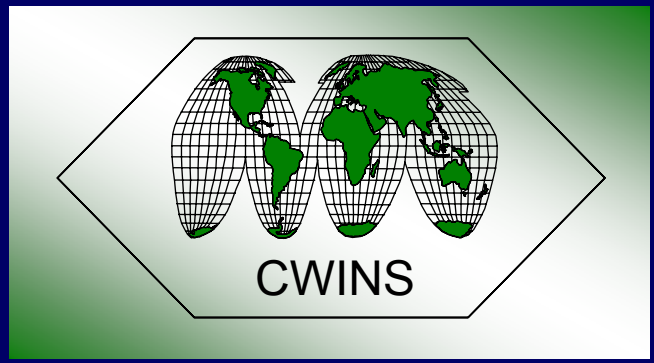
RFID Academic Convocation

AUTO-ID Laboratory at MIT



Trends in RF Location Sensing

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Outline

- Evolution of RF Location Sensing
- Applications
  - in Commerce
  - in Military and Public Safety
  - in other disciplines
- Localization Research at CWINS/WPI
  - RSS Localization
  - Accurate Localization Using TOA

Evolution of Localization Industry

- Problem of locating soldiers carrying mobile radios was first addressed in World War II
- During the Vietnam conflict US department of defense lunched a series of GPS satellites to support military operation
- In 1990 signals from GPS satellites became accessible to public
- In 1996 FCC required locating mobile phones with in 100 meters in 67% of locations
- In 1997 urban and indoor geolocation started
  - Military: SUO/SAS project
  - Commercial: PinPoint, WearNet
- In 2000 indoor WiFi localization (Newbury Networks and Ekahau)
- In 2003 UWB localization for WPANs
- In 2004 localization for sensor networks
- In 2005 outdoor WiFi localization as a GPS alternatives
  - Commercial: WiFi positioning in outdoor areas (Skyhook)
  - Military: Signals of opportunity for disaster recovery (DARPA)

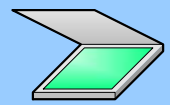
Localization in Commerce

Typical Commercial Applications

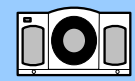
- Asset tracking in warehouses and hospitals
- Dispatching and monitoring support staff
- Locating elderly persons
- Locating children in public areas
- Emergency management in hospitals
- Invisible fencing of pets
- Tracking golf balls
- Locating surgical equipment in operation rooms
- Guiding visitors in museums
- Navigating sight impaired persons
- GPS complement for indoor applications

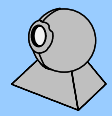
Today Everything is a Terminal!

