University of Essex

Techniques used for Location-based Services: A survey

Technical Report: CSM-428

ISSN 1744 - 8050

Prashant Solanki and Huosheng Hu

December 2005

Human Centred Robotics Group
Department of Computer Science
University of Essex

Table of Contents

Glossary of Terms

- *Radiolocation systems* – long range and accurate navigation system which measure the radio signals exchanged between a mobile unit's transceivers and a set of fixed stations.
- *Base station* – a land interface to wireless network.
- *Geolocation* – a position on earth, usually specified in terms of longitude and latitude.

List of Figures

1. Introduction to Location based services

Location is the foundation for human beings to perceive and understand the real world. With the speedy development of socio-economy, the quickening of people's living rhythms, and frequent changing of time and space, people want the location-related information to be available at any time and anywhere [Yu et al. 2003]. Location tracking has been great importance since World War II, when military planners realized its usefulness for targeting, fleet management, positioning and navigation. Location information itself does not provide good service, but if location information is mapped with some geographical and symbolic information to form Location based services (LBS) there are possibilities to create useful services. Technology used to determine the location of individual carrying mobile phones, PDA's, laptop or any personal wearable digital devices is becoming increasingly available. This technology opens a wide range of applications collectively and provides device user personalised services based on their current position or location.

There are three major components required for implementing LBS:

- Technology which is required to determine the mobile device position
- Mapping the information with dome geo-referenced database
- Wireless communication infrastructure

Basic idea to locate a person carrying a digital device is by measuring radio signals exchanged between a device transceivers and set of know base stations. Measured signals can then be used to perform some mathematical calculation to give location information. Location information can then be mapped with a geo-referenced database to find user's current position in the world and its nearby services available. Apart from personal locator system (PLS), LBS has a wide range of applications such as Emergency relief, Public safety and Security, Navigation aids, Commercial and Information services, Business safety and efficiency, Transaction and Billing, Entertainment business, distributed chats between friends and many more.

Current research topics related to LBS include network architectures and standards (Adams et al. 2003; Peng & Tsou 2003; Ahn et al. 2004), localization techniques and recording of space-time activity (Mountain & Raper 2001; Miller 2003; Spinney 2003; Worboys & Duckham 2004), market opportunities and business cases for LBS (Beinat 2001; Benson 2001; Barnes 2003), user interface customization and personalization (Hjelm 2002; Zipf 2002a, 2002b) and location privacy (Armstrong 2002; Myles et al. 2003).

In this report, we are concentrating on various technologies which can be used to locate a person or a device. The strength, weakness, accuracy, cost and various other attributes of each technology are discussed. Section 2 will provide in detail with the possible application of LBS. Section 3 will give the classification of Location based techniques. Technologies used currently in commercial areas will be discussed in Section 4. Section 5 explains how location information can be mapped with geo-referenced information. Section 6 gives the characteristics of localization techniques. At the end we will summarize the report.

2. Application of Location based services (LBS)

The driving force behind the LBS technology is a US Federal Communication Commission (FCC) mandate in October 2001, i.e. all operators of mobile communication networks must be able to accurately locate mobile callers requesting emergency assistance via 911 within 50 meters for 67% of emergency calls and within 150 meters for 95% of the calls [FCC news, 1996]. Apart from emergency service there was also the need to effectively monitor offenders on parole and trial. Tracking offenders with locator devices would enhance public safety and reduce prison population.

Though public safety was main consideration of LBS technologies but there is a wide range of services on different areas which rely on user's location information. LBS can be particularly powerful when combined with geographical information services (GIS) and other user profile information to offer personalised and location sensitive response to customers. Van de Kar and Bouwman [Van & Bouwman 2001] described the difference between emergency services, mobile network operator services and value added services. Levijoki [Levijoki] classified services into safety, billing, tracking information and proximity services. D'Roza and Bilchev [Roza & Bilchev 2003] identified five groups of application areas: communication, fleet management, routing, safety and security and entertainment. [Ratti et al.] proposed a preliminary taxonomy of LBS based on the beneficiaries of the services: single users with mobile handsets, groups of users or third parties. Some of these services have been implemented by mobile network companies as value added services to increase average revenue per user and consequently market demands. Some of the application is described below.

Emergency relief, Public safety and Security

As mentioned above, call location can be used for emergency services such as E-911 for United States and E-112 for European countries. Applications related to medical and roadside help can also be imagined, such as reducing the caregiver burden and maintaining disability people independent by tracking them and sending physiological data to health care providers. Security to teenage children, elderly people and/or disabled members can be provided by locating them. Emergency warnings or relief can be given to people by broadcasting alerts that vary with geographical location on their handsets / mobile phones.

Navigation aids, Commercial and Information services

Location information interfaced with GIS information can be used to direct user's current position and direction towards targets in an unknown environment. Automobile and many other independent manufacturers are already offering such services such as GM's Onstar, Tom Tom, Garmin, etc., using vehicle-based GPS receivers and mapping/route guide services for road vehicles. Current traffic conditions and congestion roads can be known in advance by integrating with real time data, so that users can take an alternative route. Potential business applications through which LBS service providers can earn great income is by providing users with the nearest available commercial (leisure) information. Weather forecast, tourist attraction, restaurants, shopping centres, theatres, gas station, ATM locations, are few of the examples of commercial information. [Ratti et al.] interpreted such kind of services as *Geographical distributed yellow pages*.

Business safety and efficiency, Transaction and Billing

Service organisation and transport companies could become well-organized, as well as save time and money by tracking their assets (people, pets, vehicles, trucks, contents inside the truck, etc) and better routing their fleet and personnel. They will be indirectly gaining a competitive advantage and providing improved customer service. One of the applications of LBS is location sensitive billing, in which the physical fences and gates is replaced with digital ones for parking fees, urban event fees (concerts and conventions) and ticketing for transport.

Entertainment and distributed chats between friends

Computer games that take into account the geographical position of different users can be played on cell phones. With LBS, friends can chat with each other via short messages or by digital tapestries (user can attach messages or photos to geographical location so that the other user can receive those data). Group of users can coordinate with each other via SMS and adapt to changing environment conditions – such as road blockage due to over flooding, protesters during public demonstration.

3. Positioning System classification

Depending upon where the positioning measurements are calculated and where position information is used; positioning systems are classified into three broad categories:

- Self localization
- Remote (Network) localization
- Indirect localization

3.1 Self localization

In mobile based stand alone or self positioning system, the roving receiver makes the appropriate signal measurements from geographical distributed transmitters i.e. satellites or base station and uses these measurements to determine its position. Hence, a self positioning receiver knows where it is and applications collocated with the receiver can use this information to make position-based decisions such as those required for vehicle navigation.

Pros:

- Little or no additional network
- Works with all mobiles
- Privacy not an issue as it is controlled by user
- Location capability remains in absence of wireless coverage or network assistance

Cons:

- Old handsets are to be replaced by expensive and complex ones
- Fails in radio shadows
- Additional battery consumption
- Long time-to-first-fix

3.2 Remote (Network) localization

In a network based system or remote localization system, receivers at one or more locations measure signals originating from the roving object to be positioned. These measurements are communicated to a central site where they are combined to give an estimate of the position of the object. This data is then sent to roving receivers by Short message service (SMS) or by locating position on the map.

