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Location Based Services - Positioning Techniques and its Applications

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Abstract — ***Location Based Services (LBS) are a general class of computer program level services used to include specific controls for location and time data as control features in computer programs. As such LBS is an information service and has a number of uses in social networking today as an entertainment service, which is accessible with mobile devices through the mobile network and which uses information on the geographical position of the mobile device. This has become highly significant with the expansion of the smartphone and tablet markets as well. LBS are used in variety of contexts such as entertainment, work, personal life, and indoor object search. This paper discusses various positioning techniques for accurately determining the Location Based Services along with its applications.***

Key words—Location Based Services, Positioning, Global Positioning Systems, Geographic information systems.

1. Introduction

Talk and change the world is the modern day slogan for vital means of communication for social interaction. Mobile phones and the Internet have revolutionized the communication and caused the lifestyle changes of the people. The advances in mobile telephony can be traced in successive generations from the early "0 G" services like MTS (Mobile Telephone Service) and its successor Improved Mobile Telephone Service, to First Generation (1G) Analog Cellular Network, Second Generation (2G) Digital Cellular Networks, Third Generation (3G) broadband data services to the current state of the art, Fourth Generation (4G) native-IP networks.

An increasing number of mobile phones and Personal Digital Assistants (PDA) has allowed people access to the Internet where ever they are and whenever they want [3]. From the Internet, they can obtain information on events like cinema, concerts, parties and information on places like city maps, restaurants, museums and hospitals with high-speed data access provided by Wi-Fi and mobile broadband. In recent years, the rapid development of mobile application markets and mobile commerce has been key driver of smart phone adoption [4]. The penetration of mobile wireless technologies in the recent past has resulted in larger usage of wireless data services. New and innovative applications like ring tone, wall paper downloading, MMS-messaging, video clip delivery and reservation enquiries are some of the popular services offered by the service providers today [5]. The knowledge of mobile user's location by the service provider can enhance the class of services and applications that can be offered to the mobile user. These classes of applications and services, termed "Location Based Services" (LBS), are becoming popular across all mobile networks like GSM and CDMA [5].

Consider a customer who wishes to take dinner in a restaurant searches for a restaurant in the internet via the mobile device. This search normally displays the web page of every restaurant available in the world. A useful approach is to restrict the display by adding further criteria on the city the user is, the actual time or special type of restaurant like Chinese or Greek. LBS can be used for such kind of search with respect to position and time. They are the information services accessible with mobile devices through the mobile network with the ability to make use of the location of the mobile device. From a historical point of view location based information are not a new thing which came up with the invention of mobile phones. The position specific information is also transported on one hand in a person-to person communication by post-it notes and graffiti. On the other hand methods to locally inform a mass-audience are posters (e.g. of concerts in the town) or simply traffic signs, which submit navigational information. These communication forms are usually one way communications. LBS give the possibility of a two way communication and interaction. Therefore the user tells the service provider his location like the kind of information he needs, his preferences and his position. This helps the provider of such location based services to deliver information customized to the user [3]. LBS are an intersection of technologies namely Internet, Geographic Information System (GIS), Mobile Internet and New Information and Telecommunication Technologies (NICT).

A Geographic Information System (GIS) integrates hardware, software, and data for capturing, managing, analysing and displaying all forms of geographically referenced information and allows to view, understand, question, interpret and

visualize data in different ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts..Mobile Internet refers to the use of browser-based Internet services, from a handheld mobile device, such as a smartphone, a feature phone or a tablet computer, connected to a mobile network or other wireless network. NICT refers to the convergence of audio-visual and telephone networks with computer networks through a single cabling or link system.

LBS use these existing technologies to provide services to the customer. The next section introduces the emerging trend of LBS.

1.1Components of LBS

To access a location based service, different infrastructure elements are required. The five basic components and their connections are shown in the Figure 1.

Figure 1: The Basic Components of LBS.

The component requirement of LBS includes the following.

- **Mobile Devices:** A mobile device is a tool used by the user to request the information. Possible devices are Personal Digital Assistants (PDA), Mobile phones, Laptops, navigation unit of a car and so on. The user requests via any of the above devices and the result can be given by speech, using pictures, text and so on.
- **Communication Network**: The mobile network plays a major role in LBS by transferring the user data and the service requests from the mobile terminal to the service provider and then transfers the requested information from the service provider to the user.
- **Positioning Component:** The requests placed by the mobile devices are communicated to the service provider via the communication network. For the request to be processed, the service provider has to determine the position of the mobile devices. The position can be obtained either by using the Global Positioning Systems (GPS) for outdoor positioning, or active badges, radio beacons for indoor positioning. If the position is not determined automatically it can also be specified manually by the user.

