Indoor Location Challenges for 9-1-1

Is It Real?

02/23/2015

9-1-1 Goes to Washington

TCS TeleCommunication Systems
Enabling Convergent Technologies®

Indoor Location Challenges for 9-1-1

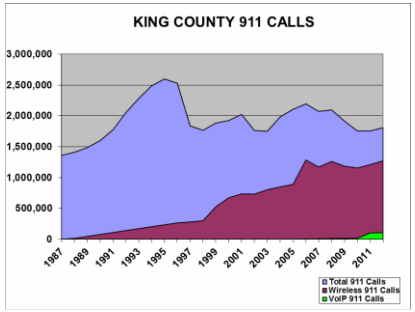
» Evidence of a Problem

- Statistics tell a story
- Analyzing real-world 9-1-1 data
- Long-term 9-1-1 data comparison
- 9-1-1 data trending
- Comparing urban/suburban to dense urban

Statistics Tell A Story

We "should" have an Indoor Location challenge

- 40% of US population has "cut the cord"
  - 2013 CDC study (37% of adults; 45% of children)
  - http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201306.pdf
- 70% of 9-1-1 calls come from wireless
  - 2012 King County, WA statistic



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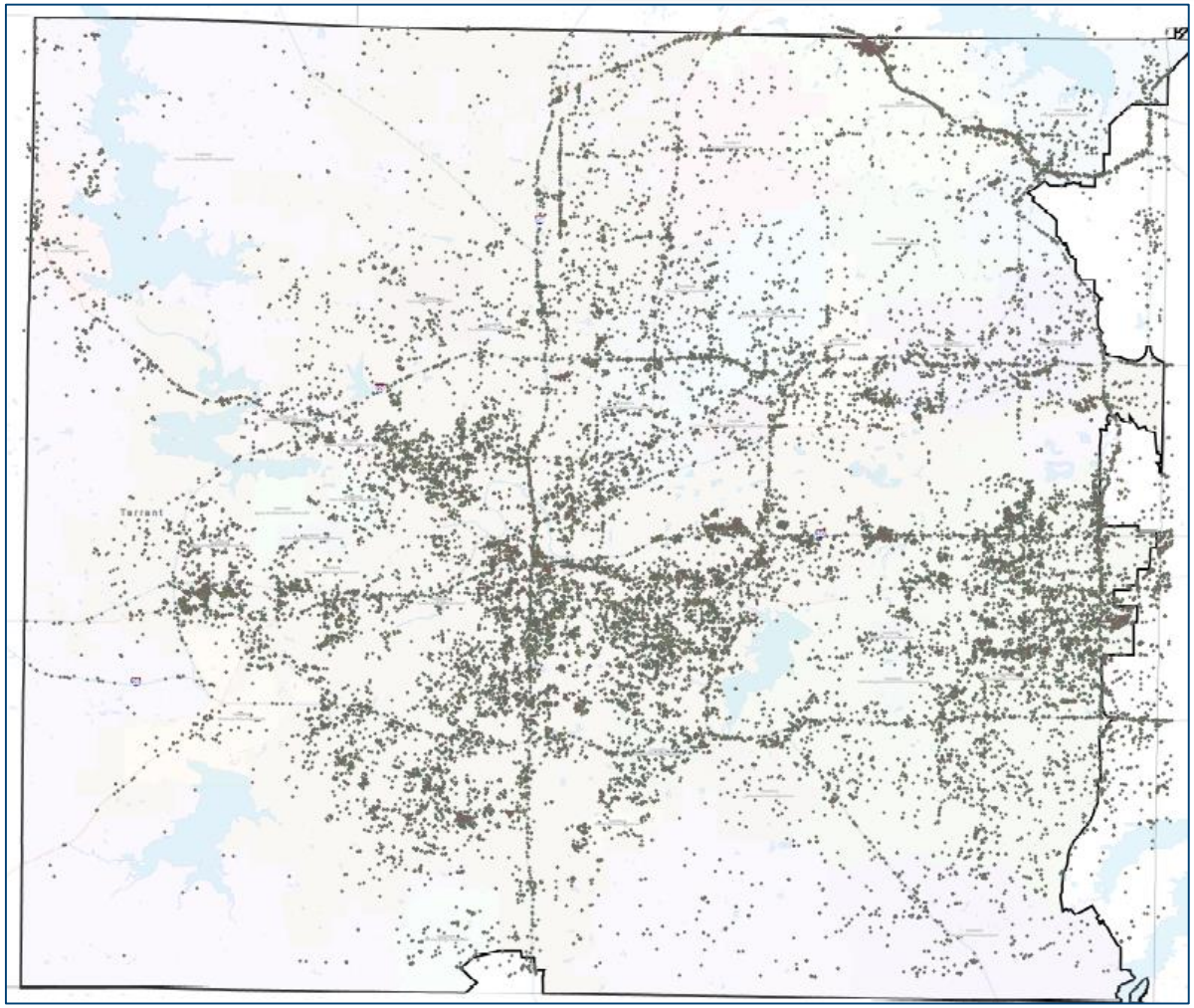
Real-world 9-1-1 Call Analysis



- » Actual 911 calls
- » Tarrant County
- » All carriers
- » August, 2013

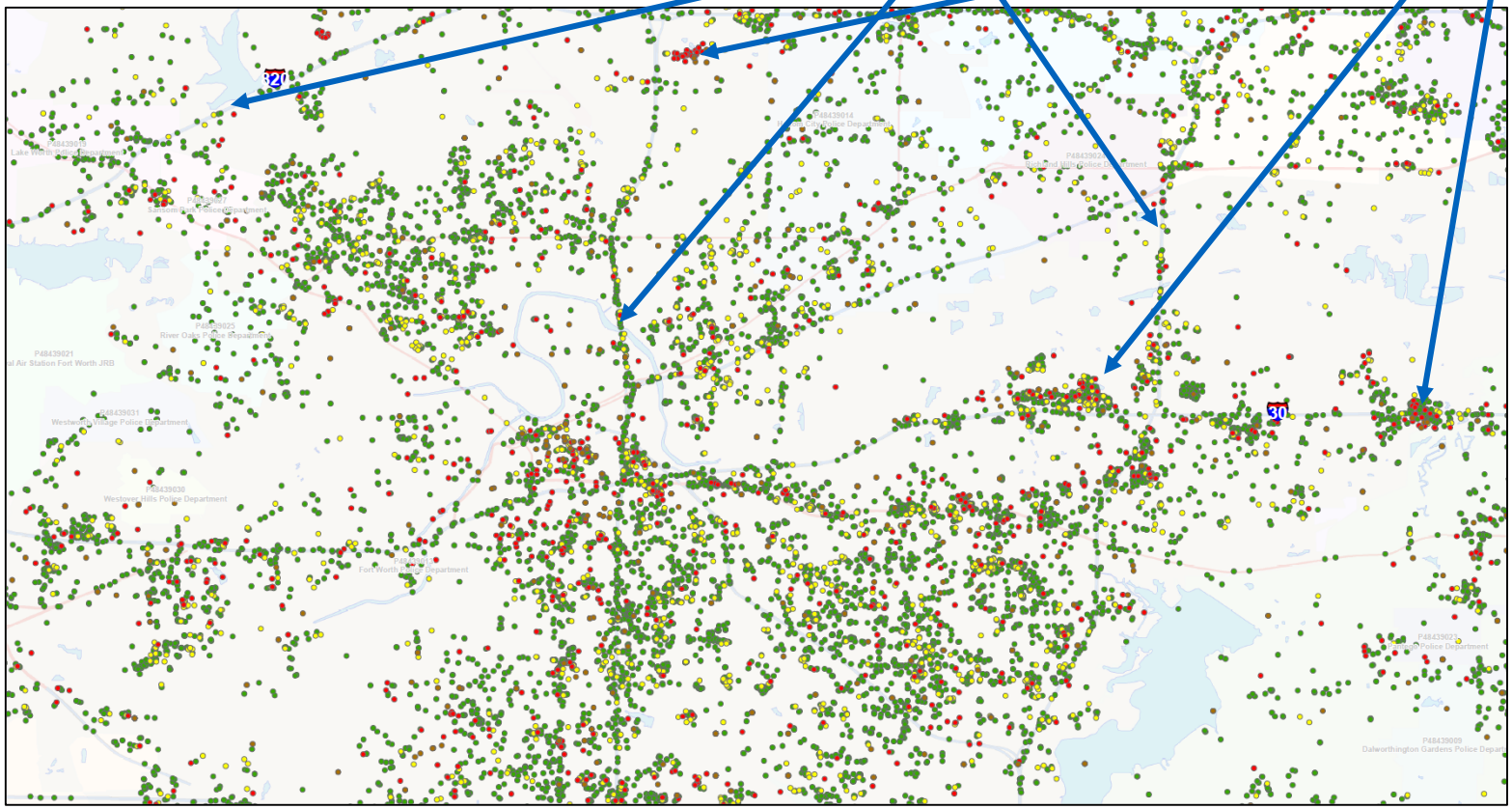
Color-code X/Y locations (using HUNC)