Pros:

- No added mobile-station complexity or cost
- Works with all mobiles
- Short time-to-first-fix
- Maps and database increase accuracy of location fix
- Continuous tracking capability for navigation applications
- Business opportunity for network operators as exclusive providers of subscriber-location information

Cons:

- Inferior accuracy
- Additional investment in infrastructure, with very high up-front costs
- Difficult network installation and maintenance
- User privacy is questionable

3.3 Indirect localization

Using a data link between the roving receiver and the remote server, it is possible to send position measurements from self positioning receivers (roving receivers) to remote sites or vice versa. A self-positioning system that sends position data to a remote location is referred as indirect remote positioning. A remote positioning system, transmitting an object's position to the roving receiver is referred to as indirect self positioning. The assisted global positioning system discussed in next section is an example of indirect positioning architecture.

Pros:

- Superior accuracy, availability and coverage
- Short time-to-first-fix
- Map and database increase location accuracy if processing done in network
- Minimal impact on battery life
- Implementation cost shared by mobiles and the network
- The System evolves with network upgrades
- User privacy is withhold

Cons:

- Network assistance increases signalling load
- Interoperability between the network and mobiles requires additional standards deployment
- New or upgraded handsets needed for initial deployment

4. How can location information of an individual be obtained?

LBS are not only forcing the development of mobile networks but also localization techniques. Currently, there are a number of techniques used commercially depending on various issues of LBS. There are listed and described below as: Indoor localization techniques, Global Positioning System (GPS), Mobile phone networks and Heterogeneous techniques. All techniques are based on trade-of between the level of accuracy and ease of retrieving location information. Such as, Cell identification technique does not provide high precision of locating devices but location information can be easily available through network cells.

4.1 Indoor Localization techniques

Indoor localization techniques for locating individual are normally used for shorter range finding and they are based on pervasive computing, in which users can access to online information and services remotely and synchronise data between computers. Indoor localization techniques are used in university or school campus, laboratories, health care or hospital buildings, etc... For instance, a user can print a document from the nearest printer or can be guided to locate classrooms on the campus.

There are various technologies available but all depend upon the signal propagation, medium in which wave travels, frequency, period, anatomy, energy, amplitude and speed of the physical wave. Technologies used in today's world for indoor localization are: Infrared (IR), Ultrasound, Radio frequency (RF), Bluetooth and Wireless LAN (WiFi). Systems developed using the above technologies is low in cost due to their mass-productivity and also there is not cost in airtime. Below we will present the basic understanding of each technology:

Infrared (IR)

Person wearing devices called as badges emit a unique IR signals i.e. identifier (ID) code via an infrared transmitter at regular interval. Infrared sensors placed throughout the building, such as wall or ceiling, picks those ID code signals, which are then communicated to location software. Positions of the placed infrared sensors are known before calculating the badge wearer location. The location of the user is determined by proximity to the sensors receiving the badge ID. The advantage of IR technology is that IR emitters have the ability to produce signals very small and very cheap. Its drawback is that it requires visual line of sight to function properly. Also it gives proximate position which in turn gives less accuracy. Though accuracy can be improved by installing more IR sensors in the building, but IR technology fails if the badges are kept in the pocket of the user.

Ultrasound

Active Bat systems developed at AT&T labs use ultrasound to locate a person wearing badge at any position in a place where IR technology fails. Ultrasound transmitters known as beacons transmit signals to the receiver placed on known positions, which then determines the receiver's location. Three receivers take the time of propagation of the ultrasound signal transmitted by the badge. Using triangulation the position of the receiver is calculated. To achieve high accuracy, this system also sends radio signals, using time differences between the ultrasound and radio signals (explained later) location and orientation of the user can be determined.

Radio Frequency (RF)

Users with reflectors or transmitters emitting a low power radio frequency signal can be detected by known receivers in the building. A transmitter normally emits some unique identifier code namely radio frequency identification (RFID). If two or more receivers receive RFID signal, location of the user is then calculated via triangulation. RF technology does not require line-of-sight but strength of the signal depends upon the density of the objects in the building and hence accuracy is limited. One of the examples of the radio frequency standard is Bluetooth, which have very short range (10meters) ad hoc networking to support.

Wireless LAN (WiFi)

The primary use of wireless LAN is to provide Ethernet connection and internet access point to PDA's or laptop computers equipped with wireless LAN cards. WiFi emits 802.11 radio frequency signals from the wireless router which can be used to determine precise location of any WiFi enabled device, such as laptops, PDAs, smart phones or RFID tags. There are three basic ways in which location of the user carrying the WiFi device can be found:

- By knowing the coordinates of the antenna, i.e. routers to which user devices are connected, with accuracy proportional to the antenna density in the system.
- By triangulating signal strength information received at multiple receiver locations.
- By mapping the observed signal strength of fixed routers placed throughout building/area into a map. So if a user is in the building, signal strength of all the access points within the user device range is matched with the building radio map.

Today, 802.11 networks are used in public places and hence later this may prove a low-cost method for LBS. The accuracy of the WiFi technology is between 20m to 40m, it can be improved by dense deployment of wireless routers. Also, WiFi routers do not stay in one position as satellites do, which will lead to errors in localization.

FIG. 1: WORLD MAP USED FOR FLIGHT TRACKING[1]

4.2 Global Positioning System (GPS)

Consider flight from Mumbai, India to London, UK [Fig. 1], the flight provider provides every passenger with 7inch LCD monitor which continuously gives following tracking details:

- Current location of airplane
- Time remaining to reach destination
- Distance remaining to destination
- Latitude, longitude and altitude of the airplane
- Speed of the airplane
- Acceleration of the airplane

How does it manage to get this detail with very high precision and accuracy? What architectures and techniques are used to get such details? How this data is transfered from base stations on the ground to

[1] http://earth.google.com/

a mobile airplane? Are the question comes around when we talk about location tracking of airplane? This is done by a radiolocation system which measures the radio signals exchanged between a mobile unit's transceivers and set of fixed stations. There are other kinds of technologies which have tried to simplify navigation and position but there are some disadvantages.

Disadvantage of other radiolocation systems[2]:

Landmarks: Only work in local area. Subject to movement or destruction by environmental factors.

Dead Reckoning: Very complicated. Accuracy depends on measurement tools which are usually relatively crude. Errors accumulate quickly.

Celestial: Complicated. Only works at night in good weather. Limited precision.

LORAN: Limited coverage (mostly coastal). Accuracy variable, affected by geographical situation. Easy to jam or disturb.

Among all above systems, global positioning system (GPS) gives high accuracy and accurate precision. It is a worldwide radio-navigation system consisting of a network of 24 satellites in six different 12-hour orbital paths spaced so that at least five are in view from every point on the globe and their ground stations. GPS uses these satellites as reference points to calculate positions accurate to a matter of meters, which has been launched by U.S. Department of Defence.

GPS works in five logical steps:

1) The basis of GPS is triangulation, more precisely called as *trilateration,* from satellites.
2) To triangulate, a GPS receiver measures distance using the travel time of radio signals.
3) To measure travel time, GPS needs very accurate timing.
4) Along with distance, you need to know exactly where the satellites are in space.
5) Finally you must correct for any delays the signal experiences as it travels through the atmosphere.

Each satellite emits radio signals, which is been used by GPS receivers – an antenna installed on a vehicle or carried by hand – to estimate the distance between satellite and receivers. As shown in Figure 2, the receiver can roughly determine its position by locking on to signals of at least three satellites, a technique commonly known as triangulation but more precisely called *trilateration*. Vehicle location in terms of latitude, longitude and altitude can be determined with four or more satellites in view. Once the vehicle position is calculated other useful information such as speed, bearing, track, trip distance, distance to destination and others can be determined using time difference between measured signals.

