E9-1-1 Technology Background and Issues

Prepared for the Wireless E9-1-1 Technology Roundtable
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1. Background

> *"When someone calls 9-1-1 they expect to get help right away. We cannot, and will not, accept a system where these callers cannot be located as quickly as possible."*
>
> - Norman Y. Mineta, Secretary of Transportation, April 8, 2002.

America is increasingly dependent on wireless phones for reporting traffic crashes and other emergencies. However, location identification service for wireless telephone users is not yet available across most of the United States. Wireless Enhanced 9-1-1 (or WE9-1-1) implementation is needed to automatically locate these calls, thereby helping to save lives and improve emergency services.

Many factors complicate the efforts to deploy wireless 9-1-1 services throughout the country. These generally fall into technical, economic, logistical, and institutional categories. All are significant and substantial. The focus of this white paper, and the corresponding Wireless E9-1-1 Technology Roundtable sponsored by the U.S. Department of Transportation (DOT), is on potential technology solutions to 9-1-1 challenges and the implications of emerging technologies and services on the future delivery of emergency response.

1.1 Overview

In the late 1960's the three-digit number "9-1-1" was introduced as the telephone code for citizens to request emergency assistance. During the next two decades, deployment expanded rapidly — today wireline 9-1-1 service is available to about 98 percent of the U.S. population.[1] In 1999, Congress designated 9-1-1 as the universal number for emergency calling in the United States.[2]

The code 9-1-1 was chosen because it best fit the needs of all parties involved. It meets public requirements because it is brief, easily remembered, and can be dialed quickly. Since 9-1-1 is a unique number, never having been authorized as an office code, area code, or service code, it best meets the long range numbering plans and switching configurations of the telephone industry.[3]

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[1] There remain 231 counties in the United States without 9-1-1 service. *Report Card to the Nation*, NENA, September 11, 2001.
[2] P.L. 106-81, Wireless Communications and Public Safety Act of 1999.
[3] *The Development of 9-1-1*; http://www.nena.org/PR_Publications/Devel_of_9-1-1.htm; accessed on September 16, 2002.

There are three core operational characteristics of most wireline 9-1-1 services that enable Public Safety Answering Points (PSAPs) to most efficiently and effectively coordinate emergency responses:

- Selectively route the call to the nearest PSAP;
- Identify the caller's telephone number to enable call back and other services; and
- Determine the address of the telephone to speed the emergency response, especially in circumstances where the caller cannot talk or does not know his location.

To facilitate such enhanced 9-1-1 (or E9-1-1) service for wireline phones, the local wireline carrier determines the caller's location through software and databases which identify and associate a caller's phone number with the corresponding customer address. However, the technical solutions used for wireline E9-1-1 are not applicable to wireless emergency calls. New technologies and procedures are necessary.

In a series of orders since 1996, the Federal Communications Commission (FCC) has taken action to improve the quality and reliability of 9-1-1 emergency services for wireless phone users by adopting rules to govern the availability of basic 9-1-1 services and the implementation of E9-1-1 for wireless services.[4] The wireless E9-1-1 program is divided into two parts - Phase I and Phase II. Phase I requires carriers, upon appropriate request by a local PSAP, to report the telephone number of a wireless 9-1-1 caller and the location of the antenna that received the call. Phase II requires wireless carriers to provide far more precise location information, within 50 to 100 meters in most cases. The deployment of E9-1-1 requires the development of new technologies and upgrades to local 9-1-1 PSAPs, as well as coordination among public safety agencies, wireless carriers, technology vendors, equipment manufacturers, and local wireline carriers. The FCC established a four-year rollout schedule for Phase II, beginning October 1, 2001 and to be completed by December 31, 2005.[5] See Appendix A for more details.

The effects of wireless phones have rippled through most regions of society – business, family, and public safety, to name a few. Over 25 percent of the 190 million annual 9-1-1 calls are now made on wireless phones.[6] Although these phones permit emergency access from a wide range of locations, they can also degrade emergency response. It is not unusual for an urban PSAP to receive dozens of calls about a highway fender-bender, which may delay answering calls from other emergencies. Moreover, the lack of automatic location information and the inability of many individuals to describe their location add to the PSAP workload and can constrain effective response.

The most important change may well be in societal expectations. America is a mobile society; we travel with our cell phones and expect to be able to use them in most cities, counties, and states. What is, and remains, a fundamentally local service – a local call to a local emergency responder – now has regional and national implications because of wireless technology. The majority of wireless phone users believe that a cellular 9-1-1 call provides the same capability as a wireline call. And once they do receive wireless

[4] *FCC Fact Shee*t, January 2001
[5] http://www.fcc.gov/9-1-1/enhanced/ accessed September 16, 2002.
[6] More than 50 percent of 9-1-1 calls at some metropolitan PSAPs are from wireless phones.

