DemAAL Summer School

16-20 September 2013, Chania, Crete, Greece

Wireless Sensor Networks

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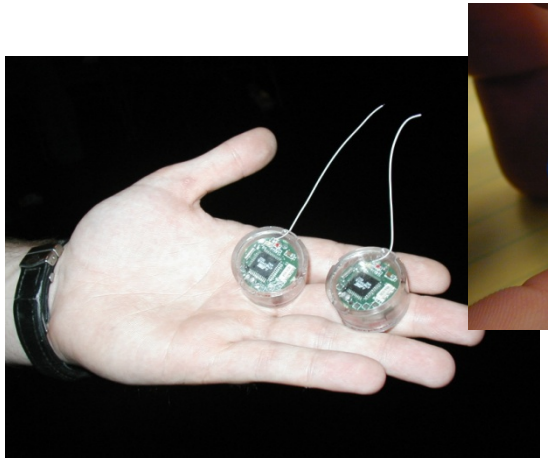
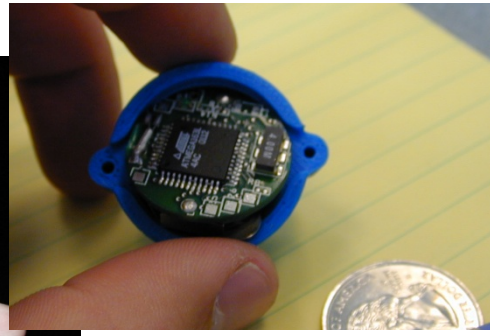
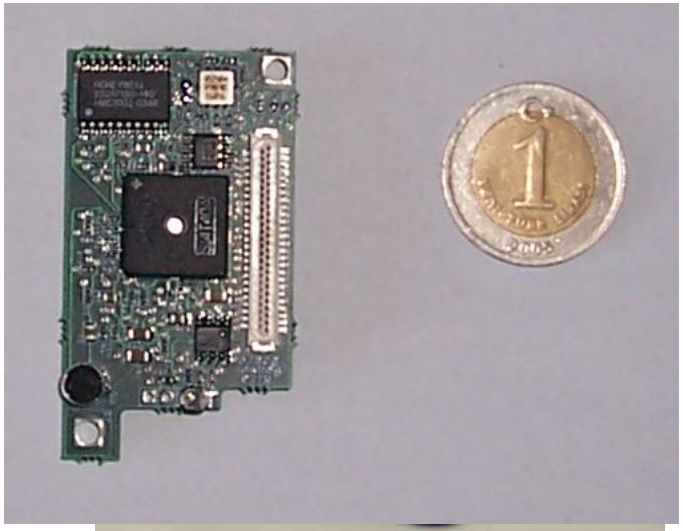
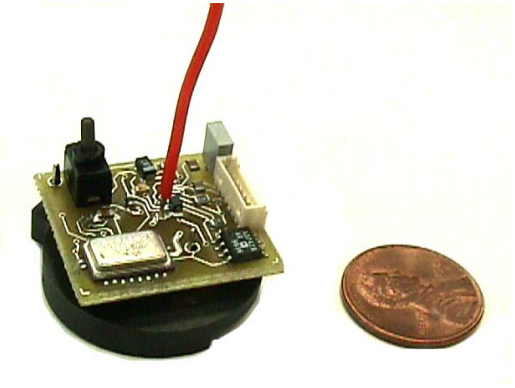
Example Sensor Nodes

