Geolocation Positioning with Wireless Cellular Network in Hong Kong

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ABSTRACT

Location Based Services (LBS) is increasingly popular worldwide as its applications cover a wide spectrum of wireless users such as manpower and fleet management, travel aids and location identification in case of emergency. Current geolocation methods for LBS may be classified as GPS-based, cellular network based, or their combinations [Soliman S., et al. (2000); Tang W., et al. (2003)]. With the GPS alone method, successful position determination relies very much on sufficient number of visible satellites. However, with cellular network or the combination of GPS and cellular network approach, real-time location of a mobile device can be determined even in very dense high-rise urban environments. Although cellular network based positioning has many potential applications in Hong Kong, in this city, it is still at the premature stage. One of the concerns is its accuracy achievement, as different applications may require different accuracy specifications. This paper discusses an investigation on the accuracy of cellular network based positioning in Hong Kong. It is found that the current LBS with this technique can generally provide better than 200m accuracy in urban area, and the positioning error can be as big as 1km in rural area.

KEYWORDS

Location Based Services, GPS, Cellular Network Based Positioning, Geolocation, GIS

INTRODUCTION

Mobile communication has been rapidly growing in almost every part of the world, and Hong Kong has no exclusion. With the support of mobile phone manufacturers and diversified services provided by Hong Kong's telecommunications companies, mobile device is not purely used for voice communication, but also for data transmission, internet surfing, and multimedia entertainment. A mobile service available in Hong Kong which may not be aware of by the general public is Location Based Services (LBS). LBS concerns the provision of position and relevant information of a mobile terminal through wireless communications or web services. At present, there are two mobile positioning services providers in Hong Kong. Sunday has introduced such service since Year 2000 and SmarTone brought in this service at the end of year 2003 [BBsend (2004)]. In addition, the recently launched "3" mobile service uses LBS for information query such as restaurants and shops around the mobile user. Although mobile positioning technology has many potential applications in Hong Kong, the use of LBS in this city is still at the premature stage. One of the concerns is its accuracy achievement and reliability. It is believed that LBS platforms now available in Hong Kong can generally provide positional information better than 500m accuracy in urban area which would be sufficient for various applications such as manpower and fleet management, transportation query and guidance system. In order to verify the accuracy achievement of current LBS in Hong Kong, an investigation was carried out by the authors. Details of this test are discussed in the following sections.

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MOBILE LOCATION SERVICES PROVIDERS IN HONG KONG

At present, six mobile phone service providers are authorized by the Office of the Telecommunications Authority (OFTA) in Hong Kong [OFTA (2004)]; they are China Resources Peoples Telephone Company

Limited, Hong Kong CSL Limited, Hutchison Global Communications Limited, New World PCS Limited, SmarTone Mobile Communications Limited and Sunday O/B Mandarin Communications Limited. Among these companies, SmarTone and Sunday are providing LBS on 2G platform, and Hutchison"3" launched its 3G mobile telecommunication services and relevant LBS in the beginning of Year 2004.

Sunday launched the mobile location service in Year 2000. It adopts NMR technique which position is determined by capturing signal strengths with six neighboring cellular base stations [BBsend (2004)]. Sunday claims that NMR based method can achieve about 150m accuracy in urban areas and about 1.5km in rural areas [Sunday (2002)]. To use this service, a JAVA SIM card is required.

SmarTone adopts the Cell ID based technology which can be operated in GSM, GPRS or UMTS networks. When a user requests the location of the mobile terminal, the network would identify which cellular base station the mobile terminal falls into. At present, SmarTone only provides textual description of the whereabouts of the mobile terminal, not the coordinates of the mobile device. [BBsend (2004)]

SYSTEM DEVELOPMENT FOR THE ACCURACY TEST

A system containing location information retrieval and map display functions was developed for this test. Location information was obtained through a Location Gateway System (LGS) in the following five steps. Details of the system are shown in Figure 1.