GPS needs to determine how long it takes a satellite signal to reach a receiver to obtain an accurate fix on a moving object or person. Assuming that signals are synchronous, GPS compares the satellite signal's pseudorandom number code (PNC) – a digital signature unique to each satellite- with the receiver's PNC to determine the signal's travel time. To compute the distance between the receiver and satellites, the above value is multiplied with speed of light.

Satellites are nearly 11,000 miles away from earth surface, miscalculating signal travel time by even a few milliseconds can cause a location error measuring as much as 200 miles. Therefore satellites uses extremely precisely and expensive atomic clocks. A receiver's clock doesn't need to be as accurate, it can correct any timing offset by measuring the distance to fourth satellite to synchronous its PNC with the satellites.

[2] http://www.trimble.com/gps/advantages.html

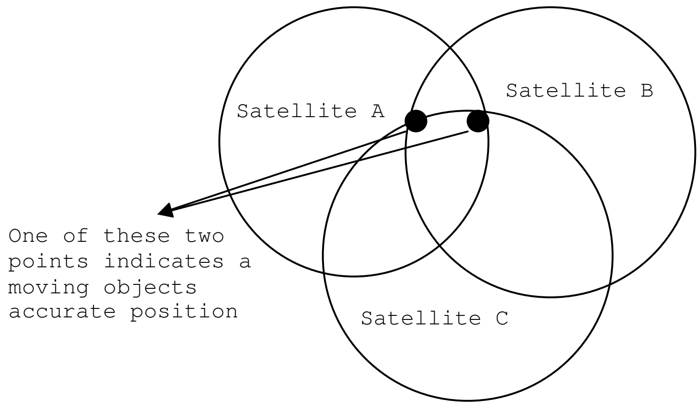


FIGURE 2: GPS TRILATERATION, SATELLITES A AND B ARE EACH AT THE CENTRE OF AN IMAGINARY SPHERE, THE RADIUS OF WHICH IS EQUAL TO THE DISTANCE TO THE RECEIVER, KNOWING THE DISTANCE FROM SATELLITE C LETS THE RECEIVER NARROW ITS POSITION TO ONE OF TWO POINTS ON THE CIRCLE THAT THE INTERSECTION OF THESE TWO SPHERES FORMS.

In order to calculate accurate location of the GPS receiver, we must know the exact position of the satellites at all times. Satellites serve as reference points. Apart from pseudorandom code, satellite signals also encode navigation data. The monitoring stations and ground antennas, which constantly check satellite's speed, position and altitude, look for any orbital (ephemeris) errors such as gravitational pull from moon, sun and solar radiation pressure. The monitors relay this information back to satellites, which incorporate it into the timing signals.

Up to now we assume that all the calculation that goes into GPS are held in vacuum, but the fact is there are several factors which limits GPS accuracy. Limitations which affect the GPS accuracy are:

- Radio signal speed is constant only in vacuum.
- ***Propagation delay*** due to water vapour and other particles in the atmosphere.
- ***Multipath errors****,* which occurs when a signal bounces off a building or terrain before reaching the receiver's antenna.
- Atomic clock discrepancies, receiver noise and interruptions to ephemeris monitoring can result in minor errors.
- Error margin increases when a receiver picks satellites that are close together in the sky.
- ***Selective availability****,* an intentional degradation of L1, civilian GPS signal.

In order to increase the accuracy of GPS and to eliminate most of the errors two cost-effective alterations can be used – Differential GPS and Assisted GPS.

4.2.1 Differential GPS (D-GPS)

Differential GPS can improve accuracy to three feet or better. D-GPS involves cooperation of two receivers: *roving receiver* and *stationary receiver.* The stationary receiver is a key element to D-GPS and ties all the satellite measurements into solid local references.

As mentioned before, a GPS receiver uses timing signals from at least four satellites to establish its position in globe. Each of timing signals is going to have some error or delay depending upon the limitation discussed above. Both receivers (roving and stationary) make satellite position measurements. If two receivers are relatively close to each other, say within few hundred kilometres, radio signals from satellites that reach both of them will traverse through same atmosphere and hence will induce identical errors [Figure 3]. The reference (stationary) receivers can compute the error differences between projected and actual signal travel time. The reference receiver does not know which satellites is used by a roving receiver to calculate its position, so it calculates the error correction for all visible satellites. Reference receivers then broadcast this information to roving receivers, which then applies corrections for the particular signals they are using.

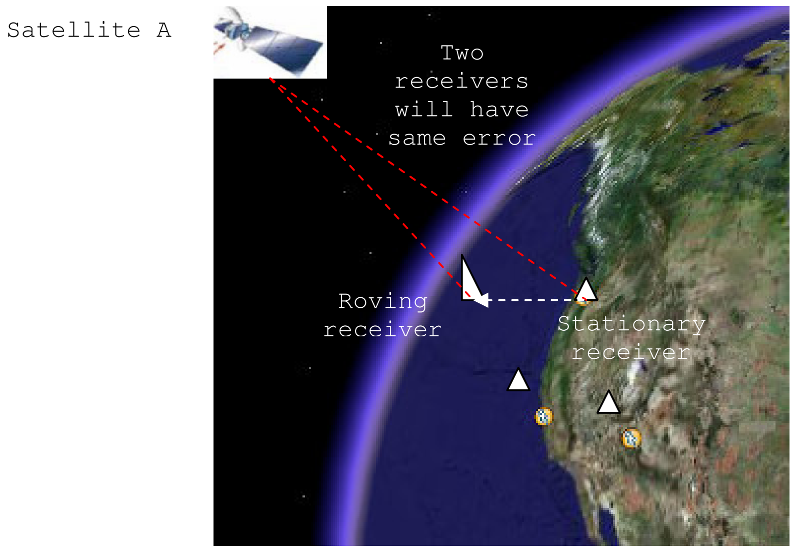


FIGURE 3: DIFFERENTIAL-GPS, ROVING RECEIVER AND STATIONARY RECEIVER WILL RECEIVE SIGNALS THROUGH SAME ATMOSPHERE[3].

