NIST Distributed Testbed for First Responders

BFRL, EEEL, ITL, and MEL
NIST

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Problem

- 9/11 terrorist attacks brought to forefront a major deficiency of first responder communication systems:
  - First responders use a multitude of radio systems that do not interoperate .....
- This hinders first responder operations.
- Federal government is committed to change this situation.

Possible Solutions

- Short Term – Improve interoperability of radio equipment in use today through
  - Frequency spectrum coordination
  - Minor hardware / software fixes in radios
- Long Term – Develop standards for highly capable, next generation first responder communication equipment and over time replace existing radios.

NIST Plan

- Develop a testbed incorporating various modern first responder technologies that goes far beyond solving the communication problem by offering a complete solution package and dramatically improved capabilities for future first responder systems.
- The testbed could serve as the nucleus for standards for next generation of first responder systems.

"Complete Solution"

- Integrated Communications (voice/data/video)
- Sensor Networks
- Geolocalization and tracking of assets / threats
- Fire growth models
- Building integrity models (VCBT)
- Command and control, authentication and security
- Human computer interactions and remote collaborations
- Various GUI and data format standards

Why NIST?

..... our long track record in facilitating development of national / international standards through research, testing, and measurements.

Networking Technologies for Next Generation First Responder Systems

Principal Components & Expectations

	Present	Future
First Responder Communications	push-to-talk radios	unicast / multicast / broadcast capabilities
	voice only	text / voice / video / sensor data
	severe interoperability problems	interoperable through new standardization
	fixed infrastructure	ad hoc network

Networking Technologies for Next Generation First Responder Systems

Principal Components & Expectations (Cont'd)

	Present	Future
Sensor Deployment	Stand alone heat / smoke sensors	multi-modal sensory capability with data fusion; possibly interoperable with first responder communication equipment
Geolocalization	GPS available outdoors; no indoor solutions	3-D localization

Network Architecture: Wireless Ad Hoc Networks

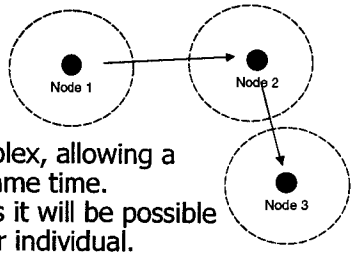
- Infrastructureless (no base stations or access points)
- Self-organized
- Adaptable to varying topology and traffic conditions
- Robust: Degrades gracefully in face of node / link failures and local congestion
- Efficient (bandwidth, power consumption, user capacity) through multihop communications & spatial reuse
- Possibility of QoS provision
- Scalable

Testbed Hardware

- Compaq iPAQs running Linux.
- Linux provides a seamless development platform, access to low level network functions and a large community of active researchers.
- Dual PCMCIA card backpack with battery.
- Low-power Strong-ARM chip, 2800mA battery capacity, ~8 hour runtime using 802.11b card.
- 10 iPAQs have Bluetooth, allowing for wireless headsets, sensors, GPS, and more!
- Full-duplex audio, with headphone jacks.

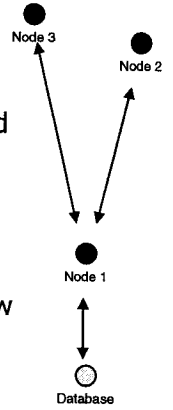
Audio Data

- Every time a node gets a new unique audio packet it rebroadcasts it so all of the surrounding nodes can hear it.
- Stations can operate in full-duplex, allowing a user to talk and listen at the same time.
- Since all the audio is in packets it will be possible to talk to only a select group or individual.
- It will also be possible to give more priority to rebroadcasting important messages if the system gets over crowded.



Location and Sensor Data

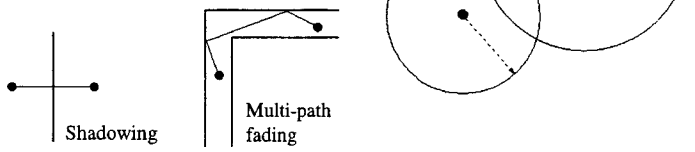
- Location and sensor data sent back to a central database.
- This data is then sent back to the interested nodes at a set interval.
- Centralizing allows post-event replay and evaluation.
- Allows for data to be easily viewed off-site.
- Network paths automatically update to allow for motion and correct for failures.

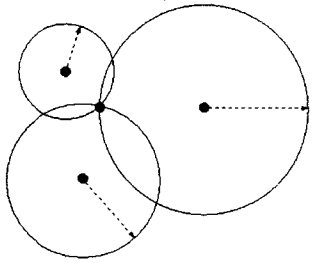


Localization

- Triangulation using signal strength
  - Works well for: indoors using UWB, outdoors using GPS.
  - Difficulties: Uncertainty of power exponent r due to shadowing, multi-path fading, and interference.

$$\text{distance} = \frac{1}{\sqrt[r]{\text{strength}}}$$





Localization: Triangulation using Database

- Deploy multiple base stations throughout area.
- At a single point in area:
  - Record signal strengths from base stations.
  - Record (x,y) position.
- OFFLINE:
  - Build database from multiple points throughout area.
- ONLINE:
  - Measure signal strengths from base stations.
  - Find closest point to reading in database.
  - Output associated (x,y) position.

Filtering Techniques

- Extrapolate mobile position through combo of database point positions
- Give higher confidence to closer base stations
- Adjacency constraints
- Kalman filtering

Conclusions

- We have only scratched the surface, and there is much more to be done!
- NIST with its diverse competencies and its established relationships with industry, academia, first responder user community, and state / federal government agencies is well positioned to make a major impact in this area.