An Approach to Regulating Location Support for Wireless Emergency Calls

December 2013

TCS TeleCommunication Systems
Enabling Convergent Technologies®

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List of Exhibits

Glossary of Acronyms

3GPP	Third Generation Partnership Project
ACMA	Australian Communications and Media Authority
A-GNSS	Assisted Global Navigation Satellite System
A-GPS	Assisted Global Positioning System
CDMA	Code Division Multiple Access
CoPL	Control Plane Location
CRTC	Canadian Radio-television and Telecommunications Commission
E-CID	Enhanced Cell ID
E-OTD	Enhanced Observed Time Difference
FCC	Federal Communications Commission
GMLC	Gateway Mobile Location Center
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HLR/HSS	Home Location Register/Home Subscriber Server
LBS	Location Based Services
LCS	Location Services
LMU	Location Measurement Unit

MME	Mobile Management Entity
MSC	Mobile Switching Center
OTDOA	Observed Time Difference of Arrival
PSAP	Public Safety Answering Point
RAN	Radio Access Network
RF	Radio Frequency
RTT	Round-Trip Time
SGSN	Serving GPRS Support Node
SMLC	Serving Mobile Location Center
SNR	Signal-to-Noise Ratio
TA	Timing Advance
TCS	TeleCommunication Systems, Inc.
TDOA	Time Difference of Arrival
UMTS	Universal Mobile Telecommunications System
VoLTE	Voice over LTE
WCDMA	Wideband CDMA

Introduction

Telecommunications regulators and wireless operators are two key stakeholders in the process of meeting the public's expectation regarding wireless emergency calls. Telecom regulators seek to install a regulatory framework that requires such calls to be supported with accurate location in order to allow emergency service providers to provide effective service. Wireless operators, who own the network and must invest in the means to determine location of the emergency calls that originate within their coverage area, want to ensure that the regulatory requirement is both technically feasible and economically viable.

This paper seeks to inform stakeholders of the variables that must be taken into consideration in implementing an effective regulatory framework for location support of wireless emergency calls. The paper begins with a technological overview of mobile location in terms of the architectural framework as well as the various positioning technologies available within that framework. It continues with an assessment of strengths and weaknesses of each positioning method using a number of parameters such as accuracy, yield, latency, and cost. Next is an overview of a few exemplary attempts at emergency regulation from around the world and how operators have responded to them. The paper concludes with a set of recommendations for the stakeholder community based on these experiences with a suggested deployment model. This paper restricts itself to Third Generation Partnership Project (3GPP) technologies (2G-GERAN, 3G-UTRAN, and 4G-LTE). 3GPP2 technologies such as Code Division Multiple Access (CDMA) and other access types such as WiMax are out of scope.

Location Services Architecture

The Location Services (LCS) architecture describes a method for locating devices connected to a mobile network in a systematic manner that enables users to enjoy a uniform service experience throughout the network. It enables the support of a wide variety of Location Based Services (LBS) while taking into account user privacy, the nature of the application (emergency, legal intercept, commercial or operator services), the accuracy and response time required by the application (quality of service), and the capabilities of the target device being located (e.g., whether enabled for Global Positioning System [GPS]). It enables the deployment of multiple location determination methods, each with specific strengths in terms of accuracy, yield, and response time; this permits the system to provide an optimal result based on the criteria described above and makes all options available in order to maximize yield.

The LCS architecture defines multiple nodes with specialized functions – for instance, the gateway function responsible for authorization and authentication of location requests and directing location requests to the appropriate part of the network, and the serving node functions responsible for performing the actual location determination procedures. In addition, it defines the interfaces and protocols that enable the relevant network nodes to interact with each other and the rest of the network to determine routing instructions, invoke positioning procedures, and obtain the measurements necessary for location determination.

The 3GPP standards organization has specified a Control Plane Location (CoPL) architecture that is commonly used for supporting emergency services. CoPL uses signaling channels to interact with the mobile and other nodes in the network, including the Home Location Register/Home Subscriber Server (HLR/HSS), the Mobile Switching Center (MSC)/Serving GPRS Support Node (SGSN), Mobile Management Entity (MME) and Radio Access Network (RAN).

Exhibit 1 below depicts a simplified, standards-defined architecture for emergency location of mobiles in a 3GPP network.

Location Services (LCS) architecture enables a wide variety of Location Based Services (LBS) while taking into account user privacy, the nature of the application, the accuracy and response time required by the application, and the capabilities of the target device being located.