E9-1-1 service in their home region, they most likely will expect it from anywhere that they use the same phone.

1.2 Current Roles and Responsibilities for E9-1-1

The key service providers in the current E9-1-1 system are incumbent or competitive local exchange carriers (ILEC/CLECs), the PSAPs, and the wireless carriers. Each of their roles is summarized below.

ILEC/CLECs. These wireline providers own and operate the physical infrastructure to connect the phone customer with the corresponding PSAP. In the case of 9-1-1 calls, the ILEC/CLEC determines a fixed location (address) for the caller using a Master Street Address Guide (MSAG), determines the proper Public Safety entity (jurisdictional boundaries) through use of a 9-1-1 database, and extracts the caller's phone number for the PSAP. The call is forwarded to the PSAP through a selective router, along with the caller address and call-back information. In many instances the tasks of associating a telephone number with an address and identifying the appropriate PSAP servicing that address are supported by third party service providers.

PSAPs. There currently are more than 5000 PSAPs in the United States. PSAPs are responsible for answering initial 9-1-1 calls and, based upon the nature of the call, overseeing the dispatch of the appropriate emergency services (i.e., fire and rescue, EMS, police, or others). Their operations are influenced by many factors including legislative mandates, complex dispatch boundaries for emergency service providers, agreements for providing backups to adjacent jurisdictions, and the emergency responder resources they can call upon. Technologies used by the more advanced PSAPs include dedicated communications lines to the 9-1-1 database and the selective router, computer-aided dispatch (CAD) terminals, and map database systems for locating 9-1-1 calls within their jurisdiction.

Wireless carriers. There are 6 major wireless carriers and approximately 100 small independent carriers providing wireless mobile phone services in the United States. The major carriers have adopted different technologies for their air interface and also have selected different handset location technologies to support implementation of Phase II WE9-1-1. The three air interface technologies are GSM, IDEN, and CDMA; however some carriers still support an analog network. In general, the smaller carriers intend to follow the lead of the major carriers in the implementation of handset location technologies. The particular air interface has consequences on the available position determination techniques and accuracy. With the increase in wireless services and Phase II, PSAPs may need to have an indication of the caller position accuracy to assist in the dispatch of emergency response assets.

1.3 Major Factors Affecting Implementation

The groundwork for national implementation of WE9-1-1 has been laid. An FCC rule established a compliance schedule for wireless carriers and defined the needs for preparing the PSAPs. What remains is to enable the public safety community, the wireless industry, and State and local governments to collaborate on implementation

approaches and to provide technical support for PSAP preparation. The primary barriers to effective implementation are primarily non-technical, such as funding, public safety readiness, and jurisdictional coordination. The DOT and other organizations are sponsoring activities to overcome these barriers. Appendix B summarizes a few of these initiatives.

A DOT-sponsored Expert Working Group developed a comprehensive set of wireless E9-1-1 implementation barriers. This document is provided in Appendix C.

2 Current Technical Challenges

2.1 Caller Location

There are several different techniques that can be used to locate a wireless handset. The key challenges are accuracy, response time, and signal penetration in buildings.

Network-based solutions will work with existing handsets by locating them based on characteristics of their transmission. Handset-based solutions mostly rely on GPS, although modified handsets can be made capable of computing location based on time of signal arrival. Network-based techniques generally lack sufficient accuracy, while GPS handset solutions must address slow position determination. Network-assisted GPS provides the most accurate solution for the most common location techniques under consideration.

In addition, there are several other approaches identified for caller location; techniques ranging from use of digital television (DTV) signals to the application of Wi-Fi systems in buildings or campuses. Both techniques have attractive features; a predominant one is the ability of the signals to reach callers within large buildings or structures which is a problem for unassisted GPS. A brief description of some of the location techniques can be found in Appendix D.

Response time is an issue for GPS-handsets. When a caller places a 9-1-1 call via a wireline phone, the telephone address and call-back number are displayed on the PSAP call-taker's console within seconds (the address may even be displayed before call pickup). For GPS capable cell phones, there is a potential problem in processing caller location in time to display this information at the PSAP in an effective manner. GPS receivers require an initialization period after they are activated, in which case the actual location would not be available for up to 45 seconds.[7] To address this potential delay, wireless carriers using GPS location solutions are adopting an assisted GPS system in which the cell towers provide ephemeris and other receiver-generated information for a rapid initialization for the GPS handset. This solution may be adequate to support the timely provision of caller location to the PSAP.

