

Location Accuracy Technologies: Today and Tomorrow

Nov. 17th, 2015

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SVP
TeleCommunication Systems (TCS)

Is 9-1-1 Location Technology Failing Us?

Lost on the Line: Why 911 is broken

YOUR CELL PHONE KNOWS EXACTLY WHERE YOU ARE, BUT 911 DOESN'T GET A VICTIM'S LOCATION IN A SHOCKINGLY HIGH NUMBER OF EMERGENCIES. THE 11ALIVE INVESTIGATORS' BRENDAN KEEFE FOUND OUT THAT THE PROBLEM IS GETTING WORSE - AND COSTING LIVES.

Brendan Keefe and
Phillip Kish, WXIA



- The Three 911 Location Challenges
- Addressing the Location Hype (It's Actually Hard)
- 911 Applications – Good Idea or Bad?
- Indoor Location Demonstration

Three 911 Location Challenges

- Call Routing Challenge
- Enhanced Location (Phase II) Challenge
- Indoor Location Challenge

**Resist conflating these challenges:
they are distinct!**

- #### 4: E9-1-1 Center stages enhanced location

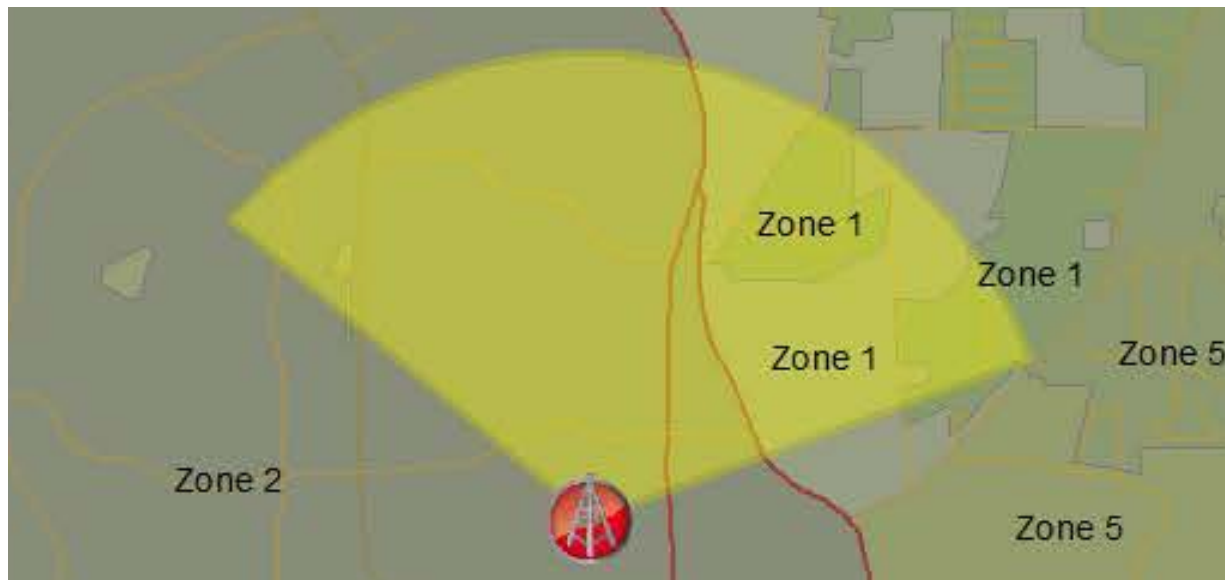


Call Routing Challenge

“[Chief of Technology] Hall [of Alpharetta Police Department] said, ‘the address of that tower determines which 9-1-1 center that call goes to. It's not based on the location of the telephone. It's the physical address of the tower, not the physical address of the phone.’”

11Alive; 01/31/15

Determining Call Routing



- Cell site plotted
- Cell sector faced
- PSAP boundaries
- Primary PSAP
- Determine route

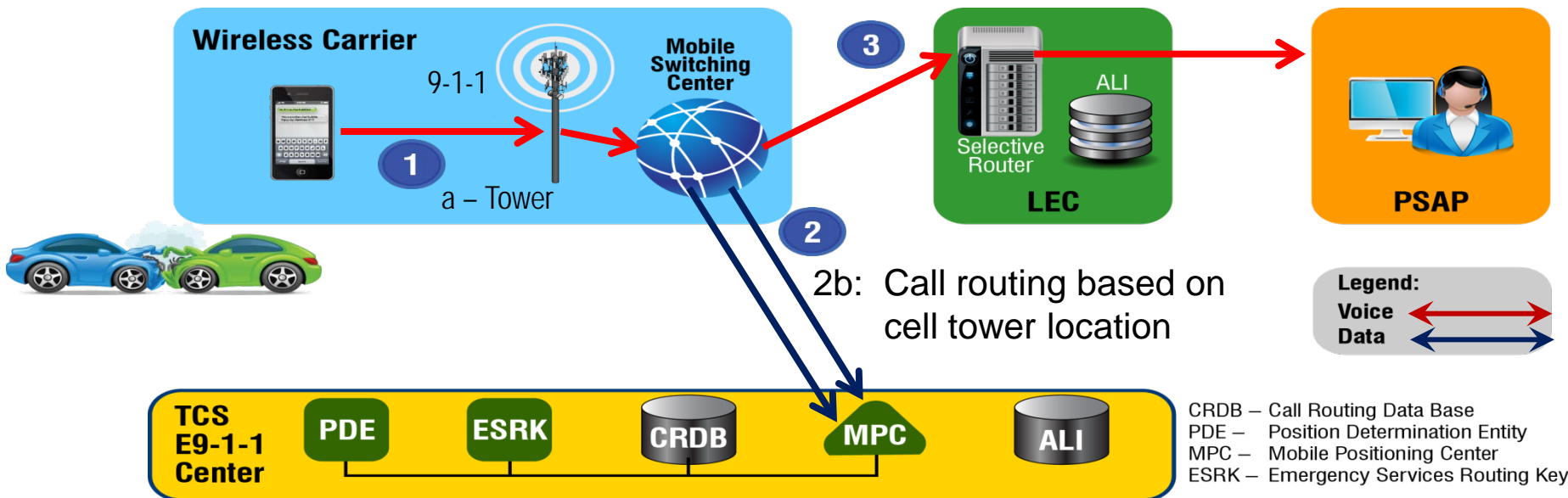
Routes can change – test them!

GeoComm

Wireless 9-1-1 Call Routing Challenge

- 1: Person dials 9-1-1
- 2a: MSC requests routing instructions
- 3: MSC routes call to designated PSAP

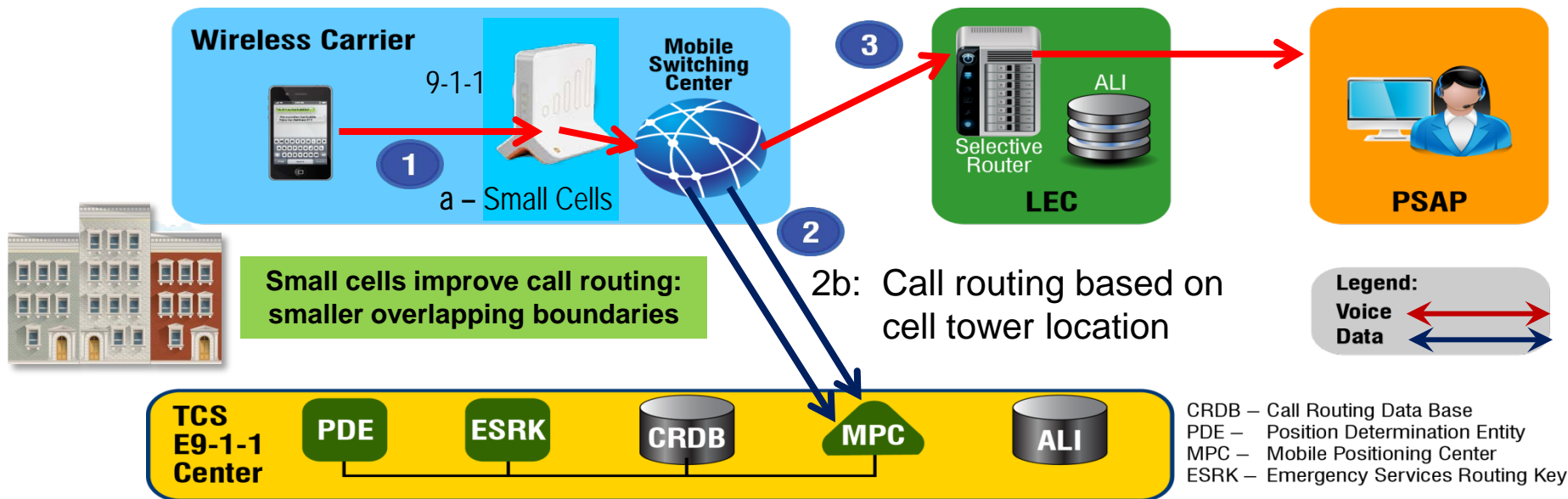
Non-final routes occur on PSAP boundaries and require PSAP call transfers



Wireless 9-1-1 Call Routing Improved

- 1: Person dials 9-1-1
- 2a: MSC requests routing instructions
- 3: MSC routes call to designated PSAP

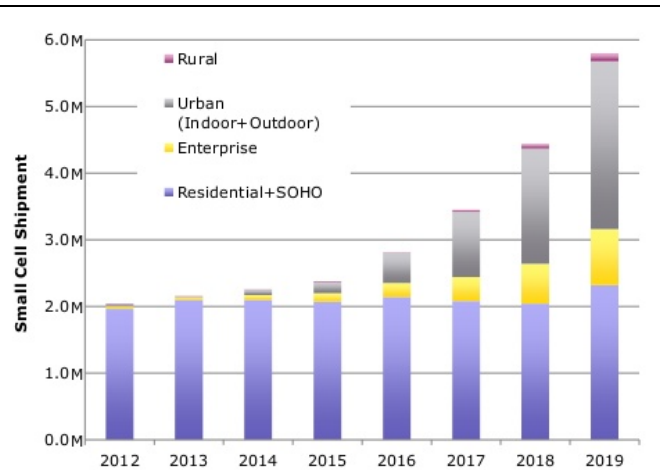
Non-final routes occur on PSAP boundaries and require PSAP call transfers



