Design Considerations for a Platform Supporting Location-Aware Services

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Abstract: - Location-aware services are key to the future growth of mobile e-commerce. Information about a user’s current location enables a wide range of new applications and can be used to increase the usability of existing e-commerce applications for users with resource-restricted small handheld devices. Systems providing location information to applications, i.e. location services, have been presented in the literature, but most of these systems are restricted to certain applications or positioning schemes. This paper discusses the requirements of a general-purpose platform enabling location-aware services independent of the scheme deployed to determine the user’s position. Considering these requirements a layered architecture for a location service is presented as well as a prototype platform which is currently being implemented in the context of a university Wireless Local Area Network.

Key-Words: - Location-aware services, middleware, cellular networks, IEEE 802.11, m-commerce, e-commerce

1 Introduction

Though currently market-expectations have become more realistic m-commerce is still receiving an enormous interest from academia, industry and potential users. McKinsey-studies [1][2] report that within three years, the annual value of goods and services transacted over mobile networks could reach USD 13 billion, or 7 percent of all e-commerce transactions. Since mobile phones are usually not shared, and personal-identification numbers often protect them, the telephone itself can be used as a means of identification. An essential factor for the future growth of the m-commerce market is the ability to determine the user’s exact position which will enable a whole range of new applications.

The geographical location is an important part of the user’s context and can be used to greatly reduce the amount of information provided to the user. This is especially useful if one considers the limited space that is available to present information on mobile terminals and the tediousness of navigating through information on a handheld device. In addition to information filtering the location can also be used to provide special information related to the user’s current context.

M-commerce is still in its infancy, and this holds even more for location-aware m-commerce applications. Yet there are start-up companies who offer these services, in cellular communication networks such as the Global System for Mobile Communication (GSM) [3]. Several schemes for locating a mobile terminal in cellular networks have been proposed and these schemes are either based on the Global Positioning System (GPS) [4] or on signal timing measurements. However, most of these positioning schemes require a modification of the mobile station, the network base stations or even both components. The costs involved in deploying these schemes is the reason why to this date such an infrastructure has not been deployed despite the United States FCC’s decision to make mobile originated emergency calls locatable by network operators [5].

The only scheme which is currently in mobile communication systems is COO (Cell of Origin). It allows mobile terminals to be associated with the footprint of a base station, whose radius can vary from a couple of hundred meters to several tenth of kilometers depending on the network type and the local infrastructure. This accuracy cannot be considered sufficient for most conceivable location-aware m-commerce applications, as the physical density of shops and warehouses requires
more precision. One must only imagine a downtown area scenario where every shop within a 100 meters broadcasts its special offers to potential customers – the word “information filtering” here quickly becomes a euphemism. The upcoming 3rd generation mobile communication networks UMTS and IMT-2000 have the potential to change this situation significantly, especially in urban areas which will be covered by so-called micro cells with a smaller footprint than the cells of today's widespread GSM networks. Furthermore the requirements of 3rd generation networks also state the necessity of in-building cells (pico cells) which shall provide high-bandwidth services to indoor areas with a high density of users. Hence, even with a positioning scheme as simple as COO pico cells will provide a far better accuracy. Pico cells have not yet been fully standardised, but it is conceivable, that the specification will build on a technology similar to Wireless Local Area Networks (WLANs). The most widespread WLAN today is based on the IEEE 802.11 standard [6], which provides data rates from 1 Mbit/s to 11 Mbit/s and ranges of up to 50 meters indoors and 500 meters outdoors. This paper presents a platform for location-aware services which is currently being developed in the context of a university WLAN infrastructure with approximately 100 access points (APs). The platform is designed to collect location information either from the network or from the mobile stations, to normalise this information and to provide it to location-aware services. Hence, the platform could also be deployed in an m-commerce scenario such as a consumer information system in shopping malls. Section 2 will summarise the requirements of other location services to present a complete requirement set for a generic location service. Furthermore section 2 will define four layers for processing location information. Section 3 will present the platform which is currently being implemented. A conclusion and outlook will be presented in section 4.

