LOCATION BASED COMPUTING

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Abstract: This paper introduces the most significant concepts concerning location based computing. Location Based Services (LBS) is the ability to find the geographical location of the mobile device and provide services based on this location information. Location related services are described as next revolution on services and functionality in the mobile network. A very important issue of location-based services is the mobile positioning. That is the technique that makes possible to estimate the geographical position of a mobile device. Various types of mobile positioning techniques have been proposed for locating mobile devices. Generally, the positioning methods can be categorized into three groups: network based, handset based and hybrid methods.

The location based or location-aware computing involves the automatic tailoring of information and services based on the current user's location. Due to technical progress in various fields, digital location information is available to software applications running on many different mobile computing platforms. Therefore, location-based computing has made possible applications with the capability to sense their location and modify their settings, user interface, and functions accordingly.

Keywords: GPS, LBS, location based computing, mobile and wireless

1. Introduction

The deployment of location-based services is being spurred by several factors:

- Competition
- Regulation
- Technology

Location Based Service (LBS) is the ability to find the geographical location of the mobile device and provide services based on this location information.

Location related services are described as the next revolution on services and functionality in the mobile network. Examples of services using mobile location are:

- Location sensitive billing
- Location of emergency calls and roadside assistance
- Driving directions and assistance
- Mobile yellow pages (e.g. where is the nearest pizza restaurant?)
- Tracking (packages, cars, people, busses etc.)
- Location based messages (commercials)

The quality of the services will depend on accuracy of the location estimates. This accuracy depends on the location technologies used, and on the network topology. Different location based applications require different levels of accuracy, with values of hundred meters up to centimetres.

The location services that wireless network operators offer could therefore be anything from safety to billing and information services to tracking, navigation and data/ video-integrated products. There are several applications based on location services apart from the billing ones. However, none of these services is currently widely deployed and routinely used by great number of people. That is the challenge for LBS to achieve critical mass and wide usage.

The components of a location-based service are shown in figure 1.

- **The Mobile Positioning Systems:** Cell of origin (COO), angle of arrival (AOA), time of arrival (TOA), enhanced observed time difference (E-OTD) and assisted GPS (A-GPS).
- **The Mobile Network:** Used to deliver LBS service to mobile users. Service gateways, which connect positioning systems with the mobile network and location-based service (LBS) applications, are essential for LBSs. Short message service (SMS), general packet radio system (GPRS) and wireless application protocol (WAP) standards support LBSs. The architecture being adopted today by many network operators is based upon mobile location centre (MLC). The MLC separates the location technology to locate the device from the application that uses location information. Since many applications can function quite well with cell of origin information, network operators can deploy advanced location technology gradually and not wait for 100-percent coverage to offer new services.
- **Location-Based Service (LBS) Applications:** Each application consists of an application server and a spatial database. The processing

centre of a location-based service is the application server that handles user interface functions and communicates with the spatial database. Components communicate with each other via application programming interfaces (APIs).

