September 2014

WORKING GROUP 1
Next Generation 9-1-1
Task 2

Final Report – Location Accuracy and Testing for
Voice-over-LTE Networks

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1 Results in Brief

1.1 Executive Summary

Current FCC location accuracy requirements under the Commission's rules Section 20.18(h) allow Commercial Mobile Radio Service ("CMRS") providers using a network-based E9-1-1 location method to begin "blending" their GPS handset-based location data with their network-based data at the different benchmarks between January 2012 and January 2019. Based on recommendations made in the CSRIC III WG3 March 2012 Report concerning certain key performance indicators (KPIs) and the different types of empirical testing, CSRIC IV Working Group 1 was charged to examine whether those recommendations still apply for network-based carriers reconfiguring to Voice over LTE ("VoLTE") platforms. WG1 examined current testing recommendations as they apply to wireless carriers transitioning to Long Term Evolution ("LTE") with respect to meeting current location accuracy parameters in 20.18.

This report documents the examination by CSRIC IV Working Group 1 Subgroup 2 with respect to the following:

1. The impact VoLTE implementation will have on carriers' ability to comply with existing wireless E9-1-1 location accuracy levels.
2. Carriers transitioning from second generation ("2G")/third generation ("3G") networks to VoLTE networks generating and delivering location information to Public Safety Answering Points ("PSAPs") during the period when they are operating both legacy and VoLTE networks. Additionally, the impact, if any, that simultaneous operation of both networks during the transition will have on carriers' overall wireless location accuracy performance.

The conclusions drawn from this report are:

1. The FCC should expect, over time, location performance with VoLTE to be slightly better than or equivalent to 2G and 3G performance.
2. It is not anticipated that modifications to existing carrier testing methods or procedures would be required due to the introduction of VoLTE. The FCC should continue to support the recommendations of CSRIC III WG3. In summary, those are:

   • Key performance indicators (KPIs) should be routinely monitored to help identify instances where system performance has degraded (relative to baseline compliance tests) and further testing and system improvements are needed at the local level.
   • Enhancements to location technology should be validated in representative environments, to ensure equivalent or improved performance. An example of this would be the introduction of OTDOA for VoLTE.
   • Spot-checking using empirical field-testing should be conducted on an as needed basis, for example, as determined by KPI monitoring or legitimate performance concerns from a PSAP.
   • Empirical data for maintenance testing may be collected incrementally over time.
   • Any significant deviations from expected prior performance levels should result in careful investigation and re-testing of the applicable test area.

- These alternative maintenance testing methods replace the need for full compliance testing every two years.
- All legitimate performance inquiries from a County/PSAP or other public safety entity shall be properly investigated with full cooperation from the wireless service provider, and any issues resolved in a timely manner.

2 Introduction

The Commission directed CSRIC IV WG 1 to examine the impact of the migration to enabled 4G VoLTE networks on the ability of carriers to meet with the Commission's accuracy levels for wireless Enhanced 9-1-1 ("E9-1-1") Phase II location information for CMRS providers. The record in the FCC's E9-1-1 Location Accuracy proceeding and the CSRIC III WG 3 2012 and 2013 Reports indicate that location technology vendors are making enhancements to the location technologies that will be used by carriers in 4G VoLTE networks.

2.1 CSRIC Structure

Communications Security, Reliability, and Interoperability Council (CSRIC) IV									
CSRIC Steering Committee									
Chair or Co-Chairs: Working Group 1	Chair or Co-Chairs: Working Group 2	Chair or Co-Chairs: Working Group 3	Chair or Co-Chairs: Working Group 4	Chair or Co-Chairs: Working Group 5	Chair or Co-Chairs: Working Group 6	Chair or Co-Chairs: Working Group 7	Chair or Co-Chairs: Working Group 8	Chair or Co-Chairs: Working Group 9	Chair or Co-Chairs: Working Group 10
Working Group 1: Next Generation 911	Working Group 2: Wireless Emergency Alerts	Working Group 3: EAS	Working Group 4: Cybersecurity Best Practices Working	Working Group 5: Server-Based DDoS Attacks	Working Group 6: Long-Term Core Internet Protocol Improvements	Working Group 7: Legacy Best Practice Updates	Working Group 8: Submarine Cable Landing Sites	Working Group 9: Infrastructure Sharing During Emergencies	Working Group 10: CPE Powering

Table 1 - Working Group Structure

2.2 Working Group 1 Task 2 Team Members

Working Group 1 Task 2 consists of the members listed below.

