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Realizing Peer-to-Peer Location-Based Services in Mobile Networks

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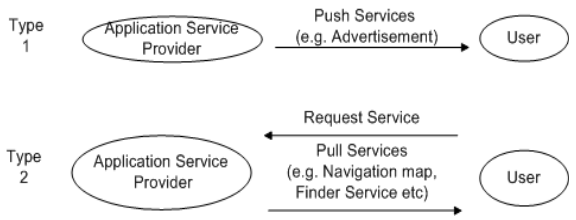
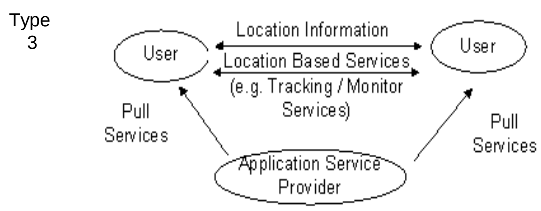
Abstract - Current Location Based Services (LBS) in GSM/UMTS Networks rely on centralized Location Enabling Servers [8] for location information provisioning via the Gateway Mobile Location Center (GMLC) *Le* interface. In this Paper, we present a framework for providing Peer-to-Peer Location-Based Services using de-centralized location information management. The proposed solution relies on the future IP Multimedia Subsystem extension to the core network in GSM/UMTS Networks. A prototype Peer-to-Peer Location-Based Service has been implemented demonstrating that such services can coexist with current LBS systems. The proposed system has the potential of making location-service solutions more open, simple and secure, thus leading to greater user acceptance and prospects for LBS market growth in future.

1 Introduction

Location Based Services have been often hyped by the industry as a potential "killer application", boosting mobile services in current GSM and UMTS networks. The key idea behind LBS is to use the user's current physical position information as a "filter" for delivering localized services and/or information relevant to a certain area related to his position. The kinds of services offered can be classified into two main types [2] as illustrated in Figure 1(a): Services which are triggered by an application service provider when a user arrives or enters a certain geographic location e.g. push-advertisements in a shopping mall or localized weather warnings, are classified as type 1 services (also called "push" or "triggered services"). Services which are typically information services requested by a user from an application service provider e.g. finding nearby restaurant/gas-stations or navigation services, are classified as type 2 LBS (so called "user-requested" or "pull services"). Location Information is also used "passively" in mobile networks for providing "location-based billing" (i.e. varying service tariffs depending on the users geographic location e.g. O2 Genion Home-Zone Service [3]) or more advanced network resource management services such as location-based routing and handover [11], but are not scope of this paper.



(a) Server-to-User Location Based Services



(b) Peer-to-Peer Services with de-centralized location information management

Figure 1 Location-Based Service Classifications

The two types illustrated in Figure 1(a) are server-to-user location-based services where location information is managed by Central Location Servers [8] and access provided via the Gateway Mobile Location Center (GMLC). Here, information on the user's current location in the mobile network is only being made available to 3rd Party location-based service providers of the operator's choice with the users consent, yet the user does not have direct control over his location information. Thus in the case of currently available and possible future location-based services, the potential abuse of location information can range from the mildly irritating (e.g. 'location-based spam') to the more serious problems such as GPS-based tracking being used by car-rental companies and using location information of customers to impose speeding tickets [4].

In this paper, we will present a third type of peer-to-peer location-based services" (Figure 1b) where the user has full control over his location information, hence better awareness to whom this information will be provided leading to an improved user privacy protection. We will first explain the location information provisioning for location-based services in current mobile networks, discussing the current centralized location information management. We will then introduce the peer-to-peer location-based service architecture using the IP Multimedia Subsystem extension to mobile networks, showing the potential advantages of de-centralized location information management on our realized prototype peer-to-peer location-based instant messenger implementation.