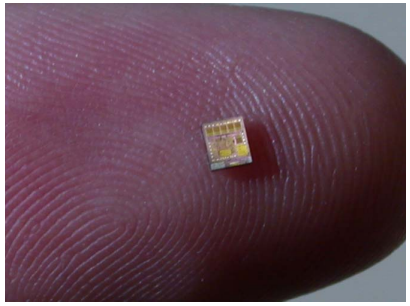




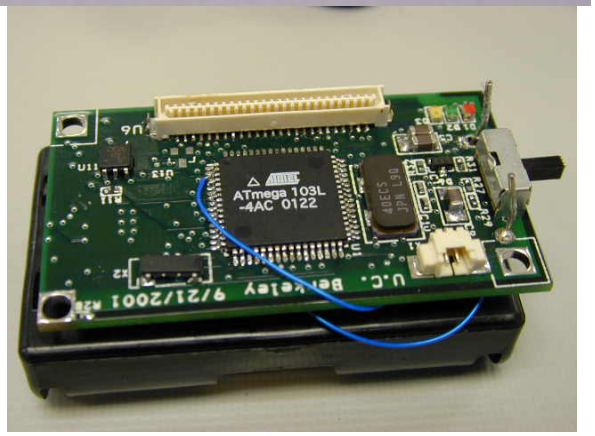
Dot Mote





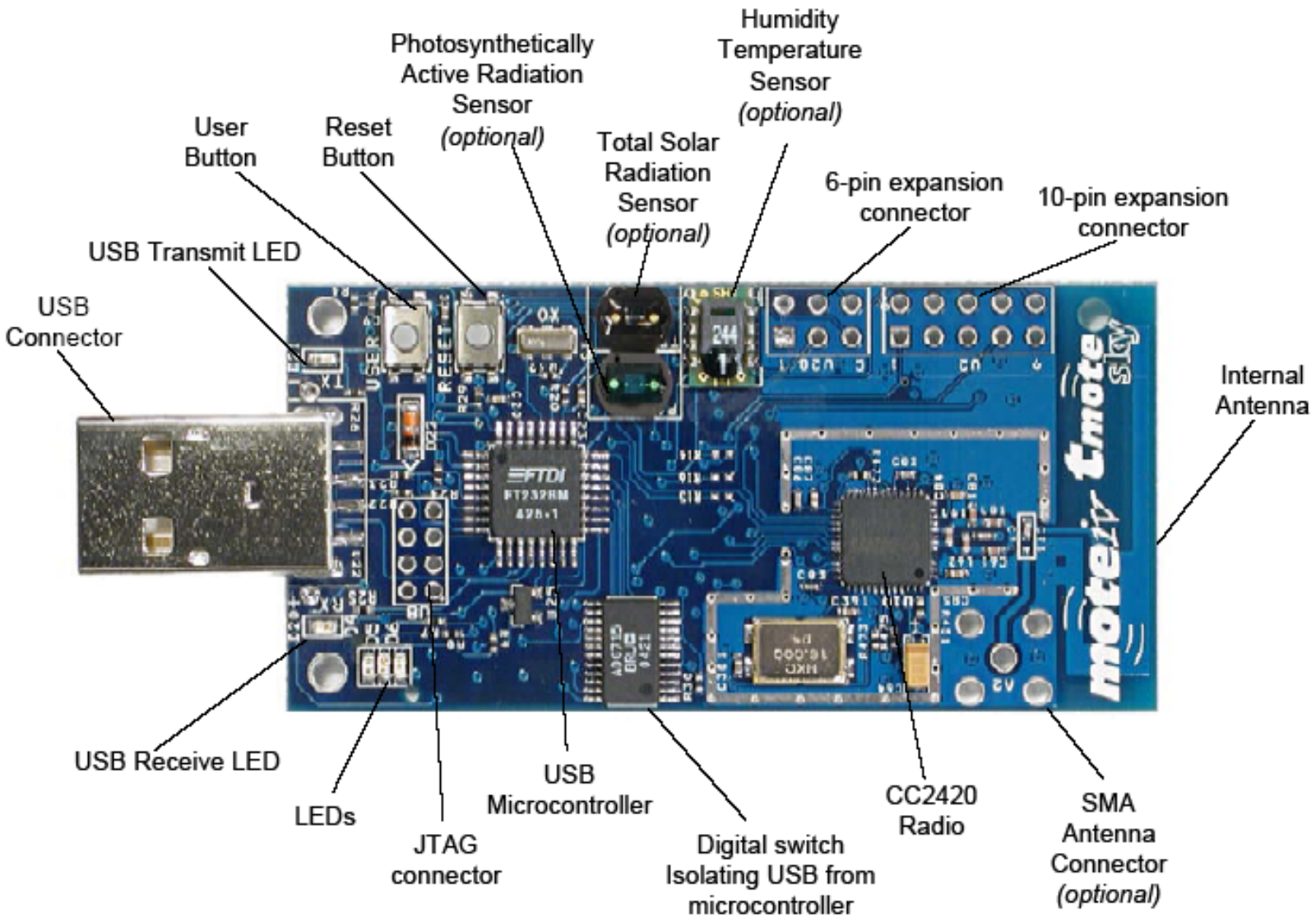


weC Mote

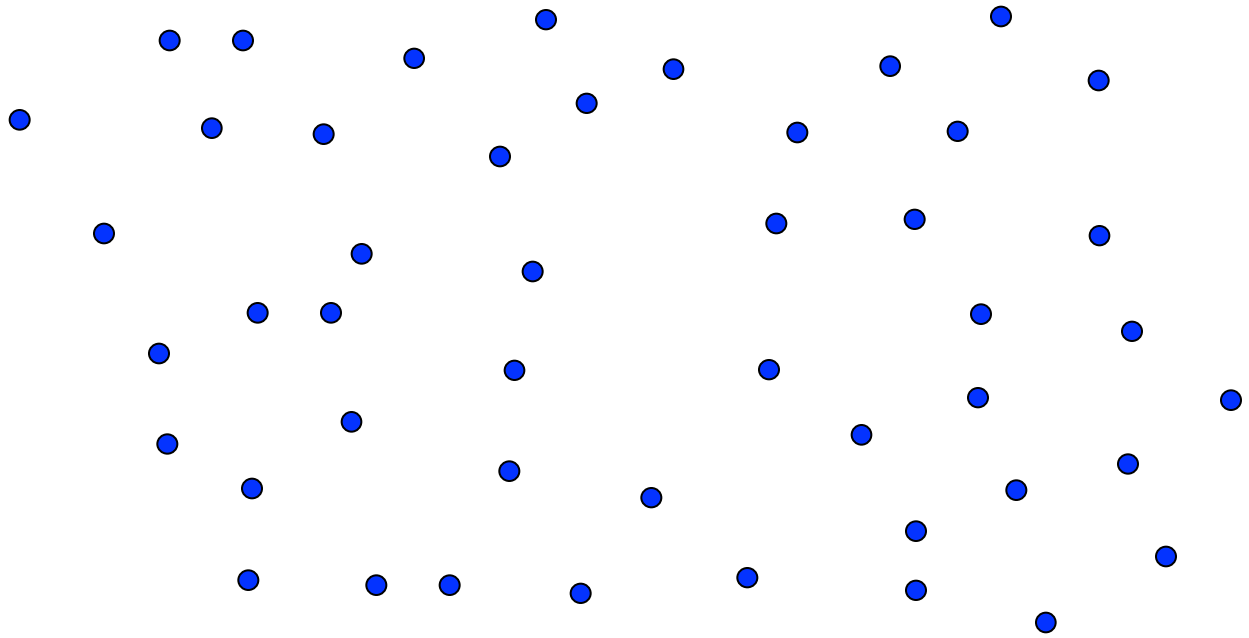


MICA Mote

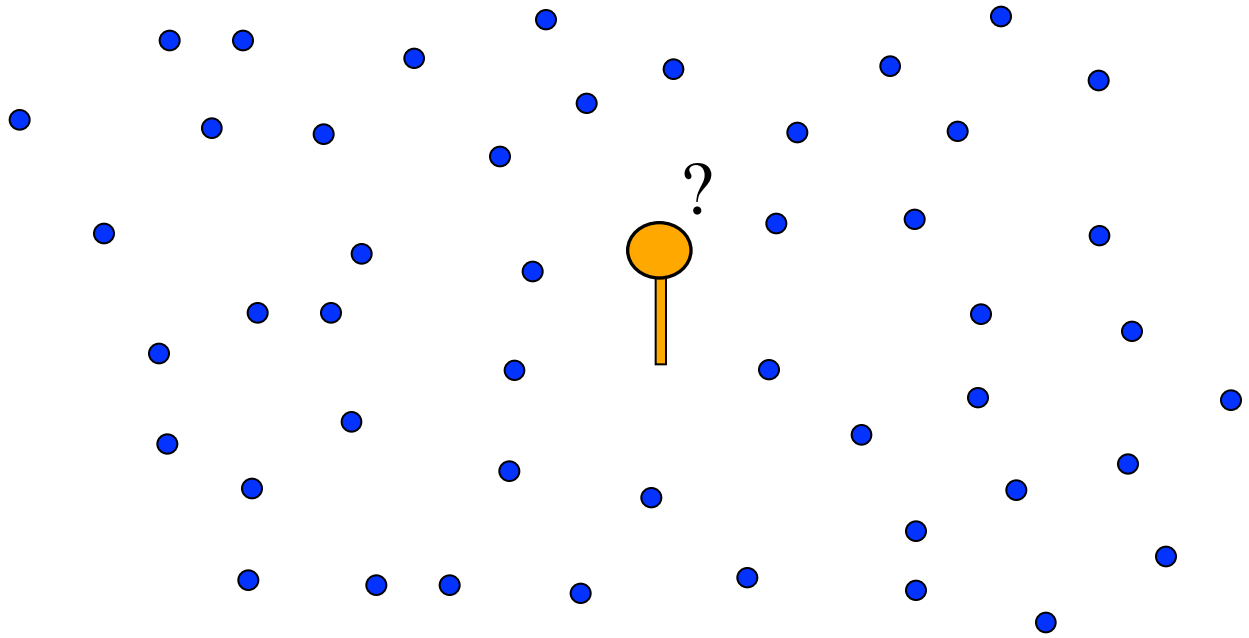
Moteiv Tmote Sky Node



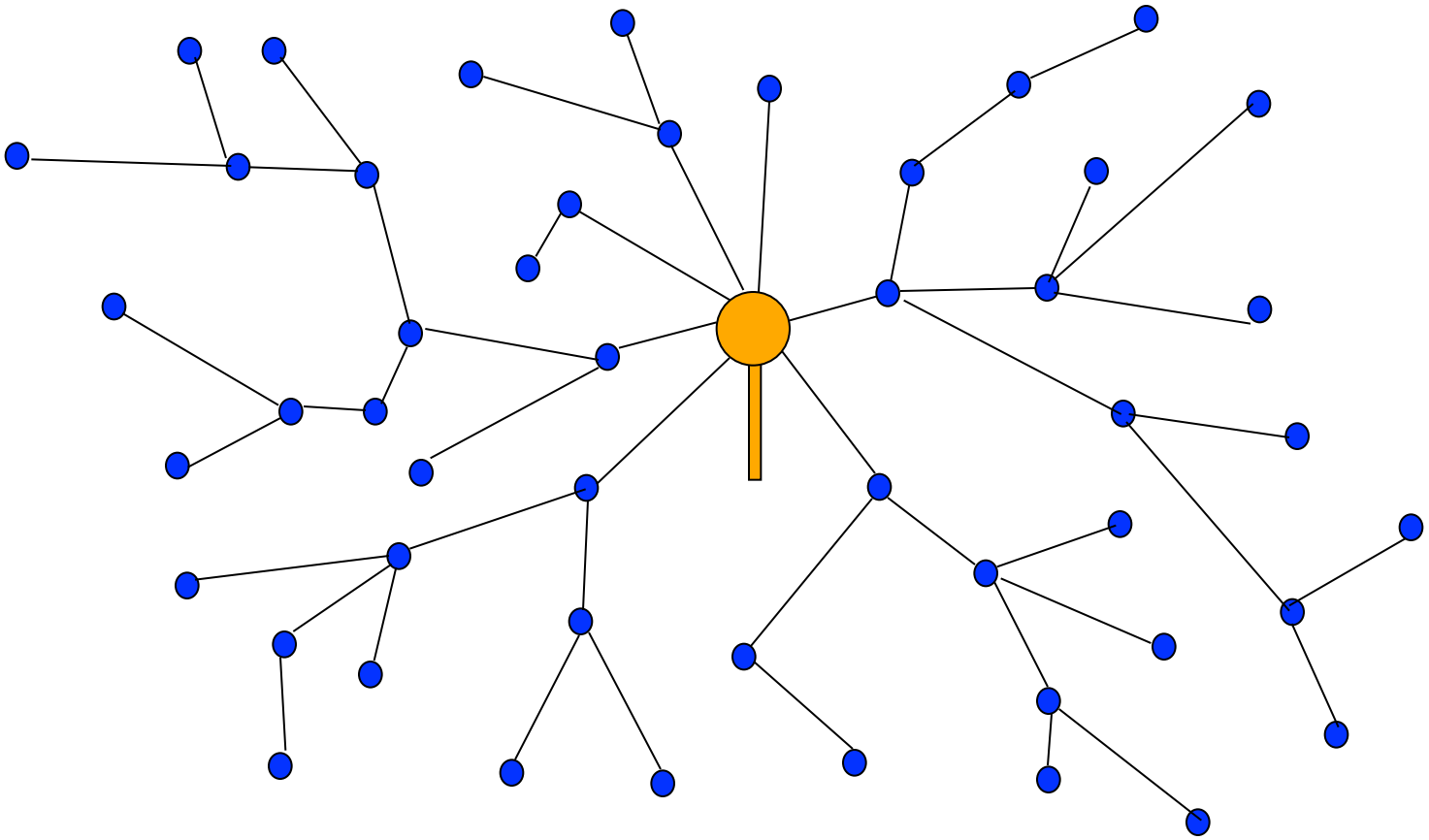
Typical WSN Operation: Sensors Deployed



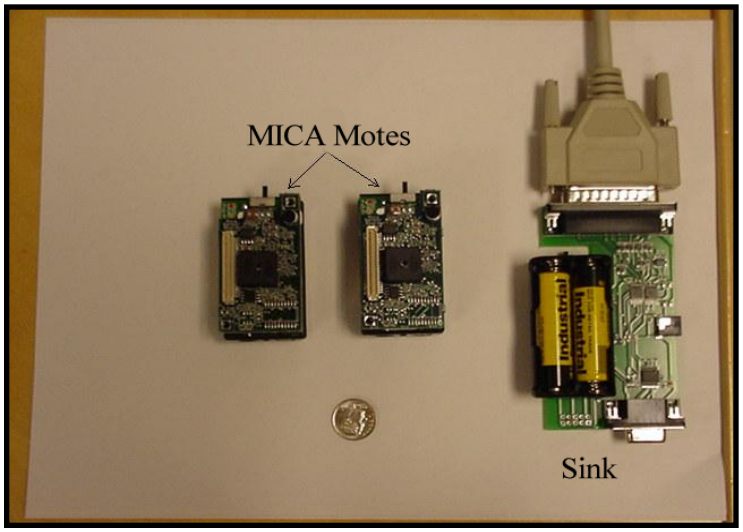
Sink is Placed for Collecting Sensor Data