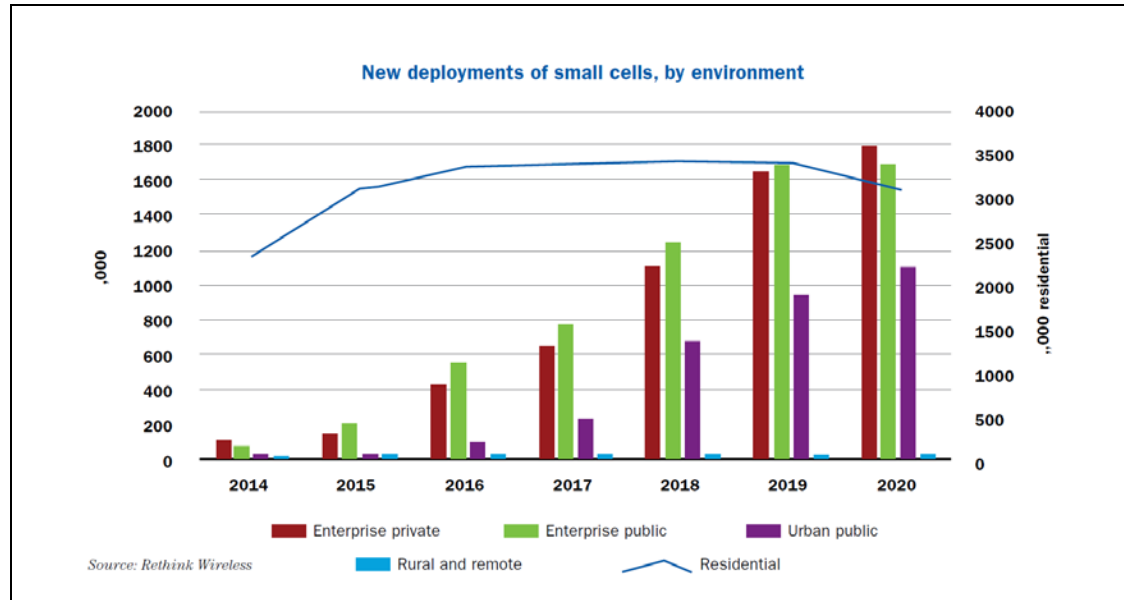
Strong Small Cell Growth

[T]he Macquarie analysts estimated that there are about 40,000 small cells deployed in the United States today.

FierceWireless 1/13/15



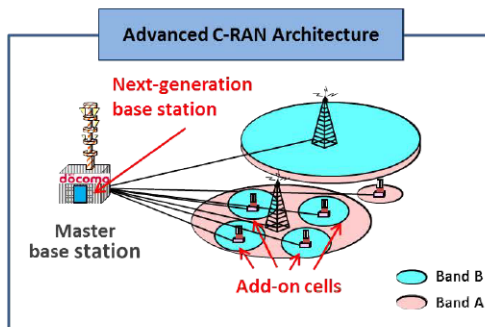
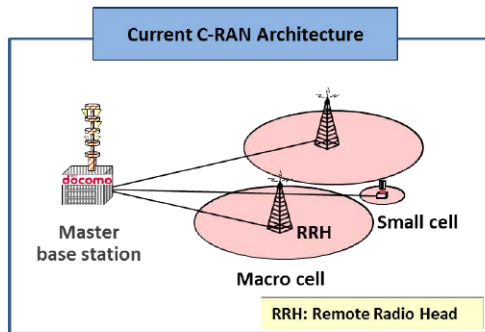
Small Cell Forum 12/14



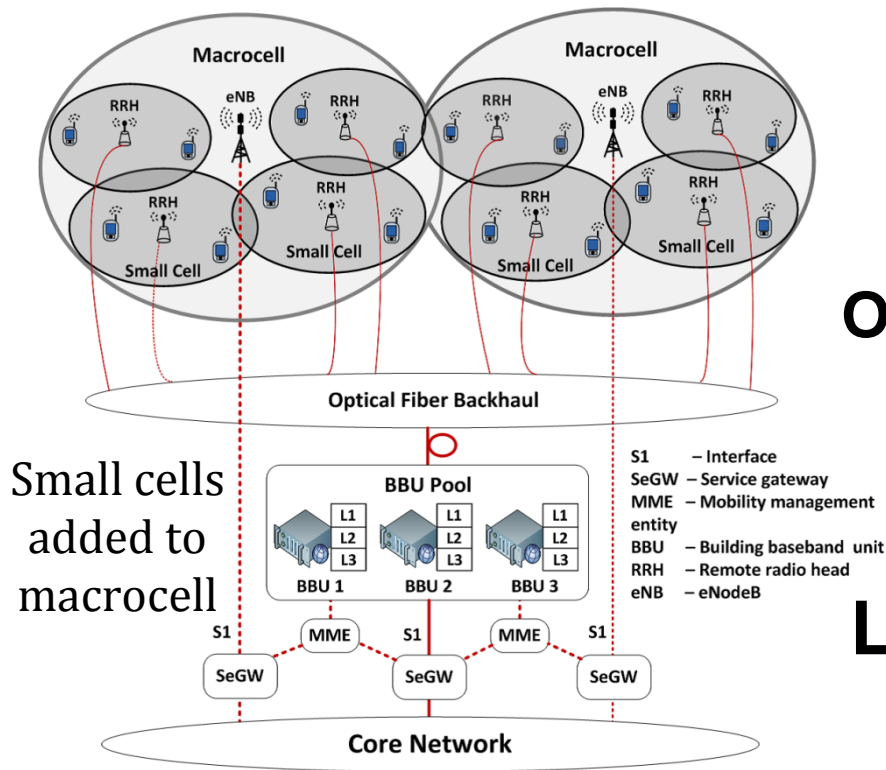
Rethink Wireless, 09/15

Small Cell Worry: Cloud RAN

Comparison of C-RAN Architectures



Via: Metrocells.blogspot.com



Problem:
Only macrocell
known

**Lose benefit
for 911**

S1 – Interface
SeGW – Service gateway
MME – Mobility management
entity
BBU – Building baseband unit
RRH – Remote radio head
eNB – eNodeB

Enhanced Location Challenge

“The third and most critical failure is that a shockingly high number of wireless 9-1-1 calls don't display the location of the cell phone.”

11Alive; 01/31/15

What was the second?

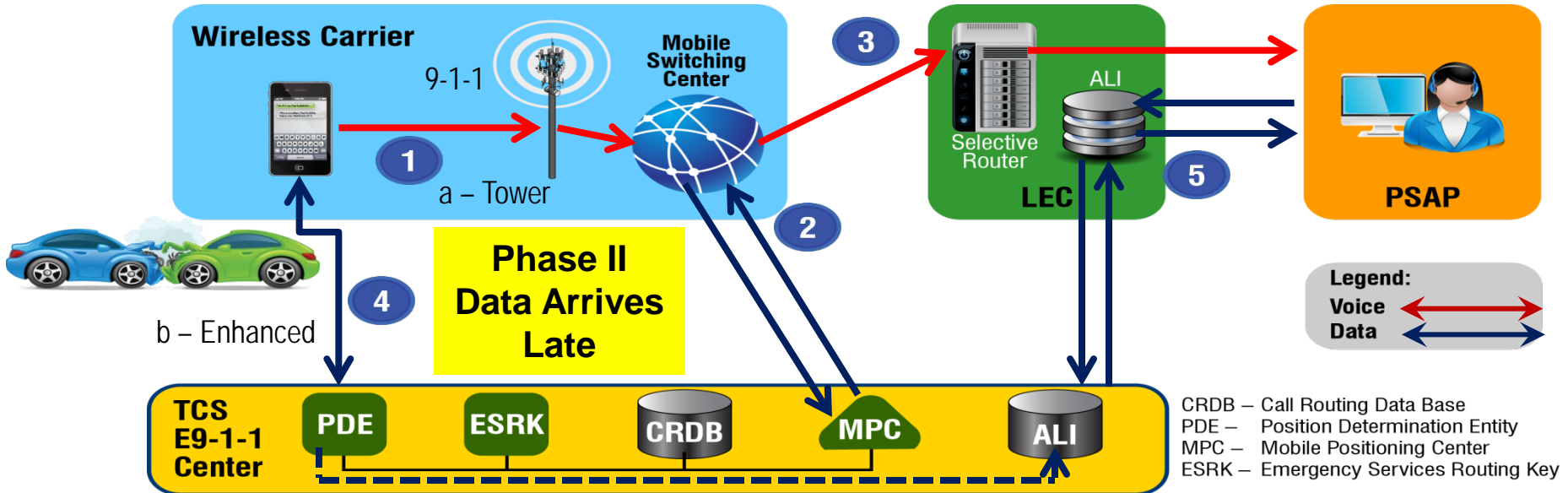
“The second failure is the mapping system that doesn't extend beyond the call center's jurisdiction.”

Not a location technology problem – a policy problem that can be corrected!

