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WORKING GROUP 4C
Technical Options for E9-1-1 Location Accuracy

Final Report

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1 RESULTS IN BRIEF

1.1 Executive Summary

1.1.1 CSRIC Working Group 4C Charter

CSRIC Working Group 4C objectives included examining E9-1-1/Public Safety location technologies in use today and identifying current performance and other limitations for use in Next Generation (NG) E9-1-1/ Public Safety applications. Additionally, the Working Group was tasked with evaluating the following items:

- Industry standards direction for location and the ability to use location for next generation services and applications;
- Emerging location technologies, including combining multiple technologies to improve location accuracy;
- The timing of when such technologies could be available;
- Security issues and vulnerabilities around future location technologies;
- Interactions with existing technologies and any backwards compatibility issues;
- Opportunities to apply next generation location technologies to current networks;
- Impacts to user equipment, networks, agencies, etc. for deployment of future E9-1-1/Public Safety location accuracy technologies;
- Barriers to deploying these technologies.

The charter proved to be one of extreme breadth because location determination and 9_1-1-accuracy requires elements ranging from electronic systems in devices and access networks, to the quality of address validation techniques, to GIS database quality, and to the ability of a public safety organization to accept and present location information for the various service types. It is also worthwhile to note that many of the resources on Working Group 4C were also assigned to other CSRIC Working Groups; and, given their subject matter expertise, were also called upon to support the development of comments in response to the multiple recently issued FCC NOIs and FNPRMs. While Working Group 4C was granted an extension of time to complete its report, the breadth of the charter still presented challenges in terms of completing detailed research for each objective. Ultimately, the thirty-five (35) members of Working Group 4C diligently investigated, reviewed, discussed and collaboratively worked to frame a report that will assist the FCC in understanding and effectively administering the multiple issues associated with present day and future location accuracy.

1.1.2 Structure of the Working Group 4C Report

The document is comprised of 9 sections and 3 appendices as follows:

Section 1: Results in Brief
Section 2: Introduction
Section 3: Objective, Scope, and Methodology
Section 4: Service Types/Applications Requiring 9-1-1 Location Information
Section 5: Location Technologies
Section 6: Reference Database Accuracy for 9-1-1 Calls
Section 7: Security and Vulnerabilities for Future Location Technologies

Section 8: Standards Development Organizations
Section 9: Conclusions and Recommendations
Appendix A: CMRS Architecture Overview
Appendix B: Project RED Summary
Appendix C: Glossary of Acronyms

While all sections of the report include useful and detailed information for consideration by the full CSRIC and the FCC, Working Group 4C anticipates that the inclination of many readers will be to focus on section 9, Conclusions and Recommendations. Therefore, section 9 has generally been structured to provide conclusions and recommendations on a section by section basis, beginning with conclusions and recommendations for each service type as identified in section 4, and ending with conclusions and recommendations related to Standards Development Organization activities identified in section 8.

1.1.3 Conclusions and Recommendations Summary

This report, including all conclusions and recommendations, is addressed to the FCC for consideration. While the complete set of Conclusions and Recommendations are contained in section 9, some of the especially noteworthy conclusions and recommendations presented in this report are:

- CSRIC 4C recognizes that the complexity and evolving nature of location issues will require an ongoing analysis effort. The Working Group recommends that the FCC establish an E9-1-1 Technical Advisory Group ("ETAG") to address specific location technology issues for 9-1-1. The ETAG concept, which interested stakeholders have championed for several years, offers the best and most constructive path towards improved E9-1-1 accuracy. The ETAG, which should include representatives from all sectors of the industry, including public safety, carriers, technology vendors and key stake holders, would work cooperatively and expeditiously to enhance location accuracy and to improve the manner in which location accuracy is measured. The ETAG would also validate the feasibility and capabilities of emerging E9-1-1 location accuracy technologies in a standardized, real-world test environment. The ETAG should study how to improve location accuracy in challenging environments, including indoor settings, urban canyons, high-rises, rural environments and areas of heavy forestation or mountainous terrain etc.

- CSRIC 4C concludes that any FCC policy should balance continual refinement of location accuracy with cost-benefit trade-offs and needs of public safety and other stakeholders so that resources dedicated to 9-1-1 issues are appropriately allocated.

- CSRIC 4C recommends that the FCC not mandate specific location technologies but should promote additional research and development of a variety of technologies through the ETAG. Mandating a specific technology could prevent carriers, access network operators, and service providers from implementing E9-1-1 location solutions that fully leverage their unique network characteristics and could stunt future competition between E9-1-1 solution vendors.

- CSRIC 4C recommends that all standards impacting 9-1-1 location accuracy provide for civic address or geodetic locations to be sent to PSAPs as appropriate for the service type involved.

- CSRIC 4C notes that APCO and NENA have advocated for federal and state Multi-Line Telephone Service (MLTS) legislation, but it has not been widely adopted. CSRIC 4C recommends that the federal government adopt national MLTS legislation. Until this national mandate is adopted, states should be encouraged to adopt MLTS legislation.

- CSRIC 4C recommends the FCC actively engage discussion on how to implement 9-1-1 auto-location for nomadic VoIP services. Auto-location is a significant issue for multiple service types and the Commission should utilize the ETAG to examine and provide guidance for the development and implementation of 9-1-1 auto-location capabilities in a fully end to end IP environment.

- CSRIC 4C recommends the FCC should consider extending E9-1-1 and location obligations to providers of over-the-top VoIP applications that are not subject to Interconnected VoIP regulations. In addition, education of the public should be required to specify limitations of such over-the-top VoIP 9-1-1 applications that are not subject to Interconnected VoIP regulations. To the extent that 9-1-1 requirements are extended to these services and new technical challenges are presented, referral to the ETAG should be considered.

- CSRIC recommends the FCC should clarify if the existing wireless 9-1-1 rules will apply to CMRS managed IMS based VoIP services. In addition, distinct location accuracy standards for IMS services should not be established. Instead, location technologies available in the access provider network should continue to be used, independent of whether or not IMS is utilized as the transport core technology. The ETAG should partner with the existing standards working groups to continue to test and evaluate these technologies.

- CSRIC 4C recommends that the FCC should clarify how femtocells and Unlicensed Mobile Access (UMA) devices should be treated for the purpose of 9-1-1, and recommends the development of a standardized set of location data that can be easily interpreted by PSAPs. 4C recommends not imposing any additional obligations on femtocell carriers until these location standards are addressed. Emerging femtocell technologies merit further study under an ETAG.

- CSRIC 4C recommends all providers including new entrants, have appropriate access to MSAG data in order to incorporate it into their business processes, especially in validation of customer-provided location information. This access should apply to future equivalent elements such as the Location Information Server (LIS) and the Location Validation Function (LVF) as referenced in the NENA i3 architecture.

- CSRIC 4C notes that the next generation emergency service requirements are focused on emerging IP based non-voice-centric emergency service requests. CSRIC 4C therefore recommends that standards work be completed as soon as possible and that regulatory guidelines be established for how Emerging Service types are integrated with the 9-1-1 system.

1.1.4 Executive Summary Conclusion

Unmistakably the expectation among consumers and public safety entities is that highly accurate location needs to be provided when calling 9-1-1 from any service. The ability to meet these expectations is an extremely complex issue involving multiple elements. The elements and components to deliver accurate 9-1-1 location range from the technologies employed by access and service providers, to the mapping databases managed by various local, state and federal entities, to the transport network which reaches the public safety agencies including the entry point to the public safety response system – PSAPs. The capability of the hardware and software at PSAPs to accept and present accurate location information is important and will increase in complexity going forward. Continued effort by all of these entities and the associated standards development organizations, preferably working as collaborative groups, such as the aforementioned ETAG, that represent all relevant stakeholders must be facilitated at the national, state and local level.

While the thrust of Working Group 4C has been in the area of technology, it must be reaffirmed that despite all the existing and future advances in capabilities of providing access to and location for calls to 9-1-1, a key component of the system is the human factor. The need for basic, recurring and timely informational training for all participants in the delivery of public safety communications is critical. Support for technical as well as operational and training standards will be key to moving forward into a much more complicated and diverse system called NG9-1-1.

NG9-1-1 will be a major change to the 9-1-1 service and adoption of these new requirements will take several years. Experience suggests that unless there is consensus among government agencies at the local, state and federal levels, as well as carriers, vendors and other service providers, NG9-1-1 implementation for many PSAPs may be protracted.

2 INTRODUCTION

This report documents the efforts undertaken by the Communications Security, Reliability, and Interoperability Council Working Group (CSRIC) 4C-Technical Options for E9-1-1 Location Accuracy. The quality of location information directly impacts 9-1-1 call routing and the effective dispatch of appropriate emergency services. Before making recommendations for improvements to CSRIC, the 4C Working Group undertook a baseline assessment of what technologies were being used today and how effective they are in providing useful and accurate locations of devices being used to call 9-1-1. Identifying the existence of technical standards for each of these technologies and whether the standard(s) are reasonable when applied in an E9-1-1 or NG9-1-1 environment proved to be a critical component of this baseline assessment

To further aid in its evaluation, the CSRIC 4C Working Group formed several subset work groups to assess location related topics. The groups reviewed current and emerging location technologies as well as evaluating service types and applications that needed these technologies to obtain location for 9-1-1 calls. Additional groups were formed to review contributions from independent location accuracy studies and to draft a summary of location related standards that are applicable to 9-1-1 calls.

This document will provide an understanding of the capabilities, limitations and standards gaps of today's location acquisition technologies and how these trends affect public safety.

2.1 CSRIC Structure

The Federal Communications Commission (FCC) created the Communications Security, Reliability, and Interoperability Council (CSRIC) to provide recommendations to the FCC to ensure optimal security, reliability, and interoperability of communications systems, including telecommunications, media, and public safety communications. The scope of the Council's recommendations includes facilitating the operability and interoperability of wireline, wireless, satellite, cable, and public data networks as well as the operability and interoperability of public safety communications systems. The Council's recommendations will also facilitate the security, robustness, and reliability of broadcast and Multichannel Video Programming Distribution facilities. The Council's recommendations will also address: (1) ensuring the security, sustainability, and resiliency of telecommunications and media infrastructure and public safety communications, throughout the United States; (2) ensuring the availability of communications capacity during natural disasters, terrorist attacks, or other events that result in exceptional strain on the communications infrastructure; and (3) ensuring and facilitating the rapid restoration of communications services in the event of widespread or major disruptions.

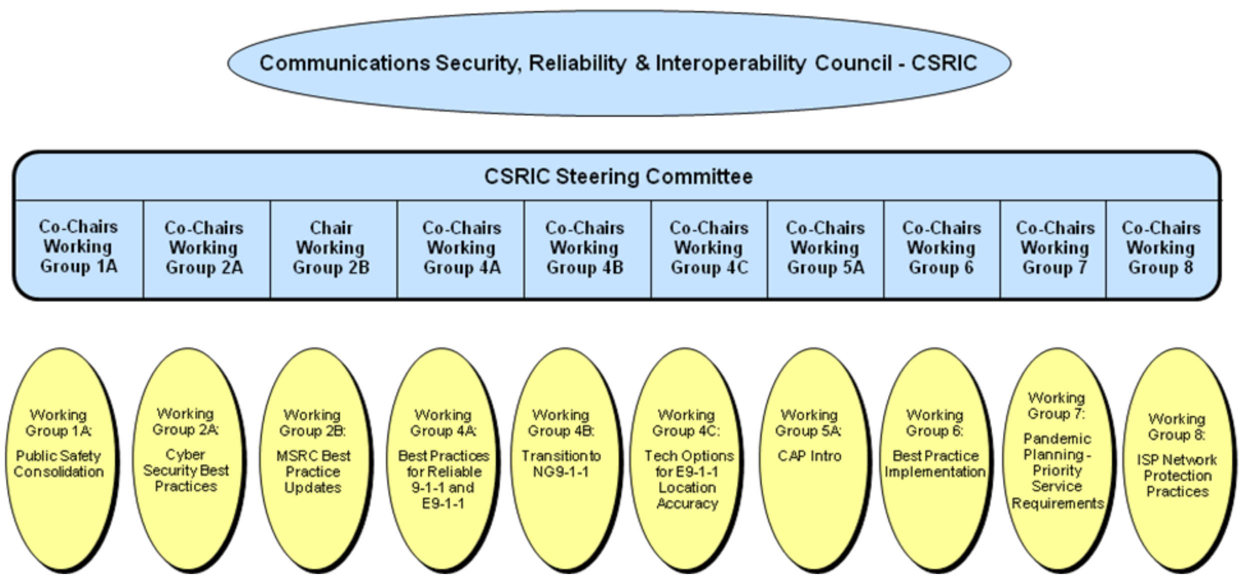

Figure 1 CSRIC Steering Committee

2.2 Working Group 4C Team Members

Working Group Co-Chairs

Craig Frost – Verizon Wireless
Stephen J. Wisely – APCO International

Working Group Subgroup Leaders
Technology Subgroup: Wayne Ballantyne-Motorola Mobility
Service Types Subgroup: Roger Hixson-NENA

Working Group Document Editor: Kathy McMahon-APCO International

Working Group 4C consists of the members listed below:

Name	Representing Company/Organization
Anderson, Michael	Ericsson
Arocho, Angel	Comcast
Aryana, Firdaus	TCS
Ballantyne, Wayne	Motorola Mobility
Barclay, Steve	ATIS
Berger, Becky	State of Montana 9-1-1 Program
Callahan, James	DC OUC
Daly, Brian	AT&T
Davis, Marlys	King County, WA 9-1-1 Program
Donovan, Patrick	FCC CSRIC Rep
Feuerstein, PhD, Martin J.	Polaris Wireless, Inc.
Hixson, Roger	NENA
Hogle, Tim	Sprint Nextel
Jensen, Ryan	T-Mobile
Kemper, Rick	CTIA - The Wireless Association®
McDermott, Twyla	City of Charlotte
Militeau, Christian	Intrado
Moody, Martin	Metropolitan Emergency Services Board
Moseley, Bob	Fraternal Order of Police (MD)
Muscat, Richard	Bexar Metro 9-1-1
Nixon, Jim	T-Mobile
Pavon, Gustavo	True Position
Pollock, Nancy	iXP
Prest, Art	Rural Telecommunications Group
Rao, Raghavendhra	AT&T
Schumacher, Greg	Sprint
Sherwood, Susan	Verizon Wireless
Thompson, Jim	CA 9-1-1 Emergency Communications Office
Tortoriello, Bill	U.S. Cellular

Table 1 - List of Working Group Members

Additional Contributors:
Jeanna Green – Sprint Nextel
Dewayne Sennet – AT&T

3 OBJECTIVE, SCOPE, AND METHODOLOGY

3.1 Objective

The objective of CSRIC Working Group 4C is to provide an overview of 9-1-1 location acquisition, determination and accuracy as it exists today and to provide guidance on how it can be improved as we move forward. The objectives outlined in the CSRIC charter included:

- An analysis of industry standards and their direction
- An analysis of location technologies and availability for use with 9-1-1
- Security issues
- Backwards compatibility and integration issues between current and emerging technologies
- Impacts to currently deployed systems and equipment
- Barriers to progress

3.2 Scope

It is acknowledged that all studies must have a clearly defined and finite scope. Accurate 9-1-1 location is an extremely complex topic and requires an ongoing commitment to research, analysis and standardization.

In the case of CSRIC Working Group 4C, the one year time allotment proved challenging when attempting to fulfill all of the desired objectives set forth in the CSRIC 4C charter. Advancements in the telecommunications industry in conjunction with the increasing expectation to provide accurate location for all types of 9-1-1calls requires a long term technical and operational analysis. The scope of this report therefore contains an initial, high-level analysis of location for both Enhanced 9-1-1 and future Next Generation 9-1-1 systems. A more thorough analysis of evolving technologies and how they integrate or augment location determination for 9-1-1 service types should be included in future initiatives.

3.3 Methodology

Working Group 4C met weekly via conference call(s) to review, research and discuss 9-1-1 location accuracy. The team realized early in the process that the document's target audience must be provided with an overview and understanding of the technologies that provide location data and also of the service types and applications that require 9-1-1 location information. Two primary sub-work groups were formed to research and develop the necessary analysis. The first sub-work group focused on defining the current and future services by which people access 9-1-1. The second sub-work group focused on available and future technologies that would be relied upon to provide accurate location. Each group met separately and in addition to the weekly conference calls for the full 4C work team. Ad-hoc sub groups convened to address other relevant topics such as the impact of 9-1-1 GIS accuracy, technical standards initiatives and review of independent public safety research projects for 9-1-1 location accuracy. Text contributions, as completed, were reviewed, edited and approved by the full membership of Working Group 4C.

The full working Group conducted over thirty-five (35) conference calls, approximately fifty

(50) subgroup calls and four multi-day face-to-face meetings in three different cities. This effort was challenging given the responsibilities that each member faced in his/her public, private or other profession. The sub-group and ad-hoc structure relied upon members volunteering to embrace additional work in conjunction with participating in the efforts of the full committee.

4 Service Types/Applications Requiring 9-1-1 Location Information

There are numerous methods used by callers to contact 9-1-1. Traditional landline telephones are becoming less prevalent, while mobile and IP services are seeing an increase in use and popularity. It is important to note that while automatic, accurate location is desired for all calls to 9-1-1, there are cases where technologies in use today are not always capable of providing it. More ubiquitous deployment of existing technologies and introduction of new technologies may show promise in enhancing location accuracy and could potentially alleviate some of the challenges being faced today. As with any deployed or new technology, it takes time to assess how it will integrate into 9-1-1 systems and what the impact will be. The gaps described herein represent issues that impact 9-1-1 location accuracy as understood today.

9-1-1 access for the purpose of this document will be classified in one of three ways: Fixed/Static, Nomadic, or Mobile.

Fixed/Static access refers to a geographic location or civic address that is mapped to a specific access point. The most common example is a legacy residential landline telephone.

Nomadic access refers to multiple locations for connection points/calling devices. A common example is a VoIP service that can be registered at a primary residence and updated when the caller is staying at their vacation home. Nomadic devices are not mobile and thus *cannot* update their registered location *during* a 9-1-1 call.

Mobile access refers to calling devices that have the ability to move and update geographic location during a 9-1-1 call. The most common example of a mobile device is a cell phone.

4.1 Single Wire-line Connection With Fixed/Static Location

A single wireline connection refers to a telephone line which travels through a copper wire or optical fiber and terminates at a specific customer premise location and is assigned a unique telephone number. These calls are typically routed over the public switched telephone network (PSTN).

4.1.1 Present Location Requirements & Determination Method

Location is defined as a pre-established address at the customer premises, which is then validated against a Master Street Address Guide (MSAG). The MSAG describes the exact spelling of streets, street number ranges, and other address elements. During a 9-1-1 call, the calling party's phone number is passed to the Public Safety Answering Point (PSAP), which uses the calling party number to look up the address in an Automatic Location Identification (ALI) database. ALI databases are commonly managed by the 9-1-1 System Service Provider (SSP). Each SSP may have its own requirements for formatting the ALI database.

4.1.2 Current Gaps or Issues

- Lack of Originating Service Provider (OSP) access to the MSAG database can cause delays in validating and provisioning user location data to ALI databases.
- Errors in the MSAG database or errors in using a correct MSAG can cause location validation failures and inaccurate 9-1-1 call routing.
- Errors in the ALI database can cause the location display to the PSAP telecommunicator to be missing or inaccurate.

4.2 Multiple Wire-line Connections With Static Location

4.2.1 PBX or MLTS

A private branch telephone exchange (PBX) or multiline telephone system (MLTS) is a phone system that serves a number of telephones and connects them to the public switched telephone network. An MLTS can be used to provide service in a multi-residence/multi-building environment (e.g., an apartment complex, a retirement village complex, or multiple businesses in a managed office park). In addition, an MLTS can provide service that spans multiple emergency service zones. The MLTS should be designed and maintained to provide a callback number and suitable location information when 9-1-1 is dialed from the MLTS.

FCC Docket 94-102 was opened to address the 9-1-1 response location problems caused by both PBX and wireless telephones. Ex parte discussions among the FCC staff and representatives of the PBX providers, PBX users, and public safety associations produced consensus that led to general guidelines to improve location capabilities, but without causing undue burden or expense to the PBX operator.

NENA has developed MLTS model legislation to provide guidance for developing State statutes and rules, as well as several technical reference documents to assist with implementation of E9-1-1 for MLTS.[1] The purpose of MLTS model legislation is to require Multi-line Telephone Systems to provide a sufficiently precise indication of the caller's location, while avoiding the imposition of undue burdens on system manufacturers, providers, and operators of MLTS. A small number of states have passed MLTS legislation since 1994[2], as shown in Figure 2 below.

Typical criteria included in MLTS legislation:

- *The number of square feet in the facility*. For example, Illinois Public Act 91-0158 requires that use of a PBX in a facility occupying 40,000 square feet or more of space must provide location information and a call back number. This includes not only the street address of the facility, but if the facility exceeds 40,000 square feet, the specific location within the 40,000 square foot area must be provided.
- *The specific usage*. For example, Minnesota requires operators of MLTS systems serving residential customers, hotels and motels, and schools to clearly identify the address and specific location of the 9-1-1 caller.

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[1] See http://www.nena.org/standards/technical/data/mlts-model-legislation-2009
[2] From http://www.nena.org/mlts-pbx/state-legislation

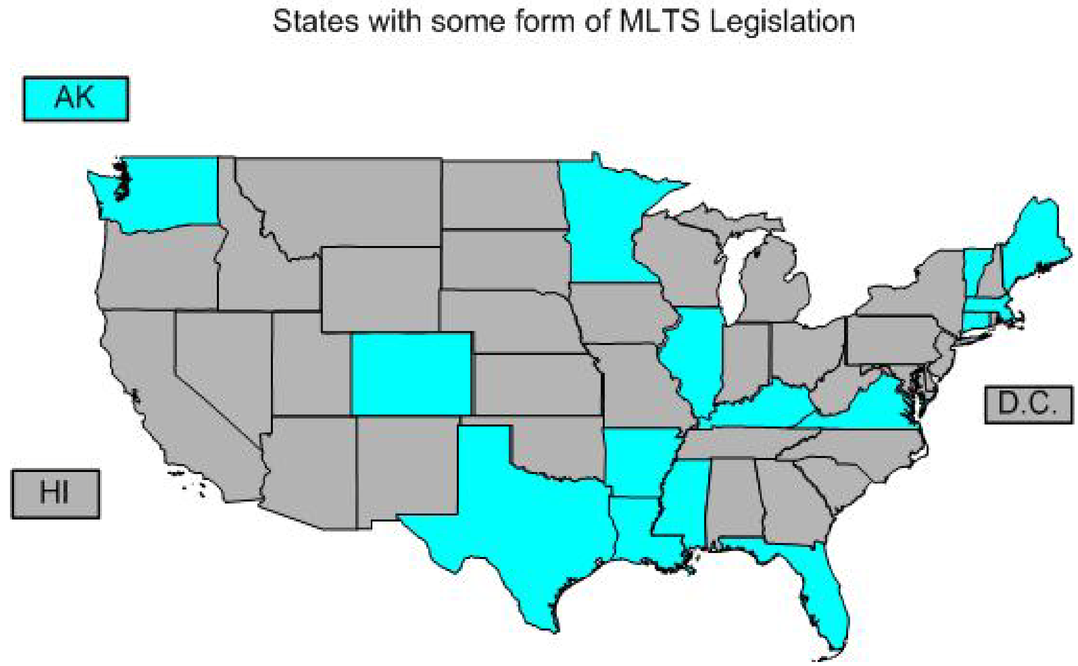

Figure 2: States shown in blue have some form of MLTS legislation

4.2.1.1 Present Location Determination Method

Phone service ordered to connect the MLTS to the PSTN has a primary telephone number and billing address associated with the service. A 9-1-1 call from an MLTS extension will provide that billing telephone number as the callback number and the billing address as the location of the caller as the default information to public safety. This information may be sufficient to locate the caller (e.g., a small office or business).

There are, however applications (e.g., warehouse/multi-residence/multi-building/schools where an MLTS is providing service that spans multiple emergency service zones) where a single location and callback number is not adequate. At the time of a 9-1-1 call, the MLTS extension (or possibly a group of extensions in the same area) is typically translated by the MLTS into a dialable number associated with the location of the extension used for the 9-1-1 call. The dialable number facilitates call routing to the appropriate Public Safety Answering Point (PSAP) and call back from public safety. An interface to the E9-1-1 ALI database is required that allows the coordination of the extension(s), the associated dialable number, and the specific address associated with that number.

4.2.1.2 Current Gaps or Issues

- There are inconsistencies in the dialing patterns used to access emergency services from within an MLTS facility (e.g., 9-1-1 to internal station, 9-1-1 straight out, other digit strings to internal security). Specific dialing patterns are also not well advertised to the public or employees in an MLTS facility.
- There are large variations in requirements among states that have MLTS legislation, and only a few states have adopted MLTS legislation.
- There is limited capability to enforce MLTS legislation at the State level and no capability at

the Federal level.

- MLTS that spans large geographic areas may also span multiple PSAP boundaries. Single location and callback numbers within these systems are not adequate for accurate 9-1-1 call routing or emergency response.
- Legislation that is based solely on square footage, without consideration of how the area is used, is not always adequate for 9-1-1 location needs.
- There are wireless or nomadic extensions to MLTS that allow callers to make calls through the MLTS when they are mobile or nomadic. 9-1-1 location display and 9-1-1 call routing in this environment has not been properly addressed.
- Caller location is not typically provided unless the customer utilizes a "Private Switch ALI" (PS ALI) product to provide separate location data to the 9-1-1 processing for ALI.
- Current MLTS legislation may need to be modified to accommodate Next Generation 9-1-1 technologies.