Step 1: the location polling system (Figure 2), developed with ESRI's GIS Active X - MapObjects, sends a request to the service gateway for the mobile device's location. According to the provided Application Program Interface (API), parameters such as the account number and mobile phone number should be included in the request for verification.

Step 2: the location gateway server of the service provider would then send a location task request to cellular base stations.

Step 3: with the provided JAVA SIM card, position of the mobile device is sent to the polling system from the internet. The information is in XML file format, which includes mobile ID number, northing and easting coordinates, street name, date and two accuracy indexes namely Cell-ID Accuracy Index (CAI) and Network Measurement Result Accuracy Index (NAI).

Step 4 & 5: Location information is returned back to the service provider and passed back to the location polling system with GIS display in XML file format.

For other applications, it is possible for the geolocation and relevant information be sent to the mobile device by SMS message.

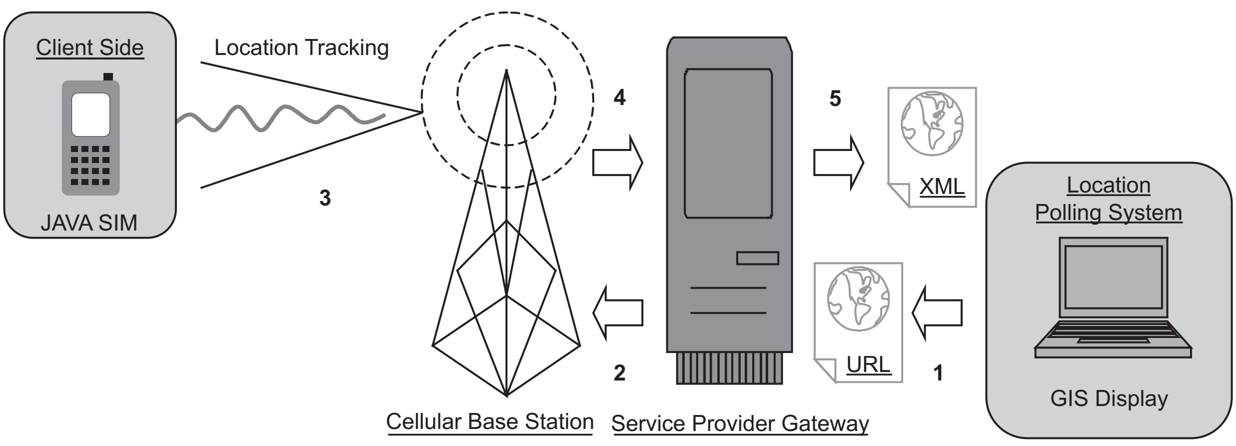


Figure 1: System Design of the LBS Test

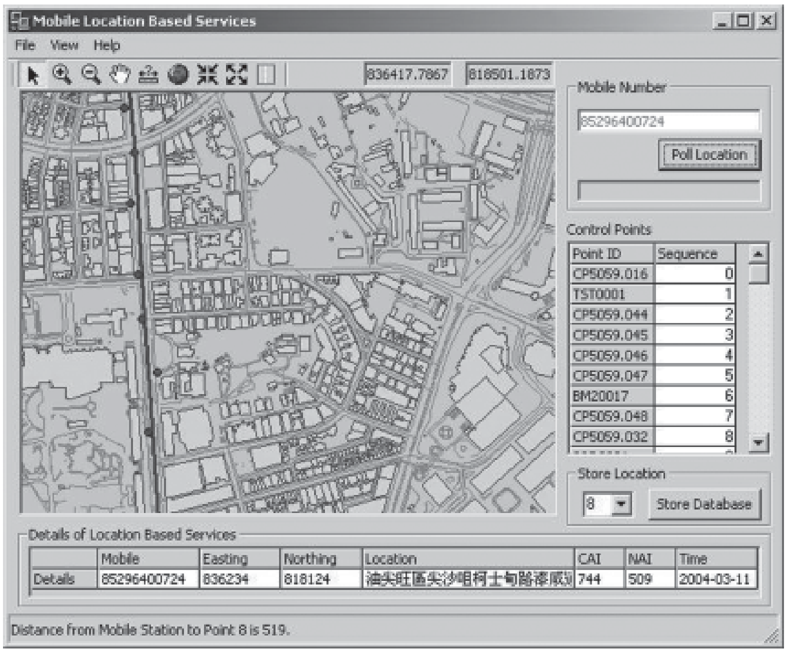


Figure 2: Location Polling System interfaced with the GIS

The location polling system described above was used to verify the accuracy achievement and stability of LBS along Nathan Road and Sai Sha Road, representing both urban and rural areas. Nathan Road is one of the busiest areas in Hong Kong surrounded by dense high rise buildings, whereas Sai Sha Road is a narrow two-way road connecting the less dense Ma On Shan and Sai Kung areas. In this test, pre-selected positions with known coordinates were used to compute the positioning accuracy. These positions include existing government survey marks and well defined features which can be clearly identified on digital maps.

As can be seen in Fig. 4a, a total of 82 points used for comparison are distributed evenly along and transverse to Nathan Road. For Sai Sha Road, 49 points were selected (refer to Figure 4e). In terms of length of the study area, it is about 3.5km along Nathan Road and 5.7km along Sai Sha Road.

