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Field Tests of Hybrid Wireless Location Technologies

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Outline

- Motivation for Hybrid Approaches
  - Network Versus Handset Based Technologies
- Wireless Location Signatures (WLS)
  - Technology Description
  - Performance (Urban, Suburban, Indoors)
- Proposed Hybrid Solution
  - Combination of WLS and GPS/A-GPS
- Test Bed Field Trial Results
- Conclusions

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Motivation for Hybrid Approaches

- No single location technology performs well in all environments
- Network based technologies – WLS, TDOA, AOA
  - Accuracy based on terrestrial radio network
  - Accuracy good in high cell density, urban and suburban areas
  - Potentially good indoor performance
  - Not as accurate in sparse rural and rural highway
    - Low cell density, poor geometry
- Handset based technologies – A-GPS, GPS
  - Accuracy determined by satellite radio network
  - Extremely accurate in open sky, suburban and rural
  - Marginal indoor performance (see A. Sage, Helios Tech, EENA'04)
  - Not as accurate in urban and indoors
    - Multipath, poor geometry, lack of satellite visibility

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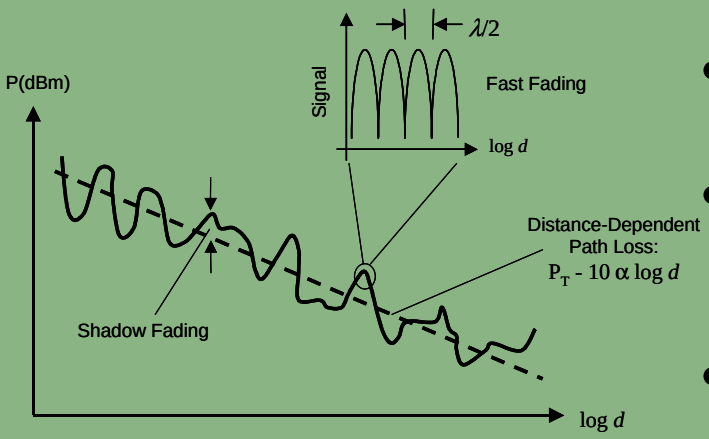
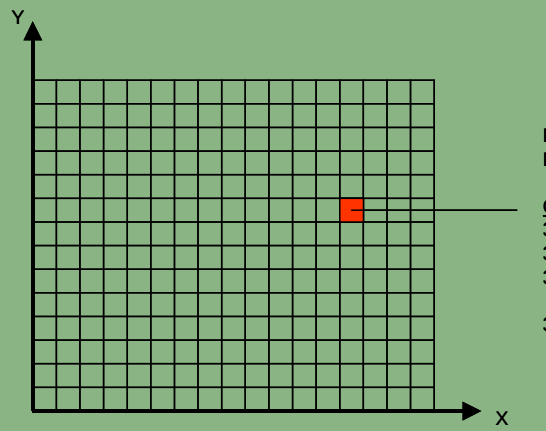
Wireless Location Signatures (WLS)





Predicted Signal Strengths
For a Single Grid Square:

Chan	RSSI
301	-57
302	-69
303	-95
:	:
320	-111

- **Network-based, no changes to RF network hardware or handsets**
- **Every location has a unique radio signature**
  - **Based on signal strengths, C/I ratios, cell identifications, time delays, network quality, etc.**
- **Handsets automatically report this information to network (GSM NMR, TDMA MAHO, CDMA PSMM/PDM)**
  - **Normally used for handovers, but WLS uses this data for location estimation**
- **WLS pattern matches against geographical database of radio environment**
  - **Statistical algorithms estimate handset location**
  - **Markov models account for motion during window**

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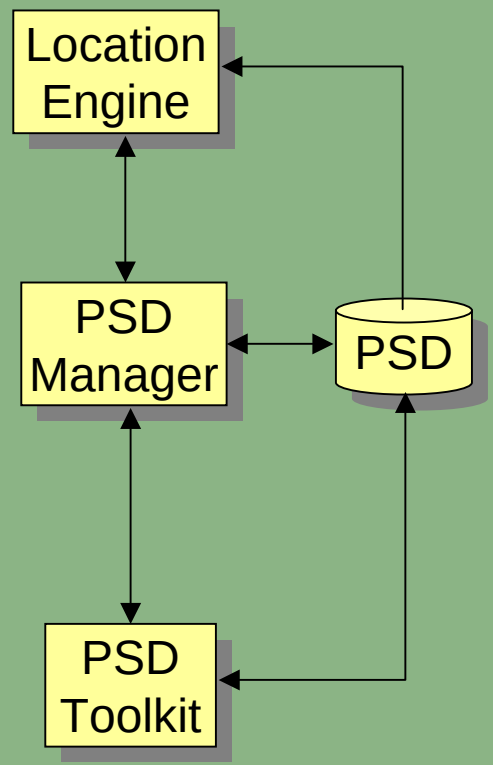
WLS System Components