Entertainment / Home Networking

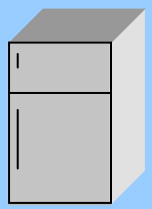


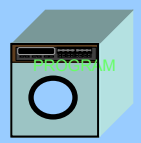
Computer/Communication





Appliances/Security

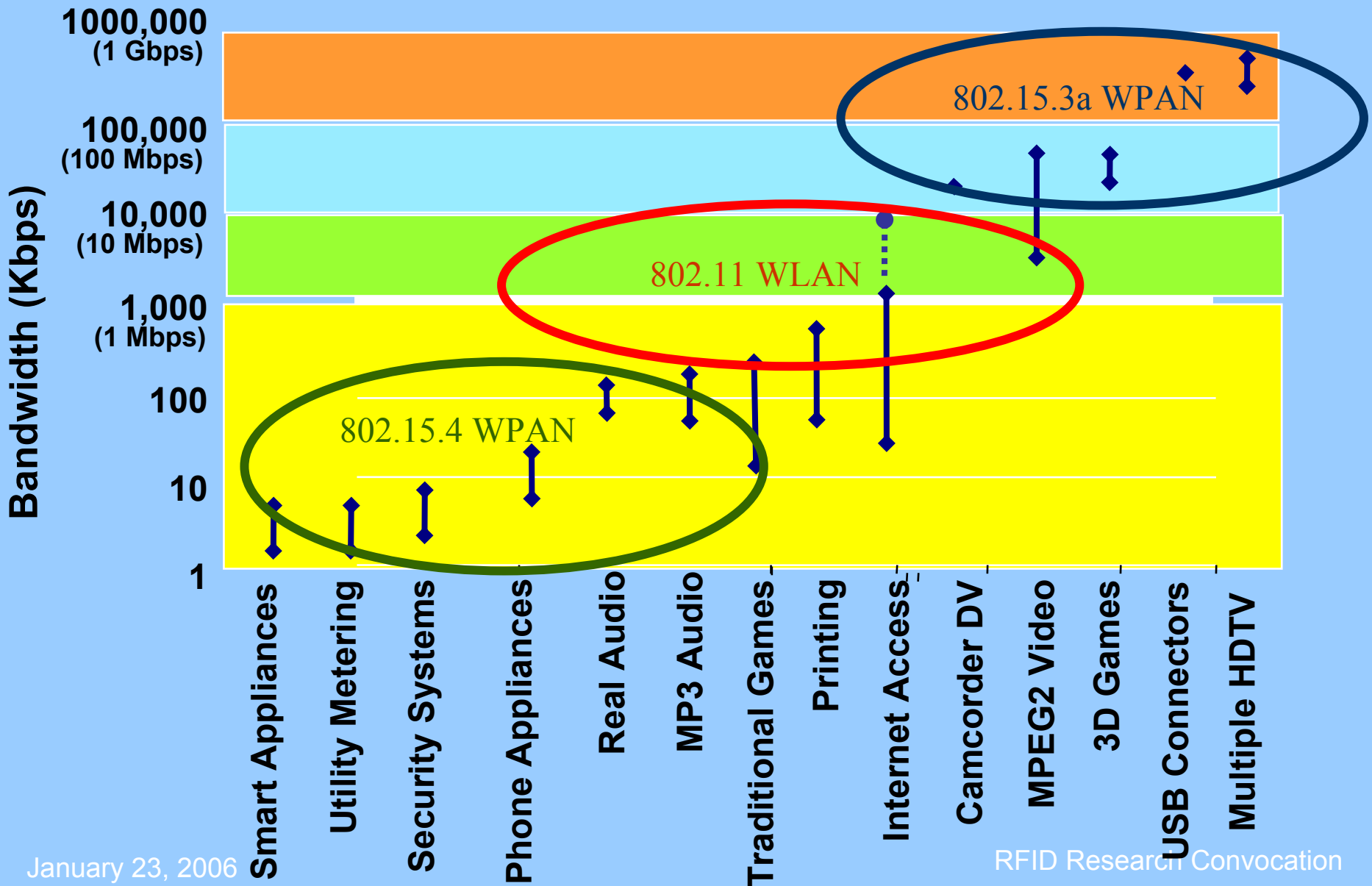




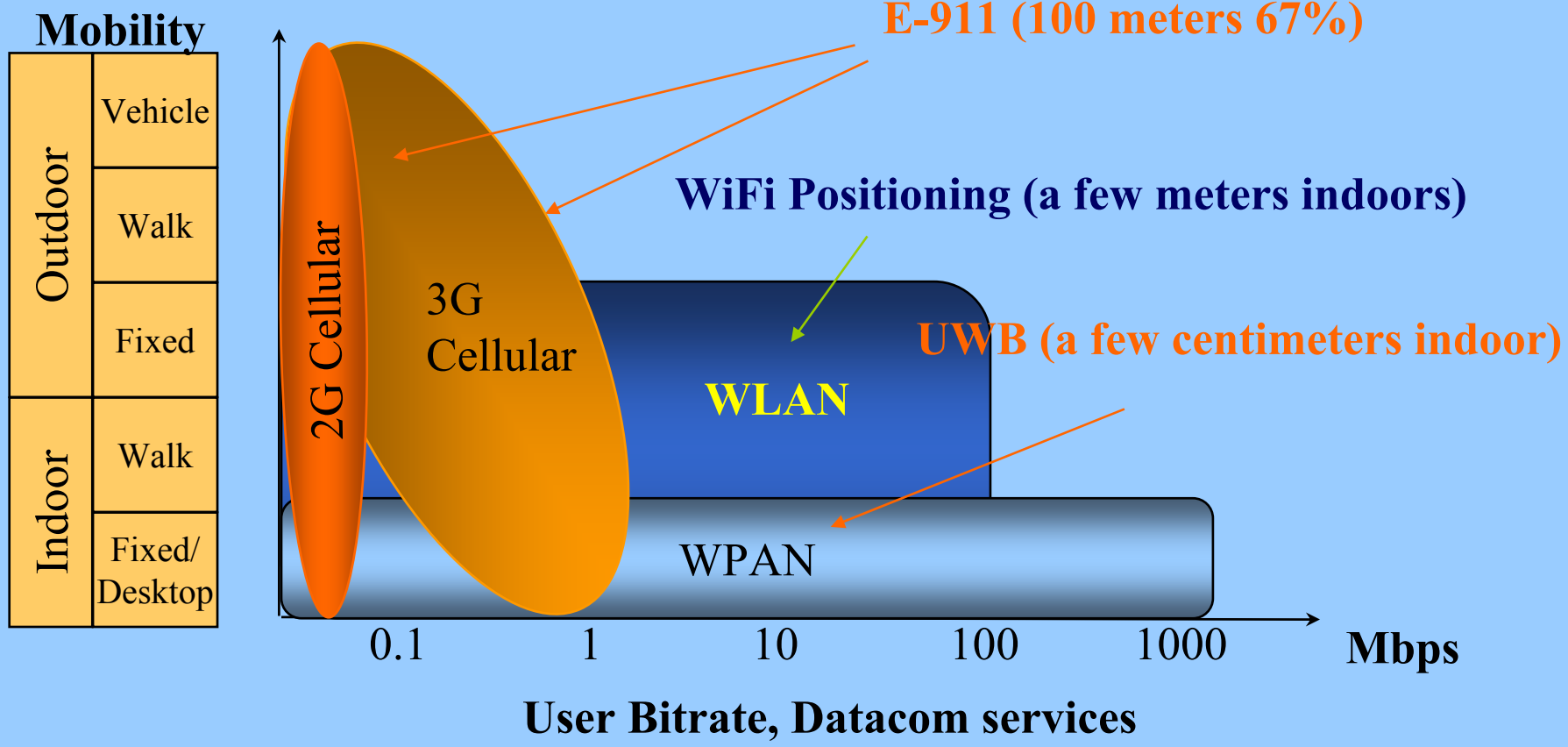
Location Sensors

Control/Metering

Standards and Terminals



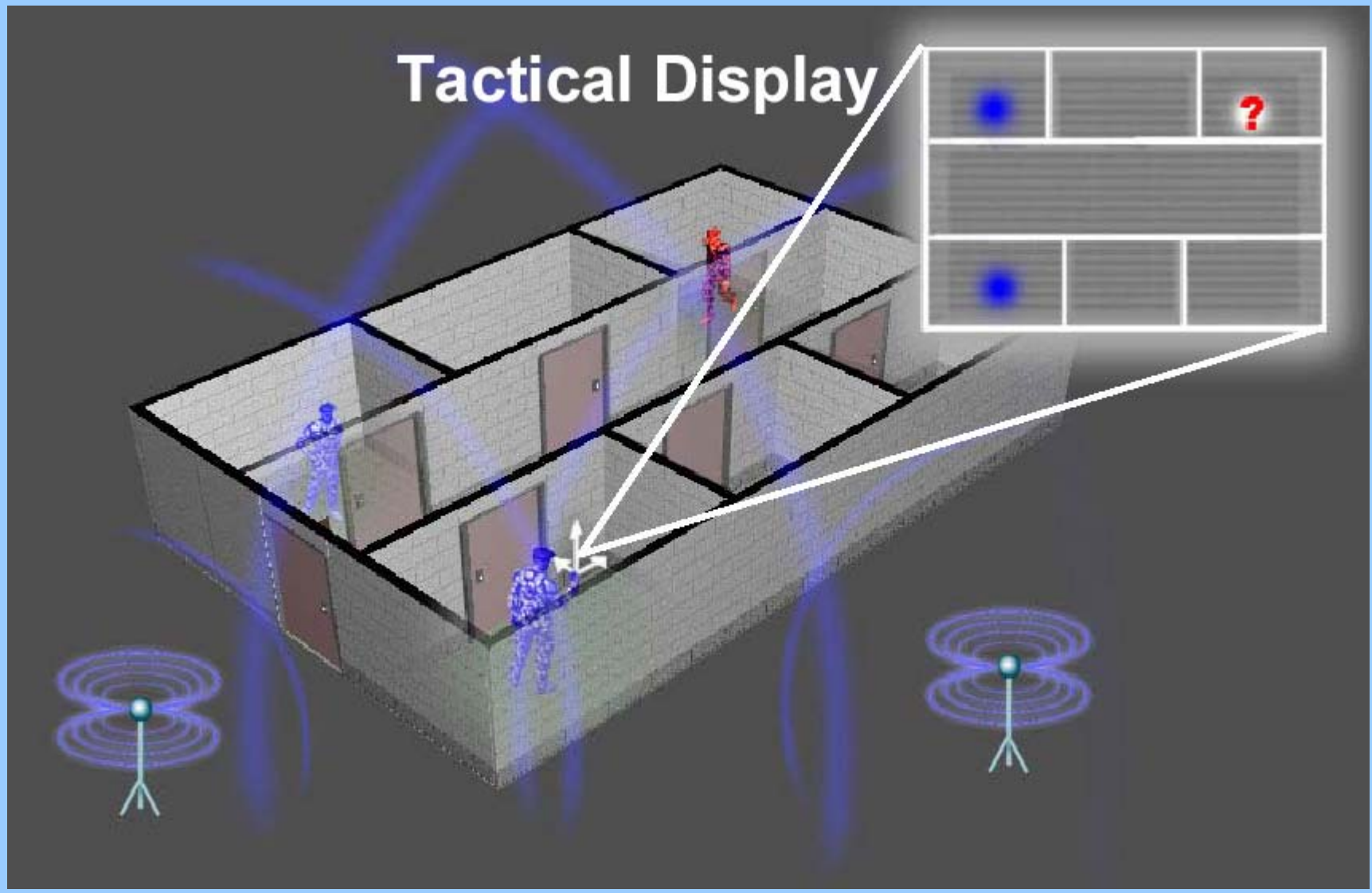