Brown = Phase I only
Green = meets stricter requirement.
Red = misses looser requirement.
Yellow = between strict/loose

Which are Indoors?
Which are Outdoors?

Uncertainty Tells a Story

- Uncertainty/Accuracy correlates
  - Can draw roadways
- Uncertainty error clusters



Tarrant County, TX – Multiple wireless carriers – August, 2013 data

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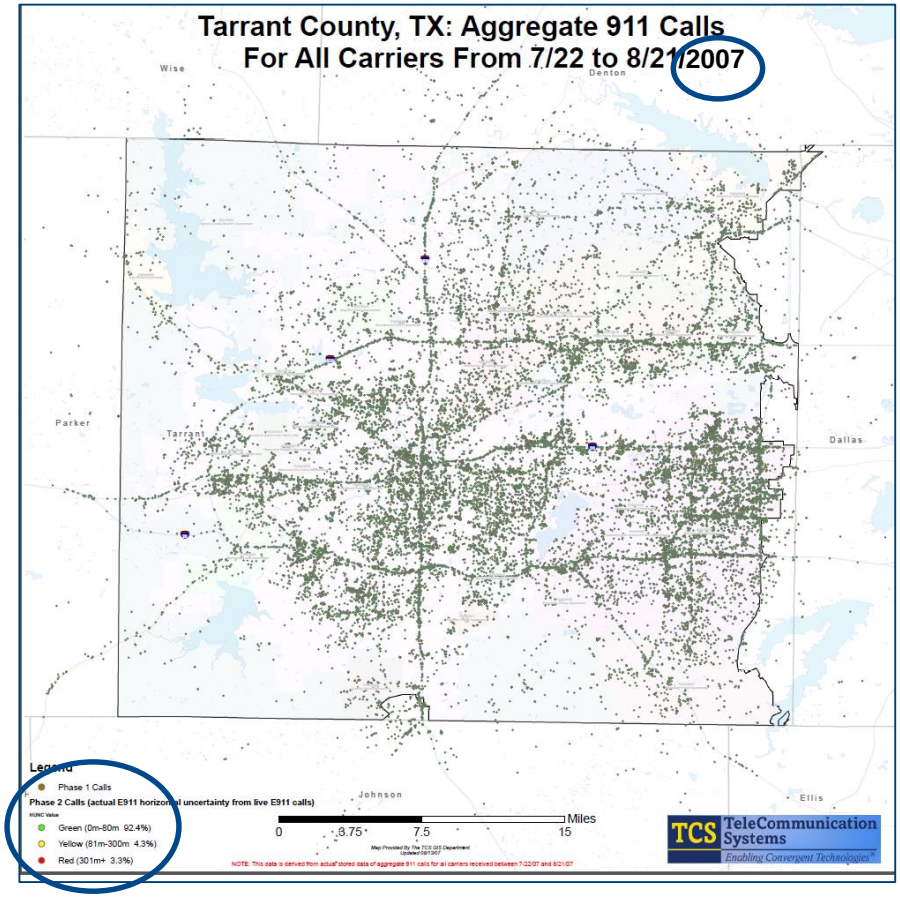
  - Long-term 9-1-1 data comparison

More "bad" location fixes – due to indoors?

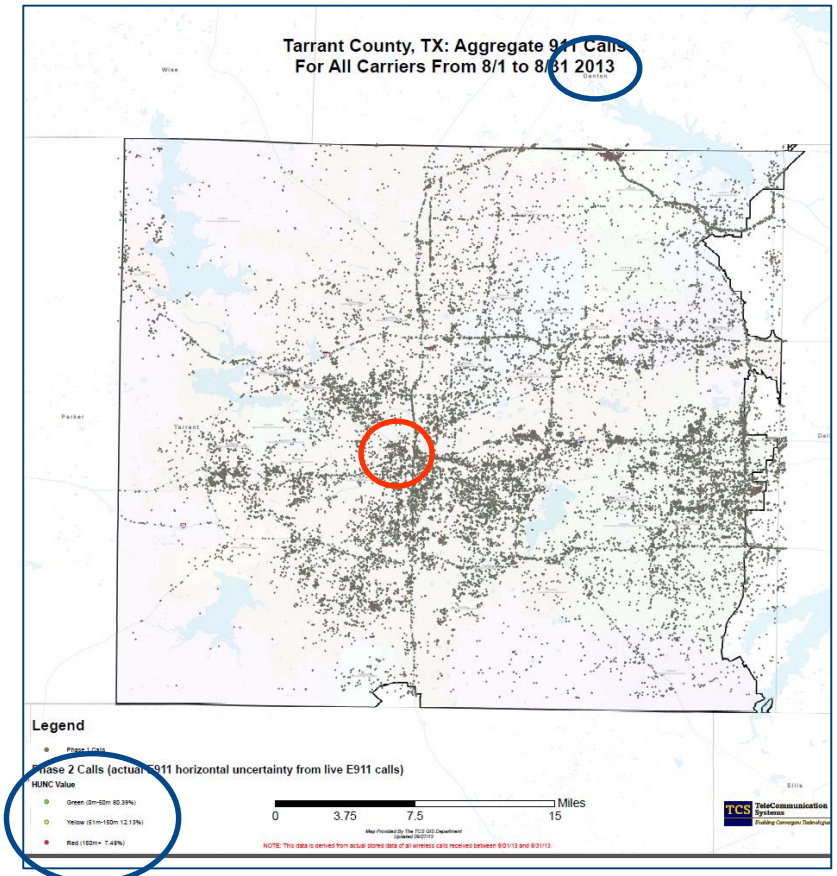


2007

3.3% exceeded Phase II upper bound (red)

2013

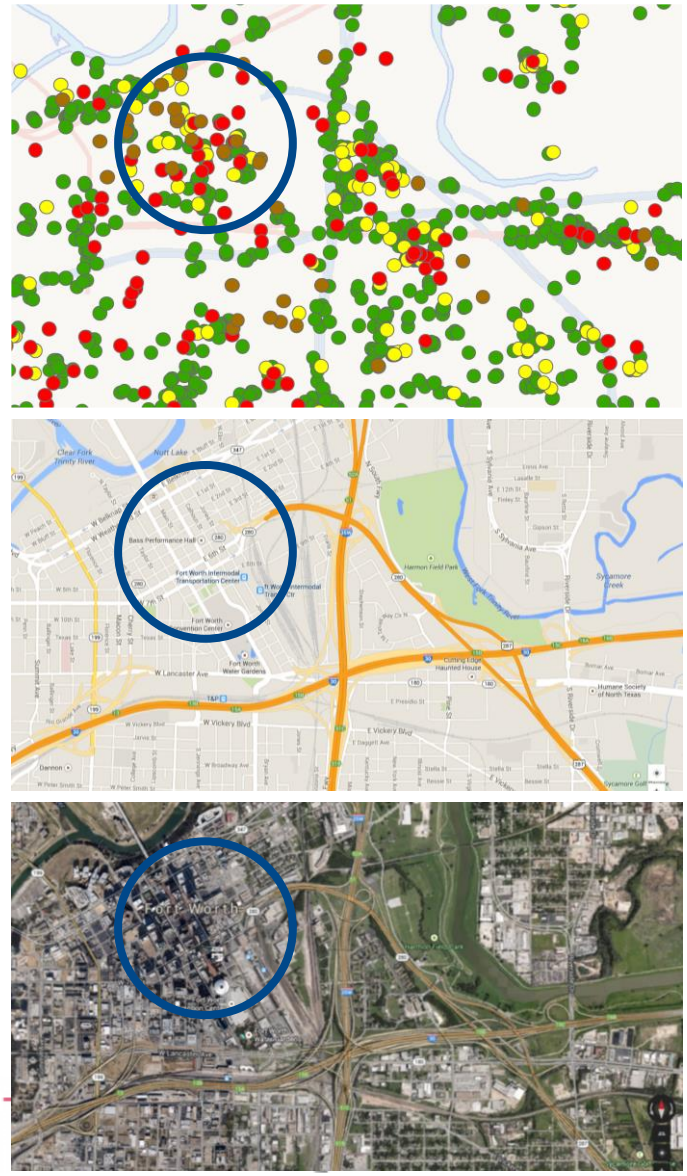
7.5% exceeded Phase II upper bound (red)