Name	Company
Jenny Hansen, Chair	NICE
Wayne Ballantyne	Motorola Mobility, LLC
Terri Brooks	TruePosition
Kimberly Burdick	Chouteau County MT - Sheriff's Office
Brent Burpee	Verizon Wireless
Kirk Burroughs	Qualcomm
David Conner	US Cellular
Bruce Cox	NextNav
Kimberly Culp	Larimer County
Khaled Dessouky	TechnoCom
Robert Ehrlich	CIHVA

Matthew Gerst	CTIA-The Wireless Association®
Jim Goerke	Texas 9-1-1 Alliance
Jeanna M Green	Sprint Corporation
Eric Hagerson	T-Mobile
Sherri Griffith Powell	L.R. Kimball
Roger Hixson	NENA
Wink Infinger	Florida State 9-1-1 Coordinator
Gerald Jaskulski	DHS (Department of Homeland Security)
Ryan Jensen	T-Mobile
Steve Leese	APCO
Sandra Lott	CenturyLink
Mike Loushine	ACS (Applied Communications Sciences)
Russ Markhovsky	Invisitrack
Roger Marshall	TeleCommunication Systems, Inc. (TCS)
Kathy McMahon	MCP
Christian Militeau	Intrado
Martin Moody	Metropolitan Emergency Services Board
Jerry Panagrossi	Invisitrack, Inc.
Ganesh Pattabiraman	NextNav
Gustavo Pavon	TruePosition
Raghavendhra Rao	AT&T
Glenn Roach	Winbourne Consulting
Roderic Robinson	TeleCommunication Systems, Inc. (TCS)
Cherie Lynn Rockwell	Butte County, CA
Chuck Ronshagen	Cassidian Communications
Ed Roth	LETA 9-1-1
Susan Sherwood	Verizon Wireless
Greg Schumacher	Sprint Corporation
Dorothy Spears-Dean	Virginia Information Technologies Agency
Kara Thielen	Viaero
David Tucker	Vermont Enhanced 9-1-1 Board
Greg Turetzky	Intel Corporation
Kathy Whitbeck	Nsight
Bruce Wilson	Qualcomm

Table 2 - List of Working Group Members

3 Objective, Scope, and Methodology

3.1 Objective

Previous CSRIC groups have explored accuracy and testing of the Global System for Mobile Communication ("GSM" or 2G), Universal Mobile Telecommunications System ("UMTS" or 3G), and 3rd Generation Code Division Multiple Access ("CDMA") or IS-2000 deployments (also included in the term 3G in this document) in relation to requirements for wireless E9-1-1. The LTE or fourth generation "4G" technology has now reached the point in the specification

development process to allow for an evaluation by CSRIC. That said, The FCC provided several tasks to Working Group 1. The membership for Task 2 is charged with questions concerning several aspects of location estimation for VoLTE", including accuracy, latency and testing. The focus of this report is not FCC rule compliance *per se* but VoLTE's potential E9-1-1 location accuracy performance and the usefulness of applying existing location accuracy testing policies and procedures to 9-1-1 calls from 4G VoLTE networks.

The task team members have formed responses to the specific questions posed by the FCC in the clarified task description as follows:

1. What impact will VoLTE implementation have on carriers' ability to comply with existing wireless E9-1-1 location accuracy requirements?

   a. How will the technologies used for generation and delivery of wireless E9-1-1 location information differ for VoLTE from those used for generation and delivery of wireless E9-1-1 location information in legacy 2G/3G networks?

   b. Can VoLTE provide location accuracy that meets the Commission's current rules and benchmarks for wireless E9-1-1 location accuracy?

      i. Can VoLTE networks and the location technologies that will be used in such networks achieve increases in location accuracy and yield and decreases in latency compared to 2G and 3G networks?

      ii. Are all VoLTE deployments the same in terms of their ability to support wireless E9-1-1 location determination? Can the Commission expect the same level of location accuracy performance across networks deploying VoLTE or will carrier performance differ?

2. How will carriers transitioning from 2G/3G networks to VoLTE networks generate and deliver location information to PSAPs during the period when they are operating both legacy and VoLTE networks? What impact, if any, will simultaneous operation of both networks during the transition have on carriers' overall location accuracy performance?

   a. Does the transition to VoLTE require any modifications to current carrier testing procedures for determining compliance with the Commission's location accuracy requirements under Section 20.18?

   b. Should prior CSRIC recommendations regarding location testing (e.g., CSRIC III WG 3 recommendations regarding testing by network-based carriers every two years) apply to carriers reconfiguring to VoLTE platforms?

The format of the document directly follows those questions.

4   Location Accuracy in VoLTE Networks

4.1   *What impact will VoLTE implementation have on carriers' ability to comply with existing E9-1-1 location accuracy requirements?*

While the network elements and protocols used in VoLTE may differ from 2G and 3G location architectures, the equivalent location capabilities are provided. Thus, the high level conclusion is that VoLTE will have no deleterious impact on the ability of operators to meet the E9-1-1 location accuracy levels that currently apply to CMRS.

4.1.1   How will the technologies used for generation and delivery of E9-1-1 location information differ for VoLTE from those used for generations and delivery of E9-1-1 location information in legacy 2G/3G networks?

