Issues for the provision of Location-dependent services over 3G networks

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ABSTRACT

The evolution of 3rd Generation (3G) mobile systems introduces a new era in advanced multimedia service provision to mobile users. The importance of localisation as a primary concept for service adaptability, downloadability and network reconfigurability is an aspect to be considered in the context of future mobile systems and networks enabling new approaches in service provision. The urgency for service differentiation, customisation and personalisation in the market of 3G's mobile services and applications has boosted the activities of many Telecommunication companies and institutions to develop or integrate positioning systems into their networks. In this paper, the state-of-the-art in architectures for the provision of Location-dependent services and the exploitation of the location information for location-aware service management and provision in 3G networks is presented.

I. INTRODUCTION

A. The industry drivers

With the evolution of broadband and 3rd generation mobile communications, the software reconfigurable radio system and network concept has been heralded as potentially offering a pragmatic solution for the provision of a wide range of sophisticated services to mobile users. The most significant near term impact of reconfigurability is likely to be in the field of service and applications innovation, as a tool to allow rapid and flexible service customization and new degrees of operator differentiation. Contrary to the application-specific mobile system design for 2nd generation systems, the potentials for flexible and adaptive service offerings that can be supported by the introduction of reconfigurable mobile systems and networks pave the path for advanced service provision schemes.

The importance of localisation as a primary factor for service differentiation and personalisation has boosted the activities of many Telcos and institutions to develop or integrate positioning systems into their networks. By combining positional mechanisms with location-specific information, it is possible to offer truly customized personal communication services through the mobile phone or other mobile devices [1]. Location is important to how people organize and relate to their world. Knowing where a person or object is at any time presents a powerful new dimension to the range of information services that can be offered [2]. Location-dependent services determine the geographic position of mobile subscribers and provide them with relational information and services via the Internet and/or wireless networks. Also called mobile location services, wireless location services, or location-based services, these systems clearly are making a major impact on how we navigate our world and how business is done.

Actually, there are three main commercial reasons that force network operators to invest in positioning services:

i) *Differentiation*: by adding positioning capabilities, operators can offer their subscribers new and attractive services. Operators who do so can compete from a more favorable strategic position.

ii) *Reduced costs*: operators who introduce positioning systems can optimize their networks to trace unsuccessful calls. With this information, they can adapt their networks (without waste or over-dimensioning) to match calling patterns.

iii) *Increased revenues*: the potential of commercial services that use positioning information is truly infinite, since professional and private subscribers are willing to pay for these services.

B. Location-dependent services classification

Position location in terrestrial networks appears to be a key application for cellular operators, since there is a variety of value-added services that are based on the ability to locate mobile terminals. They can be classified [1] as follows:

- *Information services:* Information services make use of an information bank where information is filtered according to the relative position of a user and the applications selected. Examples of information services include location-based yellow pages, events, and attractions (for example, "What is happening today in town near here?").
- *Tracing services:* Different services can use location-based information to trace mobile terminals, to provide safety, to facilitate delivery, and so on. Examples of this kind of service include the tracing of a stolen car, helping paramedics to locate persons quickly in an emergency situation, and giving a towing service or automobile repair shop the location of a motorist in need (out of gas, flat tire, dead battery).
- *Resource management:* Resource-management applications are used to manage the logistics of vehicle

fleets, freight, and service staff - for instance, repairmen with different skills and qualifications. Examples of resource management include taxi fleet management, the administration of container goods, and the assignment and grouping of railway repairmen.

- *Navigation:* Navigation applications are used to inform subscribers how they can best move from point A to point B. Applications of this kind can be adapted to vehicle or pedestrian navigation.
- *Other services:* Some positioning applications, such as network planning, map services and telematics, do not fall into the above categories. Examples of these services include hot-spot tracing ("How is my network used?"), and location-based charging.

