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Location Accuracy Technologies: Today and Tomorrow

March 15th, 2016

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Vice President
Comtech TCS

Three 911 Location Challenges

1. Call Routing
2. Enhanced Location (Phase II)
3. Indoor Location

These challenges are related, but distinct

Wireless E9-1-1 Call Baseline

1: Person dials 9-1-1

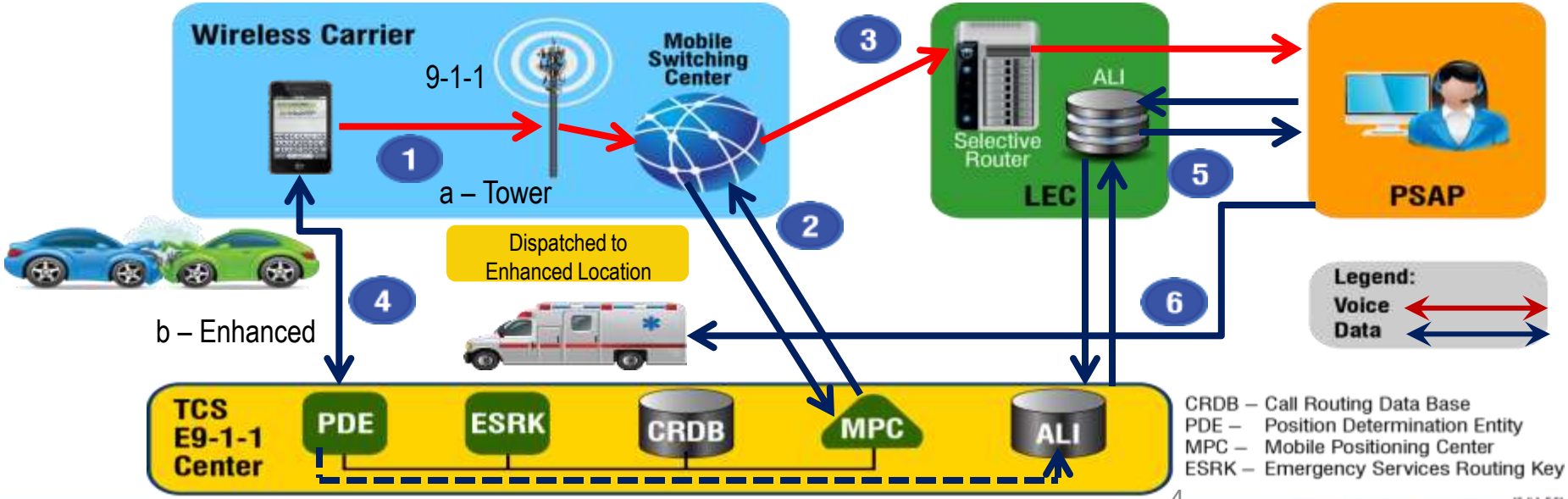
2: MSC requests routing instructions

3: MSC routes call to nearest PSAP

4: E9-1-1 Center stages enhanced location

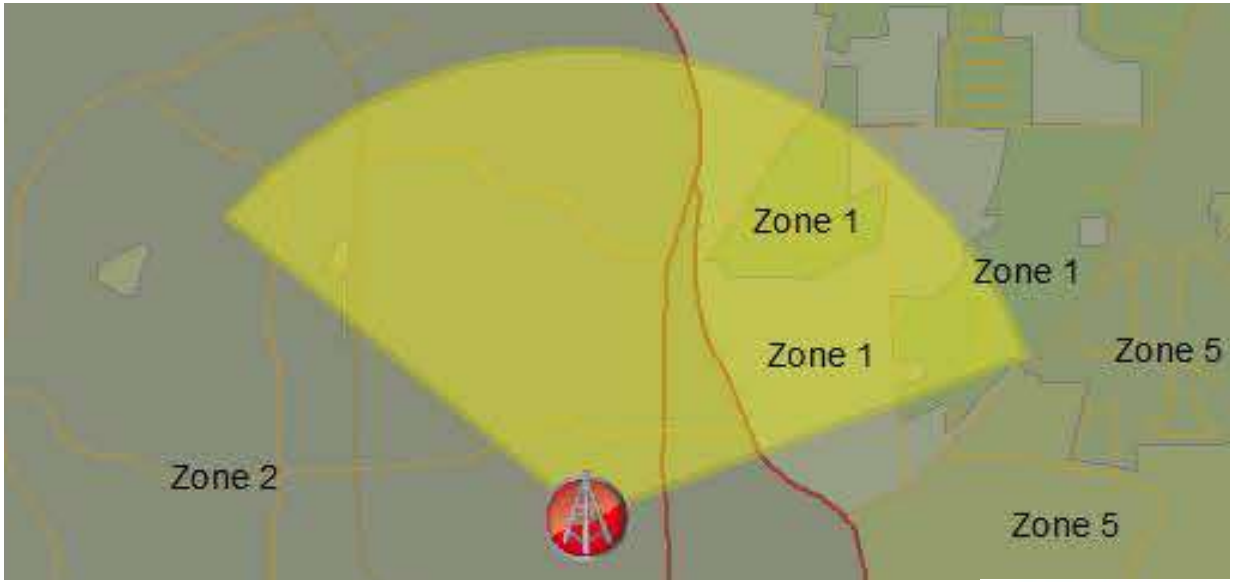
5: PSAP queries for enhanced location

6: PSAP dispatches emergency assistance



Call Routing Challenge

'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.'



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

Routes can change – test them!