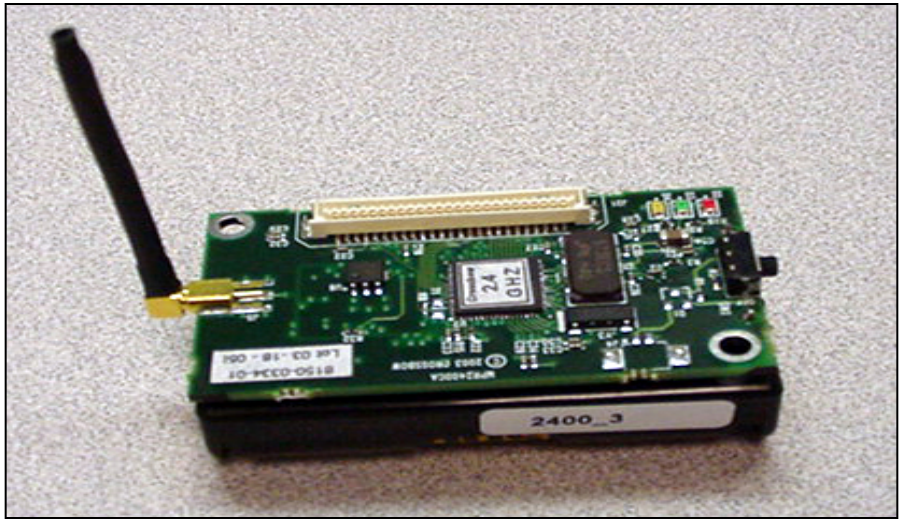


Network Topology and Routing is Self-configuring



Sensor and Sink Nodes





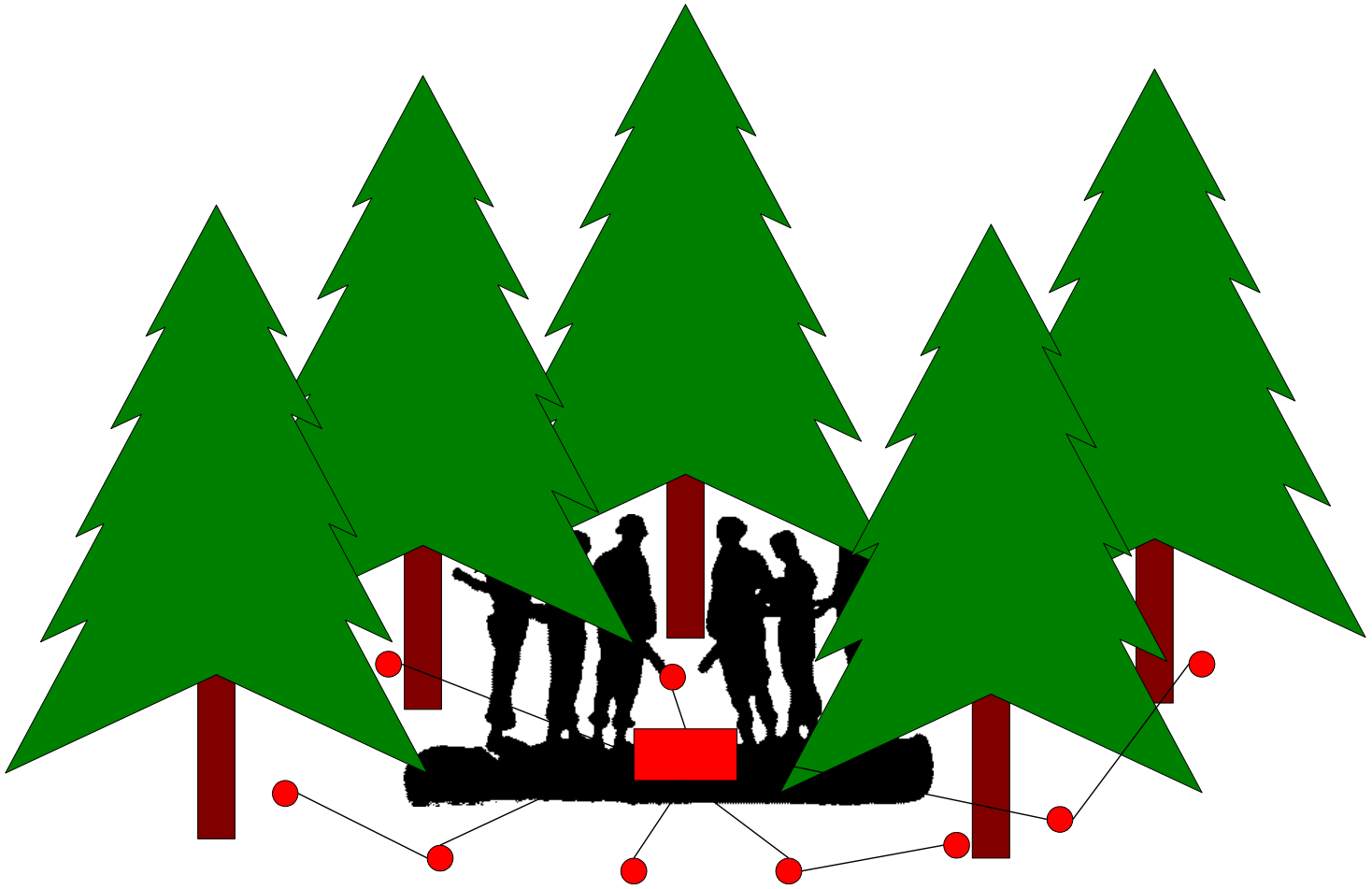
Sensor Node Features

Processor/ Radio Board	**Crossbow Mote** MPR300CB	**Arduinho Xbee** ATmega32U4
Speed	4 MHz	8 MHz
Flash	128K bytes	32K bytes
SRAM	4K bytes	2.5K bytes
EEPROM	4K bytes	1K bytes
Radio Frequency	916MHz or 433MHz (ISM Bands)	2.4 GHz (ISM Band)
Data Rate	40 kbits/sec (max)	250 kbits/sec
Power	0.75 mW	1 mW
Radio Range	100 feet	120 m
Power	2 x AA batteries; Solar Energy	3.7V LiPo

What Can the Sensors Sense?

- temperature, humidity
- light conditions (illumination)
- pressure, mechanical stress levels on attached objects
- soil makeup
- noise levels
- 3D acceleration
- tilt
- human physiological data, e.g., pulse, blood oxygen level

Example WSN: Area Surveillance



Example: Border Surveillance

Example WSN: Intelligent Wineyard



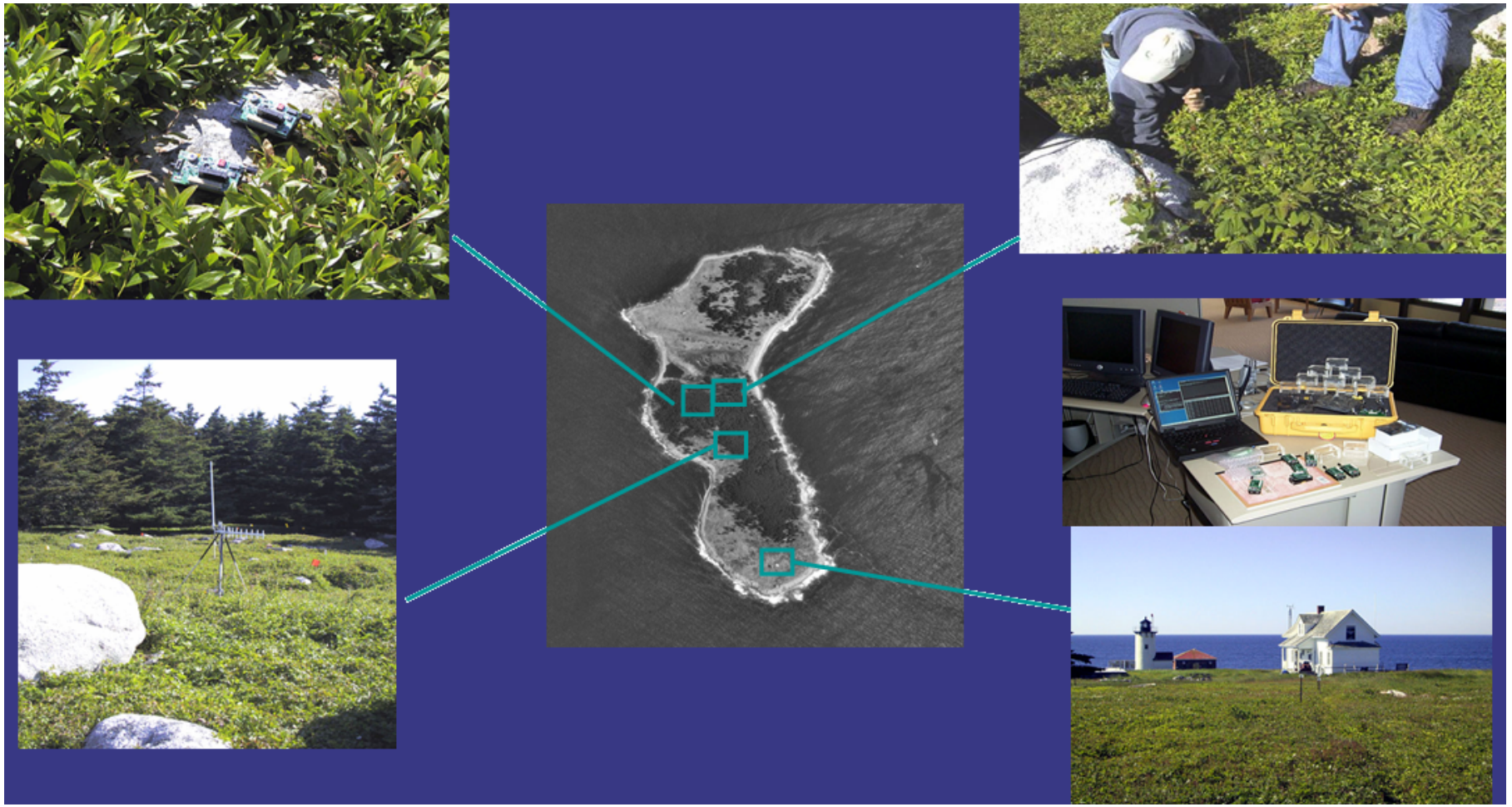
Wireless Sensor Networks

- Sensitive Agriculture: Increasing productivity by regularly monitoring environmental conditions (humidity, temperature, etc.)
  - E.g.: Wineyards in California. Grape production for high quality wines
  - Other examples: Environmental monitoring, early warning for forest fires, monitoring soil erosion

E.g., http://www.sierrawireless.com/Solutions/customer_stories/grape_networks.aspx

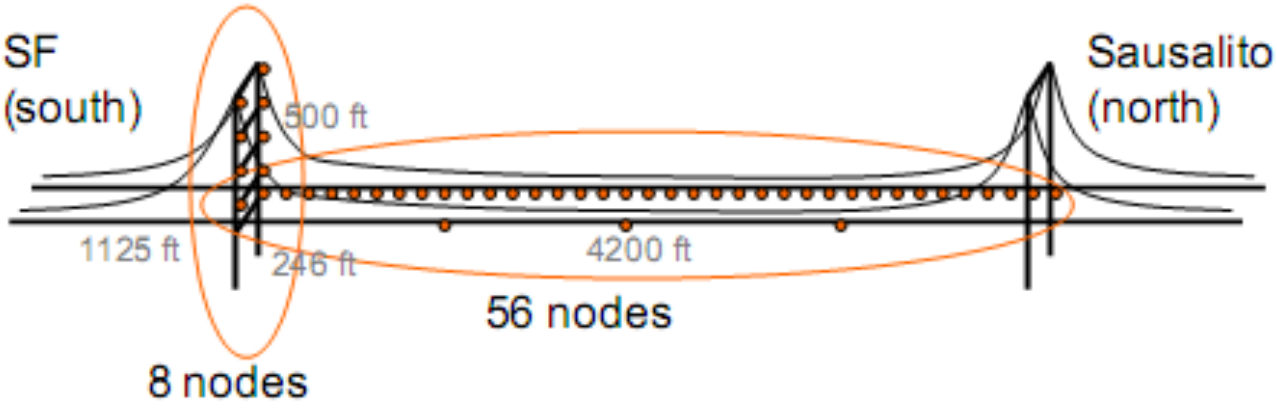
Habitat Monitoring

http://www.greatduckisland.net Great Duck Island in Maine

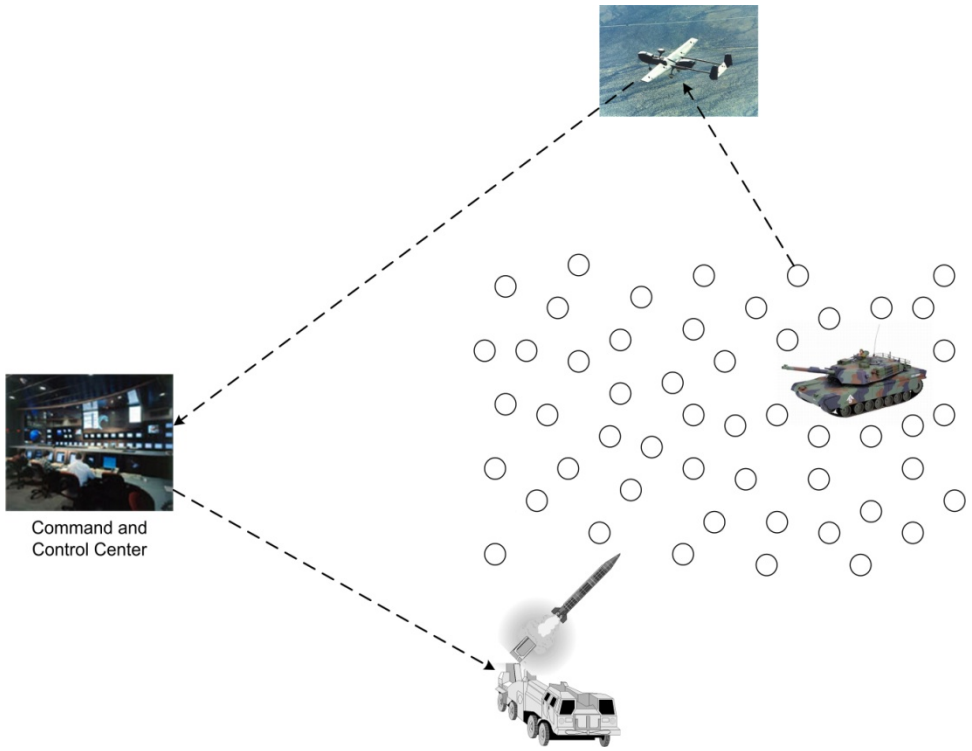


Structural Health Monitoring of the Golden Gate Bridge

- Developed by Berkeley University, 64 nodes are distributed over the main span and the tower, collecting ambient vibrations
- The sampled data is collected reliably over a 46-hop network, with a bandwidth of 441B/s at the 46th hop.