- **Service and Application Provider:** The service provider offers a number of different services to the user and is responsible for the service request processing. Such services offer the calculation of the position, finding a route, searching yellow pages with respect to position or searching specific information on objects of user interest.

- **Data and Content Provider:** All the information that can be requested by the users are not stored and maintained by the service providers. Geographic information and Location based information are requested from the maintaining authority or industry partners who maintain the requisite information.

1.2 Action of LBS on Data

There are five main and important acts on positioning data depending on the needs of the user.

1. **Locating:** locating where the user is with respect to somebody or some object.
2. **Searching:** searching a particular object, person or an event.
3. **Navigating:** Searching a way to the distinct point.

4. **Identifying:** retrieving the properties of a location.
5. **Checking:** look for events at or nearby a certain location

The two basic actions viz locating and navigating mainly rely on geospatial information. Searching, identifying and checking needs a bigger variety of different information viz

- **Static information**- contents such as yellow pages which stay constant over a period of time and could be used by other media as well
- **Topical information** that may change while the user is on the move such as traffic information and weather forecasts
- **Safety information** like roadside help in a situation when the car breaks down

2. Types of Services in LBS

Services in LBS are distinguished by two major kinds in accordance with the information delivery to the user.

- **Pull Services** deliver information directly requested from the user. This is similar to call a website in the Internet by filling in its address in the web browser-address field. Pull services are further classified into **functional service** like ordering a taxi or an ambulance by just pressing a button on the device and **information service** like searching the nearest Indian restaurant.
- **Push services** deliver information which are either indirectly or not requested from the user, which are activated by an event, which could be triggered if a specific area or location is entered or triggered by a timer. Indirectly requested information could be a news service subscription of a particular city, while not requested information could be the advertisements or warning messages. Since push services are not bound by previous user interaction with the service, they are more complex to establish [3].

In LBS, the position service plays a major role in determining the accurate location of the user. The next section discusses the various available positioning techniques.

3. Positioning Techniques

Positioning techniques are classified into two groups:

1. **Network based positioning**- The base station network is used for tracking and evaluating the user location. The device either sends the signal or is sensed by the network.

2. **Terminal based Positioning-** the location is calculated by the user device itself from signals received from base stations. Global Positioning Systems (GPS) belongs to this group where GPS satellites are used.

Positioning techniques can be implemented in two ways- **Self-positioning and remote positioning.** If the positioning receiver makes an appropriate signal measurement from geographically distributed transmitters and uses these measurements to determine its position, it is termed as Self- positioning and **remote positioning is** when a device can be located by measuring the signals travelling to and from a set of receivers**.**

3.1 Self-Positioning Techniques

- **GPS and Assisted GPS (A-GPS):** GPS is the worldwide satellite-based radio navigation system, consisting of 24 satellites, equally spaced in six orbital planes 20,200 kilometres above the Earth, that transmit two specially coded carrier signals, one for civilian use and one for military and government use[1]. The system's satellites transmit navigation messages, which a GPS receiver uses to determine its position. GPS receivers process the signals to compute position in 3D – latitude, longitude, and altitude – with an accuracy of 10 meters or less. The main advantage of this technique is that the GPS system is already in use for many years. Major disadvantage of this technique is that in order to operate correctly, it needs a clear view of the skies and signals from at least three or four satellites. This requirement excludes this option for indoor environment positioning. In Assisted GPS (A-GPS), the mobile network or a third party service provider can assist the handset by directing it to look for specific satellites and also by collecting data from the handset to perform location identification calculations that the handset itself may be unable to perform due to limited processing power. The A-GPS method is extremely accurate, ranging from 1to 10 meters [1].

- **Indoor Global Positioning System:** This system focuses on exploiting the advantages of GPS for developing a location-sensing system for indoor environments. Indoor GPS takes into account the low power consumption and small size requirements of wireless access devices, such as mobile phones and handheld computers. The navigation signal is generated by a number of pseudolites (pseudo-satellites), which are devices that generate a GPS-like navigation signal.