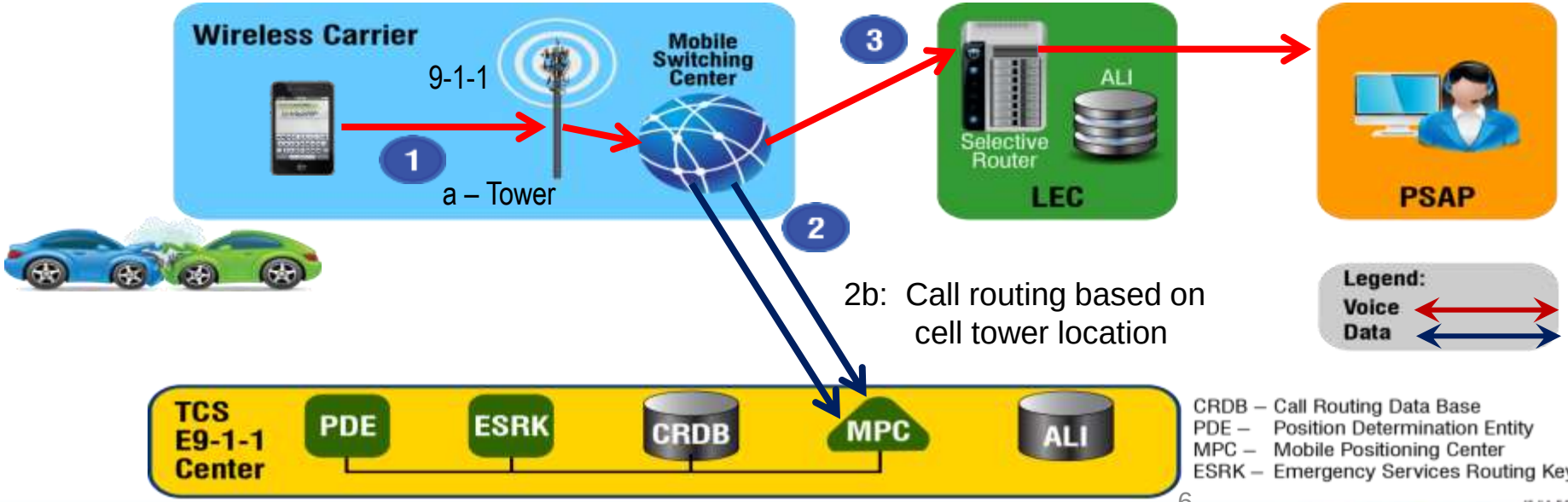
Wireless 9-1-1 Call Routing Challenge

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



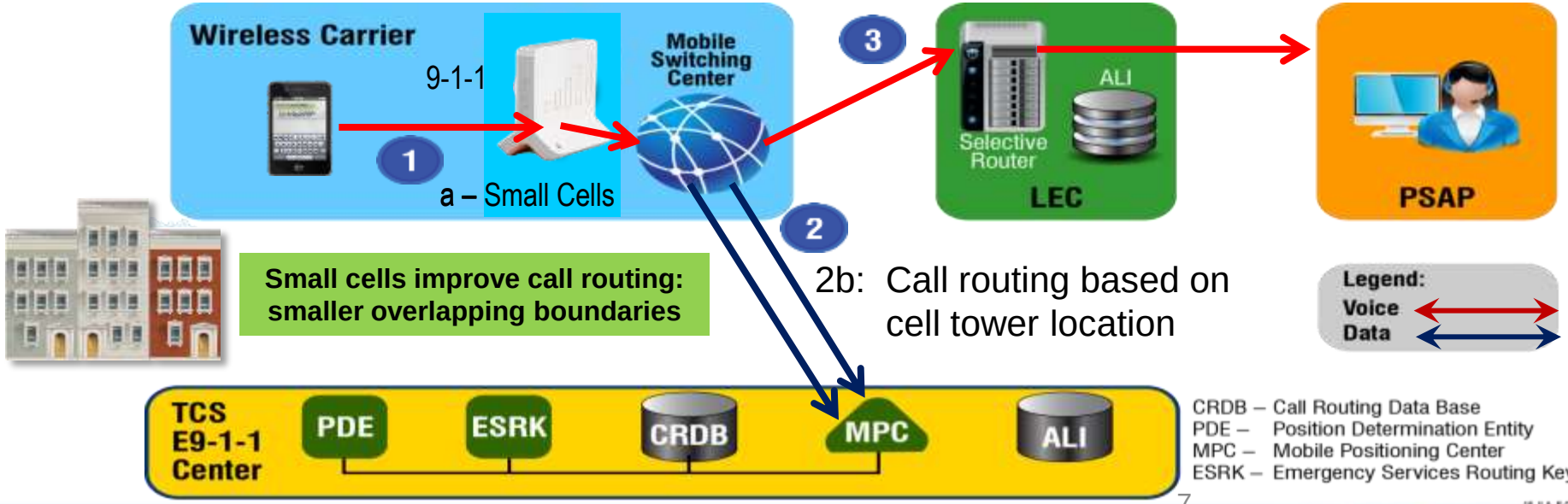
Wireless 9-1-1 Call Routing Improved

1: Person dials 9-1-1

2a: MSC requests routing instructions

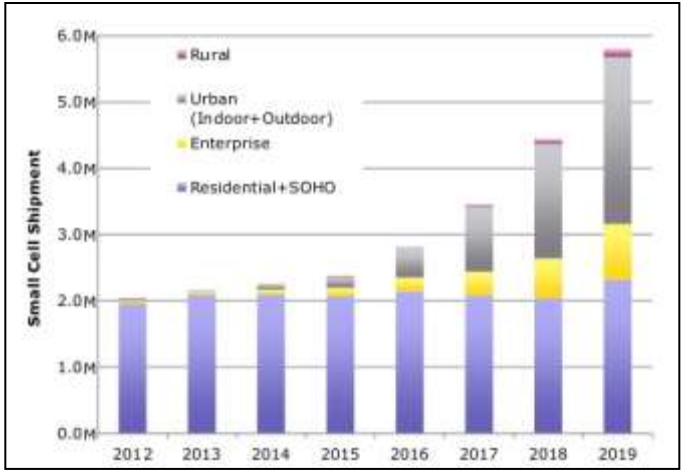
3: MSC routes call to designated PSAP

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

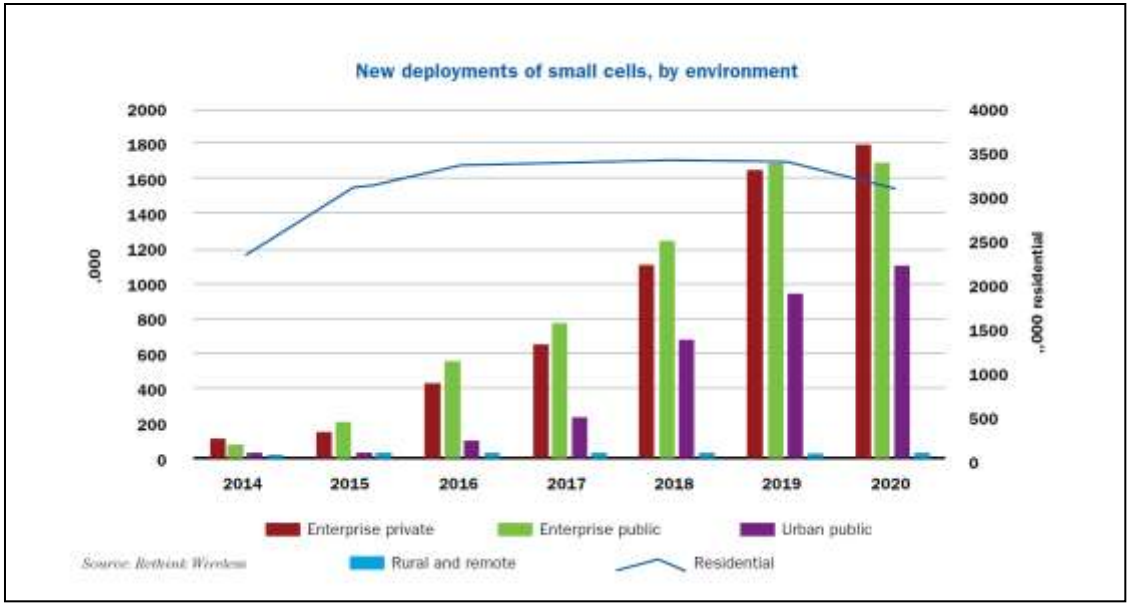


Strong Small Cell Growth

[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



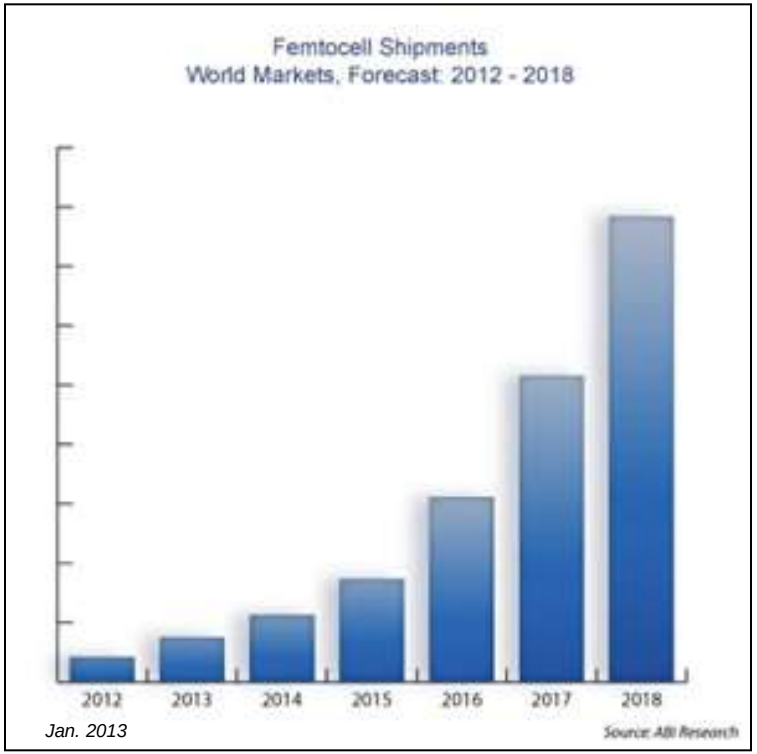
Rethink Wireless, 09/15

Strong Femtocell Growth

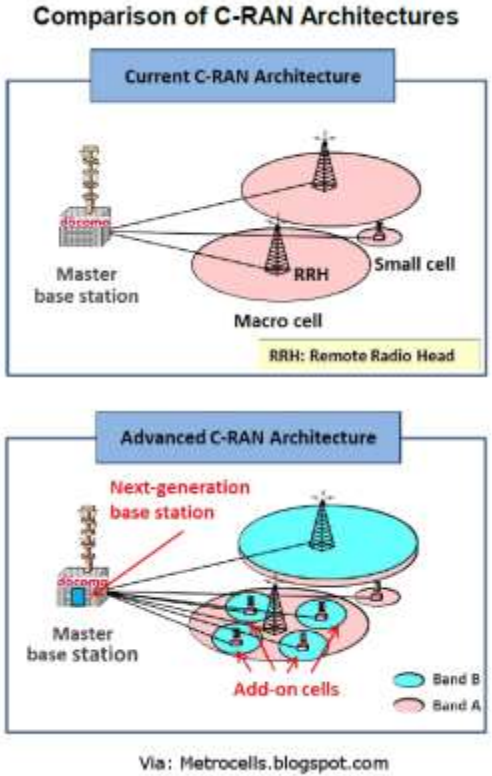
- Femtocells for home use
- Support specific users
- Generally located via GPS
- Typically associated with cell tower

