Communications Security, Reliability and Interoperability Council

June1, 2012

WORKING GROUP 3
E9-1-1 Location Accuracy

CSRIC III WG3 Final Report v2

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1 RESULTS IN BRIEF

1.1 Executive Summary

As the communications industry evolves, so does the opportunity to enhance the public's ability to contact emergency services personnel during times of crisis. Public expectation has grown to the point that one assumes public safety personnel will be able to dispatch the appropriate emergency services to any reported event. This capability is dependent upon public safety receiving the best possible location information available to them.

Working Group 3 (WG3), subgroup on Indoor Location Accuracy, was charged with:

1.1.1 CSRIC III Working Group 3 – Wireless E9-1-1 Location Accuracy Charter *Indoor Location Accuracy*

It has been widely recognized that indoor location accuracy testing poses unique challenges for carriers. For example, indoor environments are more diverse than outdoor environments. In addition, most homes and buildings are privately owned, thus, access to indoor environments for testing can be difficult.

It is frequently noted that existing location technologies do not perform effectively in all environments. Thus, issues of yield[1], not just accuracy, are relevant. For example, Assisted Global Positioning System (A-GPS) may not work deep inside a steel-and-concrete building, or even in a suburban residential basement, but may work in wood frame construction, or near office windows.

The FCC's Public Safety and Homeland Security Bureau (Bureau) has not been presented with reliable statistics on the percentage of 911 calls that are made indoors, nor has the Bureau been presented with reliable statistics on the number of emergency calls that are placed from within different types of indoor structures (e.g., the fraction of calls placed from concrete-and-steel vs. wood frame construction), or the placement of the caller within the building (e.g., near windows vs. deep inside the structure).

Today, a carrier is likely to locate an indoor 911 caller by using a combination of A-GPS and network triangulation. In the near future, additional location technologies may be able to provide indoor location determination for 911 callers, such as Wi-Fi positioning and femtocells.

1.1.2 Structure of the Working Group 3 Indoor Location Accuracy Report

The document is comprised of 6 sections and 1 appendix as follows:

[1] For the purposes of this report yield will be defined as the ratio of successful Phase 2 locations over the total number of valid location requests.

Section 1: Results in Brief
Section 2: CSRIC III Structure and Members
Section 3: Objective, Scope, and Methodology
Section 4: Introduction
Section 5: Questions Posed in WG3 Charter
Section 6: Test Bed Approach Recommendation
Appendix A: Glossary of Acronyms

2 CSRIC III Structure and Members

2.1 CSRIC III Structure

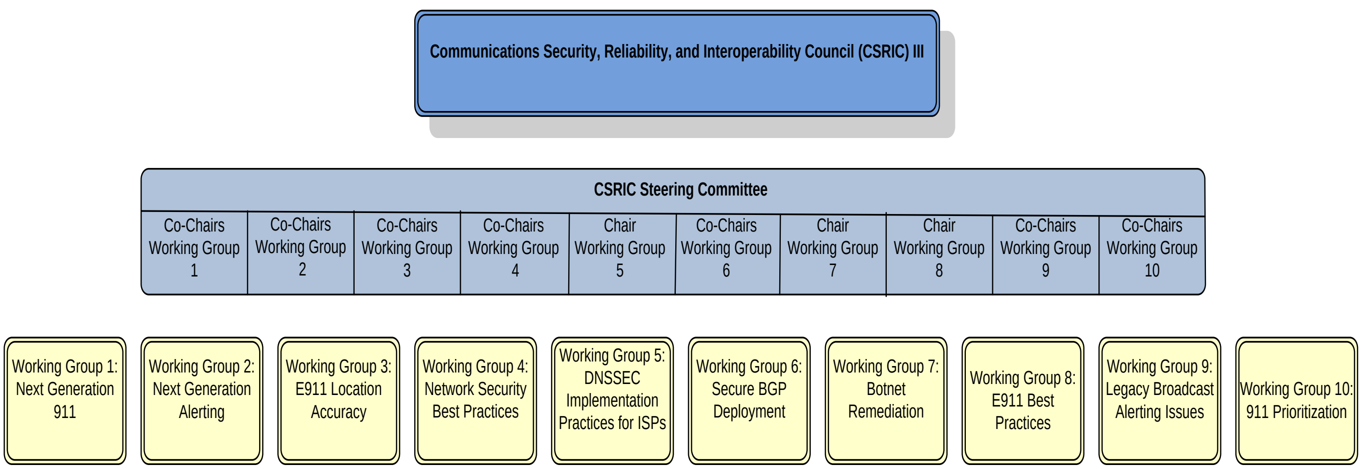

Figure 1: CSRIC III Organization Chart

2.2 Working Group 3 Indoor Sub-Group Team Members

<u>Working Group 3 Co-Chairs</u>
Stephen J. Wisely – APCO International
Richard Craig – Verizon Wireless