[7] This would not be a problem if the phone were already on and receiving location information.

2.2 Safety Telematics

Telematics service providers such as OnStar, ATX, and Cross Country communicate with PSAPs on behalf of clients who are involved in accidents or other emergency situations. The key challenges are linking to a local 9-1-1 network from long distance and transferring data into the PSAP's system.

More than 2.5 million vehicles equipped with automatic crash notification (ACN) systems are operating in the United States, a figure expected to grow to 10 million by 2005. Today, when an ACN-equipped vehicle crashes, vehicle identification, location and crash severity are automatically relayed to the service provider's response center. At that point, the response center calls the PSAP closest to the emergency via a non-9-1-1 administrative line and reads information from the display monitor for the other to re-enter at a remote location. This sort of alarm notification has, by default, followed the time-honored methods followed by the alarm industry. Even though the originating equipment may be quite sophisticated, and the response center might be highly automated, the actual alarm notification to the PSAP would work quite well over the primitive telephone systems of the 1920's. That weak link is prone to the same problems of any verbal relay system, namely misinterpretation, misrouting, and mistakes of omission. Although the delay in communicating from the response center to the PSAP is generally brief, any delays can be crucial for severely injured persons.

A new generation of ACN systems will be introduced in some 2004 automobiles. While current systems are activated upon deployment of the airbag, the new systems will have sensors capable of measuring the direction and magnitude of impact, and will be able to provide more information about the crash dynamics—a critical set of information for the emergency responders. Efforts are underway to enable response centers to directly call into the appropriate PSAP's 9-1-1 network and automatically transfer crash data directly to the 9-1-1 call taker's computer screen.[8]

2.3 Internet and Other Non-Traditional Access

The increasing public mobility and reliance on wireless devices will usher in more and more third party intermediary services, such as safety telematics described above. The challenge is to effectively integrate these services into the 9-1-1 infrastructure while retaining the unique features of 9-1-1 services. Traditional 9-1-1 network components such as selective routers and database management hardware/software platforms may require new standards to accommodate these non-traditional 9-1-1 voice and data elements.[9]

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[8] The implementation of Signaling System 7 across North America will present some new possibilities for 9-1-1. Two significant possibilities are; (1) the ability to transfer a 9-1-1 call, with ANI and ALI, to any PSAP in North America, and; (2) the ability to selectively connect to any PSAP from an operator position, emergency relay service or other authorized agency. From NENA *9-1-1 Tutorial*,"http://www.nena.org/9-1-1%20Tutorial/911Tutor01-00.pdf, accessed September 20, 2002.

[9] *NENA Review of Non-Traditional Communications to E9-1-1 PSAP Equipment*, NENA Technical Information Document, March 20, 2001, p.8

IP telephony[10] (transmission of voice over a packet network) is a growing service that raises a number of 9-1-1 issues. Since the usual Public Switched Telephone Network (PSTN) resources are bypassed when using IP, location identification is a key problem with this mode of operation. The term "voice over IP" (VoIP) derives from the VoIP Forum, an effort by major equipment providers, including Cisco, VocalTec, 3Com, and Netspeak to promote the use of ITU-T H.323, the standard for sending voice and video using IP on the public Internet and within intranets.[11] Currently, unlike traditional phone service, IP telephony service is relatively unregulated by government. FCC has indicated that it does not plan to regulate connections between a PSTN and an IP telephony service provider.[12]

3 Future Technologies and 9-1-1 Implications

3.1 New Automatic Alerting Devices

A growing number of security and alarm services provide support to homeowners, the elderly, and persons with medical conditions, to name a few. In the future, alerts will likely be generated by PDAs, wearable computers and even-implanted devices. PSAPs are well-situated to receive alarm notifications from telephone callers, and are becoming adept at utilizing enhanced information about callers gleaned from telephone billing databases and handset tracking systems. However, they are not well equipped to apply similar technology to calls that originate from non-traditional sources. There is a general concern about the increasing demands that will be placed upon the call takers and responder community, as well as the reliability of the alarm systems which trigger the call.

The current technical challenges are similar to the ones noted above for safety telematics. Future challenges may stem from the proliferation of these wireless devices, the diverse types and formats for data such as images and video, and the corresponding expectations for the public emergency communications system.