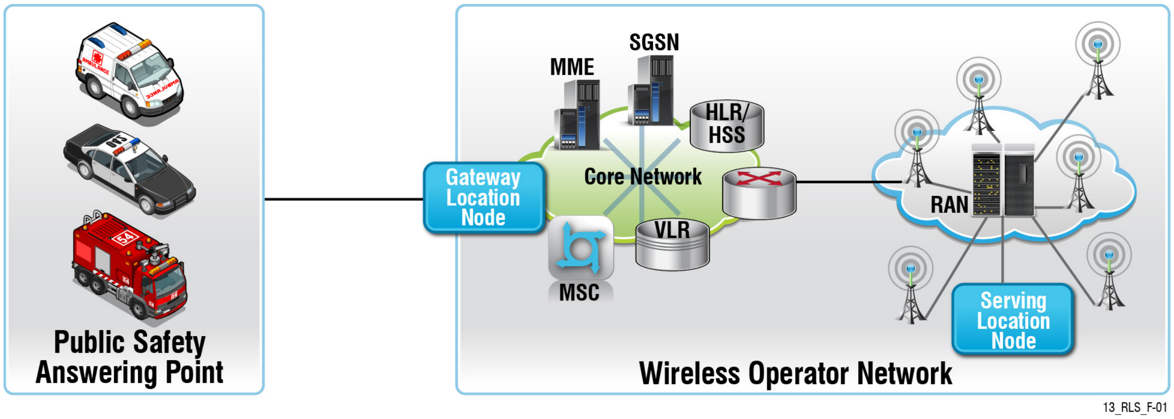

Exhibit 1. Location Services Architecture for Supporting Emergency Calls

The key location-related nodes of the architecture are depicted in red. These include:

- **Gateway Location Node.** This is the Public Safety Answering Point's (PSAP) primary interface to the wireless operator's network. Through standards-based interfaces, it allows for the automated delivery of location information for mobiles engaged in an emergency call. It provides authentication and authorization of location clients to ensure privacy and security. Within the operator's network, it may provide routing functions to ensure that emergency calls are routed to the correct PSAP. In addition, it ensures that updated location requests from PSAPS are routed to the correct serving location node for further processing.
- **Serving Location Node.** This node is responsible for the overall coordination of a location request. This includes choosing appropriate positioning technologies based on the requested quality of service (horizontal and vertical accuracy, response time, etc.); interacting with the handset and radio access network to serve assistance data and obtain handset- and network-based measurements; providing the position calculation function; providing fallback positioning in case the primary location technique of choice fails; and generally ensuring that a location result is provided to the tasking entity in the form of geodetic coordinates.

Positioning Technologies

Performance and Cost

Within the framework of the architecture described above, a number of location technology options exist, each with different performance characteristics. Performance characteristics of location technologies are measured in terms of accuracy, yield, and latency. Accuracy is the distance between the location of the mobile as determined by the network and the actual location of the mobile computed by independent means known as the "ground truth" (e.g., location as computed by a Differential-GPS receiver). Yield is the success rate (i.e., the number of times that a positioning technology successfully returns the target mobile's geodetic coordinates). Latency is the time taken to return a location.

Network topographies impact location technology performance. They are broadly classified into rural, suburban, urban, and dense-urban areas. There are no universally established definitions for these terms, nor are they all likely to be present in every network. Nevertheless, they serve to illuminate key factors that impact performance. Broadly, these topographical areas are differentiated by cell spacing/density, multipath, and line of sight to signal sources. On one end, rural areas are characterized by cell sites with large ranges; as a result, there are fewer cell sites that are audible to a mobile and consequently a higher signal-to-noise ratio (SNR) due to low interference from neighbors. Other typical characteristics of this topographical type include access to open skies (line of sight to satellites) and low multipath (fewer obstructions that deflect signals and distort flight time). On the other end, dense urban areas, typified by city centers such as New York City, have characteristics that include higher cell densities and lower cell ranges, lower SNR, higher multipath, and reduced access to open skies. In between the two ends of this topographical spectrum lie urban and suburban areas with an intermediate mix of characteristics.

The performance of wireless positioning technologies in terms of accuracy, yield, and latency vary with network topology. For example, GPS-based technologies may be highly accurate in rural areas with good lines of sight to satellites in the sky as well as low multipath. However, this very same technology suffers from frequent failures and accuracy degradation in dense-urban areas due to lack of clear lines of sight and high multipath. Conversely, technologies such as Enhanced Cell ID (E-CID) or radio frequency (RF) fingerprinting perform poorly in rural areas due to lower cell density and signal variance while performing best in dense-urban areas for precisely the opposite reasons. The variation in performance with topography implies that operators cannot rely on a single location technology to cover their entire network. Operators have to choose a mix of location technologies to suit specific topographies within their networks so that the overall performance of the system is optimized across the entire network.