4.2.2 Centrex

Centrex is a PBX-like service providing switching at the central office instead of at the customer's premises. Typically, a telephone company owns and manages all the communications equipment and software necessary to implement the Centrex service and then sells various services to the customer. In effect, Centrex provides an emulation of a hardware PBX, by using special software programming at the central office, which can be customized to meet a particular customer's needs.

4.2.2.1 Present Location Determination Method

Centrex typically utilizes a fixed telephone number ANI. Each station in the Centrex is identified by a number within the central office number set. The associated building location is supplied but not the caller's location within the building or campus.

4.2.2.2 Current Gaps or Issues

- Failure to maintain current data as changes are made to the user premises:
  - If customers extend numbers from the cable demarcation location address to other buildings;
  - If the customer does not provide updates on number assignment and location to the serving telephone company for entry in service records; and
  - If the serving telephone company does not perform these updates in a timely fashion or at all.
- Caller location is not typically provided unless the customer utilizes a PS ALI product to provide separate location data to the 9-1-1 processing for ALI.

4.3 Individual VoIP Connections with Registered Location (Static or Nomadic)

VoIP refers to communications services that originate or terminate via IP networks rather than the circuit switched PSTN. Other terms frequently encountered and synonymous with VoIP include IP telephony, Voice over Packet (VoP), Internet telephony, voice over broadband (VoBB), broadband telephony, and broadband phone.

Interconnected VoIP service is defined by the FCC[3] as bearing the following characteristics:

- The service enables real-time, two-way voice communications;
- The service requires a broadband connection from the user's location;
- The service requires IP-compatible CPE; and
- The service offering permits users generally to receive calls that originate on the PSTN *and* to terminate calls to the PSTN.

The services discussed below may be over and above the current FCC definition of interconnected VoIP for 9-1-1.

4.3.1 Voice Service Over Broadband (VoBB) with Registered Static Location

This type of VoBB service is provided by the broadband network provider who acts as Access Provider and Service Provider. Examples of these technologies are cable, DSL, and fiber optic. These VoBB services are provided based upon industry standards such as, IETF, ITU, or Packet Cable using the H.323, SIP, or IMS technologies.

Location information is realized from the physical address where the equipment is installed and where the service is activated. Since this is not a nomadic service, the service provider usage policy does not allow the Residential Gateway (RG) or external Telephone Adapter (TA) to be moved to a new location.

4.3.1.1 Present Location Determination Method

Since the equipment is installed at a specific, physical address the location is known. This pre-established address is associated with a specific telephone number and is provided as the location for 9-1-1 calls via ALI (9-1-1) database lookup.

4.3.1.2 Current Issues/Gaps

It appears that most service providers validate the customer address against the MSAG database of the applicable 9-1-1 authority for the purpose of ALI location display at the PSAP. It is less clear, however, whether the MSAG validation process includes association to the appropriate wireline ESN that is used to route calls to the correct PSAP. In some systems, the user can, contrary to provider policy, move the device within a limited area, make a 9-1-1 call, and cause a dispatch to the wrong address.

4.3.2 Nomadic Voice Service Over Broadband (VoBB)

This type of VoBB service is provided by the broadband network provider who acts as Access Provider and Service Provider. The provider's usage policy allows for the customer equipment (device) to be moved within the provider's network. If a user moves the device to an area outside the provider's network, the device will not work.

4.3.2.1 Present Location Determination Method

For nomadic service offerings, the access service provider will obtain the service address from the customer and provision the ALI database with the registered location. When a device is moved to another physical address, customers are required to update their registered location.

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[3] See FCC 05-116 IP-Enabled Services E9-1-1 Requirements for IP-Enabled Service Providers

4.3.2.2 Current Issues/Gaps

- There is a service address registered as the device location. If the user fails to update this address when the device is moved, it could result in dispatch of emergency services to the wrong location.

- The current FCC rules mandate customer registered addresses, but do not state that there is a requirement to validate against the MSAG[4].

- User provided locations are not always validated against the MSAG database of the applicable 9-1-1 authority before an emergency call is made. While it appears that most service providers validate location against the MSAG it is not clear whether the MSAG validation process includes association to the appropriate wireline ESN that is used to route calls to the correct PSAP. In cases where MSAG validation is being done, the location may be associated with a generalized ESN rather than the appropriate wireline ESN.

- In some cases, users may be able to provide false or incorrect addresses.

- There is no universally accepted and deployed method for automatically determining 9-1-1 location.

- When locations can be automatically determined, the location data cannot always be provided to the PSAP because new mechanisms and access network signaling standards are needed.

- The characteristics of automatic location determination would require additional design changes to the E9-1-1 data delivery platforms before PSAPs could receive the data.

4.4 Over-the-Top Voice Service Over Broadband

An over-the-top voice service rides on top of existing broadband infrastructure and is not integrated with the access service provider. It may be implemented as a software application on a pc, tablet, smart-phone, or other device. It may also run on a hardware telephony adaptor that connects to the broadband network.

4.4.1 Static or Nomadic Voice Service Over Broadband

Static and nomadic VoIP service may be provided by an independent VSP that runs a voice service application “over-the-top” of a broadband Internet connection delivered by an access network provider. The service may involve the use of hardware (i.e., the telephony adaptor) that connects directly to the broadband network or to the PC being used to make calls. The hardware may also provide an RJ-11 jack for connecting to legacy telephone equipment.

4.4.1.1 Present Location Determination Method

Since the broadband Access Provider is not providing a voice telephony service and is not aware

[4] See Joint Petition For Clarification Of The National Emergency Number Association And The Voice On The NET (VON) Coalition for FCC 04-36 and FCC 05-196

of the "over-the-top" voice application, this technology relies on users to provide their location information via the method specified by their VoIP Service Provider (VSP). Users must manually update their location information if they move their device.

4.4.1.2 Current Gaps or Issues

- There is a service address registered as the device location. If the user fails to update this address when the device is moved, it could result in dispatch of emergency services to the wrong location.

- The current FCC rules mandate customer registered addresses but do not state that there is a requirement to validate against the MSAG either for the purpose of displaying location at the PSAP or using the location to associate it with the wireline ESN for routing to the appropriate PSAP. [5]

- User provided locations are not always validated against the MSAG database of the applicable 9-1-1 authority before an emergency call is made. In cases where MSAG validation is being done, the locations may be associated with a generalized ESN rather than the appropriate wireline ESN.

- In cases where users provide location information, they are able to provide false or incorrect addresses.

- There is no universally accepted or deployed method to automatically determine 9-1-1 location. In cases where the access provider or the user device is able to determine location, there is no method for the VSP to acquire it.

- When locations can be automatically determined, the location data cannot always be provided to the PSAP because new mechanisms are needed to allow the VSP to provide it.

- Certain voice services, such as those provided by Skype and Net2Phone, do not currently allow 9-1-1 calls. The Sept 23, 2010, FCC NOI has requested comments on this issue.

4.4.2 Over-the-Top Mobile VoIP

For wireless mobile smart-phones, numerous third-party over-the-top VoIP software applications have been introduced and continue to be introduced in software "app stores" -- examples include Skype, Vonage Mobile, Google Voice, fring, 2Talk Phone 3G, Yahoo Messenger, and iCall Free VoIP. These applications are available for wireless mobile smart-phone devices that support 3G data and WiFi. These VoIP applications deliver the IP voice directly via the Internet to the VSP for call handling. This handling is transparent to the wireless service provider other than providing the data connection to the Internet. The applications do not use the wireless service provider's telephony infrastructure, and thus the capabilities such as service provider call routing, call handling, and location are not provided with these applications.

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[5] See Joint Petition For Clarification Of The National Emergency Number Association And The Voice On The NET (VON) Coalition for FCC 04-36 and FCC 05-196

All call handling is performed outside the wireless service provider's network within the VSP. These applications are "best effort" services that run over the mobile data networks, and, may have some issues with call quality. These applications generally do not support calls to 9-1-1.

There are some VoIP software applications that have added a feature that forces 9-1-1 VoIP application calls to fall back to the traditional CMRS circuit switched network, which is described in a previous section of this document. This requires the use of applications that are specifically designed in conjunction with the CMRS provider to operate on CMRS devices and/or network. The VoIP application itself does not directly support 9-1-1 calling.

4.4.2.1 Present Location Determination Method

There is no present location determination method for over-the-top mobile VoIP applications. They do not support calls to 9-1-1. Applications that force fallback to CMRS circuit switched networks for 9-1-1 calls use the method described for circuit switched voice and do not use the mobile VoIP service for 9-1-1.

4.4.2.2 Current Gaps or Issues

- Third party over-the-top mobile VoIP software applications do not support 9-1-1 calling.

- Over-the-top VoIP applications running on a 3G or WiFi data network may have location information available in some contexts, but even in those contexts investigation is needed on whether it is sufficiently accurate enough and potentially applicable for 9-1-1 location purposes.

- Many of these over-the-top VoIP applications are developed outside any regulatory framework and also pose security vulnerabilities.

- Over-the-top mobile VoIP applications designed to fall back to traditional CMRS circuit switched voice if the user dials 9-1-1 are not generally available in all over-the-top mobile VoIP software applications.

4.5 Commercial Mobile Radio Service (CMRS)

CMRS is an FCC designation[6] for any wireless carrier or license owner whose wireless service is connected to the public switched telephone network and/or is operated for profit, and is available to the public. Wireless services that are offered to the public are classified as CMRS, unlike private systems which are classified as "Private Mobile Services". Under the FCC definition, CMRS is a mobile service that is:

- Provided for profit -- i.e., with intent of receiving compensation or monetary gain;
- An interconnected service where users are able to place and receive calls; and
- Available to the public, or to such classes of eligible users as to be effectively available to a substantial portion of the public.

While CMRS covers cellular radio telephone systems, commercial paging systems, offshore

[6] CMRS is defined under 47 CFR 20. See http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title47/47cfr20_main_02.tpl

radiotelephone service, and others, the focus on this section will be restricted to public mobile services[7] and personal communication services[8], which are widely known as wireless cellular systems.

CMRS position reporting to emergency services systems for wireless E9-1-1 Phase II is mandated by the FCC under docket 94-102 (including orders 96-264, 99-96 and 99-245). An overview of enhanced 9-1-1 services including location is available at
< http://www.fcc.gov/pshs/services/9-1-1-services/enhanced9-1-1/Welcome.html >

The FCC's OET Bulletin 71[9], *Guidelines for Testing and Verifying the Accuracy of Wireless E9-1-1 Location Systems*, provides technical guidance for Phase II location measurement procedures. Further guidelines are provided in the ESIF technical report ATIS-0500001, *High Level Requirements for Accuracy Testing Methodologies*.

4.5.1 Circuit Switched Voice in CMRS

Circuit Switched Voice routes voice over a dedicated traffic channel using a mobile switching center (MSC). The call is carried over a cellular radio network that supports mobility as the user moves between cells towers and other service providers. Examples of these networks include CDMA, iDEN, GSM, and UMTS. An architectural overview of circuit switched CMRS networks is provided in Appendix A.

GSM, UMTS, and CDMA Circuit Switched (CS)-based CMRS networks in the U.S. adhere to standards issued by ATIS and TIA. The iDEN CS network operated by Sprint is based on a GSM network architecture, but employs a proprietary physical and MAC layer. ATIS standards are based on specifications produced by the 3rd Generation Partnership Project (3GPP[10]) which is an international organization supported by standards organizations and their member companies from North America, Europe, and Asia. TIA standards are similarly based on specifications produced by the 3rd Generation Partnership Project 2 (3GPP2[11]) which is an international organization supported by standards organizations and their member companies from North America and Asia.

4.5.1.1 Present Location Determination Method

FCC E9-1-1 phase 0 rules did not require support of location, only routing of an E9-1-1 call to the correct PSAP. Phase I rules introduced delivery of cell tower information by the originating network to the PSAP. Phase II introduced delivery of more accurate caller location information.

CMRS uses a variety of location determination technologies to meet the Phase II requirements. These are discussed in detail in section 5.

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[7] Public Mobile Services are defined under 47 CFR 22, <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title47/47cfr22_main_02.tpl>
[8] Personal Communication Services are defined in 47 CFR 24,< http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title47/47cfr24_main_02.tpl>
[9]< http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet71/oet71.pdf>

The location solution that is used for Phase II support by US GSM and UMTS networks is defined in 3GPP Technical Specification (TS) 22.071, 23.271, and other referenced specifications. The Phase II location solution for CDMA networks is defined in TIA-801 and TIA/ATIS J-STD-036.

4.5.1.2 Current Gaps or Issues

- CMRS systems (GSM, UMTS, iDEN, and cdma2000 networks) all employ two or more of the position methods described above which provide conformance with the current FCC E9-1-1 Phase II location requirements. There are thus no gaps in terms of supporting current FCC requirements.

- Accuracy is a function of the user environment. Location evaluations typically categorize outdoor environments as rural, suburban, urban, and dense urban. These environments present differing levels of challenge for the various positioning methods.

- In-building location may not be available or, if available, the accuracy of the location may be challenged.

- Accuracy differs between network- and handset-based location determination methods.

- Calls to 9-1-1 must be routed with the location information available at the time the call is made, leading to instances where the destination PSAP is not appropriate for the caller's location. In many cases, this location is not as accurate as Phase II information.

- The CMRS' ability to use Phase II location for 9-1-1 call routing is limited due to patent litigation.

- The ability to support Phase II location for roamers may be limited in some carriers' networks.

4.5.2 CMRS Managed IMS Based VoIP

While all current CMRS deployments in the U.S. are based on the circuit switched solutions described above, 3GPP and 3GPP2 have completed specifications that will deliver voice over an IP bearer channel using the IP Multimedia Subsystem (IMS). The IMS is architecture for implementing CMRS-managed VoIP and other multi-media sessions in a CMRS broadband network. Although a fundamental aspect of IMS is that it is access network independent, commercial availability of IMS-based VoIP will not likely occur until LTE or WiMAX are deployed. Since LTE and WiMAX are all-IP systems, circuit switched voice is not supported. Voice support in LTE and WiMAX uses IP. LTE voice is also known as Voice over LTE (VoLTE). An architectural overview of IMS-based voice for CMRS networks is provided in Appendix A.

4.5.2.1 Present Location Determination Method

When IMS based voice is launched, CMRS carriers are expected to use a variety of location determination technologies to meet the Phase II requirements. These technologies are discussed in section 5.

Location solutions and associated position methods have been standardized by 3GPP, 3GPP2, and OMA and can be deployed whenever CMRS carriers rollout support for emergency VoIP service. The fact that the position methods are identical to or very similar to those already defined and deployed for circuit switched (CS) mode means that performance will be identical or very similar.

4.5.2.2 Current Gaps or Issues

- It is unclear how existing FCC rules will apply to CMRS managed IMS based VoIP.

4.6 Femtocells

Femtocells are low-power wireless base stations that operate in licensed CMRS spectrum to connect standard CMRS mobile devices to a CMRS operator's network using customer-provided IP broadband backhaul connections. A femtocell carries CMRS voice and data traffic by providing wireless coverage in a very small geographic area using a small unit located at the customer's premise. Depending on the service provider, femtocells must be used either at the registered civic address or in an area where it can acquire geodetic coordinates (GPS or network location measurements) that are within the carrier's licensed area. At least one service provider requires both geodetic coordinates and a registered civic address.

An architectural overview of femtocells for CMRS is provided in Appendix A.

Customers can restrict access to their femtocell via a provisioning process. No access restrictions are imposed, however, for emergency calls from handsets (including Non Service Initialized phones) using the same air interface as the femtocell, provided the handset cannot access the macro cellular network. A mobile device that has been restricted from accessing the femtocell via customer provisioning may make an emergency call from the femtocell if there is no macro cellular service available.

Support of voice and data services over femtocells, including emergency calls, has been defined by 3GPP and 3GPP2 for many existing access types – UMTS and LTE in the case of 3GPP and cdma2000 1xRTT and HRPD in the case of 3GPP2. From the perspective of an end-user device, access to a femtocell appears very similar to access to a wireless base station. No mandatory standards differences exist, thus enabling use of femtocells by legacy as well as newer devices. This applies also to initiation of emergency calls; however, location determination methods differ as described below.

4.6.1 Present Location Determination Method

Location determination varies by carrier and/or femtocell device. There are typically two methods for location acquisition in a femtocell environment: location registration from the user or provider, and the GPS location of the femtocell unit.

9-1-1 calls can be made from anywhere within the femtocell coverage area. The location provided to emergency service will be the location of the femtocell.

Femtocells that support 3GPP UMTS are being deployed, and follow 3GPP standards including support for emergency calls. The location solution for LTE femtocell emergency calls is still evolving in 3GPP.

3GPP2 femtocells, known as Femtocell Access Points (FAPs), that support cdma2000 1xRTT access are now standardized and being deployed. A solution used to support emergency calls and location determination is defined in J-STD-036 rev C and in 3GPP2 X.S0059. These standards were released after commercial deployment of femtocells by many carriers.

When a customer moves a femtocell, the carrier performs the same location validation process that is used for initial activation.

4.6.2 Current Gaps or Issues

- Due to the lack of consistent deployment and implementation methods for femtocells relative to E9-1-1, each carrier may populate ALI data fields differently when an emergency call originates on a femtocell.

- Some carriers may populate the ALI information with the civic address of the nearest cell tower (macro cellular site), while others use the registered civic address for the femtocell. There is no consistent method for the PSAP to discern what the civic address on their ALI screen represents. 9-1-1 calls can be made from anywhere within the femtocell coverage area and the geodetic location provided to emergency service will be the location of the femtocell.

- Carriers should be MSAG validating registered civic addresses of femtocells. Absent a method to verify the registration process used by each carrier, it remains uncertain if all carriers are validating against an MSAG. It is possible for a 9-1-1 call to be made without a registered address being validated against an MSAG.

- There is no consistent process by which carriers notify the PSAP that a 9-1-1 call originated on a femtocell.

- In cases where GPS is used to determine the femtocell location, the accuracy may be degraded if the femtocell is located deep inside a building where GPS signals are weak.

4.7 Unlicensed Mobile Access (UMA)

The UMA standard[12] was developed to allow GSM networks to handle calls via broadband and WiFi in addition to handling them on the commercial mobile radio service (CMRS) network. GSM handsets with the UMA capability can be associated with WiFi access points in the same manner a laptop or other device is connected. The handset then connects to the access point using WiFi and from the access point to the GSM network via broadband IP. The same GSM authentication and communications protocols are used on UMA and GSM, thereby providing the same GSM services via broadband as are delivered via CMRS. This differs from VoIP in that

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[12] 3GPP TS 43.318, “3rd Generation Partnership Project; Technical Specification Group GSM/EDGE Radio Access Network; Generic Access Network (GAN); Stage 2

the same MSCs, services, and 9-1-1 capabilities typically available for GSM are used for UMA. The access point used for UMA can be a standard WiFi access point or a carrier-provided access point. In either case, the handset will automatically connect to only those access points to which it has been paired.

UMA can be configured to prefer WiFi for the completion of regular calls, 9-1-1 calls, or both. The user can be asked for a 9-1-1 service address in order to identify the location in which they typically use the UMA service. This allows carriers to collect additional information useful in 9-1-1 call routing. By checking the user-provided address against the location of the cell site the handset most recently connected with, the carrier can determine the likelihood that the call is being made from the user-provided location and route the call to the PSAP serving that location. Because there is no way to identify the location of the access point with certainty, the user address may not be the actual location of the caller.

4.7.1 Present Location Determination Method

When the carrier using UMA Access Points (UMA AP) directs the 9-1-1 call to the serving MSC, it is processed like a standard CMRS E9-1-1 call from their wireless network. If there is no GSM coverage available, the call can be routed as a VoIP call would be with a customer-provided address or a location determined by the IP address assignment of the access point. If that option is not available, the call can go to a dedicated response center for forwarding to the appropriate PSAP. When a customer moves a UMA AP to a new location, they must enter their new address.

4.7.2 Current Gaps or Issues

- Not all carriers are MSAG validating the customer-provided addresses for UMA calls that are routed as VoIP. Relying on non-validated addresses can cause errors in handling 9-1-1 calls at the PSAP. It is also not known if MSAG data is available for carrier use in validating customer provided addresses.

4.8 Vehicular Telematics for Emergency Services

Vehicle telematics is a technology that uses the vehicle's electronics to establish two-way wireless communication between a device and a call processing center or a PSAP to transmit voice and data information. Telematics devices are commonly installed in newer motor vehicles and can be activated manually by the vehicle owner or automatically upon a predefined trigger.

4.8.1 Present Location Determination Method

Vehicle telematics utilize two distinct calling models. The first involves the use of the vehicle's embedded wireless phone that contacts a telematics service provider call center. The other calling model utilizes the occupant's wireless phone via Bluetooth link to dial 9-1-1 directly upon a triggering event such as airbag deployment. The occupant's phone must be paired to the vehicle's telematics system prior to the event occurring.

In the first calling model, telematics service providers (TSP) rely on the use of a third party call center to receive the phone call from the vehicle module along with data such as location and other sensor information from the vehicle. The location received is presented to the call center agents as a geodetic location. As part of the location, they also generally receive Quality of

Position information related to accuracy and age of location. In some cases, they receive historical data to determine the vehicle's path and estimated current location in the event that current GPS position information is not available.

The TSP typically must contact the appropriate PSAP on a 10 digit line and verbally relay the location information of the vehicle. Telematics data can in some cases be deposited at a pre-arranged website, and a query key to that data supplied to the PSAP call taker. There are cases where the TSP utilizes a third party provider to route calls directly to PSAPs using the solution described in Nomadic VoIP. In these cases the general VoIP class of service is often associated with the call.

In the second calling model, the vehicle telematics module places a standard wireless 9-1-1 call made from a personal mobile phone (non-embedded) that is paired via Bluetooth with the vehicle. The Phase I and/or Phase II location information may be provided by the network/carrier in accordance with a standard wireless call as described in CMRS above. In some cases, in addition to the wireless device Phase II location, the PSAP can manually retrieve GPS coordinates from the vehicle's onboard GPS module by touching a pre-defined button on the call taker's telephone. The telematics module may use a synthesized voice recording to verbally transmit the GPS coordinates sampled at the time of the crash impact.

4.8.2 Current Gaps or Issues

- In the first calling model, TSP's are often not able to deliver voice and data directly to a PSAP via the 9-1-1 system. In these instances, the TSP must contact the PSAP via a 10 digit line.
- In cases where location information is conveyed verbally by the TSP, human error can be introduced.
- In the second calling model, when a PSAP receives coordinates from the wireless phone and also from the GPS in the car, there could be a difference in location coordinates provided. The PSAP will not be able to discern which one is best to use to locate the vehicle if the occupants cannot verbally relay their location.

4.9 Machine-to-Machine (M2M)

M2M refers to technologies that allow both wireless and wireline systems to communicate with other devices that utilize similar protocols. M2M uses a device (sensor, meter, etc.) to capture an event (meter reading, temperature, a measured quantity exceeding a threshold, etc.). The event is then relayed through a network to a system that translates the captured event into meaningful information.

4.9.1 Present Location Determination Method

In some cases, a static location is delivered to the PSAP based on a prearranged data exchange[13].

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[13] Alarm Monitoring Company to Public Safety Answering Point (PSAP) Computer-aided Dispatch (CAD) External Alarm Interface Exchange - APCO/CSAA 2.101.1-2008

4.9.2 Current Gaps or Issues

- It is not clear if M2M devices will contact 9-1-1 call centers directly or if they will utilize an intermediary call center. If they do contact 9-1-1 directly, it is not clear what location technologies these devices will employ.

4.10 Telecommunication Relay Service (TRS) and Private Call Centers

For the purpose of this document, telecommunication relay service and private call centers are physical places with personnel who provide interaction between a caller and a PSAP. They do not provide direct access to 9-1-1 and, hence, they need to verbally pass the caller's location information to the PSAP. When a person with a hearing or speech disability initiates a TRS call, the person uses a TTY or other text input device to call the TRS relay center, and gives the communications assistant (CA) the number of the party that he or she wants to call. The CA in turn places an outbound traditional voice call to that person or an entity such as 9-1-1. The CA then serves as a link for the call, relaying the text of the calling party in voice to 9-1-1, and converting to text what the 9-1-1 call taker voices back. There are several variations of TRS including IP and Video Relay.

4.10.1 Present Location Determination Method

There are currently no methods being used to automatically provide location of the caller to the TRS relay center.

4.10.2 Current Gaps or Issues

- Location is verbally or textually communicated to a TRS relay center by the caller. The TRS relay center must then verbally communicate the location to the PSAP.

- Location validation against MSAG is not available.

- TRS relay centers must rely on a national PSAP registry database to identify the correct PSAP that will handle the call. There are several PSAP registries in use and, to date, all have faced challenges in maintaining accurate data.

- Location requirements for TRS relay services are being considered by the FCC and DOJ and, as such, the requirements are unclear at the present time.

4.11 Satellite Service

Mobile Satellite Service (MSS) carriers serve an important role as providers of communications services in areas where the wireline and wireless networks may not extend or provide coverage. In 2003, the FCC adopted 9-1-1 emergency calling requirements for MSS carriers. Specifically, those MSS carriers providing voice service that is interconnected to the public switched network must establish call centers through which all subscriber emergency calls are routed to an appropriate public safety answering point (PSAP). MSS carriers must ensure that callers access call centers by dialing "9-1-1", that call centers ascertain the caller's phone number and location, and that call centers transfer or forward the call to an appropriate PSAP. There also exist hybrid satellite-CMRS devices. When these devices are within CMRS coverage, calls to 9-1-1 are handled by the CMRS network (as described in section 4.5); when they are on the satellite network, calls to 9-1-1 are handled as described in this section.