2 Current Realization of Location-Based Services in Mobile Networks

In the existing mobile networks, the functionalities required to support Location Services are provided via the GMLC which exists in the operator's core network. The GMLC is the first node an external LCS client (e.g. Application Service Provider) accesses to request the current geographic position information of a mobile terminal as shown in Figure 2. The Access Network can be either GERAN [14] for GSM/EDGE networks or UTRAN [13] for UMTS networks. After receiving positioning request from an external LBS client, the GMLC requests routing information from the Home Location register (HLR) or Home Subscriber Server (HSS). After the registration and authorization of the LBS client is performed, the GMLC sends a positioning request to either Serving GPRS Support Node (SGSN) or Mobile Switching Centre (MSC). The final location estimates are performed by the corresponding network entity (i.e. the TOA, TDOA positioning method), handset (i.e. if EOTD, OTDOA is used) or hybrid positioning method (e.g. A-GPS), then forwarded back to the requesting LCS client. The Target mobile terminal's privacy profile settings are always checked in the mobile terminal's home network prior to delivering a location estimate to the requesting LBS client.

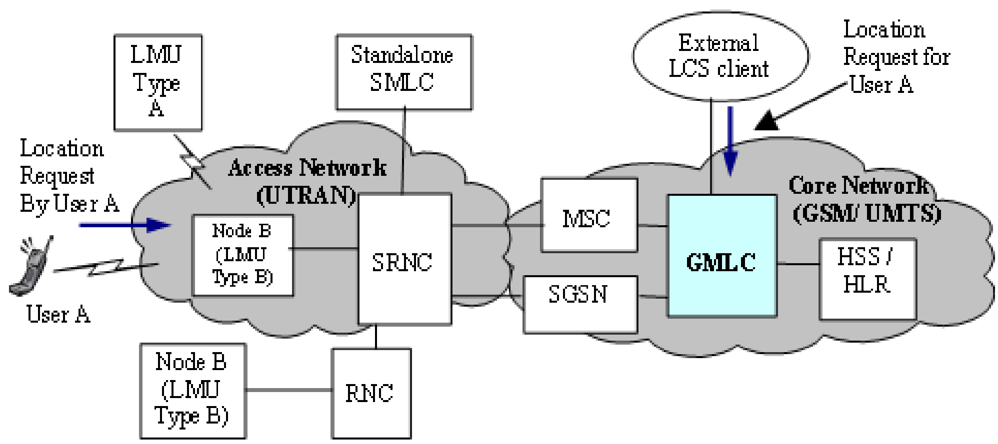


Figure 2 Standard LBS Mobile Network Architecture

Even though the above mentioned LBS network is simple and useful for many location services, it does not support advanced services like map based routing information, geo-coding services, finder services e.g. find nearby restaurant, gas-station etc. In order to provide these services, the GMLC needs new functionalities to be added to support these advanced location services. It is difficult and far too costly to extend the GMLC in already existing networks. Hence advanced location-enabling solutions such as the Siemens Location Enabling Server v2.0 [8] are deployed in mobile networks extending the location provisioning functionality of the GMLC via the *Le* interface (Figure 3).