Wireless 9-1-1 Phase II Challenge

- 1: Person dials 9-1-1
- 2: MSC requests routing instructions
- 3: MSC routes call to nearest PSAP

- 4: E9-1-1 Center stages enhanced location
- 5: PSAP queries for enhanced location



CRDB – Call Routing Data Base
PDE – Position Determination Entity
MPC – Mobile Positioning Center
ESRK – Emergency Services Routing Key

Initial Bid Timing vs. Location Fix

Washington DC

May, 2013

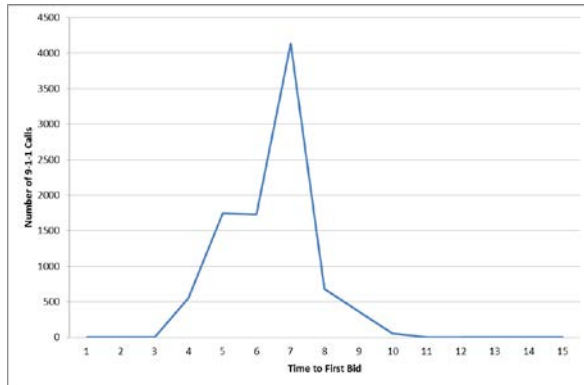
Single carrier

11,585 calls

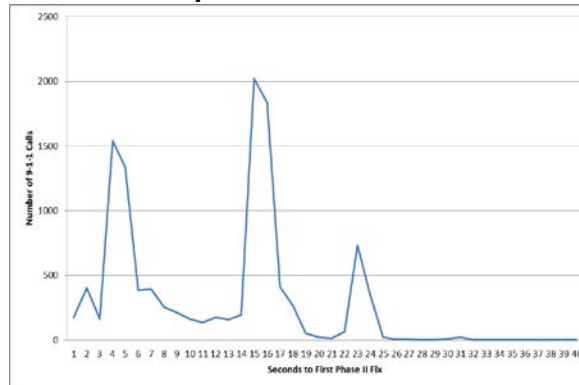
10,812 bids

6.7% abandoned

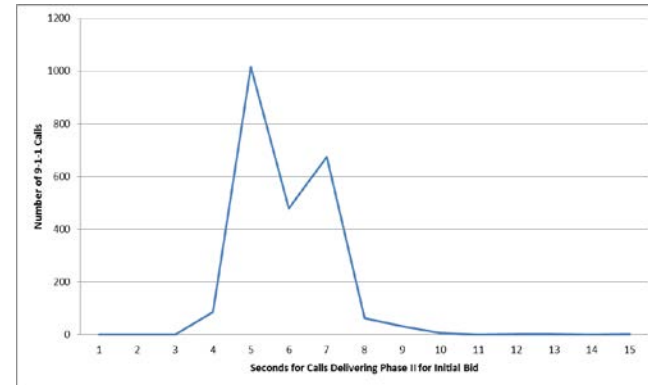
Initial Bid generally <8 sec



...but location fixes can
take up to 24 seconds



Phase II Initial Bids: 2588
23.9%



- Rebidding often is not done
 - Washington DC: 1.8% (191 of 10,811 calls)
 - CalNENA policy not to re-bid: 2006 thru 2014
 - Dispatch info sometimes overwritten by re-bids

On initial bid

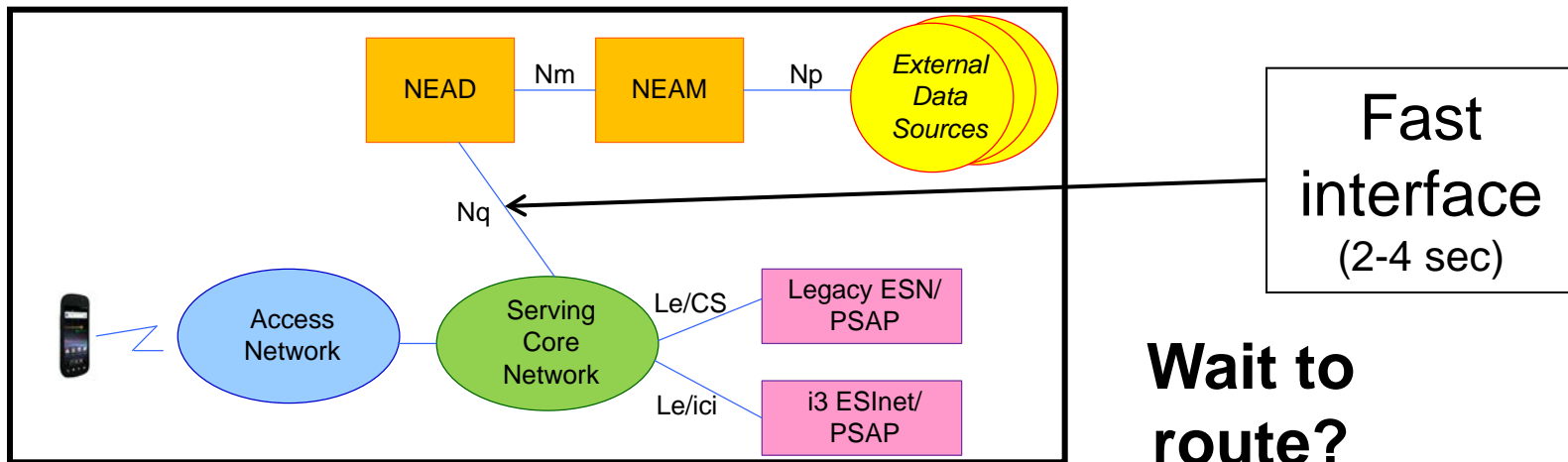
75.4%	Phase I
0.7%	Poor Phase II
21.8%	Phase II A-GPS
2.1%	Phase II AFLT

After 30 seconds:

10,794 of 10,811 calls = 99.8%

11.1%	Phase I	
1.7%	Poor Phase II	
73.2%	Phase II A-GPS	} 87.1%
13.9%	Phase II AFLT	

1. Small cells = Phase I more precise than Phase II
2. Speeding up the location fix:
National Emergency Address Database (NEAD)



NG9-1-1 brings two benefits to improving location

- Location data is pushed rather than pulled
 - No need for re-bid strategy
 - Location information can be presented as it becomes available
- Multiple location elements can be sent – courtesy of PIDF-LO
 - A-GPS fix
 - OTDOA fix
 - Street address from indoor location techniques
 - Billing/work addresses

**Presence Information
Data Format -
Location Object**



Indoor Location Challenge

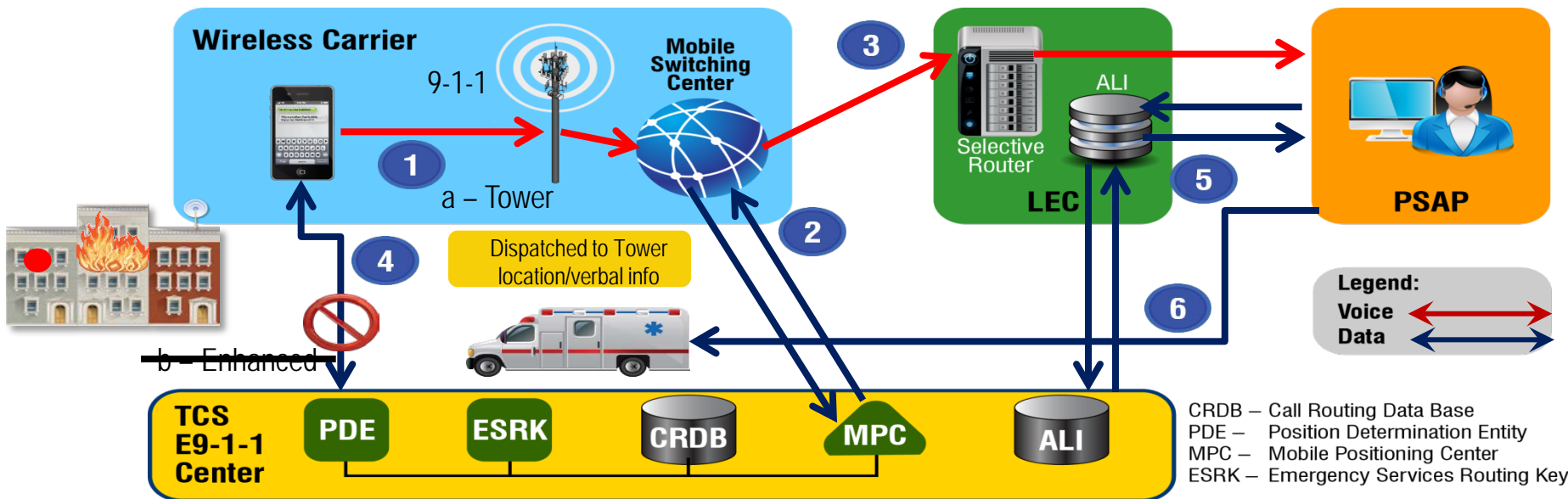
“The study finds the percentage of wireless calls made indoors has increased considerably during the past eight years—to an average of 56 percent in 2011 from 40 percent in 2003.”

JD Power & Associates; 03/03/11

Wireless 9-1-1 Indoor Location Challenge

- 1: Person dials 9-1-1
- 2: MSC requests routing instructions
- 3: MSC routes call to nearest PSAP

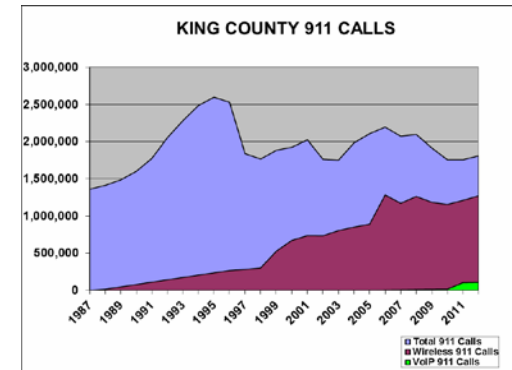
- 4: E9-1-1 Center fails to get enhanced location
- 5: PSAP queries for location (Phase I only)
- 6: PSAP dispatches emergency assistance???