3.3% → 7.5% (more calls from indoor locations?)

9-1-1 Goes to Washington

“Bad” location fixes – probably indoors…



Tarrant County, TX
9-1-1 Calls – August, 2013

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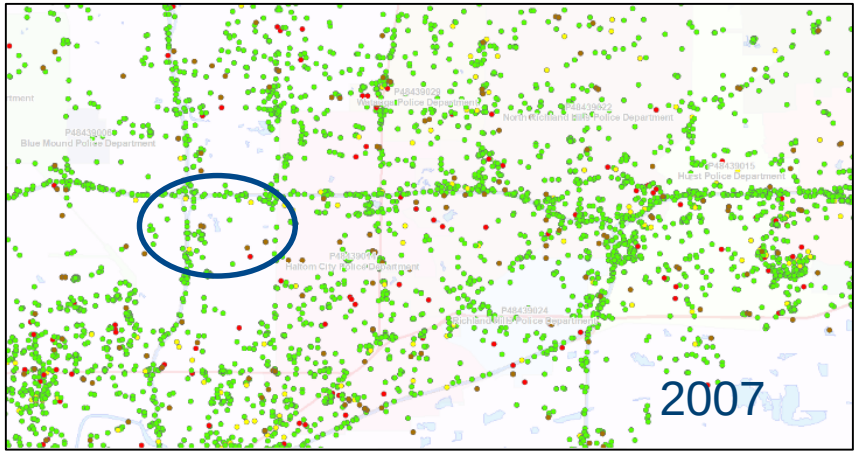
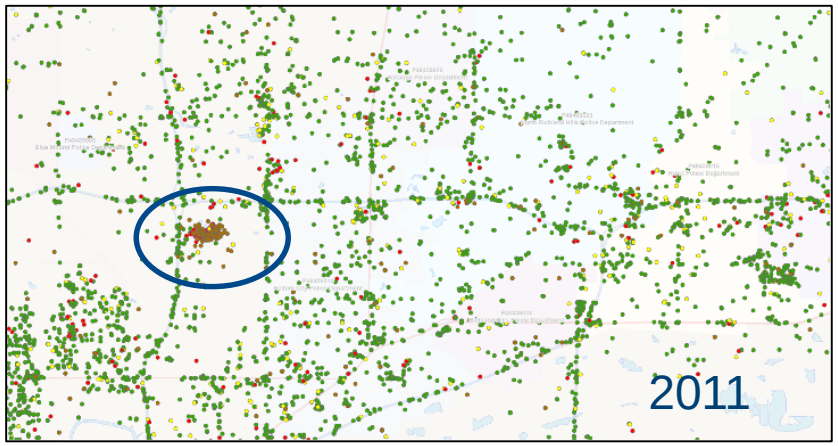
Data Trends Reveal Indoor Challenges

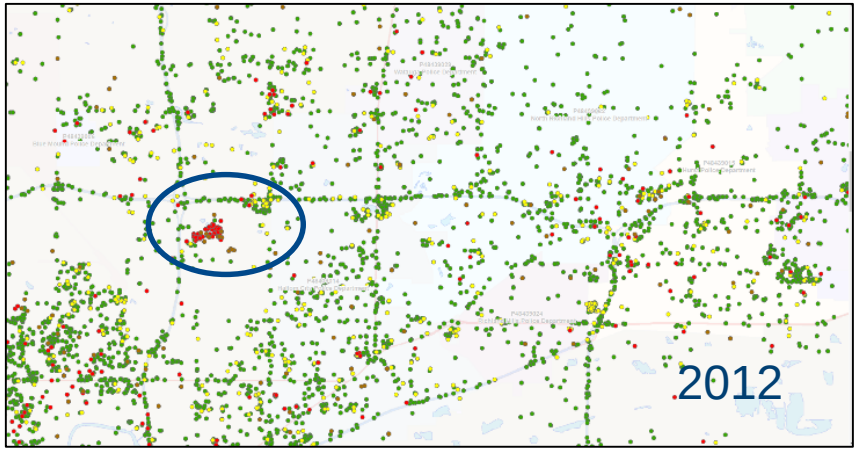
Problem area seen in 2011



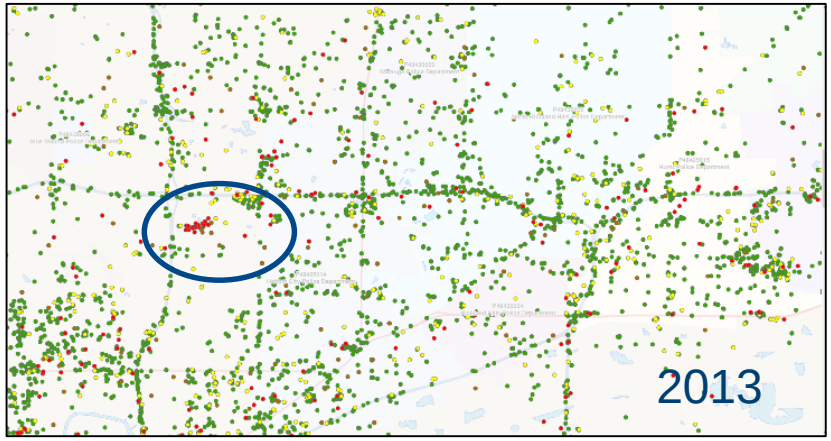
Nonexistent in 2007



Major problem area in 2011



Improved in 2012



Greatly improved in 2013

Goodrich Warehouse Built in 2007

9-1-1 Goes to Washington

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Urban/Suburban vs. Dense Urban

- Baltimore 9-1-1 calls (Nov, 2014)
- Tarrant County 9-1-1 calls (Aug, 2013)

	Tarrant County	Baltimore
HUNC <= 50m	80.4%	45.3%
HUNC 50m<-->150m	12.1%	11.2%
HUNC > 150m	7.5%	43.5%
Total	100.0%	100.0%

HUNC is a distance/range calculated by the Location Engine
Determines the range of location "error" based on Confidence value
Confidence (90% here) expresses likelihood to find device within HUNC range

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It Looks and Quacks Like a Duck!

Thank you!