<u>Indoor Location Accuracy Subgroup Co-Leaders</u>
Susan Sherwood – Verizon Wireless
Norman Shaw – Polaris Wireless

<u>Working Group Document Editors:</u>
Brent Burpee- Verizon Wireless

WG 3 Indoor Location Accuracy Subgroup consists of the following members:

First Name	Last Name	Organization
Wayne	Ballantyne	Motorola Mobility, Inc.
Andrew	Beck	CommScope
Richard	Craig	Verizon Wireless
Marlys	Davis	King County E9-1-1 Program Office
Khaled	Dessouky	TechnoCom Corporation
Jeanna	Green	Sprint
Roger	Hixson	NENA
Ryan	Jensen	T-Mobile
Marte	Kinder	Time Warner Cable
Sandra	Lott	CenturyLink
Mike	Loushine	Applied Communication Sciences
Barry	Martin	Boeing
Kathy	McMahon	APCO
Martin	Moody	Metro Emergency Services Board
Jim	Nixon	T-Mobile
Gary	Parsons	NextNav LLC
Ganesh	Pattabiranan	NextNav LLC
Gustavo	Pavon	True Position, Inc.
Raghavendhra	Rao	AT&T
Chuck	Ronshagen	Cassidian Communications
Brett	Schneider	Bexar Metro 9-1-1 Network District
DeWayne	Sennett	ATIS
Norman	Shaw	Polaris Wireless, Inc.
Susan	Sherwood	Verizon Wireless
John	Snapp	Intrado, Inc.
Dorothy	Spears-Dean	Virginia Information Technologies Agency

First Name	Last Name	Organization
Bill	Tortoriello	US Cellular
Greg	Turetzky	CSR Technology Inc.
Bruce	Wilson	Qualcomm Inc.
Stephen	Wisely	APCO
Richard Deh-Min	Wu	Nokia Siemens Networks

Table 1 - List of Working Group Members

Additional Contributors:
David Conner – U.S. Cellular

3 OBJECTIVE, SCOPE, AND METHODOLOGY

3.1 Objective

The objective of this report is to answer the questions posed in the CSRIC III Working Group 3 charter related to indoor location accuracy.

3.2 Scope

This report provides summary answers to the questions in the charter and introduces the need for a test bed to develop an in-depth understanding of various existing and future technologies for 9-1-1 in indoor settings.

3.3 Methodology

Working Group 3 met weekly via conference call(s) to review research and discuss 9-1-1 indoor location accuracy. The workgroup and ad-hoc structure relied upon members volunteering to embrace additional work in conjunction with participating in the efforts of the full committee.

Text contributions, as completed, were reviewed, edited and approved by the full membership of Working Group 3.

The working group conducted over 11 conference calls as of 5/17/2012, and 2 multi-day face-to-face meetings in 2 different cities.

4 INTRODUCTION

4.1 Overview

As wireless usage increases and as more people are using cell phones indoors (or have abandoned the usage of landline phones altogether), it is becoming clear that the need to accurately locate wireless users in indoor environments is increasing. In responding to the questions the FCC had posed to CSRIC Work Group 3, a key challenge of limited (or no) data on indoor location accuracy/performance was encountered. As this information will be critical to any strategic direction for indoor wireless location, it was determined by the working group that obtaining this data was the highest priority task associated with rendering an opinion on indoor location issues. As a result of this understanding, the group determined that establishing a test bed, in which to evaluate the performance of applicable location technologies in representative indoor environments, would be the highest priority.

The key requirement for the test bed is to create an objective and consistent test platform where the accuracy and performance of currently available location technologies can be assessed, where new and emerging technologies can be evaluated in the future, and where the efficacy of indoor testing methodologies can be proven in representative building types and morphologies. To accomplish this goal, the work group has focused on developing a framework that supports the operation and management of the test bed. Some elements of the framework will include:

- an independent 3rd party to manage testing
- establishment of a funding mechanism that is not onerous on smaller companies and yet strikes a fair balance such that no one party bears all the cost
- solicitation of appropriate location vendors for participation

The actual details of the framework, schedule and technologies to be assessed in the test bed are still being developed and will be captured in an addendum report to be submitted in Sept 2012. The present report is focused on addressing the questions that the FCC had directly asked the sub-group to address, followed by a brief description of the test bed and the framework under which it will operate.