Dispatchable location possible

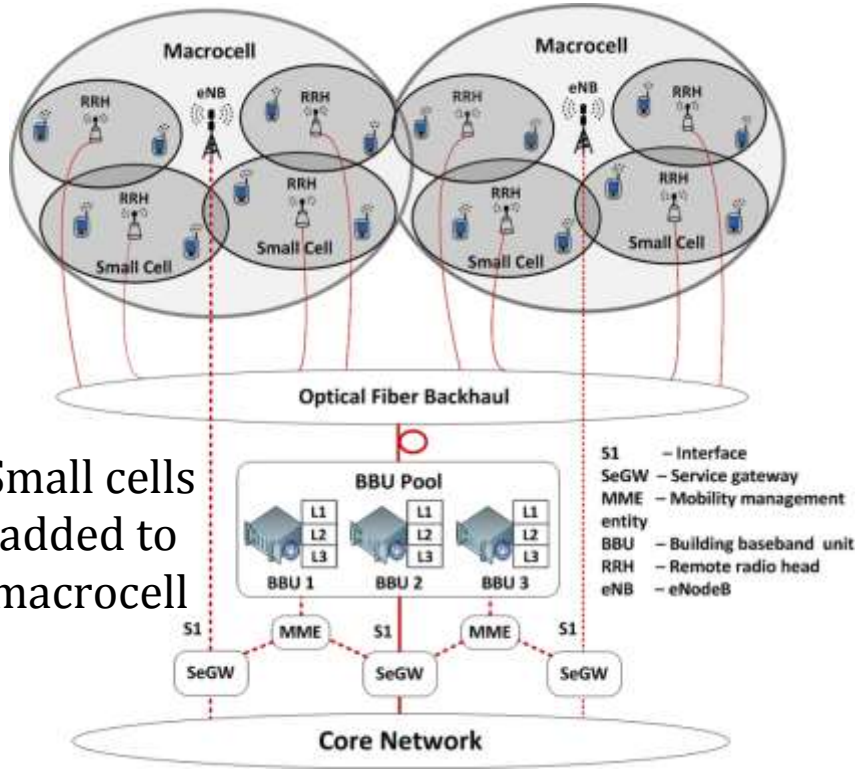
  - Follow VoIP registration process



Small Cell Worry: Cloud RAN



Small cells added to macrocell



Potential Problem: Only macrocell known

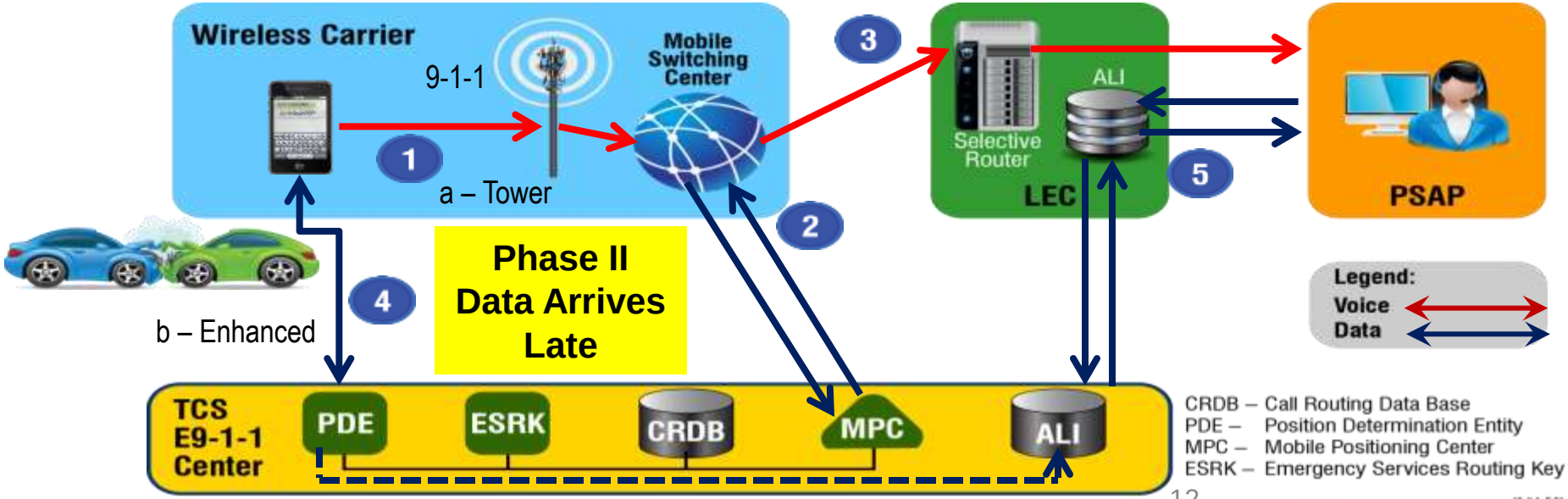
Lose benefit for 911?

Enhanced Location Challenge for Wireless 9-1-1 Calls

- Tradeoff between speed and accuracy
  - Lower accuracy solutions were fast
  - Higher accuracy solutions were slow
- This was known at the time of the FCC Phase II rules
- Sub-optimal solutions (re-bid) were suggested
- FCC focus has been on accuracy

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



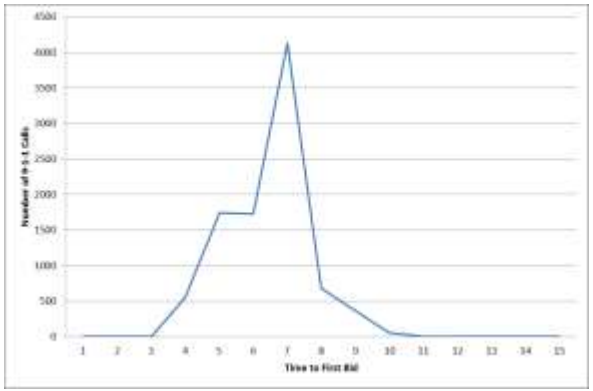
Initial Bid Timing vs. Location Fix

Washington DC
May, 2013
Single carrier

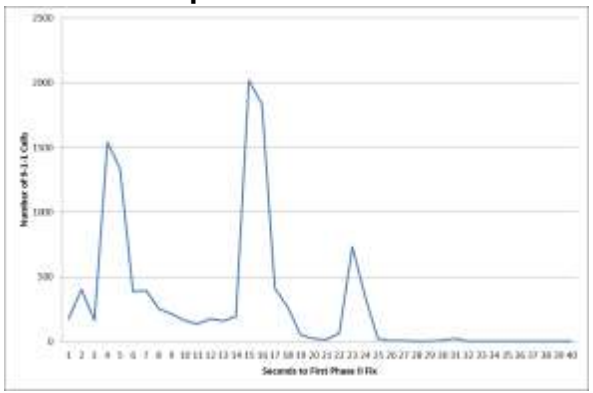
11,585 calls
10,812 bids
6.7% abandoned

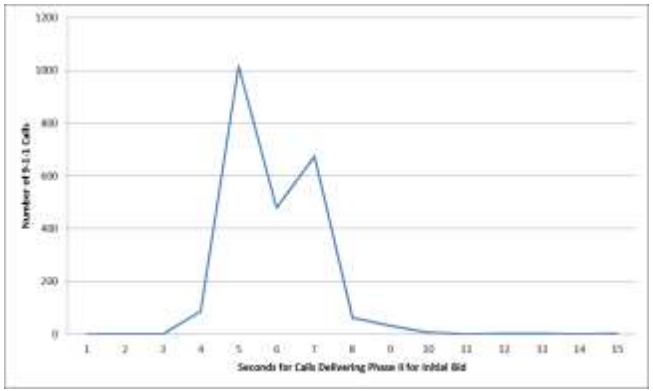
Phase II Initial Bids: 2588
23.9%

Initial Bid generally <8 sec



…but location fixes can take up to 24 seconds





Importance of Location Rebids

- 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

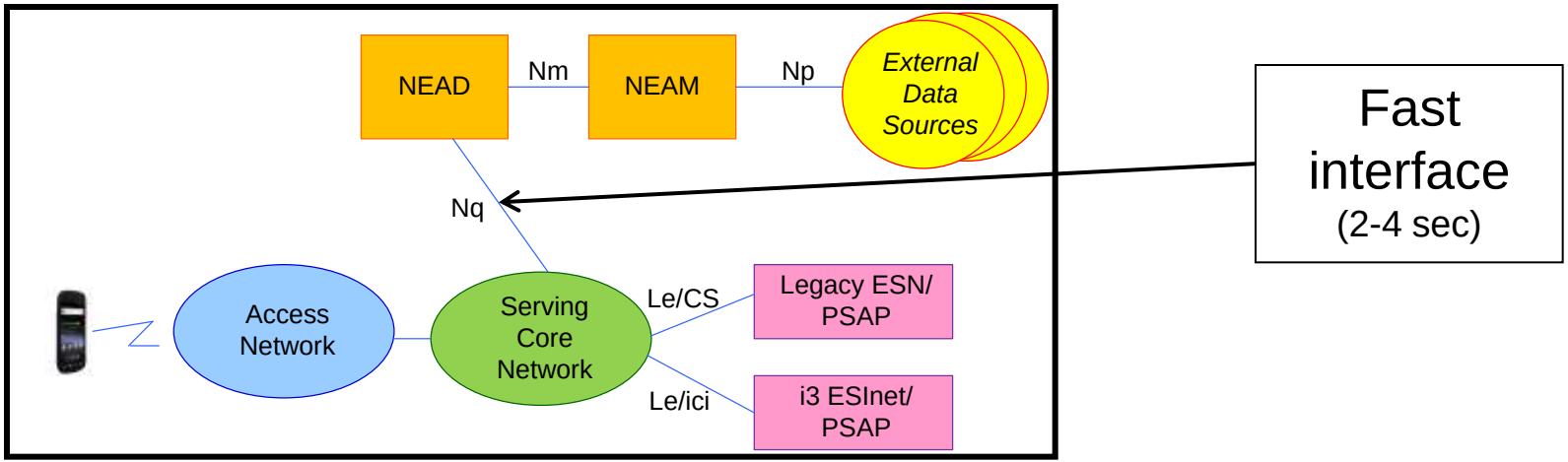
75.4%	Phase I
0.7%	Poor Phase II
21.8%	Phase II A-GPS
2.1%	Phase II AFLT