Generation of the location information uses very similar components and technologies in both 2G/3G and 4G networks. The two diagrams in Figure 1 and Figure 2 below show the major components of a 2G/3G system and a 4G system.

The same location technologies can be supported in all generations (2G/3G/4G). Assisted Global Positioning System ("A-GPS") in 3G has been extended to Assisted Global Navigation Satellite System ("A-GNSS") with the addition of new constellations, such as Global Navigation Satellite System ("GLONASS") in 4G LTE systems. Handset-measured ranging signals are employed in Advanced Forward Link Trilateration ("AFLT") in 3G CDMA systems and Observed Time Difference of Arrival ("OTDOA") systems in 4G LTE systems. Network-measured ranging signals are used in Uplink Time Difference of Arrival ("UTDOA") in both 2G/3G and 4G systems.

The content of the Phase II location estimate delivered to the PSAP out of a VoLTE 4G network includes the same position, confidence, and uncertainty parameters used in 2G/3G networks for technologies that directly generate geographic (i.e., XY) location. These will be formatted appropriately for legacy PSAPs as well as NG9-1-1PSAPs.

Delivery of the Phase I cell site civic address will continue to be delivered in the same textual format as in 2G/3G systems. Small cells deployed indoors will provide better Phase I location accuracy than outdoor macro cells. The deployment of small cells is not limited to VoLTE, but is a general trend to provide geographical re-use of limited spectrum.
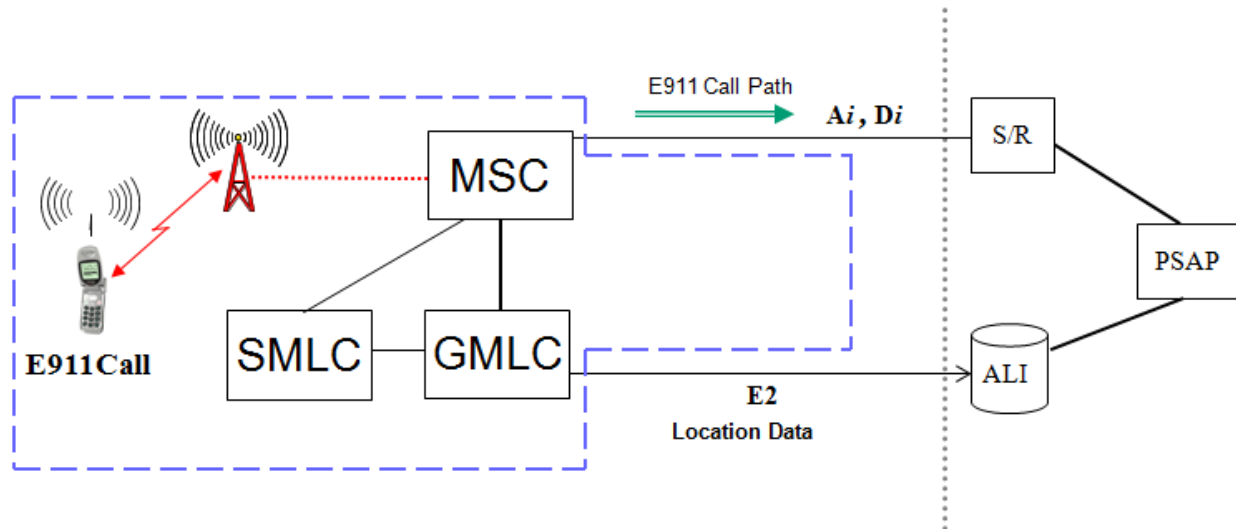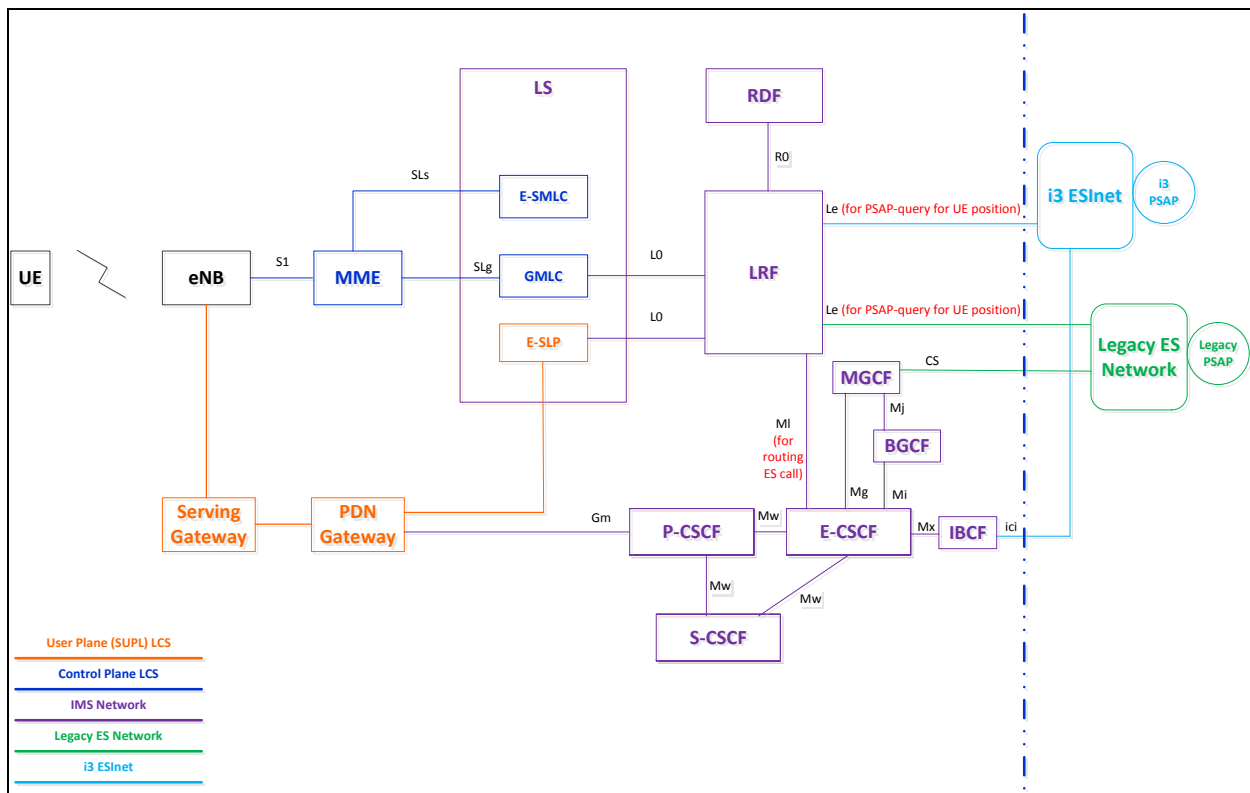
Figure 1: GSM MAP Network[1]

