E-911 LOCATION STANDARDS AND LOCATION COMMERCIAL SERVICES

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Abstract - Mobile location positioning technologies, initially developed in answer to the U.S. Federal Communications Commission (FCC) E-911 requirement have become an increasingly important topic in the standards development group. The U.S. FCC has mandated that by October 2001, mobile callers to E-911 must be located to within a certain accuracy level (i.e., 50m in 67% of cases and 150m in 95% of cases for handset-based location solution). This requirement, coupled with the consumer demand for location commercial services, has driven the cellular industry to research promising positioning techniques and new location value-added services.

In the past year, the E-OTD method has been accepted in the E-911 phase of GSM system location standards. Almost at the same time, the GPS-based location standard, IS-801, has also been developed for cdma2000. While much of the emphasis has been on the development of location technologies to comply with the E-911 ruling, another important area for consideration is the emergence of location value-added services. When the mobile information is received, it may be used within the systems to (1) improve the system performance in the different layers of the systems and (2) increase wireless system functionality for location commercial services.

I. INTRODUCTION

Mobile location has played a role in wireless communication from its inception- after all cellular radio has an inherent positioning capability by virtue of the fact that a mobile typically connects to the closest serving site. With the introduction of new positioning technologies, this capability will eventually become razor sharp for new wireless location services and wireless exploring.

Mobile location technology is becoming a hot topic for the purpose of satisfying the US FCC E-911 location requirement and for driving Location Information Applications in Europe[1]. The typical method for positioning a mobile is based on using trilateration and triangulation techniques, which require time of arrival (TOA) and Angle of arrival (AOA) information, respectively. In order to implement either of these techniques in a cellular network, the mobiles and base stations must be location-capable and the location method must perform within the location accuracy requirements of the end-user service. Recently, several location technical approaches have been proposed to the location development groups. These approaches have been tested (either via simulation or actual field testing) in difficult environments, such as in buildings, under dense foliage, and in urban canyons where measurements may be unreliable or only two (or fewer) TOA signals are received from satellites and/or base stations. In that case the traditional TOA trilateration method may not be capable of determining a mobile location. Thus, some additional location relevant information must be used for mobile positioning, such as supplemental angle of arrival or receiver signal strength measurements, or the use of, ray-launching or fingerprint based mapping-algorithms to estimate mobile location[2].

This paper can be summarized as follows. In section 2, we will briefly present the FCC wireless E-911 rulings on two different types of location technology, namely network-based solutions and handset-based solutions. Several important location techniques including network-based methods, handset-based methods, and hybrid methods will be discussed in section 3. Non E-911 location applications, e.g., system enhanced applications and location commercial services, will be emphasized and explored in section 4. Then, we will conclude with a discussion of the impact of having location information in the wireless world.

II. FCC WIRELESS E-911 RULINGS[3]

The current FCC ruling for E-911 Phase II has been issued on September 15, 1999. The FCC adopted the following revised standards for Phase II location accuracy and reliability:

For network-based solutions: The required E911 accuracy is 100 meters for 67 percent of calls, 300 meters for 95 percent of calls.
For carriers employing network-based location technologies, the FCC replaces its current plan, which requires that implementation be fully accomplished within 6 months of a Public Safety Answering Point (PSAP) request, with a revised rule requiring the carrier to deploy Phase II to 50 percent of callers within 6 months of a PSAP request and to 100 percent of callers within 18 months of such a request.

For handset-based solutions: The required E911 accuracy is 50 meters for 67 percent of calls, 150 meters for 95 percent of calls.
Without respect to any PSAP request for Phase II deployment, the carrier shall: (1) Begin selling and activating ALI-capable handsets no later than March 1, 2001; (2) Ensure that at least 50 percent of all new handsets activated are ALI-capable no later than October 1, 2001; and, (3) Ensure that at least 95 percent of all new digital handsets activated are ALI-capable no later than October 1, 2002.

Once a PSAP request is received, the carrier shall, in the area served by the PSAP: Within six months or by October 1, 2001, whichever is later: (1) Ensure that 100 percent of all new handsets activated are ALI-capable; (2) Implement any network upgrades or other steps necessary to locate handsets; and, (3) Begin delivering to the PSAP location information that satisfies Phase II requirements. Within two years or by December 31, 2004, whichever is later, undertake reasonable efforts to achieve 100 percent penetration of ALI-capable handsets in its total subscriber base.