2 Design Considerations

Several architectures have been discussed in the past, most of which are tailored to specific applications, such as tourist guides [7] or map services [8]. The design of a generic, multi-application, multi-positioning-scheme platform for location-aware services must be based on the careful inspection of the possible requirements imposed by network operators and the potential applications.

2.1 Requirements

The following set of requirements summarises the requirements for specific applications and environments as stated in [9] and [10].

1. Scalability: Depending on the size of the operator's wireless communication network, the platform must be able to cope with a large number of users.

2. Accuracy: Different applications have different accuracy requirements and different positioning schemes deliver location data with different accuracy. The accuracy can even change over time. A generic platform must thus handle location information with varying precision.

3. User privacy: The user location is very sensitive information. The user should thus be able to prevent the positioning of the mobile terminal or at least be able to determine who is accessing this information and when. More sophisticated privacy schemes are conceivable that define a group of objects which are able to locate the mobile terminal.

4. Flexibility: The platform should provide for different means of determining the terminal's position. Future more accurate positioning schemes should not require modifications to the location-aware applications using the location information.

5. Fault tolerance: The platform should be designed in a redundant manner, so that critical applications such as the localisation of emergency calls can also be supported.

6. Resource requirements: Mobile terminals have limited resources, such as battery capacity, screen size and bandwidth. The platform should consider these restrictions and be as resource-saving as possible.

7. Response time: Some applications require that position information be delivered very quickly when requested. An example for such an application would be a real-time tracking and tracing system (e.g., such as described in [11]) which require constant location updates.

2.2 Architecture Layers

Considering the diverse requirements stated above the provisioning of location information is not a simple task. For example catering for different positioning schemes implies that different coordinate system must be supported. Some positioning schemes may return the location in
terms of longitude and latitude (e.g. through GPS) while others may simply return a cell identifier. A layered approach separating the tasks of collecting location information, normalising this information and organising and providing it to applications is therefore beneficial. The following presents an overview over the conceived four layers.

2.2.1 Data collection
In the first step all data relevant to determining the mobile terminal’s position is collected. The data can be divided into “static data” and “dynamic data”. Static data refers to information which does not change frequently such as the position of the access points or base stations. Dynamic data is collected continuously and refers to information such as the user’s current position relative to some coordinate system. The kind of information that needs to be collected strongly depends on the employed positioning scheme. The most common schemes are A-GPS, E-OTD, TOA and COO:

1. Assisted GPS (A-GPS): This accurate scheme [4] requires that the mobile terminal is equipped with special hardware namely a GPS-receiver. The wireless network however does not need to be modified. A-GPS provides location information in geographical coordinates.

2. Enhanced Observed Time Difference (E-OTD): This scheme [12] also requires a modification of the mobile terminal. It measures the time differences of signals arriving from several base stations. E-OTD returns the position relative to the base stations involved in the measurements. The exact geographical coordinates of all base stations must thus be known.

3. Time of Arrival (TOA): This scheme [12] is based on measuring the arrival time of a signal emitted from the mobile terminal at several base stations. It thus requires a modification of the base stations. TOA returns the mobile station’s distance from each of these base stations. The base stations’ exact geographical coordinates must be known.

4. Cell of Origin (COO): This scheme [12] simply returns the identifier of the base station which currently services the mobile station. The position of the base stations must be known.

Depending on the implementation all positioning scheme may additionally provide information on the precision of the measurement and the shape of the location area.

2.2.2 Data normalisation
The normalised presentation of location information is calculated from the data delivered by the chosen scheme, such as coordinates of base stations, distance from the mobile station, location area shape and error margins. Normalised location data should take the form of a standardised presentation of geographical coordinates as defined in [13][14].