Figure 2: Exemplary VoLTE location architecture with NENA i3 ESInet and Legacy ES network

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[1] Figure 1 was reproduced from Figure 3.3 of ATIS-0500001, *High Level Requirements for Accuracy Testing Methodologies* (November 2011), with permission from the Alliance for Telecommunications Industry Solutions (ATIS).

In both 2G/3G and 4G systems, the voice portion of the call is handled separately from the location determination function.

In Figure 2 above, the voice is routed to the PSAP through a gateway. The position calculation process consists of a sequence of data packets between the handset or user equipment (UE) and the network position calculation function. The data packets can be carried over the control channel or the user data channel. The modules involved in the two different paths are listed below.

The voice path for an E9-1-1 VoLTE call goes from
UE→eNB→S/PGWs→CSCFs→MGCF→E9-1-1->ES Network->Legacy PSAP for the call to connect.

Phase II Location via control channel is:
E9-1-1 LBS Control Plane goes from PSAP→LRF→GMLC→MME→E-SMLC→UE then back to PSAP through the ES Network

Phase II Location via the user data channel is:
E9-1-1 LBS User Plane goes from PSAP→LRF→GMLC→ESLP→UE then back to PSAP via the ES Network

4.2 Can VoLTE provide location accuracy that meets the Commission's current rules and benchmarks for E9-1-1 location accuracy?

As discussed below, LTE-based location methods provide more flexibility, and in some cases better accuracy is expected relative to current 2G/3G-based methods. Since 2G/3G-based technologies are now compliant with the current FCC Phase II mandates for CMRS providers, VoLTE-based location is expected to meet the accuracy levels of the current CMRS outdoor location Phase II requirements for E9-1-1.

4.2.1 Can VoLTE networks and the location technologies that will be used in such networks achieve increases in location accuracy and yield and decreases in latency compared to 2G and 3G networks?

The statements below are based on an architectural analysis and system simulations of LTE location capabilities, as compared to 2G and 3G. The actual performance improvements will ultimately be characterized in carrier outdoor testing and future indoor test beds recommended by CSRIC.

The following statements can be made about VoLTE-based location performance using each of the location technologies below, which are already committed for VoLTE deployments:

4.2.1.1 A-GPS/A-GNSS

LTE is not expected to significantly improve Time to First Fix ("TTFF") as compared to 2G/3G. This is because the TTFF will be dominated by GNSS location determination time. Observed

location determination fix-type ratios based on carrier-provided E9-1-1 data logs are predominantly A-GPS, though a minority will fall back to a network-based location technology. The A-GPS TTFF is in the 8 to 24 second range, and this will not be appreciably shortened by the faster networks for message delivery. Fallback methods typically have shorter TTFF, but are typically less accurate than A-GPS.