Note the following important dates about location capable handsets: (1) Regardless of PSAP requests, carriers should start selling Phase II capable handsets no later than March 1, 2001, ensure that 50 percent of all new handsets activated are ALI-capable no later than October 1, 2001 and 95 percent of all new digital handsets activated are ALI-capable no later than October 2, 2002. Intuitively, high costs are expected for wireless E-911 implementation. Per the FCC's order, wireless carriers should be able to recover the cost they incur to implement wireless E-911. However, the responsibility for setting up cost recovery mechanism is left up to the states. Many states have already passed legislation, which applies a surcharge on wireless customers to finance wireless E-911.

III. LOCATION TECHNIQUES

In general, two different types of location techniques have been studied in the past years in order to locate a mobile station. These are network-based techniques and handset-based techniques. In addition, hybrid technologies are currently being studied.

1. Network-Based Location Techniques

Network-based methods detect the signal transmitted from a mobile station and use that signal to determine the mobile station location shown in Fig. 1. The implementation of the technique does not require any software or hardware modification to the handset. Usually, the mobile station is totally passive and does not play any role in the location determination process.

The network locates the user by making time-of-arrival or angle-of-arrival measurements on the received signals. We may describe in the following categories:

Network-based TOA Method - Mobile station transmits the signal and three or more separate base stations measure the time of arrival signals. Synchronization amongst the base stations is required.

Network-based AOA Method - Mobile station transmits the signal and three or more separate base stations measure the angle of arrival of radio signals. A calibrated antenna array is needed at the cell site.

Network-based Fingerprinting Method - Network compares a unique match of current fingerprint measured to a database of previously fingerprinted. The measurement of pre-processed RF patterns needs to be stored in the network database.

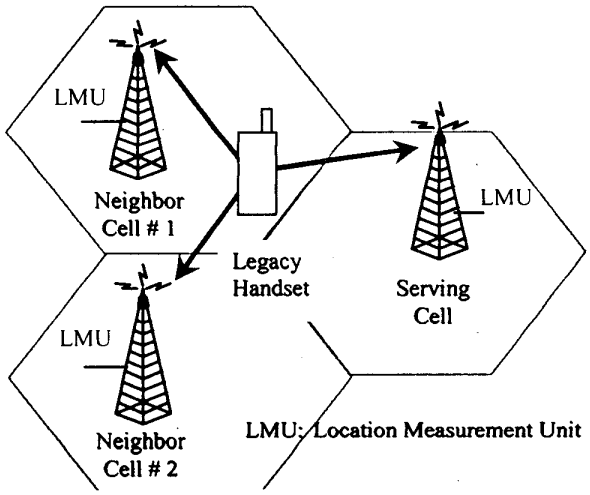

Figure 1. A network-based TOA approach.

2. Handset-Based Location Technique

Handset-based methods detect the signal transmitted from multiple base stations and/or satellites, and use these signals to determine the mobile station location. The implementation of the technique normally requires some software or hardware modifications to the handset, which presumably means that E911 location service may not be available to legacy phones.

There exist several handset-based techniques, namely network-aided GPS, E-OTD (for GSM and TDMA), IP-DL/AFLT (for WCDMA/cdma2000), and combined methods.

Network-aided GPS method[4] - A stand-alone GPS receiver could take several minutes to acquire the satellite signals. And, received signals are very weak upon entering a building. In order to combat the shortcomings of the conventional GPS[5-6], a network-aided GPS was introduced to place base stations, with GPS throughout the area of coverage to assist mobile receivers acquire the GPS signals. When a mobile GPS receiver requires its location, the base station feeds it satellite information to the mobile station through the air interface seen in Fig. 2. These information contents include a list of observable GPS satellite locations and the navigation data e.g., satellite ephemeris and almanac. This information enables the mobile station to fast searching and acquisition of the satellite signals. Therefore, allowing majority time in a time slot (20ms) for accumulating the weak energy of GPS pseudoranges inside the building. This technology has been standardized for location services in cdma2000 systems[4].