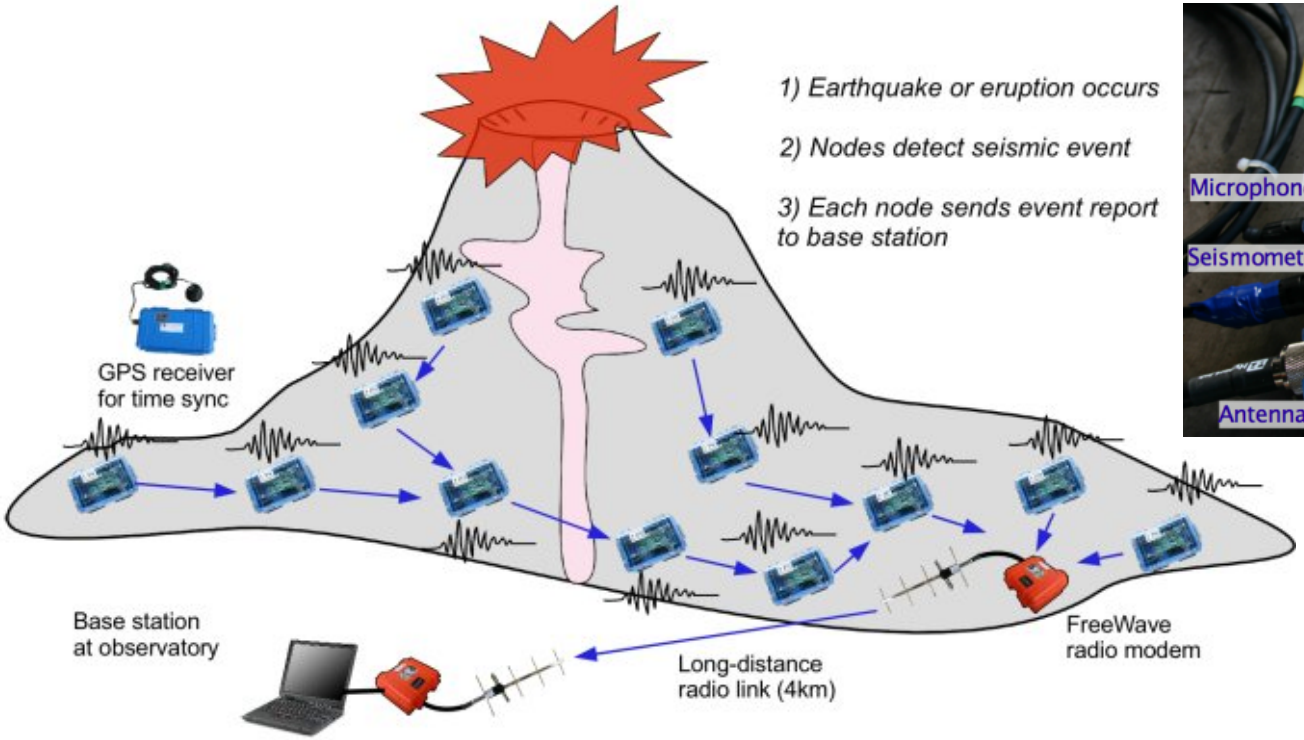
Distributed Collaborative Multi-sensor Multi-target Tracking

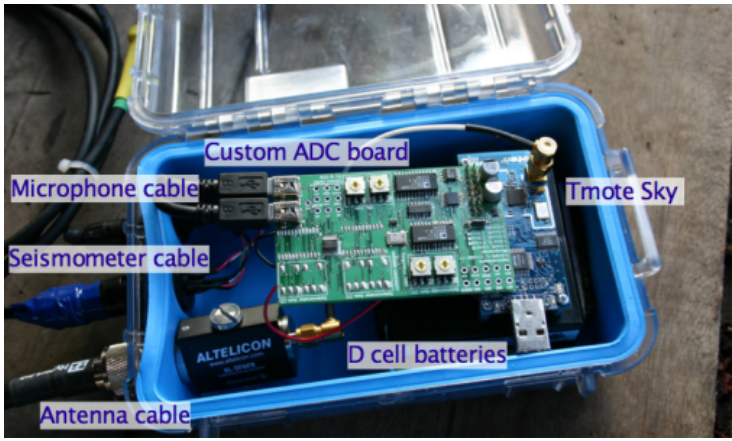


- Mutual Information Content-Based Sensor Selection (MISS).
- Information Controlled Transmission Power adjustment (ICTP).

Volcano Monitoring

- Developed by Harvard University, Deployed at Tungurahua volcano, Ecuador, in July 2004, August 2007
- 16 nodes (TMoteSky) deployed over a 3 km aperture on the upper flanks of the volcano, and measured both seismic and infrasonic signals





CodeBlue: WSNs for Medical Care

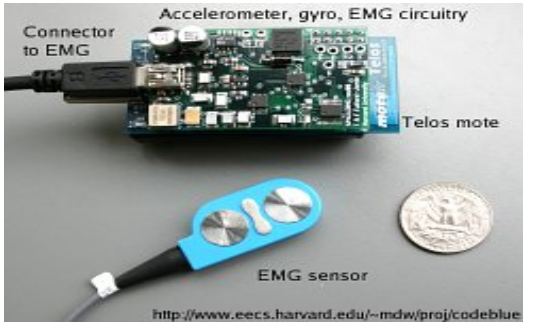
http://www.eecs.harvard.edu/~mdw/proj/codeblue

- NSF, NIH, U.S. Army, Sun Microsystems, and Microsoft Corporation
- Motivation - Vital sign data poorly integrated with pre-hospital and hospital-based patient care records

CodeBlue: WSNs for Medical Care

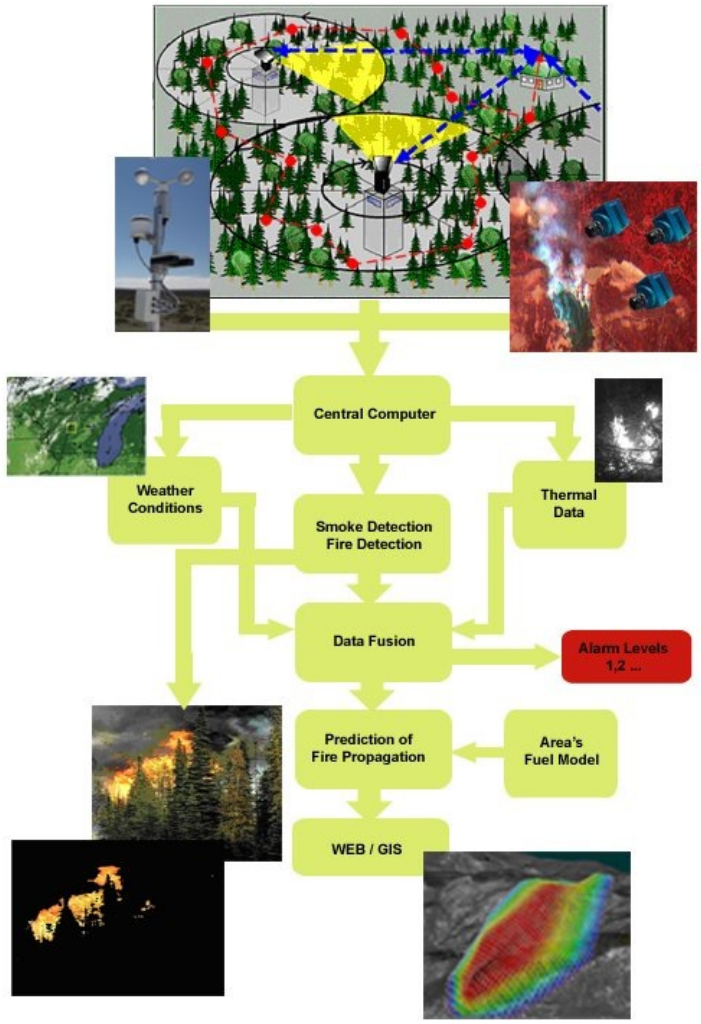
Hardware

- Small wearable sensors
- Wireless pulse oximeter / 2-lead EKG
- Based on the Mica2, MicaZ, and Telos sensor node platforms
- Custom sensor board with pulse oximeter or EKG circuitry
- Pluto mote
  - scaled-down version of the Telos
  - rechargeable Li-ion battery
  - small USB connector
  - 3-axis accelerometer



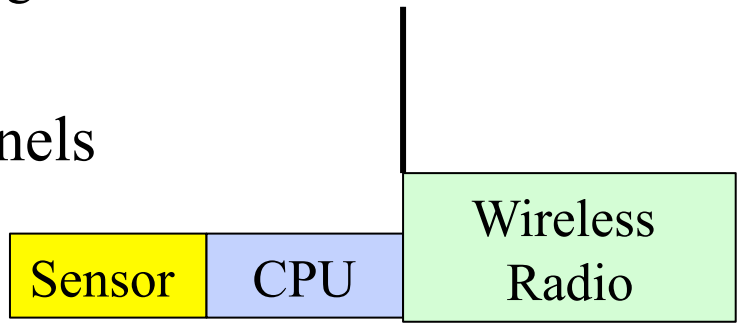
FP7 Firesense: Fire and Smoke Detection through a WSN for the Protection of Cultural Heritage Sites

- Fire Detection and Management through a Multi-Sensor Network for the Protection of Cultural Heritage Areas from the Risk of Fire and Extreme Weather Conditions



WSN Challenges

- Sensor Nodes
  - Very limited energy resources (sleep schedules)
  - Limited processing power and storage
  - Low bandwidth (bit rate)
- Unreliable communication channels
  - Battery depletion
  - Harsh environment
- Data aggregation opportunities
- Network communication model
- Routing & transport intertwined
- Network scale



Power consumption of each part

WSN Issues

- **Deployment/Coverage Issues: sensor and sink deployment**
- **Topology Control: Clustering, long term scheduling**
- **Wireless Communication Issues**

Considering power consumption for long network lifetime

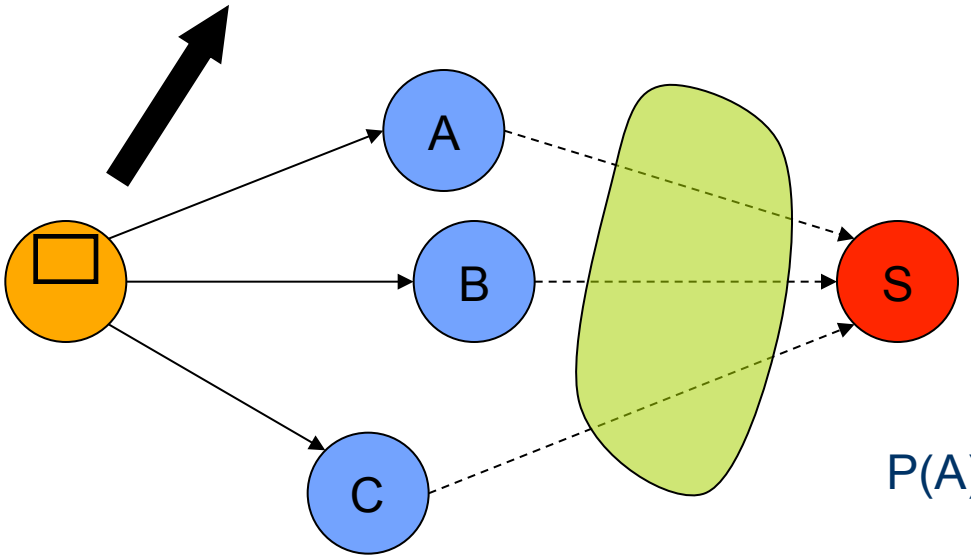
Transport/Application Layer: Reliable data delivery, data aggregation, data fusion, rate adaptation, including security
Network Layer: Addressing, convergecast routing with avoiding holes (possibly multi sink, mobile sink)
Medium Access Layer: wireless medium sharing with sleep schedules Sensor MAC protocols may involve topology control (e.g., clustering)
Physical Layer: Antennas, operation frequency, modulation

Cross layer protocols are very common in WSN!