4.11.1 Present Location Determination Method

MSS carriers that provide voice services have complied with FCC 9-1-1 requirements in ways that make sense with their networks. While individual approaches may vary, the 9-1-1 call is often handled by a third party call center, which works with callers to determine their locations. In situations when the caller's handset displays GPS information, the caller can provide latitude and longitude coordinates to the call center. If GPS information is not available on the handset, the caller provides an address to the call center. The call center then determines the appropriate PSAP to handle the call.

4.11.2 Current Gaps or Issues

- Location acquisition is handled via verbal communication with the third party call center.

- Location validation against MSAG is not available. Call centers must rely on a national PSAP registry database to identify the correct PSAP that will handle the call. There are several PSAP registries in use and, to date, all have faced challenges in maintaining accurate data.

4.12 Emerging Service Types

4.12.1 Non-Voice Initiated (NVI) Emergency Services

Non-Voice Initiated (NVI) Emergency Services are next generation emergency services supporting non-voice initiated communications between end-users and emergency authorities using session-based text and other multimedia. When standardized, NVI Emergency Services are expected to support location determination of the end device, location updates, and location transport in a manner consistent with next generation emergency voice communications. NVI Emergency Services support additional media in a two-way voice emergency communications session between end-users and emergency authorities (e.g., PSAPs). NVI Emergency Services may also support use cases for emergency services without requiring two-way emergency voice communications.

Non-Voice Initiated (NVI) Emergency Services are intended to support end-user to authority communication. NVI Emergency Services is an emerging technology and may support the following examples of non-verbal communications to an emergency services network:

- Text communication between end-users and emergency services (e.g., real time text (RTT), Instant Messaging, etc.);
- Multi-media (e.g., pictures, video clips) transfer to emergency services during a voice or NVI session with emergency services;
- Real-time video session with emergency services;

- Text communication with supplementary media (such as background audio and/or video).

NVI does not include communication for non-human initiated devices. Examples of these devices are referenced in Section 4 under "Machine-to-Machine (M2M)".

4.12.1.1 Present Location Determination Method

This is an emerging technology and it is expected that next generation networks will address 9-1-1 location determination methods for NVI services. NENA, ATIS, and 3GPP are currently addressing standards in this area.

4.12.1.2 Current Gaps or Issues

- This is an emerging technology. Current standards development efforts are focusing on IP-based originating networks and 4G technologies such as LTE and WiMAX. The evaluation and investigation of backward compatibility with existing systems is still in progress.

5 Location Technologies

5.1 Survey of Currently Deployed Location Technologies

A sub-team was formed to classify and enumerate existing Location Technologies deployed for Phase II E9-1-1. The discussion below gives an overview of each technology, where it is deployed, high-level discussion of performance, and special criteria associated with its usage. Citations are provided that link to white papers or other references providing more details of the technology.

The subject of Z-height location technology performance was considered by the 4C Working Group. While there is currently no FCC requirement to produce Z-height for a Phase II location fix, the recent FCC FNPRM and NOI published in September 2010 [FCC 10-177A1] does solicit comments on vertical location performance. Current data formats for sending location to a PSAP do not support transmission of Z-height, and therefore a change to the relevant standards is required. Moreover, the GIS databases available to the PSAP may not provide a way to utilize Z-height information. These limitations will need to be overcome before transmission of Z-height to a PSAP is practical.

Notably current Phase II deployed technologies were not designed to provide accurate Z-height, and significant development will be required for any Z-height compatible modifications or replacements. While GPS may provide reasonably accurate Z-height information in a rural outdoor setting, this is the environment where Z-height has the least value. Working Group 4C therefore recommends that an in-depth analysis of Z-height capability be deferred for future study.

5.1.1 GPS, including Assisted GPS

Conventional GPS technology, sometimes referred to as standalone GPS, was deployed in the late 80s for navigational and surveying purposes. Conventional GPS utilizes a trilateration method with four or more orbiting satellites which broadcast satellite navigation data (ephemerides and/or almanac), Doppler and code phase shift information, a list of satellites in view, and corrections for signal propagation delay conditions in the ionosphere. The GPS receiver must acquire four or more satellites and demodulate this data, and then compute its location (three satellites can be used if additional information on UE altitude is available from other sources). Due to the low data rate of the broadcast navigation data, it takes 30 seconds or more to actually get a location fix, which is an excessive TTFF (Time to First Fix) for E9-1-1 use cases. In addition, since the data must be demodulated, the radiated sensitivity of the GPS receiver is such that the unit must have a fairly large antenna, or be located outdoors, to get a location fix.

Because of these limitations, conventional GPS was determined not to be usable for UE devices seeking to meet the Phase II E9-1-1 mandate. The TTFF problem cannot be overcome by enabling the GPS receiver in continuous tracking mode for UE devices due to excessive battery life drain. This situation led to the development of so-called assisted GPS (A-GPS) techniques to improve the TTFF and sensitivity. A-GPS was one of the first deployed location methods for Phase II E9-1-1, used by at least three major carriers.

Conventional GPS has, however, been used for Telematics-based emergency services discussed in section 4. The limitations cited above are overcome in the vehicular case because the GPS receiver is continuously tracking the vehicle's position, and optimum antennas are presumably deployed.

5.1.1.1 Basic technology concept/system diagram/brief discussion

In A-GPS, the MS device contains a GPS receiver. A remote Location Server (LS) provides "assistance data" to help the GPS receiver obtain a GPS "fix" (user position) more rapidly, with better sensitivity, or both. This assistance data may consist of satellite navigation data (ephemerides and/or almanac), Doppler and code phase shift information, a list of satellites in view and corrections for signal propagation delay conditions in the ionosphere. By avoiding the need to demodulate GPS signals, A-GPS allows location determination at significantly weaker signal strengths than standalone GPS and with lower delay. Further assistance is provided by feeding the GPS receiver information such as approximate user location as determined by Cell ID, and coarse or fine time aiding. The location fix obtained is then forwarded by the LS to the 9-1-1 Network for display on the call-taker's screen.

The figure below illustrates A-GPS architecture used for E9-1-1 and LBS that is typical in concept of what has been deployed to date. The SMLC (Serving Mobile Location Center) and GMLC (Gateway Mobile Location Center) provide the function of the LS described above. The network elements are designated using 3GPP nomenclature: a 3GPP2 diagram depicts the SMLC as a "PDE"(Positioning Determining Entity the GMLC as an "MPC"(Mobile Positioning Center).

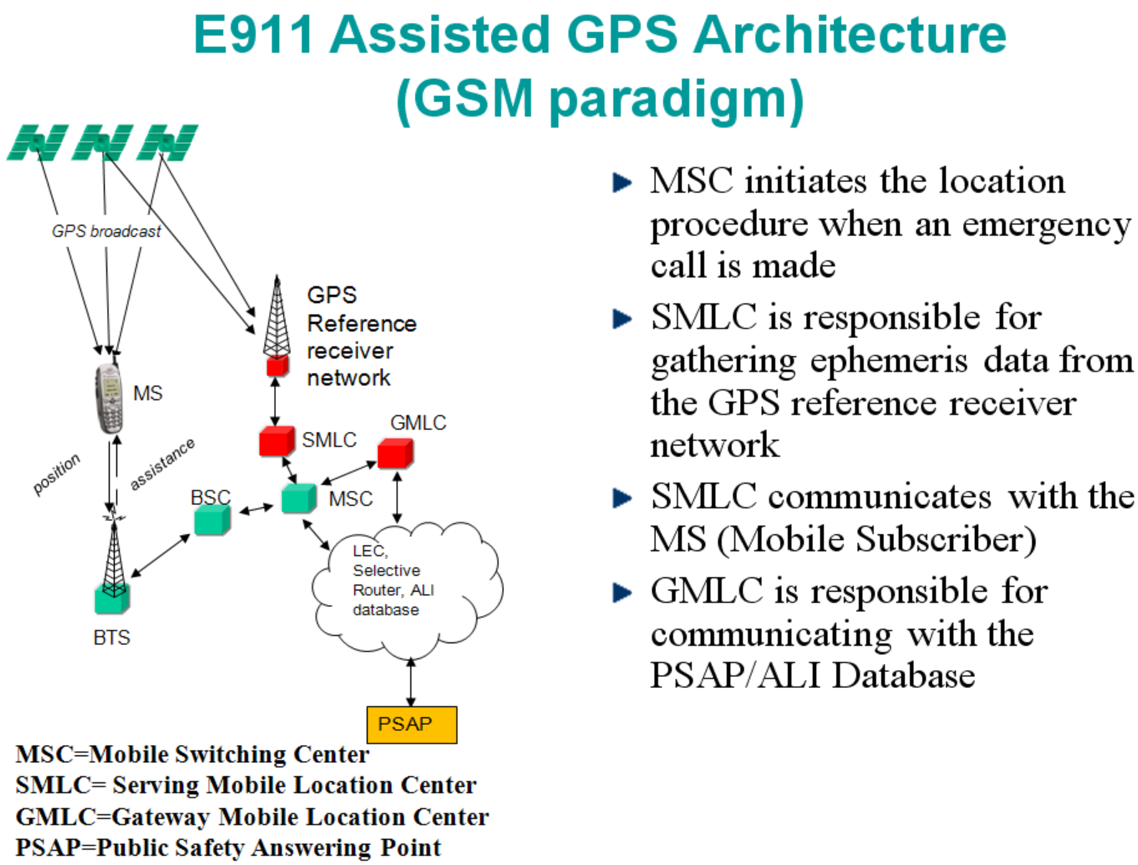

Figure 3: E9-1-1 Assisted GPS Architecture

5.1.1.2 Where deployed

Currently, A-GPS is deployed in networks utilizing CDMA, GSM, UMTS, and iDEN wireless network technologies. In some cases, the fix is computed in the UE and reported to the SMLC; in other cases, the Location Server (SMLC or PDE) computes the fix and forwards it to the E9-1-1 network.

5.1.1.3 Parametric performance (accuracy & TTFF) as a function of environment

A-GPS Accuracy and TTFF (Time to First Fix, which is the time from when user location is requested to when it is actually computed) varies greatly with the environment of the caller. In strong signal conditions (e.g., rural environment with user in clear sky conditions), the accuracy can be better than 10 m and the TTFF < 5 seconds. In some dense urban or indoors environments, accuracy may degrade to the 50-100 m range, and TTFFs can extend to greater than 30 seconds.

5.1.1.4 Special criteria or issues with the technology

GPS performance is challenged in some dense urban or indoor scenarios, as noted above. In certain environments (such as in some dense urban areas, or deep inside buildings made of concrete, brick, or steel), GPS location may not be available in a reasonable time frame. The small form-factor of cell phones limits the size of the GPS antenna that can be reasonably integrated, thus reducing the antenna gain.

On the other hand, GPS receiver technology is improving on a yearly basis, as finer silicon lithographies have allowed for an increasing number of GPS correlators (or equivalent) to be integrated onto UE GPS receivers. Most current A-GPS receivers can get a fix indoors near a window, or in many dense urban environments. Future developments such as GNSS support (i.e., the ability to receive other navigation satellite signals such as GLONASS) are expected to improve performance metrics. These are now being addressed in 3GPP standards, but the carriers' Location Servers will need to be upgraded to provide assistance for new satellite navigation systems such as GLONASS. In addition, the UE devices will have to be upgraded or replaced to support GLONASS and other satellite navigation systems.

As for location security within the wireless access network, various security mechanisms are employed to protect the E9-1-1 caller's location from unauthorized access. For example, the SUPL protocol uses TLS (Transaction Layer Security) for encryption. Control Plane procedures also provide for encryption using the existing 3GPP or 3GPP2 data encryption protocols.

5.1.1.5 Citations for each technology

GPS technology is well documented in numerous references. In particular, the reference below covers all aspects of GPS, with section 9.4 giving an in-depth discussion of A-GPS.

"Understanding GPS; Principles and Applications", E. Kaplan & C. Hagerty (editors),Second Edition Artech House, 2006.

5.1.2 U-TDOA

5.1.2.1 Basic technology concept/system diagram/brief discussion

Uplink Time Difference of Arrival (U-TDOA) is a network based location technology that requires no special software or hardware additions to the handset. Upon detection of the emergency call, various Location Measurement Units (LMUs) installed at the carrier base stations measure and compare the arrival time of the Radio Frequency signals emitted by the calling handset. Servers in the network perform the mathematical calculations to determine the caller's probable location, using a geometric process called trilateration.

The U-TDOA system is also capable of producing an "uncertainty estimate" reflective of the quality of the location estimate, which can also be provided on a call-by-call basis.

A possible implementation of a U-TDOA system is shown in Figure 4 below. The U-TDOA capable Serving Mobile Location Center (SMLC) is fully integrated to the GSM/UMTS network using 3GPP specified protocols. The network informs the location system of any emergency calls that are initiated. The SMLC controls and communicates with the LMUs installed at the carrier radio base stations. Once the SMLC estimates the caller's position, it is sent through the network to the PSAP for display on a map.

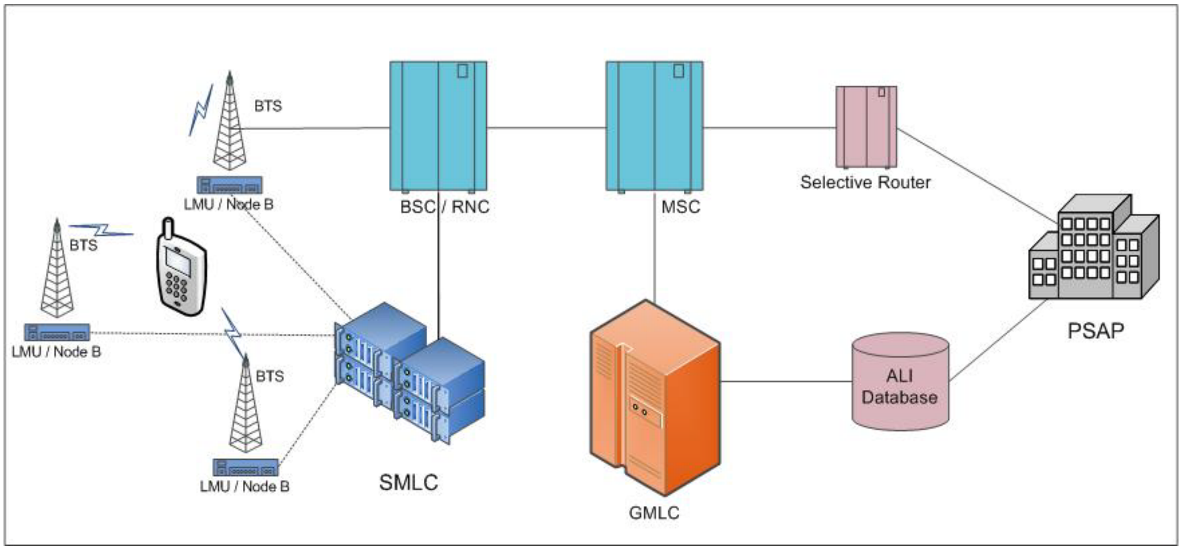

Figure 4: Possible Implementation of U-TDOA System

5.1.2.2 Deployment Profile

U-TDOA is presently deployed nationwide in Tier 1, 2, and 3 GSM networks.
A UMTS version is available. In addition, U-TDOA is capable of locating CDMA, WiMAX, UMTS, and LTE.

5.1.2.3 Parametric performance (accuracy & TTFF) as a function of environment

U-TDOA accuracy varies with the environment of the caller and also the quantity and geometry of surrounding cell sites/LMUs. U-TDOA typically provides medium-level accuracy location estimates within buildings in urban and some suburban settings where cell site density is high. It typically provides high accuracy location estimates reliably and consistently in outdoor dense urban, urban, and suburban localities where cell sites are sufficiently dense and are geographically distributed leading to good geometry between the caller and the LMU equipped cell sites. The technology has proven capable of meeting the 100m/300m requirement for network-based solutions when performance is averaged over large geographic areas.

Time to location (TTFF) is typically within 10 seconds. In urban and suburban environments, U-TDOA yield is high, typically greater than 95%, and in some scenarios as high as 99%.

5.1.2.4 Special criteria or issues with the technology

U-TDOA location accuracy can be degraded if LMUs are not deployed above a certain percentage of the Base Station sites in a given area, especially in indoor scenarios where signal power is attenuated, making it difficult for distant LMUs to detect handset uplink signals.

U-TDOA is also challenged in areas where the cell sites spacing is greater than 15 miles, where there is difficult terrain (such as large hills or mountains), or in areas where the cell site geometry is in a line providing coverage along only a major road (the “ string of pearls” configuration).

5.1.2.5 Citations for each technology

< http://www.trueposition.com/web/guest/u-tdoa >

< http://www.commscope.com/andrew/eng/product/geo/locationmethods/1214214_17008.html >

5.1.3 RF Pattern Matching Methods

5.1.3.1 Basic technology concept/system diagram/brief discussion

Radio Frequency Pattern Matching (RFPM) is a network-based location technology that requires no special software or hardware additions to the handset. The network requires the addition of an SMLC and calibration of the deployment area to generate an RF prediction database. RFPM is a software-based location method utilizing RF measurements (e.g., signal strength, signal-to-interference ratio, link quality, time delay) made by handsets or the network. Upon detection of an emergency call, the server estimates the caller's probable location by statistically comparing these measurements against the RF prediction database. RFPM methods are also called RF Signature, fingerprinting, path loss, or Received Signal Strength Indicator (RSSI) approaches. The RF prediction database is generated by RF propagation models for the deployment area and a drive test calibration procedure during initial deployment. Once calibration data is collected throughout the deployment area, location fixes can be generated anywhere in the carrier's coverage area.

The RFPM system is also capable of producing an "uncertainty estimate" reflective of the quality of the location estimate, which can also be provided on a call-by-call basis.

An example system block diagram for implementation of RFPM for E9-1-1 on UMTS is shown in Figure 5 below. In this standard 3GPP architecture, the RFPM location software resides on a Standalone Serving Mobile Location Center (SAS) (shown in yellow in Figure 5) connected to the Radio Network Controller (RNC) through a standard Iu-pc interface. To obtain cell network data (e.g., cell site locations, antenna heights, network plans, etc.), the SAS also connects to the carrier's Base Station Almanac (BSA).

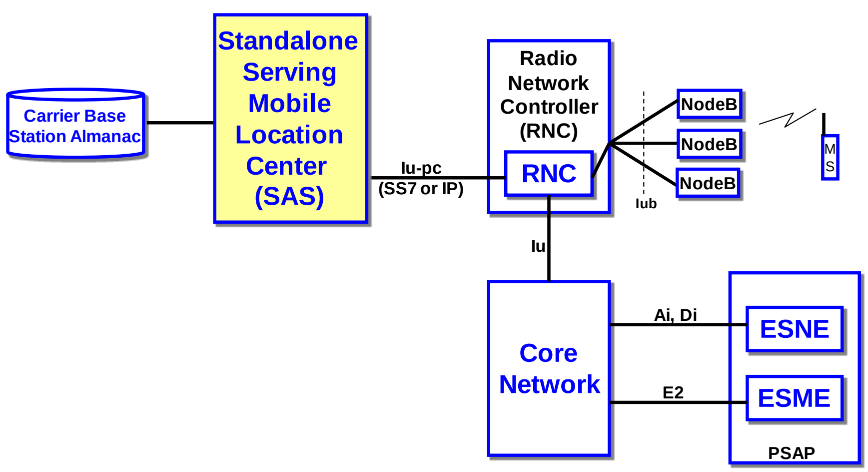

Figure 5: Example architecture block diagram for RFPM implementation on UMTS for E9-1-1

5.1.3.2 Deployment Profile

RFPM is currently deployed in a number of regional Tier II and III carriers' GSM and UMTS networks and through corporate acquisitions in regional portions of some Tier I carriers' GSM networks. In addition, RFPM is capable of locating devices in CDMA2000, iDEN, WiMAX, HSPA, and LTE networks.

5.1.3.3 Parametric performance (accuracy grades/TTFF) as a function of environment

RFPM accuracy varies with the environment of the caller and also the density of surrounding cell sites. RFPM typically provides medium-level accuracy location estimates within buildings in urban settings where cell site density is high. It typically provides higher accuracy location estimates reliably and consistently in outdoor dense urban, urban, and some suburban localities where cell sites are sufficiently dense, RF scattering is complex, and where the RF prediction database is properly maintained. The technology has proven capable of meeting the 100m/300m requirement for network-based solutions in many urban and some dense suburban settings.

The time to first fix is typically within 5-10 seconds in urban and suburban environments and within 15 seconds in rural environments. In urban and suburban environments, RFPM yield is high, typically greater than 95%, and in some scenarios as high as 99%.

5.1.3.4 Special criteria or issues with the technology

The accuracy of RFPM methods can degrade if cell network information is erroneous or missing. RFPM systems can be tolerant to some errors and omissions in this database, but if the discrepancies become too large, then performance is degraded. When physical site changes are made to a significant part of the network (e.g., greater than 15% added cell sites in a local area), then performance can degrade if drive test calibration is not performed. The number and frequency of physical changes to the network determine when drive test calibration is required. Stable networks do not require frequent drive calibration. For networks with numerous, frequent physical changes, drive testing can be required more often. RFPM is also challenged in areas where the cell site spacing is greater than 15 miles, such as in rural environments.

5.1.3.5 Citations for each technology

"Wireless Location Signatures Technology for Position Location", M. Feuerstein (Polaris Wireless, Inc.), *International Symposium on Advanced Radio Technologies (ISART)*, Boulder, Co. Mar. 2, 2004.

"Indoor/outdoor Location of Cellular Handsets based on Received Signal Strength", J. Zhu and G.D. Durgin (Georgia Tech), *Electronics Letters*, vol. 41, No. 1, Jan. 6, 2005.

"Simulation of Location Accuracies Obtainable from Different Methods", H. Bertoni (Polytechnic University) and J.W. Shuh, *IEEE Vehicular Technology Conference,* no. 62, vol. 4, pages 2196-2200, 2005.

"Design and Performance of a Minimum Variance Hybrid Location Algorithm for Positioning in Dense Urban Environments", D.S. De Lorenzo, S. C. Lo, P. K. Enge (Stanford University) and others, *Institute of Navigation (ION) International Technical Meeting*, Anaheim, CA, Jan. 2009.

5.1.4 D-TDOA (A-FLT for CDMA)

5.1.4.1 Basic technology concept/system diagram/brief discussion

Downlink Time Difference of Arrival (D-TDOA) is a location method where timing reference signals from the cellular base stations are used in a trilateration algorithm to produce a location fix. In CDMA networks, this method is designated as A-FLT (Advanced Forward Link Trilateration). It requires that all the Base Stations be synchronized in their timing, or the use of external monitor receivers which provide their own time reference. The computation of the final user location is typically performed on a server, though it could be performed on the UE if the UE has knowledge of all the base station locations.

The basic advantage of D-TDOA is that this method may use reference signals already provided by the wireless network. Additionally, the monitoring of these signals, and computation of their relative delay, may in some cases be processes already required by the UE to perform a potential Handover (HO). Thus, using these signals for location should minimize the battery life penalty.

Observed Time Difference of Arrival (OTDOA), also known as Downlink Observed Time Difference of Arrival (DL-OTDOA), is similar to AFLT in CDMA and E-OTD in GSM. OTDOA is defined for WCDMA systems (e.g., UMTS systems), but it is likely to only be deployed effectively for LTE.

OTDOA is a downlink trilateration technique that requires the User Equipment (UE) to detect at least two neighbor eNodeBs (evolved Node B or base station) in addition to the serving eNodeB. The Evolved-Serving Mobile Location Center/SUPL Location Platform (E-SMLC/SLP) server provides the UE with a list of potential neighbor cells to search. The UE measures and reports the Observed Time Difference (OTD) of the neighbor cells it detects and reports the results with their respective Physical Cell ID. The received time differences are translated into distances between the UE and the eNodeBs and then into hyperbolas, where the intersection between two or more hyperbolas defines the UE position. Synchronization between UE and eNodeBs clocks as well as multipath effects, influence the accuracy of the time difference between signals and as a result, the OTDOA accuracy.

Figure 6 below, where the eNodeB is referenced as “eNB”, shows the interaction between the UE, the serving and neighbor eNodeBs and the E-SMLC/SLP to calculate a network-based location position.

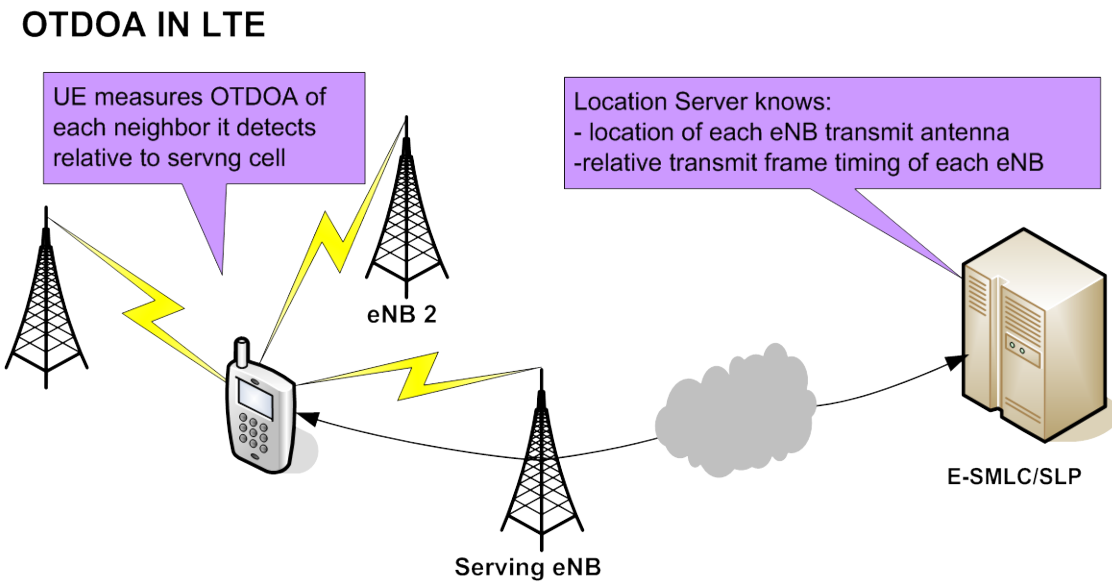

Figure 6: OTDOA in LTE

5.1.4.2 Where deployed

CDMA networks now utilize D-TDOA as a backup location method in case a GPS fix is not available. In fact, since four GPS satellites are required to get a GPS fix, CDMA handsets will use D-TDOA signals from the base stations in combination with the GPS signals to get a location fix, in the event that less than four GPS satellites are visible by the UE. This is discussed further in Hybrid Location methods below.