Besides performance, there are a few other important factors that operators use to determine the mix of technologies appropriate for their network. Operators frequently have to consider capital and operational expenditures associated with each location technology. Capital expenditure is the upfront investment an operator must make either in adding infrastructure to the network or capabilities to the handset. For example, location technology based on installation of specialized hardware units (known as location measurement units) at every base station requires high capital investment. Operational expenditure is the year-over-year cost that the operator incurs to keep infrastructure associated with that technology performing optimally. Location technologies that require the operator to drive a particular coverage area and establish a radio map, such as in RF fingerprinting solutions, require higher than average operational expenditure. This is due to the need to periodically re-calibrate the RF fingerprinting database by physically driving through the area of coverage. The higher cost profiles of certain location technologies could mean that operators choose to deploy them in limited areas where there are no other options.

Functional Overview

A number of positioning technologies exist for mobile location. These have each been treated exhaustively by other authors. Here, we present a brief overview of some of the key technologies used for treating emergency calls, taking into account performance and cost.

Assisted Global Navigation Satellite Systems

This location technology is based on mobiles making Time Difference of Arrival (TDOA) measurements of signals from satellite-based systems. The United States' GPS is the most widely available Global Navigation Satellite System (GNSS) today. Other satellite systems such as the Russian GLONASS and European Galileo have become operational in recent years or are close to achieving operational status. To aid mobiles in acquiring satellite signals, the serving location node provides "assistance data" based on a mobile's approximate location as determined by the cell tower to which it is connected. This helps the mobile to quickly lock on to satellite signals by allowing it to search only those satellites which may be visible in its immediate neighborhood as opposed to all satellites in the entire system. Post satellite signal acquisition, the serving location node may also aid in the computation of a mobile's location based on the measurements made by the mobile.

Assisted Global Navigation Satellite System (A-GNSS)-based location performs best when there is clear access to open skies, and accuracy is not degraded by multipath. Assisted Global Positioning System (A-GPS) has high failure rates in dense-urban areas with tall buildings, indoors, and under dense foliage where there is no clear line of sight to the satellites in the sky (signal obstruction).

A-GNSS requires specialized hardware in the handsets (e.g., GPS receivers in chipsets) to acquire satellite signals. In the early years, this was an issue, as there were few handsets in the marketplace with this capability. Recently, however, A-GPS capability has been commoditized and is widely available as an inherent capability of newer handsets. Furthermore, handsets may be configured such that when a user makes an emergency call, the GPS capability is automatically turned on, overriding any prior user configurations which may have disabled GPS. The serving location node in an operator's network also has to be capable of providing assistance data and computing location. Normally, these are software capabilities provided on standard hardware servers requiring modest investment. A small operational cost to procure GPS assistance data from reference networks is normally provided as a service with an annual subscription fee.

Enhanced Cell ID

For wireless telephony service, a mobile connects to a specific antenna on a cell tower known as the serving cell. Because cell towers and antennae are owned by operators, the location of the serving cell and its operating characteristics (transmit power, range, opening, azimuth, etc.) are well known and can be provisioned on the serving location node. A mobile can then be positioned based on knowledge of its serving cell and the provisioned characteristics. This is known as basic cell ID location.

E-CID augments the knowledge of the serving cell characteristics with other measurements made by the mobile or the network. This includes range measurements, power level measurements of serving, and neighbor cells in its vicinity. The serving location node computes an enhanced location by augmenting the basic cell ID location with these additional measurements.

Although E-CID can improve accuracy over a basic cell ID location, its performance ultimately depends on the range of the cell. In rural areas, where cell ranges are large, E-CID accuracy is lower than in urban and dense-urban area with smaller cells sizes.

E-CID does not require any special capability on the handset because range and signal measurements are almost always available as part of normal mobile operations. Consequently, E-CID yield is high across all topographies. E-CID can be a perfect complement/fallback to A-GPS.

E-CID technology can be made widely available at modest cost. Location computation function on the network side is usually provided as a software option on standard hardware servers, requiring only modest investment. There are no ongoing operational costs other than keeping the base station almanac up to date.

Hybrid A-GNSS

Hybrid A-GNSS location technology combines raw range measurements from multiple sources such as different satellite systems (e.g., GPS and GLONASS). Alternatively, hybrids could combine GNSS with terrestrial ranges (e.g., the same measurements that are used by E-CID such as Universal Mobile Telecommunications System [UMTS]/Wideband CDMA [WCDMA] Round-Trip Time [RTT]). By combining range measurements, the chances of successful location fix increase, especially in cases where the number of measurements available from each individual source by itself may not be sufficient to compute a location. In addition, having more sources can contribute to better geometry of the signal sources (known as geometric dilution of precision) and hence lead to a more accurate location than would have been possible with just a single signal source.

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Hybrid A-GNSS location is dependent on the same factors – such as handset-capability and network server requirements – as A-GNSS and E-CID solutions.