Example: Probabilistic Routing for WSN

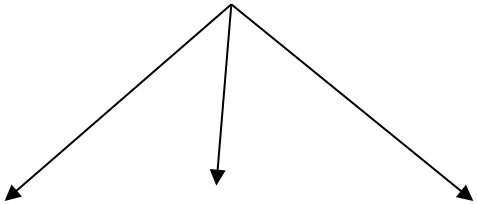
Example with Cutoff @ 150

Neighbors	A	B	C	D	E
Energy	20	40	120	185	220



P(A) = 2 P(B)

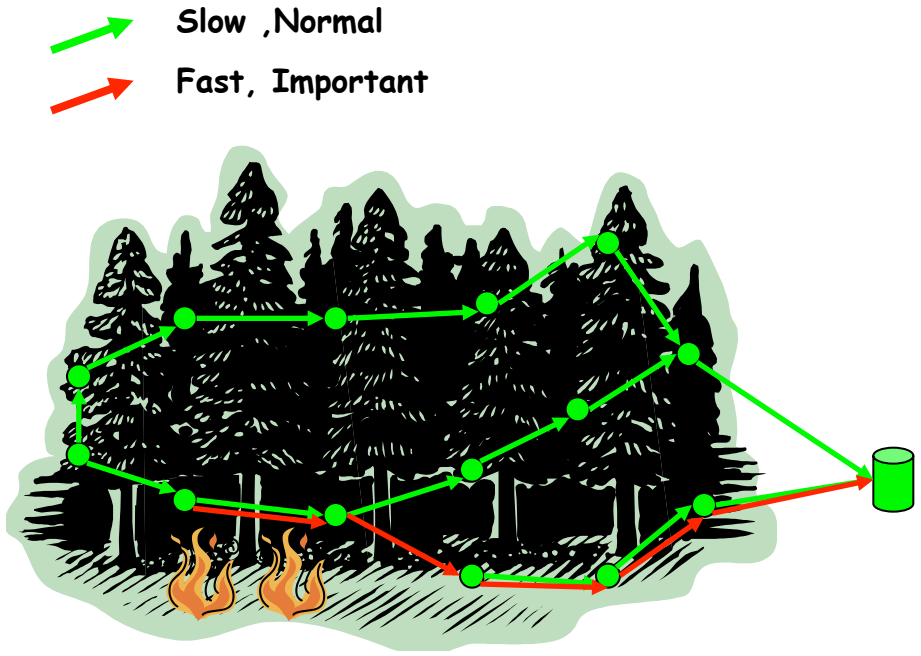
P(B) = 3 P(C)



P(A) = 0.6 P(B)=0.3 P(C)=0.1

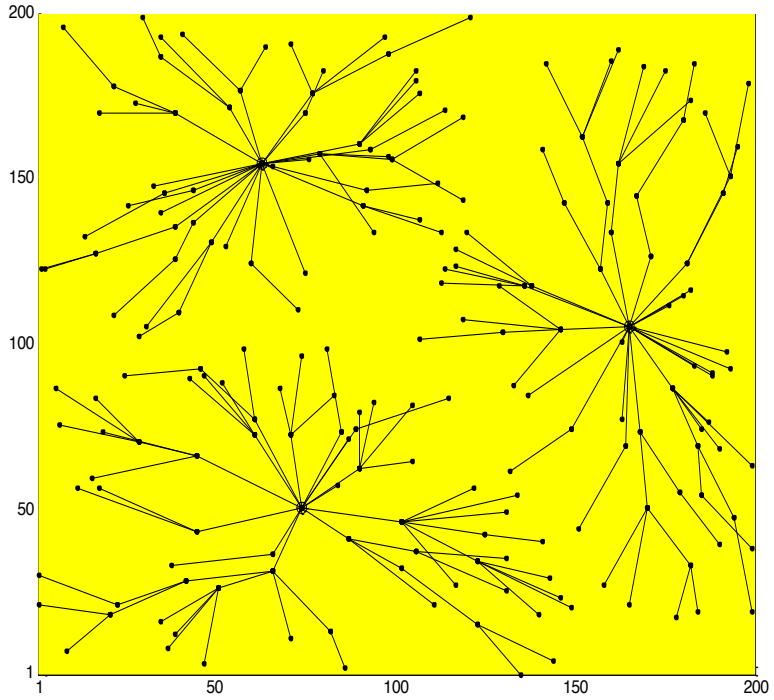
Reliable and On-Time Delivery of Critical Data in WSNs

- Mission Critical Applications
  - Border Surveillance
  - Early Fire Detection
  - Seismic Activity Monitoring
  - Health Monitoring
  - Chemical Leakage Monitoring
- Service Differentiation
- Reliability
  - Loss of any critical event is costly
- On-Time Delivery
  - Late Event = Lost Event
- Multiple sinks may be needed

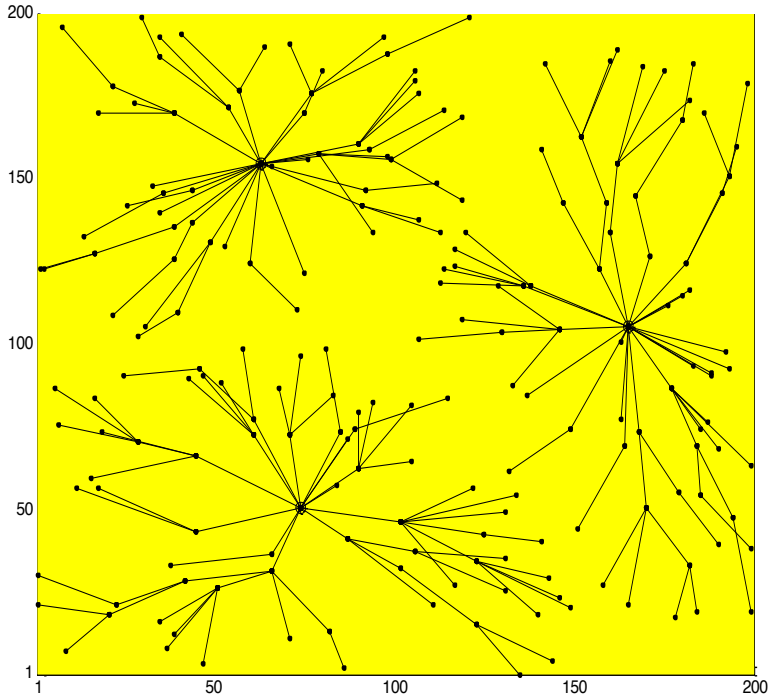


Computational Experiments / Simulations

(Matlab, OPNET, OMNET, NS-2)