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	

Improving Enhanced Location Speed

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



NG9-1-1: Push Rather Than Pull

NG9-1-1 brings two benefits to improving location

1. Location data is pushed rather than pulled
   - No need for re-bid strategy
   - Location information can be presented as it becomes available

1. 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

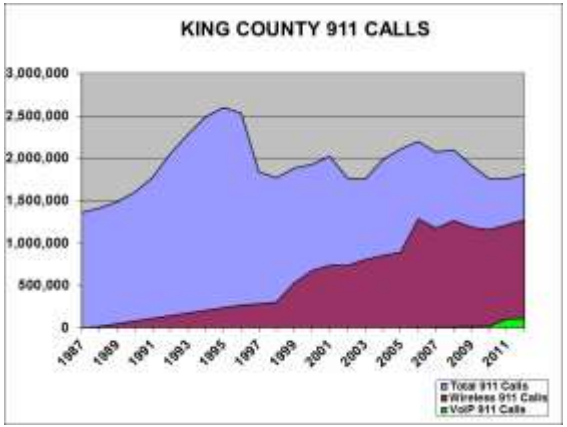
- Evidence of a Problem
  - Statistics tell a story
  - Analyzing real-world 9-1-1 data
  - Long-term 9-1-1 data comparison
  - 9-1-1 data trending
  - Comparing urban/suburban to dense urban

Statistics Tell a Story

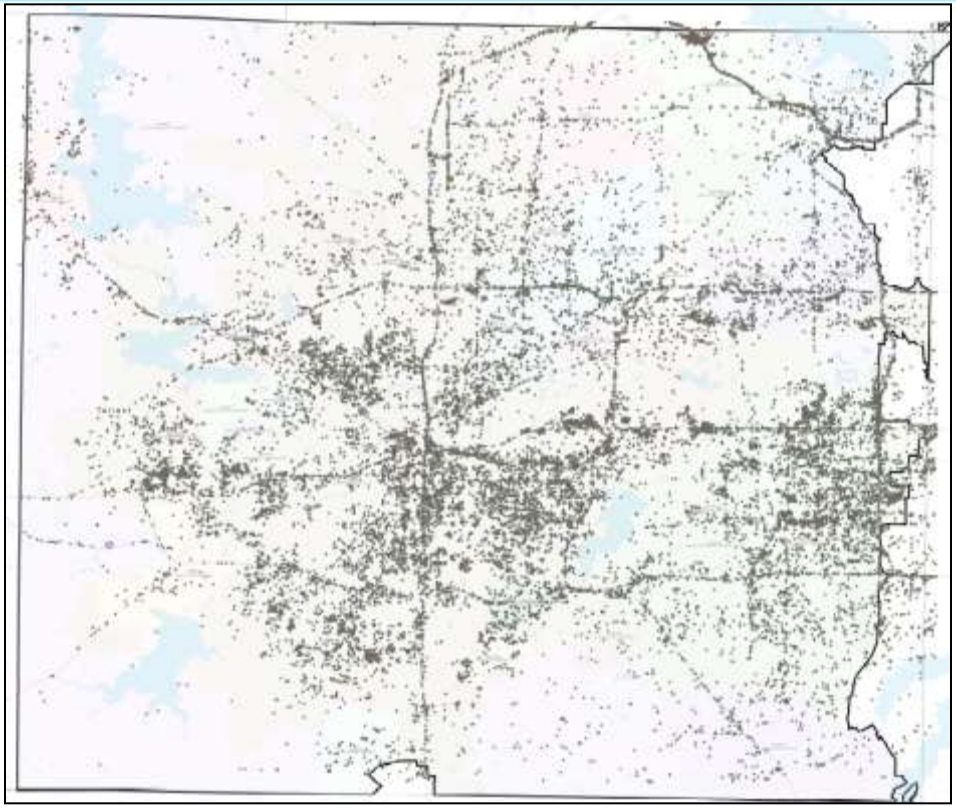
We "should" have an Indoor Location challenge

- 40% of US population has "cut the cord"
  - 2013 CDC study (37% of adults; 45% of children)

- 70% of 9-1-1 calls come from wireless
  - 2012 King County, WA statistic



Real-world 9-1-1 Call Analysis

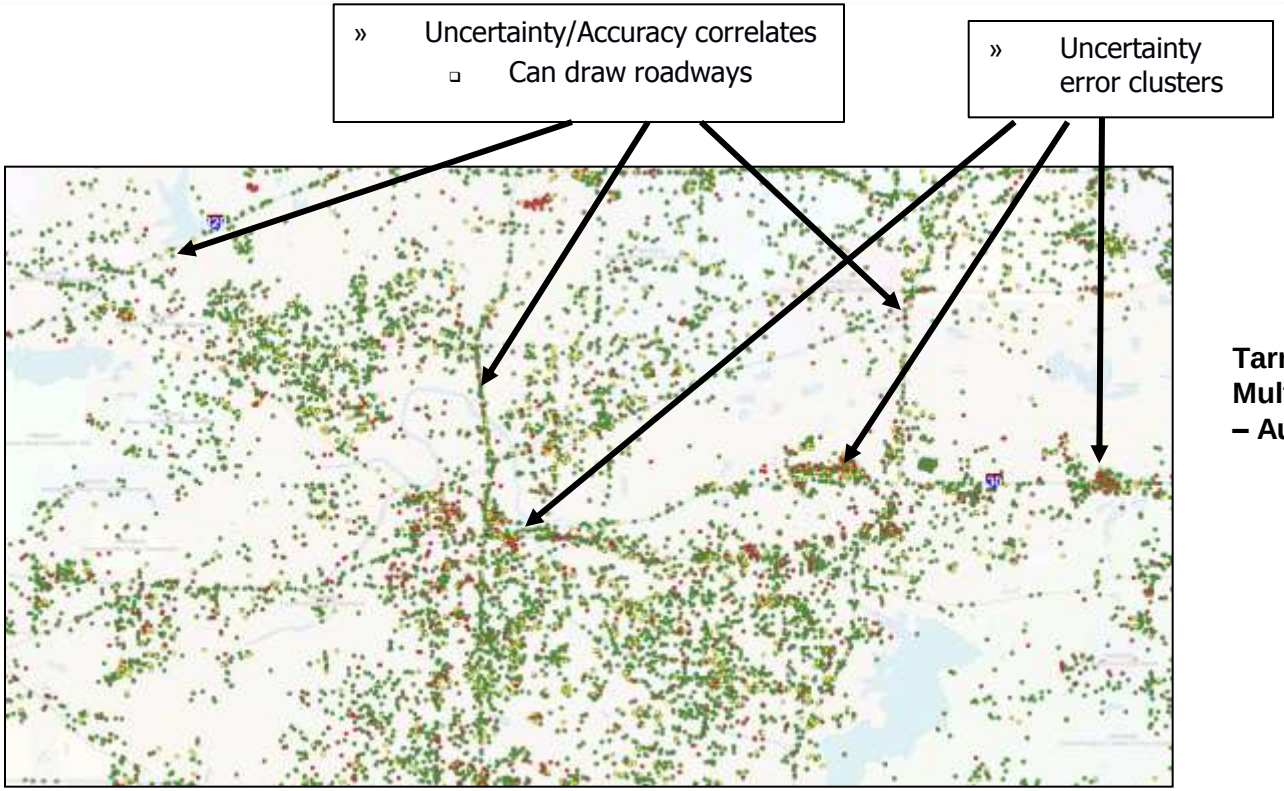


- Actual 911 calls
- Tarrant County
- All carriers
- August, 2013

Color-code X/Y locations (using HUNC)
Brown = Phase I only
Green = meets stricter requirement.
Red = misses looser requirement.
Yellow = between strict/loose

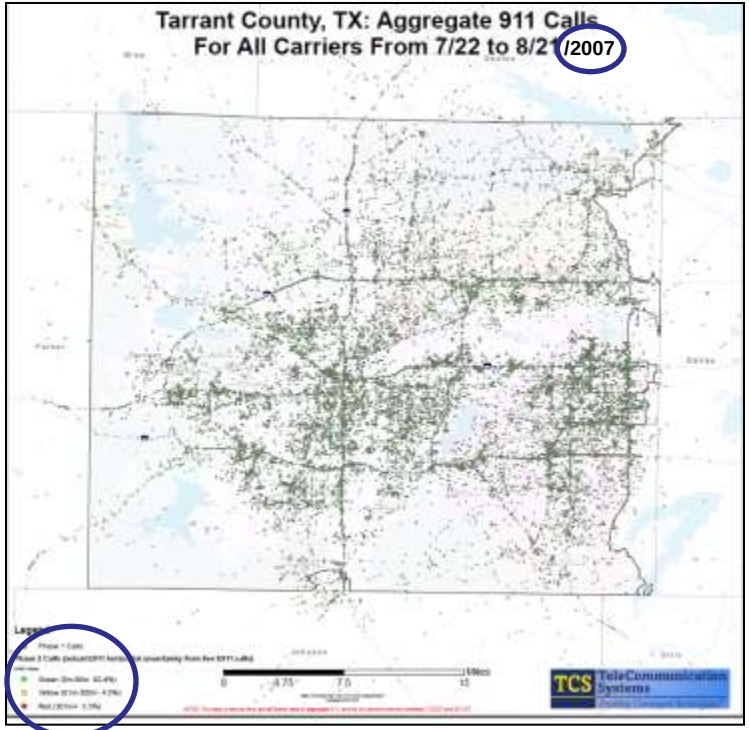
Which are Indoors?
Which are Outdoors?