The field assistant visited each pre-selected position with a mobile device installed with the required SIM card, and location polling was performed at the server side. This needs continuous communication between the server operator and the field assistant to ensure the correct locations were recorded. Location information was then stored inside a database for further analysis. By calling the MapObjects internal function FlashShape, the position of polled location could be flashed and displayed in the GIS interface. In addition, real-time calculation of distance between the known and polled location of pre-selected positions was achieved with the internal function DistanceTo. Figure 3 shows the design of the database.

LBS_Record : Table

LocationID	Mobile	Red_Label	Easting	Northing	Location	CAI	NAI	Time	DistanceTo
0	85296400724	A	835660	817468	油尖旺區尖沙咀漢口道亞士厘道 4號,漢口中心	177	125	2004-03-12 12:31:34	190
1	85296400724	B	835745	817669	油尖旺區尖沙咀海防道海防道 53-55號,海防大廈	291	113	2004-03-12 12:29:35	258
2	85296400724	B	835745	817669	油尖旺區尖沙咀海防道海防道 53-55號,海防大廈	291	113	2004-03-12 12:26:23	151
3	85296400724	B	835745	817669	油尖旺區尖沙咀海防道海防道 53-55號,海防大廈	291	113	2004-03-12 12:24:28	29
4	85296400724	B	835745	817669	油尖旺區尖沙咀海防道海防道 53-55號,海防大廈	291	113	2004-03-12 12:20:52	123
5	85296400724	B	835745	817669	油尖旺區尖沙咀海防道海防道 53-55號,海防大廈	291	113	2004-03-12 12:16:31	324
6	85296400724	C	835760	818260	油尖旺區尖沙咀柯士甸道彌敦道 192-194號,崇山大廈	109	36	2004-03-12 12:13:15	165
7	85296400724	C	835760	818260	油尖旺區尖沙咀柯士甸道彌敦道 192-194號,崇山大廈	109	36	2004-03-12 12:13:08	76
8	85296400724	C	835760	818260	油尖旺區尖沙咀柯士甸道彌敦道 192-194號,崇山大廈	109	36	2004-03-12 12:09:45	26
9	85296400724	D	835793	818538	油尖旺區油麻地佐敦道佐敦道 9-11號,高基大廈	587	361	2004-03-12 12:08:08	169

Record: 31 of 31

Fig.3 Database designed for the LBS Test

ANALYSIS OF RESULTS

Positioning error results are plotted and analyzed with ArcView GIS. Figures 4d and 4f show the distribution of pre-selected points and the generated error buffer along Nathan Road and Sai Sha Road. The followings are our findings and observations.