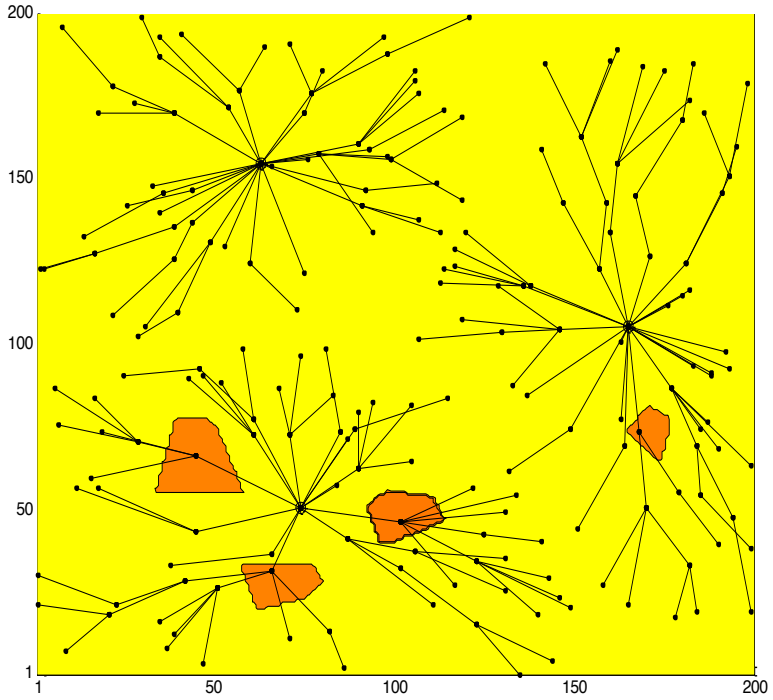
Energy map



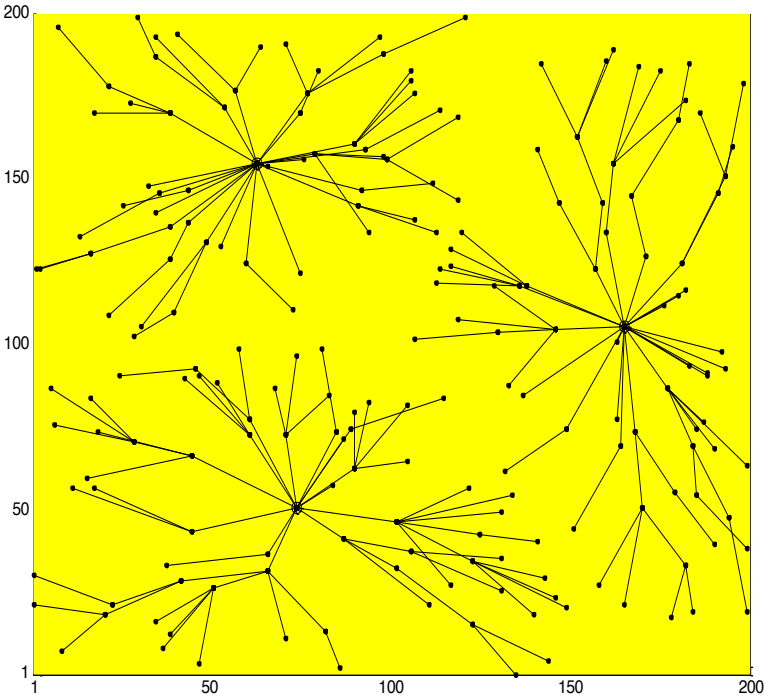
Disconnected region map

6^{th} day

Computational Experiments



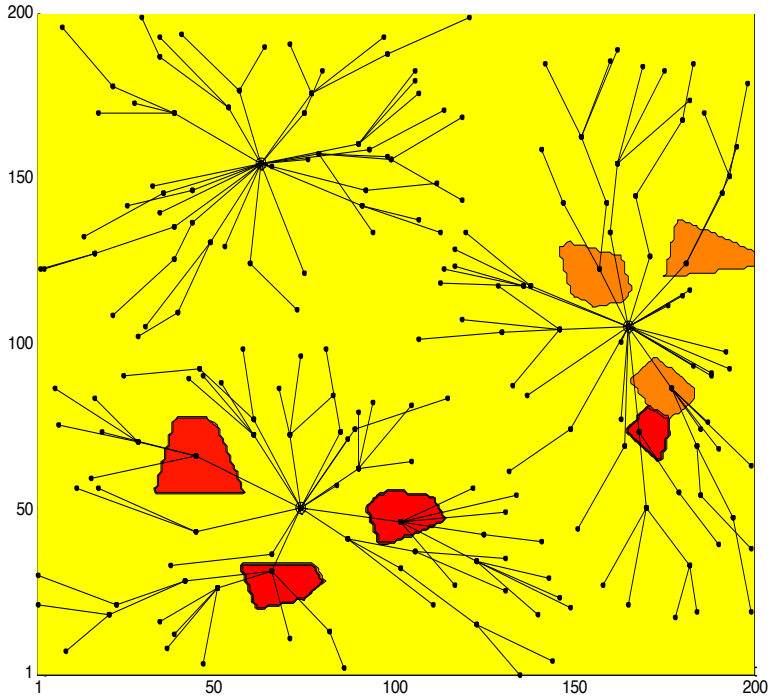
Energy map



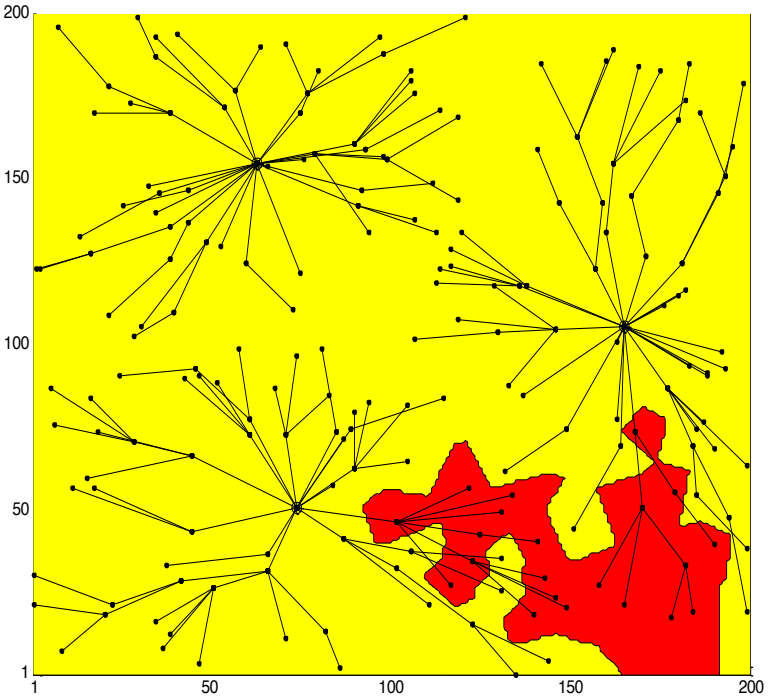
Disconnected region map

12^{th} day

Computational Experiments



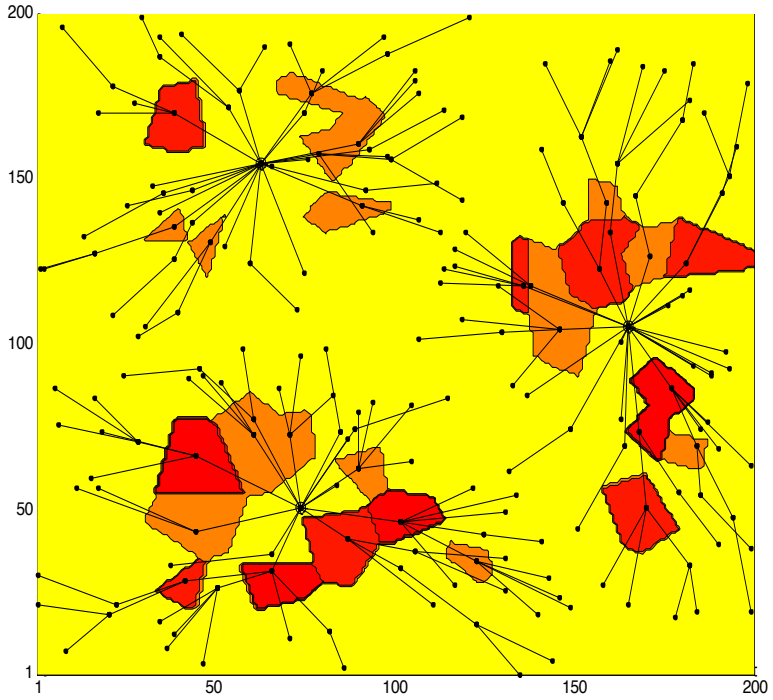
Energy map



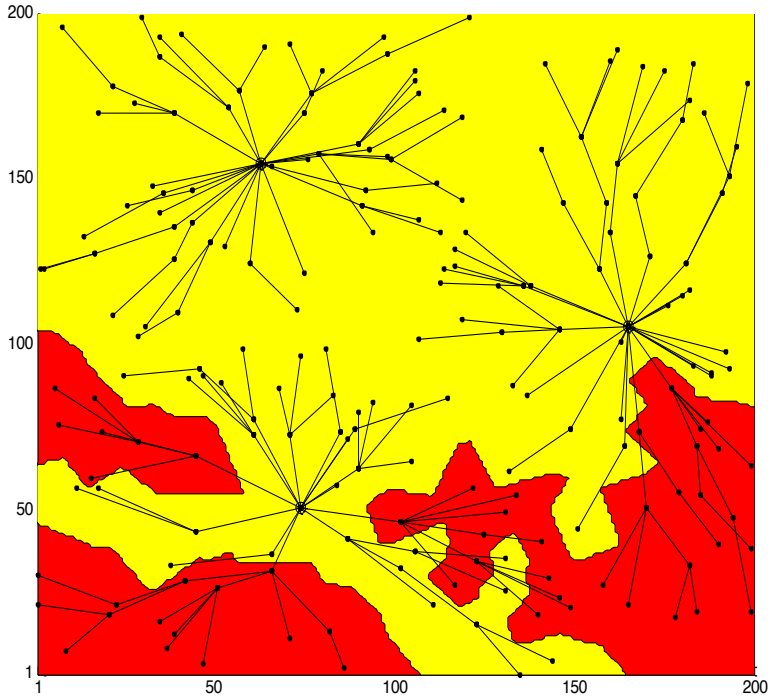
Disconnected region map

18^{th} day

Computational Experiments



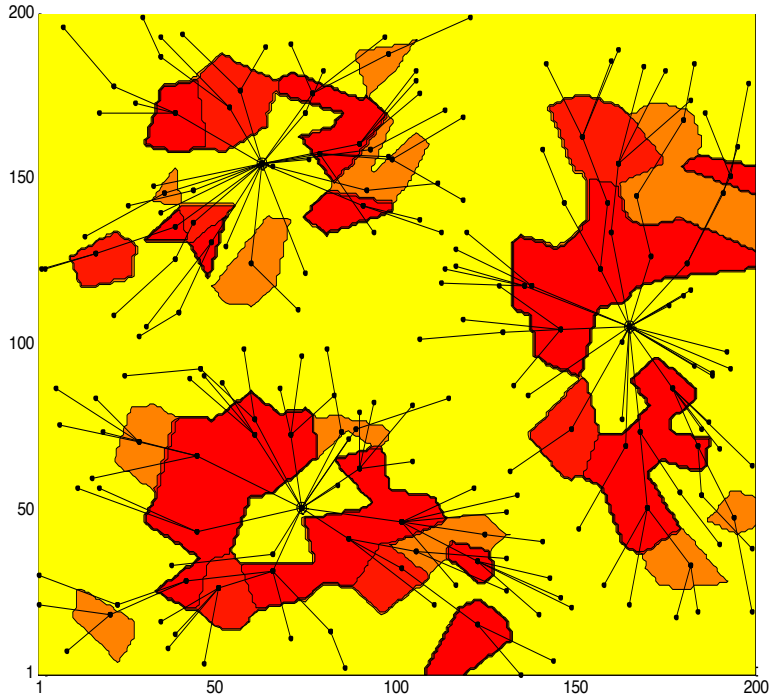
Energy map



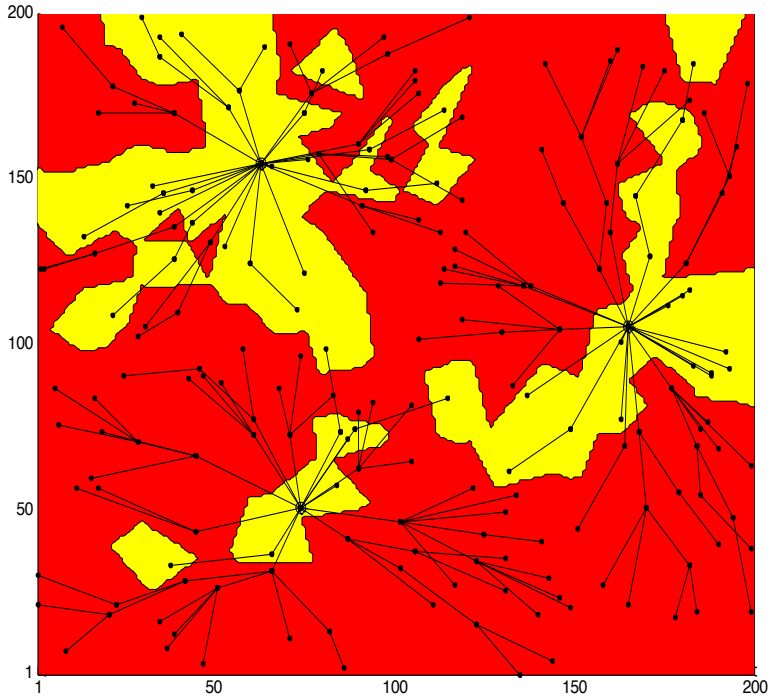
Disconnected region map

30^{th} day

Computational Experiments



Energy map

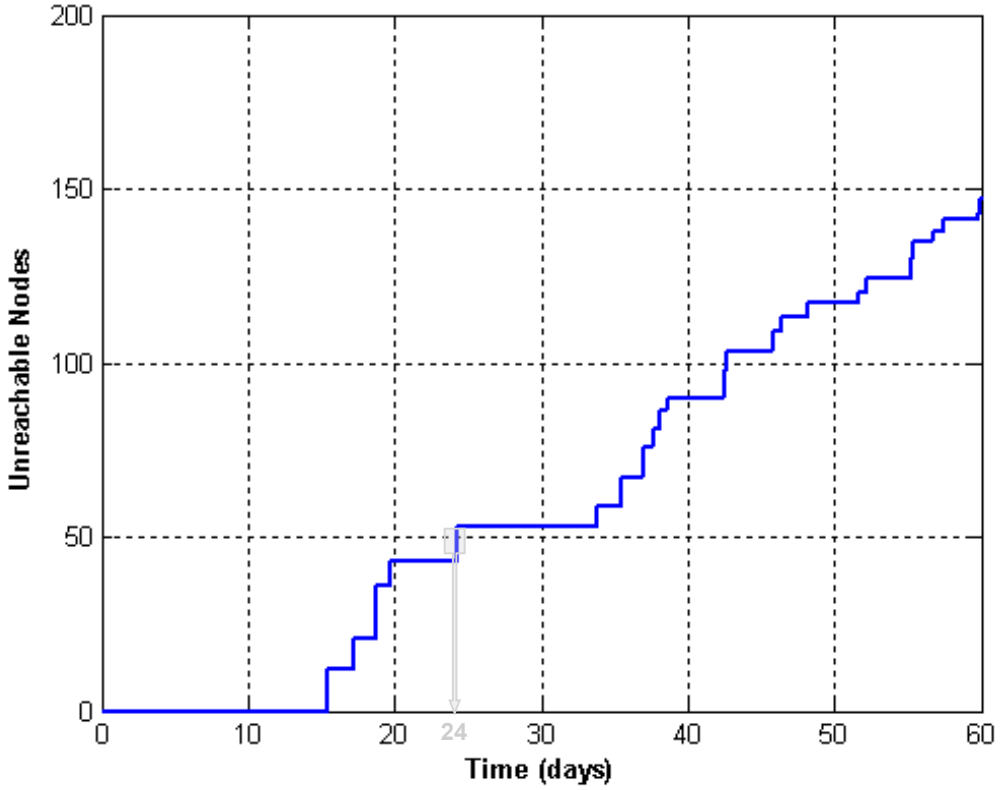


Disconnected region map

60^{th} day

Computational Experiments

- Unreachable nodes versus time

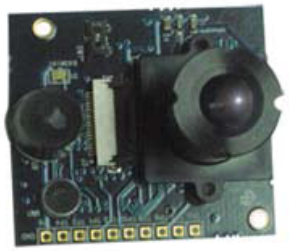


Other Issues / Types of WSN

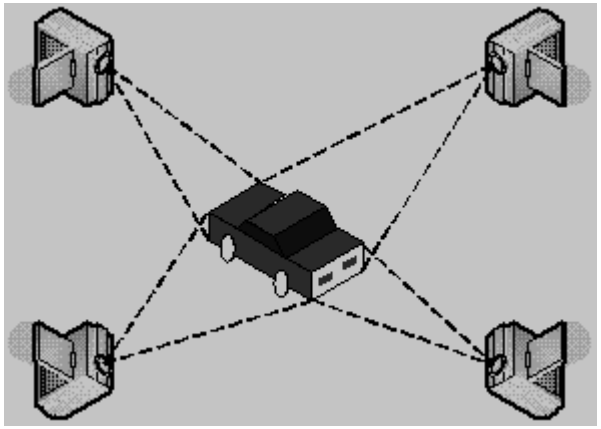