3.2 Pace of Change in Commercial and Public Communications Technologies

Wireless carriers are in a continuing process of expanding coverage and upgrading the types of services provided. An important issue is the economic and technical implications for public 9-1-1 network and emergency service delivery, as PSAP infrastructure is generally expected to have a longer life cycle than commercial systems. The challenges are to continue to deliver 9-1-1 services to all callers, while retaining appropriate previous capabilities and reliability. Service parity remains a basic objective—every potential 9-1-1 caller should have the same likelihood of a successful

[10] IP telephony is a general term for the technologies that use the Internet Protocol's packet-switched connections to exchange voice, fax, and other forms of information that have traditionally been carried over the dedicated circuit-switched connections of the PSTN.
[11] NENA Review of Non-Traditional Communications, op. cit., p.10
[12] Ibid., p.10.

9-1-1 call connection, regardless of the source of the call, whether from an ILEC, an ISP, or a wireless carrier.[13]

If planned appropriately, future 9-1-1 networks should be able to provide enhanced services enabled by commercial networks and services. For example, migration of the current circuit-switched telecommunications network to a broadband packet-switched network may resolve some of the telematics and alert device access issues.

4 Summary

One of the great strengths of our Nation is its technological expertise. A fundamental reexamination of the technological approach to E9-1-1 may reap large rewards as our public emergency network struggles to accommodate the challenges of wireless E9-1-1 along with new security concerns. Some new concepts may provide solutions to near-term issues; others may lay a foundation for longer-term progress.

As we decide upon our future path, we must strive to ensure that these innovative technologies will enhance the effectiveness of the 9-1-1 system and reduce the complexity, expense, and time required for future service deployments. And we must guarantee that future 9-1-1 system designs are sufficiently versatile to accommodate both individual emergency access and response to mass casualty events

[13] 9-1-1's Technical Future: The NENA 9-1-1 Future Path Plan; http://www.nena.org/9-1-1TechStandards/future_path_plan.htm, accessed September 20, 2002.

Appendix A
Summary of Wireless Carriers and FCC Rulings

In 1996, the Federal Communications Commission (FCC) adopted rules to implement enhanced wireless 9-1-1 services in two phases. Phase one implementation requires carriers to provide Public Safety Answering Points (PSAPs) with the telephone number of the wireless handset making the 9-1-1 call and the location of the base station that received the call. Phase two requires more precise location information, subject to certain conditions, to be phased in starting October 1, 2001 and ending with full compliance by December 31, 2005. As of October 1, 2001, no carrier was capable of introducing Phase two capabilities. The FCC received over 70 requests from the carriers to modify the Phase two deployment schedule, the accuracy requirements or both. On October 5, 2001, the FCC took the following actions:

- Approved modified compliance plans of five nationwide carriers;
- Imposed specific reporting requirements;
- Established an extension of time for other carriers to submit requests for relief;
- Initiated an ongoing inquiry on E9-1-1 technical issues; and
- Amended rules to clarify actions needed by PSAPs to make valid requests for Phase two service.

1. Compliance plans.

Both Cingular and ATT Wireless are implementing the European-based cellular Groupe System Mobile (GSM) technology in addition to their existing Time Division Multiple Access (TDMA) network.. The FCC granted both companies extensions for milestones concerning the percentage of handsets sold that are capable of implementing Enhanced Observed Time Difference (E-OTD) location computations, as well as the date that full accuracy requirements must be met. In addition, Cingular has deadlines for performing upgrades to their Nortel and Ericsson switching equipment and implementing their "safety net" location capability that will be able to locate existing (non-E-OTD) handsets to an accuracy of 1 Km or better. Both companies failed to file on time for extensions to be considered for the non-GSM portion of their networks. Discussions between these carriers and the FCC Enforcement Bureau are in progress to resolve any implementation issues.

Nextel and Sprint PCS are implementing forms of network-assisted GPS. This also requires new handsets and each company has new milestones for the percentage of handsets in use that must have this capability. In addition, Sprint has a schedule for completing conversion to their Nortel and Lucent switching equipment and performing several software upgrades.

Verizon's schedule is considerably more complex since they still support an analog network. There are numerous handset replacement and switch upgrade milestones that must be met for the different technologies they have implemented. Verizon also has

requirements to provide Phase 2 capability to St. Clair County (St. Louis), Illinois and Lake County (Gary-East Chicago), Indiana by December 31, 2001. They also have to provide this capability to Cook County (Chicago), Illinois, St. Louis County (St. Louis), Missouri, and Harris County (Houston), Texas by April 1, 2002. These are areas where Verizon tested their technology and have pending PSAP requests.

2. Reporting Requirements

From February 1, 2002 through February 1, 2006, each carrier must file a quarterly report with both the Chief of the Wireless Telecommunications Bureau and the Chief of the Enforcement Bureau at the FCC. These reports should contain specific and verifiable information to show compliance with the new implementation schedules. This includes providing information to demonstrate that the required percentage of new location-capable handsets have been sold.