C. Positioning technologies in Cellular networks

There is a variety of localisation methods that can be applied to cellular networks for subscriber positioning. In general, the localisation methods can be classified [1] in terminal-based, network-based, and hybrid, according to the place where the measurements and their evaluation take place. A terminal-based positioning solution relates to positioning intelligence that is stored in the terminal or its SIM card. These kinds of positional mechanism require a new terminal, a new SIM card, or both. In practice, this means that once the system has been installed, subscribers will have to replace their handsets or SIM cards to benefit from it. Market penetration will increase gradually as handsets and SIM cards are replaced over a period of four to five years. Examples of terminal-based solutions are the network-assisted Global Positioning System (A-GPS), and SIM toolkit. By contrast, network-based positioning solutions do not require positioning intelligence to be built into the handset (mobile terminal), which means that market penetration is 100% from the day the system or service is launched. Examples of network-based solutions include the Time of Arrival (TOA) and Time of Difference of Arrival (TDOA) methods.

Most common positioning techniques [3] include:

- *Time of Arrival (TOA)*

TOA is the time that takes for a signal to travel between the base station and the mobile terminal. If one TOA measurement can be performed, the MT is around the BTS in a radius equal to the distance that represents the TOA. According to this measurement the possible user's location is a circle with known radius. Additional measurements result in more circles and finally the MS location can be estimated with an accuracy of less than 125m.

- *Time of difference Of Arrival (TDOA)*

The mobile station listens to a series of base stations. If the transmitters (BTSs) are synchronised (very accurate clock) and the MS can perform measurements of the time difference of arrival it is possible to locate the subscriber. For this method three BTS are needed and two TDOA-measurements. Each TDOA measurement defines a hyperbolic curve as the area of location the intersection of which identifies the area of location.

- *Angle Of Arrival (AOA)*

The angle of arrival method can be applied if one of the MT or BTS is able to measure the angle of the signal arrival. Two AOA measurements are required to locate a user. AOA is also known as Direction of Arrival (DOA). This method requires array type antennas.

- *Pattern Recognition Techniques*

In all cellular networks the signal strength varies between places, due to the propagation loss. The propagation loss depends on the distance between MT and BTS and the area-obstacles as well. Therefore, it is possible to classify roads or parts of them according to the signal pattern that appears. Consequently, a pattern-matching algorithm can result in the location of the subscriber. The pattern matching is not the most accurate method for positioning, but it is the most cost efficient, since it can be easily integrated to any cellular network. The accuracy varies, but is within the 125m that the US Federal Communications Commission (FCC) specifies.

- *Satellite Positioning Systems (GPS, GLONASS, Galileo)*

The most common and accurate positioning methods are the ones based on satellite systems. GPS, GLONASS and the Galileo are three of the satellite positioning systems. GPS is based on simultaneous propagation measurements that can be performed from the mobile unit. If the object to be positioned, has a sight of at least three satellites it is possible to localise the object. The accuracy of a satellite positioning technique is between 50 and 80 meters (GPS). By means of network-assisted GPS the accuracy can be improved up to 10 meters.

It should be mentioned that current cellular networks do not use any of the above positioning techniques. The most important criteria for choosing one of the above are installation costs and accuracy. TOA has the disadvantage that it is difficult to be measured or approximated, as well as that requires additional hardware at the listening BTSs to accurately measure the TOA of the terminal-generated bursts. TDOA is a very precise method, but requires the BTSs either to be synchronised and always transmit simultaneously, or to provide the exact time-information of each transmission. Moreover, the exact morphology of the area has to be known, in order to define the hyperbolic curves of positioning. AOA requires only 2 BTSs (which is possible most of the time) and either a special antenna integrated in the terminal for self-positioning, or a special antenna at the BTS to detect the area of arrival. Pattern recognition method does not require any extra equipment, apart from accurate prediction maps and pattern recognition algorithms. Satellite positioning are the major candidates for positioning systems. The main disadvantages are the cost, the integration of satellite receivers to the terminals and the non-accurate results in cases of indoor positioning, or positioning in urban areas. In all other cases they can locate the mobile stations with quite good performance.