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275 West Street
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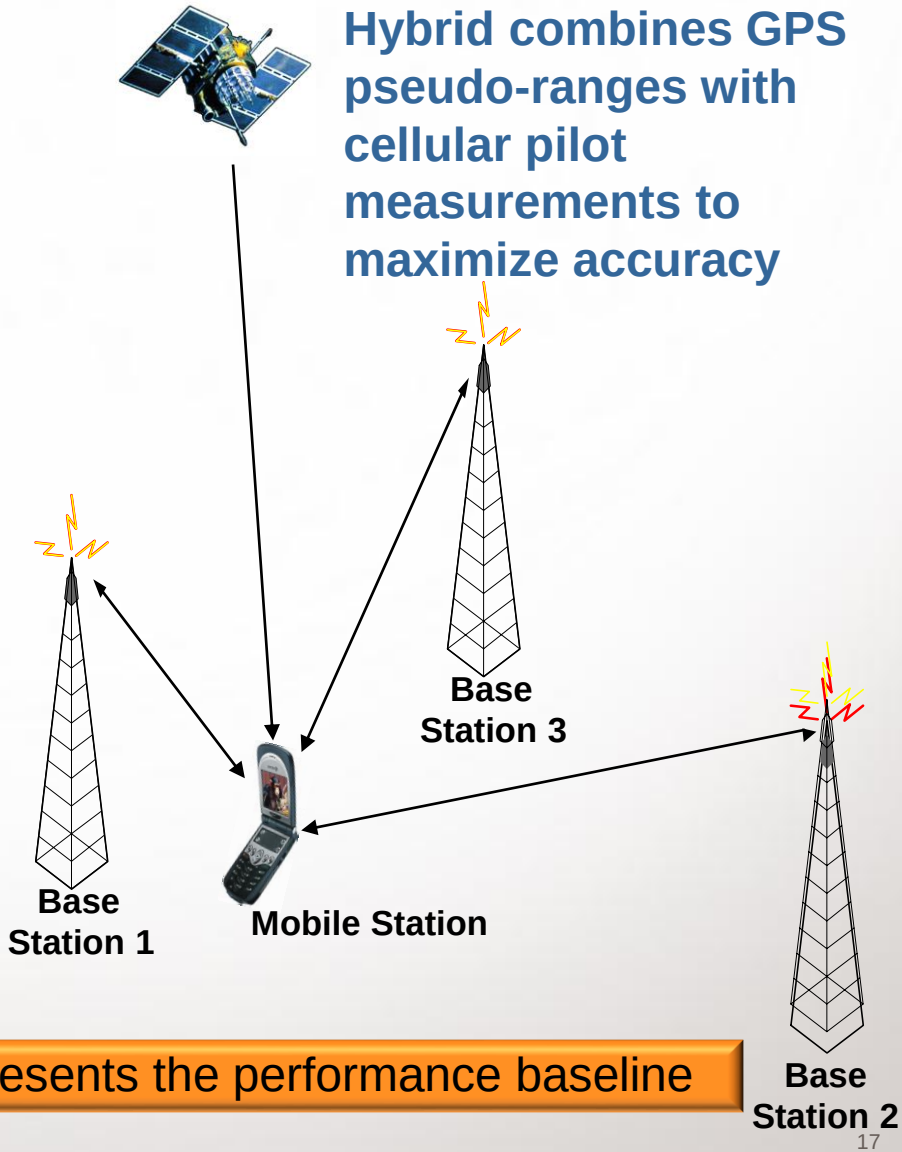
Wireless E911 Location Accuracy

February 24, 2015

Today's Technology Hybrid A-GPS/AFLT

- Works outdoors and indoors
- Outdoor fixes rely predominantly on GPS measurements and highly accurate GPS-only fixes are produced
- Hybrid fixes use both GPS pseudo-ranges and CDMA Pilot measurements in the same trilateration calculation when an insufficient number of GPS pseudo-ranges are available for a GPS-only fix
- Hybrid allows the maximum accuracy when a GPS-only solution is not possible (e.g., two or fewer GPS pseudo-ranges are available)
- Hybrid, perhaps AFLT only in some cases, allows for indoor coverage and nearly 100% yield.
- Enhanced Cell ID (E-CID) and Cell ID (CID) provide 100% yield
- Carriers without AFLT today just use GPS E-CID, and CID

Hybrid combines GPS pseudo-ranges with cellular pilot measurements to maximize accuracy



This positioning technology represents the performance baseline

Today's Indoor Accuracy

- From The CSRIC Report

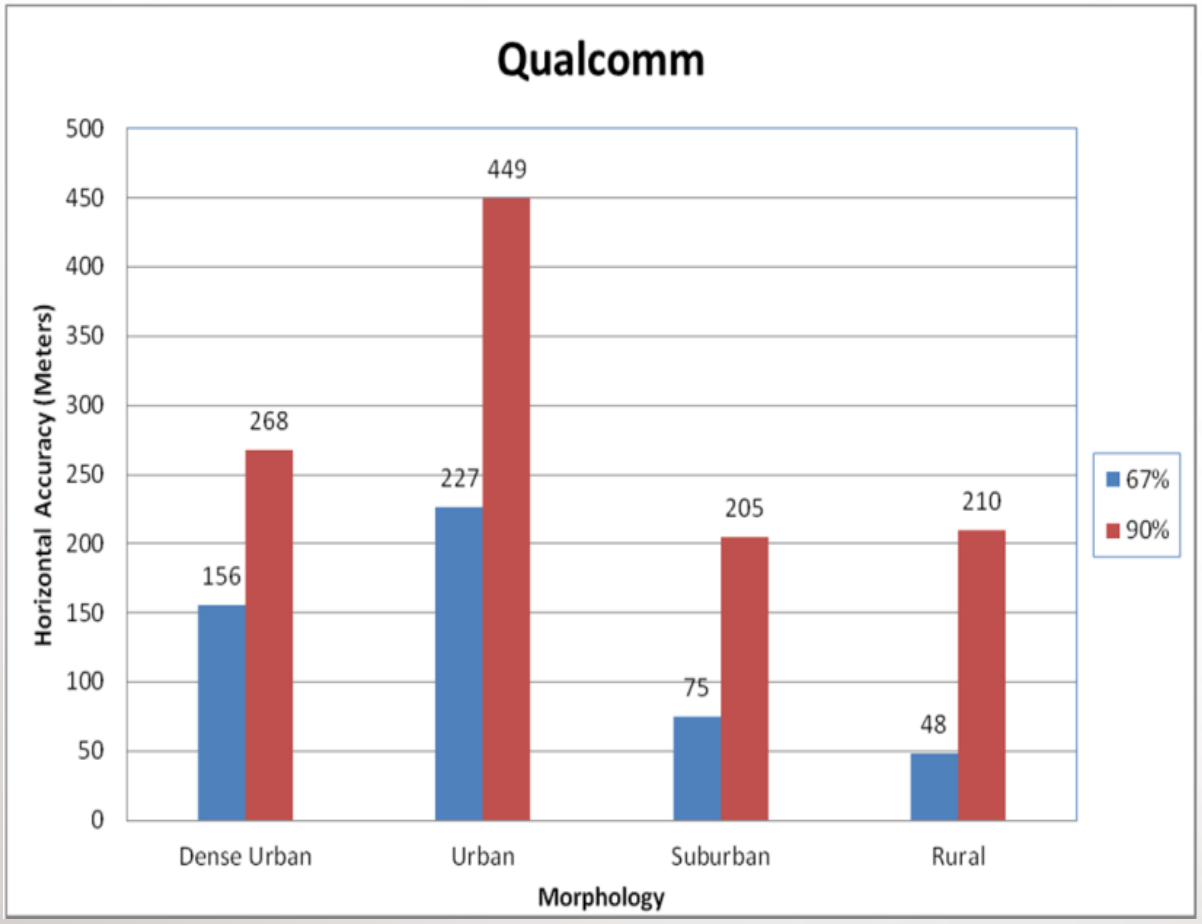


Figure 6.1.2-7. Indoor Accuracy by Morphology for Qualcomm

Newer ranging methods, such as OTDOA and Wi-Fi, will improve E911 indoor performance