The signal is designed to be similar to the GPS signal in order to allow pseudolites-compatible receivers to be built with minimal modifications to existing GPS receivers. As in the GPS system, at least four pseudolites have to be visible for navigation, unless additional means, such as altitude aiding are used [1].

Mobile Terminal Positioning over Satellite UMTS (S-UMTS): This technique suggested by Zeimpekis et al. (2002), uses only two satellites in order to provide positioning services. This system makes use of a typical Satellite UMTS constellation which can provide positioning information along with other information like cable TV and satellite telephony to name a few. The only drawback of this system is that it can be used only for services that need medium accuracy between 100-250m like local information news, rural and suburban emergency services.

3.2 Remote Positioning Techniques

In this section, we discuss the various methods used in remote positioning techniques like Cell Identification, direction of angle of arrival, time delay, absolute time of arrival, Differential time of arrival.

- **Cell Identification / Cell of Origin (COO):** This basic method relies on the fact that a mobile network can identify the approximate position of a mobile handset by knowing which cell site the device is using at a given time. The main benefit of Cell-ID is that it is already in use today and can be supported by all mobile handsets.

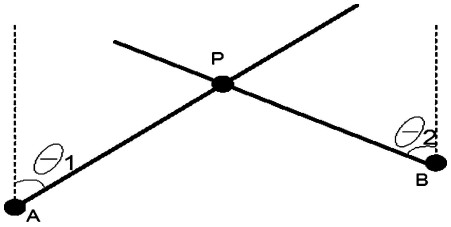

Figure 2[7]: Positioning based AOA measurement.

- **Direction or Angle of Arrival (AOA) :** In this technique, a directional antenna beam is steered in space until the direction of the maximum signal strength is detected. The location of the desired target is found by the intersection of several pairs of angle direction lines, each formed by the circular radius from a base station or a beacon station to the mobile target. AOA methods may use at least two known reference points (A, B), and two measured angles $\theta 1$, $\theta 2$ to derive the 2-D location of the target *P*. Estimation of AOA, commonly referred to as direction finding (DF), is accomplished either with directional antennae or with an array of antennae.

The advantages of AOA are that a position estimate may be determined with as few as three measuring units for 3-D positioning or two measuring units for 2-D positioning, and that no time synchronization between measuring units is required. The disadvantages include relatively large and complex hardware requirements and location estimate degradation as the mobile target moves farther from the measuring units. For accurate positioning, the angle measurements need to be accurate, but the high accuracy measurements in wireless networks may be limited by shadowing, by multipath reflections arriving from misleading directions, or by the directivity of the measuring aperture.

- **Time Delay:** Since electromagnetic waves travel at a constant speed in free space, the distance between two points can be estimated by measuring the time delay of a radio wave transmitted between them. This method is well suited for satellite systems and is used universally by them. There are two types of time delay methods: Absolute Timing or Time of Arrival (TOA) and Differential Time of Arrival (TDOA).

In **Absolute timing or Time of Arrival (TOA)** positioning information is derived from the absolute time for a wave to travel between a transmitter and a receiver or vice versa. Here the receiver knows the exact time of transmission. Alternatively, this approach might involve the measurement of the round-trip time of a signal transmitted from a source to a destination and then echoed back to the source, giving a result twice that of the one-way measurement.

In general, TOA results in two problems. First, all transmitters and receivers in the system have to be precisely synchronized. Second, a timestamp must be labelled in the transmitting signal in order for the measuring unit to discern the distance the signal has travelled. TOA can be measured using different signalling techniques such as direct sequence spread-spectrum (DSSS) [8, 9] or ultra wide band (UWB) measurements [10].

Differential Time of Arrival (TDOA) determines the relative position of the mobile transmitter by examining the difference in time at which the signal arrives at multiple measuring units, rather than the absolute arrival time of TOA.

For each TDOA measurement, the transmitter must lie on a hyperboloid with a constant range difference between the two measuring units.

The equation of the hyperboloid is given by

$$R_{i,j} = \sqrt{(x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2} - \sqrt{(x_j - x)^2 + (y_j - y)^2 + (z_j - z)^2}$$

where (x_i, y_i, z_i) and (x_j, y_j, z_j) represent the fixed receivers i and j; and (x, y, z) represent the coordinate of the target[7].