- **Location Engine**
  - Process location estimation requests from network
  - Determine handset position estimate
- **Predicted Signature Database PSD Manager**
  - Automatically update PSD for RF network changes
  - Track & alarm for PSD & network anomalies
- **PSD Toolkit**
  - Provision PSD (GIS data, parameters, etc.)
  - Maintain Location System accuracy
    - Manage PSD for network changes & anomalies
  - Test Location System accuracy off-line
    - Batch location estimation processing
    - Produce performance statistics



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Urban Test Bed San Francisco, CA

1.9 GHz

GSM

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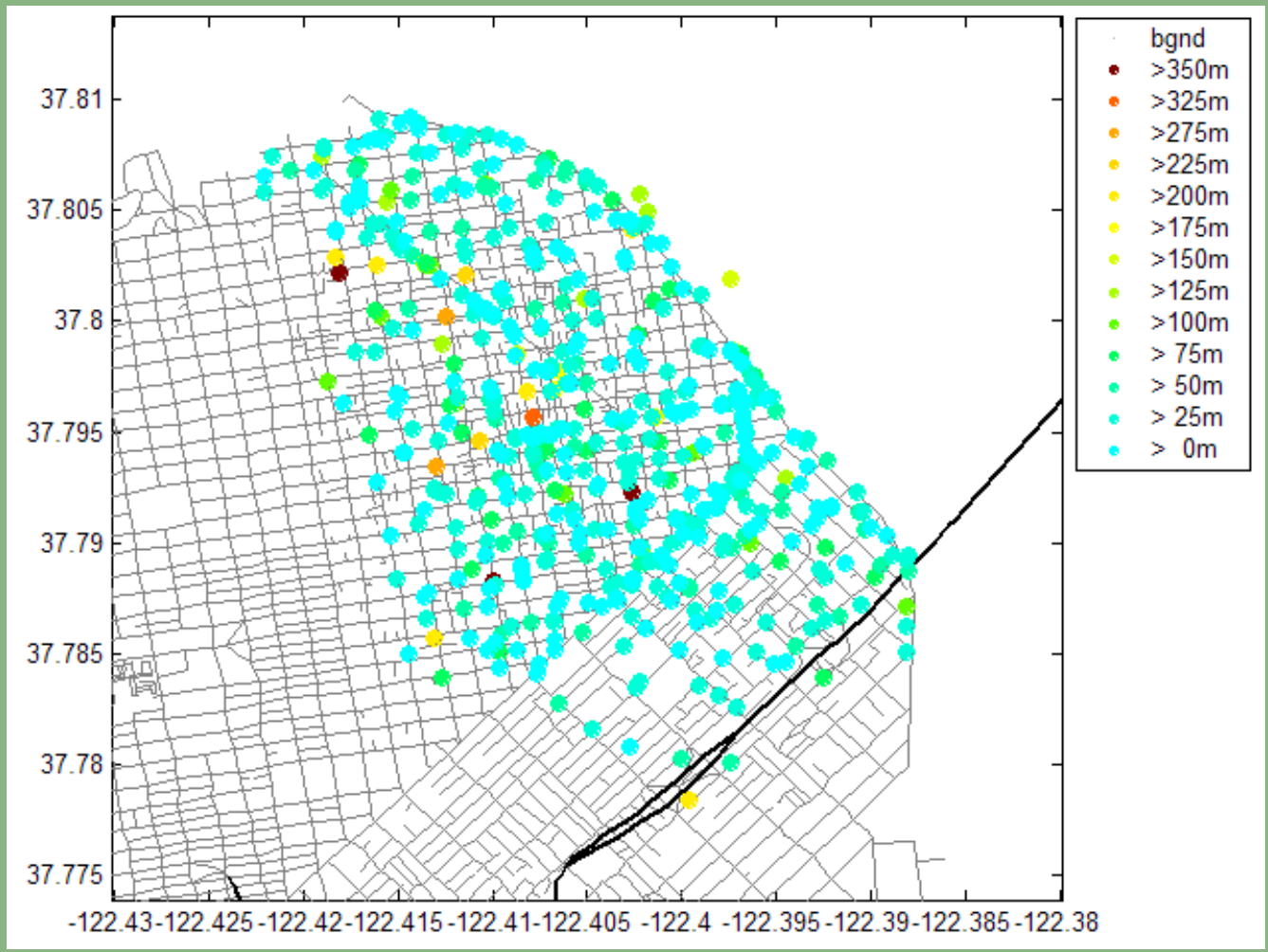
WLS Accuracy in Urban Test Bed