Dispatchable Location will provide complementary approach to locating the caller

New Technologies Improving Indoor 911 Accuracy

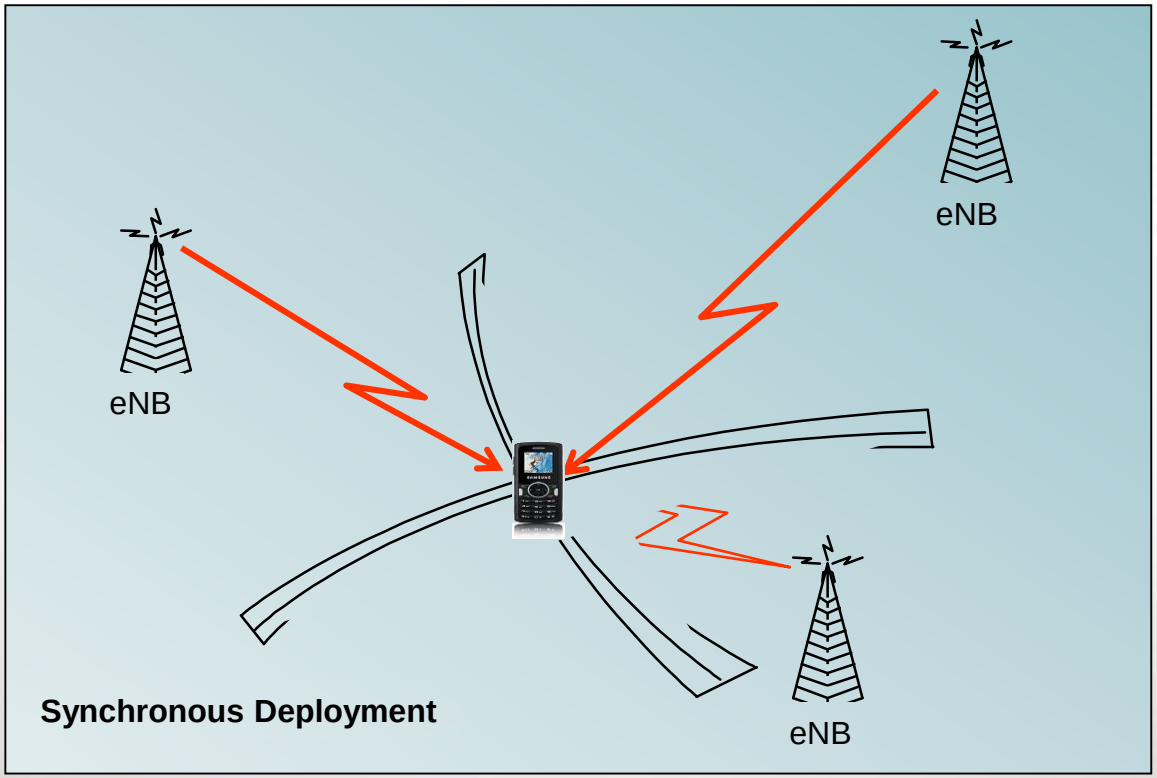
- New Access Networks
  - 4G/LTE
  - Wi-Fi
- New Positioning Methods
  - 4G/LTE Observed Time Difference Of Arrival (OTDOA)
    - A highly detectable LTE reference signal designed to outperform 3G solutions
  - Wi-Fi Positioning
    - Signal strength and ranging measurements available for E911 positioning
- New Network Topologies
  - Wi-Fi data offloading
  - Small / Femto cells
  - Both are a powerful positioning asset for wireless operators
- Use of these new networks / topologies, as well as Bluetooth beacons, for Dispatchable Location

Key Benefits of Wireless WAN (WWAN)

- Penetrates buildings – deep indoors
- Ranging is possible from cell towers giving a position indoors
  - 3G/AFLT showed we have indoor coverage
  - 4G/LTE networks with OTDOA will improve indoor accuracy
  - 4G/LTE positioning coverage for mobile user base will grow quickly
- Leverages existing infrastructure to do positioning
- Leverages LTE modem
  - No new handset hardware required
- Leverages trusted, accurate cell tower base station almanac of wireless operators
- Multiple bands available for ranging
- Strong ecosystem exists

Observed Time Difference of Arrival (OTDOA)

- Downlink positioning method (similar to AFLT) – but for 4G/LTE networks
- The mobile measures the difference in time of arrival of the new LTE signal between multiple base station pairs
- Designed to outperform AFLT (higher bandwidth, increased hearability, inter-frequency, etc.)
- OTDOA will be a useful indoor positioning technology

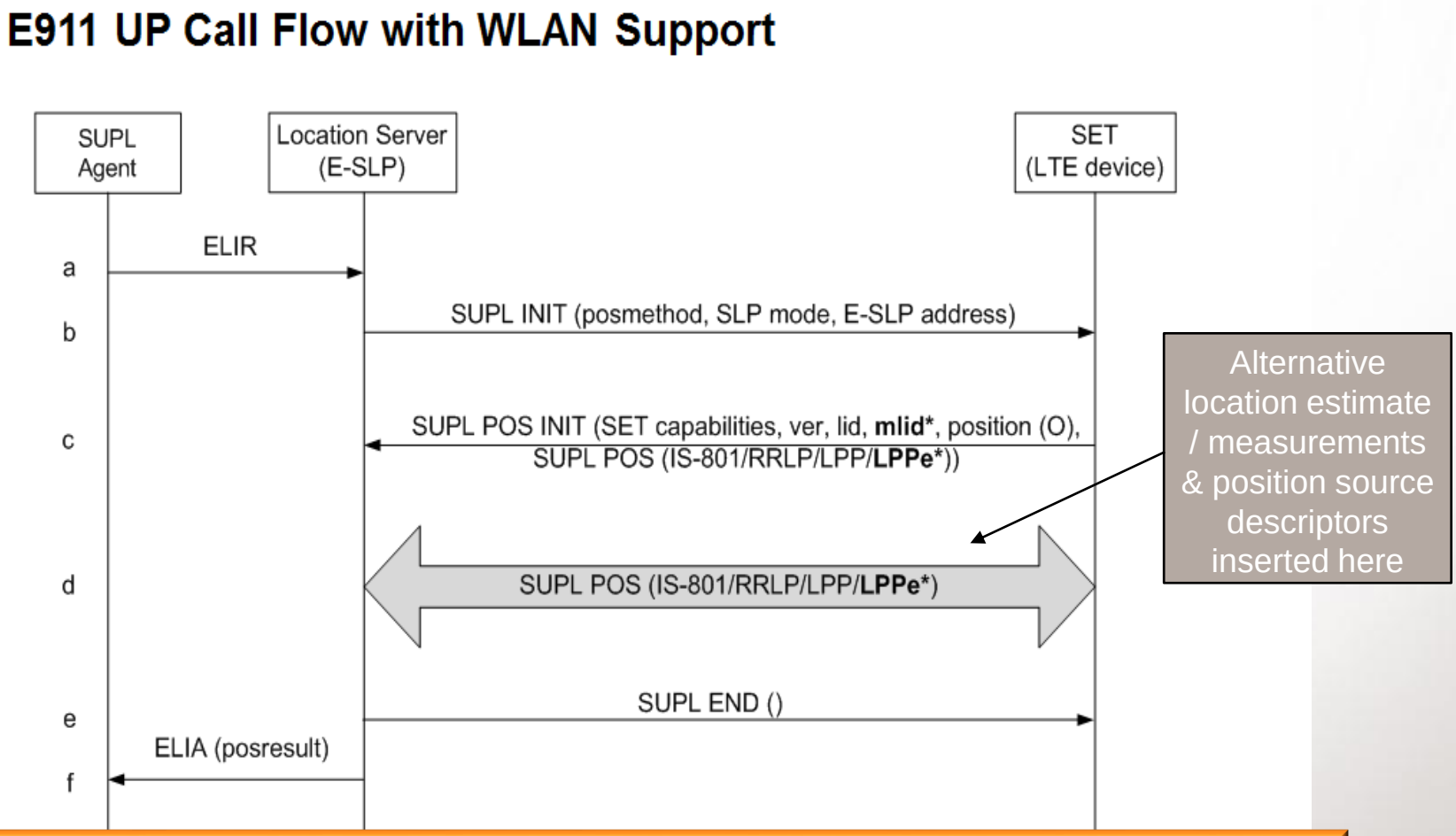


How to Leverage Wi-Fi and BT

- Wi-Fi information may be used to supplement cellular indoor positions
  - Specifications exist for:
    - How to report Wi-Fi MAC address, signal strength and time measurements along with the cellular and GPS information
    - How to report BT Identifiers
    - How to send back an alternative (potentially consumer LBS) position to the server, be it from sensor aided, device specific database solutions, etc.
- Challenges
  - Multiple decentralized Wi-Fi databases of unvalidated accuracy exist today
  - The need for and the issues with creating centralized Wi-Fi and BT database(s)
- Targeted / Phased Rollouts Possible
  - Wi-Fi Data Offloading provides the carriers with managed Wi-Fi databases to use for location
  - Leverage the forming National Emergency Address Database (NEAD)
- Wi-Fi and BT solutions can be cross checked
  - Validate Wi-Fi / BT solution against solution from OTDOA / AFLT / A-GPS methods