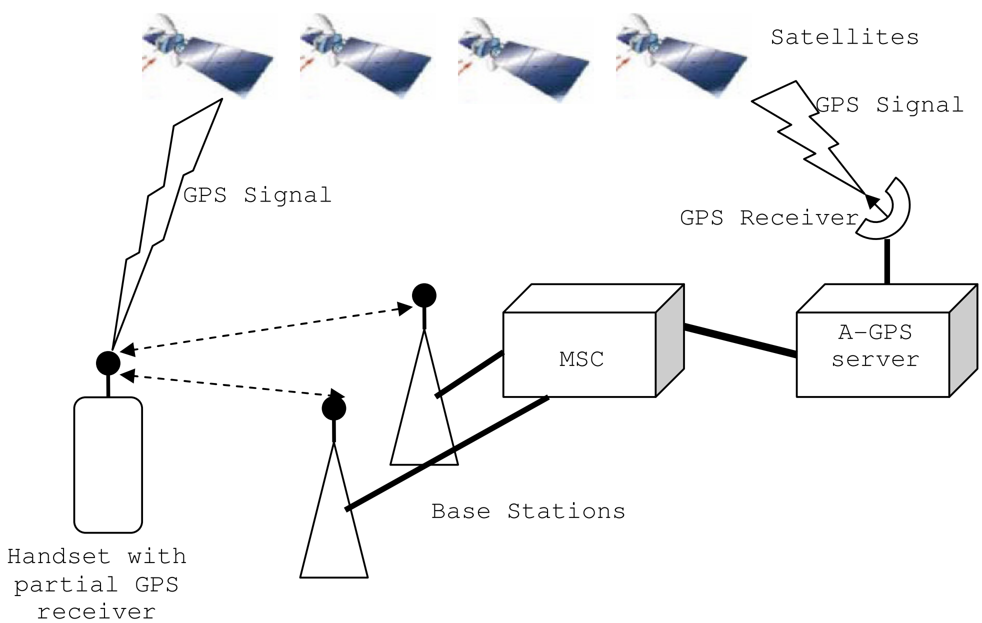


FIGURE 4: ASSISTED-GPS CONCEPT, THE MAIN SYSTEM COMPONENTS ARE WIRELESS HANDSET WITH PARTIAL GPS RECEIVER, AN A-GPS SERVER WITH REFERENCE GPS RECEIVER, AND A WIRELESS NETWORK INFRASTRUCTURE OF BASE STATIONS AND A MOBILE SWITCHING CENTRE (MSC)

[3] http://www.trimble.com/gps/advantages.html

4.2.2 Assisted Global Positioning System

GPS and D-GPS are designed for outdoor areas and cannot work in indoors or in urban areas. However, linking mobile receivers to a cellular, Bluetooth –based, or wireless local-area network infrastructure that has reference receivers with a clear view of the sky can substantially improve GPS performance in such environments. For example, in rural and suburban areas, not many base stations can locate the handset, but a GPS receiver can often see four or more satellites. Conversely, in dense areas and inside buildings, GPS receivers cannot detect enough satellites, but the wireless handset can detect two or more base stations. This alteration in basic GPS is called as Assisted GPS (A-GPS) [Djuknic, Richton 2001]. Compared to other positioning classification such as mobile-station-based, stand-alone GPS or network-based radiolocation, A-GPS technology offers superior accuracy, availability and coverage at a reasonable cost. A-GPS consists of three components [Figure 4]:

- A wireless handset with a partial GPS receiver.
- an A-GPS server with reference GPS receivers that can simultaneously "see" the same satellites as the handset
- A wireless network infrastructure consisting of base stations and mobile switching centre.

The network can accurately predict the GPS signal the handset will receive and convey that information to the mobile, greatly reducing search space size and shortening the time-to-first-fix from minutes to seconds or less. In addition, an A-GPS receiver in the handset can detect and demodulate weaker signals than those that conventional GPS receivers require. Because the network performs the location calculations, the handset only needs to contain a scales-down GPS receiver.

By distributing data and processing A-GPS optimizes air-interface traffic. Because the network assumes the burden of measurement calculations, developers can scale down the mobile receiver to allow easier, more cost effective implementation on a wide scale. A-GPS also provides better accuracy than standard GPS – within less than 50 meters when users are indoors and 15 meters they are outdoors. Another advantage of A-GPS is that clients can withhold data for privacy reasons, and the network operator can restrict assistance to service subscribers.

4.2.3 Block diagram of typical GPS system

Figure 5 shows the typical diagram of GPS system. The signals transmitted from GPS satellites are received at the antenna. Through the radio frequency (RF) chain the input signal is amplified to proper amplitude and the frequency is converted to a desired output frequency. An analogue-to-digital converter (ADC) is used to digitize the output signal. The antenna, RF chain and ADC are the hardware used in the receiver.

Software is used to process incoming digitized signals. Acquisition means to find signals of the certain satellite. The tracking program is used to find the phase transition of the navigation data. From the navigation data phase transition the sub-frames and navigation data can be obtained. Ephemeris data and pseudo-ranges can be obtained from the navigation data. Finally, the user position can be calculated for the satellite positions and the pseudo-ranges.

Performance requirements for building GPS receivers are referred from [Spilker] and are as follows:

- The user position root mean square (rms) should be 10-30m.
- It should be applicable to real-time navigation for all users including the high-dynamic user.
- It should be worldwide coverage.
- The transmitted signals should tolerate, to some degree, intentional and unintentional interference. For example, the harmonics from some narrow band signals should not disturb its operation. Intentional jamming of GPS signals is a serious concern for military applications.
- Highly atomic clocks are not required.
- When the receiver is first turned ON, it should take few minutes to find user position.
- The size of the receiver antenna should be small.

Using network Assisted-GPS technique and the design of GPS receiver shown in Figure 6 can be used to locate and track a user/vehicle. A GPS receiver is divided into hardware and software receiver. Hardware receiver consists of RF-to-IF, ADC and snapshot memory equipments, while software receiver only needs the sampled data from the GPS receiver to calculate user/vehicle position.

At request of either an external application or the mobile receiver user, the server sends information on satellites in view at the mobile receiver's approximate location, including Doppler predictions. After a snapshot of GPS satellite RF data has been stored in the handset memory, the DSP processes the data and returns the pseudo-ranges measurements to the server, along with the statistical information. This snapshot approach allows the handset to gather GPS data when it is not transmitting, thus eliminating potential self interference. This represents a significant reduction in required communications bandwidth when compared to delivering differential corrections, ephemeris and/or satellite trajectory data to the mobile receiver. In the system describe in Figure 6, the received signal is down-converted to a suitable low intermediate frequency, digitized and stored in a buffer memory as sampled data. This data is then operated upon using a programmable DSP-IC. Software receiver of GPS user positioning system can be broken down into four primary functions:

a) Determining code phases (pseudo-ranges) to the various GPS satellites.
b) Determining the time of arrival for pseudo-ranges.
c) Demodulating satellite navigation message, and

Computing the position of the receiving antennas using these pseudo-ranges, timing and navigation message data. Unlike continuously tracking hardware correlator-based receivers, this snapshot processing technique is not subject to fluctuation levels and chaining nature of the signal environments.

This server-aided GPS approach has improved upon conventional GPS performance by sharing processing and database functions between the mobile GPS receiver/processor (client) and a remote infrastructure (the server and reference network). The result is a highly sensitive, cost-effective, low-power, GPS receiving system that provides first fixes in a few seconds from a cold start, even when conventional GPS is unworkable or unreliable.

4.3 Mobile phone network localization techniques

GPS and its variation reviewed above are the basis of LBS but they are not know and implemented widespread. Also to comply with FCC ruling, it is necessary that localization techniques should work with existing cell phones networks such as Global System for Mobile communication (GSM), General Packet Radio Services (GPRS) and Code-Division Multiple Access (CDMA). Adding GPS receivers to mobile phones is one of solutions for locating individual but this will lead in replacing every mobile telephone, which will cost lot to network operators. So there is a need to find solution which will suffice with the current mobile network. There are many ways in which location can be found from the measurement of the signal and can be applied to current wireless networks. The most important measurements are: Cell identification, Propagation time, Time Difference of Arrival (TODA) and Angle of Arrival (AOA), and these involves different level of position accuracy, hardware & software investment levels and implications for the mobile network operators. Before explaining each technique, lets us find how a network works for mobile phones.