3. Extension of Time

The FCC recognized that small and rural carriers have additional challenges to deploying E9-1-1 than the national carriers have. Some lack the finances to install the new equipment. Rural carriers often have the problem of having an insufficient number of base stations to achieve the required accuracy. Any carriers that have not yet filed that believe they need additional time must file a petition by November 30, 2001. The FCC is not taking any enforcement action against these carriers until they have received and evaluated the requests.

4. Wireless E9-1-1 Technical Inquiry

The FCC will conduct an ongoing inquiry into technical issues affecting the deployment of wireless E9-1-1. This includes evaluating reports submitted by location technology vendors, handset manufacturers, network equipment manufacturers and the carriers. Issues such as standards, hardware and software development, and equipment availability will be considered.

5. PSAP Requests

The wireless carriers are required to provide location information to PSAPs within 6 months of receiving a valid request. The FCC rules defined a request as valid if the PSAP has a cost recovery mechanism in place, can perform the necessary upgrades required to receive and use the location data within six months after making the request, and has requested the necessary trunking and network services from the Local Exchange Carrier (LEC). The FCC modified the rules stating that alternatively, a PSAP request is valid if it is capable using Phase 1 location data and has Non-Call Path Associated Signaling (NCAS) technology implemented.

Appendix B
Activities to Support Wireless E9-1-1 Deployment

DOT Wireless E9-1-1 Initiative

The DOT is sponsoring the WE9-1-1 Initiative to accelerate the availability of wireless emergency location service across the United States and thereby enhance transportation safety and security. The core effort of this Initiative is to work with public safety associations and leaders to provide technical assistance, guidance, and training to accelerate PSAP readiness for wireless E9-1-1. DOT is sponsoring the development of tools and resources to facilitate local deployment, including targeted technical assistance, procurement guides, and training. DOT has contracted with NENA and APCO to deliver these products.

National Emergency Number Association (NENA) "SWAT" Teams

NENA has initiated a program to strengthen the level of involvement and strategic planning for citizen activated emergency response systems. This involves the creation of Strategic Wireless Action Teams (SWAT) to elevate and advance the issues of 9-1-1 with policy makers, government, and the private sector. The teams will provide support to relevant parties in areas of technology, operations, policy, and finance. These activities are a logical expansion of NENA's role in advancing the development and deployment of modern 9-1-1 technologies, systems and policies.

Association of Public-Safety Communications Officials (APCO) Project LOCATE

Project Locate was initiated by APCO to accelerate the deployment of WE9-1-1 systems throughout the nation. Key to the project was the identification of WE9-1-1 capable PSAPs within each State and to support the filing of necessary documents to activate WE9-1-1 caller location technologies in the PSAP operating area.

PSAP Readiness Fund

Nextel Communications recently announced the formation of a non-profit group to foster the development and deployment of Wireless E9-1-1 services. The $25 million PSAP Readiness Fund will provide grants to organizations dedicated to the deployment of WE9-1-1. These grants are expected to foster the development and timely deployment of advanced location-based services across the U.S., particularly in areas underserved by modern communications technology.

Appendix C
Barriers to Wireless Implementation and Deployment

Prepared for the US DOT Wireless E-9-1-1 Initiative
Expert Working Group Meeting 2
January 2002

Regulatory, Legislative and Administrative Policy Issues

- ***Regulatory Clarity***

  While the FCC attempts to clearly enunciate policy through rulemaking, opinions and other regulatory actions, inevitably the latter raise questions of interpretation and application. Often that leads to further requests for FCC clarification (from either the public safety and/or provider communities), and ultimately further delay. Efforts by the impacted parties to anticipate and work through these issues—to build a consensus upon which regulatory action may be based has historically been the most productive way to move forward.

  This barrier also includes actions by state regulatory commissions that must affectively address 9-1-1 system provider (LEC) and other third party issues that impact the delivery of a wireless 9-1-1 call.

- ***State Governmental Support***

  Effective deployment requires serious support from state government—the lack of which is a barrier. Such foundation ranges from state wireless legislation that establishes state policy, initiative, funding, and similar structure, to executive support and leadership from state governors. Currently, ten states have not passed wireless legislation, and state level leadership varies greatly across the country.

- ***Cost Recovery Policy***

  The ability or the "lack" of the ability to recover the costs of wireless implementation (provider or public safety) can be a barrier. By FCC rules, this is a state and local issue, not a federal one (at least in terms of mandate). The barrier also goes beyond the question of whether cost recovery exists, and includes how cost recovery will be applied—i.e., cost recovery polity. Across the country, PSAPs are struggling with developing reasonable and consistent policy of this sort.