WLAN Information in a 911 Call

Source: CSRIC Report on Indoor Location



- LPPe carries Wi-Fi and BT information
- LPPe allows for a position to be returned as well, geographic or civic
- LPPe carries uncompensated barometric pressure data
- SUPL shown here, but LPPe is equally applicable to a control plane solution

Thank You

QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, CA 92121-1714

Wireless 9-1-1 and Z-Axis

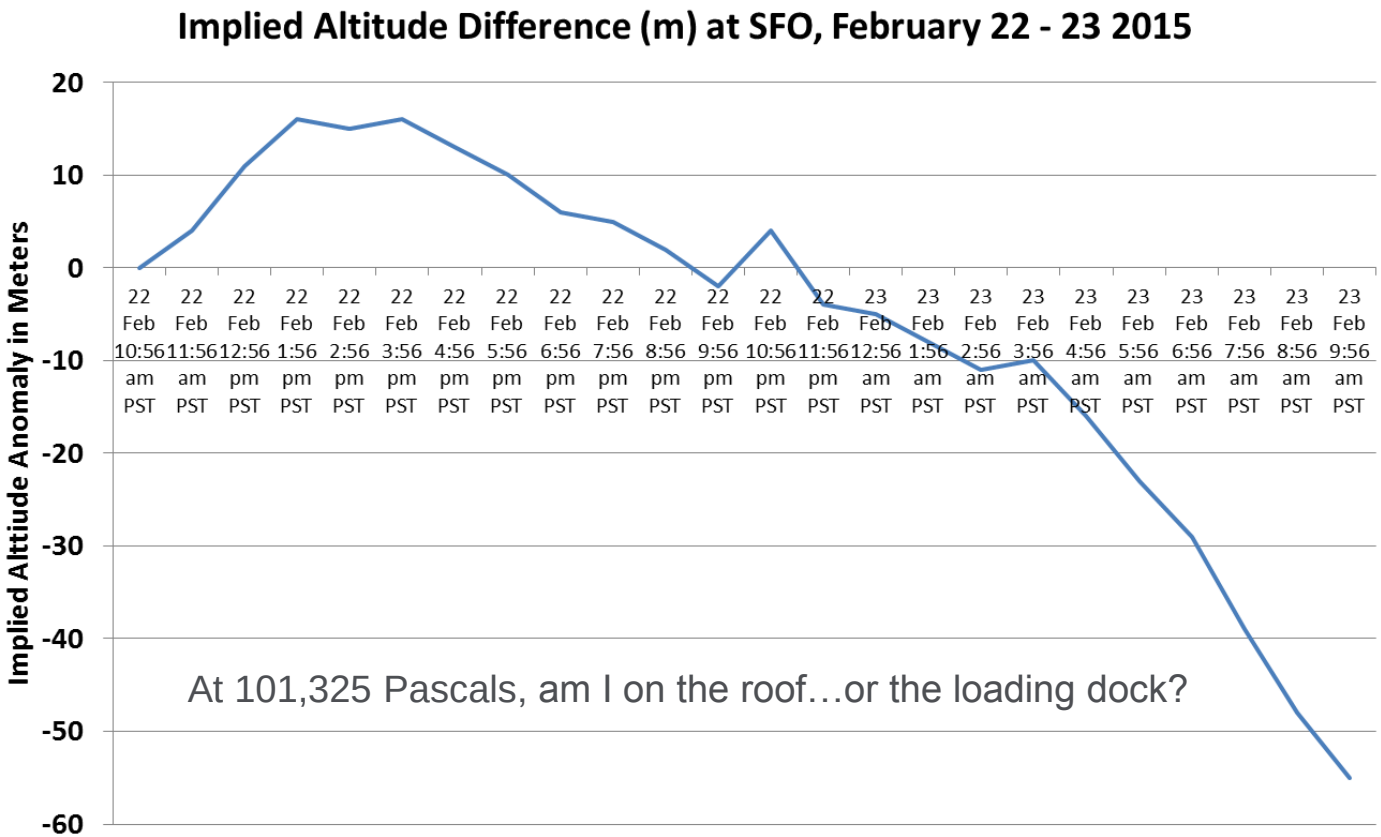
The Art of the Possible

February 27, 2015

Pressure and Altitude

- Air pressure gets *lower* as you go *higher* in altitude, in a predictable way
- FCC 4th R&O requires uncompensated (measured) barometric data to be reported
  - Pressure is often reported in “Pascals”; 101,325 Pascals is sea-level standard
  - Correlated with altitude, but an accurate altitude requires more data
  - All else being equal, ~12 Pascals = 1 meter
  - If first responder has a similar device, “pressure matching” at the incident location is viable
- Consumer-grade barometric pressure sensors sold in high volumes (e.g., Bosch BMP280, in iPhone 6) have a pressure resolution of about 1 meter today
- **BUT! Air pressure also changes *constantly* with the weather – must be converted altitude to, for example, correlate with floor height**
  - Barometic data can only tell you relative altitude

Weather-Driven Changes

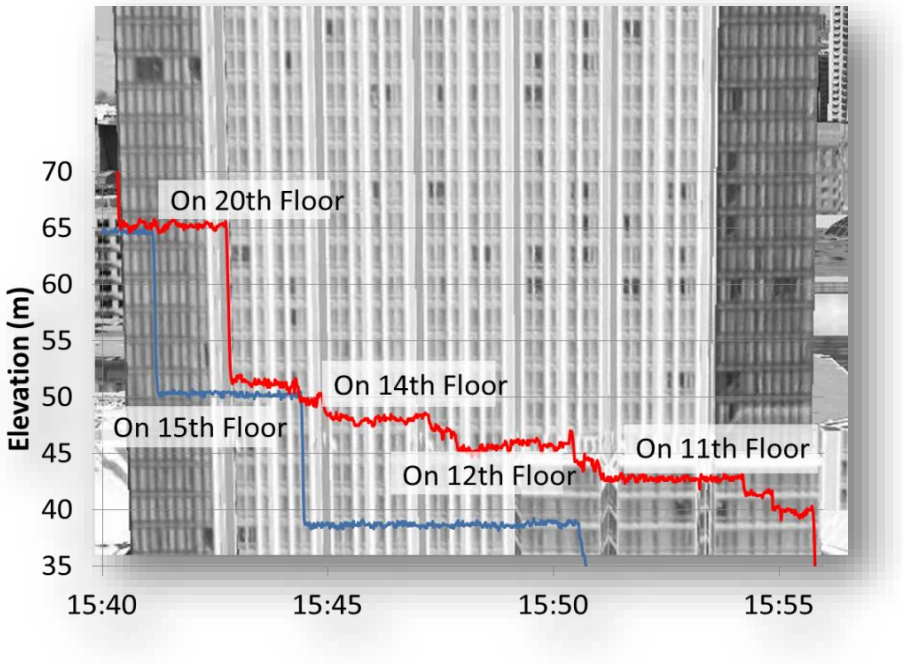


Note: building height approximate.