- Combined RFID and sensor nodes
- Wakeup radios for very low power WSN operation
- Acoustic underwater WSN
- Underground WSN
- Mobile sensors and mobile sinks
- Multimedia WSN

Multimedia Wireless Sensor Networks

- Low-cost multimedia devices
  - CMOS cameras
  - Microphones



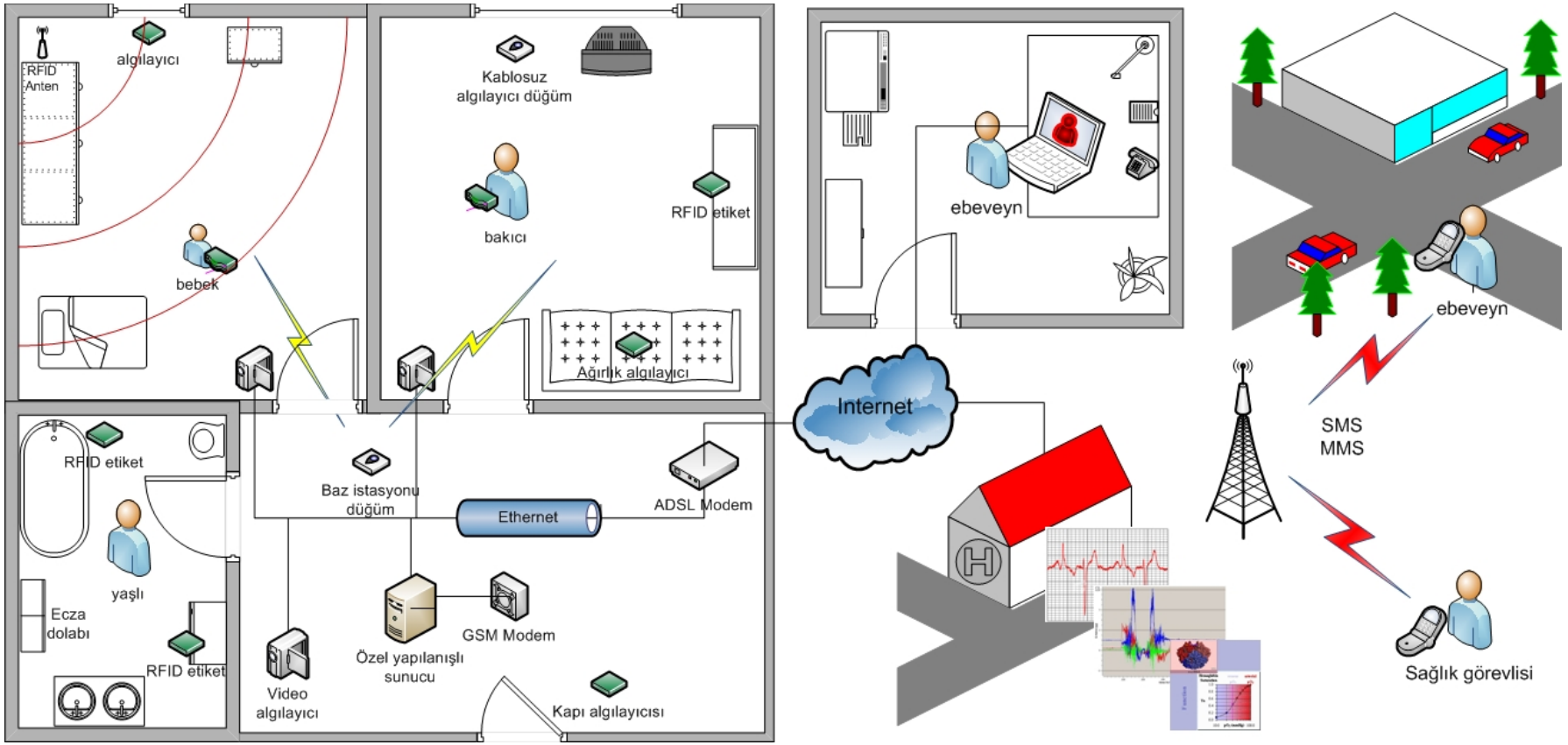
- Sensor nodes attached with a multimedia device
- Provides multiple point of view perception
- Increases the reliability of the application



Additional Challenges in MWSNs

- **Quality of Service** (QoS) perspective
- **High volume of data** compared to traditional WSNs
  - Scalar data packets: double values + packet header
  - Video data packets: ~ 1 kbit + packet header
- **Congestion**: Reliability ↘ , Latency ↗ , Energy Exp. ↗
- Load balancing as a solution
- Cross Layer Forwarding Techniques
  - Local load balancing
  - Direction-based (spatial) load balancing
  - Load distribution to multiple sinks