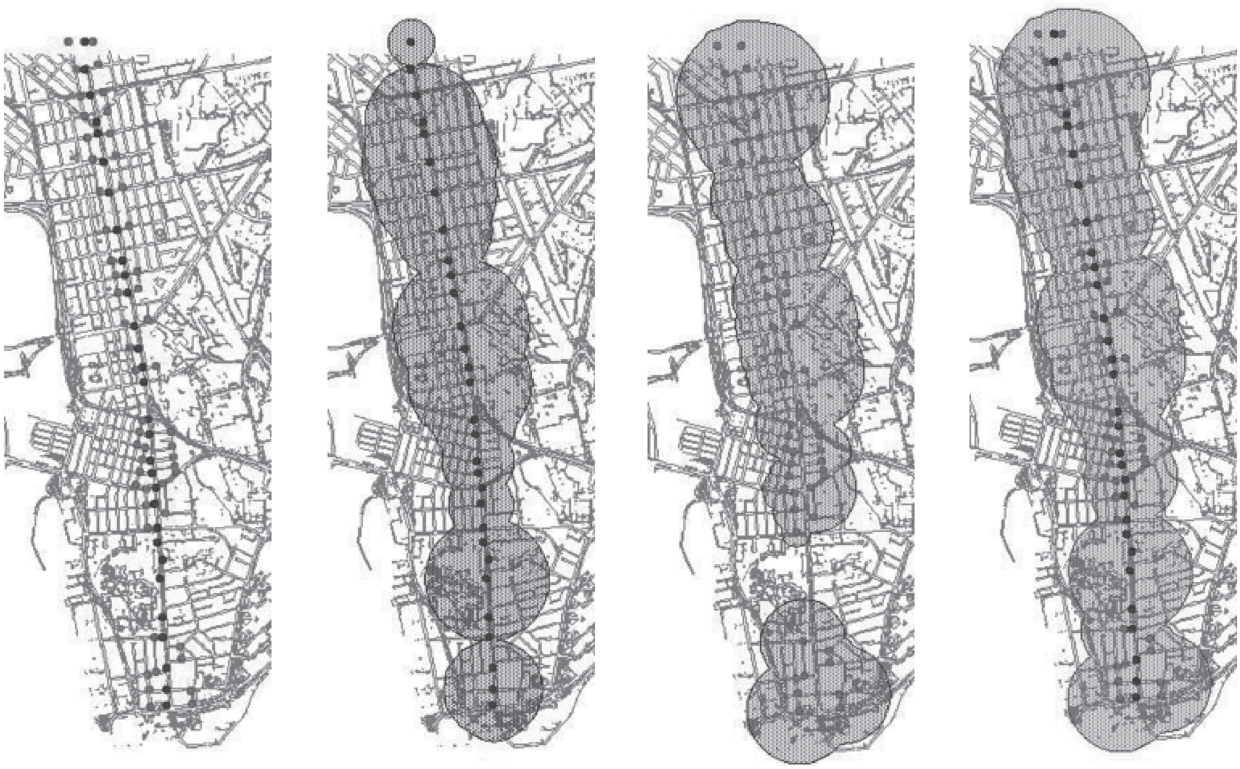
* For the test along Nathan Road, the minimum error is 26m and the maximum error is 400m. For the test along Sai Sha Road, the minimum error is 76m while the maximum error is 2662m (see Table 1). The statistics on different error range are shown in Figure 5(b) and (c) respectively.
* Diagram 5(a) compares the average positioning accuracy with NAI and CAI at different locations along Nathan Road. However, no obvious

correlation is found between these accuracy indexes and positioning error. Particularly, the positioning error in Jordan and Yau Ma Tei areas are about twice smaller than the NAI and CAI. It appears that NAI and CAI indexes do not reliably reflect the positioning accuracy.