D. The market impact of Location services

Due to the US Federal Communications Commission (FCC) requirement that operators of mobile communications networks must be able to accurately locate mobile callers requesting emergency assistance via 911 by the year 2001, there has been a lot of activity among cellular providers to examine cellular positioning options [3]. Although there is currently no such compulsion on European networks, the European Commission is considering a streamlining along the same rules to be implemented by the start of 2003. It is estimated [4] that by 2005 there will be 129m cellphone subscribers in the US, all of which, due to the FCC ruling, will have access to location services. The same goes for mobile phone users in Western Europe. By 2005 location services will be offered as standard, meaning that 188 million subscribers in Western Europe will be able to use the service. The in-car market is also going to be crucial. In Western Europe it claims that by 2005 8 million private cars (3.3 million in North America) and that 1.9 million fleet vehicles (3.8 million) will have mobile location devices fitted (3.8 in North America). The only challenge will be to offer location services that are so attractive that consumers utilise the facility supplied with their mobile. European trials have already clearly shown consumers will pay for location services linked to useful information services and, primarily, for emergency and breakdown cover that reinforces the reason they bought a mobile in the first place. Indicative market researches have placed a conservative value of $4bn for the annual global value of wireless location services in 2004.

E. The target groups

It is worth noting [1] that due to the fact that location-dependent services address some of the most basic needs, including safety, comfort, and the need to communicate, they apply equally to all four target groups:

- Society's (government) interest in location-based services stems from its role as a provider of safe and equitable environments for its citizens.
- Operators look forward to introducing location-based services into their networks because they create revenue, cut costs, and project a positive business image to the market.
- Professional end-users are attracted by the efficiency with which location-based services enable them to manage their resources. These services also function as marketing amplifiers, since location-related information is, by nature, already very specific and can readily be adapted to specific customer groups. Some professional end-users resell location-based services directly to the end-user.
- Private end-users desire location-based information and services because they tend to heighten the user's overall sense of comfort and well-being, since truly personalized services match customers' requests according to their profile, location, and time of day.

F. Non technical issues

Besides the technical and research challenges in the area of mobile subscribers' positioning, the three most important non-technical issues that rise are standardization, privacy, and security [3].

With any new technology there is always a concern regarding standards [4]. By defining standards that facilitate development without hindering innovation, standards setting bodies such as ETSI can play a major role in the deployment of positioning capability. However, the European mobile phone industry has a head start because the predominance of GSM means that they are at least all agreed on the foundation stone of a common architecture. Since the end of 2000, there is already a more comprehensive location platform that not only fills in the small gaps left in the latest release of GSM but also takes into account more sophisticated services, such as WAP and GPRS. It is possible, however, that the industry will have to wait for 3G phones and standards towards the end of 2002 before a mobile user can roam anywhere in the world – and not just GSM countries.

An issue that requires careful attention in positioning technologies is a proper regard for privacy. Privacy, like quality, must be considered at all stages from specification to operation. The most important action point in applicable privacy policies must be that people's locations should not be monitored without their permission or appropriate legal authority. This is why the European Commission has been consulted at every stage of the development of the embryonic wireless location services industry and has laid down some very clear guidelines for companies to follow to ensure privacy is protected and the European Convention on Human Rights is not breached. Also, if records are stored for market research each request must be kept in a way that it cannot be traced back to the original customer.

Finally, taking as a given that positioning systems will be gathering information on people's movements, it will be important that sites which gather this data (e.g., the Location servers) are highly secure from both physical and computer-based attacks.

II. LOCATION SERVICES IN 3G STANDARDISATION

A. The location feature in UMTS

In UMTS [5] the Location Services (LS) are being developed in phases with enhancements added in yearly releases. More specificaly:

- In *UMTS Release 99* the LCS [6] is supported in the circuit switched domain of the 3G core network, and the UTRAN R99 specifications support cell coverage (i.e. cell identity) based LCS. Although the radio interface RRC specification also supports IPDL-OTDOA and network assisted GPS (assistance data broadcasting), the UTRAN internal interfaces do not yet support these two methods in R99.)

In UMTS Release 4 the LCS [7] shall be supported equally in the circuit switched domain and in the packet switched domain including GPRS. LCS shall be supported in GERAN and in UTRAN FDD and UTRAN TDD. The positioning methods in UTRAN will be at least the 3 methods identified earlier: cell coverage based, IPDL-OTDOA (Observed Time Difference of Arrival) and assisted GPS. Furthermore, the LCS shall support the Open Service Architecture (OSA) [8] standardized API including enhancements for the support of value added services (VAS), and support for the velocity parameter in the position request /response.