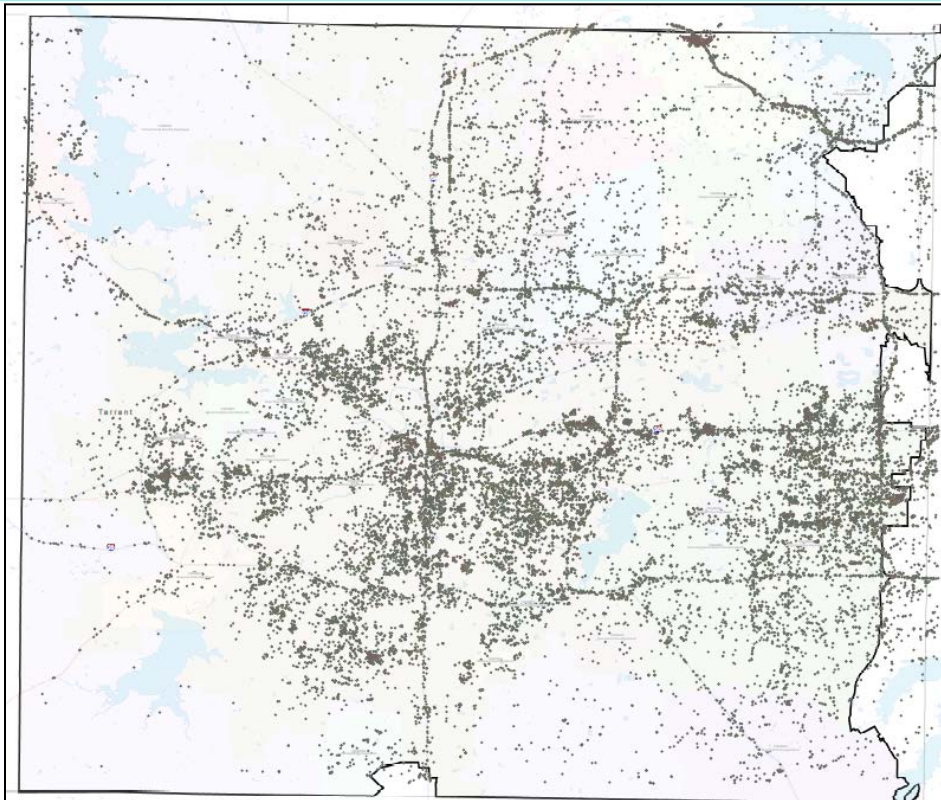
- Is there an Indoor Location problem?
- Evidence of a Problem
 - Statistics tell a story
 - Analyzing real-world 9-1-1 data
 - Long-term 9-1-1 data comparison
 - 9-1-1 data trending
 - Comparing urban/suburban to dense urban

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



Real-world 9-1-1 Call Analysis



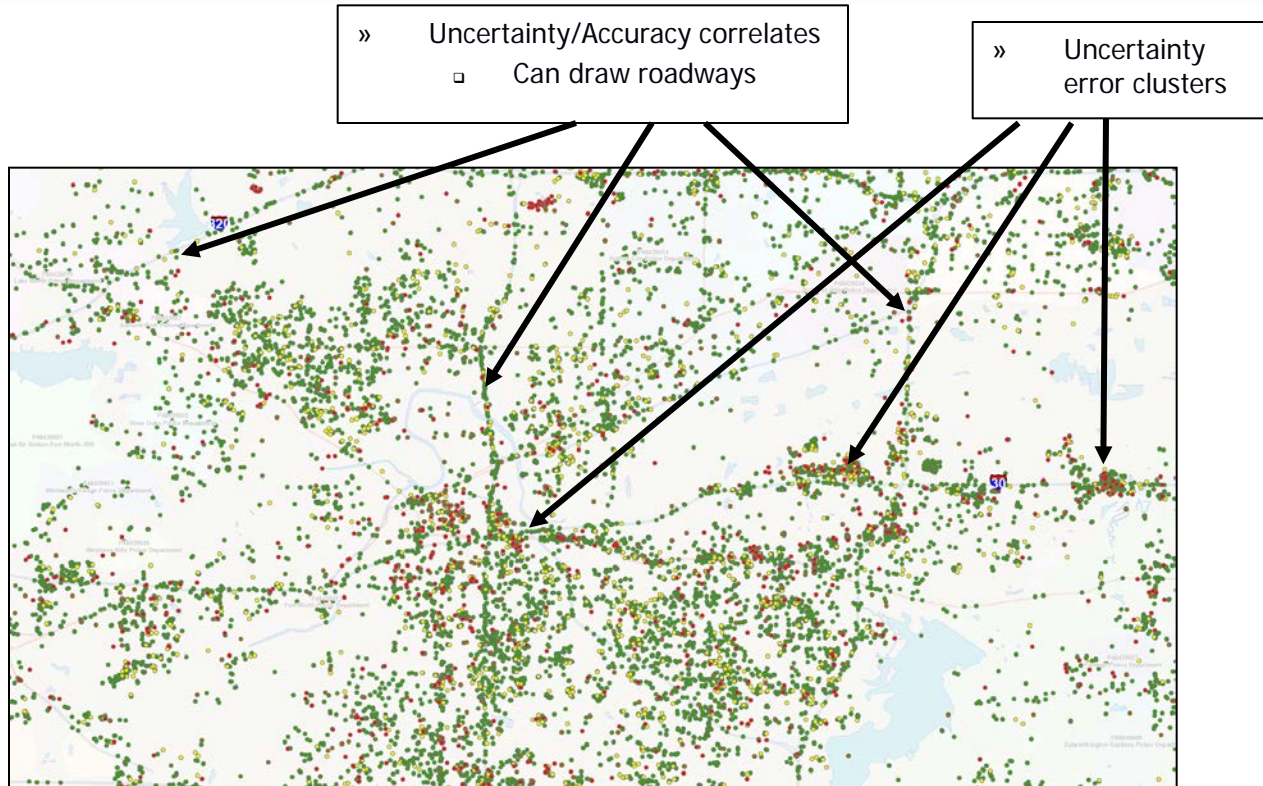
- » Actual 911 calls
- » Tarrant County
- » All carriers
- » August, 2013

Color-code X/Y locations
(using HUNC)

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

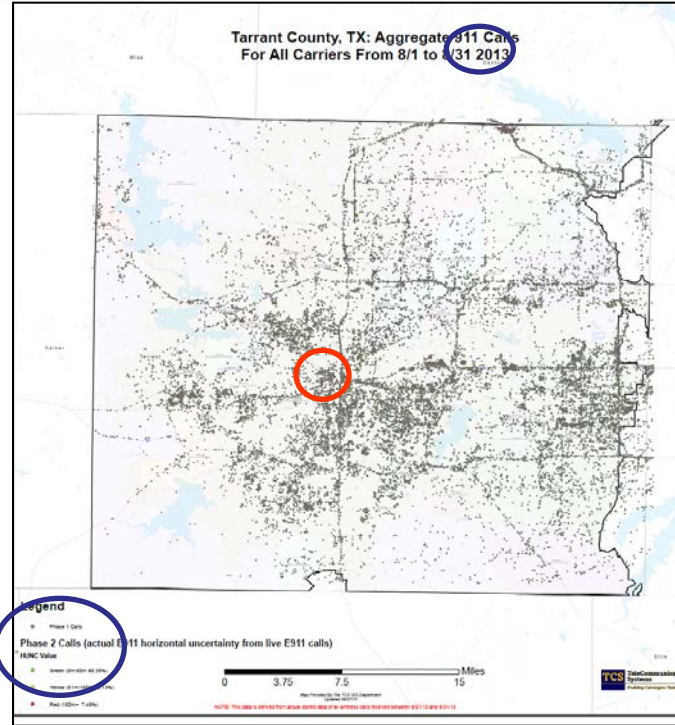
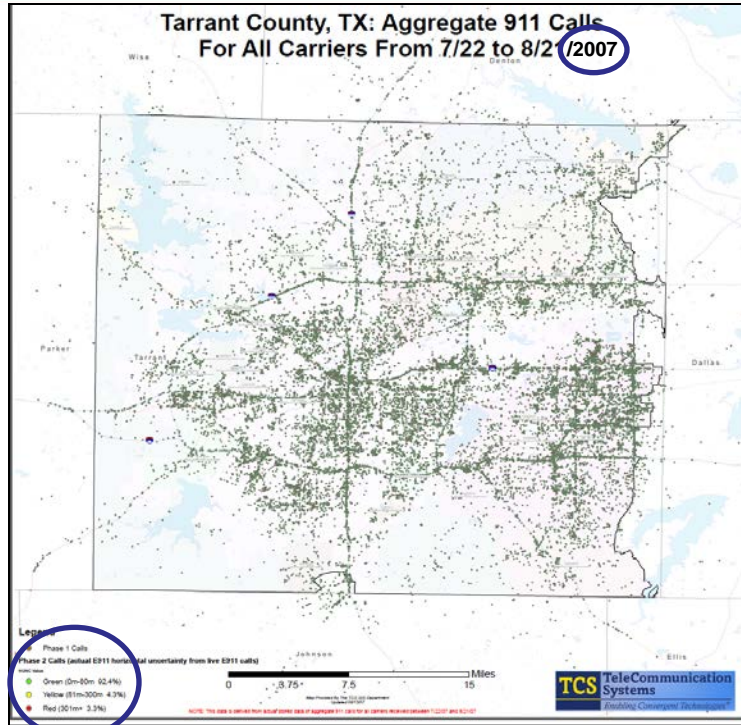
Which are Indoors?
Which are Outdoors?