* Position polling of five pre-selected positions along Sai Sha Road was not successful, and the time required for location polling was longer than that in urban area. The average time required for location polling in urban area was normally less than 10 seconds, and in rural area it was less than 20 seconds. Furthermore, 2 to 3 times longer in period was required for initial polling in both urban and rural areas.

Table 1 Summary of Field Test Result

	Nathan Road	Sai Sha Road
Length	Around 3.5 km	Around 5.7 km
Pre-selected Point	82 points	49 points
Maximum Error	400 m	2662 m
Minimum Error	26 m	76 m
Root Mean Square Error	180 m	1202 m



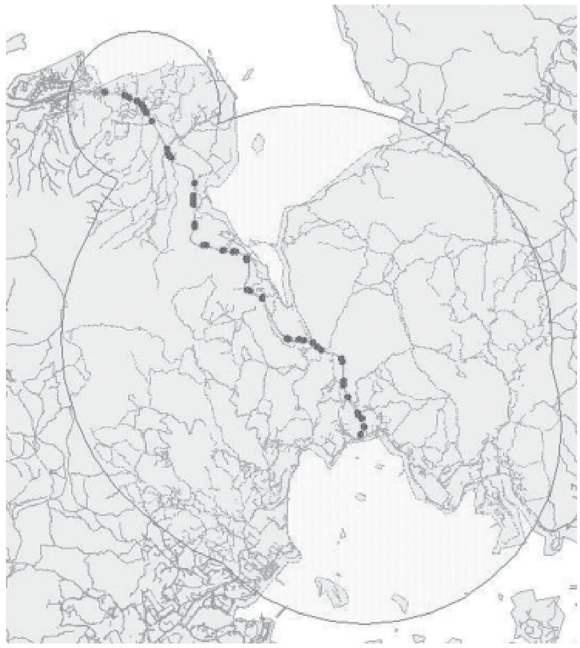
4a. Pre-selected positions along Nathan Road

4b. Error buffer

4c. Error buffer

4d. Error buffer

4e. Pre-selected positions along Sai Sha Road



4f. Error buffer

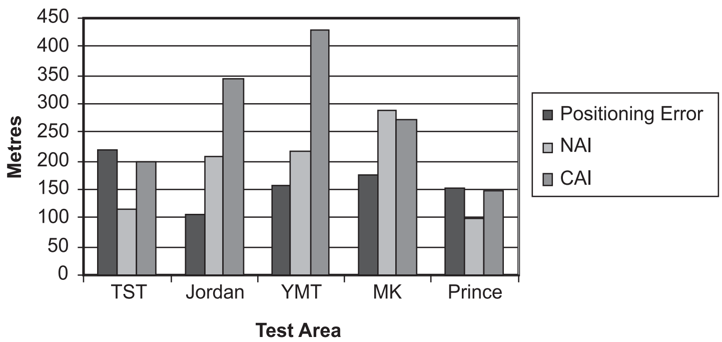


Fig. 5a: Comparison of positioning error with NAI and CAI (along Nathan Road)

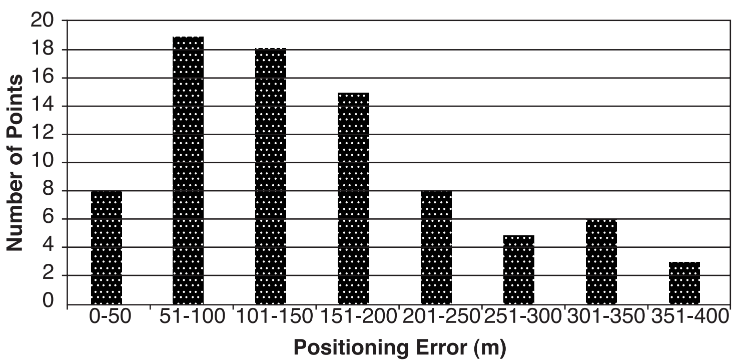


Fig. 5b: Error statistics (Nathan Road)