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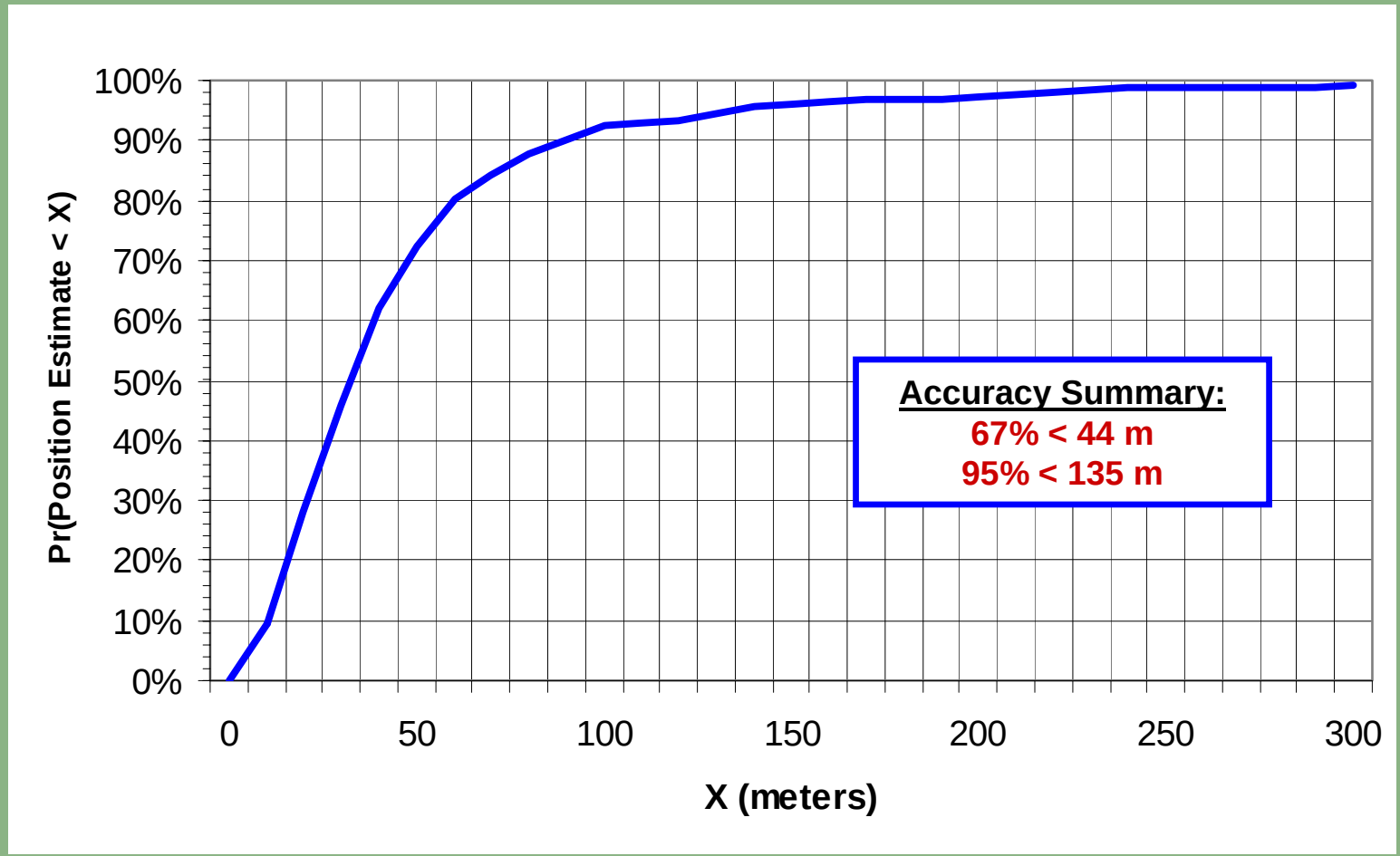
WLS Accuracy in Urban Test Bed