A mobile network called as cellular network works by converting voice, text-messages or multi-media messages on mobile phones into radio frequency (RF). Cellular networks have to keep track of all handsets, wherever in the world, and be able to send incoming call to requested mobile phones. Cellular networks consist of thousands of overlapping, individual geographic areas called as *cells*, each with a base station. Each cell within a cellular network is geographically defined by the range that RF signals propagate to continuous space. The size of the cell depends on the area of coverage that is needed and number of calls made in that area. When mobile phone is switched on, it logs on to best suitable network. When a mobile phone user is moving and enters a serving cell, network base stations are designed to recognise that the user is within the serving proximity of the station's neighbourhood. The base station then automatically locks on to mobile and hands off the call from one base station and corresponding cell to this next base station and serving cell within the network [Spinney 2003].

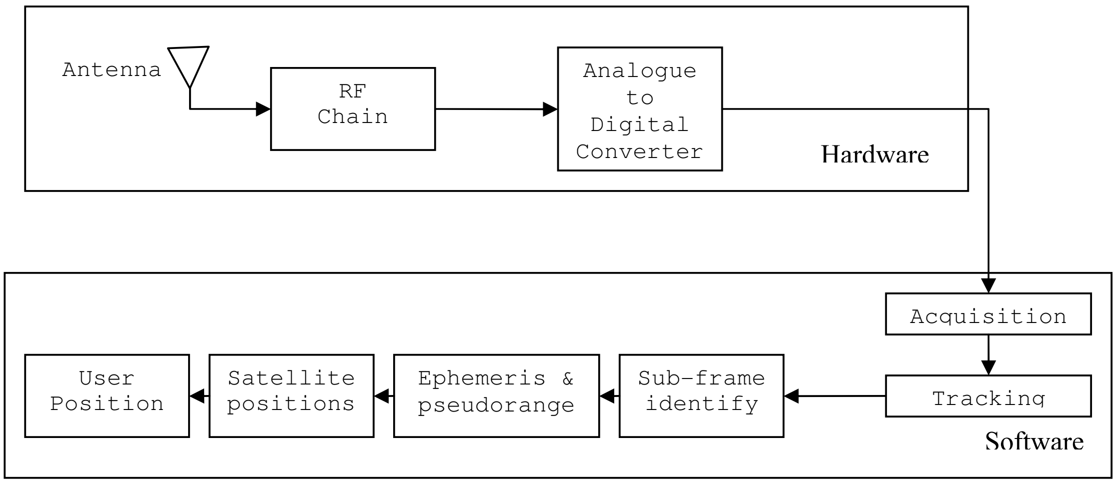


FIGURE 5: A FUNDAMENTAL GPS RECEIVER

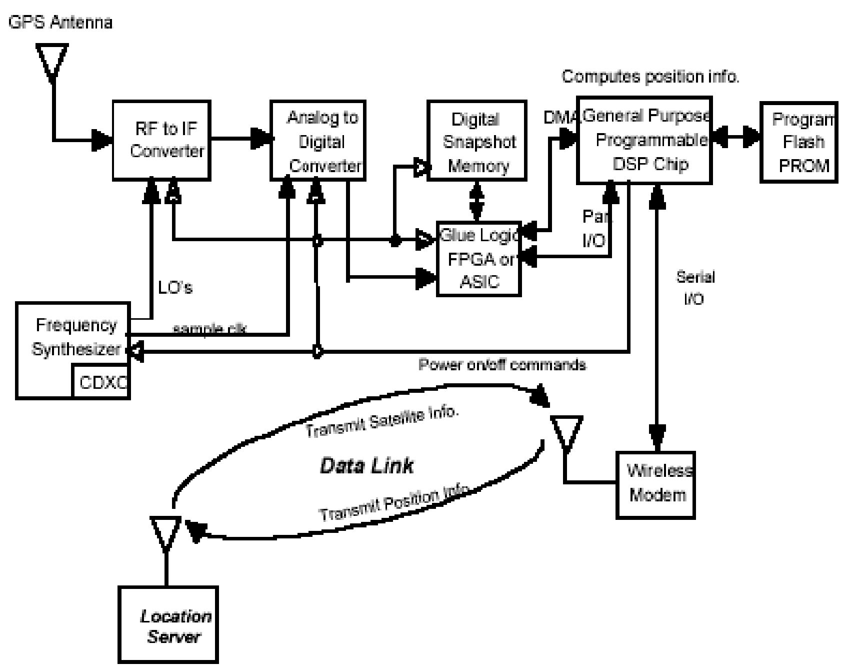


FIGURE 6: BLOCK DIAGRAM OF TYPICAL DSP BASED GPS PROCESSING SYSTEM [RAMAMOORTHY 2004]

Mobile positioning in cellular networks can be calculated either at the network end or at the device end of the user i.e. mobile phone. Locating of the mobile phone user by network requires one or more base stations to make measurement of distance to the phone and sends them back to the network where the calculation is made. While in device-centric, cell phone itself makes the calculation based on the information gathered from base stations transmitter of the established network. The later will require additional software and hardware to install in mobile phones but gives more accuracy than network-centric based localization.

4.3.1 Cell Identification

Cell Identification technique operates in GSM, GPRS and WCDMA mobile/cellular networks. It is a simple and easy way to locate a cell phone by identifying the serving cell. This technique requires identifying, communicating and locating the base station to which the mobile phone is connected. It passes the location of the base station as the location of the mobile user to location service applications. As a mobile user moves around, network keeps tabs on which base station it can reach the mobile and hence the location is updated.

The accuracy of this technique to find the location depends upon the infrastructure / physical architecture of the network i.e. the size and density of the cells. Systems with smaller cells such as in rural areas will have more precision than systems with large cells. Accuracy is in between 100meter to 20kilometer. Level of accuracy can be increase by using cell identification with either of the one – Timing advance or Signal strength.

4.3.2 Cell Identification + Timing Advance (TA)

Number of milliseconds the signal from the mobile phone travels to base station corresponds to timing advance. The time at which a terminal sends its transmission burst is critical to the efficient functioning of a GSM/GPRS network. GSM uses the Time Division Multiple Access technology for sharing one frequency between several users, assigning timeslots to the individual mobile users sharing a frequency; each mobile user can transmit only in a certain time. But the users are in different distances from the base station, and the speed of light is quite slow, so the precise time the phone is allowed to transmit (timeslot) has to be adjusted accordingly. Timing advance is the variable controlling this adjustment[4]. Distance of the mobile user from the base station is dependent upon the duration of timing advance for each mobile station. Hence, we can calculate the mobile user Geolocation information. This technology is only used if the mobile user is 550meters or more away from the base station since adjustment are calculated depending on how many multiples of 500-550 meters the mobile user is distant from a base station.

4.3.3 Cell Identification + Signal Strength

In telecommunication, signal strength is measured of how strong a signal (RF waveform) is. Mobile phone continuously measures the strength of the signal from each of the base station and reports this information back to them, so that communication between the mobile phone and the base station has optimum signal strength. Better signal strength improves quality of the call. Signal strength is measured in voltage per square area. Hence, theoretically we can calculate the proximate location of the mobile user by cell-id and signal strength. This technique is not widely used, since the measurement of signal strength depends upon characteristics of terrain, attenuation of signal in indoor, material used in buildings and climate condition.

4.3.4 Propagation Time

This involves measuring the time it takes for a signal to travel between a base station and a mobile receiver or vice versa. Alternatively, this approach might involve the measurement of destination and then echoed back to the source, giving a result twice that of the one-way measurements. Always later approach is used as the means of measuring propagation time because it does not rely on synchronization between the mobile receiver and base stations.