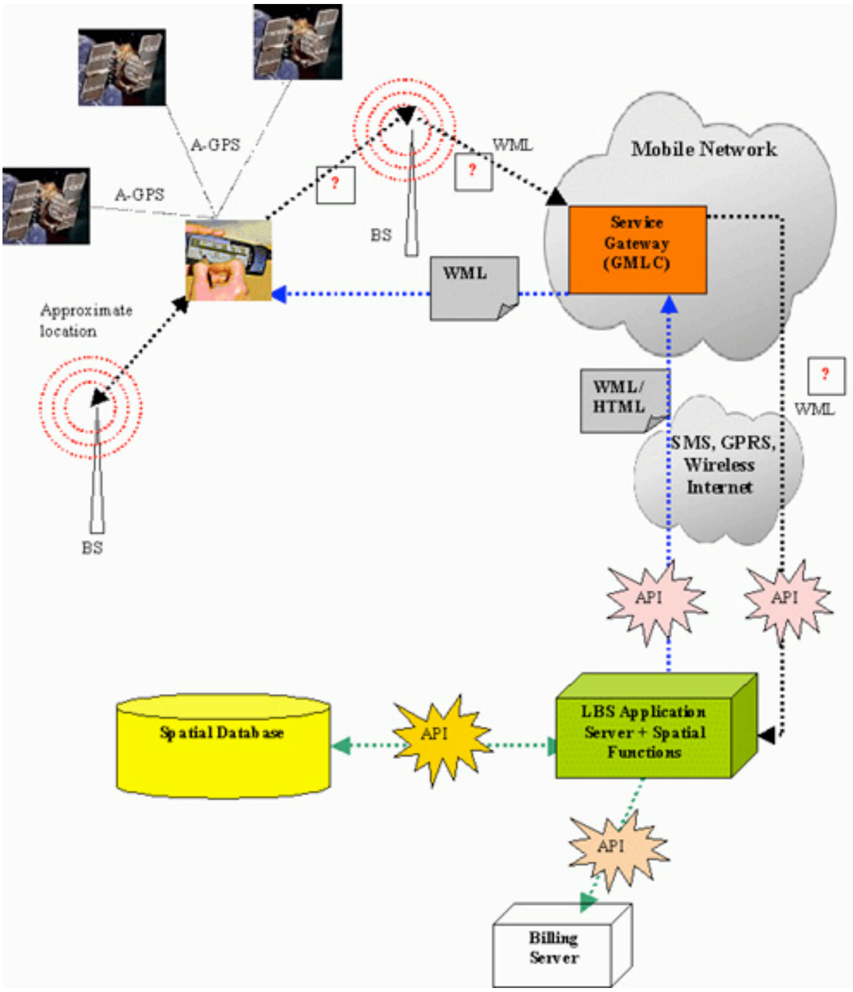

Figure 1: Components of a location-based service.

2. Mobile positioning techniques

Mobile positioning is technique that makes possible to estimate the geographical position of a mobile device. Various types of mobile positioning techniques have been proposed for locating mobile devices. Generally, the positioning methods can be categorized into three groups: network based, handset based and hybrid methods.

2.1 Handset based technologies

The location estimation is calculated by triangulation technologies based on timing or angle of signal transmission and reception at the handset. These positional mechanisms require a new terminal, a new SIM card, or both. In practice, the subscriber will have to replace their handsets or SIM card in order to use the location based services. Handset based technologies have the best accuracy, but need new or upgraded mobile terminals. The user can decide, whether he/she wants to be located or not. These technologies are relatively complex.

This category is referred to as "handset based" because the handset itself is the primary means of positioning the user, although the network can be used to provide assistance in acquiring the mobile device and/or making position estimate determinations based on measurement data and handset based position determination algorithms.

The handset-based technologies are refereed to Global Positioning System (GPS), Assisted-GPS (A-GPS), Enhanced Observed Time Differential (E-OTD).

2.2 Network based technologies

This category is referred to as "network based" because the mobile network, in conjunction with network-based position determination equipment (PDE) is used to position the mobile device. No extra hardware is needed in the user's device. In contrast to terminal based technologies, these technologies allow push services initiated by predefined events. Network based technologies have the advantage that they can be used with old mobile terminals.

The network based technologies include Cell of Origin (COO/CGI), Cell Global Identity Timing Advance (CGI TA), CGI Native Measurement Resource (CGI NMR), Enhanced-CGI (E-CGI), Angle of Arrival (AOA), Time of Arrival (TOA), Uplink-TOA (UL-TOA), Radio Propagation Techniques, etc.

2.2.1 Hybrid methods

The hybrid methods are combination of different location methods such as TOA + AOA or GPS + TOA. In this category, upgrades are needed both on the mobile terminals and in the network. The software in mobile terminals must be upgraded and new elements must be deployed in mobile network.

They can improve the likelihood of detection and allow more accurate measuring due to redundancy of data.

2.2.2 Cell of Origin (COO/CGI)

COO uses base station's cell area to identify the location of the caller. The accuracy depends upon the cell area and the accuracy can be up to 150 metres for urban area. Although the accuracy is not high and cannot be applied for emergency usage it is popular amongst the operators as it does not require any modifications in the handset or the network, hence it is comparatively cheap to deploy.

The accuracy of this method varies according to the size of the cell. The radius of a cell may vary from 100 m to 35 km. In cells that cover limited geographical area, the accuracy is fairly good. It decreases fast as the distance between the transmitter and receiver increases. Accuracy will also depend on whether the cell is an omni cell or a triangular sector cell.