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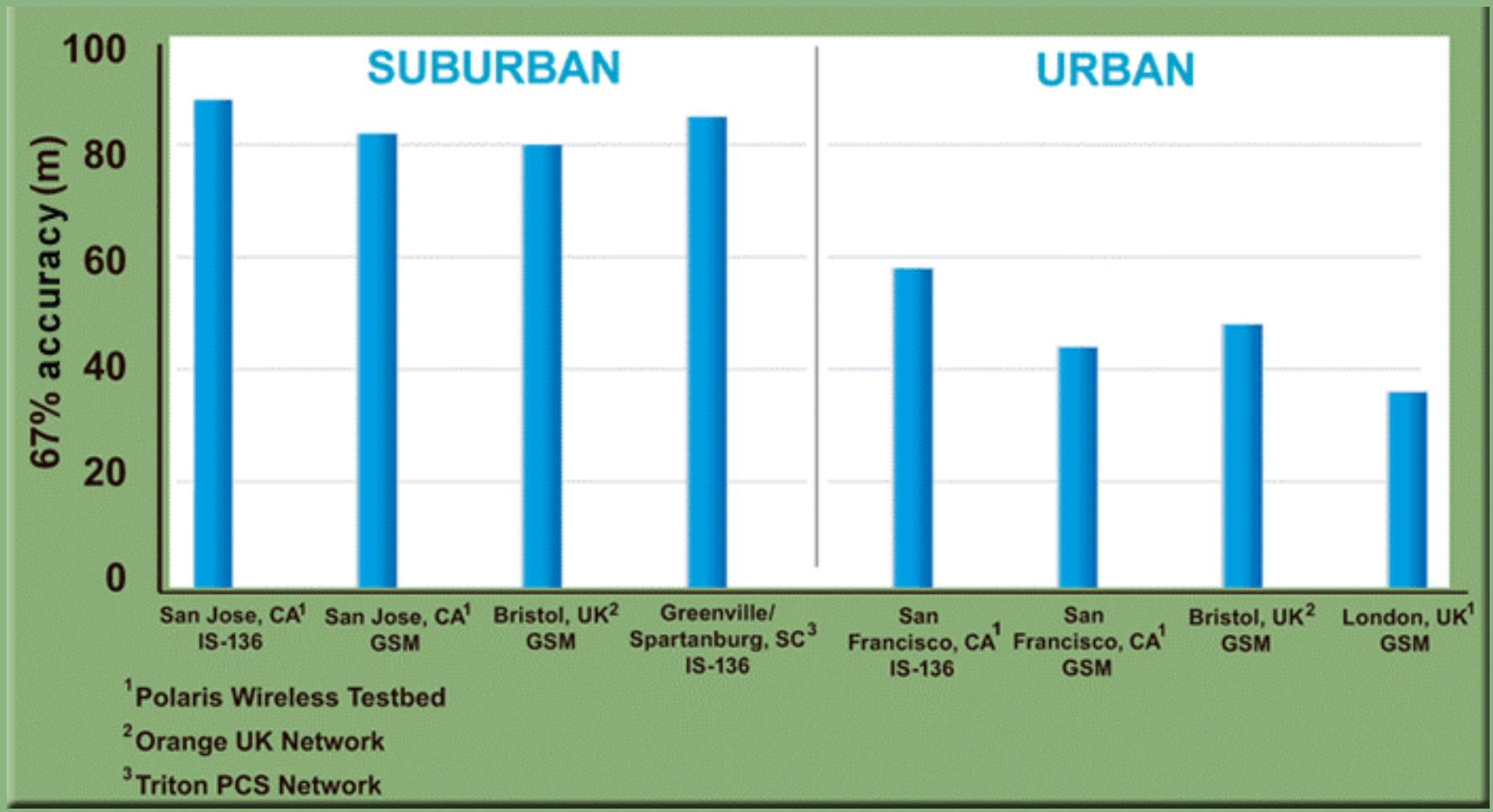
WLS Accuracy Overall Summary



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Indoor Test Bed Atlanta, GA

Georgia Tech

850 MHz

TDMA IS-136

8 sectors
3 base stations
Inside test area

+ 6 base stations
Outside test area

400-500 m cell radii

23 buildings measured

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WLS Accuracy in Indoor Test Bed

	Probability Error < 100 m	Probability Error < 300 m
Georgia Tech (see J. Zhu, G. Durgin, *Electronics Letters*, Jan. 6, 2005, Vol. 41, No. 1)	62%	96%
Polaris Wireless WLS Proprietary Location Algorithm	80%	97%