An early attempt by at least one U.S. carrier to use a D-TDOA technology (EOTD) as a Phase II solution for GSM phones ultimately ended in failure, due to non-compliance with the accuracy requirements, and the carrier subsequently moved to a U-TDOA method.

In 3GPP, the standards for O-TDOA were just released in TS 36.355 V9.2.1 (2010-06) for LTE networks, and have not been deployed by any carriers at this time.

5.1.4.3 Parametric performance (accuracy grades/TTFF) as a function of environment

OTDOA accuracy varies with the environment of the caller and also the quantity and geometry of surrounding eNodeBs. OTDOA should typically provide medium-level accuracy location estimates within buildings in urban and some suburban settings where cell site density is high. It should typically provide medium accuracy location estimates reliably in outdoor dense urban, urban, and suburban localities where cell sites are sufficiently dense and are geographically distributed leading to good geometry between the caller and the eNodeBs.

Time to first fix (TTFF) is expected to be between 5 to 10 seconds. Yield is expected to be similar to AFLT and E-OTD.

5.1.4.4 Special criteria or issues with the technology

The UE requires OTDOA software support in order to process the signals from multiple eNodeBs and interact with the E-SMLC/SLP server. Accuracy is expected to be improved with hearability improvements by Positioning Reference Signals (PRS) and tighter eNodeB synchronization. PRS requires support by eNodeB and could impact system capacity if not implemented efficiently.

OTDOA is also expected to be challenged in areas where cell site spacing is greater than 15 miles, where there is difficult terrain (such as large hills or mountains), or in areas where the cell site geometry is in a line providing coverage along only a major road (the " string of pearls" configuration).

Also note that the timing resolution and accuracy of the UE receiver is not optimized for precision timing measurements, especially in the case of severe multipath. In addition, the relative timing synchronization of the Base Stations contributes an additional source of location error.

To mitigate the Near/Far hearability problem, an Idle Period Downlink mechanism has been defined for UMTS and LTE to improve accuracy, but this reduces network capacity slightly.

5.1.4.5 Citations for each technology

3GPP, TS 36.355 V9.2.1 (2010-06), Section 6.5, Page 38 – 45.

5.1.5 Cell ID

5.1.5.1 Basic technology concept/system diagram/brief discussion

Cell ID Location is also referred to as Phase I location. Originally, before the Phase II mandate became effective in 2002, wireless carriers had to use Cell ID location to route the wireless call, and also to report the estimated location of the caller. When Phase II deployments began, Phase I location information was often still reported in case a GPS or network fix was not obtained or was not available at the time of the location query.

Currently, for Phase I location reporting in the US, the only location reported is the civic address of the cell site/sector where the 9-1-1 call originated. The XY geodetic location of the Base Station or of the cell sector centroid (midpoint) may also be sent to the PSAP along with the civic address. It is inherently a "Network Solution" in that the wireless network uses a pre-provisioned database to retrieve the Cell ID location of an UE engaged in an E9-1-1 call.

A diagram of the location geometry for a common cellular network configuration is shown below in Figure 7:

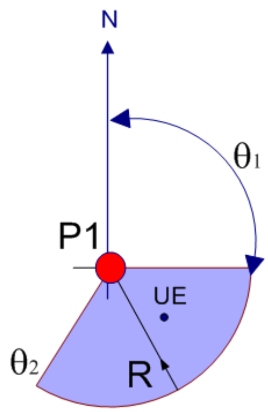

Figure 7: Location geometry for common cellular network configuration

When Phase I location is reported to the PSAP, it may include a geodetic XY, which is the location of the Base Station itself or may be the midpoint of coverage of the specific cell sector.

5.1.5.2 Where deployed

Cell ID is reported by all wireless carriers regardless of technology.

5.1.5.3 Parametric performance (accuracy grades/TTFF) as a function of environment

As first responders are rarely if ever dispatched based on Cell ID Location, the parametric accuracy is not as critical as for the Phase II technologies. Location accuracy is a function of the cell coverage radius, which can range from 0.5 km in dense urban environments, to > 10 km in rural settings. It can be mathematically proven that, in a sectored or Omni deployment, half the area of the sector or circle is contained within a radius of length 0.707*R, and the other half is outside this radius. Thus, the "location centroid" for the sectored site is at a radius of 0.707*R, and an angle halfway between the angles θ_1 and θ_2 shown above.

5.1.5.4 Special criteria or issues with the technology

There are several problems with the current Phase I location method:

- The location reported is always the civic address of the cell site and sector where the 9-1-1 call originated and is likely not the actual location of the caller.
- The coverage radius R, if provided, is not a precisely know quantity, since RF fading and call handover thresholds can allow a specific user to roam into the coverage area of an adjacent cell site but still connect to the original serving base station.
- The coverage radius R depends heavily on the terrain type and wireless usage.

As 4G coverage and higher data rates are more widely deployed, it is expected that cell coverage radii will shrink if the UE transmit power levels are held constant.

Citations for each technology

3GPP TS25.305; Section 4.3

5.1.6 Enhanced Cell ID (ECID)

5.1.6.1 Basic technology concept/system diagram/brief discussion

Enhanced variants of cell ID location also exist, known generically as Enhanced Cell ID (ECID). Other variants exist that can make use of normal operationally available measurements of the round trip signal propagation time between a mobile device and its serving base station or base stations. These variants can sometimes also make use of signal strength and signal quality measurements made by the mobile device for nearby base stations and/or by the serving base station(s) for the mobile device. The following specific variants of ECID are then possible. Each of these variants is recognized and defined by 3GPP except for Mixed Cell Sector (see below) which is supported by 3GPP2 standards. Some of the variants below are deployed as fallback methods for 9-1-1 location while others are not currently utilized.

5.1.6.2 Cell-ID with Round Trip Time measurements

This ECID variant uses, in addition to the cell ID, the serving base station measurements of the signal Round-Trip-Time (RTT). These measurements can be made by all base stations serving a mobile device in the case of UMTS. If RTT measurements to several geographically dispersed base stations are available, which happens during soft handover, the mobile device location may be found via trilateration. The RTT measurements may be complemented by measurements related to RTT from the mobile device.

5.1.6.3 Cell-ID with Angle of Arrival

This method employs angle of signal arrival measurements made by one or more base stations and (typically) one or more distance measurements determined from measurements of round trip signal propagation delay. It requires phased antenna arrays to make accurate angle measurements. Combining these measurements provides a simple way of determining location given the known base station location(s). While this method is defined in 3GPP standards, it is not in commercial use and is not considered an accurate location technique for 9-1-1.

5.1.6.4 Mixed Cell/Sector

This method makes use of cell ID from neighbor cells. It can be seen as a more accurate version of cell ID making use of neighbor cell identities whose signals can be received by a mobile device. By knowing all the cell identities whose signals can be received by a UE, it is possible to better determine where in the serving cell coverage area, a UE may be located. This method is used in CDMA 2000 when other fallback methods for 9-1-1 do not produce location.

5.1.6.5 Citations for each technology

3GPP TS 36.35J

5.2 Emerging Location Technologies

This section discusses new location methods that may someday be applicable to Next Generation 9-1-1 location. Currently, these methods are either deployed for LBS applications, or have been prototyped and installed in a limited number of environments as “turnkey solutions”. None of this discussion implies that these new technologies will, or should be, implemented as a location method for originating service provider next generation networks used to connect to a 9-1-1 system.

5.2.1 Wireless Beacon (WiFi-based)

5.2.1.1 Basic technology concept/system diagram/brief discussion

Wireless beacon location is based on WiFi (IEEE 802.11a/b/g/n) technology and is in use by a growing number of mobile devices, such as smart-phones, laptops, and tablet PCs. Both private and public WiFi Access Points (APs) have also proliferated in homes, offices, shops, and public spaces. The WiFi radios in mobile devices can be used to measure and report information from nearby WiFi APs, such as the station identifiers and signal strengths.

To locate mobile devices, a database of WiFi AP information (e.g., identifiers, approximate locations or signal maps) must first be created and maintained by the technology provider. The device must then measure information described above from visible WiFi APs and send that information to a Location Server that has access to the database. Using proprietary procedures, possibly based on Bayesian statistics or path loss models, the device location is determined by the Location Server.

Some APs cannot be sensed by the device if they do not broadcast their station identifier unless the device has previously connected to this AP. There are also cases, however, where not all of the reported APs are contained in the database (e.g., new APs, APs deep inside buildings, APs in un-calibrated areas). A device can be located with WiFi if some of its reported APs are contained in the database, but if all the reported APs are missing from the database, then location cannot be determined using this technology.

Since the radii for WiFi APs are typically small (on the order of 100 meters), this technology could produce medium level location accuracy. Newer WiFi standards, such as IEEE 802.11n, may extend these coverage radii to several hundred meters, potentially degrading location accuracy.

Current WiFi location implementations require a proprietary software application or service compatible with particular device models or operating systems. Low level WiFi device driver support is required to report the appropriate WiFi parameters.

WiFi AP databases can be populated using drive test calibration, crowd sourcing methods, or a combination[14]. Due to the dynamic nature of WiFi networks, periodic re-calibration of the AP database is required.

Example architecture for current WiFi LBS is shown in Figure 8 below. The device has a WiFi radio accessed through hardware drivers in the Operating System. The location application on the device uses WiFi measurements to estimate location through an API to a WiFi Location Server on the Internet. The WiFi Location Server contains the WiFi AP database and positioning center.

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[14] Crowd sourcing employs user generated reports of measured WiFi APs tagged with ground truth, typically from GPS. With sufficient volume, these user generated reports can be aggregated to create a database of APs.

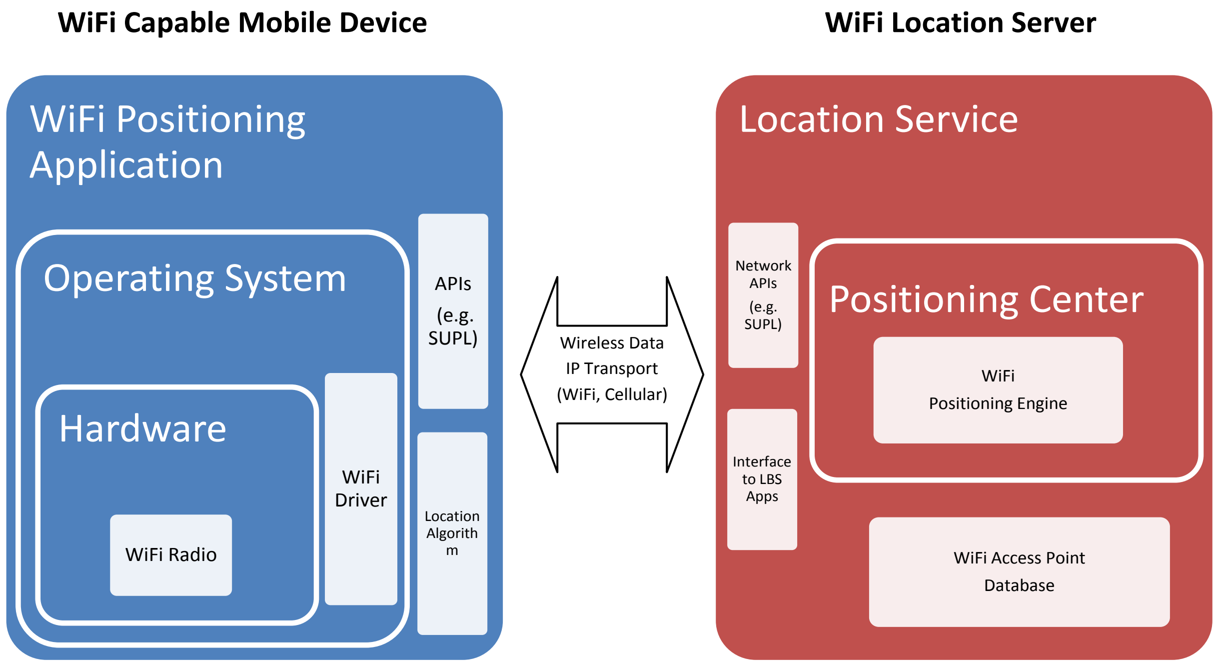

Figure 8: Example architecture block diagram of WiFi Location Service

5.2.1.2 Name of vendor(s), where deployed, and for what application

Vendors of the technology include Skyhook Wireless, Navizon, Google, Redsky, Ekahau, and others. WiFi location is deployed in many cities for consumer LBS, such as downloading local maps, identifying points of interest, and social networking. One vendor claims 70% population coverage in USA and Europe. Other vendors do not claim a wide area solution, but rather are focused on enterprise domains such as hospitals and universities.

These WiFi solutions are focused on LBS applications and are not being promoted for traditional E9-1-1 usage.

5.2.1.3 Parametric performance (accuracy and TTFF) as a function of environment

Because of the different database population, maintenance methods, and the dynamic nature of WiFi networks, performance can vary based upon how recently and accurately the AP has been calibrated. With a freshly calibrated WiFi AP database, and a high density of APs in the area of interest, the method can provide medium level location accuracy outdoors and within some buildings. TTFF is typically within several seconds.

WiFi location yields can vary based on the length of time that has elapsed since the AP database was calibrated, the AP calibration method, and density of visible APs.

5.2.1.4 Potential suitability for E9-1-1

For the following reasons, the applicability of WiFi location to safety-of-life, mission-critical applications, such as E9-1-1, needs to be evaluated:

- The current deployments for WiFi location are based on proprietary implementations. Support for transporting WiFi measurements to the Location Server is not currently available in the E9-1-1 control plane interface standards (such as those from 3GPP and 3GPP2). Support for transporting WiFi measurements to the Location Server is not available in Version 1.0 of the Secure User Plane Location (SUPL) from the Open Mobile Alliance (OMA); however, this capability is optionally available in Version 2.0 of SUPL, which is in an early stage of deployment among 3GPP carriers for LBS.

- Currently, only a fraction of cell phones in the marketplace have WiFi capability, although the penetration rate is growing rapidly with the adoption of smart-phones. In addition, many WiFi-only devices exist, such as laptops or tablet PCs.
- Operating WiFi on portable devices has implications on battery life. Users can disable WiFi for various reasons, such as personal security/privacy or to conserve battery life. If this method is considered for E9-1-1 location, the ability to override these settings must be evaluated.
- WiFi operates on unlicensed frequency-bands (2.4 or 5 GHz) in dynamic networks, which are unplanned, unmanaged, and contain a mix of public and private APs. Mobile and portable WiFi APs have been in the market for some time (e.g., MiFi cards, smart-phones with built in WiFi APs, vehicles with APs), meaning that a growing number of APs may not be stationary.

5.2.1.5 Potential availability timeframe for E9-1-1 Deployment

WiFi location methods are now actively used for LBS. It therefore warrants a more detailed study of the issues surrounding its use and implementation time frame for emergency applications with WiFi enabled devices.

5.2.1.6 Citations for each technology

"WiFi Positioning Made LBS a Reality", F. Alizadeh (Skyhook Wireless), *2nd Opportunistic RF Localization for Next Generation Wireless Devices*, June 13-14, 2010, Worcester Polytechnic Institute < http://www.cwins.wpi.edu/workshop10/pres/tech_4.pdf >.

"Accuracy Characterization for Metropolitan-scale Wi-Fi Localization", Y-C. Cheng, Y. Chatwathe, A. LaMarca (Intel), J. Krum (Microsoft), *First Annual Conference on Mobile and Ubiquitous Systems Networking and Services*, August 22-26, 2004, Boston, MA.

5.2.2 Wireless Beacon (Bluetooth-based)

5.2.2.1 Basic technology concept/system diagram/brief discussion

WirelessWERX offers a location system based on a wireless network of Bluetooth nodes that enables the mobile device's location to be determined when making a 9-1-1 emergency call from inside a building. The various Bluetooth beacon nodes are connected to multiple location nodes via Bluetooth. Every beacon node is connected to a centralized location server (including a management console) within a building via a WiFi (802.11) WLAN or potentially other backhaul. The Bluetooth beacon nodes continually broadcast their location and are provisioned to provide floor, room number, altitude, longitude, elevation, zip code, street address, and user-specific information. The mobile device obtains the location information (civic address or geo-coordinates) from the network location node(s) via a Bluetooth connection that enables location of a user within a building. A Bluetooth software application must be downloaded on the mobile device in order for the mobile device to communicate with the location node on the network. See

Figure 9 below provided by WirelessWERX for their 9-1-1 application.

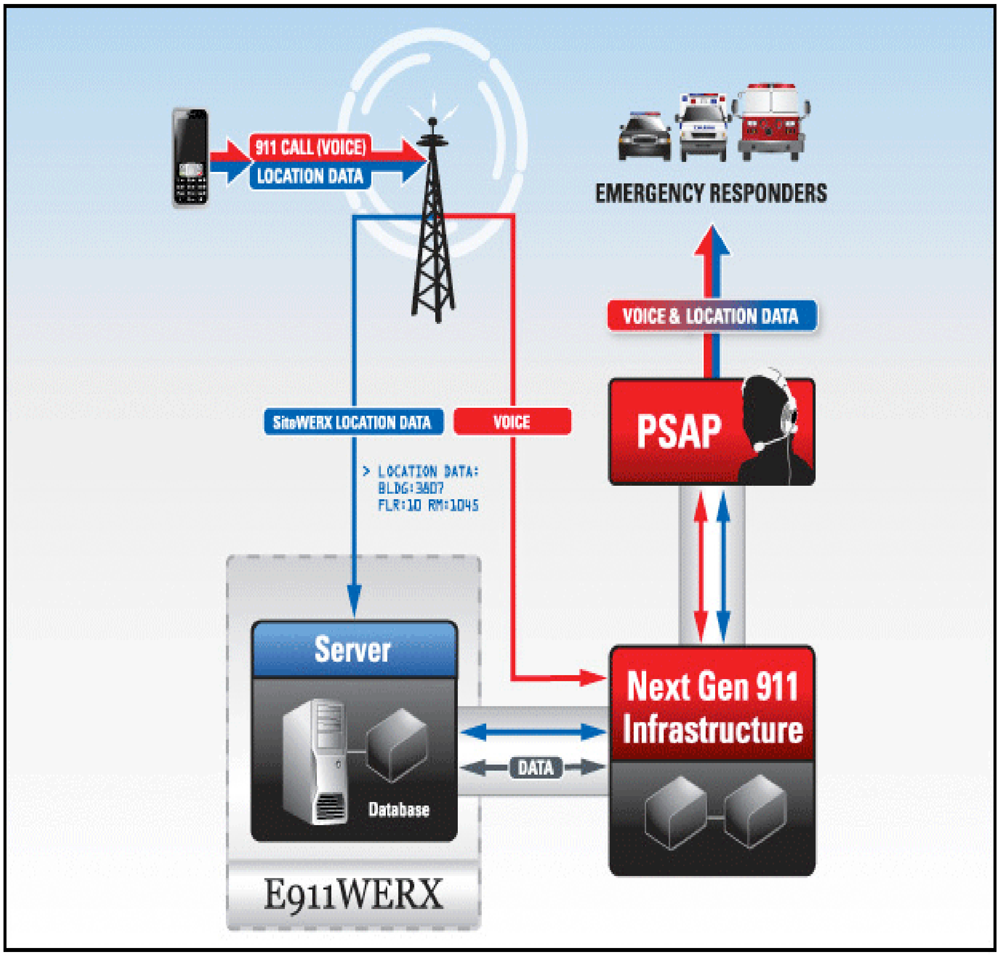

Figure 9:WirelessWERX Bluetooth based location system

5.2.2.2 Name of vendor(s) , where deployed, and for what application

The sole vendor identified by the 4C Working Group that offers this location technology for 9-1-1 is WirelessWERX. The vendor claims to provide a 9-1-1 location solution that can be deployed within a campus or enterprise environment for applications that require 9-1-1 location information. The technology has been prototyped in a pilot/trial at University Lofts, a privately developed apartment building catering to students at the University of Denver[15].

5.2.2.3 Parametric performance (accuracy grades/TTFF) as a function of environment

The vendor has provided the following performance claims: location accuracy is less than 10 meters for 90 seconds TTFF worst case. The location accuracy and yield are heavily dependent on the density of the beacon deployment.

[15] http://findarticles.com/p/news-articles/wireless-news/mi_hb5558/is_20090601/university-lofts-deploys-wirelesswerx-solution/ai_n39961204/

5.2.2.4 Potential suitability for E9-1-1

This technology is targeted for indoor applications within the enterprise environment for campus deployments using Bluetooth enabled mobile devices (between the mobile phone and the location nodes). WiFi connectivity is required between the beacon nodes and the management server that configures the beacon nodes. Each PSAP must support an interface to the Wireless WERX location server and the location server that sends the location information to the PSAP associated with a 9-1-1 call. As Bluetooth has become prevalent on most UE devices today, a Bluetooth-based location solution would not impose a significant cost burden on the device. However, there is significant deployment and maintenance overhead associated with the infrastructure of this solution. For example, a node might have significant associated cost, and it is unclear who would bear the burden for deployment and maintenance of these nodes. One idea that has been suggested is for building or apartment owners to pay for nodes.

The application is designed to run on Apple iOS, Android, Blackberry, Windows Mobile, and JAVA, and needs to be Bluetooth-enabled. The application will need to be pre-provisioned on devices using this technology.

5.2.2.5 Citations for each technology

< http://www.wirelessWERX.com/sitewerx.php >

5.2.3 Wireless Beacon (Proprietary with UE transmitter beacons)

5.2.3.1 Basic technology concept/system diagram/brief discussion

This wireless beacon technology is a terrestrial based approach for tracking objects and communicating with remote sensors. A collection of sensors deployed in the surrounding building infrastructure detects the signal of a tag embedded in the UE and calculates its location. This technology uses a network-based Time Difference Of Arrival (TDOA) based on Direct Sequence Spread Spectrum technology. This technology includes proprietary transmitters in the mobile device, and proprietary receivers that are located in the network infrastructure.

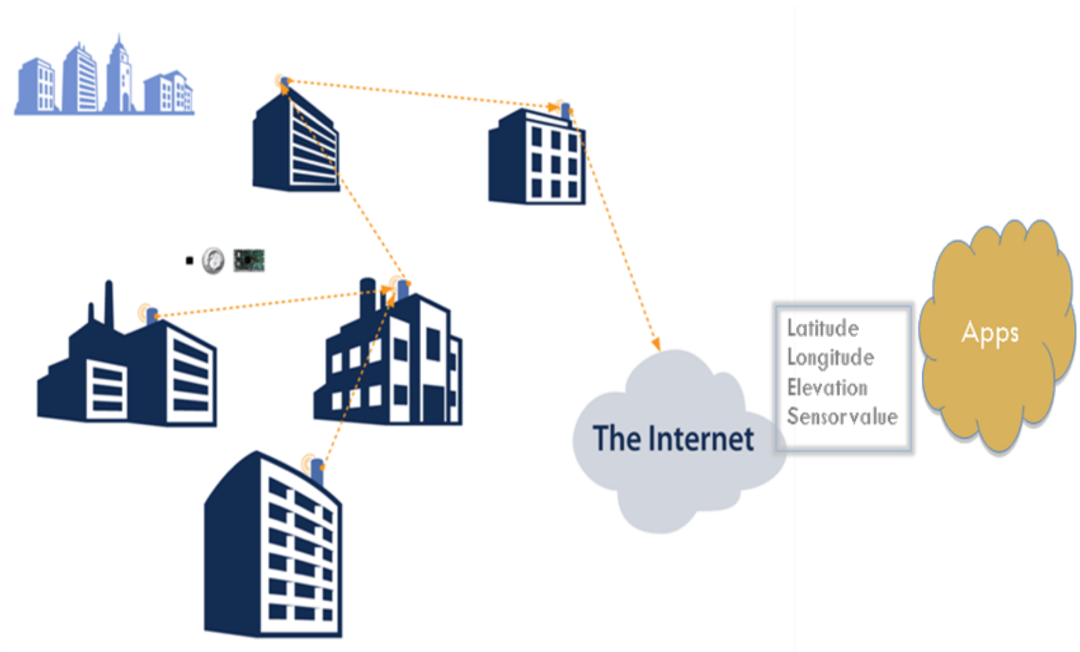

Figure 10: Recon Dynamics location system

5.2.3.2 Name of vendor(s) , where deployed, and for what application

The sole vendor identified by the 4C Working Group for this proprietary wireless beacon technology is Recon Dynamics. The technology is primarily used for location tracking, monitoring of assets, and remote sensing. The technology is not specifically developed for 9-1-1 applications.

5.2.3.3 Parametric performance (accuracy grades/TTFF) as a function of environment

The following performance claims have been provided by the vendor and may not have been independently verified. It is not known what environment or applications that these limited performance data results apply to:

- For Outdoors applications, it is 6.6 meters at 67% and 13.2 meters at 95% fix attempts;
- For Indoors applications, it is 15.4 meters at 67% and 45.4 meters at 95% fix attempts;
- The TTFF is 2 seconds.