---

[4] http://en.wikipedia.org/wiki/Timing_advance

Either measurement constrains the position of the mobile receiver to a circular locus around the base station. If another propagation time measurement is made with respect to a second base station, a second circular locus is produced [Figure 7 (a)]. It can be seen that the two circular loci gives an ambiguous position, to resolve such ambiguity either previous information concerning the trajectory of the mobile receiver or making a propagation time to the third base station.

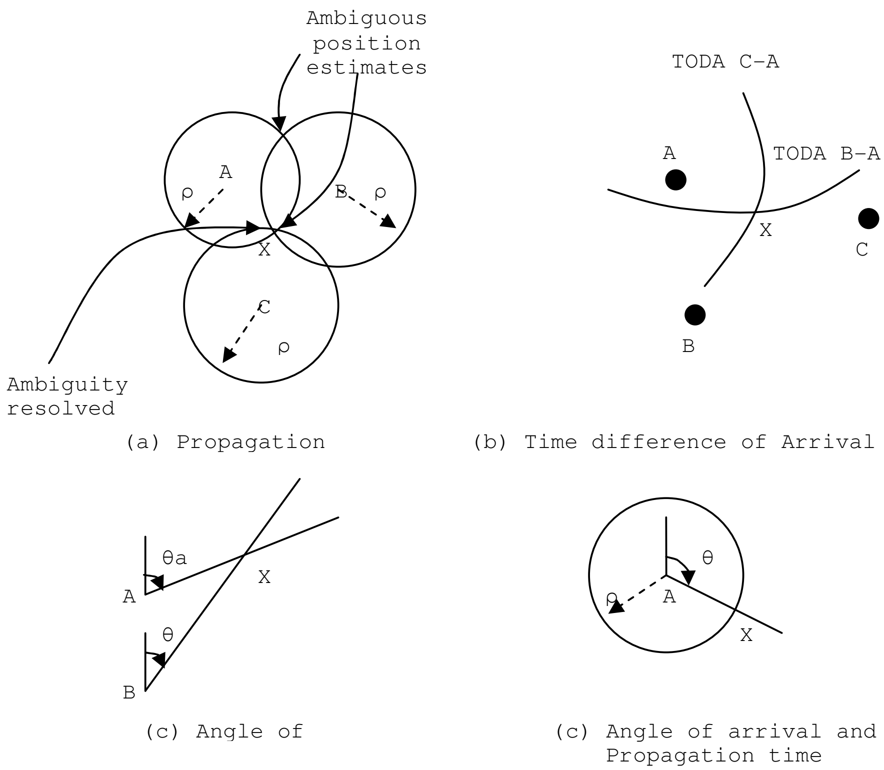


FIGURE 7: EXAMPLES OF GENERIC POSITION TECHNIQUES

4.3.5 Observed Time difference of arrival (O-TDOA)

A mobile receiver can listen to a series of base stations. Also it can measure the time difference between pair of station. If, for example, there are three base stations, two independent TDOA measurements can be made and used to locate a mobile receiver. Each TDOA measurement defines a hyperbolic locus on which a mobile receiver must lie. The intersection of the two hyperbolic loci will define the position of the mobile receiver [Figure 7 (b)].

4.3.6 Angle of arrival [AOA]

This involves measuring the angle of arrival of a signal from a base station to a mobile phone or vice versa. In either case, a single measurement produces a straight line locus from the base station to the mobile receiver. AOA measurement with other base station will yield a second straight line; the intersection of two lines gives position of the mobile receiver [Figure 7 (c)].

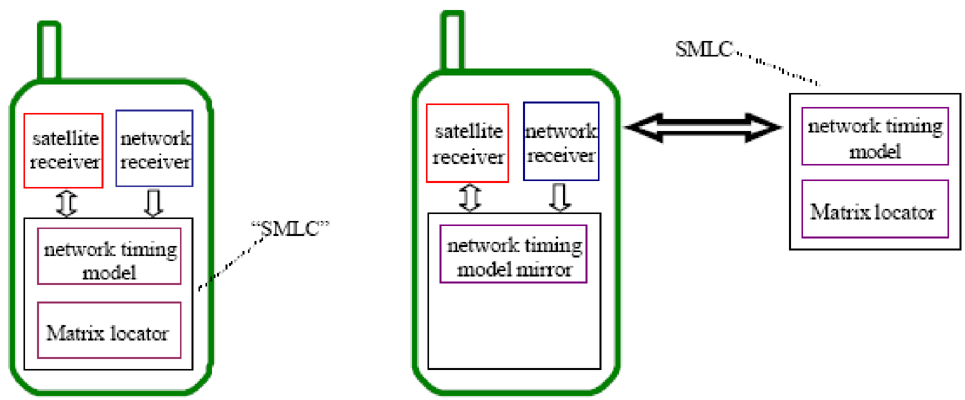
4.3.7 Enhanced Observed Time Difference [E-OTD]

E-OTD is device centric localization technique that assumes that handsets are endowed with software that locally computes location. Three or more synchronised base stations transmit signal times to the mobile device, whose embedded software calculates time differences and therefore distance from each base station. E-OTD mobile positioning techniques are in the range of 50-125m [Ratti et al.].

4.4 Heterogeneous and New technology

All techniques reviewed above are called as *homogeneous systems.* A homogeneous system uses only one source of measurements to calculate position. Mixing different type of measurements will also give location of the mobile receiver. A common example is radar, which combines propagation time and AOA to yield location of the mobile receiver. This type of system is called as *heterogeneous system*, where one or more techniques are combined to eliminate disadvantage of each other. Such as, when Cell-Id technique, give high yield but very poor accuracy, is combined with A-GPS, give high accuracy and poor yield, the result is high accuracy. In this system, when a conventional GPS system fails to locate a device user in heavily shielded environment, Cell-ID localization technique is used as a fall-back method to provide the proximate location of the user.

Though GPS gives greater accuracy compared to other independent techniques but it updates the location of the device user every 5 sec i.e. the response time is slow, which is the major drawback for real time. Cambridge Positioning Systems Ltd. have provided time aiding accurate at microsecond level by using a fall-back mechanism called as Matrix positioning method with GPS system collectively know as Enhanced-GPS [Duffet-Smith, Tarlow 2005]. The problem of using Cell-ID method as a fall-back method is that it is quite inaccurate and has a precision of 200m – 600m. E-GPS provides 1) fine time aiding is available in GSM and W-CDMA with a precision of ±5µsec and 2) the Matrix element provides an immediate initial position of the device user up to accuracy of within 100m or so when GPS system fails to locate. In this paper, we will give the basic operation of E-GPS. One can review the paper of [Duffet-Smith, Tarlow 2005] to get more detail of the Matrix based method. Figure 8 shows elements of autonomous and network-aided Matrix-enhanced satellite terminal.