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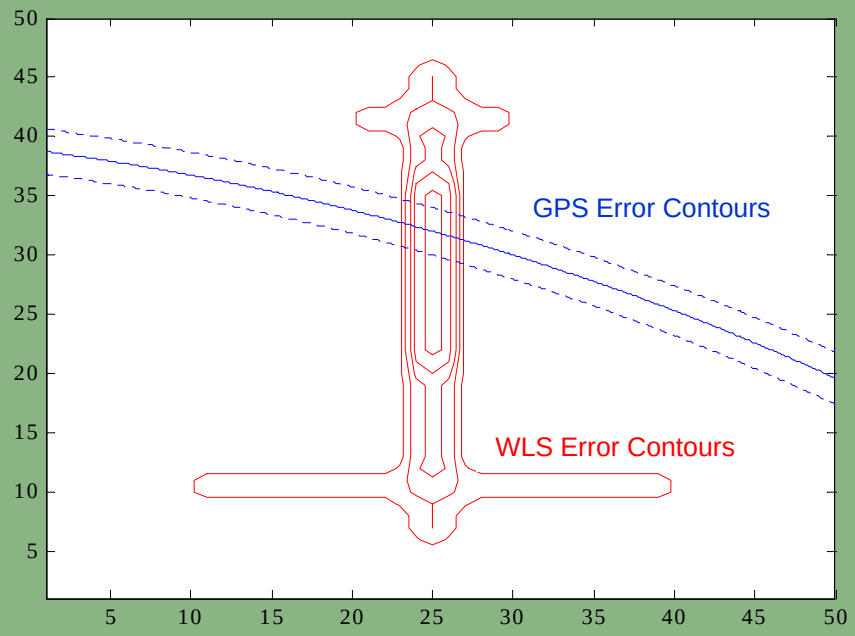
Hybrid WLS & GPS/A-GPS

- **WLS and GPS/A-GPS are complementary**
- **Combine using selection or true joint estimation**



Satellite Visibility	Position Calculation
0-1 Satellites	Use *WLS* Location Estimate
2 Satellites	Use Joint Estimate
> 2 Satellites	Use Joint Estimate If GPS in Bad Geometry or Multipath

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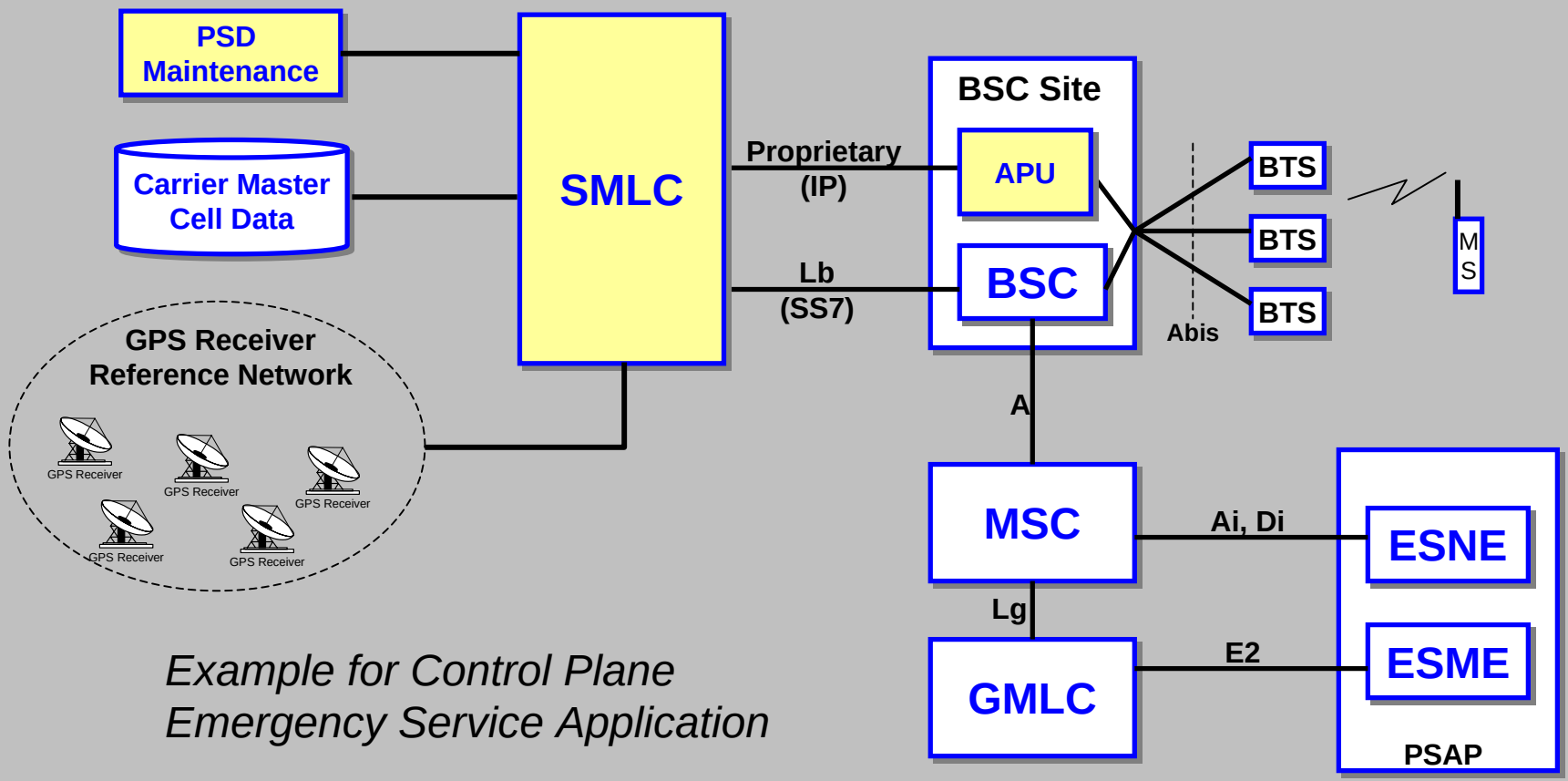
Hybrid WLS & A-GPS GSM Architecture