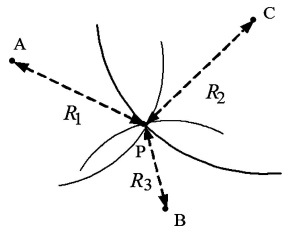

Figure 3[7]: Positioning based on TOA measurements

A 2-D target location can be estimated from the two intersections of two or more TDOA measurements, as shown in Figure 4. Two hyperbolas are formed from TDOA measurements at three fixed measuring units (A, B, and C) to provide an intersection point, which locates the target P.
The next section summarizes the performance metric parameters used to measure the position accuracy.

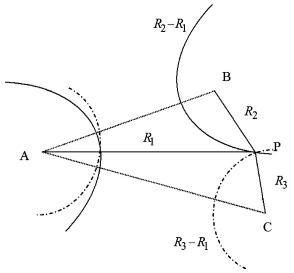

Figure 4[7] Positioning based on TDOA Measurements

4. Performance Metrics

It is not sufficient if we measure the performance of a positioning technique only by observing its accuracy. We need to consider the different techniques of positioning and locating techniques. Some of the parameters which provide the performance benchmark for wireless systems are described in this section.

Accuracy is the most important requirement of positioning systems. In this case, the mean distance error, which is the average distance between the estimated location and the true location, is adopted as the performance metrics. Higher the accuracy, the better is the system.

Precision refers to the measure of the robustness of the positioning technique as it reveals the variation in its performance over many trials. The cumulative probability functions (CDF) of the distance error is used for measuring the precision of a system. When two positioning techniques are compared, if their accuracies are the same, the system is preferred with the CDF graph, which reaches high probability values faster, because its distance error is concentrated in small values.

Complexity of a positioning system can be attributed to the hardware, software, and operation factors. Location rate is an important indicator for complexity. The dual of location rate is location lag, which is the delay between a mobile target moving to a new location and reporting the new location of that target by the system.

Scalability of a system ensures the normal positioning function when the positioning scope gets large. The positioning performance degrades when the distance between the transmitter and receiver increases. A location system may need to scale on two axes: geography and density. In Geographic scale the area or volume is covered. In Density the number of units located per unit geographic area/space per time period is covered. As more units are crowded in an area/space, wireless signal channels may become congested, and more calculation may be needed to perform location positioning. Another measure of scalability is the dimensional space of the system, which can locate the objects in 2-D or 3-D space.

The ***cost*** of a positioning system may depend on many factors.
Important factors include money, time, space, weight, and energy. The time factor is related to installation and maintenance. Mobile units may have tight space and weight constraints.

The next section discusses some of the applications of LBS.

5. LBS Applications

LBS has a variety of applications viz recommending social events in a city, requesting the nearest business or service, such as an ATM or restaurant, Assistive Healthcare Systems, Locating people on a map displayed on the mobile phone, using Location-based mobile advertising, Asset recovery and so on. They can be classified into emergency services, navigation services, tracking and management services. A few of them are briefly described in this section.

Emergency Services

One of the most evident applications of LBS is the ability to locate an individual who is either unaware of his/her exact location or is unable to reveal it because of an emergency situation like injury, criminal attack, and so on. Motorists are often unaware of their exact location when their vehicle breaks down. When exact location is automatically transferred to the emergency services the assistance can be provided quickly and efficiently. This includes public and private emergency services for both pedestrians and drivers. The Figure 5 describes the applications of LBS in emergency services. Radio beacons on marine vessels or small personal beacons transmit radio signals in the case of an emergency. The systems range from small beacons with only normal radio signals like homing signal for rescuers up to beacons which transmit their actual GPS position via satellite to the emergency services.

Figure 5[3]: Search and Rescue Operation using LBS

Navigation Services

Navigation services are based on mobile user needs for directions within their current geographical location. The ability of a mobile network to locate the exact position of a mobile user can be manifested in a series of navigation-based services. By positioning a mobile phone, an operator can let the user know exactly where they are as well as give the user detailed directions about how to get to a desired destination. In most of the current car navigation systems, the user gets the pre-calculated route via the mobile network connection.