A-GPS yield, accuracy and TTFF may modestly improve in synchronous LTE networks[2] as compared to asynchronous GSM/UMTS networks, since the finer time accuracy (1.5 – 5 uSec)[3] speeds the acquisition of the GPS signals. This effect will be most pronounced in weak signal environments such as indoors.[4] LTE time synchronization is comparable to CDMA, so little improvement is expected compared to CDMA. Some UMTS networks have been synchronized as part of network upgrades and would exhibit similarly small A-GPS improvements.

A-GNSS (e.g., GPS & GLONASS) is expected to roll out concomitantly with LTE, which will allow more satellite vehicles to be used in the location calculations. Published articles [5] show that this will lead to somewhat higher accuracy, lower TTFF, and increased yield, especially in dense urban scenarios. GSM and CDMA did not support GLONASS; while UMTS had modest support for GLONASS, LTE handsets are expected to widely support GLONASS and eventually other satellite constellations such as BeiDou[6] and Galileo[7] may be supported, as well.

4.2.1.2   OTDOA

LTE OTDOA is expected to give improved performance (accuracy and yield) compared to CDMA AFLT for multiple reasons:
1) Wider signal bandwidths allow more precise estimate of Time of Arrival.
2) The OTDOA positioning reference signal is isolated in the code, time and frequency domain,
3) The protocol has finer time/distance reporting precision for distances less than 40km.

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[2] In a Synchronous LTE or UMTS Network, GPS is used to align the signals coming from the base stations (e.g., eNBs) with timing derived from the GPS system. In an asynchronous LTE, UMTS, or other type of network, the timing of the base station signals is unrelated to GPS resulting in a slower GPS TTFF, as discussed further in footnote 4.

[3] http://www.gps.gov/cgsic/meetings/2012/weiss1.pdf
Telecom Requirements for Time and Frequency Synchronization
Marc Weiss, Ph.D.   Time and Frequency Division, NIST

[4] While the exact details of how network time synchronization improves GPS acquisition are beyond the scope of this report, the topic is well-discussed in Understanding GPS Principles and Applications, 2nd edition ISBN-13: 978-1-58053-894-7, especially pp. 535-543. Basically, precise network time availability reduces the GPS acquisition code phase "search space". In a weak signal environment, the time to analyze each "code phase/frequency" search bin is increased due to the need for longer non-coherent integration time. As a result, the benefit of precise network time availability has the most acquisition time benefit in a weak signal environment, and can make the difference between obtaining a GPS fix in 30 seconds or not."

[5] GPS World, Dec. 2011, "Consumer GPS/GLONASS: Accuracy and Availability Trials of a One-Chip Receiver in Obstructed Environments"   http://gpsworld.com/gnss-systemreceiver-designconsumer-gpsglonass-12359/"

[6] http://en.beidou.gov.cn/

[7] http://www.gsa.europa.eu/galileo-0

See Table 3 for the parametric comparison of CDMA vs. LTE.

	CDMA	LTE
Bandwidth	1.23 MHz	1.4 MHz to 20 MHz
Time Resolution	1/16 chip (~ 51ns)	$1T_s$ (~33ns) for RSTD $\leq 4096T_s$ (~40km) and $5T_s$ (~163ns) for RSTD $> 4096T_s$ (~40km) ($1T_s$ = ~10m)
Standard	3GPP2 CDMA-2000	3GPP TS36.355

Table 3 - CDMA/LTE Time Resolution/Bandwidth Parameters

Accuracy may be improved because LTE supports more flexible hybrid positioning methods than 2G/3G. The E-SMLC can initiate multiple location methods at once, such as an OTDOA location performed in the network, and UE-based A-GNSS calculated in the UE.[8]

4.2.1.3   Small Cell

Small cell deployments are more likely to happen in LTE, due to spectrum allocations in the 3.5 GHz band and rapid increases in wireless data consumption. This could lead to a more accurate Phase I location for small cells with small coverage areas, which in some cases may be accurate enough for first responder dispatching. In these cases, a more accurate Phase I location may also improve A-GNSS acquisition for weak signal scenarios.

4.2.1.4   Overall impact and validation of LTE-related location enhancements

Carrier outdoor testing and future indoor test beds recommended by CSRIC will ultimately determine the benefit of all of these changes, and produce real data to validate the expectations stated above.

4.2.2   Are all VoLTE deployments the same in terms of their ability to support E9-1-1 location determination? Can the Commission expect the same level of location accuracy performance across networks deploying VoLTE or will carrier performance differ?

Given that all carriers are converging on the same radio access network technology, namely LTE, and that carriers have announced plans to implement the same location technologies to locate VoLTE calls to 9-1-1, location performance for VoLTE in comparable topologies is generally expected to be quite similar across different carrier networks.

While there are implementation details that can affect location performance from carrier to carrier, it is expected that carriers will follow similar paths to optimize LTE location functionality.