Example for Control Plane Emergency Service Application

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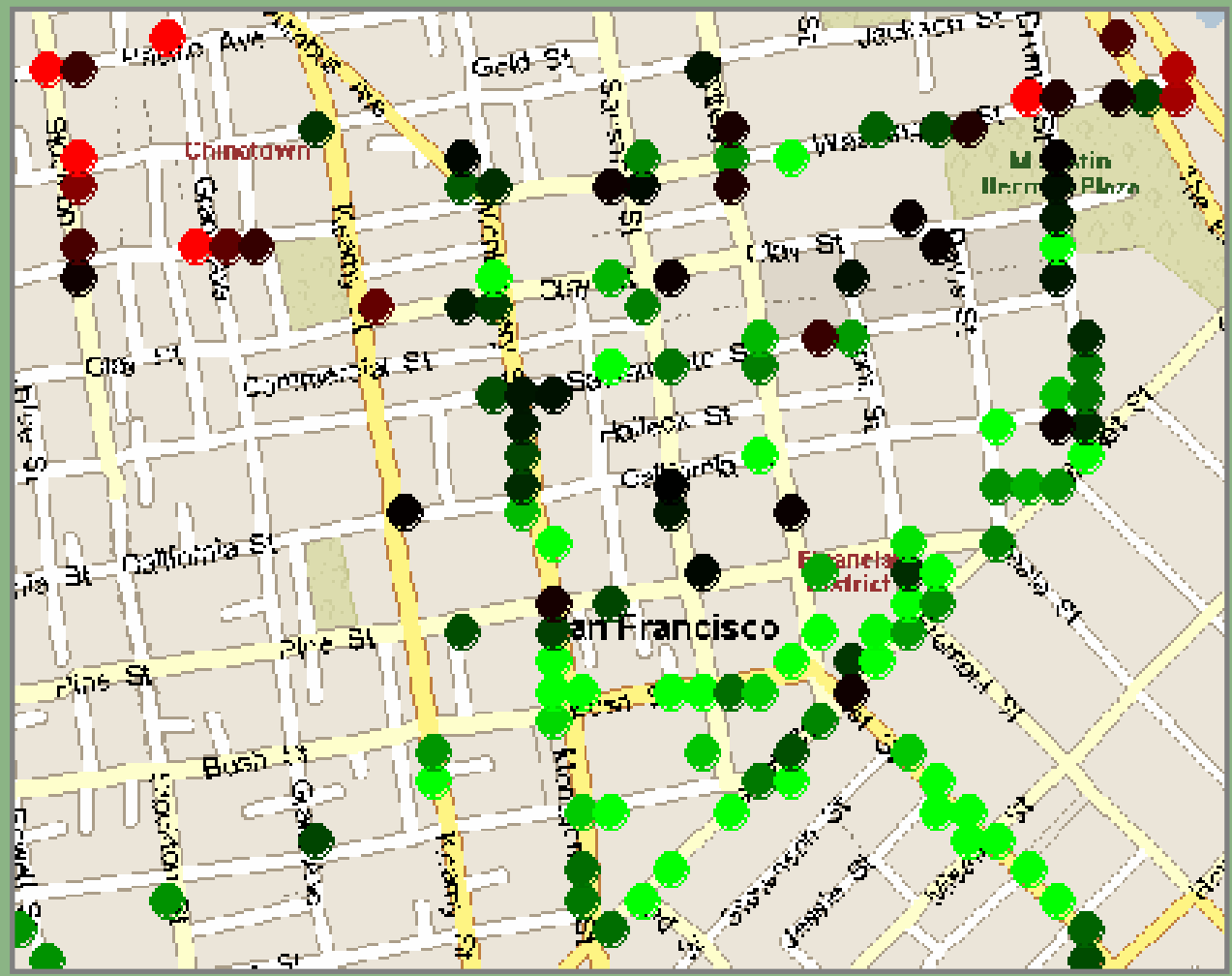
Error Comparison WLS & GPS