Uncertainty Tells a Story



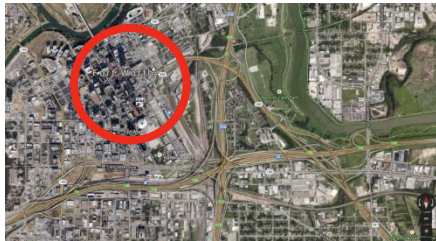
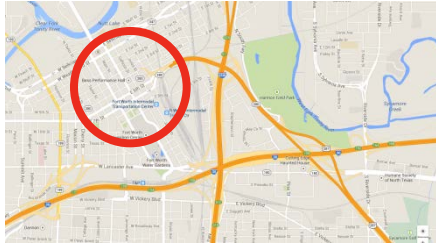
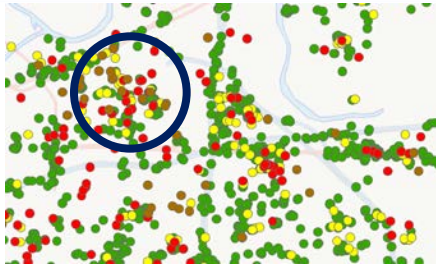
**Tarrant County, TX –
Multiple wireless
carriers – August, 2013
data**

Location HUNC Getting Worse



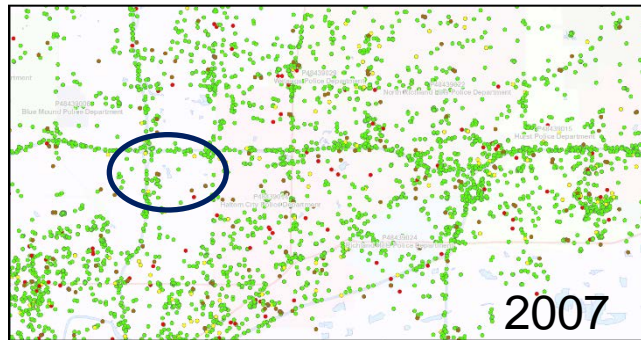
3.3% → 7.5%
(more calls
from indoor
locations?)

The Maps Tell a Story

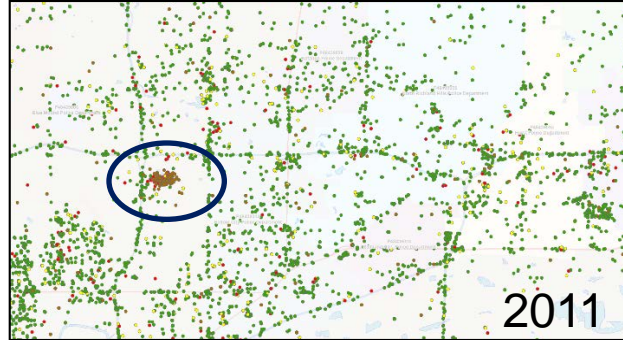


Tarrant County, TX
9-1-1 Calls –
August, 2013

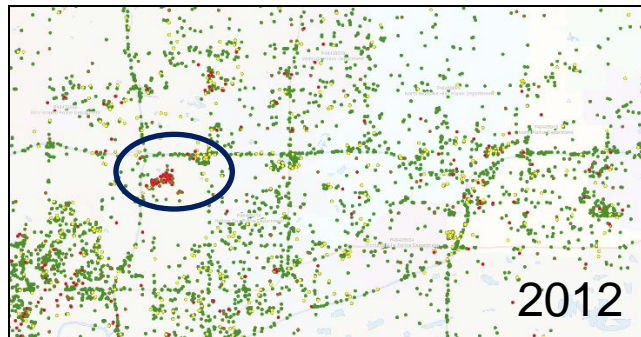
Data Trends Tell a Story



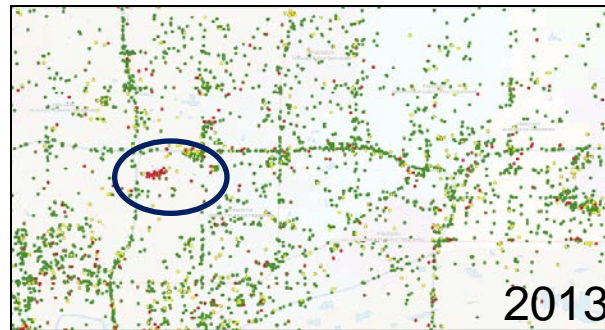
Nonexistent in 2007



Major problem area in 2011



Improved in 2012



Greatly improved in 2013

Problem area seen in 2011



**Goodrich Warehouse
Built in 2007**

Dense Urban Tells a Story

- 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%) expresses likelihood to find device within HUNC range

More Satellites = Better Indoors

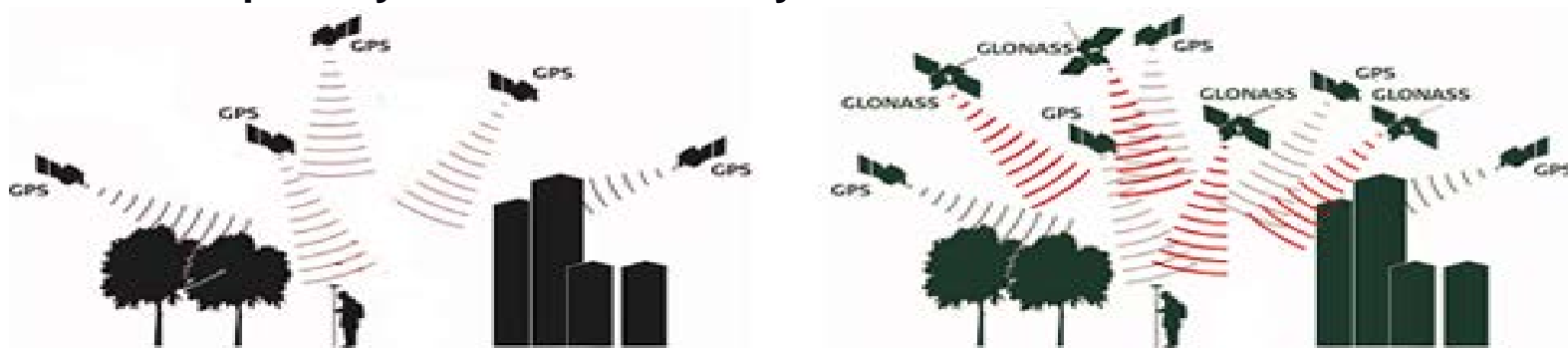
- GLONASS - Deployed now
 - Russian ownership
 - Full global coverage
 - 21+3 satellites
 - 4-7m horizontal; 10-15m vertical precision
- Galileo – Deploying
 - European Union ownership
 - Full global coverage
 - 4 satellites now; 27+3 by 2019
 - 4m horizontal; 8m vertical precision (paid)
- Beidou – Deploying (COMPASS)
 - Chinese ownership
 - Regional, expanding to global coverage
 - 30+5 satellites
 - 25m horizontal; 30m vertical precision



Combining
satellite
systems is
expected to
double
precision

A-GPS Is Improving: GLONASS

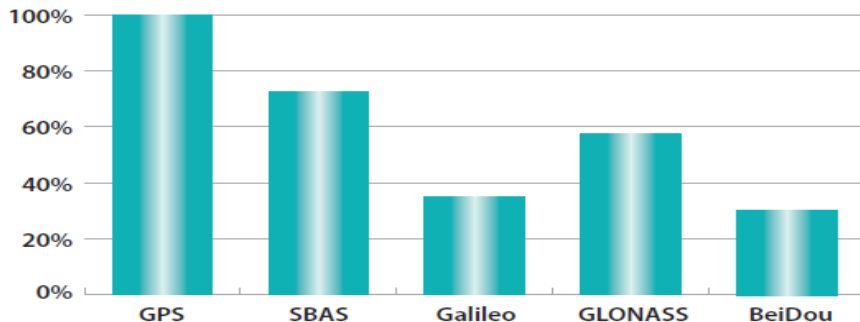
- **GLONASS is becoming prevalent in smartphones**
 - ✓ **GLONASS supplements GPS in most devices**
 - ✓ **Device makers and chipset companies support multi-GNSS constellations**
- **Five studies showed favorable results with the addition of GLONASS and GPS**
 - ✓ **Addition of GLONASS data with GPS improves the number of satellites visible**
 - **Especially true for urban canyons**



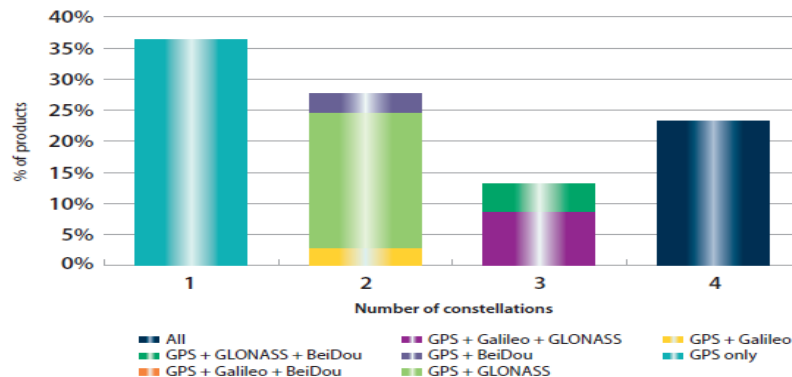
GNSS Support in Smartphones

- **The use of multi GNSS receivers in smartphones is becoming prevalent**
(Source: European GNSS Agency, 3/15)
 - ✓ **More than 60% of all smartphone chipsets support at least two constellations**
 - ✓ **GLONASS is supported in greater than 55% of smartphones**
- **GLONASS constellation completed in 2011**

Capability of GNSS receivers – LBS segment



Supported constellations by receivers – LBS segment



Source: European GNSS Agency, 3/15

GPS + GLONASS: Improves Positioning “Tremendously”

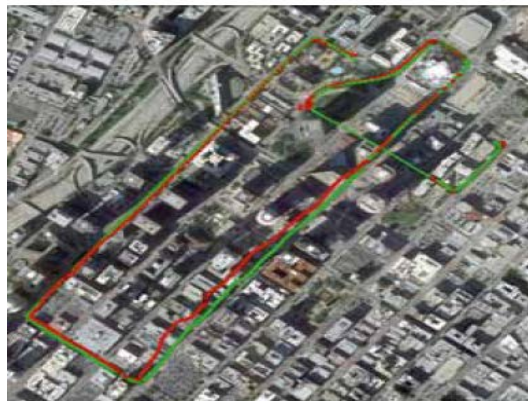
“GPS + GLONASS: Using the Best of Both Worlds”

Telit White Paper, 2012

- Tests in Los Angeles, London and Johannesburg of adding GLONASS to GPS
- Combination of GPS and GLONASS improved positioning tremendously
 - ✓ Especially in urban canyons with skyscrapers
- With the addition of GLONASS:
 - ✓ Tracked satellites never dropped below six
 - ✓ Problem of lost satellite coverage in urban canyons is dramatically reduced
- Time-to-fix also improved with the combined GLONASS and GPS

Picture 2:

Tracked way in Los Angeles. Green shows the route which was driven with GPS & GLONASS receiver, red the same route with a standard GPS-only receiver.