5.2.3.4 Potential suitability for E9-1-1

This technology is used for both indoors/outdoors asset tracking location applications, and in both enterprise and carrier network environments ranging from campus deployments to larger carrier network applications (e.g., WiMAX). It requires a proprietary hardware chipset to be installed in the mobile devices. It also requires deploying a dedicated network of receivers, as well as adding connectivity to external databases for 9-1-1 applications. Because of the proprietary nature of the technology itself, and the need for a specialized hardware chipset in the mobile devices, in addition to a dedicated network, this technology may have limited suitability for 9-1-1 applications. Location accuracy characterization over a wide range of suburban and dense urban environments must be performed, and results verified, before the suitability for 9-1-1 can be assessed. The technology uses unlicensed band transmitters in the mobile device and may be subject to uncontrolled interference under certain conditions.

5.2.3.5 Citations for each technology

< http://www.s5w.com/how-it-works/ >

5.2.4 Wireless Beacon (Proprietary with Metropolitan transmitter beacons and UE receivers)

5.2.4.1 Basic technology concept/system diagram/brief discussion

Commlabs is developing a next generation wide area positioning system using medium range beacon signals based on a GPS signal layer. This solution is attempting to address limitations with GPS performance deep indoors or in severe urban canyons. The indoor and urban canyon location limitations have remained elusive primarily from an accuracy, yield, cost, and scalability perspective.

The Commlabs' approach to determining the user's location indoors, in urban canyons, and other GPS challenged environments is to deploy a terrestrial network of highly synchronized beacons that broadcast over a metropolitan wide area and radiate a terrestrial signal utilizing licensed wireless spectrum, allowing the signals to be received in locations where GPS is most challenged. Commlabs signals are transmitted in GPS format in the 900 MHz licensed LMS band (902-928 MHz). These signals could be received by new mobile devices with firmware/software modifications in the GPS receivers (and modem chipsets) and, in many cases, requiring modified GPS hardware (RF front end). The mobile device solution could potentially be lower cost than other approaches that require a dedicated sub-system to be deployed in the mobile device.

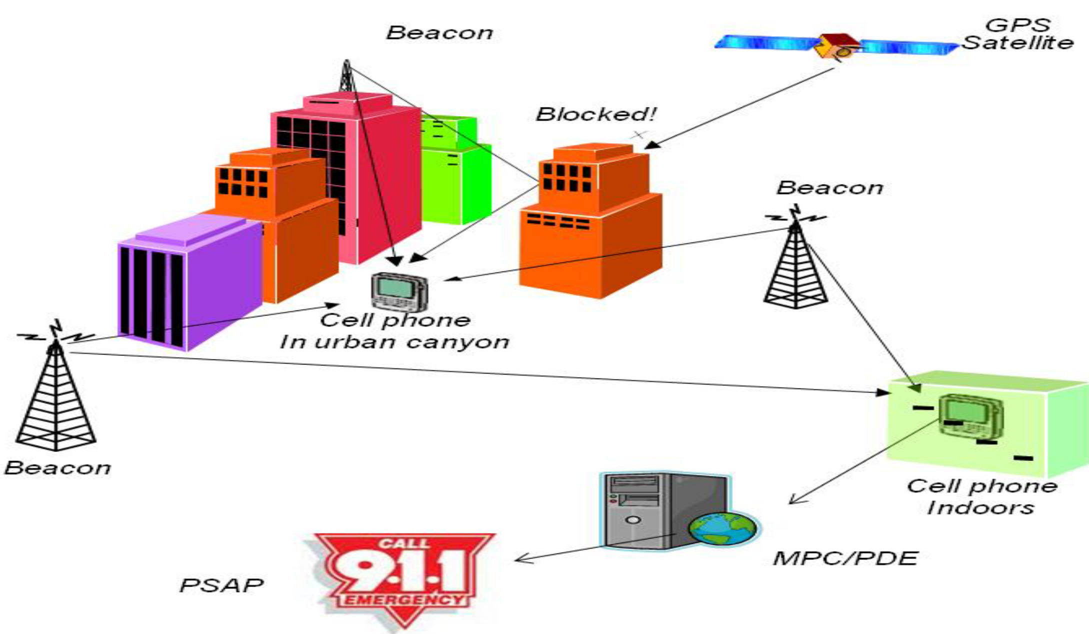

Figure 11: Wireless beacon

5.2.4.2 Name of vendor(s), where deployed, and for what application

The prototype system is currently undergoing field trials by Commlabs in the San Francisco Bay Area and is being demonstrated and tested by various partners for E9-1-1 and LBS. Complete details of this field trial were not provided to the CSRIC 4C Working Group.

5.2.4.3 Parametric performance (accuracy grades/TTFF) as a function of environment

The vendor has provided the following performance claims based upon the prototype trial in the San Francisco Bay Area:

- *2D Accuracy*: Circular Error Probable (CEP) 67% – 18m and CEP 90% – 30m.
- *TTFF*: 3-5 seconds (Cold Start) for 95% of the fixes.

5.2.4.4 Potential suitability for E9-1-1 and deployment timeframe

The system generates a latitude and longitude, which in the standard E9-1-1 call flow are being transported, thereby making it seamless with existing E9-1-1 call flows in UE based implementations.

For E9-1-1 adoption, numerous deployment obstacles must be addressed including the following:

- Deployment of the beacons in the metropolitan areas;
- Modification of GPS chipsets suitable for UE devices by GPS vendors commonly used by mobile devices;
- Incorporation of the modified GPS chipsets into mobile devices and deployment of these updated mobile devices into the market place;
- Modification of location servers to support this new technology;
- At a minimum, the standards will need to be modified for the addition of a new class mark for this technology;
- The device antenna, if it already supports the 800 MHz cellular band, could potentially be used for the Commlabs 900 MHz band. If not, the antenna system must be extended to support the 900 MHz band.

Location accuracy characterization over a wide range of suburban, urban, and indoor environments must also be performed, and results verified, before the suitability for 9-1-1 can be assessed.

5.2.4.5 Citations for each technology

http://www.commlabs.net/index.html

5.2.5 Location using DTV transmitters

5.2.5.1 Basic technology concept/system diagram/brief discussion

A single vendor, Rosum, prototyped a location system using the synchronization signals broadcast by ATSC TV towers. The principle was that, since the output power of TV broadcast signals can be as high as 1 Megawatt, there would be no issues concerning in-building penetration. Any device using this technology would need to incorporate an ATSC receiver with at least a UHF antenna. Since the ATSC transmissions are not synchronized to an external timing standard such as GPS, the Rosum solution required Location Measurement Units (LMUs) to monitor the actual signal timing. Thus, when the UE obtains timing measurements from three or more TV towers, the Rosum server would be used to calibrate these measurements with respect to GPS or another standard time base, and then compute the user location using trilateration techniques.

Several deficiencies in DTV technology were identified that indicate DTV technology as it stands now presents challenges with regard to location acquisition for Next Generation 9-1-1:

- The need for dedicated ATSC receivers in the UE device;
- The need for large UHF antennas within the device;
- The physical arrangement of DTV transmitters is not optimized for location acquisition.
- DTV transmitters are not widely available in rural areas;
- The need to virtually synchronize the DTV transmission signals to make it viable for location acquisition.

- In the second half of 2010, Rosum apparently ceased business operations. Because of this and the technical challenges noted above, the Rosum solution can no longer be considered as a candidate Location Technology for Next Gen 9-1-1.

5.2.6 Hybrid Location Combinations

5.2.6.1 Basic technology concept

Hybrid location is a general term referring to various ways of combining two or more location determination techniques for improving system performance.

All the location technologies discussed in section 5.1 could potentially be combined in a hybrid solution; however, it is better to combine technologies that best complement each other. For example, technologies using cellular network measurements (U-TDOA, RFPM, D-TDOA) combined with A-GPS technologies could offer better results compared against blending two cellular network technologies (e.g., U-TDOA plus D-TDOA). Even in these scenarios, there are environments where a hybrid solution does not produce accurate location results.

There are three hybrid combining methods described in detail below:

(1) ***Fallback Method***: Some systems use fallback methods, which invoke a second (or third) location method, when the results of the first method are determined by the access network to be unsatisfactory for various reasons. These reasons could include failure to return a fix, uncertainty above a threshold, or location timer expired.

This fallback approach could be accomplished as a sequential operation, only triggering the second (or third) location method after the primary one fails. If sequential location processing steps are used, then the location result can be delayed if this method is invoked. Fallback methods are presently deployed, for example, in iDEN networks (A-GPS fallback to Cell-ID) and some UMTS networks (A-GPS fallback to Cell-ID, Base Station Timing Method, or Enhanced Cell-ID).

(2) ***Selection Hybrid Method***: A selection hybrid location system simultaneously employs two or more location methods, then selects the location result which is most likely to provide better yield, based on various factors (e.g., the quality of available measurements, uncertainty of location fixes or environment of the user, etc.). It can be beneficial in scenarios where the primary technology (such as A-GPS) is challenged, as in some dense urban or indoor settings where obstructions in the line of sight can prevent the UE from acquiring the minimum number of measurements needed to perform a location. The secondary technology used could be technologies using cellular network measurements or some of the emerging technologies, as discussed above.

Deployment of the Selection Hybrid Method may require less change to some currently deployed location systems than the Joint Estimation Hybrid Method discussed below.

(3) ***Joint Estimation Hybrid Method***: The location system mathematically combines measurements from two or more location methods to potentially obtain better yield results than either individual location technology can achieve by itself, especially when the technologies are blended such that the strengths of one offset the weaknesses of the other. It should be noted that in strong signal conditions, where there are sufficient measurements available from both technologies, combining these measurements may result in degraded accuracy, compared to just using the result from one of the technologies. Additionally, combining results from certain location technologies, such as Bluetooth Beacon location and A-GPS, may not be feasible.

A-GPS range measurements from the visible satellites or the satellite location fix can be combined with other location technology measurements or fixes to provide hybrid location estimates. This can be useful when A-GPS is challenged due to obstructions in the satellite line of sight which prevents the UE from acquiring the minimum number of satellites needed to calculate location.

Joint estimate hybrid can work in UE-based A-GPS mode (where the UE calculates the satellite location fix) or in UE-assisted mode (where the UE sends satellite range measurements to an external entity for location calculations). In UE-based mode, the location estimates can be combined in the location domain (latitude, longitude, confidence, uncertainty) -- for example, by blending based on location fixes and associated uncertainties. In UE-assisted mode, the location estimates can be combined in the measurement domain (raw pseudo-ranges from satellites, raw network measurements from cellular systems, or emerging location schemes). Both joint estimate hybrid methods can potentially produce improved yield compared to the underlying location technologies on their own.

5.2.6.2 Known Deployment Profiles

The Fallback Hybrid Method is now deployed for some carriers, in the event that the primary location technology does not provide a fix.

The Selection Hybrid Method has not been deployed as of the date of this report.

Joint estimate hybrid products have been deployed in CDMA with A-GPS and AFLT (D-

TDOA).

5.2.6.3 Parametric Performance

Hybrid location technologies are being researched to identify their potential for improving location accuracies and yields. In some instances, improvements in one parameter may result in degradation of the other.

In addition to current evidence that hybrid technologies achieved improvements in yield, there is active research into algorithms for also improving accuracy with hybrid. The goal of these research efforts is to not only achieve increased yield, but also better accuracy than any other underlying technology alone. These accuracy improvements are being investigated by incorporating additional measurements, such as from other location systems, into the joint estimation hybrid calculation.

5.2.6.4 Potential suitability for E9-1-1 and deployment timeframe

The suitability and timeframes for these new hybrid approaches for Next Generation 9-1-1 need to be evaluated and verified.

6 Reference Database Accuracy for 9-1-1 Calls

Accurate and current location data is important to 9-1-1 agencies. Having Master Street Address Guide (MSAG), Automatic Location Information (ALI), and Geographic Information System (GIS) datasets reconciled and synchronized is crucial to both routing 9-1-1 calls and providing PSAP operators the detailed information needed to correctly verify the location of a caller and the provide proper emergency response. As today's E9-1-1 technology transitions to NG9-1-1, the need for a single, comprehensive set of geospatial standards for all public safety agencies is essential. The concept is simple; the actual implementation is not.

Historically, townships, cities, municipalities, and counties and the associated PSAPs have independently developed their own data sources and processes for addressing and mapping – i.e., de facto "standards" that meet their business needs. The MSAGs for ALI and the GIS datasets that support computer-aided dispatch (CAD) for these entities have been developed independently, developed or shaped by specific vendor solutions, and/or developed by other internal departments for various business needs. In some jurisdictions, GIS datasets do not exist outside of the CAD system. In other cases, management of the GIS data occurs with little or no coordination with public safety and other departments.

Adding to the complexity, the database structure for baseline mapping data (e.g., orthophotography), addresses, street centerlines, and buildings have been defined by the individual entities without adherence to standards or guidelines. This is due in part to the absence of pragmatic national geospatial standards. The net result is that the geographic reference system for GIS map registration varies from jurisdiction-to-jurisdiction and from state-to-state. For example, some jurisdictions use base maps referenced to the spherical latitude and longitude reference system due to CAD system dependencies while other jurisdictions have adopted the respective State Plane Coordinate System for their state. With the advent of Next Generation 9-1-1, standardized formats will be required to enable 9-1-1 call location determination for cross-boundary, regional dispatching.

Multi-story buildings considerably add to the complexity of geographic location determination of 9-1-1 calls. In addition to the engineering-level technical variables referenced in the previous sections, height or the Z-coordinate is becoming increasingly important as agencies and the general public expect precise location identification during emergency situations. However, the availability of Z-coordinate data is not imminent and requires the redevelopment of many existing technologies. Agency databases and systems must also be developed to accommodate this increasingly detailed level of information.

The major hurdle in developing current, accurate, useful, and precise GIS data is the significant time and resources required to collect, create and maintain this data. Data collection efforts are generally performed by individual agencies, without coordination with others, often without following positional accuracy standards, and often without clearly defined attribute standards. The results are usually duplicated efforts and missed opportunities for data sharing.

6.1 Enhanced 9-1-1 Data Synchronization.

An initial NG9-1-1 implementation step is the synchronization and reconciliation of MSAGs currently used for E9-1-1 services with the GIS centerline, address and Emergency Service Zone (ESZ) boundary databases.

Synchronization and reconciliation will resolve the following errors that impede emergency service provision:

- GIS database geometry errors, including appropriately "breaking" geometry for roads that cross municipal boundaries and correcting the direction of the road geometry to match the increase in street address progression;
- GIS database attribute errors, including zero address ranges, parity (odd/even) errors, address range gaps and inconsistent street name components (Street Name Not Found, Street Prefix Direction Not Found, Street Prefix Type, etc.);
- Street name spelling consistent for the road segments that represent the same street;
- Mismatches in the use of street naming conventions for highways (e.g., HY vs. HWY);
- Inconsistent use of standard street names suffixes;
- Inconsistent and non-standard use of the pre- and post- directional street name fields.

Potentially a very high percentage of MSAG entries will require an edit change. An initial assumption is that in many areas a high percentage[16] of the entries will require some type of change (e.g., move to postal suffix abbreviations, use of pre/post directional fields, house number range changes, etc.). This is a typical scenario that will be experienced by any agency or region preparing for NG9-1-1.

Because of the projected percentage of MSAG entries that will require changes, the E9-1-1

[16] In two jurisdictions, Minneapolis-St. Paul and the State of Texas the edit rate percentage was found to be 85%

service provider needs a method to implement these changes quickly during transition. If an entire state, a number of regions within a state, or a number of states are preparing for NG9-1-1 concurrently, the ability to make the MSAG changes in a timely manner can be a “choke point” for the synchronization process.

Once the MSAGs and GIS datasets are synchronized and reconciled, the ALI database can be geocoded against the GIS centerline data as another quality assurance. Wireless and Voice over IP (VoIP) calls comprise a high percentage of calls to 9-1-1 today. The ALI information for these calls is not resident in the traditional (wireline) ALI database. The ALI record (e.g., VoIP) or ALI data elements (e.g., wireless or VoIP) are provided to the 9-1-1 system at the time of the call and do not reside as assembled records in the ALI database. While methods to collect copies of these records, as built/provided, might initially be necessary to reconcile and ensure data integrity, long-term usefulness is negated as the NENA i3 architecture moves away from the traditional concept of an ALI database as a repository for validated location information records. The i3 architecture requires validation of location information against an authoritative source, directly or indirectly. The validated location information is then stored in a LIS. The information is transmitted with the call, along with a URI (pointer) to the other call related information such as Class of Service (residential service), Company ID, etc., for the PSAP to retrieve after the call has been delivered.

While MSAG to GIS and MSAG to ALI synchronization is a must for the transition to NG9-1-1, it should go away once the LIS and the Location Validation Function (LVF) are used to validate civic addresses. Consequently, it will be extremely important to ensure that all communications services that use civic address to convey location for a 9-1-1 call adhere to the following:

- Validate the location information against an authoritative source;
- Correct and re-validate location information flagged as "invalid";
- Conduct periodic re-validation of all subscriber location information.

It will also be extremely important that 9-1-1 authorities keep their GIS data accurate and current. Quality assurance mechanisms and discrepancy reporting processes must be implemented to evaluate calls that misroute due to the use of partial or invalid civic addresses.

6.2 Relevant Standards

- NENA 71-501 “NENA Information Document for Synchronizing Geographic Information System Databases MSAG with MSAG and ALI”

- National Map Accuracy Standards (NMAS). Established in 1947 by the United States Geological Survey (USGS)

- FGDC-STD-001-1998 - Federal Geographic Data Committee’s Content Standards for Digital Geospatial Metadata

- FGDC-STD-007.1-1998 - Geospatial Positioning Accuracy Standards Part 1: Reporting Methodology

- FGDC-STD-007.2-1998 - Geospatial Positioning Accuracy Standards Part 2: Standards for Geodetic Networks

- FGDC-STD-007.3-1998 - Geospatial Positioning Accuracy Standards Part 3: National Standard for Spatial Data Accuracy

- FGDC Standards –There are many relevant FGDC standards for this topic at : <http://www.fgdc.gov/standards/standards.html>.

7 Security & Vulnerabilities for Future Location Technologies

In addition to general and communications security best practices, location information requires additional privacy considerations. Implementing an authorization policy is only one facet of information security for protecting location information. Other location security aspects for consideration include authentication, data integrity and attribution, and data encryption. Data integrity and encryption should be implemented by location servers for providing security on protocols that carry location object information across IP networks. Data integrity ensures that the location information cannot be modified and tampered with by an unauthorized recipient. Data encryption ensures that the location information cannot be viewed by unauthorized recipients and carried over IP networks securely. These location security measures should be implemented at the point where location information originates and wherever location information is processed.

Location information is conveyed by the IP device/network depending upon the network configuration. Digital certificates are being used between location origination and destination points to authenticate content. The use of digital certificates only guarantees that the location data contained is authentic and originated by the location signer. Digital certificates do not protect against certain attacks such as Denial of Service (DoS); for example a miscreant steals a signed location object and attaches it to an emergency call (or multiple emergency calls). Another type of attack is location spoofing in which a false location is attached which could result in a PSAP being fooled into responding to what is thought to be a real emergency. It is important to note that emergency calls that contain no location certification and/or a failed location certification also would need careful handling so as to not deny emergency services to a legitimate caller. Finally, various security methods need to be implemented together in order to secure the delivery of location information on IP networks.

Due to the complexity of security issues and time constraints, the CSRIC 4C Working Group was unable to develop an exhaustive analysis of all potential security issues associated with location. For more information on security and vulnerabilities please refer to the CSRIC 2A report on Cyber Security Best Practices and the CSRIC 8 report on ISP Network Protection Practices.

8 STANDARDS DEVELOPMENT ORGANIZATIONS

The following sections describe known gaps within the content of technical standards that, if not addressed, have potential to negatively impact location determination, acquisition, or accuracy. The 4C Working Group noted many issues and gaps within sections 4 and 5. The standards gaps listed within this section are those identified as having impact across multiple service types or technologies. It must be noted that the list of gaps contained herein is not comprehensive and that other issues of gaps or overlap may exist.

There are many organizations, researchers, and vendors that are involved in the standards process. Many of these entities produce technical standards that directly impact the delivery of 9-1-1 calls and the determination, acquisition, and accuracy of 9-1-1 location. Aligning all of the interdependent technical specifications and interface standards related to 9-1-1 location will require significant and ongoing convergence work and will exceed the time constraints of CSRIC 4C. An additional consideration is that some standards have been drafted for international purposes and therefore may not be compatible with all facets of 9-1-1 location in the U.S.

The following are examples of prevalent standards development organizations that have drafted complex technical documents that impact 9-1-1 call delivery and location accuracy:

- **IETF**: The IETF is an open international community of network designers, operators, vendors, and researchers who focus on the evolution and operation of the Internet architecture. Session Initiation Protocol (SIP) is a critical element within the NG9-1-1 architecture and it is defined by the IETF. The NENA i3 Technical Specification for NG9-1-1 incorporates best practices and protocol standards drafted by the many workgroups within the Internet Engineering Task Force (IETF).
- **TIA**: The Telecommunications Industry Alliance (TIA) is an ANSI accredited Standards Development Organization (SDO) that develops standards for a wide variety of telecommunications solutions including radio, satellite, vehicle telematics, and healthcare devices. The TIA develops standards for CDMA2000 based CMRS networks.
- **ATIS**: The Alliance for Telecommunications Industry Solutions (ATIS) is an ANSI accredited SDO that also develops standards and solutions for telecommunications industry needs. There are a number of committees within ATIS that address 9-1-1 related issues and standards. The TIA/ATIS joint standard J-STD-036 provides a solution for handling wireless E9-1-1 calls and is referenced in many NG9-1-1documents and discussions. The ATIS Emergency Services Interconnection Forum (ESIF) recently completed the Request For Assistance Interface (RFAI) specification for the delivery of 9-1-1 calls via IP Selective Routing. ATIS also develops standards for GSM/UMTS/LTE based CMRS networks.
- **3GPP**: 3GPP is an acronym for the 3rd Generation Partnership Project which is an organizational partnership between SDOs for the purpose of developing ITU compliant global 3G and 4G telecommunications specifications for the GSM/UMTS/LTE family of technologies. ATIS is a founding partner of 3GPP, which is an international organization supported by standards organizations and their member companies from North America, Europe, and Asia. 3GPP has drafted specifications that support emergency services via CMRS-based networks and emergency services over IP using the IP Multimedia Subsystem

(IMS).

- **3GPP2: -** 3GPP2 is an acronym for the 3rd Generation Partnership Project 2 which is an organizational partnership between SDOs for the purpose of developing ITU compliant global 3G telecommunications specifications for CDMA2000 based CMRS networks. TIA standards are based on specifications produced by the 3rd Generation Partnership Project 2.
- **OMA**: The Open Mobile Alliance is a partnership forum that develops mobile service enabler specifications. By linking the activities of various wireless, information technology, and mobile application vendors, the OMA strives to develop specifications for interoperability within the mobile application industry. SUPL and OMA-DM are standards that are referenced in several NG9-1-1 documents.
- **OGC**: The Open Geospatial Consortium is an international industry collaboration forum for the developers and users of spatial data products. The technical documents produced by the OGC are used to build open interfaces and encoding for geospatial products. The OpenGIS Web Feature Service (WFS) referenced in several NG9-1-1 documents is an OGC standard.
- **IEEE**: The Institute of Electrical and Electronics Engineers (IEEE) is an association that drafts standards and other publications to advance global technologies worldwide. Examples of IEEE standards development categories are Communications, Computer technology, Antennas and Propagation, Information Sharing, and Wired/Wireless networks. The family of 802.11 standards for wireless Local Area Networks (LAN) is defined by IEEE.
- **APCO**: The Association of Public-Safety Communications Officials (APCO) is an ANSI accredited SDO. APCO drafted the standard for Wireless 9-1-1 Deployment and Management, the External Alarm Interface Exchange for PSAPs, and led Project Locate which produced an assessment of the value of Location data delivered to PSAPs for enhanced wireless 9-1-1 calls. APCO is currently engaged in joint efforts with NENA to draft technical specifications for PSAP interfaces in NG9-1-1.
- **NENA**: The National Emergency Number Association (NENA) produces standards defining NG9-1-1 and its functional components and architecture, including data standards, operational, and systems management documentation. Location and how it is provided and used in 9-1-1 services is fundamental in these standards and documents. NENA 08-003, Detailed Functional and Interface Specification for the NENA i3 Solution, is the core architectural standard for NENA NG9-1-1. NENA manages the NG9-1-1 Project and encompasses multiple Committees and Working Groups in this Project. Other standards and document relating to NG9-1-1 are listed at: http://www.nena.org/ng911-project, under Standards Status.
- **WiMAX**: The WiMAX Forum is an industry-led, not-for-profit organization formed to certify and promote the compatibility and interoperability of broadband wireless products based upon the harmonized IEEE 802.16/ETSI HiperMAN standard. Release 1.5 of the WiMAX specification includes a dedicated LBS specification providing architecture and network protocols for determining and forwarding location in an LBS or E9-1-1 scenario.
- **FGDC –** The Federal Geographic Data Committee (FGDC) is an interagency committee that promotes the coordinated development, use, sharing, and dissemination of geospatial data on a national basis. This nationwide data publishing effort is known as the National Spatial Data

Infrastructure (NSDI). The FGDC has drafted several standards related to Geospatial positioning accuracy.