(a) (b)

FIGURE 8: ENHANCED-GPS, A) ELEMENTS OF AN AUTONOMOUS MATRIX-ENHANCED SATELLITE TERMINAL AND B) ELEMENTS OF A NETWORK-AIDED MATRIX-ENHANCED SATELLITE TERMINAL [DUFFET-SMITH, TARLOW 2005]

The Matrix calculation can be performed either in the handset or in the network. Each of the terminals shown above has a satellite positioning hardware in addition to hardware normally associated with mobile phones. Box labelled as SMLC represents a software program which carries out Matrix calculation. For autonomous E-GPS, SMLC is placed within the device while calculation is carried out in the network for the network-aided terminal. "The network timings (i.e. the relative transmission time offsets) are calculated in the Matrix locator module and stored as a list in the network timing module. Solo Matrix operation is therefore confined entirely within the terminal. The 'SMLC' element within the terminal is able to compute the position of the terminal within the constraints of Solo Matrix operation, and also maintains the list of the relative transmission time offsets of the network transmitters, with a typical accuracy of better than 300 ns. These timings, together with the Matrix derived position of the terminal, constitute a high-stability clock which does not reside within the terminal, but which can be read at any time. Unlike a system in which a high-stability clock is carried around with the terminal, the 'clock' in this case is remote, but because the terminal is able to calculate its position (using Matrix), and hence its distance from any of the transmitters, the list of relative transmission time offsets provides an accurate relative time reference", [Duffet-Smith, Tarlow 2005].

The sequence of events for E-GPS is listed below.

First, in open sky conditions i.e. when a device is outside:

- A standard GPS position fix is made.
- A standard or Solo Matrix fix is made at the same time.
- The network timing model is established in the SMLC (the computing node where all Matrix calculation is made).
- If the SMLC is in the network, the adjusted network timing model is sent to the handset, and stored as a mirror list.
- The relative timings are known well within 1 ms.
- The offset of GPS time is measured with respect to one or more transmitters in the list.

Later, when FTA is needed i.e. when a GPS system fails to locate device:

- A standard or Solo Matrix position fix is made.
- The network timing model is established in the SMLC.
- If the SMLC is in the network, the adjusted network timing model is sent to the handset, and stored as a mirror list.
- The GPS time is calculated from a received network signal, the measured GPS time offset, and the adjusted network timing model.
- Time (and position) aiding is provided to GPS.

5. Mapping Location Information

It is a consensus among IT professionals that people should give priority to service rather than software itself, and the former is accomplished through the Internet, which has a substantial positive effect on both the academic and the industrial world. As a software system to gather, store, manage, analyze and display geographical information, Geographical Information System (GIS) aims at providing better service, which is made possible by technology and called on by market [Spilker].

From the perspective of the market, it is very necessary for men to get geographical location information at any moment or in any place. Almost 80 percent of information is related with geographical location information in resource management, socio-economic activity and daily life. Drawing maps and directions often predates the development of written languages in many primitive societies and act as best language of communication between people. Map is useful tool to perceive the world. Location or position tracking with GPS technique, independently does not answer where in the mobile receiver is, where he want to get to and how to achieve this in most effective way. But combining location information with GIS can be a solution to LBS.

A GIS is a computer system capable of capturing, storing, analyzing and displaying geographical referenced information; i.e. data identified according to location. GIS is also defined as the procedures, operating personnel and spatial data that go into system. The power of a GIS comes from the ability to relate different information in a spatial context and to reach a conclusion about this relationship. Most of the information we have about our world contains a location reference, placing that information at some point on the globe. For example, when the rainfall information is collected, it is important to know where the rainfall is located. This is done by using a location reference system, such as longitude and latitude, and perhaps elevation. Comparing the rainfall information with other information, such as the location of marshes across the landscape, may show that certain marshes receive little rainfall. This fact may indicate that these marshes are likely to dry up, and this inference can help us make the most appropriate decisions about how humans should interact with the marsh. A GIS, therefore, can reveal important new information that leads to better decision making[5].

Many computer databases that can be directly entered into a GIS are being produced by Federal, State, tribal, and local governments, private companies, academia, and nonprofit organizations. Different kinds of data in the map form can be entered into a GIS. A GIS can also convert existing digital information, which may not yet be in the map form, into forms it can recognize and use. New places which are not present in the database can be uploaded via coordinates from GPS receivers into GIS.

[5] http://erg.usgs.gov/isb/pubs/gis_poster/

6. Attributes of localization techniques

Some useful attributes for LBS technology have been listed in [Hightower and Borriello 2001], which can be used to distinguish techniques for determining location. This includes:

Physical versus symbolic location

Location information given to user carrying device (end-user) in terms of co-ordinates of the world is represented as physical location, for instant GPS provide physical location in terms of longitude, latitude and elevation. While location information provided to end-user in terms of symbolic references, such as the target in being in a particular restaurant or in certain neighbourhood, is represented as symbolic location.

Absolute versus relative location

Providing location information by comparison with some reference, such as how far one device is from another, is a relative location of that device. It gives the proximate information from absolute location data of different objects, e.g. people to know who else from a set of contacts nearby. While GPS, cellular and other indoor systems give an absolute location data i.e. either in terms of common coordinate system or symbolic name.

Localized location computation

As mentioned earlier, location data can be calculated either by device-centric or by network-centric. Later rely on calculations made by network such as the timing of arrival or multipath approaches automatically reveal a subscriber's location. It yields lower privacy. While in former, network gives information to the handheld device to calculate its own position. This means that network does not know where the end-user can be unless he/she is willing to reveal this information, hence leading to more privacy protection.

Accuracy and precision

Different resolutions are been provided by different techniques, ranging from centimetres from radio frequency to kilometres from cell ID approaches. Precision is referred to as how often a degree of accuracy can be obtained.

Scale

This attribute refers to limit of location techniques within which it can locate a device user, i.e. size of area within which the technique works. For example, Indoor localization techniques can locate objects in a room or a building, wireless LAN networks can locate objects in a campus or large building, cellular network techniques are restricted to country or city and GPS system can locate objects worldwide.

Cost

The majority of LBS applications requires high accuracy at a reasonable cost to optimise the return on investment. The cost of implementing any technique depends upon large number of factors such as handset device modification, infrastructure modification, maintenance activity, network expansion plans, etc.

Appendix A shows the table which gives summary of strength, weakness, accuracy and precision and cost for technologies widely used by location technology developers.

7. Summary

In this report, the detailed description of location techniques has been provided. Initially, introduction to location based services and its current research topics are been provided. Further, end user applications are presented which make use of location information and show how it can add valuable services for individuals in their daily life activities. Then a detailed description of the various technologies for acquiring location information in a mobile network is presented. Comparative analysis of these location determination technologies in terms of their strengths, weakness, cost, performance and availability is carried out. Companies such as Lucent Technologies Inc., Snap Track Inc., and many more are extensively using the above technologies to provide LBS. Today, these technologies are supported by a multitude of wireless networks deployed worldwide such as GSM, CDMA, TDMA, 3G, etc. At the end, it will be user's experience and government economics of incorporating this approach in a client/server environment will eventually drive this technology.

References

[Mann and Helal] W. Mann and S. Helal, *Smart Phones for the Elders: Boosting the Intelligence of Smart Homes,* The International Centre on Technology for Successful Aging (ICTA) Rehabilitation Engineering Research Centre on Technology for Successful Aging, University of Florida,

[Yu et al., 2003] M. Yu, J.T. Zhang, Q.Q. Li, Jingnan Huang, *Mobile geo-information services Concept , J. Reality &Problems,* AsiaGIS, 2003

[Bajaj et al., 2002] R. Bajaj, S.L. Ranaweera, and D.P. Agarwal, *GPS Loation- Tracking technology,* University of Cincinnati, April 2002

[Ramamoorthy, 2004] A. Ramamoorthy, *New approaches in GPS based location systems Map India 2004,* Map India Conference 2004.