The picture shows a single test track in Los Angeles.

There were several instances where GPS was not able to determine a position.

With GPS + GLONASS, this did not happen as the receiver never lost signal.

There is also a huge difference in the accuracy of ground track.

Consumer GPS/GLONASS: Accuracy and Availability

“Consumer GPS/GLONASS: Accuracy and Availability Trials of a One-Chip Receiver in Obstructed Environments”

STMicroelectronics, 12/11

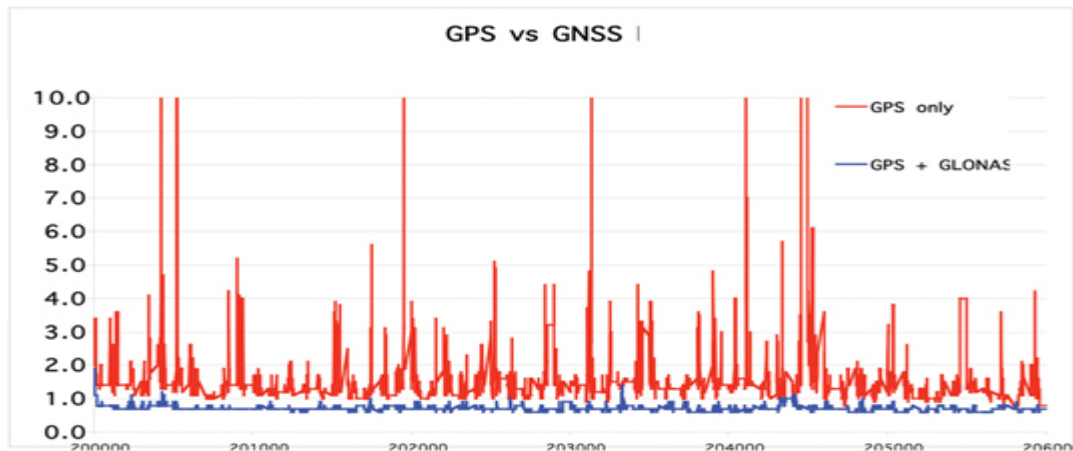
- Tests in London, Tokyo and Texas
 - ✓ Determine impact of GLONASS+GPS satellites in urban areas
- Increase in satellites seen for a combined GPS + GLONASS
- An accuracy improvement of 2.5X

Good “yield” improvement

Constellation	GPS	GPS + Glonass
Visible Satellite*	4.4	7.8
No Fix	380 minutes	Never
HDOP*	5.3	2.1
Error*	x meter	(x* 0.4) meter

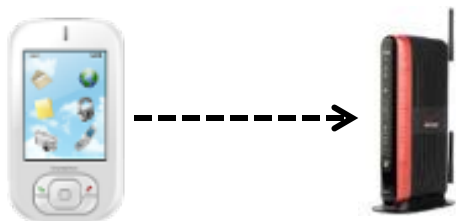
HDOP = Horizontal Dilution of Precision
It is a measure of error:
reduction=improved accuracy

2.5x accuracy improvement



Solution: Wi-Fi Indoor Location

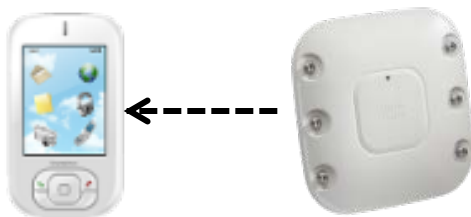
- Smartphone locates nearest Wi-Fi Access Point



Smartphone detects Wi-Fi AP

- AP presents its MAC ID
- Smartphone measure signal strength
- Smartphone presents info to location server

- Nearest Wi-Fi Access Point locates nearby smartphone



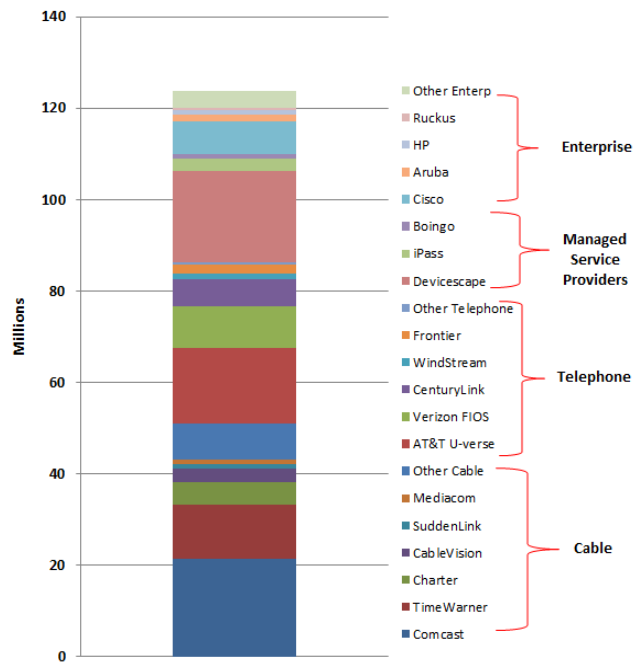
Wi-Fi AP detects smartphone

- Smartphone presents its MAC ID
- AP measure signal strength
- Multiple APs can triangulate the smartphone
- AP system presents info to location server

Enterprise Wi-Fi Location

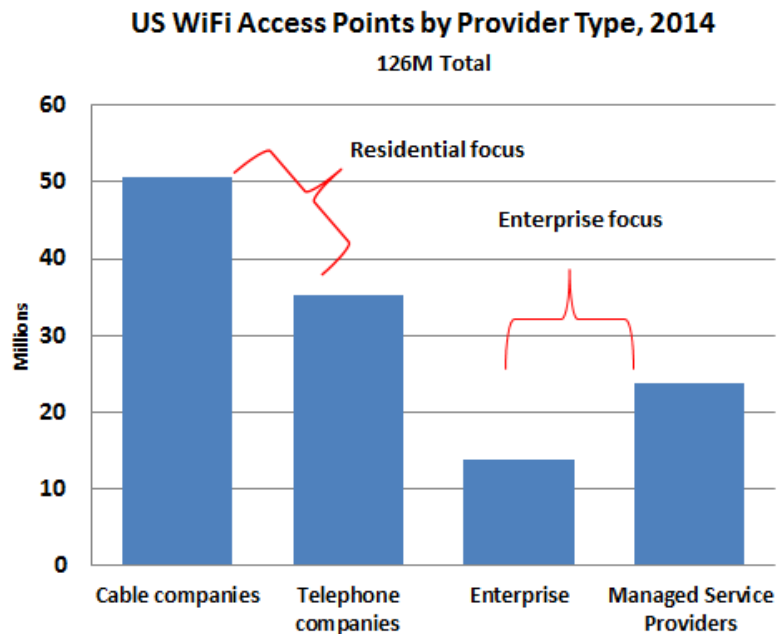
Wi-Fi Availability in the U.S.

There are over 126M WiFi Access Points in the US from identifiable residential and enterprise providers. Approximately 86M are deployed in residences and 40M in enterprises/public access areas.