5 Questions Posed in WG3 Charter

5.1 Question #1

QUESTION: Do you agree with the basic premises of the following?

"It has been widely recognized that indoor location accuracy testing poses unique challenges for carriers. For example, indoor environments are more diverse than outdoor environments. In addition, most homes and buildings are privately owned, thus, access to indoor environments for testing can be difficult.

It is frequently noted that existing location technologies do not perform effectively in all environments. Thus, issues of yield, not just accuracy, are relevant. For example, Assisted Global Positioning System (A-GPS) may not work deep inside a steel-and-concrete building, or even in a suburban residential basement, but may work in wood frame construction, or near office windows.

The FCC's Public Safety and Homeland Security Bureau (Bureau) has not been presented with reliable statistics on the percentage of 911 calls that are made indoors, nor has the Bureau been presented with reliable statistics on the number of emergency calls that are placed within different types of indoor structures (e.g., the fraction of calls placed from concrete-and-steel vs. wood frame construction), or the displacement within the building (e.g., near windows vs. deep inside the structure).

Today, a carrier is likely to locate an indoor 911 caller by using a combination of A-GPS and network triangulation. In the near future, additional location technologies, such as Wi-Fi positioning and femtocells may be able to provide indoor location determination for 911 callers."

ANSWER: We believe there are three key points that are captured in the paragraph above and are addressed by the Work Group individually:

Statement of the problem:

- Percentage of Indoor vs. Outdoor 911 calls. No sources for accurate numbers have been identified for indoor vs. outdoor 9-1-1 calls. We acknowledge that the proportion of indoor calling is increasing and is quite significant. It is generally acknowledged that 25% of the residences in the United States no longer have a land line telephone[2] and further it is generally accepted that wireless 9-1-1 calls to PSAPs average from 50-70% of the total[3].
- Although gathering this information is difficult, having exact ratios is not critical for addressing indoor location needs. The approach recommended by the working group is to characterize indoor accuracy separately from outdoor accuracy.
- We acknowledge yield issues are more problematic in an indoor environment than outdoor because of RF attenuation. In response to the question, we consider yield to be very relevant in evaluating potential technologies. The test bed approach proposed by the working group aims to provide an objective framework for assessing the performance and yield of the technologies under consideration.

Testing for indoor location

- The working group agrees that indoor location testing is logistically challenging, expensive, and may require differing industry accepted methods of testing. For example, predictive modeling can work in concert with empirical validation to yield the desired characterization of indoor performance. We anticipate varying performance levels across different representative indoor environments.
- Indoor environments are defined as within permanent structures in which the structure of the building restricts visibility to the sky. ATIS 500013[4] discusses indoor environments in some depth and provides broad categories of representative environments.
- Among the major challenges to indoor testing are access to buildings and reliable determination of ground truth[5], which can be labor intensive (see ATIS 500013).
- Due to the complexity of indoor testing, the working group recommends a flexible and efficient approach that relies on field testing in representative environments.

[2] Article by the Center of Disease and Prevention Control entitled “Wireless Substitution: Early Release of Estimates From the National Health Interview Survey, January - June 2010” by Stephen J. Blumberg, Ph.D., and Julian V. Luke, Division of Health Interview Statistics, National Center for Health Statistics

[3] Federal Communications Commission website, http://www.fcc.gov/guides/wireless-911-services

[4] ATIS Technical Report 0500013, Approaches To Wireless E9-1-1 Indoor Location Performance Testing, www.atis.org

[5] Ground Truth is defined as the true geographical location specified in latitude and longitude for the actual location of the test call.

Current and Future Technologies

- There are current and future technologies that should be vetted in an objective environment. As described in section 6, Working Group 3 has committed to developing the test bed framework for vetting and reporting these future technologies.

5.2 Question #2

QUESTION: Define the scope of "indoors." Should it include non-residential structures, such as airports, stadiums, malls, and warehouses?

ANSWER: Indoor environments are defined as within permanent structures in which the structure of the building restricts visibility to the sky. This includes non-residential structures, such as airports, stadiums, malls, parking garages, warehouses, and underground areas where wireless signal is available. Broad categories of indoor environments are provided in ATIS 500013.

5.3 Question #3

QUESTION: Is it necessary to establish the ratio of indoor vs. outdoor 911 calls? If so, how should such a ratio be determined? Should indoor testing be a separate parameter that is independent of outdoor measurements? In this scenario, a Commercial Mobile Radio System (CMRS) provider would have to independently meet both the indoor and outdoor criteria.