Location Measurement Unit-based technologies

Location Measurement Units (LMUs) are specialized hardware units deployed in the network at known locations (normally co-located with base stations). They make timing measurements of signals emitted by a mobile as part of normal operations. Location determination is a mathematical process of triangulation using the timing measurements made by multiple LMUs and knowledge of the location of the LMUs.

LMUs perform well in topographies where the cell geometry lends itself to triangulation and signal distortion due to multipath is low, such as urban and suburban areas. LMU performance in dense-urban areas may experience degradation caused by distortion of signal timing due to multipath.

The capital expenditure associated with this technology is quite high because it requires specialized hardware units to be deployed in nearly every base station within the coverage area (deployment in sparse mode is possible). No special mobile capability is required, which means older handsets without GPS chipsets can be located using this technology. There is a modest operational cost involved in keeping LMUs functioning optimally.

Radio Frequency Fingerprinting Technology

RF fingerprinting is based on a mobile's reading of its immediate signal environment. A mobile reports signal strength measurements and cell IDs of serving and neighbor cells in its vicinity. These readings are compared with a database of RF patterns throughout the coverage area established a priori. The closest match of previously measured characteristics with measurements from the target mobile indicates the mobile's location. The RF patterns database is established by dividing a geographic area into a set of contiguous smaller areas. Signal measurement data is collected by physically driving the area, or predicted and assigned to the relevant area based on location.

RF fingerprinting performs best in dense-urban areas where the variance in signal patterns are numerous (higher cell densities and high multipath) and allows for identification of unique locations with fewer false positives. Conversely, performance is poor in rural areas where cell distances are large and the mobile observes very little variance in signal patterns.

Performance of this location technology is directly linked to the accuracy of the observations in the RF patterns database. Operators incur higher ongoing operational costs associated with keeping the database up to date to reflect current network conditions, such as the addition of new cell sites, and significant changes in topography that might change the signal patterns in the area. This is normally done via a combination of drive-collection and RF prediction. No special mobile capability is required; therefore, older handsets without GPS chipsets can be located using this technology.

Other Location Technologies

Besides the tools discussed above, there are a few other technologies which are likely to play a part in the service of emergency calls in the near future.

Observed Time Difference of Arrival (OTDOA) is a multilateration technique that is conceptually similar to A-GNSS location and is based on a mobile's TDOA measurements of downlink signals from serving and neighbor cells. A network server provides assistance data to the mobile, aiding signal acquisition and computing a mobile's location based on measurements returned. Although defined by 3GPP for 2G and 3G, it was never implemented widely, as the RANs weren't time-synchronized. It is expected to be implemented widely for 4G-LTE, where the E-UTRAN is expected to be time-synchronized. As emergency calls move from circuit-switched networks to IP-based (Voice over LTE [VoLTE]), OTDOA can be expected to play a part.

A Terrestrial Beacon System, another multilateration technique, is conceptually similar to A-GNSS and OTDOA in that the mobiles make TDOA measurements of signals from multiple sources. Where A-GNSS uses satellite systems as the signal source and OTDOA uses RF signals from the operator's E-UTRAN, terrestrial beacon systems may use alternate signal sources such as Bluetooth, metropolitan beacons, or WiFi access points. In all of these cases, the precise location of the beacon source is known to the serving location node. The mobiles may be assisted by a serving location node with assistance data to help with signal acquisition and optionally position computation functions.

Exhibit 2 below summarizes the performance of the 3GPP location technologies discussed in the section above.

Exhibit 2. Performance of 3GPP Location Technologies

Typical System Performance					Network Topography			
Positioning Method	Latency (Sec)	Cap-Ex	Op-Ex	Accuracy and Yield	Rural	Suburban	Urban	Dense-Urban
Basic Cell ID	0.1-2	Low	Low	67th percentile	5,000-10,000m	2,000-8,000m	1,000-5,000m	200-1,500m
				95th percentile	8,000-15,000m	5,000-10,000m	3,000-8,000m	200-2,500m
				Yield	100%	100%	100%	100%
2G-E-CID (TA, RXLEV)	0.2-2.5	Med	Low	67th percentile	1,000-2,000m	500-1,000m	250-750m	100-300m
				95th percentile	3,000-8,000m	1,000-3,000m	500-1,000m	200-500m
				Yield	95-100%	95-100%	95-100%	95-100%
3G-E-CID (RTT)	0.5-3	Med	Low	67th percentile	50-100m	50-150m	75-175m	60-175m
				95th percentile	75-150m	100-200m	150-300m	80-225m
				Yield	25-35%	35-50%	45-75%	30-45%
LMU-based	0.2-9	High	Low	67th percentile	45-450m	45-90m	45-90m	67-90m
				95th percentile	112-2,340m	90-270m	90-270m	180-270m
				Yield	95-100%	95-100%	95-100%	95-100%
RF Fingerprinting	0.2-5	Med	High	67th percentile	500-3,000m	200-800m	50-100m	50-100m
				95th percentile	1,000-5,000m	500-1,500m	200-500m	50-200m
				Yield	50-80%	60-100%	80-100%	90-100%
A-GPS	7-30	Med	Med	67th percentile	3-25m	7-25m	8-30m	8-40m
				95th percentile	4-50m	10-50m	10-60m	10-85m
				Yield	90-100%	70-100%	50-80%	30-60%
Hybrid A-GPS + RTT	7-30	Med	Med	67th percentile	3-28m	7-43m	9-105m	23-162m
				95th percentile	5-80m	11-180m	75-260m	130-303m
				Yield	90-100%	70-100%	50-80%	30-60%