In 3G networks the capability to determine the (geographic) location of the user equipment (UE) is provided by making use of the UTRAN radio signals and other sources. There are many different possible uses for the location information [6], [7]. The positioning feature may be used internally by UTRAN network (or attached networks) for position-assisted handover or to support other features such as home location billing, by value-added network services, by the UE itself or through the network, and by "third party" services. It is possible for the majority of the UE (active or idle) within a network to use the feature without compromising the radio transmission or signalling capabilities of the UTRAN. The position information shall be reported in standard formats, such as those for cell-based or geographical co-ordinates, along with the time-of-day and the estimated errors (uncertainty) of the location of the UE.

The uncertainty of the location measurement is network design (implementation)-dependent at the choice of the network operator. The uncertainty may vary between networks as well as from one area within a network to another. The uncertainty may be hundreds of metres in some areas and only a few metres in others. It is the intent for the system design that an uncertainty of less than ±50 metres should be achievable in a typical terrestrial radio environment. In the event that the location measurement is also a UE assisted process, the uncertainty may also depend on the capabilities of the UE. In some jurisdictions, there is a regulatory requirement for location service accuracy that is part of an emergency service. In the United States, for example, the current requirement is for accuracy within 125 metres for 67% of the emergency calls.

B. The logical reference model

Figure 1 shows the logical reference model for LCS whereby a LCS Client is enabled to request location information for one or more certain target UEs from the LCS Server supported by a PLMN [7].

The operation begins with a LCS Client requesting to the PLMN LCS server for the location information of one or more than one target UEs within a specified set of parameters such as QoS. This functionality may be provided using one or more of the existing toolkits, including but not limited to CAMEL and OSA. The LCS Client may reside in an entity (including an UE) within the PLMN or in an entity external to the PLMN. The LCS server, which is aware of the network and UE capabilities and available resources, will first verify the request with the authorisation function. If the client is authorised the server will:

- request measurements, typically from the UE and the Node-B radio apparatus,
- send the measurement results to the appropriate calculating function,
- receive the result from the calculating function,
- send the results to the LCS client, and
- send appropriate accounting information to the position billing function.

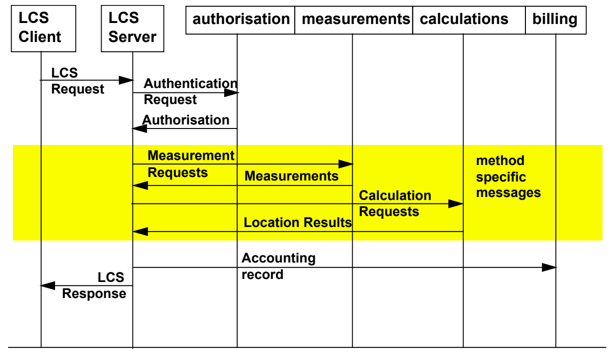

Figure 1*:* General sequence for location feature

As part of its operation, the calculating function may require additional information. This may be obtained directly by communication with the database, or it may happen through a request to the LCS server, which will mediate the request and return the information from the appropriate database. The client may make use of the position information itself, or further process and then forward the information to other authorised clients within or external to the UTRAN.

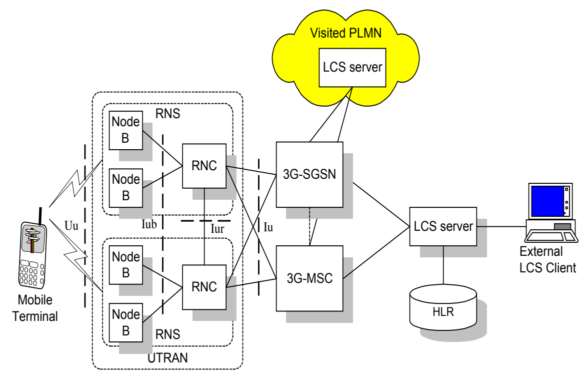

Figure 2: General Arrangement of LCS

There may possibly be available independent information that is able to supply the position information directly, or may be able to supply auxiliary information to the calculation function. Fox example, a UE mobile equipped with navigation equipment, might be able to return the exact position information when the measurements are requested (instead of just some measurements). The LCS Server, as part of its activity to supervise the positioning process, may query the UE or other elements of the network to determine their capabilities and use this information to select the mode of operation.