[Djuknic, Richton, 2001] G.M. Djuknic and R.E. Richton, *Geolocation and Assisted GPS*, Bell Laboratories, Lucent Technologies, Computer (ISSN 0018-9162), February 2001

[Drane et al., 1998] C. Drane, M. Macnaughtan and C. Scott, Computer Systems Engineering, University of Technology, Sydney, IEEE communication magazine, April 1998

[Spilker, 1978] J. J. Spilker, *GPS signal structure and performance characteristics,* Navigation , Institute of Navigation, vol. 25, no. 2, pp 121-146, 1978

[Bao & Tsui 2005] J. Bao and Y. Tsui, *Fundamentals of Global Positioning System Receivers- A Software Approach,* Second Edition, Wiley Inter-Science, 2005

[Shiraji & Yamamoto] M.T. Shiraji and S. Yamamoto, *Human Tracking Devices: the active Badge/Bat and Digital Angel / Verichip systems,* ECE 399 Project paper #1.

[FCC news, 1996] *"FCC Adopts to implement Enhanced 911 for Wireless Services",* FCC News, CC docket no. 94 – 102, June 12, 1996

[Van & Bouwman, 2001] E. Van de Kar, and H. Bouwman, *The development of location based mobile services*, Edispuut Conference, Amsterdam, October 17, 2001

[Levijoki] S. Levijoki, *Privacy vs. location awareness*, unpublished manuscript, Helsinki University of Technology

[Roza & Bilchev, 2003] T. D'Roza and G. Bilchev, *An overview of location-based services.* BT Technology Journal 21(1): 20-27, 2003

[Ratti et al.] C. Ratti, R.M. Pulselli, S. Williams and D. Frenchman, *Mobile Landscape: using location data from cell-phones for urban analysis*, SENSEable City lab, MIT, Cambridge, USA

[Spinney, 2003] J.E. Spinney, *Mobile positioning and LBS application*, Geography 88 (4) 256 – 265, 2003

[Agarwal & Agarwal, 2003] S.C. Agarwal and S. Agarwal, *Location based services*, Tata Consultancy services, September 2003

[Hightower & Borriello, 2001] J. Hightower and G. Borriello (2001) Location systems for ubiquitous computing. IEEE Computer August: 57-66 KRNIC (2003) Survey on the usage of wireless Internet. Korea Network Information Centre, accessed June 1, 2003, http://isis.nic.or.kr/english/sub04/sub04_index.html?sub=01V&id=81

[Adams et al., 2003] P.M. Adams, G.W.B. Ashwell, and R. Baxter, *Location-based Services - An Overview of the Standards*. BT Technology Journal 21(1): 34-43, 2003

[Ahn et al., 2004] Y.S. Ahn, S.Y. Park, S.B. Yoo, and H.Y. Bae, *Extension of Geography Markup Language (GML) for mobile and location-based applications.* Computational Science and its Applications - ICCSA 2004, Lecture Notes in Computer Science 3044: 1079-1088, 2004

[Peng et al., 2003] Z.-R. Peng and M.-H. Tsou, *Internet GIS: Distributed Geographic Information Services for the Internet and Wireless Networks*. John Wiley, Hoboken, NJ, 2003

[Miller, 2003] H.J. Miller, *What about people in geographic information science? Computers, Environment and Urban Systems* 27(5): 447-453, 2003.

[Moutain & Raper, 2001] D. Mountain and J. Raper, *Positioning techniques for location-based services (LBS): characteristics and limitations of proposed solutions*. Aslib Proceedings: new information perspectives 53(10): 404-412., 2001

[Worboys & Duckham, 2004] M. Worboys and M. Duckham, *GIS - A Computing Perspective*. CRC Press, Boca Raton, FL, 2004.

[Barens, 2003] S.J. Barnes, *Developments in the M-commerce value chain: Adding value with location-based services*.Geography 88(4): 277-288, 2003

[Beinat, 2001] E. Beinat, *Location-based Services - Market and Business Drivers.* GeoInformatics 4(3): 6-9, 2001

[Benson, 2001] J. Benson, *LBS technology delivers information where and when its needed*. Business Geographics 9(2): 20-22, 2001

[Zipf, 2002a] A. Zipf, *Adaptive context-aware mobility support for tourists. In Trends & Controversies: Intelligent Systems for Tourism*. IEEE Intelligent Systems 17(6): 57-59, 2002

[Zipf ,2002b] A. Zipf. *User-Adaptive Maps for Location-Based Services (LBS) for Tourism.* In Wöber, K., Frew, A., Hitz, M. (eds.) Proceedings of the 9th International Conference for Information and Communication Technologies in Tourism, Innsbruck, Austria. Springer. Heidelberg, Berlin, 2002

[Hjelm, 2002] J. Hjelm, *Creating Location Services for the Wireless Web*, John Wiley, New York, 2002

[Armstrong, 2002] M.P. Armstrong, *Geographic information technologies and their potentially erosive effects on personal privacy*. Studies in the Social Sciences 27(1): 19-28, 2002.

[Myles et al., 2003] G. Myles, A. Friday, and N. Davies, *Preserving Privacy in Environments with Location-Based Applications*. IEEE Pervasive Computing 2(1): 56-64, 2003.

[Duffet-Smith and Tarlow, 2005] P.J. Duffett-Smith and B. Tarlow, *E-GPS: indoor mobile phone positioning on GSM and W-CDMA*, Cambridge Positioning Systems Ltd, 2005

[Google Earth] www.google.com

Appendix A: Summary of attributes of location technologies

Techniques	Strength	Weakness	Accuracy	Cost	Scale/ Coverage	Location technology developers
GPS	High accurate No new infrastructure required Enhanced privacy for user	Poor service in urban areas New handsets required Delay in calculating location Bulky size of receivers	50 – 100 meters	Initial cost is driven by handset i.e. GPS receiver. Maintenance cost is negligible	Worldwide	SIRF Technology, Santa Clara, California
A-GPS	Very high accurate Eliminates many cost imposed by GPS handset, e.g. can be smaller, longer battery life Reduces delay in calculating location Rapid time-to-first-fix	New handset required	5 – 15 meters (outdoor) < 50 meters (indoor)	Cost driven by handset	Limited to country or city	Lucent Technology, Murray Hill, N.J. Snap Track Inc., San Jose, California
Cellular Network						
Cell ID	Available now No handset modification required Easy and simple to implement	Lower accuracy	200 – 300 meters	Low initial cost Cost to maintain is low	Limited to availability of Network	-
AOA	No handset modification	Problem with multipath reception special antennas and receivers at base station Loss of privacy for end-user	100 – 300 meters	Low initial cost Cost to maintain is low	Limited to availability of Network	www.TeleSentinel.com
O-TDOA & E-OTD	Enhanced privacy for end-user Good accuracy	Requires handset changes Difficult to implement Requires Location measuring unit	50 – 250 meters	Initial & maintenance cost is high Some network investment is required	Limited to availability of Network	Cambridge positioning system, Cambridge, UK Cell-Loc, Calgary Alta, Canada True Position Inc. Wayne, Pa.
Indoor localization technique	Best used for indoor localization of end users. Can be used in urban areas where dense deployment of sensors present	End-user should carry badges Dependent upon dense deployment of sensors such as WiFi, Infrared receivers Gives proximate location information	20 – 50 meters	Cost for building the database for wireless access point Low in cost	Limited to network area such as room, building, campus and depends upon WiFi routers	Skyhook Wireless, Boston, USA