Regulatory Approaches

Regulators around the world have taken various approaches to location support for wireless emergency calls, and operators have responded to the regulations in a variety of ways. A few exemplary cases are examined in this section.

United States

The U.S. was among the first countries to require mobile operators to provide location for mobile emergency calls. As early as 1998, the U.S. Federal Communications Commission (FCC) directed operators to implement a phased approach. In the initial phase, wireless networks were required to present calling line identification and base station identity for emergency calls. In a subsequent phase, location that met certain statistical targets was to be provided. These targets specified accuracy and yield metrics that operators had to meet over a well-defined coverage area, such as a county or PSAP coverage area. Over the years, the FCC has refined these regulations to provide improved accuracy to emergency responders while taking into consideration the practical difficulties that operators face in providing accurate location in certain topographical areas.

The U.S. operator's toolkit to meet the FCC regulation has changed over time. Initially, when the regulation went into effect, networks were predominantly 2G. In 2G, E-CID measurements, while widely available, were of lower precision (e.g., timing advance [TA] in 2G-GSM has a precision of only approximately 554 meters). In addition, A-GPS capable handsets were still not prevalent in the marketplace. Due to a variety of technical issues, downlink TDOA technologies such as Enhanced Observed Time Difference (E-OTD) did not meet the mandated target. While RF fingerprinting technologies did find favor with a few smaller Tier II and III regional operators, for large U.S. Tier I operators with nationwide coverage, this wasn't practical due to the periodic requirement to drive-collect calibration data for the entire network. This imposed too great an operational cost. Operators responded by implementing LMU-based technology, the only option that could meet the mandate, albeit with very high initial overhead costs.

Over the past decade, networks in the U.S. have transitioned from 2G to 3G technology, where the precision of network measurements are tighter. In addition, penetration of GPS-capable handsets in the marketplace has increased. This has enabled operators to cap their investment in the LMU technology and move to a combination of A-GPS and E-CID techniques to meet the FCC mandate. As of this writing, none of the U.S. Tier I 3GPP operators have networkwide commercial deployments of LMU or RF fingerprinting technologies for 3G to support emergency calls.

The transition to 4G-LTE has begun, and voice services will increasingly move from circuit-switched to packet-switched networks. Several new trends have begun to emerge. These include the commoditization of GPS capability as a standard feature of newer handsets; the operational status of additional GNSS systems such as GLONASS; the higher precision of E-CID network measurements in LTE; and the practical feasibility of additional multilateration techniques such as OTDOA due to the expected deployment of a synchronized E-UTRAN. Collectively they indicate that a combination of A-GNSS, OTDOA, and E-CID will be the dominant method by which operators will meet the U.S. FCC mandate. Other LTE technologies standardized by 3GPP, such as LMU and RF fingerprinting, may be limited to niche areas where they perform best and no other options are available.

Canada

Entering the game much later, the Canadian regulator, the Canadian Radio-television and Telecommunications Commission (CRTC), took a fundamentally different approach to regulation. Unlike the U.S., Canada did not mandate specific accuracy targets that operators had to meet. Instead, it was understood that operators would provide a GPS location when the mobile was so equipped. This fit well with the state of the industry at a time when A-GPS was already widely available and networks in Canada were using 3G technology with more precise network measurements to back up A-GPS. This was further reinforced by the expectations of consumers, who were already used to GPS for commercial services and expected at least that same level for emergency calls.

Operators in Canada have responded to the CRTC regulations for location support by deploying a combination of A-GPS; and E-CID for both 2G and 3G. There have been no widespread commercial deployments of LMU or RF fingerprinting solutions. It is interesting to note that, despite the differences in regulatory approaches, operators in both the U.S. and Canada have converged on A-GPS; and E-CID as the primary location technology of choice. Unlike their U.S. counterparts, Canadian operators have been able to take a more economical route to this endpoint, without having to invest in expensive technologies. As networks transition to 4G, Canadian operators, like their U.S. counterparts, are expected to extend the A-GPS; and E-CID approach to cover 4G-VoLTE emergency calls, and they might augment that with the deployment of LTE-OTDOA.