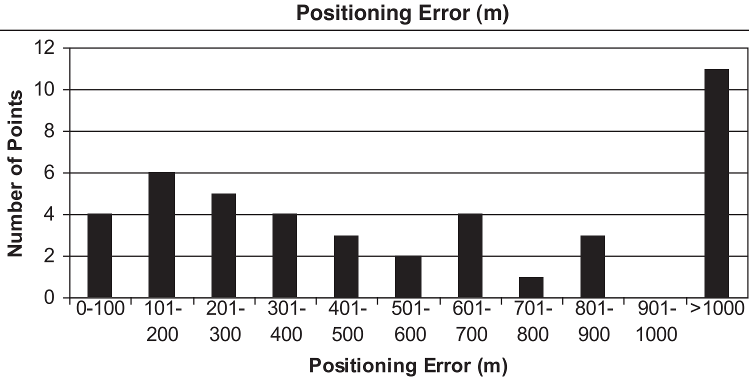


Fig. 5c: Error Statistics (Sai Sha Road)

CONCLUSION

According to the field test results, geolocation determination with cellular network of the service provider subscribed for this test can generally perform better than 200m from actual location in urban area and the error can be bigger than 1km in rural area. Accuracy of the mobile position fixing depends on many factors, such as the number of cellular stations and cell size in the network, geometric configuration of cellular network, signal strength, and positioning method. For example, the Time of Arrival (TOA) and Time Difference of Arrival (TDOA) positioning methods determine positions with distances between cellular stations and the mobile device, which require the signal transmission and reception time information. However, blockage; diffraction and reflection of signals propagating through different environments would cause the Non-Line-of-Sight (NLOS) time delay error. This error would lead to the error in distance determination and would eventually cause serious positioning error.

To increase the accuracy of LBS in Hong Kong, one may argue that GPS alone system can generally achieve better than 20m accuracy, which is far better than the current cellular positioning methods. It should be noted that, the GPS alone method is very susceptible to signal obstructions and multipathing, whereas in dense high rise environments, successful and accurate position determination will become much more difficult, if not impossible. The combination of GPS and cellular network positioning can solve the problems of blind network coverage and unreasonable results in rural areas, since most New Territories areas are quite open to the sky.

The trend for LBS in Hong Kong, from the point of view of the authors, will gradually move to the hybrid positioning technique, which is the combination of AGPS and cellular network positioning. One of such systems namely gpsOne(tm) developed by Qualcomm has been applied in CDMA networks, to provide high accuracy indoor and outdoor location based services [Qualcomm (2004)]. As of February 2003, over ten million gpsOne(tm) terminals are on the market. Moreover, the China Unicom has already launched this service in all provincial capital cities and some central cities [Wang K., et al., (2004)], with the claimed accuracy between 5 to 50m [China Unicomm (2004)]. Wang et al. (2004) have been carrying out investigations on using gpsOne(tm) for vehicle navigation applications. There are also discussions on the use of gpsOne(tm) to relieve the traffic jam in large functions such as Olympic Games in Year 2008 and Shanghai Expos in Year 2010.

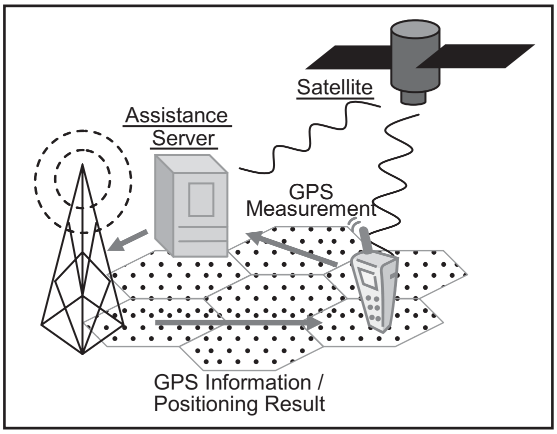
It is hoped that similar accuracy level location based services will be developed in Hong Kong to support a spectrum of applications such as manpower and fleet management, travel aids, location identification in case of emergency, and to provide guidance for visually impaired persons. Applications of LBS are only limited by our imagination.