8.1 Standards Gaps that Impact Multiple Service Types or Technologies

- NENA i3 supports the use of all shapes in 3GPP standards. TIA/ATIS J-STD-036B requires a single shape (point and circle) used towards PSAP. Converting shapes to the one in J-STD-036B may add location error.
- NENA i3 draft specifications support the use a civic address (as per IETF RFC 5491) as a means to describe a user equipment (UE) location. 3GPP specifications for GSM, WCDMA, and LTE do not currently allow for civic addresses to be used a description of the UE position.
- NENA i3 supports the use a civic address for 9-1-1 location (as per IETF RFC 5491). However, other standards (such as TIA/ATIS J-STD-036B) do not allow for a civic address to be sent to a PSAP.

8.2 Open Issues from NRIC VII

8.2.1 Consistent Format for Location Information

- **Standardization of Class of Service (COS)**: NRIC VII made recommendations for standardizing a specific list of COS values for Wireless Phase I and II calls. Standardized COS values must also be established for all 9-1-1 service types to assure that PSAPs are able to identify the type of location they are receiving.

- **Confidence and Uncertainty**: Work is continuing within ATIS/ESIF to address inconsistencies within the meaning of uncertainty estimates and how this information should be used by PSAPs.

- **Latitude/Longitude display with Phase I wireless calls**: Lat/Long coordinates are in some cases still being displayed at the PSAP in association with Phase I calls. The issue for PSAPs is that the coordinates may represent the physical location of a cell tower or they may represent a geodetic point near the center of a cell sector. Coordinate data is only valuable when the PSAP is able to discern the type of location referenced. Absent the context of what it represents, coordinate data can cause confusion and inaccurate dispatch of emergency resources.

- **Cell Sector Identification and Orientation**: For consistent presentation of data, NRIC VII recommended that sector and orientation always be included in the ALI address field and that the cell sector description should be included in the ALI location field. To date, there are still inconsistencies in how cell sectors are being represented within ALI data.

8.3 Technical Standards Development Status

8.3.1 IETF GEOPRIV & ECRIT
A focus in the IETF GEOPRIV working group has been expressing uncertainty regions -- not any sort of confidence value indicating the probability that the target is actually within the region. RFC 5491[17] describes a set of simple shapes that can be used to describe uncertainty regions within the general PIDF-LO presence and location data structure[18].

An individual draft [3] has been submitted that adds a confidence field to PIDF-LO, but it has not yet been taken up by the Working Group (there is not currently a milestone to work on confidence).

A document within the IETF ECRIT working group on "rough location" [4] is worthy of mention. This document describes the level of precision required for a location value to be usable to route an emergency call. The description includes an algorithm for deciding whether or not a location value is useful for routing an emergency call, based on the boundaries of local jurisdictions. While the original intent of the document was to put constraints on "location fuzzing" by networks that recognize the caller's precise location, it may also be read as providing precision requirements when the caller's precise location is not known. This document is not yet an RFC, but its technical content is basically complete and it has passed a Working Group “Last Call”.

8.3.2 NENA:
NENA continues to develop Requirements, Standards, and Information documents around the technical and operational aspects of NG9-1-1, from ingress interfaces from Originating Service Providers, through call and data processing, database management, interfaces and data access to PSAPs, and data interfaces within the PSAP environment. In this work, NENA interacts and coordinates with multiple other SDOs and governmental organizations at national and international levels. NENA also develops PSAP operations standards to provide more specific procedures for PSAP use in handling emergency calls and data associated with calls and dispatch processes. NENA has just completed NENA 08-003, Detailed Functional and Interface Specification for the NENA i3 Solution, which is the NENA Standard for the core architecture of NG9-1-1.

As a specific example regarding future expansion of NG9-1-1 service capabilities, the NENA Next Generation Messaging Working Group recently completed work on the Non-Voice-Centric Emergency Services Technical Information Document (TID). The associated document addresses the Emergency Services Community’s desire to have multimedia emergency services supported with the same general characteristics as emergency voice calls. As a result, the TID identifies suggested requirements needed to communicate with emergency services using mechanisms that are not primarily voice.

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[17] <http://tools.ietf.org/html/rfc5491>
[18] <http://tools.ietf.org/html/rfc4119>

NVC Emergency Services as defined in this TID focuses on Next Generation Network (NGN) technology and does not include legacy messaging services, such as Short Messaging Service (SMS). In addition, NVC Emergency Services does not include support of calls from non-human initiated devices (e.g., fire alarms).

There will be significant impacts to the entire emergency services system resulting from the changes in networks and devices as described in this document. Many systems in the emergency services network must eventually change. New end-to-end messaging relationships must be established.

Although the end-user device requirements and the origination network requirements are out-of-scope for NENA, requirements are proposed to provide an end-to-end solution for NVC Emergency Services. These requirements will be liaised to the appropriate Standards Development Organizations (SDOs) for consideration in addressing NVC Emergency Services.

8.3.3 3GPP

3GPP completed specifications to support emergency calls and associated location determination for CMRS circuit switched networks back in 2000 and did the same for CMRS packet based networks in 2010. The location support defined by 3GPP is based on control plane architectures though allowance is made to support user plane architectures (e.g., defined by OMA) for CMRS packet based networks.

3GPP is currently enhancing support for emergency calls and associated location determination over CMRS IMS-based packet-based networks. These enhancements will enable more reliable use of a network provided cell ID for emergency call routing purposes and will support emergency calls made from private enterprise VoIP networks.

3GPP has also started work on defining support for non-voice emergency services (NOVES) such as text based messages, IM and video. It is expected that this will be incorporated as part of the IMS-based solution.

Future 3GPP work depends on consensus over all 3GPP worldwide partners and their members, but, based on recent activity, it is likely that additional location support will be added for Femtocells – i.e., to improve location accuracy inside buildings. In addition, new positioning methods are being defined in OMA (e.g., for methods involving A-GNSS, WiFi and Bluetooth) that may be enabled for location support of emergency calls made over 3GPP CMRS networks.

8.3.4 3GPP2

3GPP2 has a distinct solution for emergency calls and associated location support over 3GPP2 CMRS circuit switched networks. This was completed in 2000 and is defined in ANSI TIA/ATIS J-STD-036. For support of emergency calls and associated location over 3GPP2 CMRS packet based networks, 3GPP2 shares the same IMS based solution that has been defined by 3GPP. For location support in this case, 3GPP2 makes use of a user plane location solution such as the SUPL solution defined by OMA.

3GPP2 has also developed a specific solution including location support for circuit switched emergency calls made over femtocells. This is documented in the latest revision C of J-STD-036 and in 3GPP2 X.S0059.

8.3.5 ATIS

ATIS as an organizational partner in 3GPP standardizes the solutions for North America as defined by 3GPP to support emergency calls and associated location determination in both CMRS circuit switched and CMRS IMS-based packet based networks. The 3GPP solution for CMRS circuit switched networks was adapted by ATIS for CMRS networks subject to the FCC E9-1-1 phase 2 mandate in ANSI TIA/ATIS J-STD-036. The 3GPP solution for CMRS packet based networks (which is based on use of IMS) is currently being adapted by ATIS in a similar manner. The associated work is expected to occupy at least this year (2011). Furthermore, this standard will be aligned with the NENA i3 solution (which includes the definition of the ESInet and ESInet interface) and will define specific requirements and functions for an originating CMRS network and associated end device.

ATIS is also looking into support of medical and health related emergency services – e.g., location requirements on CMRS networks and other solutions to support medical devices that may provide data to 9-1-1. It is expected that once an initial evaluation has been completed, suitable proposals to advance a solution or solutions will be taken into 3GPP.

8.3.6 OMA

OMA provides application level solutions for CMRS and other networks that have little or no dependence on particular access technologies.

From the perspective of emergency services, OMA has defined a user plane location solution known as Secure User Plane Location (SUPL) that is currently in use for LBS and could be used in the future to support location determination for emergency services. This solution uses the same position methods as already defined by 3GPP and 3GPP2 for their control plane solutions. It also allows additional position methods defined in OMA within a new positioning protocol known as LTE Positioning Protocol extensions (LPPe).

OMA is currently defining new position methods and positioning capability in the LPPe protocol. The intent is to make this available for consideration in 3GPP IP based networks including the IMS based solution for emergency services. LPPe includes additional support for A-GNSS location and support for WiFi, Bluetooth and femtocell based positioning.

9 CONCLUSIONS AND RECOMMENDATIONS

The discussion in sections 4 and 5 provided an analysis of Service Gaps, along with discussion of Existing and Deployed Location Technologies. There are two areas of general impact worth noting:

- **Transition from wireline to mobile wireless telephony.** As more and more of the population moves away from landline service and relies solely on mobile telephony devices, a larger percentage of E9-1-1 calls are being made via mobile telephony. This growth in wireless 9-1-1 calls has reached or is approaching 70% in many urban 9-1-1 Centers.

- **Services initially targeted for Static or Nomadic usage, which have now become mobile or being used differently than originally intended.** Examples include VoIP applications that were deployed initially for home use, but later became available as software clients for PCs and mobile devices. These services may now use self-registered location methods no longer appropriate for a mobile or even a nomadic environment. The obvious solution is to deploy automatic location methods for these new services; however, this is not a straight-forward process. The communication software client that can access 9-1-1 should have access to a location technology. The situation may appear restrictive and it may be necessary to educate the general public, who traditionally do not realize the potential challenges with location.

The following summarize the consensus conclusions and recommendations of CSRIC Working Group 4C.

9.1 General Conclusions and Recommendations For E9-1-1 Location Accuracy

The conclusions contained within sections 6, 7, and 8 apply to 9-1-1 location regardless of Service Type or Technology.

- CSRIC 4C concludes that an FCC policy should balance the continual refinement of location accuracy with the cost-benefit trade-offs and needs of public safety and other stakeholders so that resources dedicated to 9-1-1 issues are appropriately allocated. Balancing NG9-1-1 transition issues and initiatives for non voice integration, for example, need to be considered.

- CSRIC 4C recognizes that the complexity and evolving nature of location issues will require an ongoing analysis effort. The workgroup recommends that the FCC establish an E9-1-1 Technical Advisory Group ("ETAG") to address specific location technology issues for 9-1-1. The ETAG concept, which interested stakeholders have championed for several years, offers the best and most constructive path towards improved E9-1-1 accuracy. The ETAG, which should include representatives from all sectors of the industry, including public safety, carriers, technology vendors and key stakeholders, would work cooperatively and expeditiously to enhance location accuracy and to improve the manner in which location accuracy is measured. The ETAG would also validate the feasibility and capabilities of emerging E9-1-1 location accuracy technologies in a standardized, real world test environment. The ETAG should study how to improve location accuracy in challenging environments, including indoor settings, urban canyons, high-rises, rural environments and areas of heavy forestation or mountainous terrain etc.

- CSRIC 4C recommends that the FCC not mandate specific location technologies but should promote additional research and development of a variety of technologies through the ETAG. Mandating a specific technology could prevent carriers, access network operators, and service providers from implementing E9-1-1 location solutions that fully leverage their unique network characteristics and could stunt future competition between E9-1-1 solution vendors.

- CSRIC 4C recommends that all standards impacting 9-1-1 location accuracy provide for civic address or geodetic locations to be sent to PSAPs as appropriate for the service type involved. (Example: it is preferable for static service types to utilize a civic address format).
- CSRIC 4C recommends that the FCC explore options to assist localities with moving forward to synchronize their GIS data in preparation for NG9-1-1.
- CSRIC 4C recommends that as 9-1-1 location technologies evolve, security issues remain at the forefront of the technology development.
- CSRIC 4C recommends coordination among the standards development organizations who are drafting standards that impact 9-1-1 location accuracy.

9.2 Conclusions and Recommendations Based on Service Type

9.2.1 Conclusions and Recommendations for Single Wire-line Connection with Fixed/Static Location

It was noted in section 4.1 that the lack of Originating Service Provider (OSP) access to the MSAG database can cause delays in validating and provisioning user location data to ALI databases. It also was noted that problems associated with access to the MSAG appear to be limited to specific jurisdictions, at least for Interconnected VoIP and their third-party agents. Errors in the MSAG database can cause location validation failures and inaccurate 9-1-1 call routing. Errors in the ALI database can cause the location display to the PSAP operators to be missing or inaccurate.

Conclusions:

Use of the traditional ALI database for single wireline connection for static locations with MSAG validated address and associating the wireline for call routing have been in use for many years. There are many detailed and comprehensive NENA standards associated with the traditional ALI database, the MSAG, etc. In addition, state PUC rules, state or local laws or requirements associated with 9-1-1 or local interconnection may also address, support, or supplement NENA standards for these issues. Errors can occur in any process, and state and local governments and service providers must continue to fund and support current efforts to maintain data quality. Existing standards and requirements for the traditional ALI database appear to be comprehensive and sufficient for circuit switch providers' use.

9-1-1 database management is a critical function of both the PSAP and the Originating Service Provider that impacts the user location data available for incident response and, thus, effectiveness of the system. A greater effort on the part of PSAPs and OSPs should be made to improve 9-1-1 database accuracy. Service providers should correct 9-1-1 database errors promptly. Greater attention to 9-1-1 database accuracy should be observed by all involved. Location validation failures and inaccurate 9-1-1 call routing leads to inconsistent and ineffective 9-1-1 service.

Recommendations:

- Existing ALI database standards and requirements appear to be comprehensive and sufficient as to circuit switch providers using the traditional ALI. Therefore, CSRIC 4C does not believe that there are issues for the FCC to address in the purely traditional context because of well-settled standards and requirements.

- CSRIC 4C recommends the development and enhancement of standards for 9-1-1 database management that will reduce errors and decrease location validation failures.

9.2.2 Conclusions and Recommendations for Multiple Wireline Connections with Static Location

As discussed in section 4.2, there are inconsistencies in the dialing patterns used to access emergency services from within an MLTS facility (e.g., 9-1-1 to internal station, 9-1-1 straight out, other digit strings to internal security). Specific dialing patterns are also not well advertised to the public or employees in an MLTS facility.

There are large variations in requirements among states that have MLTS legislation, and only a few states have adopted MLTS legislation. **There is limited capability to enforce MLTS legislation at the State level and no capability at the Federal level**. However, there has been some progress with local authorities to promote voluntary compliance by entities such as large corporations, school districts, and campuses.

The issues described above have been problematic for many years. New MLTS technologies may not be easily mapped to existing laws, thereby causing inconsistent compliance. Education and awareness on these issues is having incremental success in achieving voluntary compliance. For example, when parents and local officials understand that using an MLTS can result in emergency responders showing up at the wrong campus, voluntary efforts to correct the problem have received attention and improvements. Educational awareness efforts have also helped with large corporations recognizing potential liability issues. Nevertheless, budget constrained federal, state and municipal governments are facing challenges when trying to address MLTS location issues.

Conclusions:

CSRIC 4C concludes that private systems are not easily regulated. There are significant variations in requirements among states that have MLTS legislation, and only a few states have adopted MLTS legislation. Additionally, 9-1-1 call routing of wireless and nomadic extensions in an MLTS environment has not been properly addressed. Single location and callback numbers within systems that span large geographic areas or which span multiple PSAP boundaries are not adequate for accurate 9-1-1 call routing or emergency response. Legislation that is based solely on square footage, without consideration of how the area is used, is not always adequate for 9-1-1 location needs. Caller location is not typically provided unless the customer utilizes a “Private Switch ALI” (PS- ALI) product to provide separate location data to the 9-1-1 processing for ALI.

Recommendations:

- CSRIC 4C notes that APCO/ NENA advocated for federal and state legislation, that has not been widely adopted. CSRIC 4C recommends that the federal government adopt national MLTS legislation to provide consistent requirements for equipment manufacturers and MLTS installations. Until a national mandate is adopted, states should continue to be encouraged to adopt MLTS legislation.

- CSRIC 4C recommends standard dialing patterns for 9-1-1 in MLTS systems be adopted.
- Finally, CSRIC 4C recommends current MLTS legislation be reviewed to determine if modifications are required to accommodate Next Generation 9-1-1 technologies.

9.2.3 Conclusions and Recommendations for Centrex

As noted in Section 4.2.2, gaps in CENTREX systems include a failure to maintain current data as changes are made to the user premises, especially if customers extend numbers from the cable demarcation location address to other buildings; if the customer does not provide updates on number assignment and location to the serving telephone company for entry in service records; and if the serving telephone company does not perform these updates in a timely fashion or at all.

Conclusions:

Centrex has typically been associated with carrier provided switching that did not require MLTS solutions to provide 9-1-1 location. Issues such as demarcation point changes can introduce MLTS issues into the Centrex service.

Recommendations:

- CSRIC 4C recommends that caller location be provided for all Centrex implementations.

- Traditional Centrex services adequately address 9-1-1 location and, therefore, nothing further is recommended .

- When MLTS like issues are introduced into the Centrex service, the recommendations listed in section 9.2.2 above apply.

9.2.4 Conclusions and Recommendations for Voice Service over Broadband (VoBB) with Registered Static Location

As noted in section 4.3.1, an identified gap is whether every service provider validates the customer address against the MSAG database of the applicable 9-1-1 authority. In some systems, the user can, contrary to provider policy, move the device within a limited area and make a 9-1-1 call and cause a dispatch to the wrong address.

Conclusions:

To date much of VoBB has leveraged the legacy 9-1-1 architecture which includes the traditional ALI database. In those cases, there appears to be no substantive differences from other service providers also using the legacy 9-1-1 architecture and traditional ALI database.

Recommendations:

- CSRIC 4C recommends customer addresses be validated against the MSAG database of the applicable 9-1-1 authority.

- For VoBB providers using the existing traditional ALI database approach that includes MSAG validation for ALI and for 9-1-1 SR routing, no changes are recommended.

- VoBB providers who are transitioning from legacy 9-1-1 architectures to a new architecture must employ extensive testing to ensure a comparable level of 9-1-1 service.

- The lack of clear 9-1-1standards and requirements fosters inconsistent 9-1-1 service and must be resolved.

- Service providers and 9-1-1 authorities must work collaboratively in support of migration efforts from existing legacy architecture to interim and next generation 9-1-1 environments. Collaboration should include advance notice and implementation reviews between service providers and 9-1-1 authorities to assess impacts and adequately plan upcoming transitions that will support future NG9-1-1 environments.

9.2.5 Conclusions and Recommendations for Nomadic Voice Service over Broadband

In section 4.3.2, it was noted that currently there is a service address registered as the device location. If the user fails to update this address upon device relocation, dispatch of emergency services to the wrong location may occur. In some cases, users may be able to provide false or incorrect addresses. Current FCC rules mandate a registered location from the service provider and that the service provider provides a mechanism for customers to update registered locations. However, the mandate does not clearly state an MSAG validation requirement.

Conclusions:

In cases where MSAG validation is accomplished, locations may be associated with a generalized ESN rather than the appropriate wireline ESN.

The ability to automatically determine 9-1-1 location is a logical goal for this service type. Regrettably, there is no universally accepted and deployed method for automatically determining 9-1-1 location for nomadic VoBB. When location can be automatically determined, the location data may not be able to be delivered to the PSAP because transport and access mechanisms are unavailable. The receipt and display of auto-location data requires design changes to the emergency service platforms.

Recommendations:

- CSRIC 4C recommends the FCC clarify that MSAG validation is a requirement for registered locations.

- CSRIC 4C recommends the FCC actively engage discussion on how to implement 9-1-1 auto-location for nomadic VoIP services. Auto-location is a significant issue for multiple service types and the Commission should utilize the ETAG to examine and provide guidance for the development and implementation of 9-1-1 auto-location capabilities in a fully end-to-end IP environment.

- CSRIC 4C recommends that at the conclusion of the ETAG analysis, appropriate technical standards be required or developed to ensure timely implementation.

9.2.6 Conclusions and Recommendations for Over-the-top Static or Nomadic VoBB

The content in section 9.2.4 and 9.2.5 for static or nomadic VoBB address interconnected VoIP subject to FCC 9-1-1 requirements. This section addresses Over-the-top services that may not be subject to FCC regulations. Certain voice services, such as those provided by Skype and Google

Voice, do not currently allow 9-1-1 calls. The Sept 23, 2010 FCC NOI has requested comments on this issue.

Conclusions:
There are no mandates to require 9-1-1 location for Over-the-top Static/Nomadic VoBB despite the fact that customers may expect this capability.

Recommendations:

- CSRIC 4C recommends that public education be required to specify the limitations of Over-the- top Static/Nomadic VoBB when used to contact 9-1-1.

- CSRIC 4C recommends the FCC consider extending E9-1-1 and location obligations to providers of Over-the-top Static/Nomadic VoBB.

- To the extent that 9-1-1 requirements are extended to these services and new technical challenges materialize, referral to the ETAG should be considered.

9.2.7 Over-the top Mobile VoIP

As noted in section 4.4.2, third party over-the-top mobile VoIP software applications do not support 9-1-1 calling. We are unaware of any Over-the-top VoIP applications running on a 3G or WiFi data network that have access to location based services suitable for 9-1-1. Many of these Over-the-top VoIP applications are developed outside any regulatory frameworks. Over-the-top mobile VoIP applications designed to fall back to traditional CMRS circuit switched voice if the user dials 9-1-1 are not generally available.

Conclusions:
CSRIC 4C concludes that applications developed outside any regulatory framework pose security vulnerabilities such as location spoofing.

Location may be accessible by commercial Over-the-top applications, however at this time the location may not be suitable or accurate enough for 9-1-1. When location is accessible, there is currently no method to transfer that location to 9-1-1 transport mechanisms.

Recommendations:

- CSRIC 4C recommends the FCC should consider extending E9-1-1 and location obligations to providers of Over-the-top mobile VoIP applications.

- CSRIC 4C recommends public education should be required to specify limitations of over-the-top VoIP 9-1-1 applications.

- To the extent that 9-1-1 requirements are extended to these services and new technical challenges materialize, referral to the ETAG should be considered.

9.2.8 Conclusions and Recommendations for Circuit Switched Voice in CMRS

As noted in section 4.5.1, CMRS systems (GSM, UMTS, iDEN, and cdma2000 networks) commonly employ the position methods described above which provide conformance with the current FCC E9-1-1 Phase II location requirements. Consequently there are no gaps in terms of supporting current FCC requirements.

Location accuracy differs between network and handset based location determination methods and is also a function of the user environment. Location evaluations typically categorize outdoor environments as rural, suburban, urban, and dense urban. These environments present differing levels of challenge for various positioning methods. In-building location may not be available, or, if available, accuracy of the location may be degraded.

Calls to 9-1-1 must be routed with the cell site/sector information available at the time the call is made. In many cases, this location is not as accurate as Phase II information. The CMRS' ability to use Phase II location for 9-1-1 call routing is limited due to the TTFF and other non technical issues.

Conclusions:

CMRS circuit-switched networks are widely deployed and supporting E9-1-1 Phase II location determination for many years, based on both international (3GPP and 3GPP2) and national (ATIS and TIA) standards. These are mature standards and leave no apparent gaps in technology implementation. However, currently deployed location methods can be challenged in certain environments (e.g., rural, indoors, or urban canyons). Location technologies are continuing to demonstrate performance improvements.

Recommendations:

- CSRIC 4C recommends that the ETAG address potential improvements to in-building location performance.

- The FCC recently released PSAP/county-level accuracy rules that will take time to implement. CSRIC 4C recommends that the FCC evaluate the impact of these rule changes prior to making significant additional modifications to the 9-1-1 and E9-1-1 rules.

- CSRIC 4C does not view Z height as a priority issue and recommends that the ETAG address viability for 9-1-1.

9.2.9 Conclusions and Recommendations for CMRS Managed IMS Based VoIP

As noted in section 4.5.2, CSRIC 4C believes it is unclear how existing FCC CMRS rules will apply to CMRS managed IMS based VoIP.

Conclusions:

CMRS IMS based VoIP networks have not yet been deployed but the standards on which they will be based are now complete and provide for E9-1-1 Phase II location determination using position methods the same as or similar to those already defined or deployed for CMRS circuit-switched networks. Hence, no standards gaps exist with regard to location determination. These standards assume that CMRS IMS based VoIP networks will have the same Phase II accuracy requirements as CMRS circuit-switched networks.

Recommendations:

- CSRIC recommends the FCC clarify if existing rules will apply to CMRS managed IMS based VoIP services.

- CSRIC 4C recommends the FCC not establish distinct location accuracy standards for IMS services and recognize that standards are based on AGPS and EOTD. The ETAG should partner with the existing standards working groups to continue to test and evaluate these technologies.

9.2.10 Conclusions and Recommendations for Femtocells

In section 4.6, CSRIC 4C notes that due to the lack of consistent deployment and implementation methods for femtocells relative to E9-1-1, each carrier may populate ALI data fields differently when an emergency call originates on a femtocell. Some carriers may populate the ALI information with the civic address of the nearest cell tower (macro cellular site), while others use the registered civic address for the femtocell. 9-1-1 calls can be made from anywhere within the femtocell coverage area and the geodetic location provided to emergency service will be the location of the femtocell.

Conclusions:

There is no consistent method for the PSAP to discern whether the civic address or latitude/longitude on their ALI screen represents a femtocell. This prevents the PSAP from potentially recognizing a more accurate location for the caller.

In cases where GPS is used to determine the femtocell location, the accuracy may be degraded if the femtocell is located deep inside a building where GPS signals are weak.

The FCC rules currently classify femtocells as a CMRS service. Not all femtocell type products are deployed the same way and therefore the CMRS classification is not embraced by all stakeholders.

Recommendations:

- CSRIC 4C recommends that if the registered address of a femtocell is displaying on ALI, the carriers must MSAG validate that registered address.

- The FCC should clarify how femtocells be treated for the purpose of 9-1-1and should avoid imposing any further obligations on femtocell carriers until this matter is addressed.

- Emerging femtocell technologies merit further study, and the ETAG is the most appropriate group to conduct such a review.

