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Suitability of Positioning Techniques for Location-based Services in wireless LANs

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Abstract - The steady rise of mobile computing devices and local-area wireless networks has fostered a growing interest in location-aware systems and services. Local services will be one of the most exiting features of the next generation wireless systems. This paper gives an overview of the main concerns of location-based services (LBS) which are already established in the area of mobile phone networks. Transferring LBS to an indoor wireless network, especially WLAN, is the next step. As a first step for any kind of LBS a positioning system is required. Different techniques exist in all major wireless networks which have basic procedures in common. This paper presents, analyses and categorises state-of-the-art techniques for indoor positioning and examines the suitability to support LBS in WLANs.

1 Introduction

The emerging world of mobility is characterised by a multiplicity of new technologies, applications, and services. With the ability of mobility, location identification has naturally become a critical attribute, as it opens the door to a world of applications and services that were unthinkable only a few years ago. The steady rise of mobile computing devices and local-area wireless networks has also fostered a growing interest in location-aware systems and services. Our everyday life changes because Internet applications are nowadays involved everywhere. Activities like gathering information from any networked site on world, exchanging documents, information transfer via e-mail, telephone and video conferences, e-learning or web-shopping are done everywhere, anytime. The common characteristics of all these operations are the elimination of the spatial distance between the involved partners and the time constraints. Furthermore, the information can be accessed with different devices, from classic hardwired PCs via WLAN-capable notebooks and PDAs to mobile phones.

The introduction of wireless communication in recent years opened new opportunities for communication and interaction provided by so-called location-aware or location-based systems and services. A key feature of such systems is that the application information and/or interface presented to a user is a function of his or her physical location. The granularity of position information needed could vary from one application to another. For example, locating a nearby printer requires coarse-grained positioning information whereas locating a book in a library requires a more fine-grained information.

The rest of the paper is organised as follows: In Section 2, we describe location-based services, categorise them and point out the main concerns influencing location-aware services while in Section 3 a technology overview for indoor-positioning is given. Section 4 outlines the potential of WLAN for positioning and summarises techniques and algorithms. Conclusions and future work are presented in Section 5.

2 Location-based services

Services depending on the current position of the user are well known in mobile phone networks. Provider established different commercial location-based services (LBS) like a "friend finder" [1] or a "nearest hotel finder" to bring more comfort to their customers. These services can be generalised and transferred to other wireless networks. In this paper we verify the requirements and the possibilities to apply LBS in wireless LAN (IEEE 802.11). The underlying positioning technique is essential for any application build on this basis and is discussed in Section 3.

2.1 Categories for LBS

Services based on the location of devices have different accuracy needs, but can be categorised by the provided service type [7] as follows:

Emergency The clearest application for location-based services is summarised in this category. Individuals – unaware of their exact location – in a case of an emergency (injury, criminal attack, etc.) use their mobile device. In a case of life-threatening injuries a call for assistance is possible automatically revealing the exact users location and alarm emergency forces immediately using the positioning capability of the mobile device. LBS of this category can be applied indoor and outdoor.

Navigation Entering a foreign city or area the user's needs for directions within the current geographical location can by satisfied with applications in this category. These services allow to find special places (shops, hotels, gas stations, etc.) depending on the users location with detailed maps or route descriptions (positions, directions, traffic conditions, points of interest) transferred to the mobile device. Well established car navigation systems already provide these services. The potential of general LBS in this category is the indoor navigation combining the flexibility and functionality of the mobile devices like handhelds.

Information Providing information to a user depending on his/her position are placed in this category. Travel services provide information about local sightseeing objects, yellow page services notify users of special local institutions like public swimming pools or tourist centers. Infotainment services notify about local events or location-specific multimedia content to interested users.

Discovery and Tracking Services in this category help to find lost things or persons. Examples are finding stolen cars or lost children and elderly people in malls. Similar applications allows companies to locate their field personnel (salesman or maintenance/repair crews) or even product tracking for supply chain management.

Billing Depending on the location of users different location-sensitive billing systems can be applied. With these systems consumers can be dynamically charged like a network operator can price calls from mobile phones when the user is in his "home zone".