Localization Accuracy



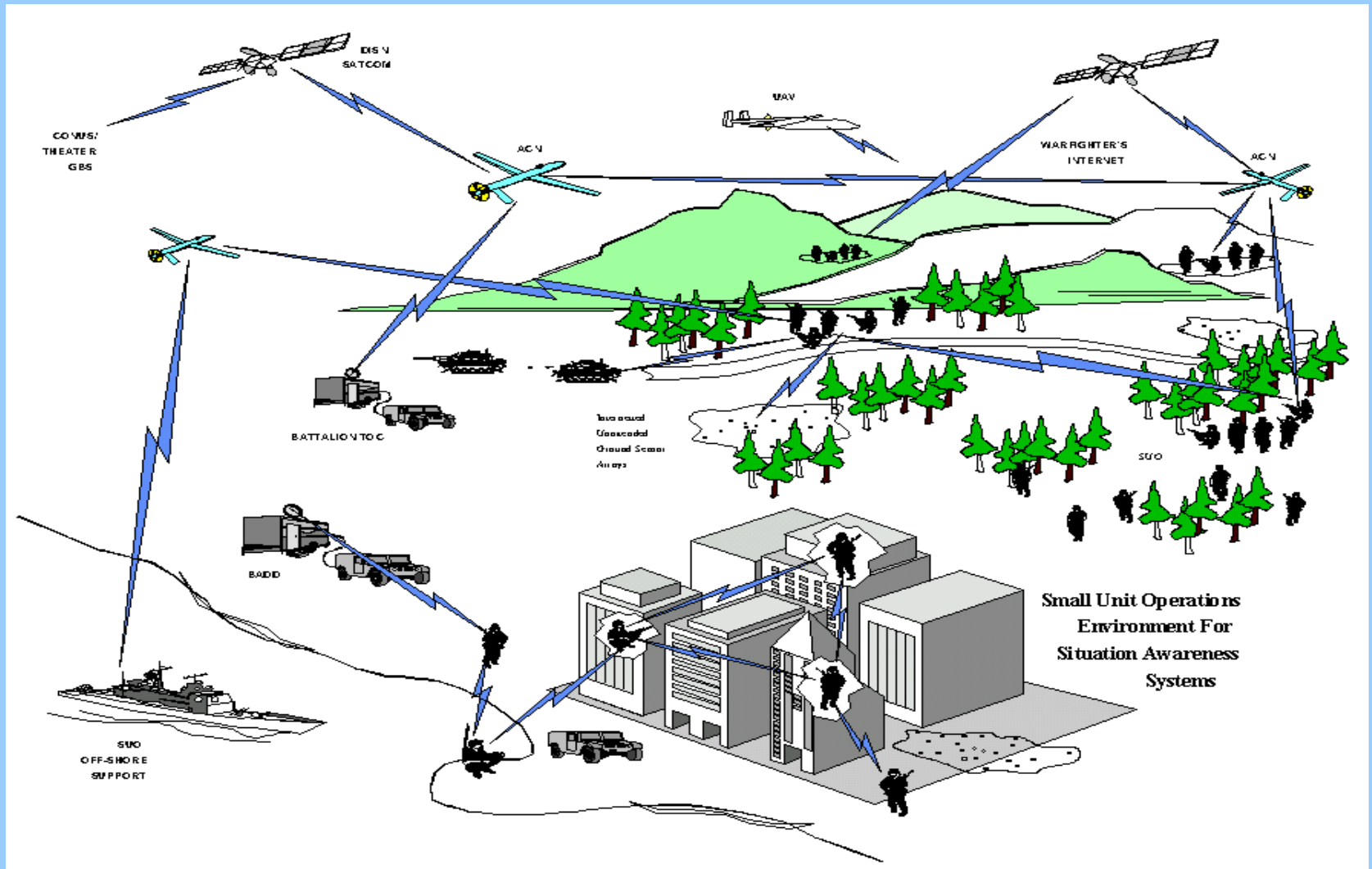
Accurate Localization in Military and Public Safety

Typical Applications

- Navigation for fireman
- Navigation for policemen
- Providing situation awareness for soldiers
- Tracking inmates in prisons
- Tracking in disaster recovery zones


Tactical Display
?

