DEVELOPMENT AND DEPLOYMENT OF GPS WIRELESS DEVICES FOR E911 AND LOCATION BASED SERVICES

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ABSTRACT

The Federal Communications Commission recognized as early as 1994 that the rapid adoption of wireless technology in the USA was destined to put additional strain on emergency dispatch and rescue personnel due to the absence of any location information associated with a wireless handset. Previously, the FCC had gone to considerable effort to ensure that all landline phones were associated with an unambiguous street address, so that rescue personnel could be dispatched efficiently during a 911 call. The FCC was compelled by their duties to establish a mandate for the development of "Automatic Location Identification" (ALI) technology by the wireless industry. This paper will outline a system that requires no changes to the wireless network and can provide a wide range of location capabilities, including precise location solutions with GPS. This system was designed for flexibility, and can be used for both commercial location-based services, as well as E911 / PSAP solutions.

INTRODUCTION

The FCC's "E911 mandate" is regarded as an "unfunded federal mandate" by the wireless carriers. The carriers are businesses, and thus interested in deploying services that generate additional revenues and additional profits. In the mid 1990s there was no commercially available location technology that would fulfill the E911 requirements, and could be deployed economically be the carriers.

Thus a great technological race began to produce a location determination system that wireless carriers would deploy.

Unfortunately, over 5 years have passed, and the deployment of ALI technology is currently very limited to small geographies. There are a number of technological factors for the slow rollout, but cultural factors have also played an issue. Privacy advocates are understandably concerned about the security of such personal information. Certainly security should be the primary concern during commercial transactions. However, when a user's life is dependent on the timely dispatch of an ambulance, the system must operate in a different fashion.

Tremendous technological progress during the last five years has finally led to a hybrid system architecture that is both flexible and accurate and can be used for applications ranging from navigation services to E911 dispatch.

TECHNOLOGY OVERVIEW

The original E911 mandate has provided an impetus for significant development of miniaturized location determination systems in the last few years. Despite private sector investments totaling over $100 million in the last few years, no location determination solution is

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commercially available that has been widely adopted by the wireless industry.

Over the past several years multiple technologies have been presented to the wireless industry for the location of devices in their network. The solutions have ranged from crude location capabilities that have little or no impact on the infrastructure of the wireless network to very precise location determination systems which require extensive modifications to the network.

A multitude of location technology for wireless devices have been proposed and implemented in the past several years. These break down into two general categories: network-based and handset-based. The position computation for "handset" solutions is computed in the handset, whereas the position computation for "network" solutions takes place on the network. Handset-based solutions frequently utilize information from the network to improve the solution. One major advantage of the network solutions is that they frequently require NO MODIFICATION of the handsets – which means that the consumer does not need to upgrade their handsets.

For a handset based solution (the most stringent FCC condition), the FCC requires that position accuracy must be greater than 50 meters 67% of the time, and greater than 150 meters 95% of the time. The FCC requirement for network based solutions allow position errors that are twice as large, i.e. 300 meters 95% of the time.

ALL positioning technologies rely on some sort of "triangulation" either based on the distance to satellites or based on the distance to cell towers. Furthermore, all of these positioning technologies require knowledge of:

- Transmitter location
- Transmitter timing information
- As many measurements as possible

Thus we could further subdivide the location solutions into terrestrial and satellite based solutions.

CURRENT NETWORK TECHNOLOGIES

Network based technologies generally use terrestrial measurements from one of more cell towers. These network based technologies have led to concerns among privacy advocates, because the user does not have a switch to disable this function. On the other hand, network based solutions are semi-automatic and do not require any special actions by the user during the stressful situation following an accident while dialing E911.

Cell-ID

By far the simplest approach is to estimate the user's position based on the location of the nearest cell tower. The accuracy is dependent on the cell size and varies from 10m (a micro cell in a building) to several kilometers (for a typical digital cell tower). The coverage radius of analog towers is even larger and can exceed 10 kilometers.

This approach is frequently referred to as "Phase I" in the wireless community.

TDOA

For situations where multiple towers can "hear" a given handset, it is possible to utilize "Time Difference of Arrival" Simply put, the signal from the cell phone should arrive at the closest tower first. The difference in propagation times can be used to derive the location of the cellular phone. However, this is more difficult than it first appears, since the clocks in each cell tower have errors which must be calibrated. "Location Measurement Units" are used for this calibration process. A minimum of 1 LMU is needed for every 3 cell towers – which significantly increases the cost and complexity of this system.