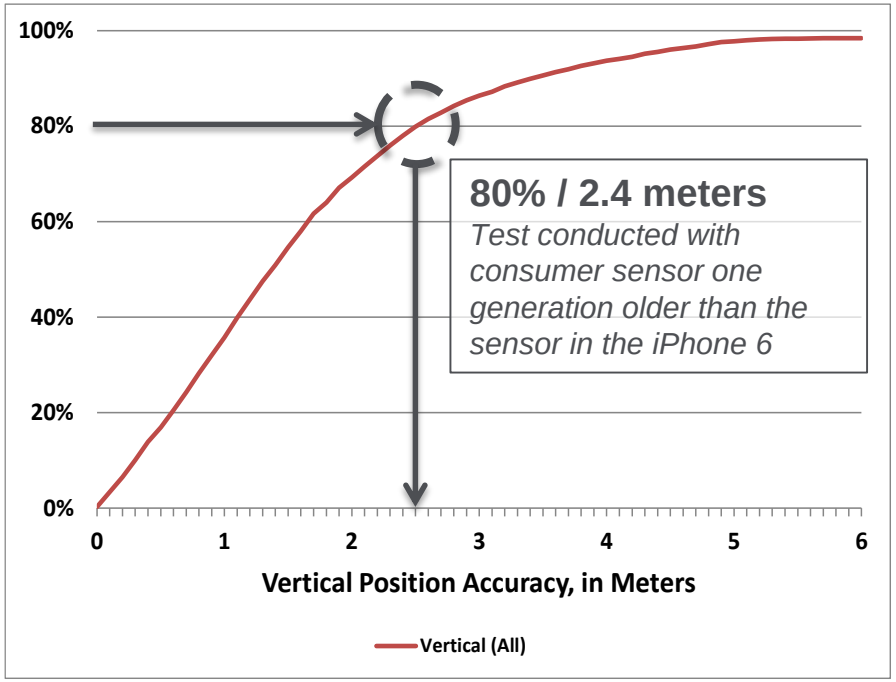
Z-Axis: Floor-Level Altitude is Possible Today

NEXTNAV

Live Test at Intercontinental Hotel

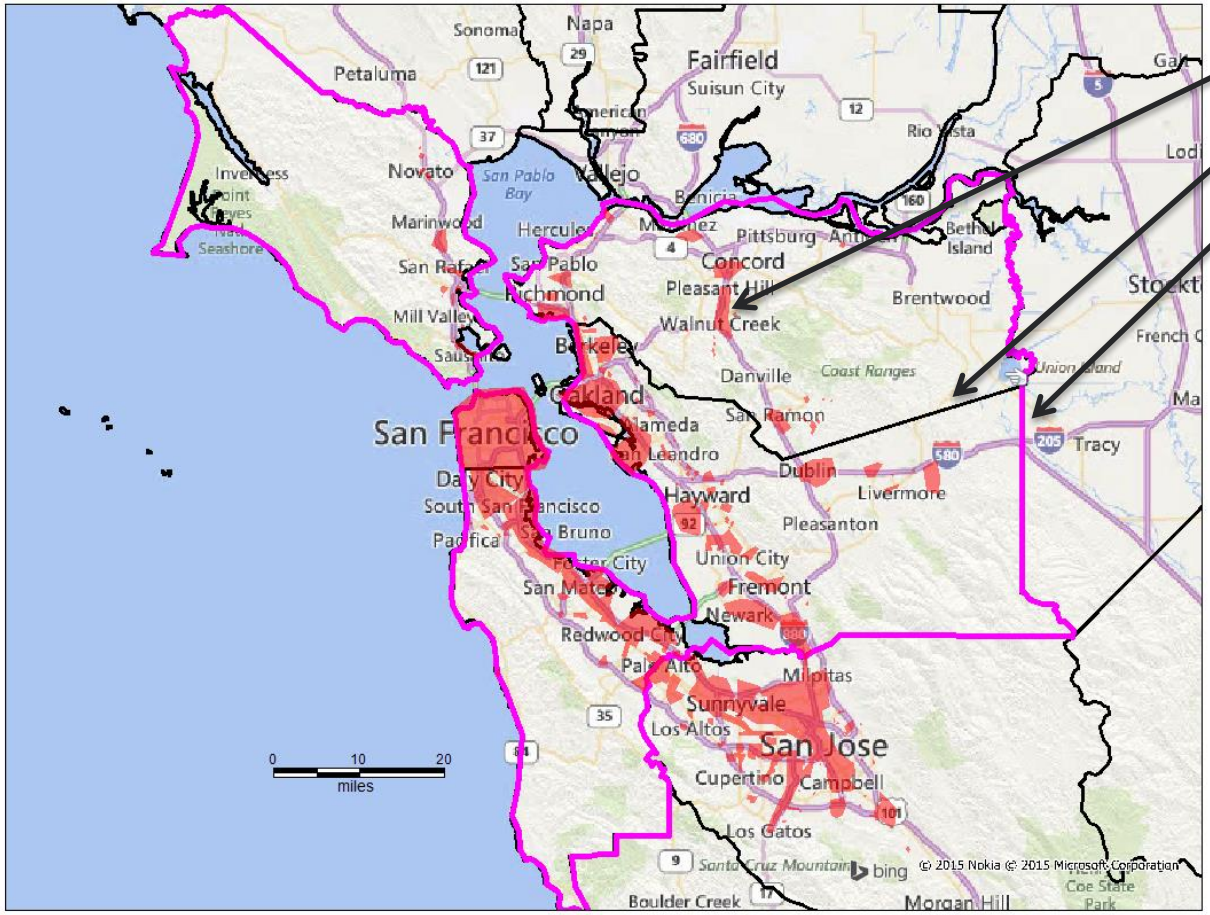


Vertical Accuracy Distribution



MBS provides for the use of real-time environmental information to be used with consumer-grade barometric pressure sensors in-use today

San Francisco CMA (Test Market)



Higher-density Areas in Red

County Boundary in Black

CMA Boundary in Magenta

Key Takeaways

- Horizontal and z-axis systems perform differently in different areas
- Counties, are not homogeneous; 6 test CMAs contain 58 counties
- Example: Oakland vs. Pleasanton
- Likely GNSS-dominated in Pleasanton; without new technologies, Oakland will suffer
- Stay vigilant with new monitoring authority

Federal Communications Commission

Public Safety and Homeland Security Bureau

Overview:
Indoor Location Accuracy
4th Report and Order

911 Goes to Washington

National Emergency Number Association

February 24, 2015

911 Calling Trends

The Indoor Location Problem:

- Increased likelihood that wireless 911 calls will come from indoor environments:
  - Consumers replacing traditional landline telephony with wireless phones
  - The majority of wireless calls are now made indoors
  - The majority of calls to 911 are from wireless phones, even if landline is available
- Location information for indoor wireless calls lacks the address-specific information provided with most wireline calls
- Traditional location accuracy technologies optimized for outdoor calling

Indoor Location Proceeding: Key Milestones

Date	Milestone
February 2014	**Third Further Notice of Proposed Rulemaking** ▪ Feb. 20: http://www.fcc.gov/document/proposes-new-indoor-requirements-and-revisions-existing-e911-rules
March – December 2014	**Extensive Period of Comment and Record Building**
November 2014 – January 2015	**APCO, NENA, & Nationwide Carrier Roadmap** ▪ Nov 18: http://apps.fcc.gov/ecfs/document/view?id=60000986637 ▪ Jan 21: http://apps.fcc.gov/ecfs/document/view?id=60001014958 ▪ Jan 23: http://apps.fcc.gov/ecfs/document/view?id=60001016138
January 2015	**CCA Parallel Path** ▪ Jan 16: http://apps.fcc.gov/ecfs/document/view?id=60001014209 ▪ Jan 23: http://apps.fcc.gov/ecfs/document/view?id=60001016022
January 29, 2015	**Fourth Report and Order** ▪ http://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db0203/FCC-15-9A1.pdf

Key Decision Points of the Order

- Establishes clear metrics and timelines for wireless carriers to implement technical solutions that will improve location for indoor wireless calls
- Draws from the November 2014 APCO-NENA-Nationwide Carrier Roadmap Agreement and Addendum, as well as the CCA Non-Nationwide Carrier Parallel Path Agreement
- Adopts dispatchable location and improved horizontal location requirements
- Requires near term delivery of uncompensated barometric pressure data and long term development and deployment of z-axis solution
- Builds in “backstop” requirements to ensure measurable improvement in indoor location
- Creates an open, independent, transparent, and realistic test bed
- Assesses performance using live 911 call data in representative cities