Technical/Operational Issues

- ***Selecting and Deploying an Appropriate Phase II Location Solution***

  Phase II requires the deployment of location technology designed to meet accuracy standards promulgated by the FCC. What location technology is best, and how the resulting accuracy will be verified are questions that must be addressed, and, therefore, potential barriers. Historically, this has been a matter of some debate between carriers and the Public Safety community, and potentially affects the pace or timing of deployment. While the "selection" part of this barrier is becoming an "old" issue as the FCC approves deployment plans that incorporate specific technologies, solutions must still be implemented, and location accuracy verified.

- ***Product Development Cycles***

  Wireless implementation (and particularly its second phase), depends upon the timely and coordinated production and availability of Phase II capable handsets, appropriate network infrastructure upgrades and similar technical enhancements. This barrier is one of the current factors cited most often by carriers seeking waivers of FCC required implementation timeframes, and hence greatly affects the timing and pace of deployment.

- ***Establish Baseline Criteria for Service***

  Effective wireless E9-1-1 service requires a well coordinated and linked technical and operational environment. How wireless E9-1-1 works "technically," impacts how service is provided "operationally." A number of overlapping operational and technical issues still exist that affect this relationship. To a large extent, these issues require an effective working relationship between the carrier and public safety communities.

- ***Wireless Service Provider(WSP)/9-1-1 System Provider (usually a LEC)/PSAP Interconnection Issues***

  Effective wireless E9-1-1 requires productive, timely and efficient relationships between the three major parties identified above. Trunking must be ordered and provisioned, technical interface issues addressed, and overlapping database functions coordinated. And, all of this must occur within a diverse and complicated regulatory environment. If all of this doesn't work well, the pace of deployment can be materially impacted.

- ***Changing Industry and Technology***

  The technological foundation upon which wireless E9-1-1 rests continues to change and evolve at a rapid rate. The wireless industry in this country, for example, is moving rapidly towards the third generation of wireless service. Technical wireless 9-1-1 solutions today may not work tomorrow. Or, tomorrow may bring better solutions, opportunities and challenges—things like ACN, telematics, and other non-

traditional forms of 9-1-1 calls. Our task today is to not do something now that will preempt our ability to address and accommodate changing technology in the future.

- ***Other Technical and Programmatic Issues***

  Other issues of this sort continue to be identified, and include things like embedded databases, mobility, wireless number portability, and outdated network infrastructure.

Awareness/Education Issues

- ***Wireless Consumer Education***

  No matter how similar we attempt to make wireless to wireline service, there will always be differences. Wireless customers need to understand those distinctions and similarities (including the limitations of, and how to place an effective wireless 9-1-1 call). Ultimately, that is a public education effort.

- ***PSAP Training and Education***

  Being an effective PSAP partner in the wireless implementation process requires information and knowledge of the FCC requirements and rules, implementation detail and procedure, and a variety of other similar things. Essentially this represents a PSAP education effort.

Resource Issues

- ***Funding From all Sources***

  The cost of deployment must be recovered in some fashion. When and how that occurs are issues. Furthermore, FCC policy requires that PSAPs have the ability to recover their costs before they can request wireless service from a carrier—a PSAP readiness issue.

- ***PSAP Readiness***

  In addition to the above, FCC rules require that a " . . . PSAP has ordered the equipment necessary to receive and utilize the E9-1-1 data and the equipment will be installed and capable of receiving and utilizing that data no later than six months following its request; and the PSAP has made a timely request to the appropriate local exchange carrier (LEC) for the necessary trunking and other facilities, including any necessary Automatic Identification Location (ALI) database upgrades, to enable the E9-1-1 data to be transmitted to the PSAP. " This requires funding, network enhancements, equipment, mapping and similar resources.

Project/Implementation Management Issues

- ***Stakeholder Collaboration***

  This barrier or issue speaks to the growing array of stakeholders in the implementation process, and how those stakeholder interests will be addressed in a productive and coordinated way.

- ***Effort Coordination***

  Effective implementation of wireless E9-1-1 requires that activities be planned, coordinated and monitored in an efficient and productive way. However, institutional and administrative approaches to this process vary greatly across the country. While a state and local responsibility, the '99 Wireless Telecom Act encourages states to adopt statewide, single points of contact for such activity.

- ***Information Base***

  No entity currently maintains comprehensive information regarding the status of deployment, who's doing what and how, implementation policy and procedure, and similar data of mutual interest. Such information is essential to monitor, coordinate and minimize implementation effort.