Field trial in San Francisco test bed

Green = WLS Better
Black = Neutral
Red = GPS Better

- WLS better in urban canyons
- GPS better in open sky



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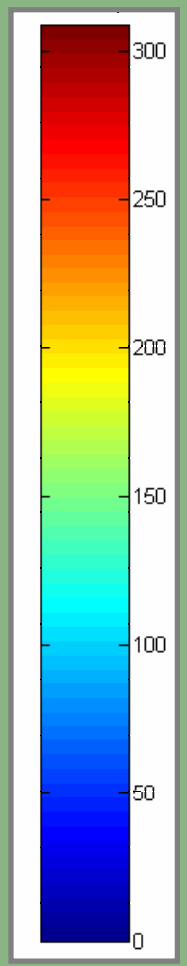
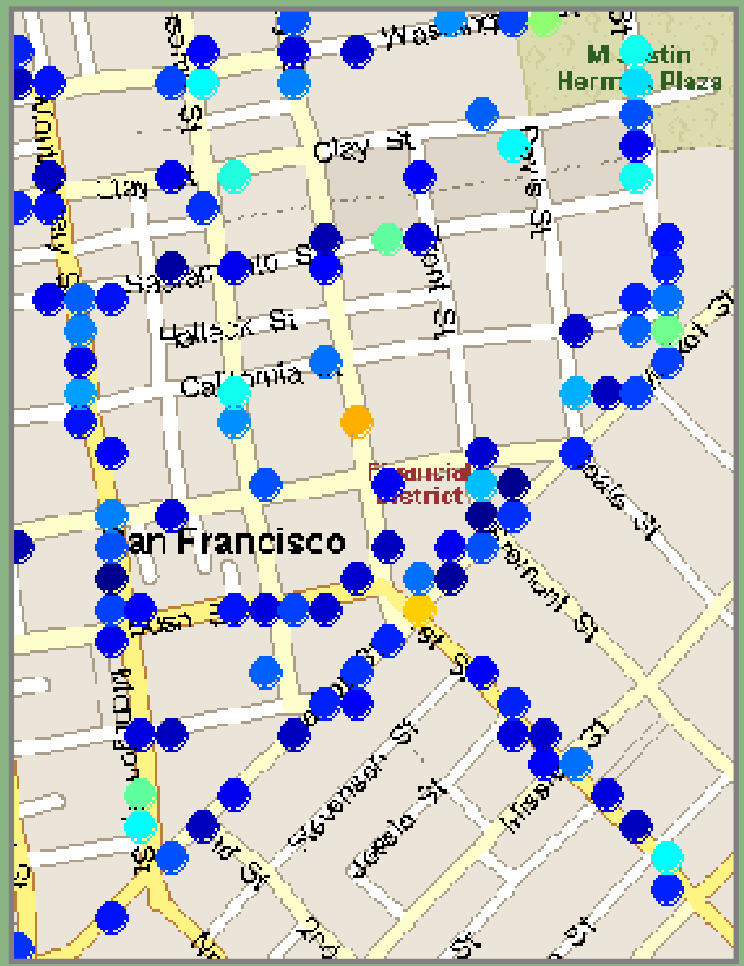
WLS Accuracy When GPS Gets No Fix





Color Scale

Error (meters)