APPENDIX A:

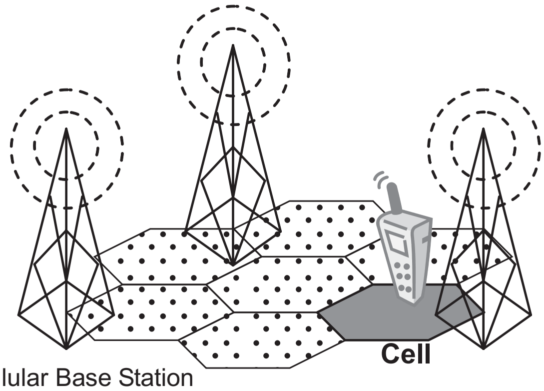
BRIEF DESCRIPTION OF AGPS, CELL-ID, TOA, TDOA AND NMR

Assisted GPS (AGPS)

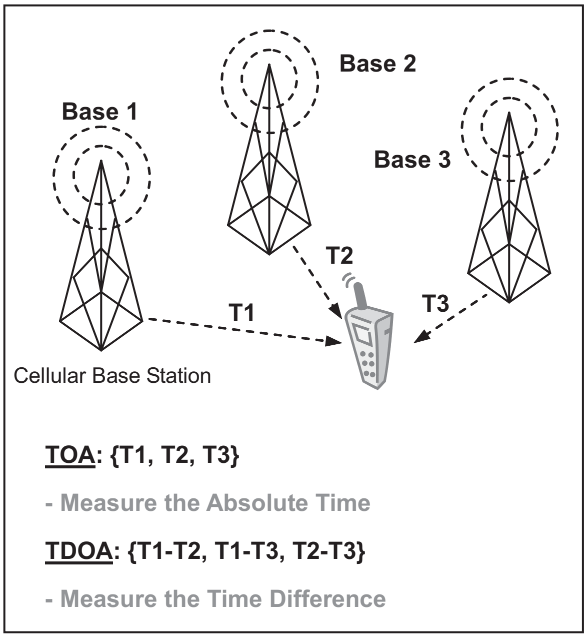
This positioning method combines GPS positioning technique with assistance of wireless network. The mobile device contains a GPS module for range data collection. Reference GPS receivers are also connected to the wireless network, whereas GPS information is sent from the assistance server to the mobile device. Very quick satellite searching and range measurement can therefore be performed by the mobile device. The range measurements are then sent to the assistance server for position calculation. With this arrangement, the power consumption and size of the mobile device can be significantly reduced. Moreover, by combining the estimated and collected GPS data, position determination is possible when insufficient GPS data is collected at the mobile device location due to for example, signal obstruction by high rise buildings.



Cell-Identity (Cell-ID)
This is the basic wireless location technique. A mobile device which position falls within a cell of a wireless network is approximated with the cellular station's position. The accuracy is therefore dependent on the cell size, distribution of cellular station and density.



Network Measurement Report (NMR)
NMR stands for Network Measurement Report, which is based on the measurement of received signal strength from serving cell as well as neighbor cells. The measured signal strength pattern is compared with the predicted one inside a pattern database. With a signal strength matching algorithm, an estimated position can be derived by identifying which cell the mobile handset is located [Kunczier H., et al. (2002)].



Time of Arrival (TOA)
At least three base stations are needed to receive signals from mobile handset and hence triangulate the mobile position based on the absolute signal time arrivals. As a result, synchronization of the network base stations is important.

Time Difference of Arrival (TDOA)
This technology only differs with TOA in that it uses the arrival time difference between two stations rather than the absolute time of arrival at a certain base station. In order to achieve accurate positioning, the base stations must be precisely synchronized in time, which is usually done by GPS.

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