Despite the differences in regulatory approaches, operators in both the U.S. and Canada have converged on A-GPS; and E-CID as the primary location technology of choice.

Australia

Australia has followed the Canadian approach. Although the Australian regulator, the Australian Communications and Media Authority (ACMA), requires operators to support emergency calls with location, no specific accuracy target was set. Operators initially implemented E-CID based technologies and are now moving to upgrade to A-GPS.

In the coming years, the industry will be working to resolve accuracy and yield issues in specific topographies (e.g., in indoor locations, where an increasing number of wireless emergency calls are being placed). Technologies such as terrestrial beacon (WiFi, Bluetooth, and metropolitan beacon systems) and perhaps even RF fingerprinting and LMUs will play a part in these specific topographies.

TCS Recommendations

With a decade of experience in location support for emergency calls, TeleCommunication Systems, Inc. (TCS) believes that a combination of A-GPS; and E-CID deployed networkwide offers the best balance between cost and performance. This takes into consideration the interests of the emergency service providers and the general public, for whom an accurate location is essential to the timely delivery of emergency services. It also takes into account the interest of the operator, who must make the economic investment to provide this location.

The key elements of the TCS approach follow:

- We recommend a phased approach to regulation (e.g., an initial phase requiring caller identification and cell-based location, followed by a phase with location based on higher accuracy methods).
- We recommend that regulators do not set specific accuracy mandates at this time.
- With the increasing prevalence of GPS-capable smartphones in the subscriber population, an optimal approach would stress regulators encouraging operators to provide GPS-based location when a handset is so capable. Where A-GPS fails, operators could fall back to E-CID or hybridize with E-CID with minimal additional investment. With deployment of LTE, additional multilateration techniques also may be added to this mix.
- Once initial implementations are off the ground, regulators can assess the quality of service received by subscribers in various network topographies. Where the combination of A-GPS and
- E-CID location technologies performs poorly, augmentation with other technologies such as LMUs, RF fingerprinting, and beacon-based systems can be considered. Given the higher cost profiles of these other technologies and the specificity of the topography where they perform best, their deployment should be limited to specific areas of the network in order to harmonize both technical and economic interest.

A combination of A-GPS; and E-CID deployed networkwide offers the best balance between cost and performance.

A Sample Phased Deployment

In this section, we present an example of how an operator could implement a phased approach to supporting wireless emergency calls with location.

Phase 1: Supporting an Emergency Call with Cell ID-Based Location

In the initial phase, a basic cell ID location is provided in an automated fashion for all mobile call originations.

To enable this, an operator would only have to deploy a gateway node known as a Gateway Mobile Location Center (GMLC). The GMLC is normally available as a software solution running on standard hardware servers. The GMLC provides an interface through which location can be delivered to the PSAPs; either pull or push mode can be supported.

This phase allows both operators and emergency service providers to provide basic location support quickly. For the operator, only a modest investment is required to implement a GMLC system. PSAPs can use this phase to implement the necessary infrastructure at their end to receive location in an automated fashion.

