetooth network, the Bluetooth LAN access points (BTLAP) have to be installed properly. The networks must be configured as infrastructure networks in Multi-User mode [10]. In this mode the BTLAP must always become the master of the piconet. If mobile terminals refuse to allow the BTLAP to become master then the mobile terminals cannot gain access to the network.

- **WLAN solution**

To take advantage of the user’s position, the WLAN networks have to be configured in infrastructure mode. Mobile terminals with WLAN-enabled are connected to a WLAN access point, which in turn is connected to the IPv6 core network. When users move from one network to another network, the position of the user will be known by the movement detection mechanism of mobile IPv6 as mentioned in section IV.

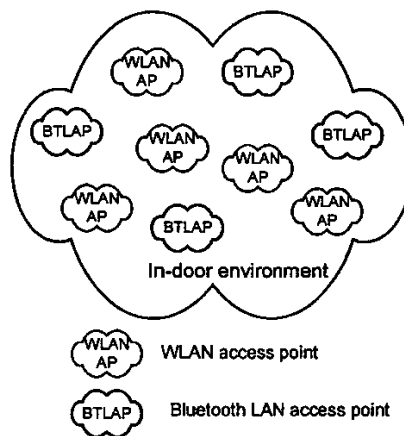


Fig. 6. In-door location service architecture

VII. Conclusions and future work

In this paper, we have presented the concept of mobile location services over an IPv6 core network. A user’s position will be automatically obtained by the movement detection mechanism of mobile IPv6. Correspondingly, the user’s position inside a building or in hotspot areas can be provided, using Bluetooth and the 802.11 WLAN standards family. These technologies are expected to form an integral part of future networks.

Future networks can support higher data rate, this means the more detailed location data can be sent through the network and more attractive user interface (e.g. multimedia user interface) can be launched. In our future work, we plan to design user-friendly interfaces, especially paying attention to security and privacy issues.

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