In general, there exists two types of network-aided GPS methods (1) network-assisted GPS method: the position is calculated by the mobile station, (2) network-centered GPS method: the position is calculated at the network.

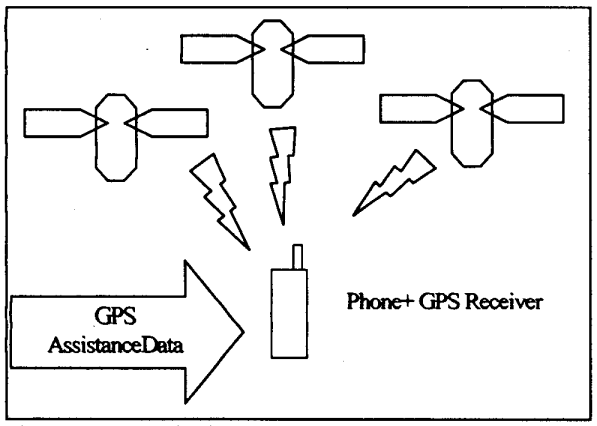

Figure 2. Network-aided GPS approach.

EOTD Method[7] - The Enhanced Observed Time Difference (EOTD) positioning technology is based on using the TDMA mobile to monitor a group of base stations. The mobile measures the Time Difference of Arrival (TDOA) between the beacon carrier of the serving base station and the neighbor base stations in its candidate list. In GSM this TOA difference is called the Observed Time Difference (OTD) and is one of the requirements for pseudo-synchronous handover. Since there is no current specification to synchronize TDMA networks, it is necessary to measure the frame emission times (FETs) of the base stations in the network. The difference between local GSM time at each cell site is called the Real Time Difference (RTD). In general, the RTD values between cell sites will drift as a function of time, so they must be monitored and regularly updated to the network. One method to obtain network timing is to deploy Location Measurement Units (LMUs). LMUs would be used to estimate the differential FETs of the cell sites and report these measurements to the network. EOTD technology that has been standardized for location services in GSM-based systems[8].

IPDL/AFLT Method - IPDL/AFLT (Idle Period Down Link/Advanced Forward link trilateration) methods are used in the CDMA systems shown in Fig. 3. IPDL is used in the WCDMA systems have been proposed as a remedy for the hearability problem[9-10]. The strongest candidate at the moment is the IPDL. The idea of IPDL is that each base station at it's turn ceases completely from transmission for a short predefined period of time, and this way provides an efficient measurement period for all the terminals within its' coverage area. In effect the IPDL tries to improve the Signal-to-Interference-Ratio (SIR) of the measurements by attenuating the strongest interferer, the serving base station.

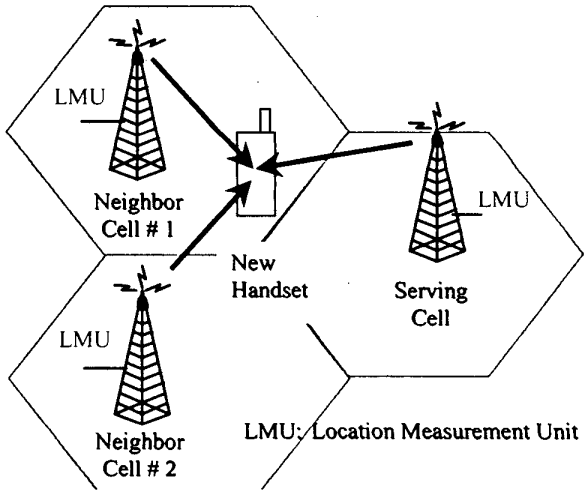

Figure 3. Handset-based TOA approach.

In the CDMA systems, the terminal itself is measuring the timing of all the nearby base stations it can receive. One of the received base stations (e.g. the serving or the strongest base station) is selected as a reference BS. Then timing differences of all the other measured base stations are calculated with respect to this reference BS, and this way the measured TDOAs are obtained. The actual location calculation is then carried out by utilizing these TDOA values. Since WCDMA networks are asynchronous, LMUs would be used to estimate the differential FETs of the cell sites and report these measurements to the network or use GPS to synchronize the base stations.