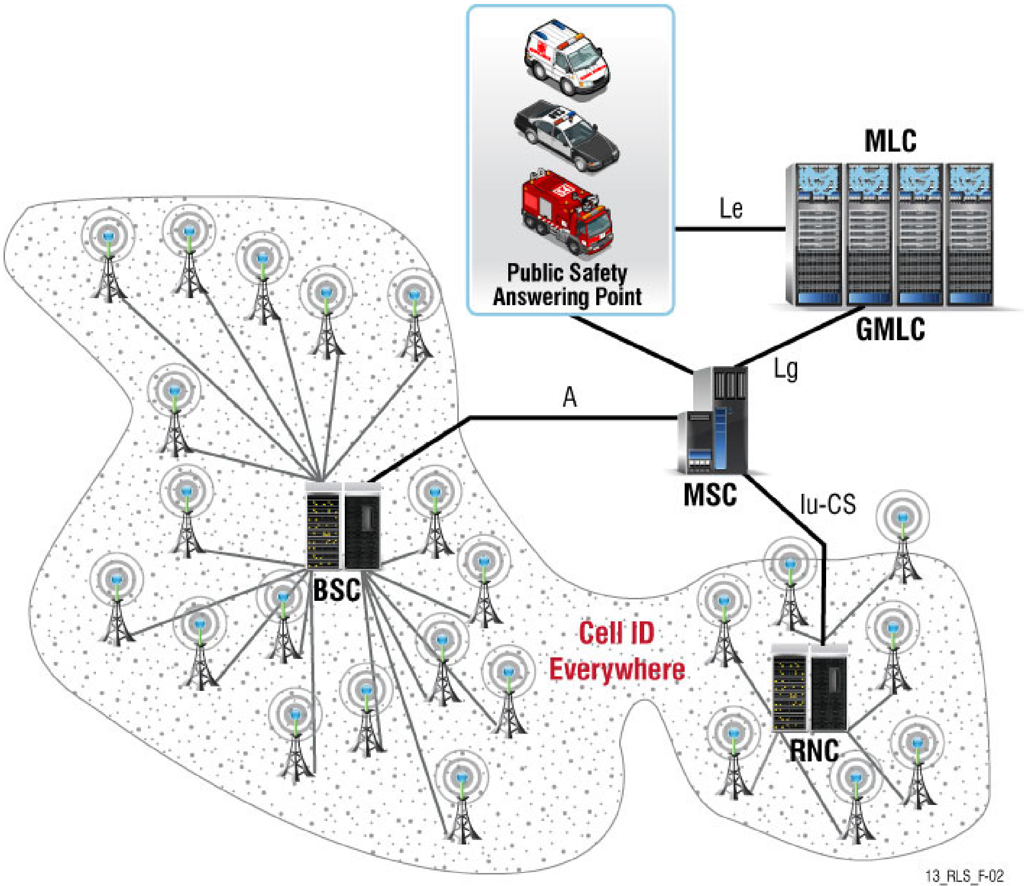

Exhibit 3. Phase 1: Cell ID Location Throughout the Network

Phase2: Supporting an Emergency Call with Higher Accuracy Location

In the second phase, the basic cell ID location is enhanced with A-GPS and E-CID location fixes.

To enable this, an operator would add a serving location node known as the Serving Mobile Location Center (SMLC). Normally, these are provided as an additional software option on the same hardware server as the GMLC. The SMLC provides A-GPS when a mobile is capable of supporting it. Because A-GPS is based on satellites, it could be available throughout the network. Where A-GPS fails, the SMLC falls back to E-CID based on network measurements provided by the RANs. The SMLC also may provide a location fix based on a hybrid of A-GPS and E-CID measurements.

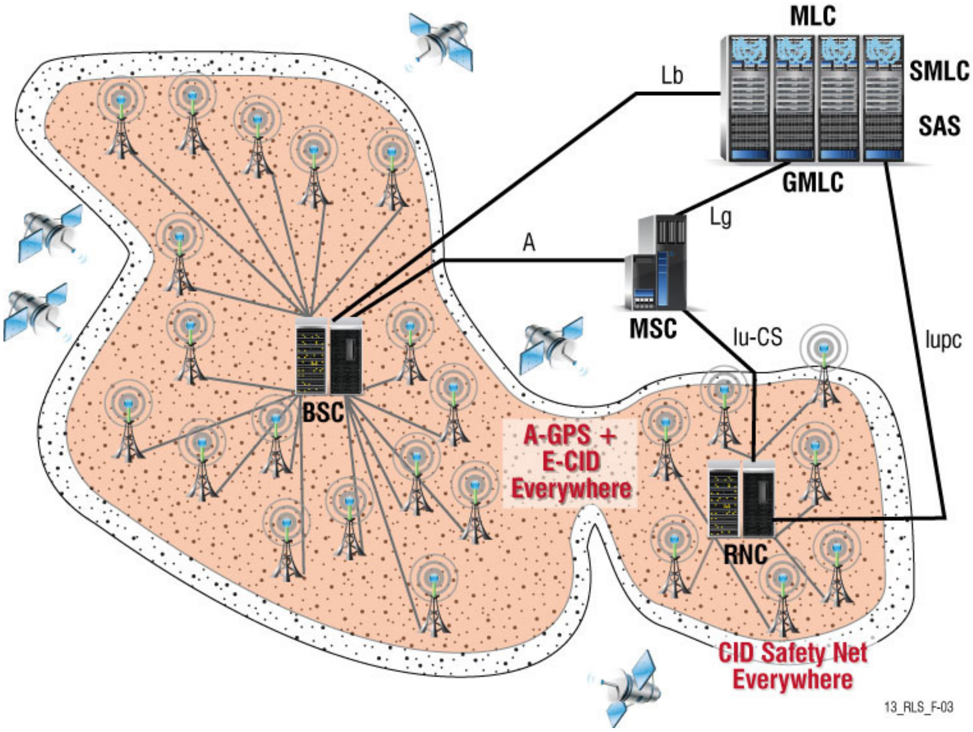

Exhibit 4. Phase 2: Adding Higher Accuracy Location Support –
Basic Cell ID Overlaid with A-GPS: and E-CID

This phase allows an operator to add higher accuracy location capability (i.e., SMLC) to the network with modest incremental investment.