The main objective of this paper is to show the transfer of general location-based services to an indoor wireless data network. Therefore the demands and requirements of every above mentioned category have to analysed and verified. Therefore the main concerns for LBS are introduced in the next section.

2.2 Main concerns for LBS

To decide which positioning technique is suitable for location-based services in wireless LANs it is necessary to look at the major needs and targets which have a great influence on the acceptance and usefulness of future applications and services (see Section 4). Those aspects can be formulated as questions:

Scenario/Category In which category (see Section 2.1) can the planned scenario be classified? Does the chosen technology and positioning technique inhibit future applications?

Technology Does the chosen technology need additional hardware on the infrastructure side and the client side?

Accuracy Which fluctuations in terms of accuracy are acceptable to provide the service? What is the minimum mean accuracy and worst case accuracy?

Interference Tolerance Outdoor wireless networks suffer from atmospheric interferences, indoor wireless networks from shadowing and multi path propagation because of reflection and refraction. Do the services tolerate these interferences?

Scalability When location-based services grow from one building to several buildings or even many separated blocks of buildings, does the positioning technology scale as well as the services? What can be done if a higher accuracy is required?

Security and Privacy Remote positioning and device tracking harm the users privacy. The users admission is usually needed. Security aspects to guarantee only authorised access have to be applied.

Place of Data Collection The location-sensible data can be collected and handled on server-side or on client-side. Both places have pro and cons.

2.3 General location techniques

Many ways exist to locate a user or respectively a mobile device in a wireless network. A position can be *symbolic* (informal or abstract "the station is in the center of the city"), *absolute* or *relative* to some point [8]. Some general techniques are common in all different networks (infrared, Bluetooth, RF-based, mobile phone or satellite-based networks). They can be categorised/described as follows:

Cell-of-Origin This technique is easy to realise and determines the current base stations (one or more) to which the mobile device is currently connected. These base stations (BS) exist in all wireless networks (mobile phone base stations, access point in WLAN, etc.). Due to the known position and BS range a relatively exact position can be determined.

Signal Strength In this category the exact location of a mobile device is determined using the current signal strength from a device to a BS. The signal strength decreases with increasing distance, but multi path fading and shadowing have a dominant effect in indoor and outdoor environments. Measurements to more than one BS can improve the accuracy.

Time-based A more accurate techniques than signal strength or cell-of-origin are time-based systems. Approaches like time of arrival (TOA) and time difference of arrival (TDOA) belong to this category. Similar to TOA is angle of arrival (AOA). Both determine the position according to the time of a received signal [15]. This allows a high accuracy which can be increase by repetitions or the number of BS and is also effected by multi path fading and shadowing. A disadvantage is the need for a precise clock in the mobile device for synchronisation.

These techniques are frequently used. They can be enhanced by additional effort considering *probability distributions* [19, 13] or *motion tracking* [11] of device locations. Even *neural networks* [18] are employed to achieve a higher accuracy.

3 Technology overview for indoor positioning

The major question arising from Section 2.2 is which underlying technology for an indoor positioning is the most suited for custom applications. Innumerable examples in recent years worked at the problem to determine and track the users position in an indoor wireless network. The satellite-based Global Positioning System (GPS) is established for outdoor services, but to make GPS available within buildings can only be achieved with correction technology as in assisted-GPS under great expenses. Infrared-based systems like ActiveBadges [17] are frequently used for indoor systems, but suffer from short range transmitters and the huge amount of additional hardware. Ultrasonic waves are another established and mature positioning technology used in systems like Cricket [12]. They also need a lot of additional hardware and have a tolerable accuracy.

Unfortunately, all these technologies suffer from significant drawbacks like poor scalability, need for extensive deployment of sensors and/or prohibitive expenditure for deployment and maintenance. The most promising technology uses radio frequency (RF) electro-magnetic waves. RFID devices as a passive component and WLAN devices as an active components allows a precise and low-cost positioning. Most systems [3, 6, 14] focus on the latter devices and its technology because such systems have the potential to leverage existing data networking functionality with location-aware services since the protocols in WLAN are robust and technically mature. RADAR [3] developed at Microsoft Research was one of the first systems in this field implementing simple algorithms to calculate the users position on a central server. RADAR inspired many other researcher to develop a big variety of algorithms for more accurate positioning (see next Section) because generalising the system to multi-floored buildings or three dimensions is still a nontrivial problem.

