Location Accuracy Technologies: Today and Tomorrow

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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

2b: Call routing based on cell tower location
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

Small cells improve call routing: smaller overlapping boundaries

2b: Call routing based on cell tower location
The Macquarie analysts estimated that there are about 40,000 small cells deployed in the United States today.

FierceWireless 1/13/15

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

Jan. 2013
Small Cell Worry: Cloud RAN

Potential Problem: Only macrocell known

Lose benefit for 911?

Small cells added to macrocell
• 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

Phase II Data Arrives Late

Legend:
Voice
Data

TCS E9-1-1 Center
PDE
ESRK
CRDB
MPC
ALI

Legend:
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

Initial Bid generally <8 sec
11,585 calls
10,812 bids
6.7% abandoned

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

Phase II Initial Bids: 2588
23.9%
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

<table>
<thead>
<tr>
<th>Phase</th>
<th>Initial Bid Percentage</th>
<th>After 30 Seconds Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>75.4%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Poor Phase II</td>
<td>0.7%</td>
<td>1.7%</td>
</tr>
<tr>
<td>Phase II A-GPS</td>
<td>21.8%</td>
<td>73.2%</td>
</tr>
<tr>
<td>Phase II AFLT</td>
<td>2.1%</td>
<td>13.9%</td>
</tr>
</tbody>
</table>
1. Small cells = Phase I more precise than Phase II
2. Speeding up the location fix:
   National Emergency Address Database (NEAD)

Fast interface (2-4 sec)
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
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?
Tarrant County, TX – August, 2013 data

Uncertainty Tells a Story

» Uncertainty/Accuracy correlates
  - Can draw roadways

» Uncertainty error clusters

Tarrant County, TX – Multiple wireless carriers – August, 2013 data
Location HUNC Getting Worse

3.3%→7.5%
(More calls from indoor locations?)
Problem area seen in 2011

Goodrich Warehouse
Built in 2007

Data Trends Tell a Story
Dense Urban Tells a Story

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

<table>
<thead>
<tr>
<th></th>
<th>Tarrant County</th>
<th>Baltimore</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUNC &lt;= 50m</td>
<td>80.4%</td>
<td>45.3%</td>
</tr>
<tr>
<td>HUNC 50m&lt;--&gt;150m</td>
<td>12.1%</td>
<td>11.2%</td>
</tr>
<tr>
<td>HUNC &gt; 150m</td>
<td>7.5%</td>
<td>43.5%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0%</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

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.
• Today’s Solutions:
  – Small cells
  – Femtocells
  – Using A-GPS (yes, it can work indoors...depending on conditions)
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
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
“GPS + GLONASS: Using the Best of Both Worlds”

- 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

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 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**

<table>
<thead>
<tr>
<th>Constellation</th>
<th>GPS</th>
<th>GPS + Glonass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible Satellite*</td>
<td>4.4</td>
<td>7.8</td>
</tr>
<tr>
<td>No Fix</td>
<td>380 minutes</td>
<td>Never</td>
</tr>
<tr>
<td>HDOP*</td>
<td>5.3</td>
<td>2.1</td>
</tr>
<tr>
<td>Error*</td>
<td>x meter</td>
<td>(x* 0.4) meter</td>
</tr>
</tbody>
</table>

**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
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 Availability in the U.S.

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

Indoor Location

Indoor Map

SDWA Operator Control Panel

Enterprise Wi-Fi AP Controllers

Dispatchable Location

Indoor Location

Locate9-1-1

SDWA Operator Control Panel

Time zone: Pacific Time (US & Canada)

Unassigned Calls

Home at this time

My Active Calls

(925) 767-8329  04:56

Other Active Calls

Home at this time

Recent Calls.

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March 15-16, 2016 • Kansas City, MO
Satellite Overlay for Campus View
Expanded Indoor Location View

Indoor Map (Expanded View)

Dispatchable Location

Indoor map: 801 MT VERNON PL NW, APCO Conf, Washington DC
Multi-faceted Location: Seattle
National Emergency Address Database (NEAD)

Pre-Standards ”NEAD” Location (Wi-Fi APs)

Dispatchable Location (Address, Floor, Additional Info)

Wi-Fi Access Points

NEAD
Comtech TCS Global Wi-Fi Service (Geodetic Location)

Global Wi-Fi Service (Enhanced Location)

Geodetic Location
Other Data Sources

- Bluetooth Data from Mobile Device
- Data from Caller-supplied
- Billing Data

Other Data Sources (Enhanced Location)
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!
“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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