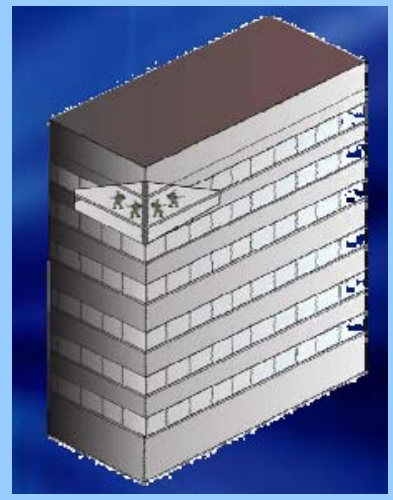
SUO-SAS and Urban Fighting



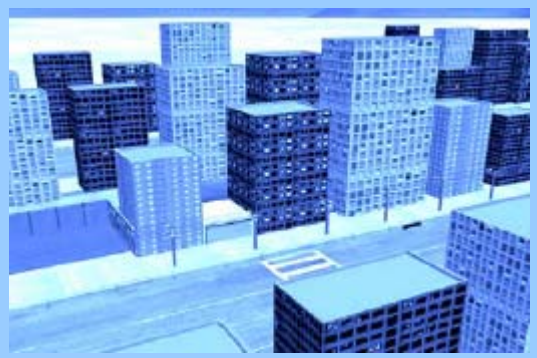
Localization Everywhere

Robot in rubble

Inside caves



Forces inside buildings



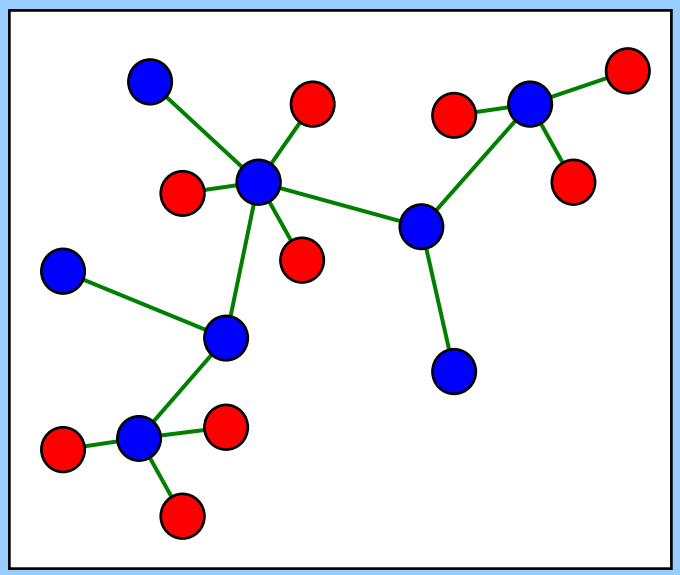
Urban canyons

Unattended ground sensors

Using Signals of Opportunity

Localization in other Research Areas

- Location-based handoff
- Location-based routing in *ad hoc* networks
- Location-based authentication and security