Uncertainty Tells a Story

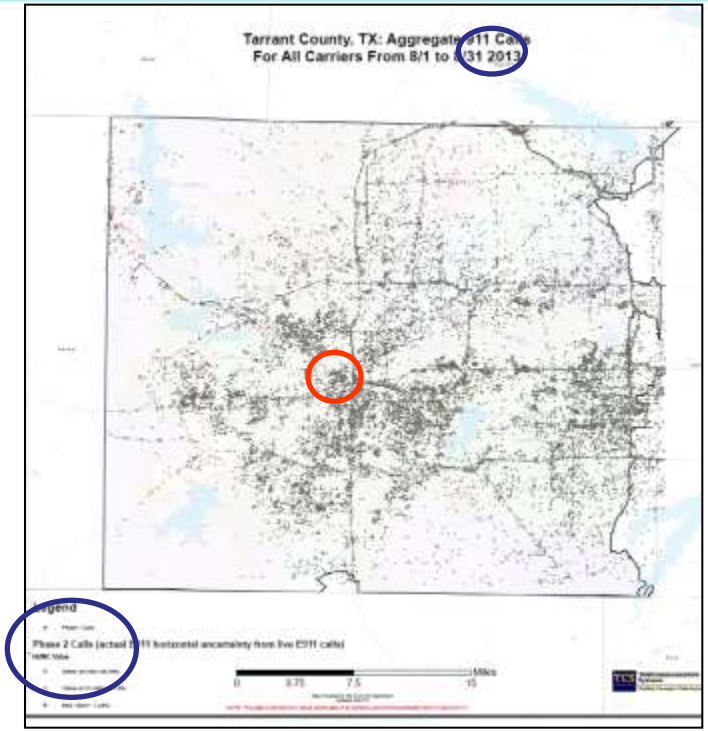


Tarrant County, TX – Multiple wireless carriers – August, 2013 data

Location HUNC Getting Worse



3.3% exceeded Phase II upper bound (red)

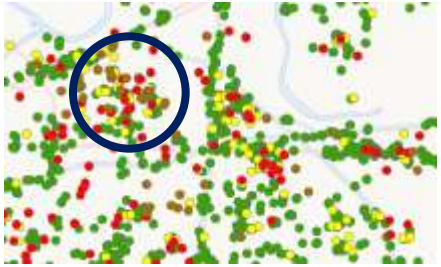


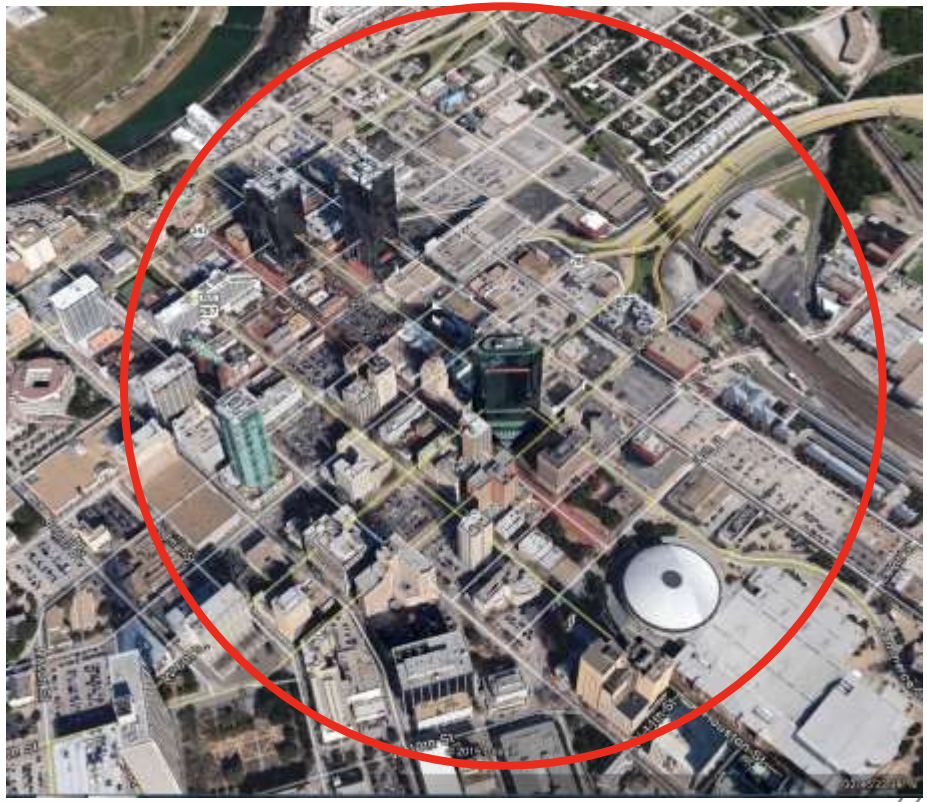
7.5% exceeded Phase II upper bound (red)

3.3% → 7.5%

(More calls from indoor locations?)

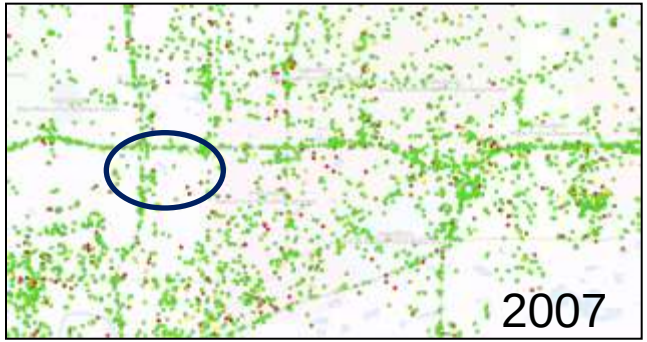
The Maps Tell a Story



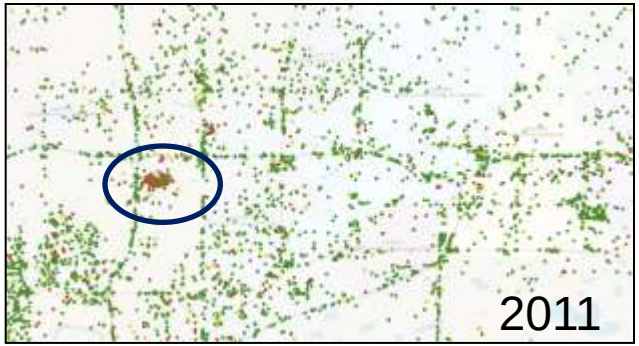


Tarrant County, TX
9-1-1 Calls –
August, 2013

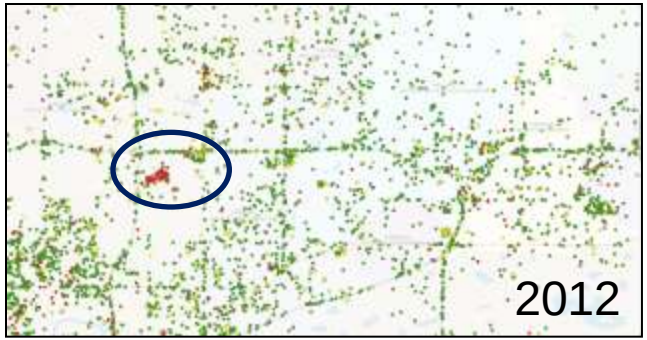
Data Trends Tell a Story



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

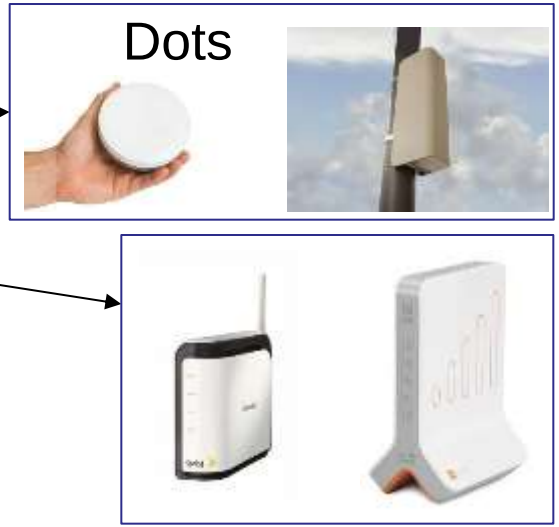
- Baltimore 9-1-1 calls (Nov, 2014)
- Tarrant County 9-1-1 calls (Aug, 2013)

	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

Solutions in Progress

- Today's Solutions:
  - Small cells
  - Femtocells
  - Using A-GPS (yes, it can work indoors…depending on conditions)



A-GPS and Indoors

Legend

- True Location
- Motorola
- Sanyo

Royal Institute of Navigation
The Journal of Navigation
July, 2011 Vol. 64 No. 3
pp. 381-399

NO. 3 POSITIONAL ACCURACY OF ASSISTED GPS 395

Table 3. Horizontal error statistics for static indoor tests.