WLS accuracy good where GPS cannot get a position fix due to obstructions

Option for simple fallback approach

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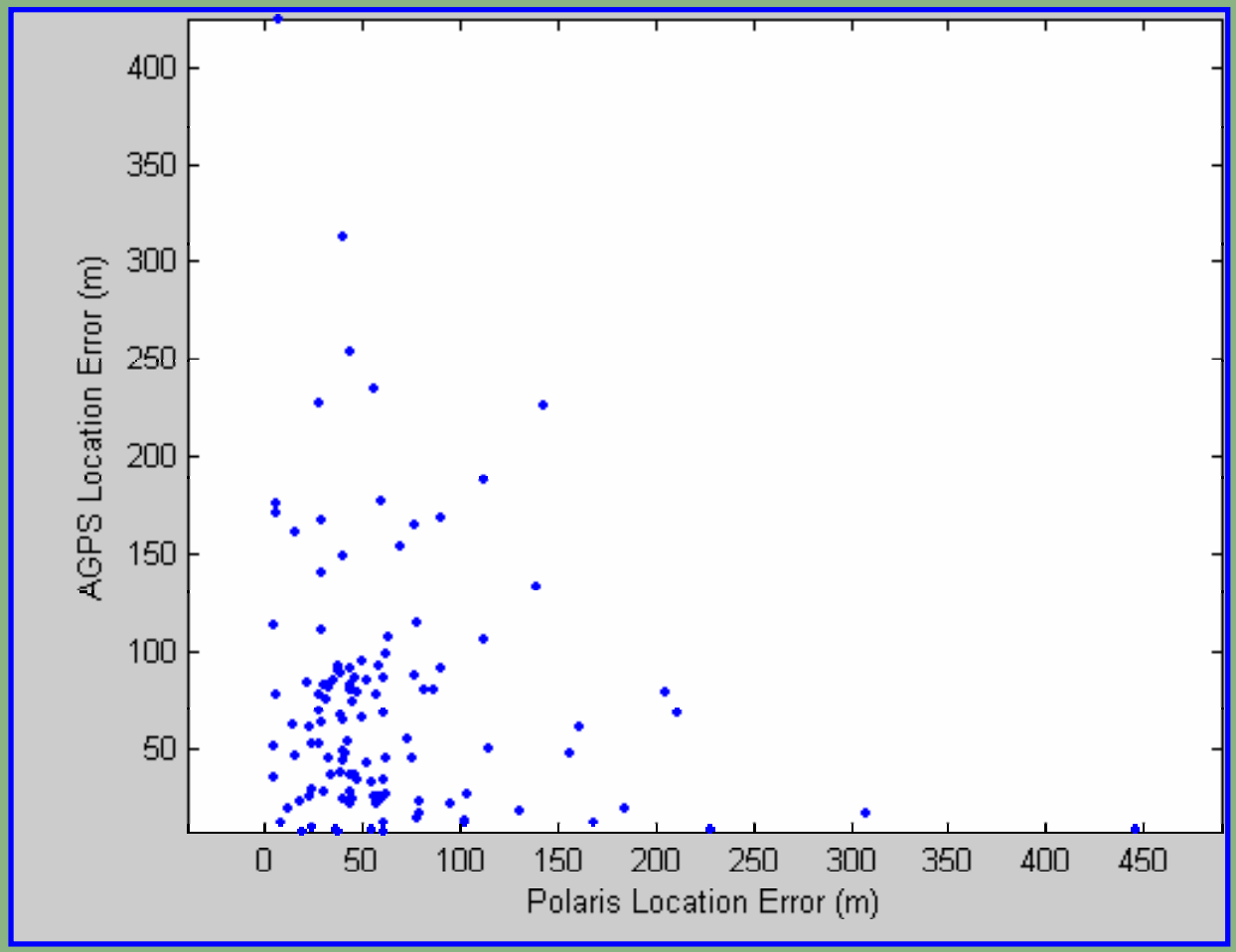
WLS & GPS Error Scatter Plot



Errors from WLS and GPS do not tend to be correlated

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Conclusions

- **Hybrid approaches needed to maintain good accuracy in all environments**
  - **Location based services demand consistent performance**
- **Network and handset based technologies are highly complementary**
  - **Network based approaches excel in urban and indoors**
  - **Handset based approaches excel in rural**
  - **Wireless Location Signatures (WLS) plus GPS/A-GPS**
- **Field trial results in San Francisco urban test bed demonstrate that WLS and GPS errors not correlated**
  - **Potential for joint estimate or binary selection algorithms**