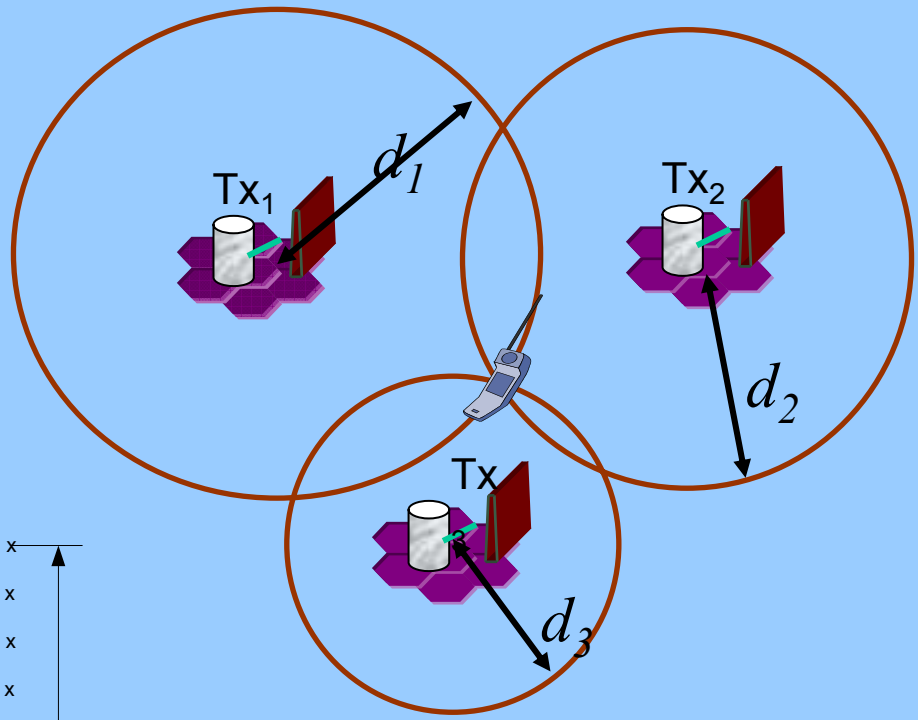
Localization Research at CWINS/WPI

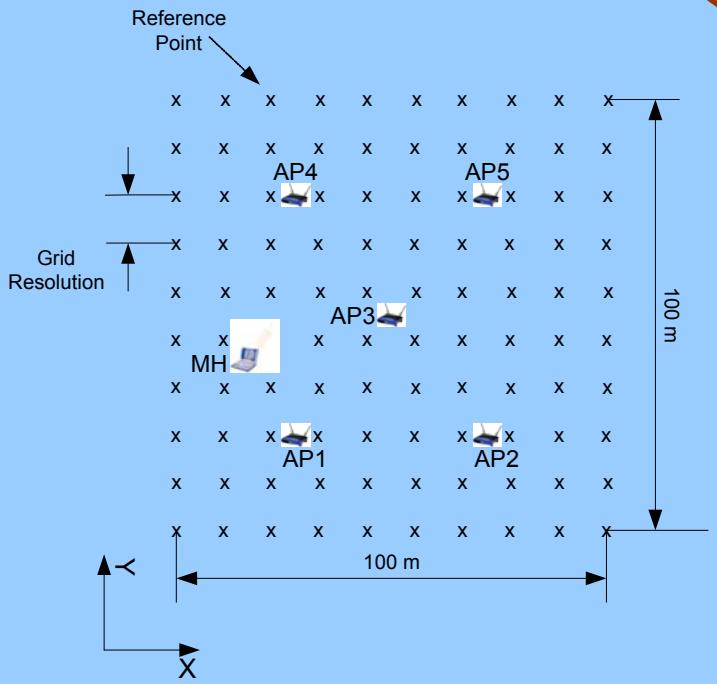
Two Technologies

- RSS
  - Simple hardware
    - Accuracy is not sensitive to multipath and bandwidth
    - Does not need synchronization
    - Can work with any existing infrastructure and card which can measure power
  - For accurate localization
    - Needs high density of references or long training procedure
    - Needs more complex and computationally intensive algorithms
  - Used for WiFi Positioning by Ekahau, Newbury Networks, PanGo, Skyhook.
- TOA
  - Suitable for accurate indoor positioning
    - Only needs a few references
    - Does not need training
  - More complex hardware
    - Accuracy is sensitive to multipath and bandwidth
    - Needs synchronization of the reference time
  - Used in GPS, PinPoint, WearNet, 802.15.3 and 4.

Two Classes of Algorithms

Distance Based Localization





Pattern Recognition

RSS Localization at CWINS

- Microsoft: Nearest Neighbor algorithm based on signature data collection in a training period.
  - P. Bahl and V. Padmanabhan, “RADAR: an in-building RF-based user location and tracking system,” *IEEE INFOCOM*, Israel, March 2000.
- Ekahau: Uses a statistical algorithms for localization with improved accuracy and reduced training data.
  - T. Roos, P. Myllymaki, H. Tirri, P. Miskangas, and J. Sievanen, “A Probabilistic Approach to WLAN User Location Estimation,” *International Journal of Wireless Information Networks*, Vol. 9, No. 3, July 2002.
- CWINS: Develops a real time laboratory testbed and a framework for comparactive performance evaluation of localization algorithms.
  - M. Heidari and K. Pahlavan, Performance Evaluation of Indoor Geolocation Systems Using PROPSim Hardware and Ray Tracing Software, IWWAN’04, Oulu, Finland, May 2004.
- CWINS: Uses channel modeling techniques (Ray Tracing and WiFi channel models) to eliminate the need for training data and improve the performance.
  - A. Hatami, and Kaveh Pahlavan, " Comparative statistical analysis of indoor positioning using empirical data and indoor radio channel models," *Consumer communications and networking conference*, 2006.

Challenges for TOA Estimation

- Coverage
  - Existing knowledge only supports coverage of the total power while in TOA estimation we are keen on the coverage of the DP. We need more measurement and modeling effort to solve this problem.
- Bandwidth
  - Common belief: increase in bandwidth increases the resolution therefore UWB is the final solution
  - Problem: Increase in bandwidth reduces the coverage of the first path, which means ***UWB is not the ultimate solution for Indoor Geolocation***
- UDP
  - Errors caused by UDP conditions are very large
  - Detection of UDP is difficult, so we can not avoid UDPs
  - If we detect the UDP and avoid, coverage become very small
- Therefore: we need research in algorithms which operate in UDP conditions and provide good coverage with reasonable bandwidth

TOA Research at CWINS

- Modeling of the behavior of TOA sensors (for NSF)
- UWB
  - For high-resolution short distance (for DARPA)
- Super-resolution algorithms
  - For signals of opportunity (with NSF and RCI)
- Diversity Techniques
  - AOA (with Draper Laboratory)
  - Space and cooperative location estimation (with IWT)

Conclusion

- Localization is one of the fastest growing industries attracting strong research investments from military and commerce
- Variety of applications are emerging around RSS and TOA based technologies
- CWINS is the oldest laboratory working in both RSS and TOA technologies with close ties to commerce and military
- Localization for RFID applications is one the areas of interest at CWINS for future research