Unit Type	GPS Type	Sample Size	% GS Fixes	Horizontal Error Statistics (meters) Min	Max	Avg	50th	68th	95th	RMSE
Motorola	Assisted	478	99·8	0·74	90·69	15·16	9·78	15·15	47·90	21·64
Sanyo	Assisted	1513	99·9	0·16	32·04	8·78	6·23	9·33	24·44	11·33
Garmin	Autonomous	319	17·7	0·41	23·22	9·11	7·62	10·03	20·86	10·61
Juno	Autonomous	1800	100·0	0·35	18·94	5·10	4·02	5·64	12·86	6·16

In the **static indoor test**, mobile phones and GPS units were placed in very close proximity on top of a regular wooden desk on the **second floor of a two-story residential structure**. The second floor of the structure consisted of a **wood frame with cement stucco** while the **roof consisted of a wood frame with asphalt shingles**. While GPS signal reception within this structure is possible (even without using a high-sensitivity chipset), the reception was severely affected by the building materials, resulting in lower expected accuracy.

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

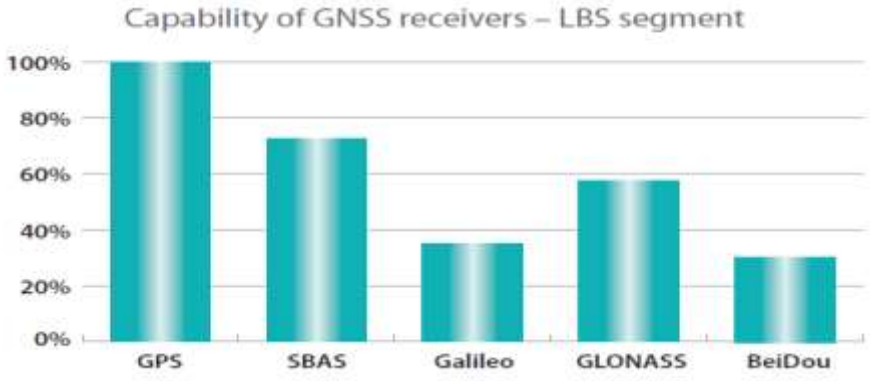
Combining satellite systems is expected to double precision: better, faster fixes, potentially reaching deeper indoors

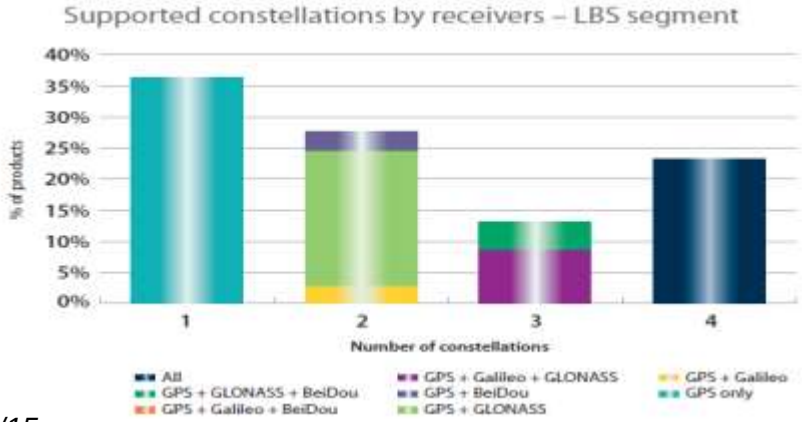
A-GPS is Improving: GLONASS

- 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
  - ✓ Location accuracy improved in navigation tests in city environments
  - ✓ Tests showed that time-to-fix was improved

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





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

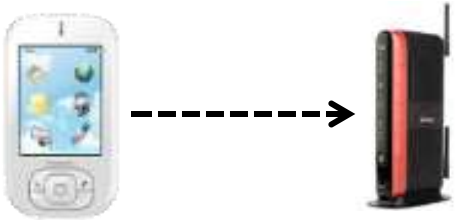
Constellation	GPS	GPS + Glonass
Visible Satellite*	4.4	7.8
No Fix	380 minutes	Never
HDOP*	5.3	2.1
Error*	x meter	(x* 0.4) meter

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

2.5x accuracy improvement

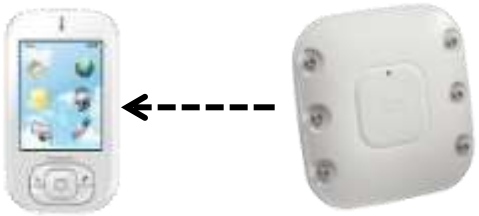
Solution: Wi-Fi Indoor Location

- 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

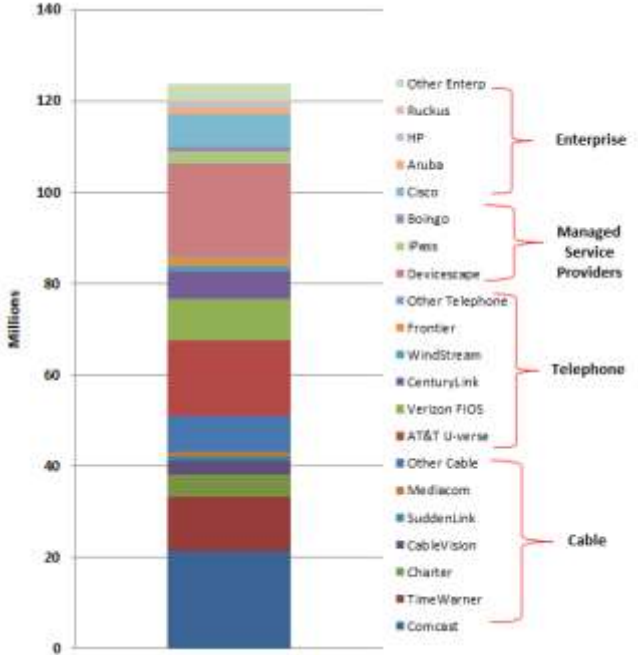


Wi-Fi AP detects smartphone
- Smartphone presents its MAC ID
- AP measure signal strength
- Multiple APs can triangulate the smartphone
- AP system presents info to location server