AOA

"Angle of Arrival" systems require that the direction to the cell phone can be determined accurately. This system requires only two towers that can hear the cellular handset. However, most digital wireless systems utilize three antenna sections at each cell site. These antennas can only resolve the general direction of the cellular handset to approximately 60 degrees.

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New expensive antennas must be installed at a majority of the cell sites to implement AOA.

a-GPS

The "Global Positioning System" utilizes a constellation of approximately 24 satellites orbiting the earth. Assisted GPS or augmented GPS may be implemented as a network based solution by transmitting the measurements from the handset to a server on the network that can determine the handset's location.

CURRENT HANDSET TECHNOLOGIES

EOTD

"Enhanced Observed Time Difference" uses differences in timing data received from surrounding base stations to calculate position on the handset. Some people regard EOTD as the opposite of TDOA. The accuracy of EOTD is expected to be around 125m, and unlike GPS it is not reliant on a clear sky above. Like TDOA, it is necessary to use LMUs for calibrating the cell tower timing information to produce accurate location fixes.

GPS

The "Global Positioning System" was built with primary purpose of enabling autonomous navigation by military units. Microelectronics have made GPS receivers portable and affordable. Nonetheless, autonomous GPS is susceptible to interference or jamming, and does not perform well in urban canyons.

CARRIER PERSPECTIVE

As mentioned earlier, the carriers are businesses and will not invest large sums of money for the common good of their subscribers without a clear path to recoup their investment in a timely manner.

As the pioneers of ALI technology for E911 rushed to market in the late 1990s, many claims were put forward about performance. This caused most of the wireless carriers to become rather jaded when they realized the actual state of the technology.

Furthermore, many technology distributors distributed self-serving propaganda about the costs required to install and maintain a nationwide system capable of providing E911 functionality. With some estimates approaching $20 per subscriber, most of the carriers decided to delay indefinitely the purchase of Location Determination Technology. Essentially all of the US Carriers filed E911 waivers in the fall of 2001 because they were not planning to deploy any sort of E911 system for the Phase II deadline of 01 October 2001.

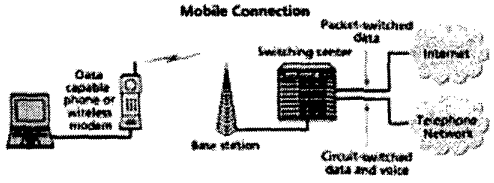
It appears now that wireless carriers are willing to consider any system that can provide both LBS and E911 functionality.

PSAP PERSPECTIVE

There are thousands of Public Safety Answering Points (PSAPs) throughout North America, ranging from single station PSAPs in rural areas to 50 stations PSAPs in metropolitan areas. They are typically funded by local municipalities and their equipment ranges from archaic Plain Old Telephone Service (POTS) lines to modern Intelligent Work Stations (IWS).

The typical 911 dispatcher spends a large portion of their time answering calls about cats which are stuck in trees. A small proportion of the time, they have to handle life-threatening situations. During these times, it is essential that they have the best information possible about a given caller. For wireline 911 calls, there is a database with information about past calls, and the caller's street address.

Approximately 50% of all calls to E911 now come from wireless phones. This is very frustrating for the dispatchers, who can not get access to the most crucial piece of information – the actual location of the caller.



LBS PERSPECTIVE

Location Based Service providers are focused on taking position information that is

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similar to that provided to the PSAPs during and E911 call. These services require some knowledge of the user's physical location. Some prototype services already exist, but they are very low tech. Users punch in the local zip code at a prompt. This sort of coarse location information is more than adequate for "regional" information, like weather information. This regional information is also of relatively low value to the consumer, as there are multiple ways to obtain this information.

However, as more precise location information is available, users are willing to pay more to get information that is more personalized. For example, most cell phone users would pay extra for turn by turn driving directions, especially when they are late to an important client meeting.

Basic Architecture

This system consists of two primary pieces of hardware. The "X-Pak" GPS accessory module records GPS satellite measurements as well as cell timing information from nearby cell towers. The X-Pak transmits data via SMS to the "X-GPS" Location Server. SMS is used to transfer data from and to the phone. SMS transmissions utilize the data channel, and thus do not interfere with the normal operation of the voice channel.

X-GPS Advantages

Latency for E911 applications is one of the most crucial attributes of a system. When your emergency phone call is truly a matter of life and death, 60 seconds is a long, long time. "Time to First Fix" is the interval between the time you turn on a GPS device, and the time you are first able to report a position (even if it is 2D).

Autonomous GPS receivers will exhibit great TTFF when performing warm starts outdoors, with typical times under 30 seconds. However, it is well known that when an autonomous receiver does not have a clear view of the sky, due to buildings or heavy foliage, that the TTFF will increase dramatically.