Tracking and Management Services

Tracking services are applicable both to the consumer and the corporate markets. One popular example refers to tracking postal packages so that companies know where their goods are at any time. Vehicle tracking can also be applied to locating and dispatching an ambulance that is nearest to a given call. LBS also enable companies to locate their field personnel like salespeople and repair engineers so that they are able, to dispatch the nearest engineer and provide their customers with accurate personnel arrival times.

Foursquare

Foursquare is a location based social-networking service that allows the users to “check-in” at a venue using mobile devices. Location is identified using the GPS in the mobile device or by network location provided by the application being used. Each user on checking-in gets user points. Users have the option to post their check-in updates in the social networking sites like Facebook and Twitter. There are various versions of Foursquare for the different mobile operating systems. Foursquare was founded by Dennis Crowley and Naveen Selvadurai, and as of April 2012, there have been more than 2 billion check-ins with Foursquare[12]. Many Business owners have used Foursquare to successfully drive their business goals by posting the advertisement on it and reaching the customers. The customers also give feedback and express their suggestions which in turn helps in the business.

Loopt

Loopt is a truly location based service that not only allows check in but also shows the exact location on the map relative to user’s friend location and also displays the restaurants, movie theatres, parks and other areas of interest in the vicinity. Loopt pulls the geographic information from the nearest cellular towers to triangulate the user’s position and the relative

distance from user's friend whose location is shown on the map. Loopt is completely permission based and the user has the privilege to hide the location information from friends. It also allows real time messaging, photo sharing, likes and share the information on the social networking sites.

Gowalla
Gowalla is very similar to Foursquare and uses "passport stamps" that a user collects upon every check-in to various places. In addition to features of Foursquare, Gowalla also features photo integration and the ability to comment on friend's location. An interesting feature of Gowalla is "trips", where the user update can guide the friends through various spots with recommendations on where to check-in.

Few more applications based on locations are – whrrl, Rally up, BlockChalk, brightkite, and MoPho.to.
Clearly there are location based applications for everyone using the smartphone, which takes care of the privacy and the broadcasting of the messages.

6. Privacy and Security
LBS are highly beneficial while it could divest the users of their privacy. There are LBS standalone services like FourSquare, Google Latitude or Gowalla that use a smart phone's GPS coordinates to publicize a user's location. The social network platform Facebook also publishes the uses location by default, exposing hundreds of millions users to all kinds of privacy invasion ramifications.

There must be in-built security mechanisms while providing Location Based Services, so that the user feels secure with the location information which is broadcast. Localized Encryption and Authentication Protocol (LEAP) [11], Location Blurring [12] are some of the methods employed to secure the user location information.

7. Challenges
The major challenges to LBS are in terms of
- Positioning techniques- different levels of accuracy, quality of position, response time
- Privacy- "Right to be left alone", users care about their privacy and are concerned about any intrusions
- Interoperability- expand LBS from niche to mass market service, standardize the services and reduce the cost and business risks
- Emergency Services- timely delivery of accurate emergency call locations to the closest emergency help centres

7.1 Addressing the Challenges
Handling information related to a person's location requires appropriate attention to be given to privacy and security. One option would be to allow the user an option to set the privacy preferences via an interface. This can also include information such as, who can access the location information and under what circumstances? For example, the user can share the location information only in certain preferred circumstances such as in places like work related, travel or while hanging out with friends to find where the other friends are currently located. The user at will, can disable the location based or switch off the location sharing when not required. Any LBS applications should cater to the privacy needs of the user and address these challenges efficiently.

8. Conclusions
This paper discusses the Location Based Services, its techniques and applications. It introduces the components of Location Based Services, challenges for providing the services, uses information about the user's location to answer queries relating to the user's current location. These questions are answered by determining the user location using self-positioning techniques discussed namely GPS, A-GPS, Indoor Global Positioning System, or remote positioning techniques like Cell of Origin (COO), Direction or Angle of Arrival (AOA), and time delay techniques like Time of Arrival (TOA), Differential Time of Arrival (TDOA). The paper discusses different performance metrics and applications of LBS in emergency, navigation and tracking and management services.
The key factors to success of LBS is compelling applications, wide range of LBS-capable handsets, IP based standards, Good Business Models and User awareness and promotions.
Similar to their usefulness in the consumer market, location based applications can provide great value to the business. The applications discussed in the paper are only a few of the many available today. Although it is a modest beginning, there is a bright future for the location based service applications in the enterprise and the consumer market.

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