ANSWER: Work Group 3 does not believe it is necessary to establish the ratio of indoor vs. outdoor 911 calls because indoor testing should have separate performance requirements that are independent of current outdoor testing methodologies. Although no sources for accurate numbers have been identified for indoor vs. outdoor 9-1-1 calls, having exact ratios is not critical for addressing indoor location capabilities.

5.4 Question #4

QUESTION: Should indoor locations be sampled in a statistical manner within each county or PSAP coverage area?

ANSWER: Consensus within the working group is that such widespread indoor testing would not be practical; as noted in the response to question 1. We anticipate varying performance levels across different representative indoor environments. Testing in representative environments combined with predictive modeling can yield the desired characterization of indoor performance.

QUESTION: Should the Commission establish a set of typical indoor scenarios and test each handset model, or class, in one or more model environments? This approach may be appropriate if performance is likely to depend on handset characteristics, such as the GPS chipset, or antenna configuration. Are there other test methodologies that should be considered?

ANSWER: Current carrier handset validation is very comprehensive. CSRIC feels the issue of handset validation is being adequately addressed, and that no further action is required by the Commission.

Handsets play an important role in the location process for many location methods. With dozens of handset models available to the public at any given point in time, it is impractical to include each handset model in the location accuracy compliance testing process. It is expected that carriers utilizing any handset-based location technology will properly validate each new handset model in various use case environments prior to approval for sale.

This validation process will vary from carrier to carrier, and may be conducted by the carrier, the handset manufacturer, third parties, or some combination of these. Carriers have the overall responsibility to ensure that each new handset model meets minimum location performance standards within their network, and is representative of other handset models sold and utilized by the carrier for compliance testing.

A comprehensive handset validation process may include:

- Lab Testing
    - Location Protocol Functionality Tests
    - Standardized GPS Conformance Test Cases
        - Various Simulated Indoor Conditions
        - Various Simulated Outdoor Conditions
    - GPS Receiver Sensitivity Tests (Radiated and Conducted)
        - Acquisition Sensitivity
        - Tracking Sensitivity

- Empirical Field Testing
    - Various Morphologies
    - Static Tests
    - Drive Tests

A proper on-going handset validation process allows the carrier to provide new handset models for sale with a reasonable assurance that each device will perform properly when needed for emergency services. Handset validation processes will evolve over time as more information becomes available.

5.5. Question #5

QUESTION: For CMRS providers that primarily rely on A-GPS, would measuring the effective sensitivity (e.g., measured in dBm) of the GPS receiver, using a suitable bench setup, be sufficient to estimate the achievable indoor location yield and accuracy?

ANSWER: Sensitivity testing, either radiated or conducted, by itself would not be sufficient. The consensus of the work group is that bench testing is not adequate to replicate relevant use environments.

QUESTION: Are there other factors that should be taken into account?

ANSWER: Multi-path, path loss, user motion, and mode of use are examples of other factors that need to be taken into account. In addition, the specific forms of GPS assistance, and the entity used to determine the location fix (UE or location server), have considerable influence on AGPS performance. Bench testing has a role in validation testing. However these factors combine in very complex ways that cannot be captured in bench testing.

5.6 Question #6

QUESTION: If a GPS sensitivity measurement were used to predict indoor yield and accuracy, how would the receiver sensitivity be translated into these parameters, given the difficulty of statistically estimating the GPS attenuation characteristics across indoor locations? Should such a translation be avoided?

ANSWER: Such a translation should be avoided since it does not capture the effects of other factors which impact location accuracy, for example, those listed above in the answer to question 5. The working group believes that testing in representative environments combined with predictive modeling would yield more credible results.

5.7 Question #7

QUESTION: Some networks use hybrid location technologies, i.e., combine A-GPS with triangulation. As long as an indoor location allows wireless carriers to provide service, would the performance of the triangulation technique differ substantially indoors, e.g., due to differences in multipath characteristics for indoor locations, or strong dependence of the technology on signal strength?

ANSWER: When users take their mobile device to an indoor location, the radio signals it receives and transmits are subject to additional attenuation, scattering, and multi-path. This includes GPS signals from the satellites, downlink signals from the base station to the mobile device, and uplink signals from the mobile device to the base station. The extent of the signal degradation depends on the nature of the construction materials, and the layers of construction obstructing the various signal paths.

All location technologies will be affected to varying degrees by signal degradations and harsh multi-path in an indoor environment. The specific impact on each technology needs to be investigated and assessed in a controlled environment such as the proposed test bed.

5.8 Question #8

QUESTION: When testing for location accuracy and yield, should the ability of a carrier to use distributed antenna systems, WiFi, or femtocells be considered? If not, should these techniques be considered at a later date, when they are more likely to be used for 911 purposes? If such techniques should be considered now or at a later date, how should they be considered?

