Wireless Location Accuracy Issues
A White Paper Prepared for the USDOT Wireless Implementation Project

November 18, 2005

Wireless location accuracy depends largely on the capabilities of location determination technologies (LDT) used by wireless carriers to provide wireless E9-1-1 Phase II service. LDT has matured significantly, and carriers are fully utilizing several methods in the provisioning of wireless E9-1-1 Phase II. Phase II stands at about 42% deployment across the United States (as of May 2005), in terms of the number of Public Safety Answering Points (PSAPs) having at least one carrier implemented for Phase II. The present LDT methods, and several alternatives available or which may become available, are listed in Attachment A. The ability of network-based LDT technologies to achieve mandated accuracy levels is challenged in rural areas, due to the limitations in tower placement in the rural environment, and the resulting limits on triangulation capabilities.

A major question throughout the recent history of wireless E9-1-1 Phase II has been the level of accuracy being attained in the provision of the service. Associated concerns are how carriers test their networks for compliance and accuracy, how carriers report the data to show compliance, and how location information is presented to PSAPs. Consistency of location data has been and is an issue, across LDT technologies and carrier procedures. A contributing factor in this area is the lack of standards early on, and the proliferation of varying approaches that have resulted. Many PSAPs note that the differing ways location data is handled and presented is as much a problem for PSAP use as the question of accuracy levels.

Interpretation of the OET-71 accuracy testing recommendations from the FCC has been a controversial subject among wireless carriers and public safety authorities. In response to an issue presented to ESIF in 2003, a subcommittee was formed to detail the technical process involved to meet the FCC requirement for wireless accuracy compliance testing against the criteria defined in the FCC mandate and subsequent rulings. This technical methodology was based on both FCC OET-71 content and wireless carrier and vendor perspectives on appropriate methods. Public safety representatives had input to these definitions, but the subcommittee did not define policy aspects of compliance testing, such as frequency of testing, geographic area associated with the testing process, how test results would be reported, and availability of test data to public safety authorities.

In 2004, the NRIC VII advisory process to the FCC undertook the above policy issues in its Focus Group 1A. In late 2003- early 2004, FG 1A reported on negotiated agreements between the involved wireless carriers and public safety national organizations. These included proposals to set the formal compliance process as averaged results by state, along with several other interdependent agreements, including ongoing ground truth based accuracy testing during so-called maintenance testing at cell and sector levels. Two of these agreements – maintenance based accuracy testing, and uncertainty/confidence parameters - also depended on further technical definition by ESIF. (See NRIC FG1A report content at www.nric.org) At the time of writing of this White Paper, the development by ESIF on these items of the NRIC agreements remain to be fully defined and worked, so that carriers can begin to accomplish these accuracy and data provisioning processes, and provide information to validate the levels of accuracy being attained by wireless location determination technologies.

While the NRIC FG1A agreements were not fully accepted by all Public Safety organizations, most of the involved parties appear to believe that the dialog on resolutions and enabling actions has been advanced significantly.

At this point in time, the effectiveness of LDT systems in providing call location data for wireless E9-1-1 continues to have timeliness issues. The ability of some LDT systems to identify location such that it can be available at the PSAP when the initial query for data occurs is limited. PSAPs can not be sure whether they will have accurate caller location at the appropriate point in wireless E9-1-1 call handling, and often have to re-bid one or more times to acquire true caller location data. It is presumed that the technology will continue to evolve, and reach a point where a high percentage of calls can successfully provide caller location upon initial ALI query by the PSAP equipment.

Wireless Location Determination Technologies

Present Technologies

Analysis of presently deployed technologies: The initially deployed Phase II E9-1-1 solutions fell into two basic categories: (1) GPS-based, and (2) U-TDOA (uplink TDOA). More recently, a network-based technology referred to as Wireless Location Signatures (WLS) has also been deployed. (WLS employs signal strength pattern matching of handset measurements with a geo-referenced database of the RF environment.) Generally speaking, the GPS solutions added more cost to the handsets (e.g., a GPS receiver), as well as some infrastructure cost (assist servers), but did provide the best accuracy in clear-sky scenarios (< 10m radial error). Performance was not as good in dense urban and some indoor scenarios.

Conversely, the U-TDOA and WLS solutions provided good accuracy in urban scenarios (where many base stations are used in the position determination) but do not perform as well as GPS solutions in rural scenarios. There is no cost or functionality impact to the handset for U-TDOA or WLS. The U-TDOA solutions which require an LMU (Location Measuring Unit) to be added to each cellular tower add network costs. WLS will add some infrastructure costs, but does not necessitate that hardware be added to each tower. WLS will impose drive testing costs to maintain the wireless signature database, but this could perhaps be combined with conventional drive testing used to verify cellular coverage. Neither WLS nor U-TDOA impose additional handset hardware costs. U-TDOA will work with all legacy handsets, whereas WLS will work with legacy handsets from some, but not necessarily all, wireless technologies. This trade-off (better accuracy with modified handsets versus lower accuracy with any handset) has been

carefully considered by the Carriers and the Commission. Each technology has clear advantages and disadvantages.