2.2.3 Data provisioning
In the final step the normalised location information must be provided to the applications. This requires the definition of an interface which fulfils the needs of a wide range of location-aware applications, i.e. it must provide sufficiently accurate data using a format and protocol that can be understood by small handheld devices. The data provisioning component must however ensure, that the data is only provided to authorised parties. If the location information is not stored on the mobile station but collectively in the fixed part of the wireless network then the data must be carefully organised to cater for the scalability requirement.

2.2.4 Data usage
In the final step location-aware applications can access the information provided by the data provisioning layer. Applications can either be installed on the mobile terminal or in the fixed network (e.g. web applications where a servlet or CGI-script requests the location information).

3 The Prototype Platform
An architecture that complies with the design considerations of section 2 can be implemented completely on the mobile terminal, solely within the fixed part of the wireless network or in a hybrid fashion. Each approach has its advantages and disadvantages which will not be discussed here. The following describes the prototype platform for location-aware services which is currently being developed at the Aachen University of Technology. Within the project MoPS (Mobile Professors and Students) the university is currently in the process of installing a WLAN infrastructure for students and employees. The prototype platform shall serve as a testbed for a variety of location-aware. Fig.1 depicts an overview of the prototype platform. The access points in the lower right serve the mobile stations
and are continuously queried by the Data Collector. It normalises the data and stores it in the Location Database which is indexed by the terminal’s IP-address. The MPC is the data provisioning unit and provides an interface for location information to web-based applications or applications on the mobile terminals.

3.1 Data collection layer
In a WLAN environment it is currently not possible to employ a positioning scheme other than COO. Equipping the hardware (access points and pc-cards) with special means for determining the terminals position has so far not received much attention. Also it is questionable whether schemes such as E-OTD and TOA will be feasible in a WLAN context, as they would require a very precise clock due to the small cell sizes. Additionally multi-path fading presents a serious problem in closed office environments with winding corridors. Hence, the prototype platform uses COO to determine the user’s position.

The use of COO requires knowledge about the exact geographical coordinates of all access points and the possibility to associate a cell’s unique identifier with the unique identifiers of its serviced mobile stations. The association between the identifiers can be done either locally at the mobile stations or within the fixed part of the wireless network.

Most WLAN solutions offer an interface (e.g. HTTP, SNMP, FTP) to query the access points about the currently serviced mobile stations. However, these interfaces are neither standardised nor very well documented and can thus vary from vendor to vendor. Likewise on the mobile stations the identifier of the currently servicing access point cannot be retrieved due to the lack of appropriate interfaces.

The prototype platform queries the access points about the IP- and MAC addresses of the mobile stations in its domain. The queries are done on a regular basis (polling) which is necessary, because the employed access points do not provide an event subscription and notification mechanism – or at least such a mechanism is not documented. Furthermore the geographical coordinates of all access points and the cell shape and size will be determined and stored once the installation of the WLAN is completed.

3.2 Data normalisation layer
The normalised location format is based on an XML-presentation of the standard WGS-84 [13]. The data collection layer described above returns the associations between the access points and the mobile stations in their domain. Taking the known geographical position and the footprint of an access points the mobile stations can be localised with an accuracy of around 20 to 40 meters. The accuracy depends on the range of the access point
which can vary depending on the hardware vendor and the environment. The data is then written into a database for further processing by the provisioning layer.

3.3 Data provisioning layer
The prototype platform maintains the location information for all users in a subnet at a central server. As the potential number of users in our university scenario is very large (nearly 40000 students), the provisioning layer not only provides a standardised interface for applications but also organises the data in a distributed fashion to provide for scalability.

The communication interface between the applications and the platform must be independent of the employed positioning scheme. An industry consortium has specified a protocol for accessing location information. This protocol – called Mobile Positioning Protocol (MPP) [15] – has been designed for use in the context of GSM, but can also be used in a WLAN environment with minor modifications. MPP is currently being evaluated by ETSI and considered for standardisation.