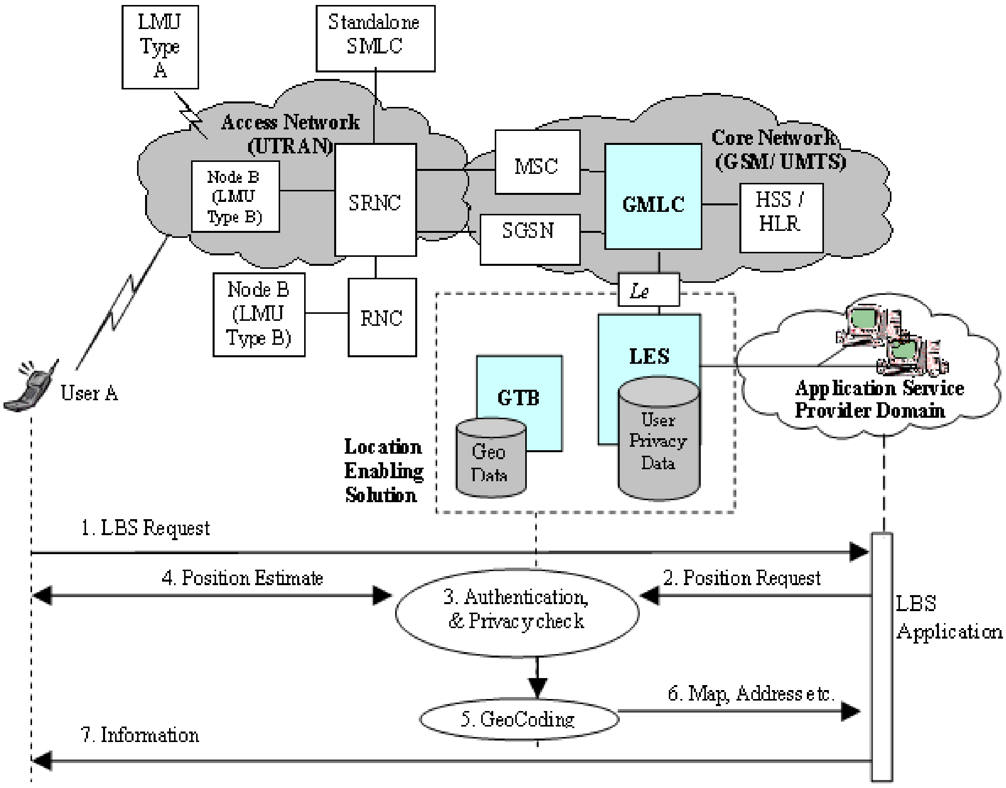


Figure 3 Location Enabling Solution Architecture for LBS

The Location Enabling Solution is comprised of the Location Enabling Server (LES) and the Geo-Toolbox (GTB) holding Geo-information such as Map and Point of Interest (POI) data (e.g. Hotel, Cinema, Gas Station Information etc.). The GTB hosts also basic location services such as "find-nearest-POI", routing and navigation functions. These functions are provided via the LES to the LBS Application Provider via a standardized XML API using the MLP protocol as specified by the Open Mobile Alliance (OMA) [15]. This API is the only interface to the LBS Application Provider providing the necessary location information. One of the additional primary tasks of the LES is to perform privacy and access control including temporary storage of user data, provide configurable user privacy profiles for each subscriber and handle access rights quotas of external application providers. As a user privacy database is maintained, privacy-enabled location-based services can be provided without impact to the mobile operator HLR. Last but not least, it also supports LBS roaming and production of appropriate LBS billing records.

The Secure User Plane Location (SUPL) architecture will be the next evolutionary step as specified by the OMA [16], ensuring better user location information privacy and security, as well as location information control from various location sources with no impact to the core network infrastructure. Currently released solutions focus on advanced mobile -network (WCDMA and GSM) as well as -positioning support (enhanced cell ID and A-GPS) [17]

3 Comparison of Centralized and De-Centralized Location Information Provisioning

Current mobile network operators prefer a *centralized location management* for location based service provisioning for 3rd Party application service providers via location enabling servers as shown in the previous section. The positioning of mobile devices is carried out in the access network (GERAN/UTRAN) part of the mobile network [2]. The most common and readily available positioning method here uses the base station Cell ID where a user is currently booked into. This method however is not very accurate since its accuracy depends on the base station service area (cell size) which can range from a few hundred meters to several kilometers. The more accurate positioning methods such as EOTD/OTDOA, TOA or AOA are not implemented in current mobile networks due to the high upgrade costs (hardware and software) in the access network and mobile devices [9]. Instead, mobile operators are rolling out the new hybrid Assisted-GPS standard which can provide high positioning accuracy (only a few meters) with little impact on the existing access network infrastructure and mobile device integration costs. As it is the case with standard GPS (without the initialization problems), location information is generated at the mobile device, but only capable of being accessed from the mobile network [6]. Hence control over the user's location information, thus user privacy control remains on the operator's side. The mobile operator's intend is to keep control over location information access, thus being able to generate revenue from location-based services.