Future trends for improved accuracy, GPS: for the GPS-based solutions, location accuracy is well known [1] to be < 10 m in clear sky conditions and proper GPS antenna orientation. Differential correction techniques using WAAS or locally broadcast corrections can achieve clear sky accuracies of < 3 m, by compensating the effect of ionospheric propagation delays. (Use of an L1/L2 frequency GPS receiver would be impractical and costly for a handset-based GPS receiver.) It must be noted that differential corrections would have limited benefit for weak signal/urban canyon scenarios, as the location error will be increased due to poor S/N and degraded satellite geometry, and the differential correction will not help much from a percentage error standpoint.

Going forward, new satellite navigation systems such as Galileo or the L5 channel for the US GPS system will offer somewhat higher power, e.g., by 3 dB, and this will also help improve the S/N and thus the accuracy. On the other hand, smaller handset form factors will lead to smaller GPS antennas and correspondingly lower S/N ratios for a given radiated GPS satellite power.

Future trends for improved accuracy, U-TDOA: for the U-TDOA solutions, there may be opportunities to improve S/N at the base stations. Possible methods include increased power during E9-1-1, or disabling DTX. Further details are not available at the present time.

Future trends for improved accuracy, WLS: for the WLS solution, accuracy improvements have been achieved by capitalizing on additional measurement parameters obtained by the handset or related data available in the wireless network. As the wireless standards evolve in the future, additional and more diverse data will be available that can be used by the WLS technology.

Future trends for improved robustness: this refers to the opportunity for improved location yield, i.e., getting a fix in a larger percentage of environments. For the GPS technologies, continued improvements in CMOS logic density will allow for more GPS correlators or equivalent processing hardware to be cost effectively integrated onto a GPS receiver IC. This will enable assisted GPS sensitivities to increase by 6 dB or greater (with respect to presently deployed technologies). Thus, better indoor and dense urban location coverage will be obtained for the same equivalent IC die area allocation.

[1] Kaplan et al., Understanding GPS Principles and Applications, Artech House 1996, p. 325

Going forward, combining GPS, U-TDOA or WLS with other methods described below in "New Technologies" can provide a multi-faceted solution to give outdoor and indoor coverage.

New parameters reported to PSAP: One potentially beneficial parameter is the uncertainty estimate and corresponding confidence level which can be provided on a call-by-call basis. This information can be used to notify public safety officials about the statistical accuracy of the location estimate. Currently, the uncertainty estimate and corresponding confidence level are not standardized and are not required per the FCC's mandate. This represents a potential area for improvement in the various technical forums.

Other parameters that could be provided to PSAPs are heading, velocity, and altitude. All three existing location technologies are capable of providing some level of heading/velocity information, but only the GPS based technology is capable of determining the altitude of the caller.

New technologies under development: Other location technologies either exist or are under development. Some of those are outlined and discussed briefly in this section.

E-OTD (Enhanced Observed Time Difference of Arrival) This technique employs timing-base triangulation analogous to the U-TDOA methods now deployed, except that the pseudo-ranges are measured by the handset with respect to nearby base station transmissions. Some carriers considered this approach but ultimately chose not to deploy it. Accuracy was nearly as good as U-TDOA, but since it required MS (mobile subscriber) software modifications it did not qualify as a legacy technology and thus struggled to meet the 50/150 m requirements.

RF Fingerprinting: This approach was also considered by certain carriers. One company offering it was US Wireless. It relies on Bayesian statistics to correlate a set of signal characteristics measured by "radio cameras" (i.e., hardware sensors) located at each base station with a stored set of signal characteristics in a database to determine location. Ultimately, this approach was not deployed due to the need to periodically calibrate the entire coverage area, insufficient accuracy, and the excessive cost of deploying hardware sensors and additional backhaul at every base station.

HDTV Sensors (Rosum Corporation) This scheme employs embedded HDTV receivers in the MS to decode timing sync symbols in the HDTV data header. Location Measuring Units (LMUs) must also be deployed to monitor the relative timing offsets of the different HDTV transmissions. It takes advantage of the fact that HDTV broadcast power levels are very high and thus the receiver will rarely have signal marginality issues. Accuracy has been demonstrated to be good. So far no carriers have deployed this technique, most likely due to (1) late arrival of the technology, (2) incomplete coverage in rural areas, (3) handset cost concerns. It should be noted that this approach could never provide an accurate Z-height estimate due to the nearly coplanar configuration of the HDTV towers.

WiFi Sensors: this applies to cellular phone units now under development which may also employ WLAN network functionality to provide high speed data/IP voice when the phone is in the domain of the corporate enterprise. Location inside the WLAN network can be determined by a number of different solutions provided by firms such as Ekahau or Bluesoft. This must be viewed as a potentially valuable "extension technology" to provide indoor location; it can never replace GPS, U-TDOA, or WLS solutions as a complete solution.