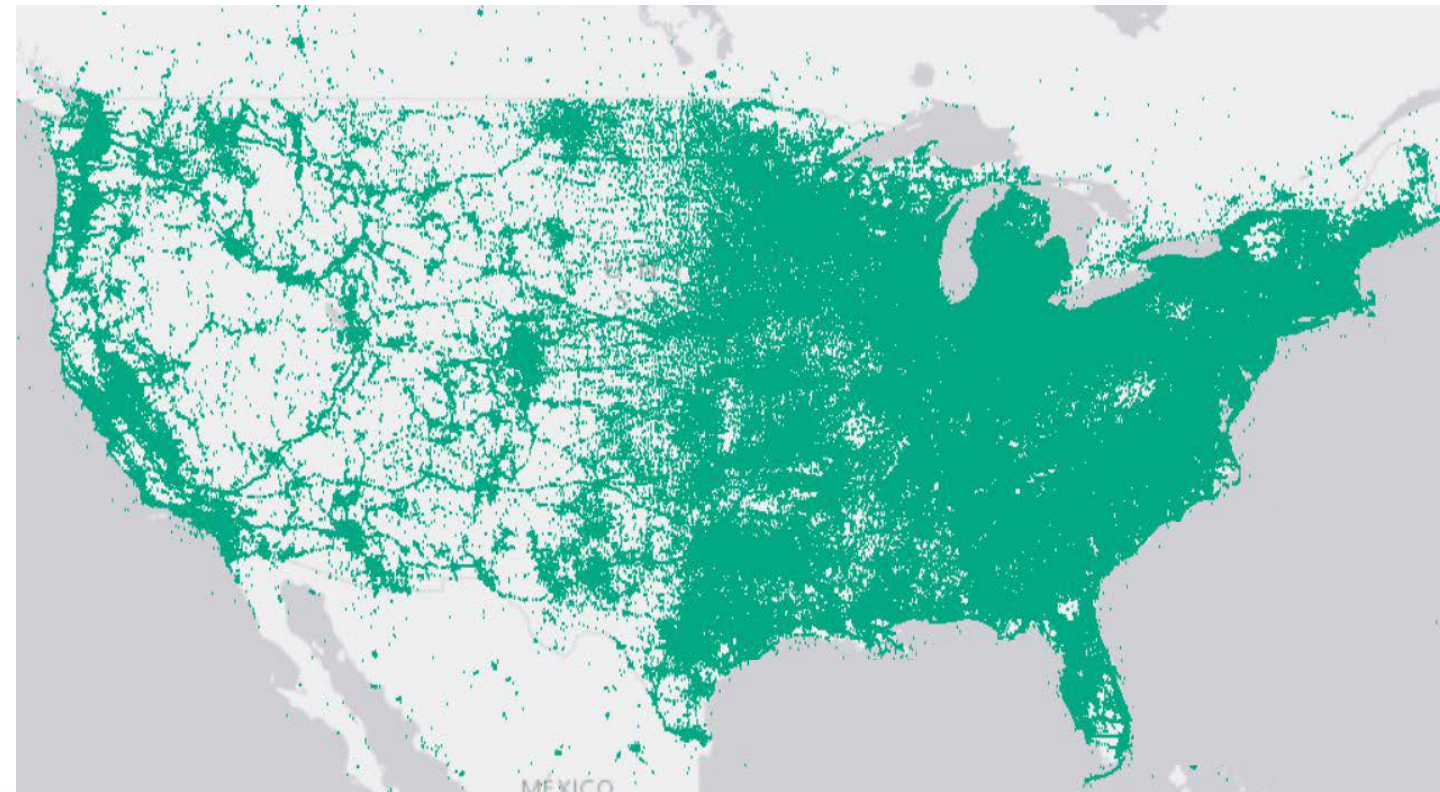


Wi-Fi Access Points by Provider, 2014

Source: company information and ABI Research, 2014



TCS Wi-Fi Access Point Database



149M Access Points

Wi-Fi coverage exists
And it Maps to population

Enterprise Indoor Location – Washington DC

LocatE9-1-1™

SDWA Operator Control Panel

Time zone: Pacific Time (US & Canada)

Operator: Tim ▾

Unassigned Calls

None at this time

My Active Calls

(925) 787-8329 04:56

Other Active Calls

None at this time

Recent Calls

(925) 787-8329 04:44 Aug 17
 (925) 787-7467 04:49 Aug 17
 (925) 787-8329 04:49 Aug 17
 (925) 787-8329 04:51 Aug 17

End Session

Refresh Location

Indoor Location

Cisco M...
 Address: 500 F Street NW, APCO Conf, Washington DC
 X: 577.4 feet, Y: 314.11 feet
 Latitude: 38.90544444 degrees,
 Longitude: -77.023288497 degrees

Show other data sources

Indoor Map



Wi-Fi AP
 Controllers
 (2 Cisco MSEs)

Dispatchable
 Location

Indoor
 Map

Satellite Overlay for Campus View

LocatE9-1-1™

SDWA Operator Control Panel

Time zone: Pacific Time (US & Canada)

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(925) 787-8329 04:51 Aug 17

End Session

Refresh Location

Cisco MSE

Address: 801 MT VERNON PI NW, APCO Conf, Washington DC

X: 577.4 feet, Y: 314.11 feet

Latitude: 38.9043465942 degrees,

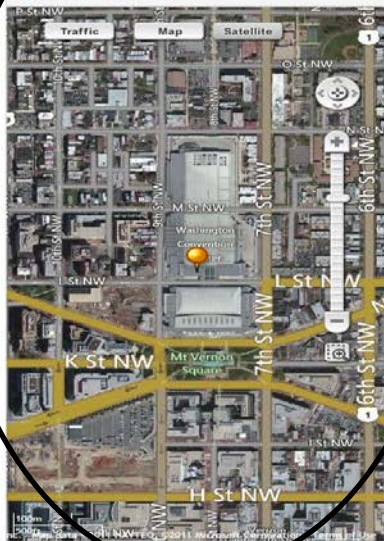
Longitude: -77.023288497 degrees

Show other data sources

Indoor Map

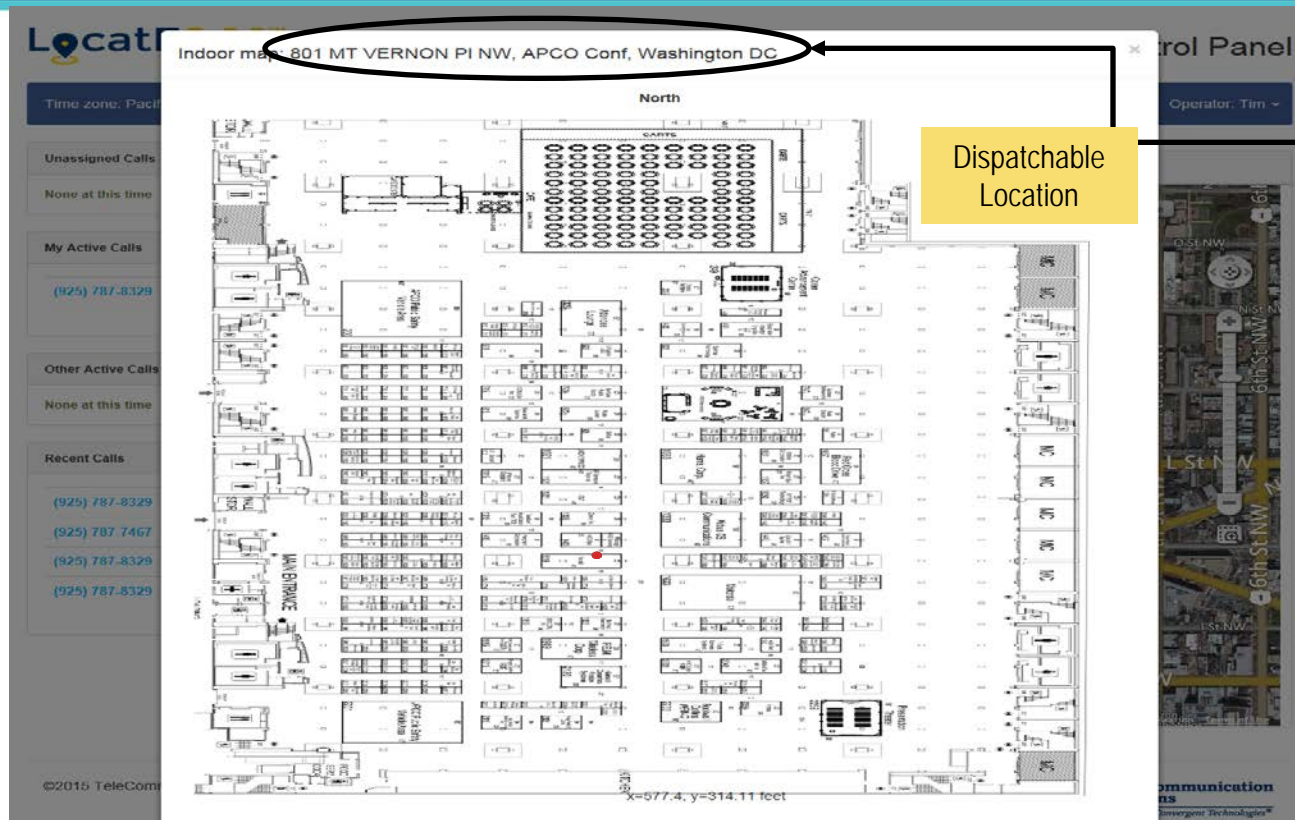


Outdoor Location Map



Satellite
Map
(Campus View)

Expanded Indoor Location View



Indoor
Map
(Expanded
View)

Multi-faceted Location – Seattle, WA

LocatE9-1-1™

SDWA Operator Control Panel

Time zone: Pacific Time (US & Canada)

Operator: Tim ▾

Unassigned Calls

None at this time

My Active Calls

(206) 450-0649 13:43 ✓

Other Active Calls

None at this time

Recent Calls

(206) 321-7809 08:50 Aug 17
 (206) 450-0649 12:52 Aug 17
 (925) 787-7467 13:23 Aug 17
 (206) 450-0649 13:30 Aug 17

End Session

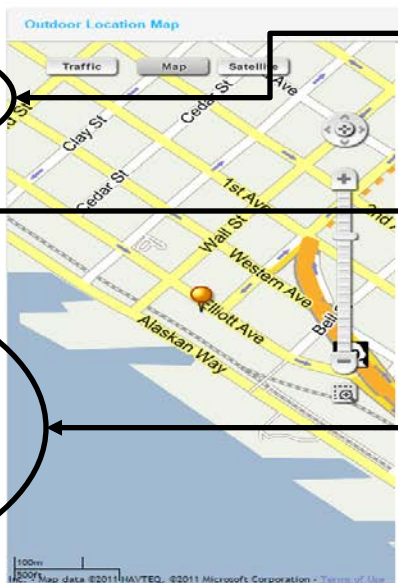
Dispatch Location

Cisco MSE

Address: 2401 Elliott Ave, Second Floor, Seattle WA
X: 86.86 feet, **Y:** 29.37 feet
Latitude: 47.6128051584 degrees,
Longitude: -122.3498916432 degrees