2.2.3 Cell Global Identity Timing Advance (CGI TA)

The single-cell timing advance (TA) positioning method uses the Cell Global Identity (CGI) and the Timing Advance (TA) parameter to determine the location of the MS. The CGI identifies the cell where the MS is located. A cell can be a circular (omni) or a triangular sector. The TA parameter is estimate of the distance from the MS to the serving BTS. The measurement is based on the access delay between the beginning of a time slot and the arrival of bursts from the mobile. The access delay is proportional to the distance between the base station and the mobile.

TA values are divided into 64 slots (0-63), each with a radius of 550 m. This means that a MS which is 600 m away from the serving BTS, will have a TA value of 1. By using the TA value, the location of the MS can be constrained further than the cell identity, as the location of the terminal can be narrowed to a circle or a sector in steps of a 550 metres radius from the BTS.

2.2.4 CGI NMR

The Native Measurement Resource (NMR) is originally used for cell handover in GSM network. This information has been used as the main ingredient and use in estimation algorithm. First, the NMR must find the serving cell and its six surrounding cells. From these cells, a number of them are used to estimate the position using some form of triangular computation.

2.2.5 Enhanced-CGI (E-CGI)

Enhanced CGI is a Cell-ID based positioning technology. It can be network-based and may not require network modification nor change of SIM cards. The investments of the network operators are minimal, and no cost of the subscribers required at all. The methodology requires identity of cell in which mobile user is located to be determined. Triangulation computation is employed and results are verified with other network information available. The advantage of Enhanced-CGI location resolution, beside its ability to be network based includes minimum deployment integration with existing wireless infrastructure and rapid services introduction.

2.2.6 Angle of Arrival (AOA)

This method involves analysis of the angle of arrival (AOA) of a signal between mobile phone and cellular antenna. The angle of arrival (AOA) method requires the installation of directional antennas or antenna arrays. The method determines location of MS based on triangulation. The intersection of two directional lines each formed by a radial from a BTS define a unique position for the MS. This method requires the MS to have knowledge of a minimum of two BTSs (or one pair). If available, more than one pair can be used (most common is tree BTSs which yields two pairs).

The accuracy of this method varies according to the knowledge the bearing towards the surrounding BTSs. The method also requires line-of-sight to the involved BTSs for the position estimate to be accurate.

2.2.7 Time of Arrival (TOA)

The difference in time of arrival for a signal from mobile user to more than one base station is used to calculate the location of the device. This needs synchronisation of cellular network using GPS or atomic clock at each base station. The cell sites are fitted with location measurement units (LMUs). By measuring the signal from mobile phone, the LMUs can triangulate the user's position. The cost benefit analysis is not very much in favour of the usage of this technology, as the cost of implementing this is very high as compared to the enhancement in the performance. While TOA is more accurate than COO technology, it is expensive because of the large number of LMUs required.

2.2.8 Uplink-TOA (UL-TOA)

Based on measurement of TOA of a signal from a mobile terminal to 3 or 4 measurement units, the uplink TOA located at the based station receives the signal and measures the value of the uplink time of arrival. Then the mobile position centre (MPC) will provide an estimated position by calculation of time difference of arrival by subtracting pairs of UL-TOA values.

The uplink time of arrival (UL-TOA) method is quite similar to E-OTD, except that the calculations are performed by the network and not by the MS. This method works by having all BTSs within range listening to a burst from the MS. When a base station receives this burst, it records the time and sends it to a server. The server gathers the information from multiple BTSs. By comparing the time of arrivals and BTSs positions, the server can calculate the position of MS.

The accuracy of this method varies according to the knowledge of surrounding BTSs, propagation of the received signals and synchronisation of the clocks in the network. Since this solution is entirely network based, the investment cost for the operator is high.