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[8] 3GPP TS 36.305 sec 4.3 "Standard UE positioning methods; Network assisted GNSS methods, downlink positioning methods, enhanced cell ID method, hybrid positioning using multiple methods from above.   In 2G/3G, the SMLC can only initiate multiple location methods sequentially.

Different wireless carriers will utilize a variety of vendors to supply needed location functionality in both networks and handsets. Since any deployed location technology will be standardized, different vendor implementations are not expected to result in significant differences in location performance, assuming similar field conditions and deployment parameters.

These expectations for similar performance across various carrier/vendor implementations have been demonstrated through practical experience with A-GPS – where different carriers have obtained similar yield and accuracy figures – even with different network and handset implementation parameters.

Specific location technologies currently planned and announced for use for VoLTE E9-1-1 include:

- A-GPS
- A-GLONASS
- OTDOA

A-GPS and A-GLONASS (collectively A-GNSS) are expected to perform similarly across different carrier and vendor VoLTE implementations, just as A-GPS has for previously deployed radio access networks.

OTDOA, while fully standardized, allows various options that can affect location performance. For example, Positioning Reference Signals ("PRS") can be transmitted on the downlink at different duty cycles and durations. PRS muting increases "hearability" between adjacent towers, by only one tower transmitting at a specific time in a given area. PRS muting patterns can be optimized to specific geographies (e.g., urban canyons versus rural). Actual field data collected over many months, with different traffic volumes and tower spacing in rural versus dense urban cores will go into the continuous improvement process by the carriers. In dense cell spacing, increasing the number of towers heard will increase the number of directions from which data is collected. This is expected to improve accuracy. TTFF should not change significantly.

It is reasonable to expect that carriers and their vendors will work carefully to ensure these location technologies are optimized and implemented properly relative to E9-1-1 location performance. Furthermore, these implementation options can be adjusted and adapted, as needed over time, to address any specific performance gaps for a given carrier.

Given these considerations, it is reasonable for the Commission to generally expect the same level of location performance across various carrier networks deploying VoLTE.

4.2.3   Location Technologies that could potentially be deployed for VoLTE

The discussion in the following sections covers location technologies that could potentially augment location performance, but are not currently committed for VoLTE implementations in the US. These technologies have either (a) already been deployed in 2G or 3G networks, or (b) used for cLBS applications, or (c) are in an advanced state of prototyping and validation.

Additionally, other technologies discussed in the CSRIC III report, "Leveraging LBS and Emerging Location Technologies for Indoor Wireless E9-1-1 (Mar. 14, 2013)"[9], may eventually be considered for enhancement of VoLTE location.

4.2.3.1 UTDOA

Location accuracy of UTDOA deployed on LTE networks should comparable to, or better than, the accuracy achieved by UTDOA deployed on 3G or 2G networks, and location latency for UTDOA deployed on 4G (LTE) networks should be similar to that achieved for UTDOA deployed on 2G (GSM) networks, depending on the assigned periodicity and bandwidth of the Sounding Reference Signal ("SRS") configuration[10].

4.2.3.2 Wi-Fi

In addition to the committed LTE location methods discussed above, other location methods such as Wi-Fi for VoLTE have been standardized. Wi-Fi for position calculation has been standardized in Secure User Plane ("SUPL") 2.0 and is available for deployment on GSM, UMTS, CDMA and LTE. SUPL Multiple Location IDs support reporting of Medium Access Control ("MAC") Address for unique user identification latitude and longitude lookup, signal strength for Received Signal Strength Indicator ("RSSI") position calculation and round trip delay for RTT position calculation. These are only available in UE-Assisted user plane call flows where the position is calculated by the E-SMLC in the network.[11]

Wi-Fi support for control plane UE-Assisted call flows is standardized only for LTE in the LPPe protocol[12]. LTE control plane LPP protocol can be extended with the External Protocol Data Unit ("EPDU"), to support LPPe protocol to transmit the same Wi-Fi parameters available in SUPL Multiple Location IDs (Mac Address, signal strength, round trip delay).[13]

Wi-Fi measurements could be reported along with OTDOA and A-GNSS measurements. The combination of multiple sources of information can be used to cross-validate the other systems.

4.2.3.3 Terrestrial Beacon System (TBS)

Terrestrial Beacon Systems are one of the newer positioning techniques that are under consideration to augment the existing positioning methods. Similar to GPS, the system is air interface agnostic. The performance of NextNav's Rev 1 implementation of TBS was benchmarked during CSRIC III, and the Rev 2 implementation was tested under similar conditions (not under CSRIC oversight) [14]. This technology is currently in the process of being

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[9]http://transition.fcc.gov/bureaus/pshs/advisory/csric3/CSRIC_III_WG3_Report_March_%2020 13_LeveragingLBS.pdf

[10] SRS is the Sounding Reference Signal specified in LTE and used to test reception quality for uplink channel-dependent scheduling.