Phase 3: Supplementing A-GPS: and E-CID with Specialized Technologies

If prior phases indicate that specific areas within the network are not adequately served with A-GPS and E-CID, operators and regulators could optionally consider limited deployments of additional technologies to increase performance.

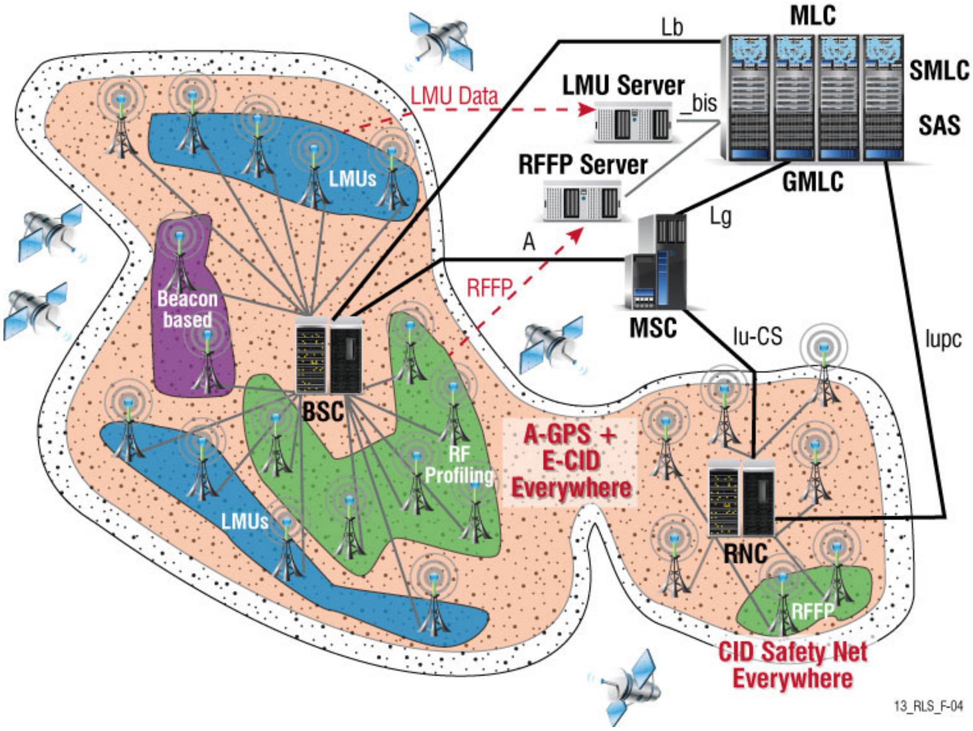

Exhibit 5. Phase 3: Optional Deployment of Specific Technologies Overlaid with A-GPS: and E-CID

For example, operators could consider selective deployment of LMU, RF fingerprinting, and beacon-based technologies overlaid on top of the A-GPS: and E-CID. As noted in the positioning technology section, LMUs come with overhead costs and RF fingerprinting solutions have a recurring operational expenditure; however, these could be contained through limited deployment in areas where they perform best and where the combination of A-GPS: and E-CID does not provide adequate performance.

Conclusion

Emergency calls deserve the best location a network can provide. A number of positioning technologies exist to determine mobile location. The performance profile of these technologies – measured in terms of accuracy, yield, and latency – vary with network topography. As a result, no single technology can meet the needs of a network with significant topographical difference. Furthermore, the location technologies have varying cost profiles, which will influence what is deployed.

Experience has shown that a combination of A-GPS and E-CID implemented networkwide offers balance between performance and cost. Regulators are encouraged to work with operators toward this end, as it offers an acceptable solution, quickly and economically. Setting specific accuracy targets may not be the only means to this end.

As technology evolves and networks move to 4G, additional multilateration techniques may be added to the mix. Options such as LMU-, RF fingerprinting-, and beacon-based solutions have a place in this mix of technologies. The cost of their implementation compared to the gains returned will determine how widely and where they are implemented.

About TeleCommunication Systems, Inc.

TeleCommunication Systems, Inc. (TCS) (NASDAQ: TSYS) is a world leader in highly reliable and secure mobile communication technology. TCS infrastructure forms the foundation for market-leading solutions in Enhanced 9-1-1 (E9-1-1), text messaging, commercial location, and deployable wireless communications. TCS is at the forefront of new mobile cloud computing services, providing wireless applications for navigation, hyperlocal search, asset tracking, social applications, and telematics. Millions of consumers around the world use TCS wireless apps as a fundamental part of their daily lives. Government agencies utilize TCS' cybersecurity expertise, professional services, and highly secure deployable satellite solutions for mission-critical communications. Headquartered in Annapolis, Maryland, TCS maintains technical, service, and sales offices around the world. To learn more about emerging and innovative wireless technologies, visit www.telecomsys.com.

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