Show other data sources

Indoor Map



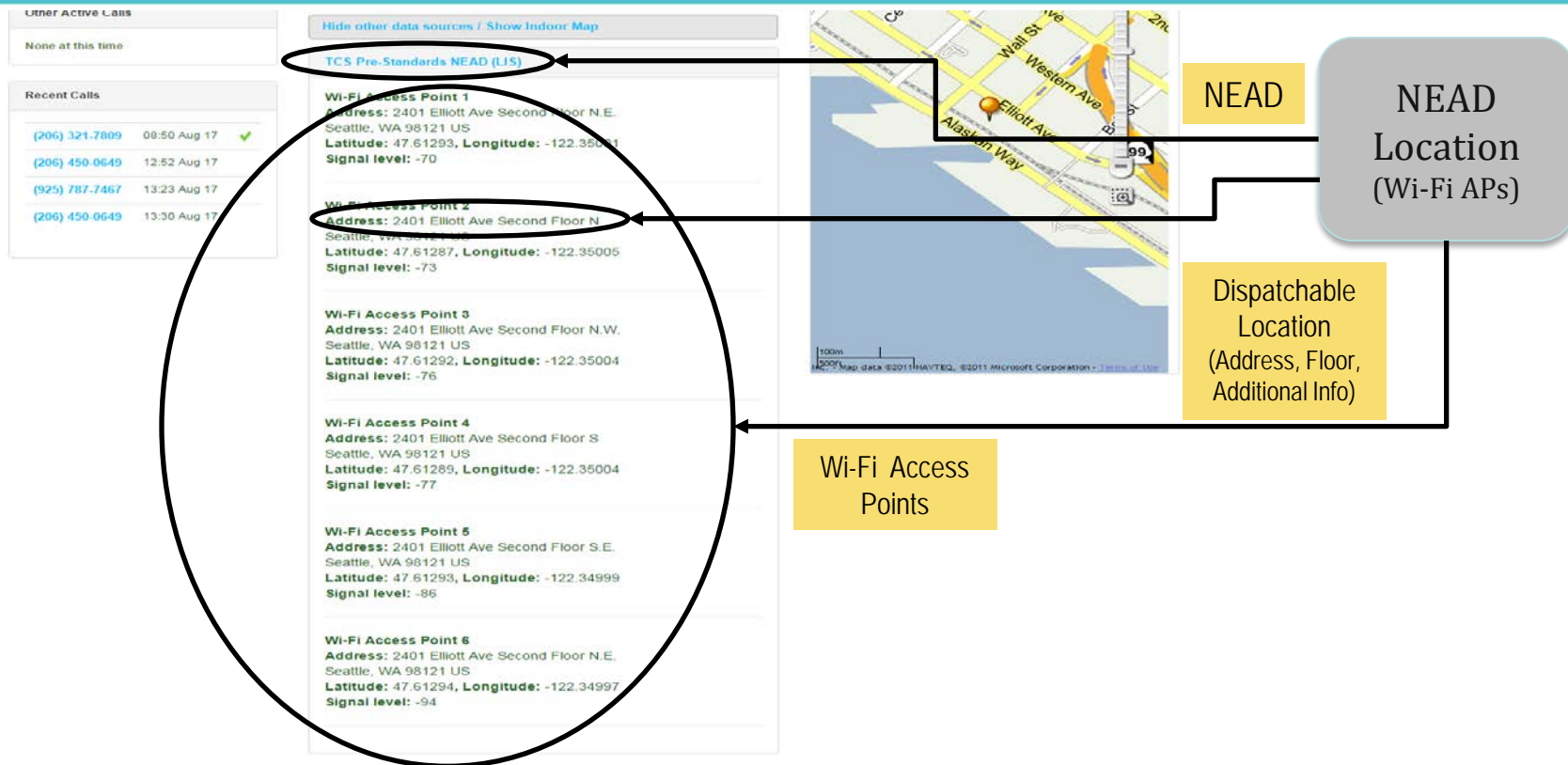
Enterprise
Location
(Indoor Map)

Dispatchable
Location

Other Data
Sources

Indoor Map

National Emergency Address Database (NEAD)



The screenshot displays the NEAD interface with the following components:

- Left Panel:**
 - Other Active Calls:** None at this time.
 - Recent Calls:**
 - (206) 321-7809 08:50 Aug 17 ✓
 - (206) 450-0649 12:52 Aug 17
 - (925) 787-7467 13:23 Aug 17
 - (206) 450-0649 13:30 Aug 17
- Main Content Area:**
 - Buttons:** Hide other data sources / Show Indoor Map
 - Section Header:** TCS Pre-Standards NEAD (LIS)
 - Wi-Fi Access Point 1:**
 - Address: 2401 Elliott Ave Second Floor N.E.
 - Seattle, WA 98121 US
 - Latitude: 47.61293, Longitude: -122.35001
 - Signal level: -70
 - Wi-Fi Access Point 2:**
 - Address: 2401 Elliott Ave Second Floor N.
 - Seattle, WA 98121 US
 - Latitude: 47.61287, Longitude: -122.35005
 - Signal level: -73
 - Wi-Fi Access Point 3:**
 - Address: 2401 Elliott Ave Second Floor N.W.
 - Seattle, WA 98121 US
 - Latitude: 47.61292, Longitude: -122.35004
 - Signal level: -76
 - Wi-Fi Access Point 4:**
 - Address: 2401 Elliott Ave Second Floor S
 - Seattle, WA 98121 US
 - Latitude: 47.61289, Longitude: -122.35004
 - Signal level: -77
 - Wi-Fi Access Point 5:**
 - Address: 2401 Elliott Ave Second Floor S.E.
 - Seattle, WA 98121 US
 - Latitude: 47.61293, Longitude: -122.34999
 - Signal level: -86
 - Wi-Fi Access Point 6:**
 - Address: 2401 Elliott Ave Second Floor N.E.
 - Seattle, WA 98121 US
 - Latitude: 47.61294, Longitude: -122.34997
 - Signal level: -94
- Map:**
 - Shows a street map of Seattle with a red pin at the location of the Wi-Fi Access Points.
 - Labels include: Wall St, Western Ave, Elliott Ave, Alaskan Way, and 99th Ave.

- Annotations:**
- A large black circle highlights the list of Wi-Fi Access Points.
- A yellow box labeled "NEAD" points to the "TCS Pre-Standards NEAD (LIS)" section header.
- A yellow box labeled "NEAD Location (Wi-Fi APs)" points to the list of access points.
- A yellow box labeled "Dispatchable Location (Address, Floor, Additional Info)" points to the address and floor information for each access point.
- A yellow box labeled "Wi-Fi Access Points" points to the list of access points.

Global Wi-Fi Services (Geodetic Location)

LocatE9-1-1™

SDWA Operator Control Panel

Time zone: Pacific Time (US & Canada) Operator: Tim

Unassigned Calls
None at this time

My Active Calls
(206) 450-0649 13:43 ✓

Other Active Calls
(925) 787-8329 13:51

Recent Calls
(206) 321-7809 08:50 Aug 17
(206) 450-0649 12:52 Aug 17
(925) 787-7467 13:23 Aug 17
(206) 450-0649 13:30 Aug 17

End Session Refresh Location

Cisco MSE

Hide other data sources / Show Indoor Map

TCS Pre-Standards NEAD (LIS)

TCS Global Wi-Fi Service

Latitude: 47.612912
Longitude: -122.350012
Source: wifi

Mobile Device

Mobile Device data on this call is unavailable
Uncompensated Barometric Pressure data for this call is unavailable

Bluetooth Device

Bluetooth Device data on this call is unavailable

Supplementary Data

Supplementary Data on this call is unavailable

Outdoor Location Map

Traffic Map Satellite

Clay St Cedar St 1st Ave 2nd Ave Western Ave Elliott Ave Alaskan Way

100m 500ft

Map data ©2011 HIA/TEQ, ©2011 Microsoft Corporation - Terms of Use

Global
Wi-Fi
Services
(Enhanced
Location)

Geodetic
Location

Other Data Sources

LocatE9-1-1™

SDWA Operator Control Panel

Time zone: Pacific Time (US & Canada) Operator: Tim ▾

Unassigned Calls

None at this time

My Active Calls

(206) 450-0649	13:43	✓
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Other Active Calls

(925) 787-8329	13:51
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Recent Calls

(206) 321-7809	08:50 Aug 17
(206) 450-0649	12:52 Aug 17
(925) 787-7467	13:23 Aug 17
(206) 450-0649	13:30 Aug 17

End Session Refresh Location

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Outdoor Location Map



Other Data Sources
(Enhanced Location)

Data from
Mobile Device

Bluetooth

Billing Data
Caller-supplied

What Can a PSAP Manager Do?

- To help with call routing:
 - Pay attention to boundaries
 - Track call transfers – if too many, change boundaries
- To help with caller location:
 - Determine a rebid policy/strategy for your center
 - Get data; look for error clusters; encourage small cell use
- To help with Indoor Location:
 - Help get addresses in the NEAD (National Emergency Address Database)
- Get GIS maps for neighboring counties!

Addressing the Location Hype

“In an era when your mobile phone can tell Facebook, Uber or even video games where you're located – with amazing accuracy – 911 operators are often left in the dark.”


USA Today; 02/22/15

- 911 location data is tested more rigorously:
 - Outdoor location testing regularly reported to FCC
 - 240M calls annually receive close scrutiny from public safety
- Commercial location not independently tested/validated
 - A-GPS (lat/lon) location was within 50m 91% of time
 - My location is outside Ritz-Carlton – in park across Ellis Street
 - Horizontal uncertainty put me within 3 buildings
 - Confidence says 95%:
 - Ground truth testing revealed closer to 61.7%
 - “Uber parks down the block from my apartment...”

Enterprise Wi-Fi® Demo

Using Cisco Mobility Service Engine
Two Floors – first multi-floor commercial demo!

Questions

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