- ***Negotiation of Contracts***

  Interconnection and the provision of service require contracts, service agreements and similar contractual and legal infrastructure. The diversity in such documents and what should be included in those documents has been both a problem and time consuming. Sample service agreements, provisions in those agreements, and similar resources need to be drafted.

- ***Timely Requests from PSAPs***

  Some PSAPS are hesitant about moving on with wireless E9-1-1 implementation during this formative time, thus delaying service. Such PSAPs should be encouraged to move ahead, to reasonably request and deploy.

- ***Prioritized Deployment***

  While existing Phase II requests to carriers are limited, they outstrip the capabilities of carriers to respond within FCC requirements. It would appear that deployment will need to be prioritized. How that prioritization should take place and what it should be are issues that must be resolved.

Appendix D
Caller Location Technologies

There are several different techniques that can be used to locate a wireless handset. Infrastructure-based solutions will work with existing handsets by locating them based on characteristics of their transmission. Handset based solutions mostly rely on GPS, although modified handsets can be made capable of computing location based on time of arrival. The following are brief descriptions of some of the basic techniques that have been tested by the wireless service providers.

Location Technology Overview

Time of Arrival

The time of arrival method for locating handsets relies on being able to estimate how long it takes a transmission to reach a base station. Since radio waves travel at the speed of light, the distance (d) from a base station can be estimated from the transmission delay. This however, locates the handset as being on a circle with a radius d, with the base station at the center of the circle. If the estimate is made from three base stations, there will be three circles that intersect at the handset, shown in Figure 1.

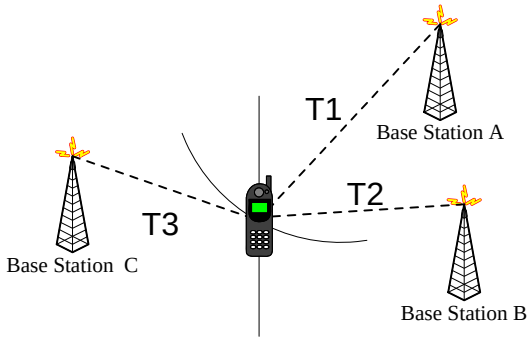

Figure 1. Time of Arrival

Time Difference of Arrival

Time difference of arrival is similar to TOA, however pairs of base stations compare the difference they measure in time of arrival of the same handset signal. If three base stations are used, there are three sets of difference times that define a single solution. TDOA is sometimes preferred to TOA because in most implementations, there is less data that needs to be exchanged over the air since the computation of TDOA can be performed at a central processor.

TOA and TDOA estimates normally need at least 3 base stations to make a meaningful estimate of location. There must also be a common time base exchanged so the units can be synchronized. An advantage of TDOA is that only the base stations need tight synchronization to be able to make the computation.

Angle of Arrival

Angle of arrival is a technique that is based on classic radio direction finding. Using a highly directional antenna, a line of bearing is determined between a base station and a subscriber. If lines of bearing from two base stations cross at an acute angle, an estimate of position can be made. As shown in Figure 2, three or more base stations are normally required to provide acceptable accuracy.

This technique requires a line of sight between the handset and the base station, since reflected signals will provide a false line of bearing. Line of sight transmission is not necessary for cellular communications, so this technique is often used in combination with another location technique, such as TDOA

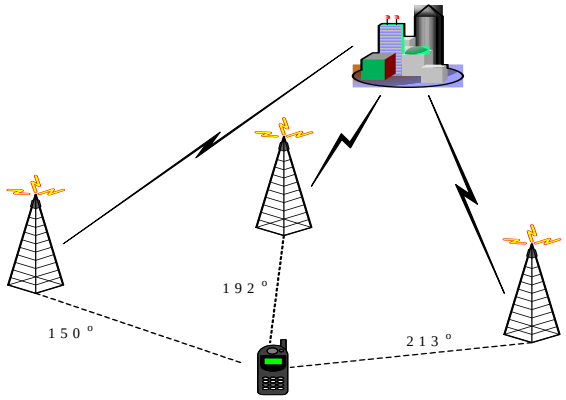

Figure 2. Angle of Arrival

Signal Strength

The signal strength method uses the power received to estimate the distance from a base station. If the transmit power is known, either a handset or a base station can, using path loss equations, estimate the distance from each other using a measurement of the received power. If the distance from three base stations is estimated, the location of the handset can be determined.