Dispatchable Location

- Public safety's "gold standard"
  - Equivalent to wireline location information
  - Important advantages for deaf, hard of hearing, and speech disabled
- Leverages Wi-Fi, beacons and other technologies to provide street address information with wireless 911 calls
- Defined as "street address of the calling party, plus additional information such as suite, apartment or similar information necessary to adequately identify the location of the calling party"
  - 445 12th St, SW Wash., DC, Floor 7, 7-A727 vs. coordinate of:38.883463,-77.028342, + 10m above ground height
- Establishes National Emergency Address Database (NEAD)

Horizontal Standards

Wireless providers must provide:

- Dispatchable location, or
- Latitude/Longitude (x/y) coordinates within 50 m of the caller for:
  - 40% of calls within **2 years**
  - 50% of calls within **3 years**
  - 70% of calls within **5 years**
  - 80% of calls within **6 years**
- Non-nationwide carriers can extend the 5- and 6-year deadlines by six months and one year respectively based on timing of VoLTE deployment in their networks

Vertical Standards

Within three years:

- Provide uncompensated barometric data to PSAPs from any capable device
- Develop z-axis metric proposal to be submitted for Commission approval

Z-axis Metric:

- In **top 25 CMAs within 6 years** and **top 50 CMAs in 8 years**:
  - Populate NEAD with reference points equal to 25% of population of CMA, or
  - Deploy z-axis technology to cover 80% of population of CMA
- Non-nationwide carriers have an additional year to achieve these benchmarks

List of Top 50 Most Populous Cellular Market Areas[1]

1. New York-Northern New Jersey-Long Island, NY-NJ-PA
2. Los Angeles-Long Beach-Santa Ana, CA
3. Chicago-Joliet-Naperville, IL-IN-WI
4. Dallas-Fort Worth-Arlington, TX
5. Philadelphia-Camden-Wilmington, PA-NJ-DE-MD
6. Houston-Sugar Land-Baytown, TX
7. Washington-Arlington-Alexandria, DC-VA-MD-WV
8. Miami-Fort Lauderdale-Pompano Beach, FL
9. Atlanta-Sandy Springs-Marietta, GA
10. Boston-Cambridge-Quincy, MA-NH
11. San Francisco-Oakland-Fremont, CA
12. Detroit-Warren-Livonia, MI
13. Riverside-San Bernardino-Ontario, CA
14. Phoenix-Mesa-Glendale, AZ
15. Seattle-Tacoma-Bellevue, WA
16. Minneapolis-St. Paul-Bloomington, MN-WI
17. San Diego-Carlsbad-San Marcos, CA
18. St. Louis, MO-IL
19. Tampa-St. Petersburg-Clearwater, FL
20. Baltimore-Towson, MD
21. Denver-Aurora-Broomfield, CO
22. Pittsburgh, PA
23. Portland-Vancouver-Hillsboro, OR-WA
24. Sacramento--Arden-Arcade--Roseville, CA
25. San Antonio-New Braunfels, TX
26. Orlando-Kissimmee-Sanford, FL
27. Cincinnati-Middletown, OH-KY-IN
28. Cleveland-Elyria-Mentor, OH
29. Kansas City, MO-KS
30. Las Vegas-Paradise, NV
31. San Jose-Sunnyvale-Santa Clara, CA
32. Columbus, OH
33. Charlotte-Gastonia-Rock Hill, NC-SC
34. Indianapolis-Carmel, IN
35. Austin-Round Rock-San Marcos, TX
36. Virginia Beach-Norfolk-Newport News, VA-NC
37. Providence-New Bedford-Fall River, RI-MA
38. Nashville-Davidson--Murfreesboro--Franklin, TN
39. Milwaukee-Waukesha-West Allis, WI
40. Jacksonville, FL
41. Memphis, TN-MS-AR
42. Louisville/Jefferson County, KY-IN
43. Richmond, VA
44. Oklahoma City, OK
45. Hartford-West Hartford-East Hartford, CT
46. New Orleans-Metairie-Kenner, LA
47. Buffalo-Niagara Falls, NY
48. Raleigh-Cary, NC
49. Birmingham-Hoover, AL
50. Salt Lake City, UT

Technology Certification Test Bed

- Open, transparent, permanent, and technology-neutral
- Will utilize realistic indoor environments across four morphologies: dense urban, urban, suburban, and rural
- Managed by an independent administrator
- Will demonstrate and characterize performance of each technology, which will be later validated by that technology's performance as reflected by live call data

Live 911 Call Data

- Beginning at 18 months, providers will report aggregate live 911 call data from the six test cities:
  - Quarterly for all nationwide providers
  - Every 6 months for non-nationwide providers
- The reports will show “positioning source method” for each 911 call (e.g., satellite, DL, OTDOA, other technologies or hybrids)
  - Measurements will be reported for each of the morphologies in each city
- PSAPs will be entitled to obtain live call data from wireless providers in their area
- Enforcement only if:
  - they have implemented policies that are designed to obtain all 911 location information made available by wireless providers; and
  - they have first attempted to resolve the issue informally with the wireless provider

Test Cities for Live 911 Call Data

- Six test cities developed by ATIS ESIF as representative of all dense urban, urban, suburban and rural morphologies:
  - San Francisco Bay Area, CA
  - Chicago, IL
  - Atlanta, GA
  - Denver/Front Range, CO
  - Philadelphia, PA
  - Manhattan, NYC

Measuring Compliance

Technology	Test Bed Call Performance	Actual 911 Call Performance	Carrier Performance	
Technology A	<50 m for 90% of test calls	<50 m for 50% of live calls	90% * 50% = 45%	45% + 20% = 65%
Technology B	<50 m for 100% of test calls	<50 m for 20% of live calls	100% * 20% = 20%	

- *Technologies should perform at an ideal level in the test bed*
- *Performance in the test bed will be certified by the provider and will serve as a baseline against which the live call performance of that technology will be measured*

Carrier Performance	Year	FCC Benchmark
65%	2	40%
	3	50%
	5	70%
	6	80%

Reporting Requirements

- At 18 months, nationwide wireless providers must
  - Begin reporting live 911 data
  - Submit initial implementation plan for meeting indoor requirements at 3- and 6-year benchmarks
    - Non-nationwide providers have an additional 6 months to submit these plans
  - Submit a progress report on the deployment and implementation of indoor requirements
  - Submit a privacy and security plan for the National Emergency Address Database
- At 36 months, all wireless providers must submit a progress report on the implementation of their initial plan and assessment of any dispatchable location deployment efforts
  - Nationwide wireless providers must submit a z-axis metric to Commission for review and approval

Certification Requirements

- Compliance Certification
  - Certification is required within 60 days of each location benchmark
  - Providers must certify:
    - that technology being used has been certified in the test bed;
    - that the technology deployed across carriers' networks is consistent with test bed deployments AND deployments in test cities for live 911 call data
  - Providers must re-certify any time a new technology is introduced into the network
- NEAD Privacy and Security
  - Prior to activation of database, wireless providers must certify that NEAD is only being used for responding to 911 calls

Other Requirements

- Confidence and Uncertainty (C/U)
  - Sets a standardized confidence level of 90%, which eliminates uncertainty around this information
- Maximum latency (Time To First Fix)
  - Establishes a 30-second maximum latency period for E911 location
    - For a 911 call to be counted towards compliance with existing location accuracy requirements, the location fix must be provided within 30 seconds of call initiation
  - Applies to outdoor calls under the existing Phase II rules
  - Defers applying latency standards to indoor calls pending further development of indoor location technology

Conclusion

- The Order is a turning point:
  - Creates a permanent testing regime for evaluation of location technology
  - Requires the use of live 911 call data to measure performance
  - Opens the door to the use of millions of Wi-Fi and Bluetooth wireless access points to support 911 location
- This is a floor, not a ceiling
- Data collection, measurement and reporting = Transparency