We conducted a series of simple tests using one autonomous receiver, and one X-Pak communicating with our server. We visited several locations to collect data, and to determine the differences in acquisition time for the two configurations.

The results of this test are shown below. In every single test case the network centric solution produced a solution as fast or faster than the autonomous GPS receiver. In fact there were several test cases in which the autonomous GPS receiver did not get a position fix, even after waiting 6 or 7 minutes.

Examining only the cases for which both receivers were able to track satellites, we see that TTFF is reduced by a factor of 2 by employing a network centric solution.

This is a relatively small sample, speaking statistically. But it indicates a strong correlation between increased TTFF and operation in autonomous mode.

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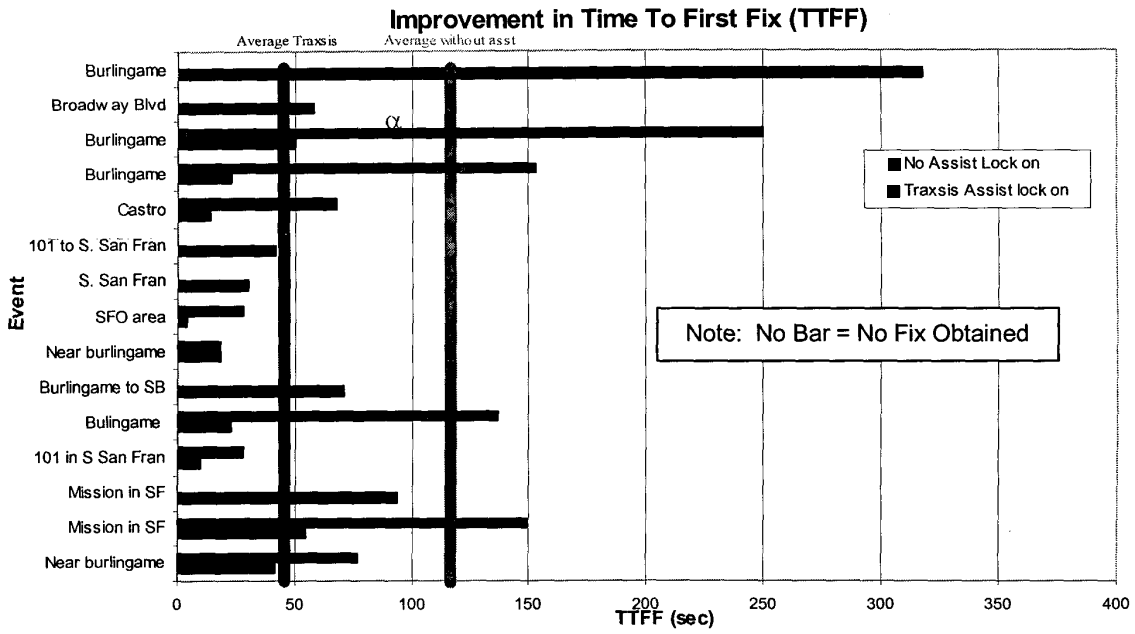

Figure 1) TTFF results for autonomous vs. networked 1

E911 Architecture

Standards committees for CDMA, GSM, and TDMA met in the late 1990s to create standards for how the various components would inter communicate.

The objective is very similar in all air interfaces – providing the location of the wireless user directly to the PSAP. Unfortunately, the implementations are all rather different.

The primary challenge with E911 is that the most accurate solution available is needed in the minimum time possible. Cell tower (Phase I) information can be used for initially routing the call, which must happen within the first 6 seconds after completing the call. This coarse position information is good enough to get the 911 call into the appropriate call center, but it is note adequate for dispatching emergency vehicles. Precision location information from a GPS receiver from the device is nominally available at this point, so that the dispatcher can focus on understanding the scope of the emergency, rather than asking extensive questions about the user's location.

E911 Considerations

The rapid adoption of wireless technology by Americans has led to a dramatic increase in call volume to emergency dispatch centers. A large portion of these calls are accidental or non-emergency calls, and are merely a nuisance to the dispatchers. Another large portion of the calls are legitimate emergencies, where the only priority is to dispatch the nearest possible vehicle to the scene.

In a tiny fraction of the situations, the caller is actually moving, and dynamic Location Determination will prove to be essential. In these situations, the dispatcher will need to do an "ALI REFRESH" to get updates location information for the given phone number. Our system is designed to provide updates as frequently as once every 10 seconds, enabling dispatchers to track an incident in real time from their console.

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