In today's mobile networks, privacy control is implemented by querying the mobile user whether he wants to let himself be positioned before he can carry out the location-based service. This legally upholds the user's privacy rights, but does not give any indication to which 3rd party this location information is handed to.

Although mobile operators favour centralized location information management, a de-centralized system where location information is directly exchanged and completely controlled by participating peers increases user awareness and trust for location-based services. With the introduction of the IP Multimedia Subsystem [1] in Mobile Networks, IMS-based de-centralized communication is possible allowing direct interchange of data (hence also location information) between participating peers.

The mobile user always "knows best" about his current physical position, hence satellite- (e.g. GPS, A-GPS [10]), indoor- (e.g. WLAN [12]) and short-range- (e.g. RFID, IrDA, Bluetooth) based positioning systems can currently deliver the best possible and most up-to-date positioning accuracy as the positioning information here is actually generated at the handset device. However each time a location update is needed, the handset has to be queried- and the location information returned to the requesting peer through the network.

Thus, in a decentralized location network when the location data is requested, the location information is generated at the user mobile handset using independent GPS device attached to the mobile via IrDA/Bluetooth and the information is provided only to a (trusted) known requesting peer or application service provider of the user's choice, thus offering him full control over his location information and hence over his privacy. Using this technique, the location information is send directly from peer to peer using IMS-based signaling bypassing location servers in the mobile operator network, thus enabling mobile operator independent positioning and location-based services. The concept for mobile operator independent positioning for location-based services is not new [5].

4 The IMS-based Architecture for Peer-to-Peer Location-Based Services

With the introduction of the IP Multimedia Subsystem (IMS) [1] in current 2.5G (GPRS) and 3G (UMTS) data networks, VoIP, Push-to-Talk and other peer-to-peer services like Instant Messaging

(IM) can be realized alongside well established mobile network services e.g. SMS, MMS and existing LBS solutions. IMS provides common signaling platform for these data and multimedia services.

The realized Location-Based IM solution can be seen in Figure 4, where we have used the IMS as a signaling platform. The *Gm* interface between mobile terminal and IMS interacts with the Proxy Call State Control Function (P-CSCF) using the Session Initiation Protocol (SIP) [7] with extensions for Instant Messaging and Presence information. This interface is used for registration of mobile terminals with the IMS network, call setup /termination and instant message communication signaling. Network services hosted on Application Servers (e.g. Presence Server) are configurable by a user via *Ut* interface for managing user profiles and privacy settings.