AFLT method is used in cdma2000 systems, all the base stations are synchronized by using GPS.

Combined GPS/FLT Method[4] - This technique integrates GPS measurements and handset-based forward link trilateration (FLT) measurements with a time synchronization in such a combined system. There are many different ways to fuse GPS and FLT measurements. Some techniques may be better than others.

3. Hybrid location techniques[11]

These techniques combine handset-based methods with network-based methods. The mobile station collects GPS measurements and signals from the wireless base stations. The mobile station then sends the information back to the network location determination center along with geolocation measurement made by the base stations. Hybrid methods use knowledge of the mobile station's reference time and pilot phase measurements, and round trip delay measurement made by the base station to compute the location. This allows base stations to be used to improve the availability of the location determination under the conditions of limited transmitter visibility.

IV. LOCATION INFORMATION APPLICATIONS

When the mobile location information is known, it can be used within the wireless systems to (1) improve the system performance in the different layers for system enhanced applications and (2) increase wireless system functionality for location commercial services.

1. System Enhanced Applications

Location information can be used to improve the system performance in each horizontal layer. It can also provide applications cross layers vertically. Some examples are given as follows:

Intelligent handoff - System uses the signal strength and MS location information to reduce the unnecessary dropped calls as well as maintain quality of services[12].

User behavior modeling - System tracks of calls and the dropped calls to track mobility patterns and user distribution.

Efficient channel allocation - System detects mobile location and velocity to dynamically allocate channel capacity in the serving cell and also reserve channel in the target cell for each user[13].

Signal level map generation - System tracks Rx signal strength to identify poor quality areas and enhance the deployed system performance. This signal map can also used as a mechanism for handoff and power control purposes[14].

2. Location Commercial Services

Tracking Services - Fleet management, (tracks, taxis, buses) provids an environment where timely allocation of staff and timely instructions to dispatch staff, tracing of elderly people and children who need support of others, car navigation linking with the map portal and provides real-time user's current position and surrounding area information.

Tariff Services - Network provides tiered services for home zone and office zone with low cost calls.

Value Added Services - Mobile station requests the nearest ATM, cheapest gas station, location WAP based Internet services, local broadcasting, local traffic information.

Commercial Safety - Calls rescue for emergency cases and transmits the user's current location information for emergency roadside assistance, nearest doctor and medical clinic.

Connecting Services - Network notifies the user's current location to friends and searches the location of friends, such as chatting room services in the Internet.

The core of the required information blocks in the location commercial services is shown in Fig. 4. When a service is requested from the user to the Location Based Service center, the network will pull out the information from the End-User Profile, Location Information, and Offering Information together and generate valuable recommendations. Then, Location Based Service center will send the recommendations to the End-User. For instance, Internet services can provide different levels to the End-User. Current Internet search machines do not have any selectivity. The data is overloaded to the user with free of charge. Once location based services are in place, it will transfer massive information into selected knowledge, such as on-line recommendation, consultancy. These services are based on where you are and the End-user pays a fee for the quality services.

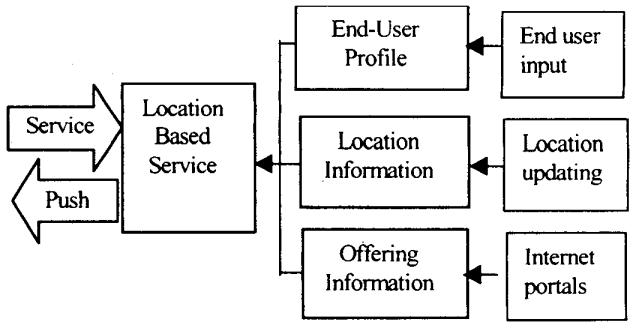

Figure 4. The core blocks of location commercial services.

V. CONCLUSIONS

In this paper, the current FCC E-911 requirements have been described in detail. The various location techniques, which have been developed by the Standard Development Group, have been presented for GSM and CDMA/WCDMA systems. Beyond E-911 location request, Location Information Applications have driven the cellular industry to research promising location value-added services. We have explored and briefly presented location commercial services in two areas: (1) enhancement of system performance in the different layers and (2) increasing wireless system functionality for location commercial services.

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