An MPP-server (referred to as MPC in [15]) is essentially an HTTP-server which responds to a predefined set of requests. A location query takes the form of an HTTP-request to a URL with the following syntax:

http://Servername/PositionRequest/Direct?<Parameterlist>

The main parameters are:
1. USERNAME, PASSWORD: A request must always include a user name and password to prevent unauthorised access. (To increase the level of security, protocols such as TLS or SSL may also be used.)
2. POSITION_ITEM: This parameter identifies the mobile stations for which the location should be returned. In the original MPP specification the user’s phone number is used to uniquely identify the mobile station. The prototype platform uses IP- or MAC-addresses for this purpose.
3. POSITION_TIME: This parameter specifies the time for which the user location should be returned. This can be used to access historical information, but the prototype platform currently only returns the present location.

The complete set of parameters can be found in [15].

An XML-response is generated from the request-data using the information stored in the database by the normalisation layer. The standardised position information can describe different location area shapes, e.g. a circle segment or a point. Since only COO is used for determining the position the result currently always takes the form of a sphere, i.e. the longitude and latitude of the center is returned as well as the height and the sphere’s radius. Future implementations will also consider the actual location area (cell footprint) because the spherical shape can be limited by thick concrete walls or other obstacles.

In large networks which service many users with frequent location updates load balancing becomes an issue, since a central server may quickly become a bottleneck. In a first step the prototype platform will have a separate MPP-server for each subnet. In later stages an approach with distributed LDAP-databases is being considered.

3.4 Data usage
The data provisioning layer offers a flexible interface for location-aware applications. The location information can either be queried by applications running on the mobile terminal itself or by other applications if they have appropriate access rights. A first demonstration service will show a map of the user’s surroundings which is dynamically updated as the user moves. Other applications such as an alarm service for lost or stolen PC-cards are planned for the future.

4 Conclusion
The result of the work presented in this paper is an architecture for a location service, which can serve a wide range of location-aware applications independent of the schemes deployed for actually determining the user’s position. Especially m-commerce applications may benefit from this architecture as it allows for quick deployment of new services and offers the flexibility to accommodate future positioning schemes with higher precision.

Other solutions which have been presented in the past focus on a single application, a single positioning scheme or both. For example [7] presents a tourist guide service which is based on a WLAN infrastructure and uses GPS to increase the accuracy. The application interface however focuses on the requirements of a single application and alternative positioning schemes are not considered. [9] presents an architecture which meets the scalability requirement but relies
on special hardware for the mobile terminals. An architecture which integrates different wireless access networks has been described in [16]. It however lacks a focus on location services. The prototype platform is currently being implemented. By using a modified MPP to implement the location data provisioning layer, a unified interface can be provided to diverse applications, thus easing the task of the application developer. The system is expected to meet the stated requirements under the given conditions. (For example the accuracy will lie within a couple of tenth of meters. This may not be sufficient for some applications but is due to the unsatisfactory support of IEEE 802.11 for location services and may be improved in the future.) Fault tolerance however is currently not given, since an MPP-server presents a single point of failure. This may be relieved with the future integration of a distributed database which may also provide redundancy. Future work will focus on the issues of improved accuracy and security and on the integration of fixed network terminals. System evaluation and measurements of the response times depending on system load and other factors will be conducted once the implementation of the prototype platform is completed.

Relevant topics which are not addressed in this work are service discovery, roaming within one type of network and handover between different types of access networks. These open issues revolve around the question of how to deal with a multitude of small, local area wireless network providers and are presently being discussed under the label 4th generation mobile networks (4G). The success of future location-aware m-commerce applications depends on the success of the 4G working groups.

References:
[3] Digital cellular telecommunications system (Phase 2+); Location Services (LCS); (Functional description) – Stage 2 (GSM 03.71 version 8.0.0 Release 1999).