This technique will not work with existing handsets that use power control. Personal Communications Systems (PCS) using code division multiple access (CDMA), such as Verizon and Sprint PCS, can carry the greatest amount of voice traffic if all handsets appear to be equal distance from the closest base station (called the near-far problem). Handsets that are very close automatically reduce their power, while handsets that are far away will increase their power. It has been proposed that to increase the accuracy of

locating handsets for E9-1-1, future handsets may be designed to automatically go to full power when emergency calls are made. This will decrease the communications capacity of the cell, but only on the occasions when a 9-1-1 call is in progress. An alternate method for CDMA is to perform distance calculations based on the ranging capabilities of spread spectrum signals.

Network-Assisted GPS

The most common form of a handset-based solution is to embed a Global Positioning Satellite (GPS) receiver in the handset. This will provide the most accurate location information of any of the methods described. It is also possible to enhance the location information using differential GPS corrections providing accuracy better than 10 meters. Network-assisted GPS (A-GPS) uses network assistance to enable the handset to compute a location, even if the view to the GPS satellites is blocked.

In A-GPS, shown in figure 3, the work normally done by GPS receivers is performed by location measurement units (LMUs), placed either at the base stations or at strategic locations throughout the network. These receivers acquire the satellites in view, demodulate the navigation signals, and provide the handsets with the required navigation information including timing, which satellites are in view, estimates of Doppler shift, and differential corrections. All the handset receiver has to do is be able to track the carrier phase, which can be done at a significantly lower power level. This also greatly reduces the time to calculate the first “fix”. The end result is a cell phone that can be located at most (but not all) indoor locations, urban canyons, and parking garages. The signal seen by the handset is reflected and usually marred by multipath, but the FCC does not require full GPS outdoor accuracy, nor does it require that all phones be located. Also, many location systems incorporate more than one of the above mentioned techniques to meet the FCC mandate.

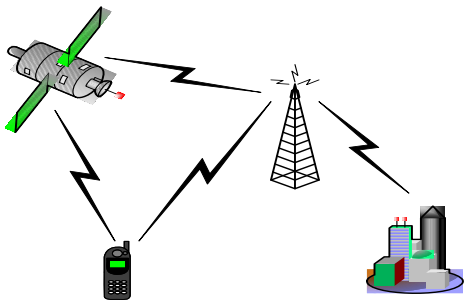

Figure 3. Network Assisted GPS

Issues Concerning Deploying Location Technology

All of the network-based techniques described suffer from a lack of accuracy for several reasons. Wireless systems deployed in populated areas consist of many base stations with a relatively close spacing. The systems are engineered so that the handsets should be heard by only one or two base stations to keep from interfering with other users (which would reduce system capacity). Although this is good communications design practice, this does not provide good radio location accuracy, since many methods rely on three or more base stations to determine location. Also, the base stations were originally placed for maximizing communications capacity, not performing radiolocation. Network providers may have to add additional base stations or LMUs to be able to provide the required accuracy.

In rural areas and along major highways, much of the coverage is linear. The base stations are laid out in a "string of pearls" arrangement. This provides good communications coverage where the majority of calls are expected to be made, but provides very poor accuracy for network-based location techniques. Also, hilly terrain can obstruct a handset from seeing a sufficient number of base stations to compute location.

Even when the handset can be heard by 3 base stations, the signal is usually badly distorted by multipath interference (the sum of a direct and many reflected waves), fading and other detrimental effects. Providers of network-based systems usually use a combination of location techniques and also implement proprietary algorithms to increase the accuracy.

In addition to locating a caller using latitude and longitude, the issue of incorporating elevation has become important with the increasing use of cell phones in high rise buildings, parking structures, bridges, and overpasses. A-GPS-based solutions can be enhanced to include elevation, but the accuracy when used indoors may be of limited use. For other locations such as highways with multiple overpasses, map data bases with terrain feature overlays may be very helpful to a PSAP.

There are multiple technologies (CDMA, GSM, analog, iDEN, IS-136 etc.) and many different carriers using each technology. Each carrier can choose the location method to be deployed, and certain methods work better for certain technologies. They can also purchase products from vendors who have made proprietary enhancements to the location determination method. This becomes an issue when locating handsets that are either roaming, or not an authorized subscriber of a network. Even though the handset has the proper air interface, the location technology (or version of the technology) may not be compatible, and the carriers cannot guarantee they can provide location beyond a certain sector of a certain cell. There is also the issue of the carriers ability to enable the PSAPs to call back these phones if the call gets disconnected.

Carriers have reported difficulty in obtaining enough equipment to perform the necessary upgrades in a timely fashion. They have also cited manufacturer's inability to produce

enough handsets for the carriers to be able to get replacements to their customers in order to meet FCC required goals. The FCC has given all the major carriers waivers which relax the interim milestones for deploying location-capable handsets and performing network upgrades.