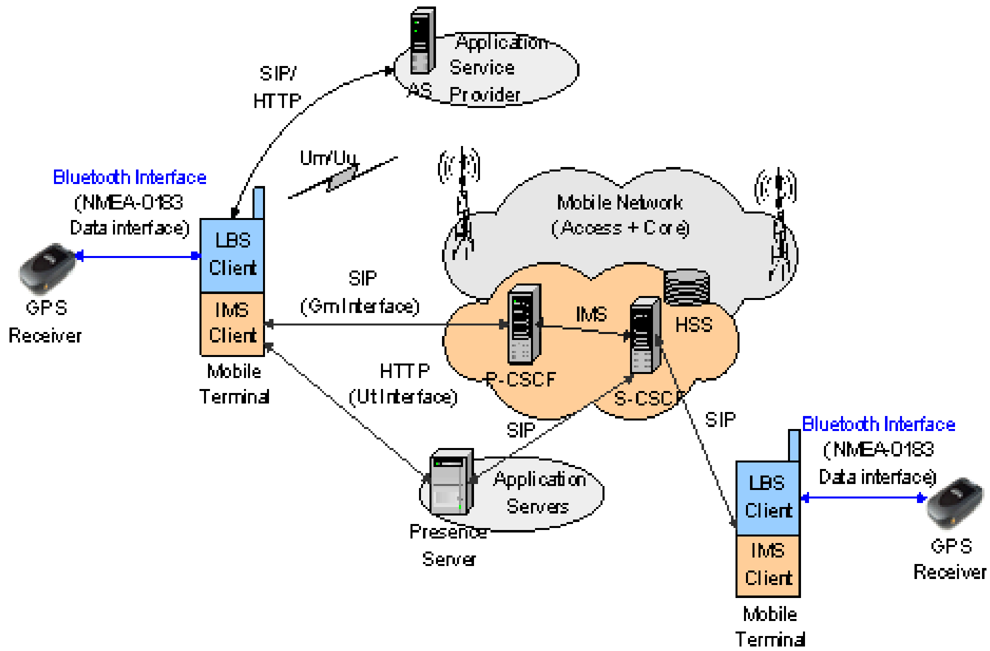


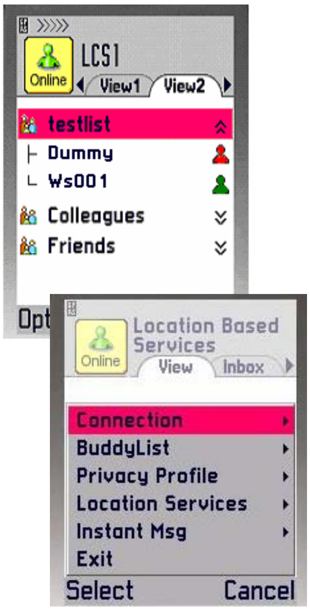
Figure 4 IMS Architecture for the Peer-to-Peer Location Based Instant Messaging Prototype

There are two basic modules on the user mobile terminal: an IMS (IP Multimedia Subsystem) client-for the instant messaging service, and a LBS- client component for the location information provisioning. The location information requests are signaled via specially encoded instant messages between the IMS clients on the participating mobile devices. A GPS positioning device at the mobile terminal is used for sending the raw location coordinates (Longitude-Latitude-Altitude) to the requesting peer. Using this location information, a map or street address can be obtained from an external Map server of the positioned peer (e.g. Map24.de) via GPRS. The interface between LBS client and an application service provider uses standardized HTTP or SIP based communication. While between LBS client and GPS receiver, Bluetooth interface with NMEA-0183[1] data protocol is used. An IMS Testbed providing the necessary IMS functionality needed has been implemented based upon the NIST SIP project [18].

A positioning request between two mobile peers is carried out as follows (Figure 5b): A mobile peer (User B) registered with the location-based IM service can request the position of another fellow registered peer (User A) from his Messenger Menu (Figure 5a). Depending on User A's privacy

[1] NMEA (National Marine Electronics Association) 0183 is a serial communication standard for encoding and sending GPS and other navigational information between devices.

setting, a message IM pop-up will be displayed on User A's display showing User B's request. If User A's privacy setting is set to "accept allowed" for User B, no message will appear in this case. If the request of User B is granted by User A, the GPS coordinates will be read out from the local Bluetooth GPS unit. These coordinates will be converted to a special IM Message format and transmitted to User B. Once the required position coordinates are received by User B, a Map showing User A's location can be received from the online map server. Alternatively, User B can calculate the distance to the remote peer User A using the location information from his own GPS device. Using this principle, it would be possible to find nearby friend/business associates, triggering an instant message if an associate comes into range. This could be realized by performing periodic location requests to registered peers. Similarly, this could be used to provide a location-based "Dating Service", where an application provider (just as another "trusted" peer in the network) could trigger an instant message to participating peers, if a minimum threshold distance is reached and their dating profiles match.