3. Radio Propagation Techniques

These techniques utilize a previously determined mapping of radio frequency (RF) characteristics to determine an estimate of mobile device position. The strengths of RF signals arriving from more access points in wireless LANs relate to the position of mobile terminal. They can be used to derive the user's location. In heterogeneous environment, e.g. inside a building or in a variegated urban geometry, the received power is a very complex function of the distance, the geometry and materials. The complexity of the inverse problem (to derive the position from the signals) and the lack of complete information, motivate to consider flexible models based on a network of functions (neural networks). Specifying the value of free parameters of the model requires a supervised learning strategy that starts from a set of labelled examples to construct a model that will then generalize in an appropriate manner when confronted with new data, not present in the training set.

The advantage of the method is that it does not require ad-hoc infrastructure in addition to the wireless LAN, while the flexible modelling and learning capabilities of neural networks achieve lower errors in determining the position, are amenable to incremental improvements, and do not require the detailed knowledge of the access point locations and of the building characteristics. A user needs only a map of the working space and a small number of identified locations to train a system, as evidenced by the experimental results presented.

3.1 Global Positioning System (GPS)

The NAVSTER GPS is a worldwide radio-navigation system formed from a constellation of satellites and their ground stations. The satellites are circling at about 24,000 kilometres above the Earth. There are 24 satellites. Additional operational satellites placed in orbit will replace satellites as they fail.

GPS uses these "man-made stars" as reference points to calculate positions accurate to a matter of meters. With advanced forms of GPS you can make measurements to better than a centimetre! It is like giving every square meter on the planet a unique address. GPS provides continuous coverage and the satellite range is determined from phase difference.

The ground stations, also known as the “Control Segment”, monitor the GPS satellites, checking both their operational health and their exact position in space. The master ground station transmits corrections for the satellite's ephemeris constants and clock offsets back to the satellites themselves. The satellites can then incorporate these updates in the signals they send to GPS receivers. There are five monitor stations: Hawaii, Ascension Island, Diego Garcia, Kwajalein, and Colorado Springs.

GPS receivers have miniature dimensions. They consist of just a few integrated circuits and so become very economical. That makes the technology accessible to virtually everyone.

The determination of position may be described as the process of triangulation using the measured range between the user and four or more satellites. The ranges depend of time of propagation of the satellite signals. Four satellites are required to determine the three coordinates of position and time. The time is involved in the correction to the receiver clock. It is ultimately eliminated from the measurement of position.

Each satellite contains an atomic clock synchronised with a central clock located at the GPS control centre in Colorado, USA. High precision is possible through use of atomic clocks. Each satellite has two cesium clocks and two rubidium clocks, which maintain time with a precision of a few parts in 1013 or 1014 over a few hours, or better than 10 nanoseconds. Every satellite transmits a continuous radio signal, giving its position and the time the signal was sent. When your receiver on the ground picks up these signals it can work out your precise location (latitude, longitude and altitude) based on the time it took for the signals from four different satellites to reach your receiver.

3.2 Assisted-GPS (A-GPS)

The GPS method has high accuracy outdoors, but is complicated indoors or in certain urban areas because GPS needs to contact with the GPS satellites to function. It needs to be able to see four or more satellites, and when a GPS receiver receives a signal from the satellites, the time of arrival of the signal is used to calculate the receiver’s position. When a GPS receiver is switched on, it does not know the precise time and location. Thus, it takes some time for the GPS receiver to obtain its position. Assisted GPS (A-GPS) is used to solve this problem to get detailed positioning information in the GPS receiver. The assisted GPS (A-GPS) method uses a GPS receiver in the MS to find the MS position.

Satellite signal is relatively weak and additional data are needed. The additional data about the MS location is provided by the network or by the MS itself. These two methods are known as network A-GPS and MS A-GPS. In order to overcome this drawback, the GSM network provides the location measurement unit (LMU) to correct the received signals for yielding better measurement. One LMU must be deployed every 300km in the network. In MS A-GPS, additional information can be received by the MS in form of special broadcast messages. This additional information can be CGI for serving BTS and/or TA. The method can also use E-OTD to provide additional information about the MS location.

3.3 Enhanced Observed Time Differential (E-OTD)

This refers to reversed TOA or handset based TOA. The basic method employs with TOA, only the handset is much more actively involved in the positioning process. Specially equipped handsets are required.