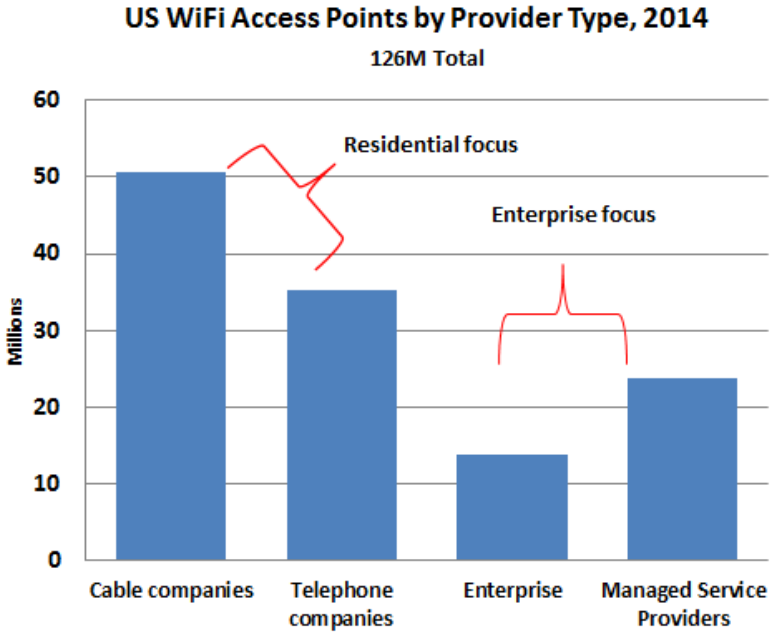
Enterprise Wi-Fi Location

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

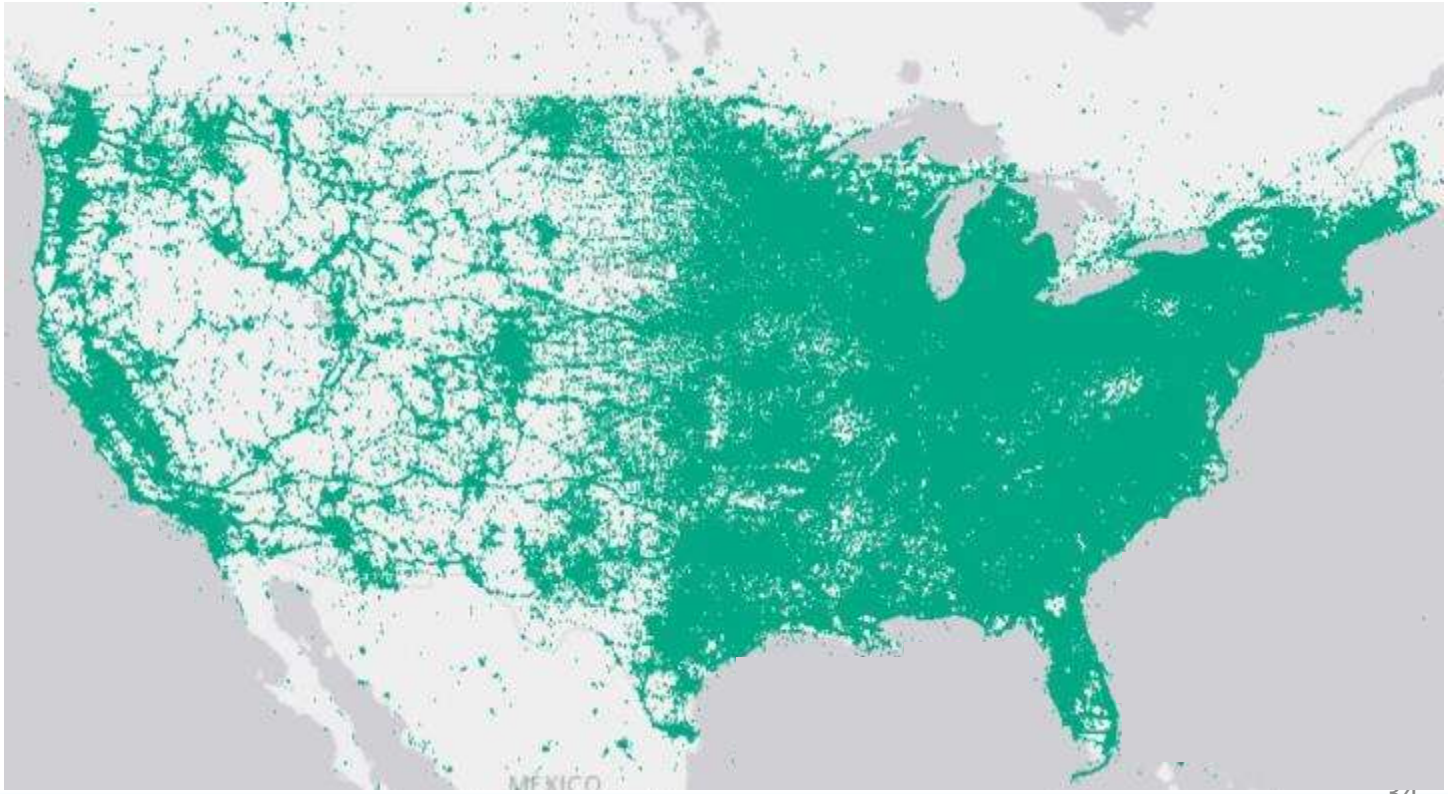


Wi-Fi Access Points by Provider, 2014



Source: company information and ABI Research, 2014

Comtech TCS
Wi-Fi Access Point Database



149M Access Points

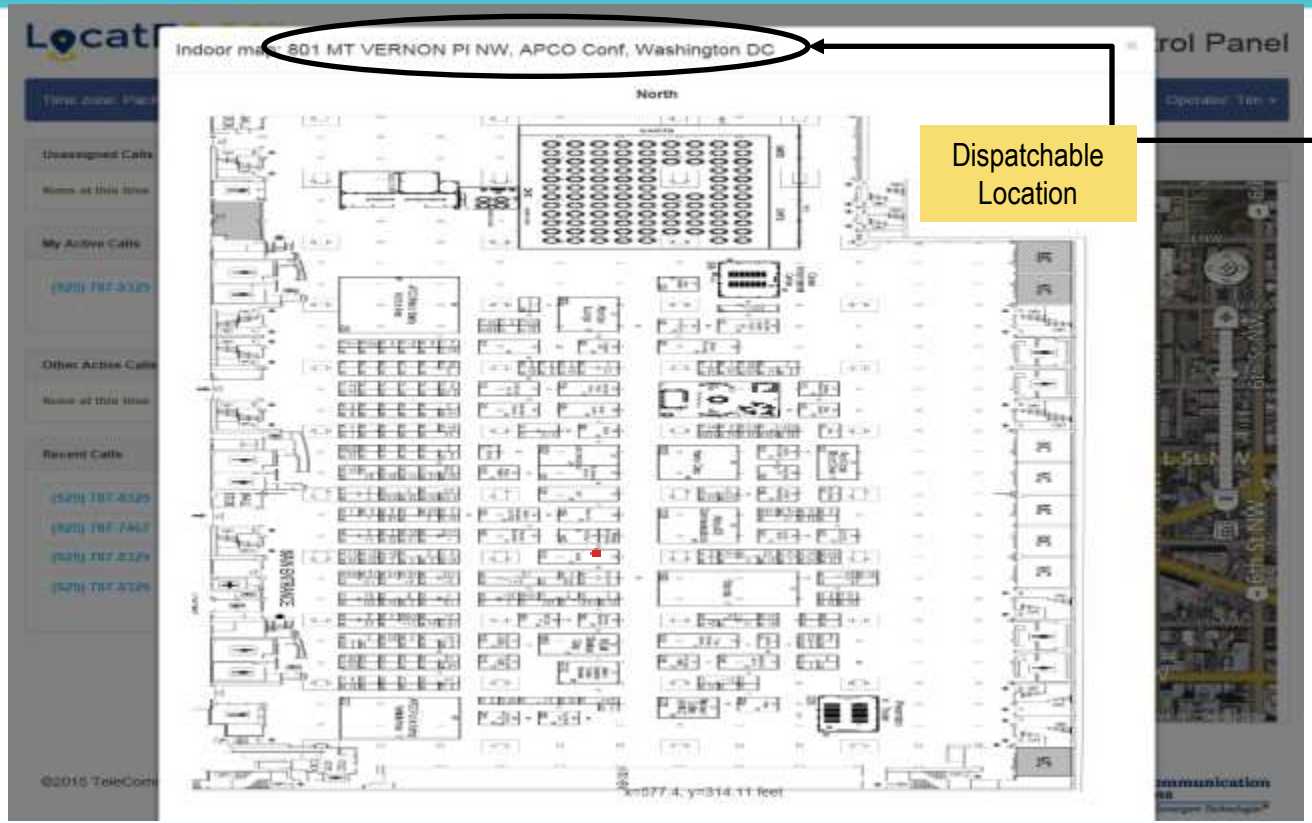
Wi-Fi coverage exists
and it maps to population

Enterprise Indoor Location – Washington DC

Satellite Overlay for Campus View

Satellite Map (Campus View)