- CSRIC 4C recommends the development of a standardized set of femtocell location data that is discernable by the PSAP.

- Standards related to deployment methods of femtocells for 9-1-1 should be developed.

9.2.11 Conclusions and Recommendations for Universal Mobile Access (UMA)

As noted in section 4.7, for UMA not all carriers are MSAG validating the customer provided addresses for UMA calls that are routed as VoIP. Relying on non-validated addresses can cause errors in handling 9-1-1 calls at the PSAP. It is also not known if MSAG data is available for carrier use in validating customer provided addresses.

Conclusions:
CSRIC 4C concludes that a lack of standards for consistent validation methods for UMA calls to 9-1-1 present challenges for location accuracy. Absent a specified or standard method to require validation of the address, there are inconsistencies among carrier processes.

Recommendations:

- The recommendations listed in section 9.2.10 with regard to regulatory issues also apply to UMA.

- CSRIC 4C recommends all providers including new entrants have open access to MSAG data in order to incorporate it into their business processes, especially in validation of customer-provided location information.

- CSRIC 4C recommends that standards related to validation methods of UMA for 9-1-1 be developed.

9.2.12 Conclusions and Recommendations for Vehicular Telematics

In section 4.7, two models were described for vehicular telematics services. In the first calling model, TSP's are often not able to deliver voice and data directly to a PSAP via the 9-1-1 system. In these instances, the TSP must contact the PSAP via a 10 digit line. In cases where location information is conveyed verbally by the TSP, human error can be introduced. There are cases where the TSP utilizes a third party provider to route calls directly to PSAPs using the solution described in Nomadic VoIP. In these cases the general VoIP class of service is often associated with the call.

In the second calling model, when a PSAP receives coordinates from the wireless phone and also from the GPS in the car, there may be a difference in location coordinates provided.

Conclusions:
The PSAP may have difficulty discerning which coordinates are best to use in the second calling model to locate the vehicle if the occupants cannot verbally relay their location.

The PSAP may have difficulty discerning telematics calls unless a telematics class of service is implemented.

Recommendations:

- No location related recommendations are being made

9.2.13 Conclusions and Recommendations for Machine-to-Machine (M2M)

CSRIC 4C noted in section 4.9 that it is not clear if M2M devices will contact 9-1-1 call centers directly or will utilize an intermediary call center. If contacting 9-1-1 directly, it is unclear what location technologies these devices will employ.

Conclusions:
CSRIC 4C concluded that it is premature to determine how this technology will be used in 9-1-1 and how location accuracy will be impacted

Recommendations:
- CSRIC 4C recommends that additional research and evaluation be conducted on how M2M will impact 9-1-1.

9.2.14 Conclusions and Recommendations for Telecommunication Relay Service (TRS) and Private Call Centers

In section 4.10, CSRIC 4C notes that location is verbally or manually communicated to the TRS relay centers by the caller. The TRS relay center must then verbally communicate the location to the PSAP. Location validation against MSAG is not applicable. TRS relay centers must rely on a national PSAP registry database to identify the correct PSAP that will handle the call. There are several PSAP registries in use and, to date, all have faced challenges in maintaining accurate data.

Conclusions:
CSRIC 4C concludes location requirements for TRS relay services are being considered by the FCC and DOJ and, as such, the requirements are unclear at the present time.

Recommendations:
- CSRIC 4C recommends the FCC and DOJ develop requirements for TRS location.

9.2.15 Conclusions and Recommendations for Satellite Service

In section 4.11, CSRIC 4C notes that for the satellite service, location acquisition is handled via verbal communication with a third party call center. Location validation against MSAG is not applicable. Call centers must rely on a national PSAP registry database to identify the correct PSAP that will handle the call. There are several PSAP registries in use and, to date, all have faced challenges in maintaining accurate data.

Conclusions:
CSRIC 4C concludes that data available to the PSAP to interpret location information obtained via verbal communication with the third party call center may not be accurate or available.

Recommendations:
- CSRIC 4C recommends that the potential for automatic location from satellite devices be investigated and evaluated.

9.2.16 Conclusions and Recommendations for Emerging Service Types

As CSRIC 4C notes in section 4.12, for emerging service types, current standards development efforts are focusing on IP based originating networks and 4G technologies such as LTE and WiMAX. The evaluation and investigation of backward compatibility with existing systems is still in progress.

Conclusions:
Regulatory rules for location do not currently exist.

Recommendations:

- CSRIC 4C recommends that standards work be completed as soon as possible (i.e. NOVES and other initiatives).

- Regulatory guidelines should be established for how Emerging Service types are integrated with the 9-1-1 system. The expectation is that location accuracy at least be comparable to what is deployed today.

9.3 Conclusions and Recommendations on the Use of Emerging Location Technologies

Section 5.2 reviewed Emerging Location Technologies and their potential suitability for future E9-1-1 applications. While a number of these technologies offer some promise for improved performance in challenging environments, there are several barriers to adoption that need be to be addressed and overcome. Despite claims of certain technology proponents, CSRIC 4C has not identified any location technology available to improve accuracy that does not require further research and development before implementation.

9.3.1 Device Barriers for adoption of emerging technologies

For telephony devices, the probability of adoption of a new technology will be increased if it leverages sub-systems that are already present in the device. A relevant example is the emerging location technologies offered by Wireless WERX and Rosum.

The Rosum solution required DTV receivers (including a TV UHF band antenna) to be embedded in their mobile devices. The burden of adding this dedicated location subsystem to a mobile device was met with opposition by the device industry due to a number of technical constraints, and contributed to the lack of success of Rosum in promulgating their technology.

Wireless WERX and other Bluetooth based location technologies rely on the use of Bluetooth devices which are becoming prevalent in mobile devices. Regardless, special software clients must be installed and properly configured for such a system to work properly. These software clients need to be preloaded or embedded at the middleware or service layer to ensure that they will work as planned.

9.3.2 Infrastructure Barriers for adoption of emerging technologies

In addition to the technology issues above, UE support for an emerging technology is not sufficient to ensure success. In the Wireless WERX and Rosum comparison, Rosum relied on an existing infrastructure of ATSC towers as location beacons. However, in the WirelessWERX solution, a mass deployment of in-building beacons is required to make this a universally adoptable system.

Some of the other emerging technologies described in section 5.2 also depend on beacons or receivers deployed across a metropolitan area. At the present time, it is unclear who would be responsible for deploying and maintaining this type of location infrastructure. One idea that has been suggested is that building or apartment owners deploy and maintain the infrastructure[19].

9.3.3 Maintenance of Location Beacon Sources

The location technologies discussed in this report rely on beacon signals. It is therefore relevant to discuss what organization/group is responsible for maintaining the accuracy and reliability of the beacon source. For example, the GPS location method relies on a precisely controlled constellation of satellites that transmit distinct reference signal patterns along with information accurately describing their position. The U.S. Government maintains and assures the reliability of the GPS system.

Location solutions such as AFLT, U-TDOA, RFPM and D-TDOA rely on signals transmitted by or received from network elements in the wireless carrier's system. The wireless service provider must also maintain an accurate database of the base station locations. They must properly maintain timing of the reference signals and monitor receivers used in the location system. The reference signals must be operating properly in order to keep the cellular network fully functional. Wireless service providers are responsible for assuring the integrity of these functions.

The robustness and accuracy of location systems required for LBS may NOT guarantee its suitability for 9-1-1. For example, some WiFi location systems described in section 5.2.1are used only for LBS, and the user is not explicitly given any guarantee of location accuracy. CSRIC 4C encountered at least one provider of such a service that explicitly stated that it was *not* intended for 9-1-1usage. The reason may be due to the fact that the location beacon sources (e.g.; WiFi APs) are *not* explicitly controlled or maintained by any WiFi location provider. The owner of the AP is able to move it at any time, and the WiFi location provider will not be aware of its relocation until recalibration is performed.

9.3.4 Conclusions on Adoption of Emerging Location Technologies

As discussed above, any new technology candidate must provide a practical solution to the three requirements described above: (1) Leveraging of hardware subsystems or MAC layer protocols already present in the UE device (2) a realistic plan for deploying any added beacon (or other) infrastructure required to support the solution in a metropolitan area, and (3) a maintenance/support plan to maintain the integrity of said infrastructure. So far, the CSRIC 4C committee has not identified any Emerging Location Technology that addresses all three of these requirements.

Ultimately, the selection and deployment of a new location technology must be based upon evidence that the solution provides an identifiable improvement over existing methods which are evolving to give better performance. In the semiconductor industry, for example, there have been many new memory technologies that have been highly touted as the replacement for DRAM; yet, for 30 years now, none of them have proven to give enough of an advantage to displace DRAM in most computing architectures. Likewise, many of these emerging location technologies are being heavily promoted by the provider, based on some promising trial data in certain scenarios, but a thorough validation of performance must be executed before adoption,

[19] <http://www.wirelessweek.com/News/2010/01/Technology-WirelessWERX-Bluetooth-911/>

assuming all other barriers to adoption are addressed properly. Even if the new technology proves positive after this thorough validation, it must offer an advantage, and not just equivalence, over existing location methods in certain environments before actual deployment consideration.

9.3.5 Recommendations on Adoption of Emerging Location Technologies

From the analysis in section 5.2, CSRIC 4C recommends that emerging technologies such as WiFi, wireless beacon and Bluetooth beacon methods be further researched for use as additional 9-1-1 location technologies, but only if the limitations discussed in 5.2 and above are overcome. These should be considered supplemental technologies to A-GPS and any currently deployed network location technologies for environments where the deployed technologies may not perform adequately, such as indoor settings. The above recommendation reflects what is known and understood at the time this report was written. Continuing research of new technologies is necessary.

9.4 Conclusions and Recommendations for new access methods for Emergency Services

Early stage standardization efforts commenced for new 9-1-1 access methods, most notably Text-based messaging combined with multimedia. The NENA NVC (Non-Voice-Centric) and 3GPP NOVES (Non-Voice Emergency Services) initiatives are resulting in high level requirements for networks and devices.

9.4.1 Conclusions

Detailed **location** requirements for these access methods are yet to be developed. The discussion of location technologies contained in this report applies directly to these emerging 9-1-1 access methods. While location transport methods are yet to be determined for non-voice, the need for accurate location across diverse environments and device types exists just as strongly for non-voice 9-1-1 sessions as with voice calls.

Next generation emergency services requirements developed through the NENA NG Messaging Working Group's efforts are focused on IP-based non-voice-centric emergency service requests. As this is a component of a major change to the 9-1-1 service, adoption of these requirements will take several years. Experience suggests that unless consensus exists among government agencies at the local, state and federal levels, as well as carriers, vendors and other service providers, implementation for many PSAPs could take a long time.

9.4.2 Recommendations

- CSRIC 4C recommends the next step in the development process for non-voice emergency services is to liaise these requirements to the appropriate standards development community.

APPENDIX

Appendix A: CMRS Architecture Overview

Circuit Switched-based CMRS

Circuit-switched CMRS uses what is defined as a "Control Plane" location solution that makes use of procedures, signaling, and resources which are distinct from those used to transfer voice and data traffic. The Control Plane signaling involves the use of existing signaling interfaces and signaling protocols to transport location related content such as GPS assist data, UE location measurements, and actual location data back and forth to a location server. The alternative method to Control Plane signaling is termed "User Plane", where typically secure IP-based transports such as TCP/TLS are used to connect to a Location Server. The most well-known example of a User Plane location method is SUPL (Secure User Plane Location), which is often used for 3GPP Location-based services (LBS). Control Plane Location was developed for E9-1-1 calling because it was perceived at the time to be better integrated with the existing infrastructure, which could not then guarantee to support an IP data session active concurrently with a voice call. An architectural overview of the Control Plane solution is shown in Figure A1.

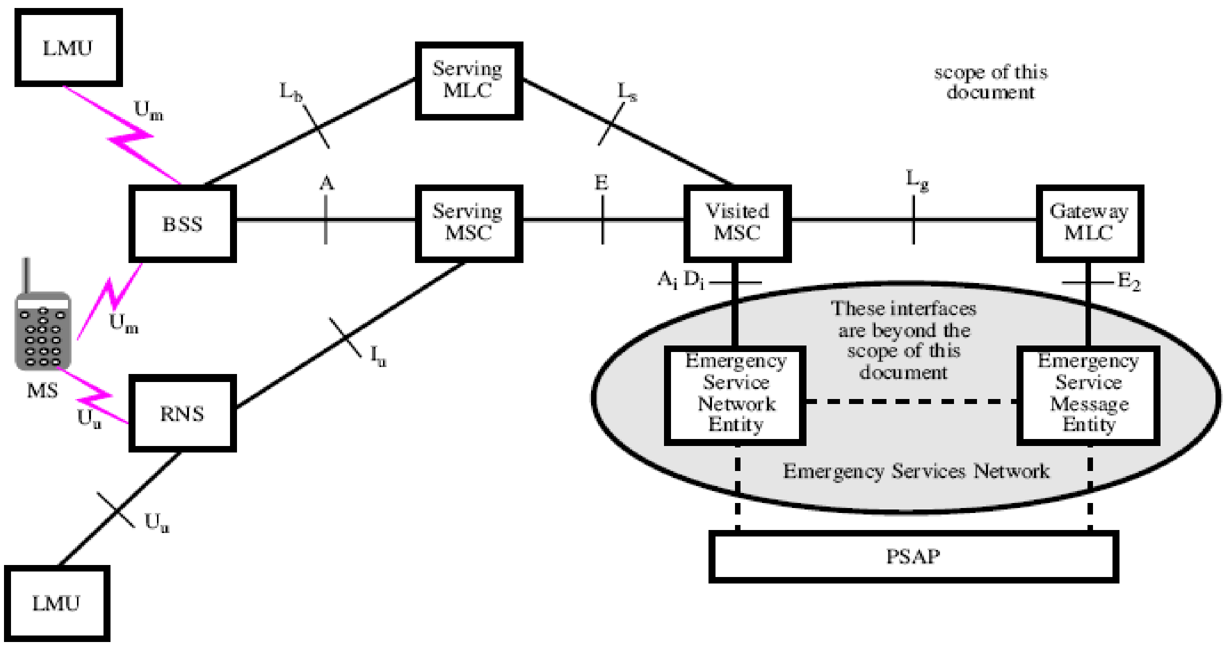

Figure A1: Architectural Overview of Control Plane solution

Location determination is supported by a number of position methods that are implemented in one or more of the entities shown in Figure A1. These entities comprise the following:

- *Visited MSC*: GSM or UMTS Mobile Switching Center (MSC) that is anchoring switching services for a mobile user at the time an E9-1-1 call is originated.
- *Serving MSC*: GSM or UMTS MSC that is connected to the serving base station for an emergency calling user at any time during an E9-1-1 call.
- *BSS*: GSM Base Station Subsystem serving an emergency calling user at any time during an E9-1-1 call.
- *RNS*: UMTS Radio Network Subsystem that is providing base station services similar to a BSS for an emergency calling user during an E9-1-1 call.

- *Serving MLC*: Serving Mobile Location Center (SMLC) coordinating location support for an emergency calling user.
- *LMU*: Location Measurement Unit employed for some terrestrial positioning methods (e.g., U-TDOA, OTDOA).
- *MS*: Mobile Station representing the device (e.g., phone, smart-phone, PDA) from which an emergency call is originated.

Standalone GPS is supported entirely within the MS and makes use of measurements of signal timing by the MS for typically 4 or more GPS satellites together with orbital and signal-related data that can be captured from these signals and used to convert the timing measurements into a location estimate.

A-GPS is supported by the MS and SMLC and frees the MS from having to capture data transmitted by GPS satellites by having both the transmitted data and additional data delivered to the MS by the SMLC.

U-TDOA is supported by the SMLC and LMUs and is transparent to the MS. LMUs measure the timing of signals transmitted by the MS (e.g., signals employed for uplink voice traffic) and transfer the measurements to the SMLC for location determination.

RFPM is supported by the SMLC and BSS or RNS. Signal strength, signal-to-interference ratio, and/or time delay measurements made by the MS, BSS or RNS are transferred to the SMLC for location determination."

ECID is supported by the SMLC and BSS or RNS. Signal strength, signal quality, and/or signal propagation timing measurements of the MS made by the BSS or RNS together with normal operational signal measurements received at the BSS or RNS from the MS are transferred to the SMLC for location determination.

Cell ID location is supported within the SMLC and involves using knowledge of just the serving cell identity to produce a location estimate – e.g., which might be the coordinates of the cell tower or the centroid of the cell coverage area.

Some additional support is provided by the visited MSC and BSS or RNS for all methods in terms of helping transfer location related messages and, in the case of U-TDOA, coordinating measurements. Once a location has been determined, it is provided to the Gateway MLC (GMLC) by the visited MSC for onward transfer to the PSAP.

The A-GPS, U-TDOA and RFPM position methods have been designed to support both the 67% and 95% FCC Phase II accuracy requirements while ECID and Cell ID are intended to help support these requirements – e.g., provide a location estimate when one is not possible using either of the other methods.

In the case of 3GPP2 cdma2000 1xRTT networks, A2 shows an overview of the architectural solution. Note that this figure omits base stations (connected to the MSC) and the MS but is otherwise comparable in detail to A1.

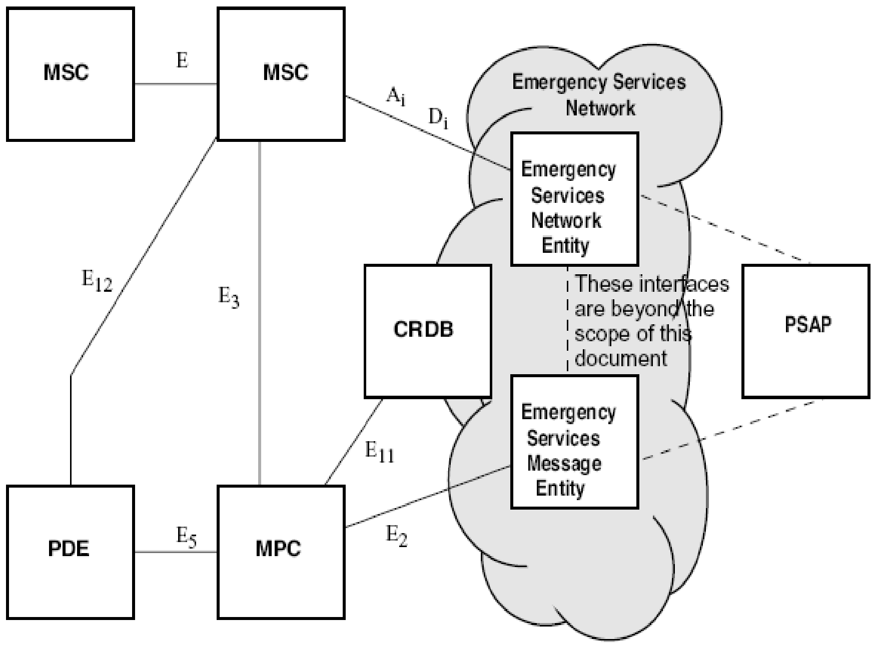

Figure A2: Overview of E9-1-1 Phase II solution applicable to cdma2000 1xRTT

In this architecture, the Position Determining Entity (PDE) has the same role as a 3GPP SMLC, and the Mobile Position Center (MPC) has the same role as a 3GPP GMLC.
Position methods applicable to the 3GPP2 solution comprise A-GPS, AFLT and cell ID. A-GPS and cell ID are functionally the same as employed for the 3GPP solution (though the network signaling employed is different). AFLT (Advanced Forward Link Trilateration) is similar to 3GPP E-OTD and OTDOA in making use of downlink signal timing measurements by an MS. However, because cdma2000 1xRTT base stations are accurately synchronized to GPS time, whereas GSM and UMTS base stations employ asynchronous timing, timing measurements are easier to obtain at an MS and LMUs are not required to determine the real base station timing differences.

In addition to supporting accurate location delivery to a PSAP, location determination can also provide a role in routing an E9-1-1 call to the correct PSAP. In some cases, routing may be entirely based on knowledge of the serving cell which can be included via an appropriate 10 digit North American Numbering Plan (NANP) parameter in the call origination request (e.g., SS7 ISUP IAM message) to direct any selective router to transfer the call to the PSAP serving the area covered by the serving cell. However, because PSAP boundaries may sometimes traverse the area covered by a cell, provision is made for obtaining a more accurate location estimate before a call is routed using U-TDOA, RFPM, ECID or AFLT. In such cases, the SMLC (for GSM or UMTS) or PDE (for cdma2000 1xRTT) determines an approximate location estimate for an MS in the first second or two after an emergency call origination has been requested by an MS. The location estimate is subsequently transferred to the GMLC (for GSM or UMTS) or MPC (for cdma2000 1xRTT) where it is converted into a 10 digit NANP parameter representing the intended destination PSAP for inclusion in the call origination request.

Packet Switched-based CMRS (IMS-based Voice)
For packet-switched CMRS (VoIP), the voice traffic would be carried over an IP bearer on the radio interface to the user device and within the originating CMRS network. Depending on the PSAP capability, the voice traffic would be delivered to the PSAP using either existing CS resources (e.g., via a PSAP selective router) or new IP associated resources if the PSAP is IP capable. Because the difference between these alternative possibilities concerns only the PSAP side and the interface to the PSAP side, it has been possible to produce essentially a single 3GPP solution and a single 3GPP2 solution to support both possibilities. Moreover, the 3GPP and 3GPP2 solutions share a common core network component based on the IP Multimedia Subsystem (IMS) – implying greater efficiency of implementation than was possible for the CS case where 3GPP and 3GPP2 solutions differed significantly in most network aspects. For CS capable PSAPs, the procedures and signaling defined in J-STD-036 could continue to be used – at least for initial deployment. For an IP capable PSAP, new procedures and signaling are needed. These have been defined by IETF and NENA. However, there is currently no universal industry wide agreed end to end solution comparable to the J-STD-036 solution for CS mode. Nevertheless, NENA has been working on defining such a solution (the i3 standard) and more recently ATIS has started defining a related and (it is expected) compatible solution specifically applicable to CMRS network origination.

Note that when an operator provides end devices with both CS access and IP access (e.g., using LTE or UMTS from 3GPP or HRPD from 3GPP2) over the same geographic area, it is possible to employ a procedure known as Circuit Switched Fallback (CSFB) to originate an emergency call using CS mode if a user initiates an emergency call while the device has IP access but not CS access. In that case, the emergency call would be established using the architecture and procedures described in section 4.4.1 once the CSFB procedure has switched the access mode to CS. This provides an additional deployment option to operators that could be used initially before IMS deployment is fully mature.

Despite the lack of a universally agreed end-to-end solution allowing for use of IMS in an originating CMRS network in the all IP case, the existence of complete IMS based 3GPP and 3GPP2 solutions applicable to an end device and an originating CMRS network will allow deployment of emergency VoIP support by CMRS carriers in the case that a phase 0, Phase I or Phase II capable CS mode PSAP has not been upgraded with any new capability. This would be enabled by making use of existing procedures and signaling defined in J-STD-036 for CS mode PSAPs. Hence, deployment of emergency VoIP capability by CMRS carriers will be possible, once normal VoIP services are deployed.

The 3GPP and 3GPP2 solutions for emergency VoIP support employ a common solution in the core network based on IMS and use of the Session Initiated Protocol (SIP) for call related signaling. The IMS architecture and related procedures are defined in 3GPP TS 23.228 and the architecture and procedures applicable to emergency VoIP calls are defined in 3GPP TS 23.167. An outline of the architecture and procedures for emergency call establishment and location support is shown in Figure A3.

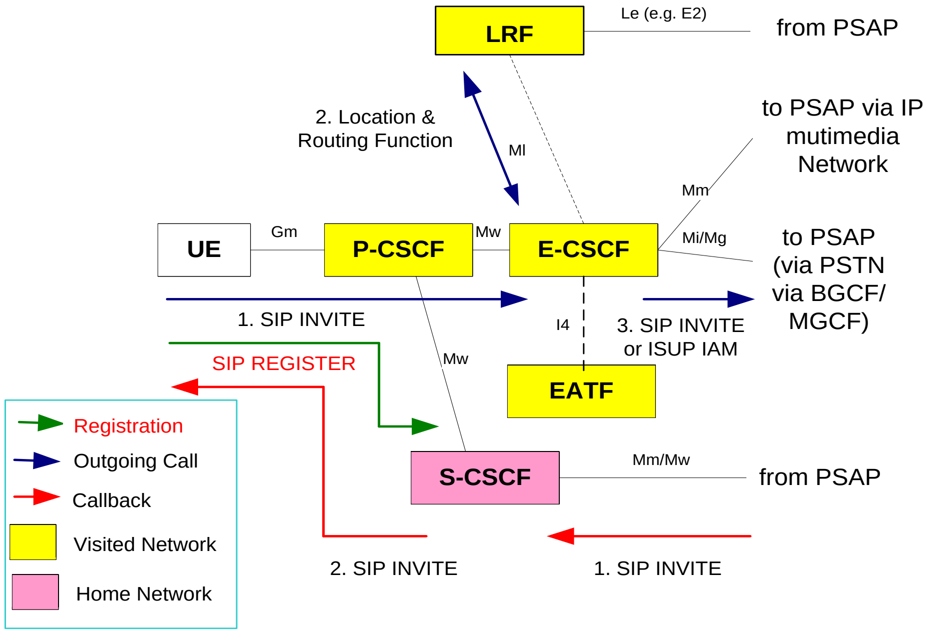

Figure A3: Overview of the CMRS IMS Solution for VoIP Emergency Calls

CMRS network entities most applicable to support of VoIP emergency calls comprise the following entities shown in the figure:

- *P-CSCF*: Proxy Call Server Control Function (CSCF), which is the point of entry into a serving network IMS for any originated emergency call.
- *E-CSCF*: Emergency CSCF, which provides dedicated emergency call handling including of a call to the correct PSAP.
- *LRF*: Location and Routing Function, which supports location determination and selection of the correct PSAP based on location.
- *EATF*: Emergency Access Transfer Function, which may be applicable if an IP-based emergency call is later converted to a CS mode call due to handover from an IP supporting access to a CS access type.
- *S-CSCF*: Serving CSCF, which is located in the home operator's network and supports emergency SIP registration of a user device following user instigation of an emergency call and prior to originating the call in the serving network.
- *UE*: User Equipment.