[11] OMA-TS-ULP v2.0

[12] OMA-TS-LPPe

[13] 3GPP TS 36.355 Evolved Universal Terrestrial Radio Access (E-UTRA) LTE Positioning Protocol (LPP)

[14] Differences between Rev 1 and Rev 2 technology are documented in TechnoCom Report: NextNav Technology Rev-2 Indoor Test Report

standardized in 3GPP, OMA and other standards bodies. In 3GPP it is part of the study item on 'Indoor Positioning'.

4.2.3.4   Hybrid positioning systems

Each positioning system can operate in isolation or in combination with other systems. A-GNSS is one example of hybrid combining of measurements from two different positioning systems (e.g., GPS + GLONASS, or GPS+BEIDOU). This is an example of a tightly coupled hybrid combination in the measurement space. A second kind of hybrid combination is a loosely coupled, cross checking of results between cell tower computed positions, e.g. via OTDOA and Wi-Fi computed positions.

Multiple combinations of different technologies can be combined together to produce a more reliable and accurate position estimate than any one system alone. GPS works well in outdoor environments, but has limitations in some indoor environments. Other location methods can fill in the gaps, each with different strengths and weaknesses.

(http://apps.fcc.gov/ecfs/document/view?id=7520937523) and included improved beacon timing synchronization, assisted modes of operation, waveform modifications etc.

5 Transition from 2G/3G to VoLTE

5.1 How will carriers transitioning from 2G/3G networks to VoLTE networks generate and deliver location information to PSAPs during the period when they are operating both legacy and VoLTE networks? What impact, if any, will simultaneous operation of both networks during the transition have on carriers' overall location accuracy performance?

The scope of these questions is specifically referring to carrier-deployed VoLTE for an LTE Radio Access Network ("RAN"), using an IMS Core Network ("CN") for the transport of VoLTE calls across the network. Note that, Multimedia Messaging Emergency Services ("MMES") and Rich Communications Services ("RCS") are out of scope.

The expectation is that initial location accuracy will be as good, if not better, compared to legacy 2G/3G networks. Performance improvements over time are expected as the location technologies in 4G are optimized.

Carriers will do what makes the most sense to support customer expectations regarding emergency support and the availability of wireless E9-1-1 Phase II location accuracy on the 4G network. It is likely that carriers will leverage the underlying 2G/3G networks for E9-1-1 support wherever possible until 4G networks and associated location technologies are fully deployed and optimized and 2G/3G networks are decommissioned. It is expected that in the early stages of 4G network deployments, carriers will be deploying E9-1-1 location technologies that are similar to current solutions available on their 2G/3G networks; namely, A-GPS supplemented by a network-based location technology for areas where GPS is challenged.

Without knowing each specific carrier's network implementation and transition plans, it is unlikely that the operations of one network (2G/3G) will impact the operations of the other network (4G) as they are separate network architectures. However, some of the E9-1-1 Phase II location technologies being deployed on 4G networks (e.g. OTDOA) are new and are only now in their initial deployment by some carriers being implemented on completely new network infrastructures. As with E9-1-1 Phase II on 2G/3G networks, it will take some time to optimize the key attributes of the location technologies for 4G. Some examples of network tuning during this transitional period are:

1. Cell Tower location provisioning
2. RF parameters for mutual cell hearability to maximize the number of towers measured by the UE
3. Degree of synchronization.

5.1.1   Does the transition to VoLTE require any modifications to current carrier testing procedures for determining compliance to the Commission's location accuracy requirements under Section 20.18?

The transition to VoLTE should not require any modifications to current carrier testing procedures. It is the evolution of the E9-1-1 location determination platform that would affect outdoor carrier-testing procedures as new location technologies are incorporated into 4G networks. Where the same location technologies are used, current carrier testing procedures should not change, but new location technologies may require different testing methods.

With the proliferation of indoor small cells and other indoor-specific technologies, testing in a set of representative environments (e.g., a common indoor test bed), should be sufficient.

Before location accuracy testing occurs, the 4G networks with their associated location technology should be allowed to fully deploy across the network and allow for the carriers to monitor the technology and its day-to-day performance on a fully operational commercial network.

5.1.2   Should prior CSRIC recommendations regarding location testing (e.g., CSRIC III WG3 recommendations regarding testing by network-based carriers every two years) apply to carriers reconfiguring to VoLTE platforms?

CSRIC III WG3 produced reports on both outdoor and indoor wireless location performance and testing. Those recommendations continue to be applicable as carriers reconfigure to VoLTE. Where the underlying location technology is the same as previously used for compliance testing (e.g., A-GPS) and no significant changes to field conditions or deployment options have occurred, there is no need to repeat county-level compliance testing for a change in radio access network (e.g., the introduction of VoLTE).   As suggested by CSRIC III WG3, once outdoor county-level compliance has been certified to meet accuracy requirements, a systematic method of 'spot-checking' representative areas that have previously been tested and shown compliant can be employed to verify that changes (such as a different radio access network) have not resulted in any significant deviations from expected performance levels.