Expanded Indoor Location View



Multi-faceted Location: Seattle

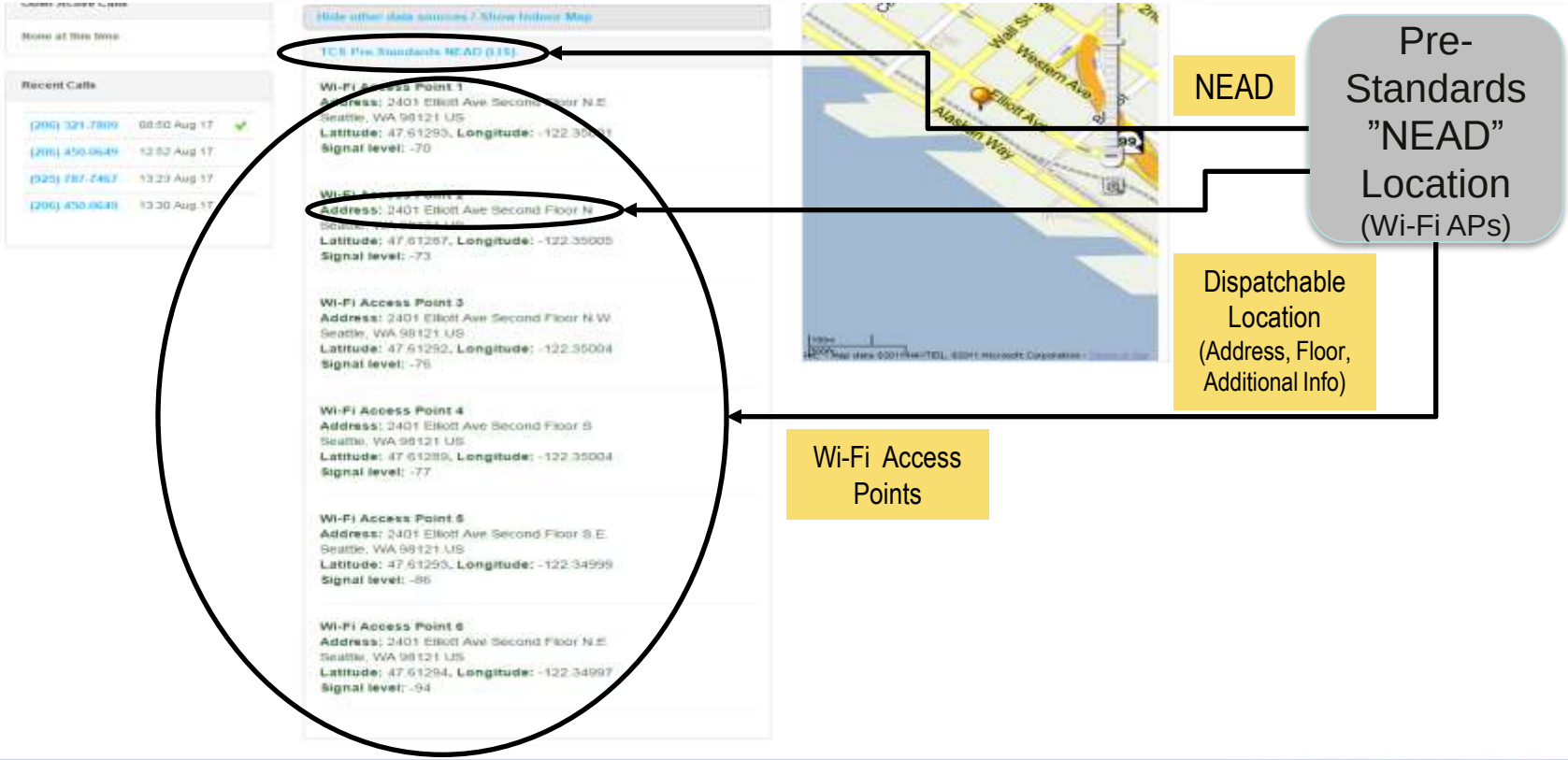
Enterprise Location (Indoor Map)

Dispatchable Location

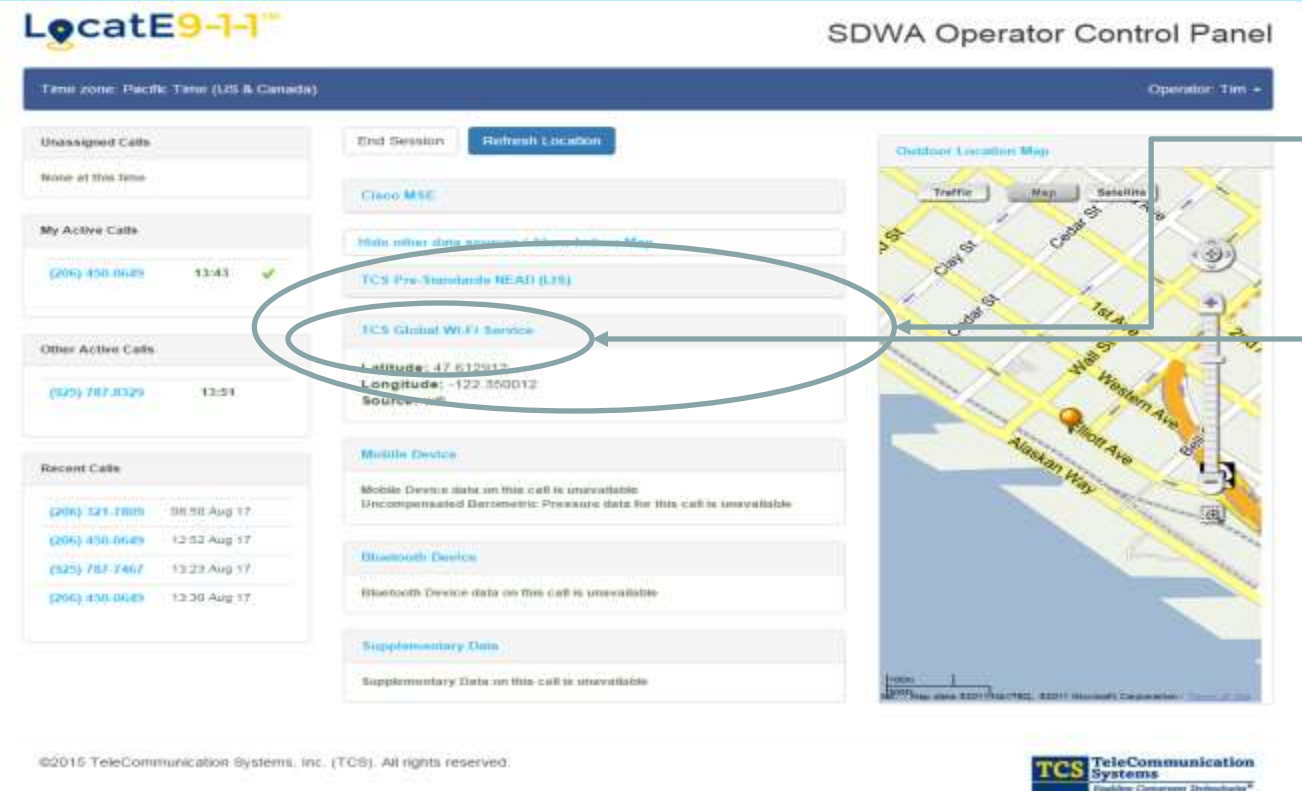
Other Data Sources

Indoor Map

National Emergency Address Database (NEAD)



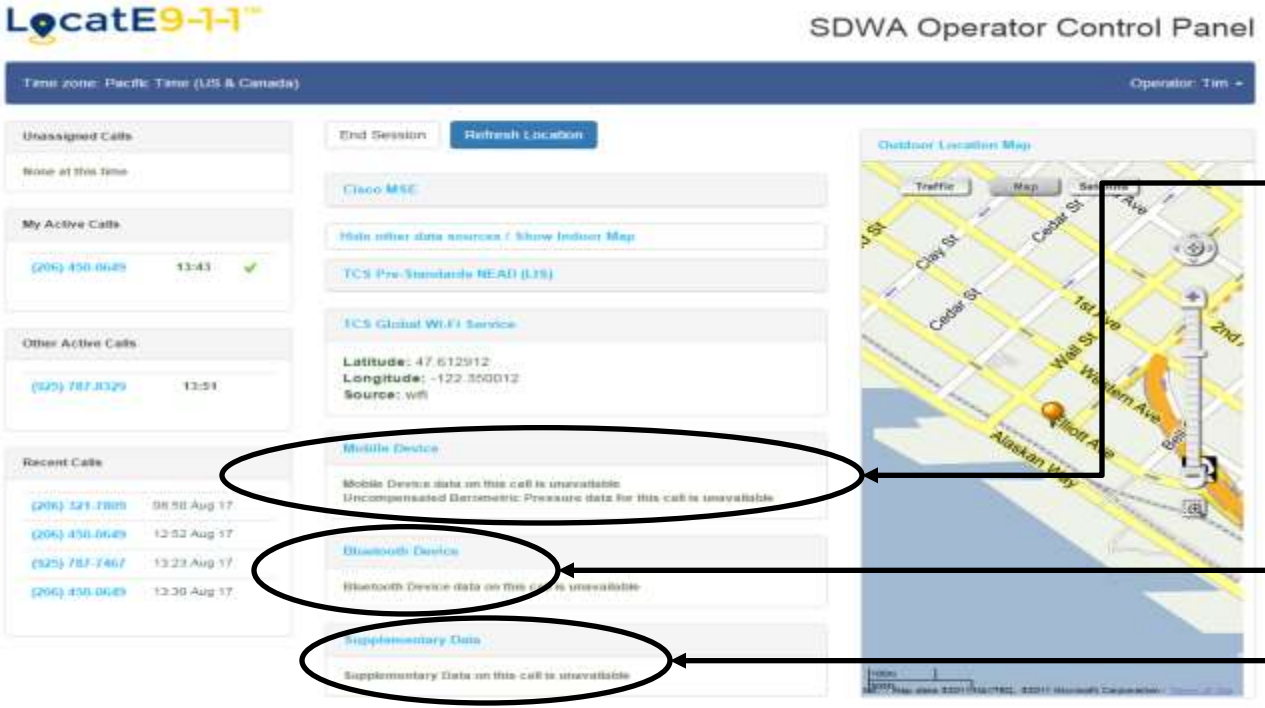
Comtech TCS Global Wi-Fi Service (Geodetic Location)



Global Wi-Fi Service (Enhanced Location)

Geodetic Location

Other Data Sources



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!

“They Can Send a Man to the Moon”

“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

Commercial Apps Have Problems Too

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

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