4 Suitable positioning for LBS in WLAN

To build a successful architecture for location-based services in WLANs many aspects have to be considered (see Section 2.2). Using a pre-existing infrastructure with access points has advantages in low costs and no necessary constructional changes. The access point have the technology, coverage and density for an indoor positioning system.

Depending on the application an accuracy of a few meters is adequate – this accuracy can be sufficient for every service categorised in Section 2.1. Simple positioning with a cell-of-origin technique would not be appropriate because the cells are to wide [10] and due to the WLAN standard [9] devices keep connections to access point even if a stronger signal from a new one is available. More accurate techniques use signal strength to determine the devices's location. Here the positioning exactness is disturbed by reflections, refractions and other interferences, but can be increased using intelligent algorithms. Algorithms like *weighted k nearest neighbour* [4], *bayesian algorithm* [5] compare current measurement points with a database of reference values do estimate the current position. For services in the information or billing category this technique is enough.

Other approaches use more complex algorithms computing probabilistic signal strength distributions [19, 13] to achieve a higher accuracy for services in the navigation or emergency category. Instead of calculating Euclidian distances to known signal vectors these algorithms model how the signal strengths are distributed in different geographical areas based on a sample of measurements collected at several known stations. A probabilistic framework is a complex system which needs a long training phase, but achieves a high accuracy.

Motion tracking can feed history monitoring algorithms with additional information [2]. Using the premise that the mobile user cannot switch from one set of coordinates to another totally arbitrary location, from one instant of time to the next helps to report a better position. If privacy and/or security issues prohibit any history monitoring only approaches which try to correct the current measurements with a differential correction [16] are suited. To conclude all these principles the best solution for a positioning technique for WLAN is based on the pre-existing infrastructure using the access points enhanced by probability distribution approaches.

In order to proof the suitability of WLAN positioning techniques for location-based services we present a sample scenario for a prototype. A user with a wireless LAN-capable device enters a region in the range of an access point (AP). The device registers and receives – open network assumed – local address, gateway and DNS information. Subsequently, the AP transmits all this information to a device management service, which stores the current device position along with additional properties such as installed operating system, activated browser, available bandwidth etc. Finally, the accuracy of the determined position is stored. The value of this attribute expresses the uncertainty due to the location computation based on signal characteristics. If two and more APs are reachable by the device, the accuracy is increased significantly.

The created device table is used in twofold manner. The contained information is forwarded to the service management in order to filter the relevant data accordingly. On the other hand this information can be used for broadcasting messages, for example all users in the range of the AP can be identified immediately in case of emergency. In following, solely the usage of the position for tailoring location-aware information will be described. The gained position data is forwarded to the service management component, which firstly selects all services available for the current device position. Subsequently, the activated browser presents a list, where the user can choose the desired services. The response is used to activate the corresponding services, which can be located anywhere on the Internet. In case of internal services like maps, solely the relevant region has to be determined. A number of database queries delivers the contained hardware devices in that area and their status, the personnel information about the people working in the offices around etc. In case of external services such as bus departure schedule, an adapted agent is used to query the provider's web-site entering the relevant bus station and the current time. The local service component must solely format the delivered data for the given properties of the users display. The position of the user is monitored permanently. As soon as the position changes the new data is given to the service management component in order to evaluate, which services has to be updated. For example, the map and device information will be adapted to the new current position. On the other hand no action for the bus departure schedule is required in this case. The schedule can be updated e.g. every hour or on demand.

5 Conclusion

The main objective of this paper is to show the transfer of location-based services – which are well known in the field of mobile phone networks – to an indoor wireless network, especially wireless LAN. As a first step a positioning technique is required to this kind of services. Therefore a categorisation of established services and general techniques for positioning is presented. After analysing relevant existing systems the best suitable technique is promoted. It reflects the trend for WLANs in mobile networks and builds a foundation for LBS in WLANs.

As future work, we plan to develop an architecture for location-based services using WLAN positioning techniques. Furthermore, we aim to integrate semantic web approaches to support dynamic discovery and composition of services.

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