Not shown in the figure is access network specific support which depends on the type of wireless access. For 3GPP defined networks, the access type can be either UMTS or LTE, although operators have not deployed VoIP on UMTS networks due to a variety of technical challenges. For 3GPP2 defined networks, it would be HRPD.

Location determination is coordinated by the LRF in the above figure and for 3GPP based networks may employ either a control plane solution or user plane solution such as the Secure User Plane Location (SUPL) solution defined by the Open Mobile Alliance (OMA), which is an international organization supported by both 3GPP and 3GPP2 member companies. The position methods defined for both control plane and user plane solutions are functionally identical or very similar to the position methods defined and used for CS mode, thus using control plane or user plane does not impact location accuracy itself. Position methods that are functionally identical comprise standalone GPS, A-GPS, and A-GNSS. Position methods that are very similar comprise ECID, AFLT, OTDOA, and U-TDOA – the difference with CS mode usage concerning only the different signals that are measured as opposed to the general procedures and methods of location computation.

The 3GPP Standards-based IP voice architecture in 3G and 4G protocol technologies is based solely on IP Multimedia Subsystem (IMS), as described above, and this is what wireless carriers are expected to adopt for their own managed VoIP clients with 9-1-1 capability. It must be noted that, unlike the Circuit-switched CMRS protocols described above, IMS Voice with 9-1-1 Location support has not yet been deployed as of the date of this report, and it is likely that IMS-based voice will be deployed starting with LTE technologies (Voice over LTE, or VoLTE). It must also be noted that currently available “Over-the-top” wireless and wireline VoIP services now utilize H.323, SIP, or proprietary signaling protocols rather than IMS. (For 9-1-1 calling, there is at least one VoIP application using circuit-switched fallback, while many others do not support 9-1-1 at all.) While these use the 3GPP 3G/4G networks purely as a data pipe, they may eventually all be required to support 9-1-1 calling with location. In those cases, it is possible that 9-1-1 VoIP location could be implemented using non-IMS or non-CMRS standard location delivery methods that are nonetheless still compatible with the i2.5 and i3 architecture specifications defined by NENA.

Femtocells in CMRS

Femtocells, also known in standards as Home Node Bs (HNBs), are small cellular base stations, typically designed for use in a home or small business. It connects to the cellular service provider’s network via broadband (such as DSL or cable). The femtocell concept is applicable to all standards, including GSM, UMTS, CDMA2000, and LTE solutions.

In the case of UMTS, femtocells are known as Home Node Bs (HNBs) and replace the entities (Node B and RNC) used in the access network for macro and pico cell support. Figure A4 shows an overview of the architecture defined to support HNBs by 3GPP and one method by which location can be determined.

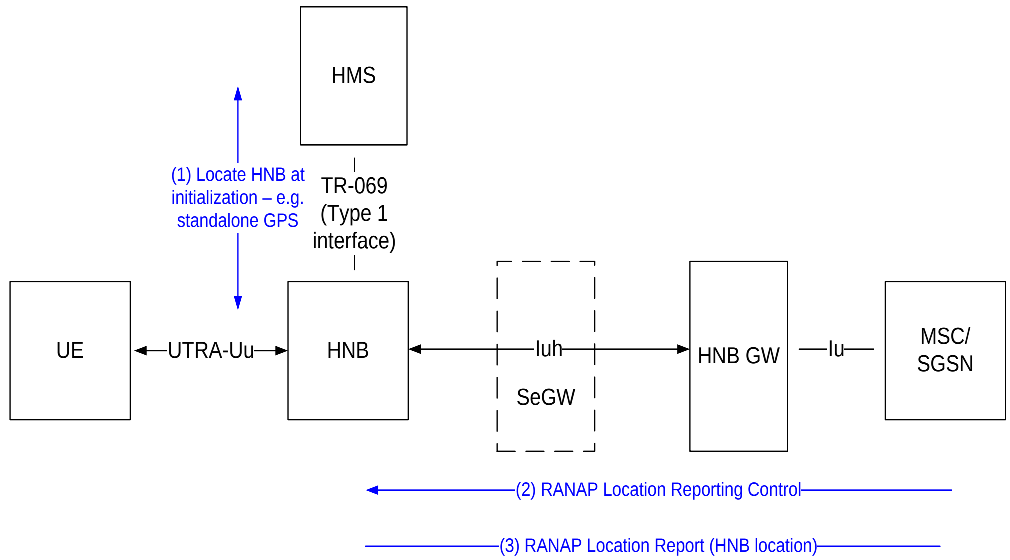

Figure A4: Overview of the 3GPP HNB Solution

HNBs would typically be purchased and installed by users (not an operator) and hence their existence including identity and location would not become known until an HNB had attached to the operator network (e.g., via a DSL or cable link) and powered on. At that time, an initialization procedure would be performed to verify that the HNB is authorized to provide service on behalf of the home operator. The initialization procedure provides information on the HNB to relevant entities within the operator's network – particularly the HNB Management System (HMS), any HNB Gateway (HNB GW) used as an intermediary between the HNB internet connection and operator core network, and the CS or IP associated switching elements (MSC or SGSN respectively). Initialization also configures the HNB and verifies that the HNB is in a valid operator licensed area. This is typically (though not always) done by obtaining the location of the HNB – e.g., using standalone GPS in the HNB. Once an HNB has been correctly initialized, it is able to provide authorized voice and data services to authorized users (e.g., not necessarily to all users of the operator as would be the case for macro and pico cell associated base stations).

If a user who is accessing an HNB instigates an emergency call (which would normally use CS mode, though could in the future employ VoIP), one option is that the network may force the user device to attempt the call using an available macro cell. In that case, any location determination would occur as described for CMRS networks. Alternatively, the user may be permitted to place the emergency call using the HNB. In that case, call origination will proceed in a similar manner to that defined for pico or macro cell access in both the CS mode and VoIP cases. However, location determination will not currently employ exactly the same solutions and position methods (though this may change in the future). Currently, the location of the HNB would typically be used as a good approximation for the location of the mobile device – e.g., as shown in Figure A1. The HNB location would have been obtained when the HNB initialized (and might possibly have been re-obtained at a later time). Assuming standalone GPS was used, location accuracy would typically conform to E9-1-1 Phase II requirements as for the case when GPS is used on a device. Since a femto coverage area is normally very limited – e.g., to 50 meters or less and often much less when a femto is used within a small office, home, or apartment – the femto location will be a very good approximation for the device location. This means that E9-1-1 Phase II requirements will be supported.

3GPP femtocells that will support LTE access are known as Home E-UTRAN Node Bs (HeNBs). As with LTE macro networks, these will only support emergency calls using VoIP and not CS mode. The location solution for emergency calls over an HeNB is still evolving in 3GPP, but is likely to employ the same or almost the same position methods as currently defined for emergency VoIP calls over LTE macro and pico cells. Hence, compliance with E9-1-1 Phase II requirements is expected.

3GPP2 femtocells, known as Femtocell Access Points (FAPs), that support cdma2000 1xRTT access are now standardized and being deployed. The solution used to support emergency calls and location determination is defined in J-STD-036 rev C and in 3GPP2 X.S0059. Figure A5 shows the architecture applicable when a FAP is attached via a legacy MSC that is also used to support 1xRTT services via macro and pico cells.

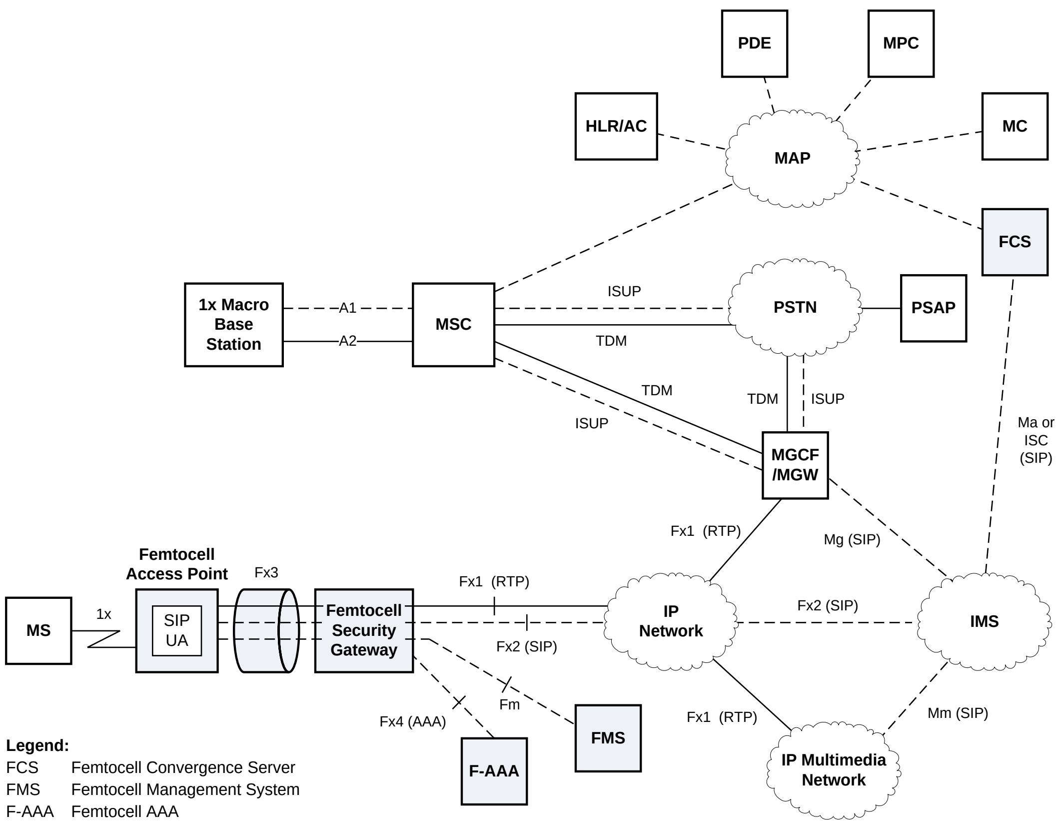

Figure A 5 Overview of the 3GPP2 FAP Solution for connection via an MSC

From the perspective of the MS and PSAP, emergency call origination and location determination are the same using a FAP as via a base station for a macro or pico cell. However, within the cdma2000 network, location determination can make use of both the FAP location and position methods applicable to 1xRTT macro and pico cell access. FAP location could be determined using standalone GPS (as for 3GPP UMTS femtocells) and would have similar expected accuracy and -- again, due to the very small coverage area of a FAP -- would be a good approximation for the MS location meeting existing location accuracy requirements. Additionally, in case the FAP derived location is not considered accurate enough, the A-GPS and AFLT position methods described earlier for CMRS cdma2000 networks can be used to directly locate the MS. The combination of both alternatives means that from a standards perspective, location support for 3GPP2 1xRTT femtocells is expected to conform to E9-1-1 Phase II requirements.

Appendix B: Project RED Summary

Background[20]

In June 2008 the State of California initiated a project called Routing on Empirical Data (RED). The concept of the project was to breakdown historical WPH2 PSAP Call Detail Records (CDR) by WSP and sector in order to view the jurisdiction the call originated in order to determine optimal routing. Within the state of California, CPUC 2892 directs that all cellular 9-1-1 calls must be initially routed to the highway patrol. In 2000, an amendment was added with four stipulations to be met in order for calls to be directly routed to local agencies. These stipulations are: The 9-1-1 call originates from a location other than a freeway, the alternate routing is economically and technically feasible, alternate routing will benefit public safety and reduce burdens on dispatchers for the highway patrol, and that the CHP, 9-1-1 office, the PSAP, and the wireless providers determine it is in the best interest of and provide a more effective emergency service to the public. The RED Project was established to meet all of these stipulations.

The state 9-1-1 office captures the CDR data for all PSAPs within the state of California. The latitude and longitude of each CDR record was plotted over a geographic map with PSAP jurisdictional boundaries to determine the initial location of the caller. An evaluation of the map showing where calls originated and where the optimal routing of the sector could be, was conducted by the PSAP, County Coordinator and California Highway Patrol. Based upon the results indicating which PSAP received the majority of calls from the sector, the sector can potentially be rerouted to the more appropriate PSAP. The RED Project has evaluated over 50M individual CDR records during the first three phases in order to obtain the statistical data needed for the project. More information on the RED Project can be found at: <http://www.cio.ca.gov/PSCO/911/msdocs/CALNENA2010WirelessE911RoutingOnEmpiricalData.ppt>.

Findings

The results of the first three of the six region project encompassing the entire State of California have resulted in over 51% of the evaluated sectors being directed to a different PSAP than originally deployed. The more effective routing of sectors has greatly reduced transfers between PSAPs and thus reduced the California E9-1-1 busy conditions from 4.9M (42%) in 2007 to 1.2M (8%) in 2009. The outcome has resulted in 9-1-1 calls being handled more expeditiously and improvements in response times. Some additional results from the project have revealed that:

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[20] Elements of a Research Proposal and Report; Source: http://www.statpac.com/research-papers/research-proposal.htm

- Telecommunications Verification Worksheets (TVW's) and coverage radius projections provided by the WSPs do not always compare accurately to the actual cell site coverage or the actual WPH2 CDR, because these estimates are often affected by atmospheric and other conditions that change over time.
- Approximately 20% the initial location estimates are falling outside of these projections.

The State of California recently completed their 2010 research and statistics and the results continue to show improvement for routing or wireless calls.

The attached maps for San Bernardino County in California counties cover virtually every topographic feature variance in the United States. San Bernardino County (*see figure 1 and 2*) covers the desert, coastal mountains, interior mountain ranges with heavy forestation the plains and densely populated areas. In the wireless E9-1-1 environment, where seconds count, if the dispatcher can rely on accurate location data as reported by the WSP, the more likely they are to dispatch emergency services to the location reported by the cell phone. In many instances 9-1-1 services can be dispatched in the direction of the callers' location before the dispatcher is able to pinpoint the exact location of the caller. One challenge is that some location estimates result in Phase 1 being delivered to the PSAP due to multiple variables. In some instances, a Phase 2 location may be available but not delivered to the PSAP as a result of short call duration, re-bid timing, or no re-bid requested.

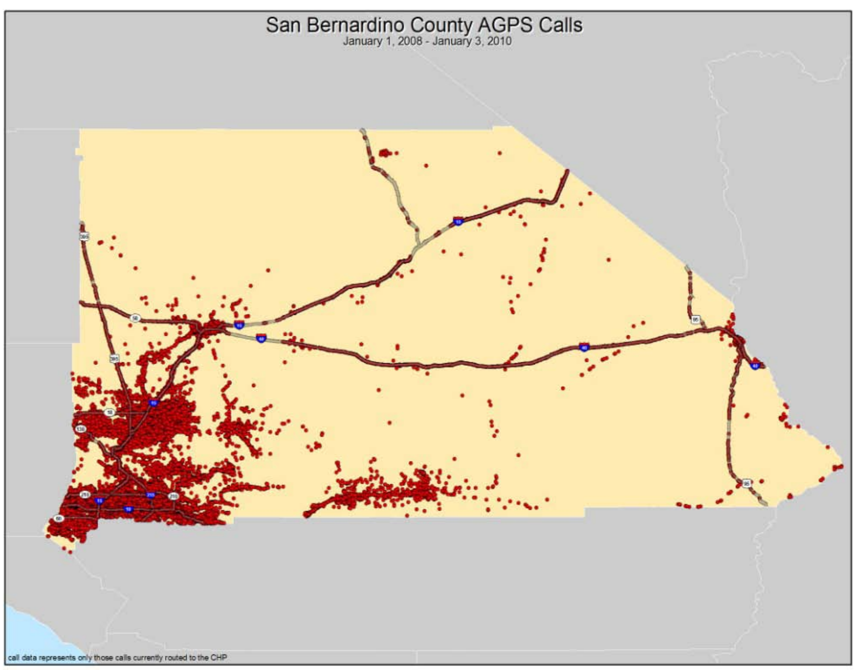

Figure 1 San Bernardino County Carrier A & B Calls

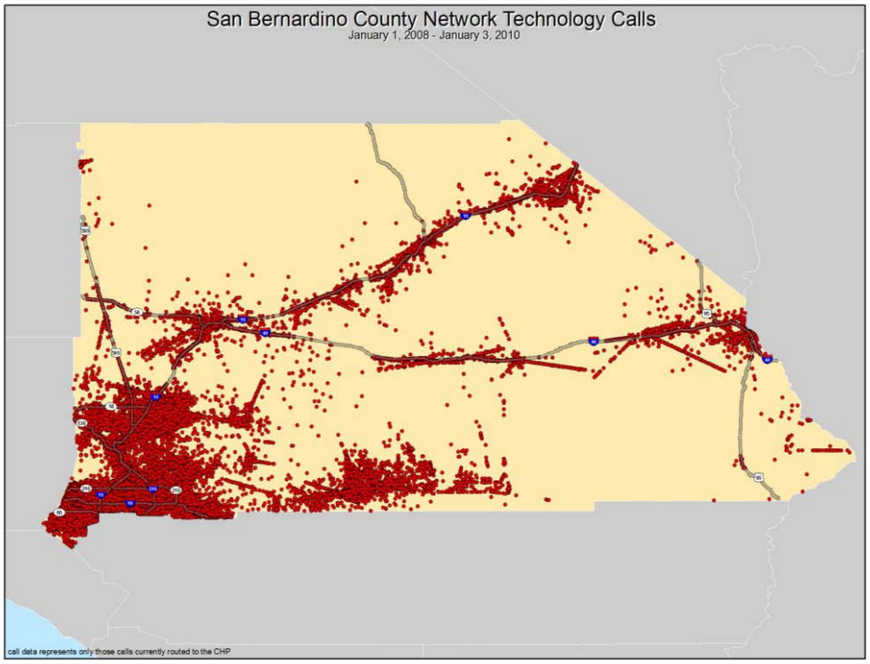

Figure 2 San Bernardino County Carrier C & D Calls

Phase I calls adversely affect 9-1-1 response times because the caller's exact location has to be verbally provided by the caller, thus emergency services cannot be dispatched until this information is obtained. While a Phase I location can be followed by a Phase II Location within 30 seconds without counting negatively against yield, this rebidding process to ascertain if more accurate location information is available from the WSP.

Conclusions
Wireless location technology developments should continue to be monitored for performance improvements that are technologically and economically feasible. The location information provided by today's cell phones has reduced 9-1-1 response times and saved countless lives but every reasonable effort should be undertaken to ensure the best location technology is provided by the device to the 9-1-1 dispatcher.

A scientific ground truth measurement method should be used to determine the statistical accuracy to demonstrate compliance with the 94-102 standards, ensuring that the location provided by the WSPs to the PSAPs is the most accurate location available.

A reference for PSAP testing best practices[21] is APCO's Project LOCATE. The complete report can be found at <

As location technology continues to evolve and improve, the general public and public safety expect to see continually increasing high-accuracy (Phase 2) location estimates. Continual improvement to location accuracy for all service types is desired and essential to effective

[21]< http://www.apcointl.org/new/commcenter911/documents/71896_Locate_Perf_Test.pdf>

emergency response.

Public Safety's position has always been that when a PSAP receives a 9-1-1 call from a person who cannot communicate or is unaware of their location, **the location reported by the wireless instrument or device can be the single most important factor between the life and death of that caller**.

<http://www.cio.ca.gov/PSCO/911/msdocs/CALNENA2010WirelessE911RoutingOnEmpiricalData.ppt

Appendix C: Glossary of Acronyms

Acronym	***Definition***
3GPP	3RD Generation Partner Project
3GPP2	3rd Generation Partnership Project 2
A-GPS	Assisted-Global Positioning System
A-GNSS	Assisted - Global Navigation Satellite System
ALI	Automatic Location Identification
ANI	Automatic Number Identification
ANSI	American National Standards Institute
AP	Access Points
APCO	Association of Public Safety Communications Officials
AS	Access Provider
ATIS	Alliance for Telecommunications Industry Solutions
ATSC	Advanced Television Systems Committee
Ca	Communications Assistant
CDMA	Code Division Multiple Access
CDR	Call Detail Record
CMRS	Commercial Mobile Radio Service
COS	Class of Service
CPE	Customer Premise Equipment
CS	Circuit Switched
CSCF	Call Server Control Function
CSRIC	Communications Security, Reliability and Interoperability Council
D-TDOA	Downlink Time Difference of Arrival
DL-OTDOA	Downlink Observed Time Difference of Arrival
DoS	Denial of Service
DSL	Digital Subscriber Line
DTV	Digital Television
E9-1-1	Enhanced 9-1-1
ECID	Enhanced Cell id

ECRIT	Emergency Context Resolution with Internet Technologies.
E-CSCF	Emergency Call Server Control Function
EOTD	Enhanced Observed Time Difference
ESIF	Emergency Services Interconnection Forum
E-SMLC/SLP	Evolved-Serving Mobile Location Center/SUPL Location Platform
ESN	Emergency Services Number
ESZ	Emergency Services Zone
E-UTRAN	Evolved Universal terrestrial Radio Access Network
FAP	Femtocell Access Points
FCC	Federal Communications Commission
FGDC	Federal Geographic Data Committee
FNPRM	Further Notice of Proposed Rulemaking
GIS	Geographic Information Systems
GLONASS	Russian Global navigation Satellite System
GMLC	Gateway Mobile Location Center
GNSS	Global Navigation Satellite System
GPRS	General packet radio service
GPS	Global Positioning System
GSM	Global Standard for Mobile Communication
HeNBs	Home E-UTRAN Node Bs
HMS	Home Node Bs Management System
HNBs	Home Node Bs
HNB GW	Home Node B Gateway
HO	Handover
HRPD	Homeland Security Presidential Directive
HSPA	High Speed Packet Access
i2	NENA Interim VoIP Architecture from Enhanced 9-1-1 Services
iDEN	GSM based proprietary Sprint network
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMS	Internet Protocol Multimedia Subsystem
ION	Institute of Navigation
IP	Internet Protocol
ISART	International Symposium on Advanced Radio Technologies
ITU	International Telecommunications Union
LAN	Local Area Network
LBS	Location Based Services
LIS	Location Information Server

LRF	Location and Routing Function
LMU	Location Measurement Units
LPP	LTE Positioning Protocol
LPPe	LTE Positioning Protocol extension
LS	Location Server
LTE	Long Term Evolution
LVF	Location Validation Function
M2M	Machine-to-Machine
MAC	Media Access Control (address)
MLTS	Multi-Line Telephone System
MS	Mobile Station
MSAG	Master Street Address Guide
MSC	Mobile Switching Center
MSS	Mobile Satellite Service
NENA	National Emergency Numbering Association
NG9-1-1	Next Generation 9-1-1
NGN	Next Generation Network
NOI	Notice of Inquiry
NPRM	Notice of Proposed Rule Making
NRIC	Network Reliability and Interoperability Council
NSI	Non-Service Initialized (as in phones)
NVI	Non-Voice Initiated Emergency Services
NVC	Non-Voice Communications
OET71	Office of Engineering and Technology Bulletin No. 71
OGC	Open Geospatial Consortium
OMA	Open Mobile Alliance
OMA-DM	Open Mobile Alliance - Device Management
OSP	Originating Service Provider
OTD	Observed Time Difference
OTDOA	Observed Time Difference of Arrival
PBX	private branch telephone exchange
P-CSCF	Proxy Call Server Control Function
PRS	Positioning Reference Signals
PS ALI	Private Switch ALI' (PS ALI)
PSAP	PSAP - Public Safety Answering Point
PSTN	Public Switched Telephone Network
RED	Routing on Empirical Data
RF	Radio Frequency
RFPM	Radio Frequency Pattern Matching

RG	Residential Gateway
RNC	Radio Network Controller
RSSI	Received Signal Strength Indicator
RTT	Round Trip Time or Real Time Text (2 references found)
SAS	Standalone Serving Mobile Location Center
S-CSCF	Serving Call Server Control Function
SDO	Standards Development Organization
SGSN	Serving GPRS Support Node
SIP	Session Initiation Protocol
SMLC	Serving Mobile Location Center
SMS	Short Message Service
SP	Service Provider
SSP	System Service Provider
SUPL	Secure User Plane Location
TA	external Telephone Adapter
TDD	Telecommunications Device for the Deaf or Time Division Duplex Mode
TDOA	Time Difference of Arrival
TIA	Telecommunications Industry Association
TID	Technical Information Document
TLS	Transaction Layer Security
TDR	Technical Requirements Document
TRS	Telecommunications Relay Service
TSP	Telematics Service Providers
TTFF	Time to First Fix
TTY	Teletypewriter also known as TDD
TVW	Telecommunications Verification Worksheet
UE	User Equipment
UHF	Ultra high frequency
UMA	Unlicensed Mobile Access
UMTS	Universal Mobile Telecommunications System
U-TDOA	Uplink Time Difference of Arrival
VLAN	Virtual Local Area Network
VoBB	voice over broadband
VoIP	Voice over Internet Protocol, Voice over IP
VoLTE	Voice over Long Term Evolution
VoP	Voice over Packet
VSP	VoIP Service Provider
WCDMA	Wideband Code Division Multiple Access

WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WPH2	Wireless Class of Service code for Enhanced 9-1-1 Phase II
WSP	Wireless Service Provider