Figure 2 depicts the general arrangement of the Location Service feature in the 3G networks. Communication among involved entities makes use of the messaging and signalling capabilities of the UTRAN.

III. LOCATION-AWARE SERVICE DISCOVERY AND CHARGING IN 3G NETWORKS

Taking into consideration the huge range of services available to the mobile users of the forthcoming 3rd generation networks and the competitive nature of the new era, the demand for an efficient and simple mechanism for personalised VAS discovery and provision, as well as charging for their usage, to mobile subscribers is rapidly raising.

To support the realization of these mechanisms and accomplish ordered transition to new era, within the scope of the applicable business relationships, the standard UMTS infrastructure will probably be supplemented with an intelligent mediating component providing a registrar for value-added services. The existence of this mediator will be announced to the subscribers, possibly as a parameter of the subscription details and will export operational interfaces toward the involved players: a) The value-added service provider: For the dynamic registration, update and de-registration of value-added services with the Service registrar. b) The subscriber/user: To support the personalised discovery and browsing of value-added services in the service registrar, as well as the negotiation of terminal capabilities, user preferences and location with the platform.

In such a framework [9] the concept of localisation is of great importance since offers enviable opportunities for customisation and adaptation to the users requirements. In a Location-aware VAS discovery mechanism, the mediating component between VASs and users, caters for the provision to the subscribers of listings with the registered and available VASs in the serving network that only apply to the location area, the preferences and the terminal device of the user. Through these listings the user will be given the ability to readily select the VASs he desires. Taking into account the location of the requesting user, as well as the applicable preferences by his user profile and his terminal capabilities, the mediating component is able to filter the amount of available local services to restrict their number into those that only obey the aforementioned combination. As a consequence the user is presented with customised and personalised VAS listings. Such a mediating component could be situated either on the network of the interconnecting, serving operator or somewhere on the external IP world. In the former the location-specific information of the user is obtained by direct communication with the LCS server of the network, while, in the latter, interaction with the OSA API might be required to this end. The same stands for the retrieval of the User Profile and the terminal capabilities specific information. Additionally to the VAS discovery mechanism, which takes into consideration the location of the user, the User Profile information might also be location-aware. By discriminating user preferences according to the location (e.g., Home, office, vacation) and the time of the day and by maintaining different User Profiles for each instance (e.g., Home-, office-, vacation- dependent Profiles) [8], better personalisation and customisation can be achieved during the service filtering mechanism. In such a case the service discovery function takes into account only the profile that better applies to the current location and status of the user, customising the VASs filtering and provision accordingly.

In a location-aware charging model the network operators will provide their subscribers with the ability to define their own home zones comprising by some favourite places of them (e.g. home or work environment, the mother's house, etc). The location information for each subscriber will be compared against service zones established for him, so that he bills the same low "Home Zone" flat rate when he uses his cell phone from these areas. Outside home zones he will be billed at a higher rate, while different rates may be applied in different zones based on the time of day or week. It is required the phone to indicate to its owner if he is in his home zone, as well as to warn him when he roams outside its borders, while a call is in progress or prior to its initiation. In such a scheme the subscribers will have the opportunity to select the most concurrent provider and save money and the operators to customize and differentiate their services attracting new subscribers.

VI. CONCLUSIONS

Localisation can be considered as a primary factor for service differentiation and personalisation in the 3rd Generation era of mobile communications. In order to support service adaptability and reconfigurability in 3G mobile networks and systems, positioning mechanisms, offering location-specific information, must be developed or integrated to cellular networks. Indeed, in case that the research and non-technical issues can be overcome, the prospects for mobile telephone positioning are very promising. Although it is impossible to imagine all the possible applications of mobile subscribers positioning, the applications will range from simple location based information provision to emergency calls handling.

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