ANSWER**:** Each of these access technologies need to be considered to the extent they may contribute location information into the E911 system. These are network access technologies and are not location technologies. In some instances location may improve, and in other instances location may degrade. In particular, commercial LBS technologies such as the use of WiFi access points will be addressed in the report on leveraging LBS technologies. Distributed antenna systems and femtocells should also be considered in the appropriate time frame. Accordingly, the proposed test bed architecture should include all applicable technologies in due time. Indoor location performance on macro networks should be given test bed priority over localized access technologies.

6 Test Bed Approach Recommendation

As WG3 went through the process of answering the questions posed by the FCC in Section 5 of this document, it became clear to the group that there is a lack of independently verifiable data on location technology performance that could be used to adequately characterize the capability of existing and emerging 911 technologies for indoor environments.

The group discussed various methods that could be developed to address this gap and came to the conclusion that simplistic approaches to attacking the problem, although allowing for shorter turn around on the data collection effort, would perhaps create more questions and uncertainty than exists today.

The consensus of the group is that to be of any real value in providing the FCC and the industry as a whole with the information necessary to assist with informed decision making, a structured approach using a test bed that includes carefully selected representative environments is required to assist with obtaining this information.

The test bed is proposed as a two stage approach so as to facilitate the collection of actionable information as soon as possible. Stage 1 will evaluate existing location technologies that are ready to test and produce audited results by March 2013. Stage 2 will focus on emerging technologies as they become mature and available for evaluation. Results from stage 2 will be released as solutions are tested, dependent on technology availability.

WG3 has developed a plan framework for developing and managing the proposed test bed. This is detailed in a forthcoming report. Highlighted components of this test bed proposal include:

- WG3 will provide general oversight of the stage 1 test bed creation including setting objectives, deliverables, broad test plan parameters, recommendations on technologies to be tested, and recommendations on groups to provide impartial management and test execution services.

- A neutral third party will provide day-to-day program management and scheduling of the test activity, including oversight of the test house activities described below. This group would hold sufficient technical competence to coordinate the various vendor, carrier, public safety and test teams and ensure tests are executed fairly, in accordance with the test plan.
- A paid, independent third party technical test house will execute the test plan and generate the test report(s). Funding sources are under discussion and may include participation fees from interested carriers and those vendors wishing their technology to be tested. The independent technical test house will perform the following functions:
    - Technical oversight of testing and methodologies being used by vendors
    - Quality analysis of fairness and validity of testing and results
    - Describe results and detail the considerations taken into account
    - Collect and publish the data
    - Produce the test report for each vendor/technology tested
    - Provide an evaluation of the performance of the technologies tested
- An independent group (e.g. CSRIC WG3 for stage 1, 3rd party for stage 2) will analyze and verify the collected results and evaluate the economic, logistical and feasibility aspects of the technologies tested. Location technology vendor input will be solicited by this group to aid in this analysis.
- Each location technology vendor will contribute “in kind” materials, personnel, to support the evaluation of their technology.
- San Francisco, CA has been proposed as the test bed location since it provides all of the common scenarios (dense urban, suburban etc) in addition to a variety of terrain/morphology/accessibility. San Francisco is currently used by multiple carriers to assess location technologies. Participating carriers will provide the necessary infrastructure and system data access to support comprehensive testing of the technologies involved in the test bed and will work with the technology vendors.
- It is expected that public safety and government officials will assist in assuring physical access to structures as required.
- The test bed is expected to remain operational until all mature stage 2 technologies can be tested. This is estimated as a 2 to 3 year lifetime.
- More than one test bed location may be selected, but the cost and duration of testing increases significantly if more than one test bed is chosen. WG3 recognizes additional test bed locations may be required to account for regional morphology differences.

APPENDIX A

Glossary of Acronyms

Acronym	***Definition***
A-GPS	Assisted-Global Positioning System
APCO	Association of Public Safety Communications Officials
ATIS	Alliance for Telecommunications Industry Solutions
CMRS	Commercial Mobile Radio System
CSRIC	Communications Security, Reliability and Interoperability Council
E9-1-1	Enhanced 9-1-1
FCC	Federal Communications Commission
GPS	Global Positioning System
LBS	Location Based Services
NENA	National Emergency Numbering Association
OET 71	Office of Engineering and Technology Bulletin No. 71
PSAP	Public Safety Answering Point
RF	Radio Frequency
RTT	Round Trip Time
U-TDOA	Uplink Time Difference of Arrival
WG3	Working Group 3
WiFi	Wireless Fidelity