Enhanced Observed Time Difference (E-OTD) systems operate by placing location receivers, overlaid on the cellular network as a location measurement unit (LMU) at multiple sites geographically dispersed in a wide area. Each of these LMU has an accurate timing source. When E-OTD software enabled mobile and the LMU receive a signal from at least three base stations, the time differences of arrival of the signal from each BTS at the handset and the LMU are calculated. The differences in time are combined to produce intersecting hyperbolic lines from which the location is estimated. E-OTD schemes offer greater positioning accuracy than cell of origin, between 50 and 125 meters, but have a slower speed of response, typically around five seconds and require software modified handsets.

The three basic timing quantities associated with E-OTD location are defined as follows:

- Observed Time Difference (OTD). This is the time interval that is observed by a mobile station (MS) between the receptions of signals (bursts) from two different BTSs in the cellular network.
- Real Time Difference (RTD). This is the relative synchronisation difference in the network between two BTSs.
- Geometric Time Difference (GTD). This is the time difference between the receptions (by a MS) of bursts from two different base stations due to geometry.

The E-OTD method can be either handset based or handset assisted. In handset based E-OTD, the MS performs OTD signal measurements and computes its own location estimate. In this case the network provides the MS with the additional information such as BTS coordinates and the RTD values. In handset assisted E-OTD, the MS performs and reports OTD signal measurements to the network and the network computes the MS's location estimate.

Comparison of location technologies

Each of these technologies offers different degrees of accuracy. But accuracy level needs are particularly service dependent and terrain specific. Table 1 shows a brief comparison of the different location methods.

4. Location Aware Computing

The basic concept of a location aware system is that it knows where each system component is located and can use the information to enhance the overall system operation. The enhancement might take the form of providing the initial service (mobile telephony) or enhancing an existing service (automatic call redirection based on current location, building environment management). Completely new services are also possible.

The location-aware computing involves the automatic tailoring of information and services based on the current location of the user. Today, thanks to technical progress on many fronts, digital location information is available to software applications running on many different mobile computing platforms. This new type of location-aware or location-based computing has made possible applications with the capability to sense their location and modify their settings, user interface, and functions accordingly. The location aware computing environment uses location information to control where and how information is presented to the customer. In this environment each mobile computing device is aware of its current location and the location of other fixed and mobile computing devices. The mobile system takes advantage of the devices available at any location to present the richest information environment possible to the customer. The key to the environment is the use of a mobile location tag. This tag indicates the presence of a device at a particular location.

5. Conclusion

Up and coming new services such as the Mobile Internet are taking the industry to unprecedented levels. The ultimate Internet device is actually a mobile device - not a fixed computer - to be used for personal communication, entertainment, information, commerce or embedded in any device that needs to communicate via the Internet. All of these mobile devices and services will be empowered by location. Accessing this new type of information opens up a whole new range of use of the mobile terminal. Location-based services are forecast to be soon one of the most important sources of operator revenue. It is estimated that by 2006 mobile location services will generate revenue of more than 20 billion USD. Worldwide, mobile location connections will rise from 2 million in 2001 to 565 million in 2006. This will represent 29% of all mobile connections. The field of location-sensing is blossoming so much that it has been suggested that in the future it will be standard for every computer operating system to know the location of the computer it is running on.

Method	Accuracy	Coverage	Cost
CGI + TA	Limited accuracy Guideline estimate: 100-1100 m	Indoor / outdoor: no limitations	In network: MLCs In handset: no cost
TOA / UL-TOA	Guideline estimate: 50-200 m	Indoor / outdoor: no limitations	In network: MLCs and LMUs In handset: no cost
AOA	Guideline estimate: 300 m	Indoor: limited coverage Outdoor: some limitations in case line-of-sight cannot be obtained	In network: directional antennas and MLCs In handset: no cost
A-GPS	High accuracy Guideline estimate: 10 – 20 m	Indoor: limited coverage Outdoor: some limitations in case line-of-sight cannot be obtained	In network: MLCs and hardware to provide D-GPS information. In handset: additional HW
E-OTD	Guideline estimate: 50-400 m	Indoor / outdoor: no limitations	In network: MLCs and LMUs (less LMUs than in UL-TOA required and less expensive LMUs) In handset: “no cost” (added SW only)

Table 1: Comparison of LBS services and positioning techniques