CSRIC III WG3 "Final Report – Outdoor Location Accuracy" (14 March 2012) section 5.4.2 "Proposed Maintenance Approach" remains the recommended approach, including for carriers reconfiguring to VoLTE platforms. Note that this CSRIC III recommendation does not include automatic re-testing by network-based carriers every two years.

6 Conclusions

It is not anticipated that modifications to existing outdoor carrier testing methods or procedures would be required due to the introduction of VoLTE. If specific indoor requirements are adopted in the future, we anticipate that different testing methodologies would be required, such as testing in representative indoor environments. It is premature to speculate on specifics of indoor test procedures in advance of specific indoor requirements.

As discussed in Section 4, the FCC should expect, over time, location performance with VoLTE to be slightly better than or equivalent to 2G and 3G performance. These expectations should be validated via the maintenance testing methodology, including representative testing or "spot-checking" as described below.

The FCC should continue to support the recommendations of CSRIC III WG3. As summarized below from the CSRIC III WG3 "Final Report – Outdoor Location Accuracy" (March 14, 2012) section 5.4.2 "Proposed Maintenance Approach", the goal of maintenance testing is to identify a method that verifies continued optimal performance of E9-1-1 location systems at the local level. This CSRIC report recommends the following maintenance testing approaches in lieu of repeated county-level compliance testing:

- Key performance indicators (KPIs) should be routinely monitored to help identify instances where system performance has degraded (relative to baseline compliance tests) and further testing and system improvements are needed at the local level.
- Enhancements to location technology should be validated in representative environments, to ensure equivalent or improved performance. An example of this would be the introduction of OTDOA for VoLTE.
- Spot-checking using empirical field-testing should be conducted on an as needed basis, for example, as determined by KPI monitoring or legitimate performance concerns from a PSAP.
- Empirical data for maintenance testing may be collected incrementally over time.
- Any significant deviations from expected prior performance levels should result in careful investigation and re-testing of the applicable test area.
- These alternative maintenance testing methods replace the need for full compliance testing every two years.
- All legitimate performance inquiries from a County/PSAP or other public safety entity shall be properly investigated with full cooperation from the wireless service provider, and any issues resolved in a timely manner.

7   Appendix 1 – Acronym and Symbol Definitions Table

Acronym	Definition
2G	2nd Generation or GSM
3G	3rd Generation or UMTS or CDMA
3GPP	3rd Generation Partnership Project
AFLT	Advanced Forward Link Trilateration
A-GNSS	Assisted Global Navigation Satellite System
A-GPS	Assisted-Global Positioning System
ALI	Automatic Location Identification
BGCF	Border Gateway Control Function
CDMA	Code Division Multiple Access
cLBS	Commercial Location Based Services
chip	Pulse of a direct-sequence spread spectrum (DSSS) code
CN	Core Network
eNB	Evolved NodeB
EPDU	External Protocol Data Unit
E-CSCF	Emergency Call Session Control Function
E-SLP	Emergency SUPL Location Platform
E-SMLC	Evolved Serving Mobile Location Center
ES	Emergency Services
IBCF	Interconnection Border Control Function
GLONASS	Russian Global Navigation Satellite System
GMLC	Gateway Mobile Location Center
GSM	Global System for Mobile Communications
GNSS	Global Navigation Satellite Systems
GPS	American Global Positioning System
IMS	IP Multimedia Core Network Subsystem
KPI	Key Performance Indicator
LBS	Location Based Services
LPP	LTE Positioning Protocol
LPPe	LTE Positioning Protocol extension
LS	Location Server
LRF	Location Retrieval Function
LTE	Long Term Evolution
MAC	Medium Access Control
MGCF	Media Gateway Control Function
MME	Mobility Management Entity
MMES	Multimedia Messaging Emergency Services
MSC	Mobile Switching Center
ns	Nanosecond

Acronym	Definition
OMA	Open Mobile Alliance
OTDOA	Observed Time Difference of Arrival
PDN	Packet Data Network
PGW	Packet Data Network Gateway
PSAP	Public Safety Answering Point
P-CSCF	Proxy Call Session Control Function
PRS	Positioning Reference Signal
RAN	Radio Access Network
RCS	Rich Communications Services
RDF	Routing Determination Function
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
RSTD	Reference Signal Time Difference
RTT	Round Trip Time
S-CSCF	Serving Call Session Control Function
SMLC	Serving Mobile Location Center
SR	Scheduling Request
SRS	Sounding Reference Signal
SUPL	Secure User Plane
TBS	Terrestrial Beacon System
T_s	Basic unit of time in an LTE system
TTFF	Time to First Fix
UE	User Equipment
UMTS	Universal Mobile Telecommunications Systems
UTDOA	Uplink Time Difference of Arrival
VoLTE	Voice over LTE