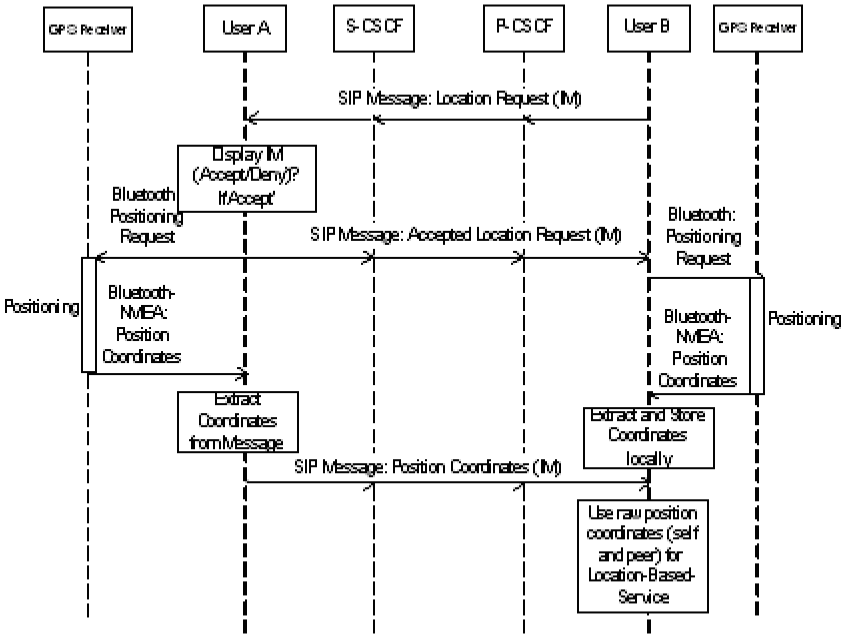


Figure 5(a)
Mobile Terminal Screens of Location-Based IM Application

Figure 5(b)
Signaling showing Peer-to-peer communication for Location Information

The current location-based instant messenger as seen in Figure 5(a) offers a very simple privacy profile setting, as well as location-based services "track buddy distance" and "get location map of a buddy". The location request between two peers is only possible if both peers are online. Hence it is necessary to know the presence status (online/offline) of the peer before sending any location requests. This is taken care by buddy lists and presence information handling stored on the presence server. As with most commercial IM clients, the user can organize his peer contacts under various lists which can be arranged by the scope of user's interest e.g. friends, work colleagues, family etc. Each peer has a public ID called SIP URI (Uniform Resource Identifier) as a contact address.

5 Conclusion and Outlook

In this paper, we have introduced a working prototype realizing Peer-to-Peer Location-Based Services for GSM based Mobile Networks. We have shown that future Peer-to-Peer Based Location Services can 'coexist' with current centralized Location-Based Services introducing the IP Multimedia Subsystem in the Core Network. Also, it is important to note that the Peer-to-Peer Location Services can also be deployed in the mobile networks which do not currently have any location-enabling infrastructure, as no GMLC or any location enabling servers are needed for the deployment of Peer-to-Peer location services.

We have compared the existing LBS mobile network realizations using centralized location information provisioning to the de-centralized approach taken in our peer-to-peer location-based IM prototype. We think that both approaches can be supported in mobile networks, extending and improving location-based service offerings, hence increasing user acceptance of location-based services in the near future. We have given an outlook on other peer-to-peer location-based services usage scenarios which can be realized using this IMS peer-to-peer architecture. As a future goal, in order to improve the user privacy even further, we can extend the presence server functionality of the instant messaging system by introducing user profiles holding trusted/unwanted peer information, as well as globally available "black- and white lists" (similar to trusted certificates from internet websites or existing email spam-filter systems). Users would be able to specify trusted location-based service providers and black-list unwanted providers offering "location-based spam". Furthermore, future modifications should allow users to specify the degree of accuracy offered to particular requesting peers e.g. allow high positioning accuracy for emergency services and only "building", "city" or just "country" level resolution of accuracy to specific friends or service providers.

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