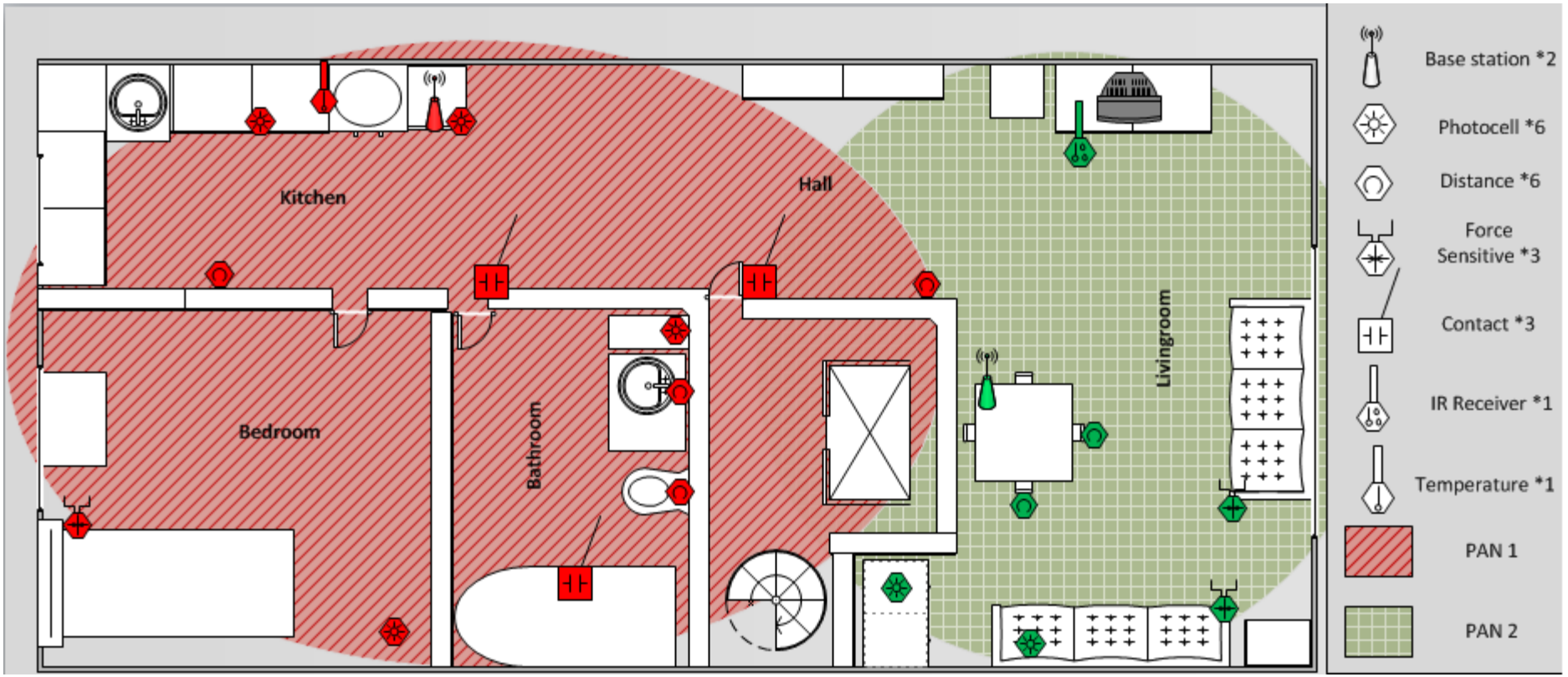
Child and Elderly Care using MWSN



Activity Recognition with Ambient WSN

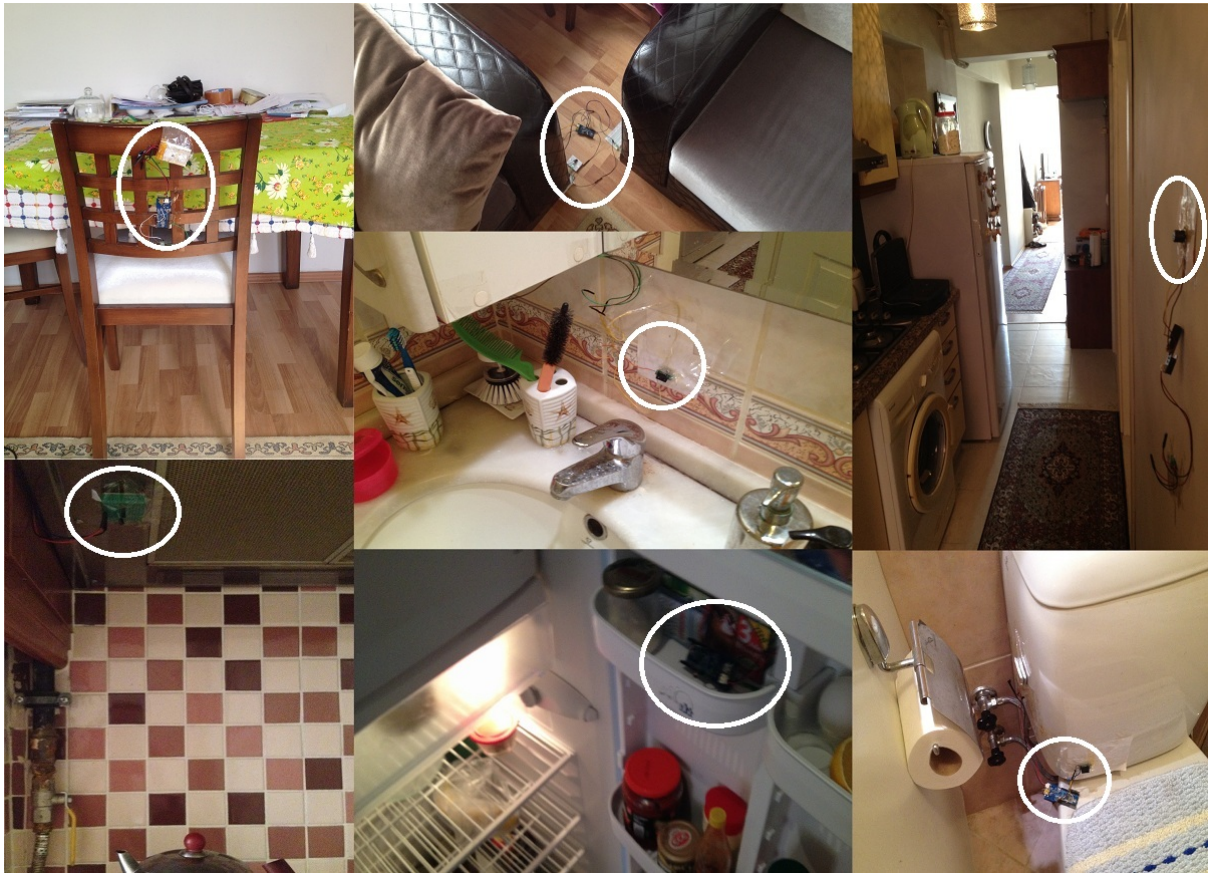
- Real world setting in real homes
- Publicly available for the community
  - http://www.cmpe.boun.edu.tr/aras/
- Annotated (by the residents)
  - Develop & evaluate novel machine learning models
- Multiple residents
- Rich data set
  - 2 Houses, 20 sensors, 30 days in each house
  - 27 activities
  - 1023 – 2177 activity labels
  - 26 million sensor readings
  - Seconds resolution

HOUSE A - Layout



Multimodal Sensors in House A

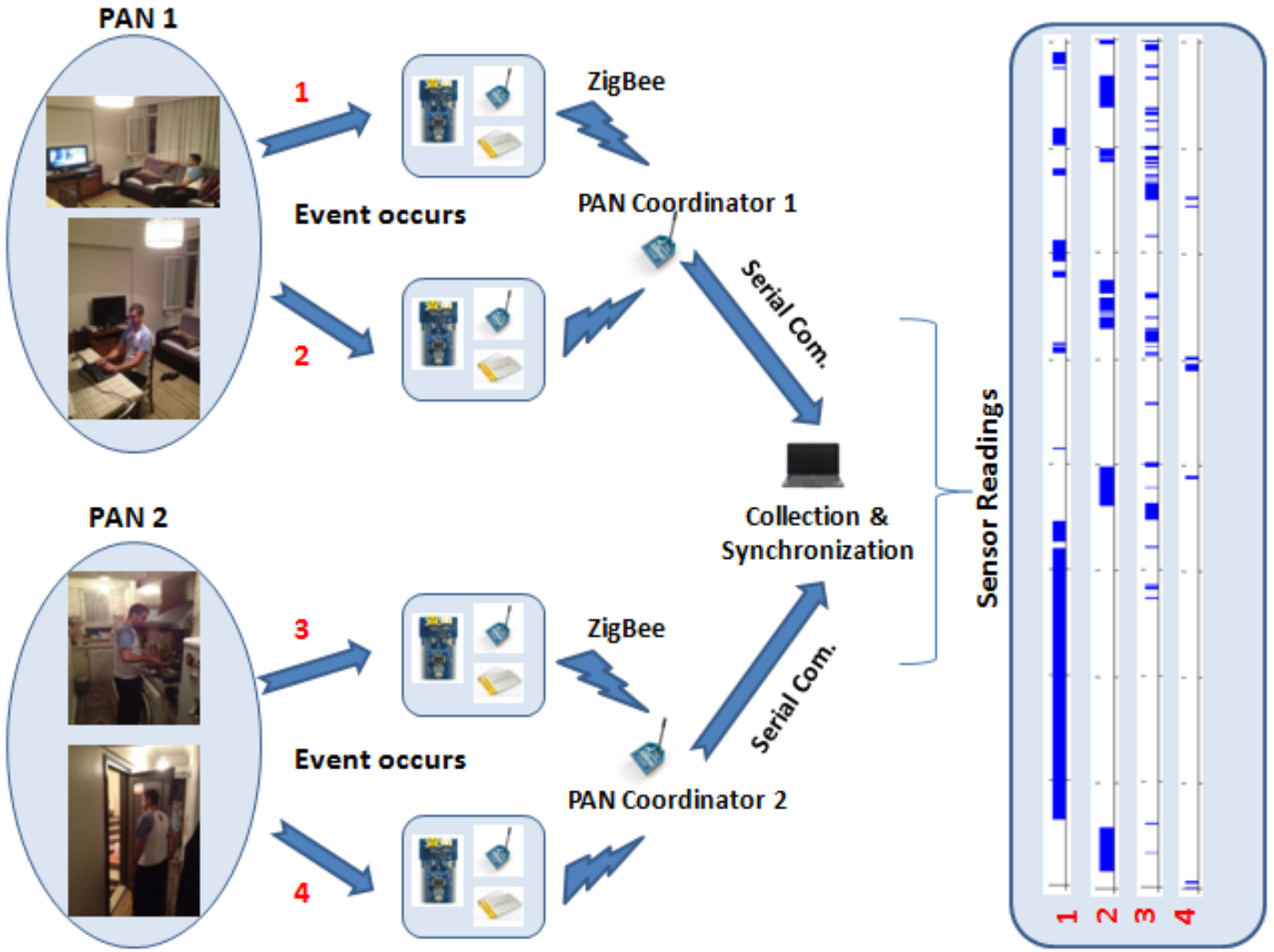
- 50 m^2
- Single bedroom, living room, kitchen, bathroom
- 25 years old 2 males



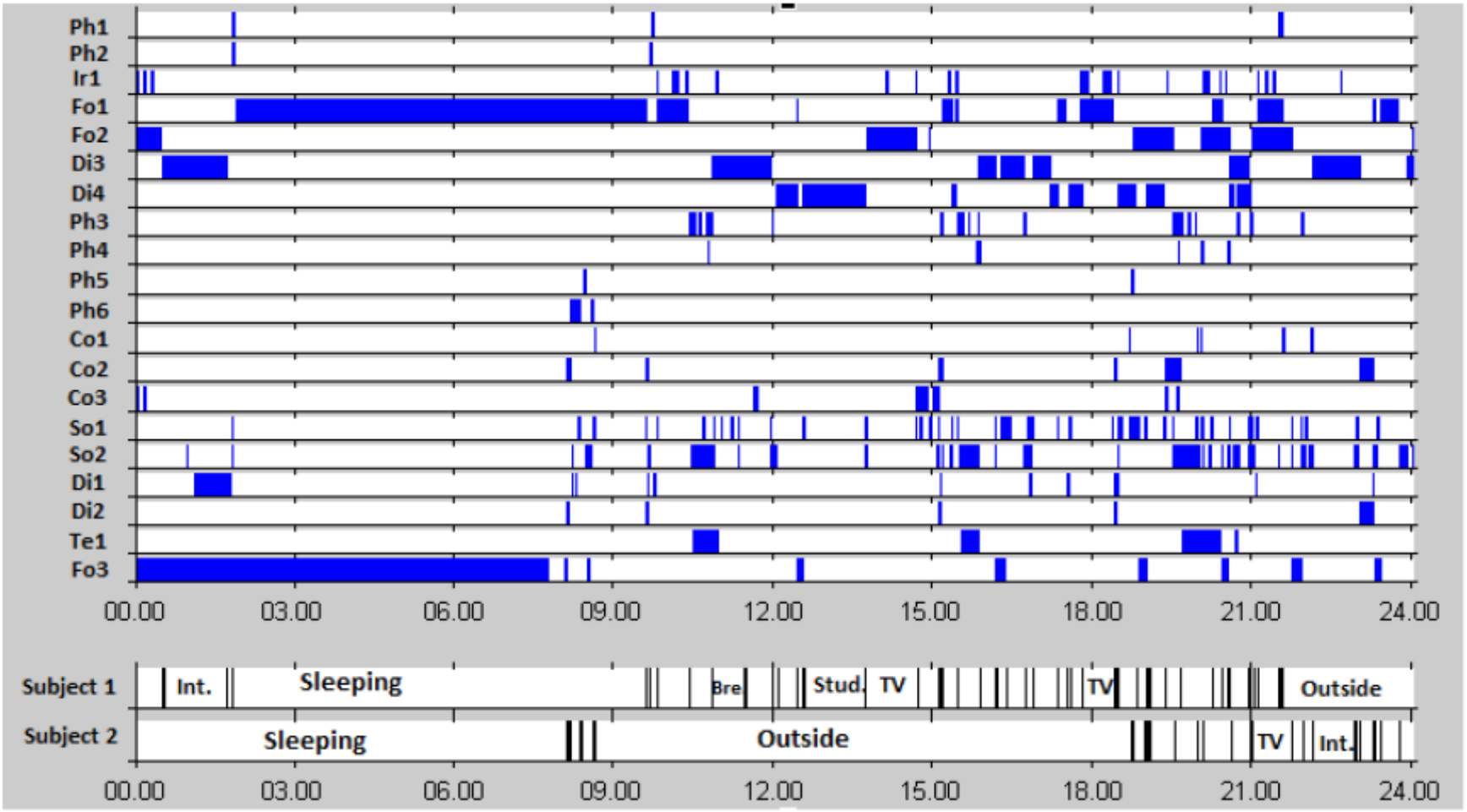
Multimodal Sensors in House B

- 90 m^2
- 2 bedrooms, living room, kitchen, bathroom
- Married couple, age average 34

AAL WSN System Overview



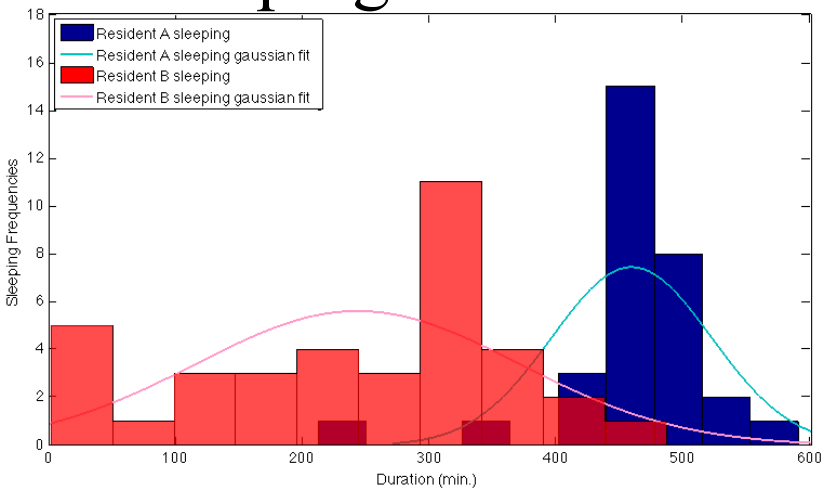
Sensor Readings and Annotation



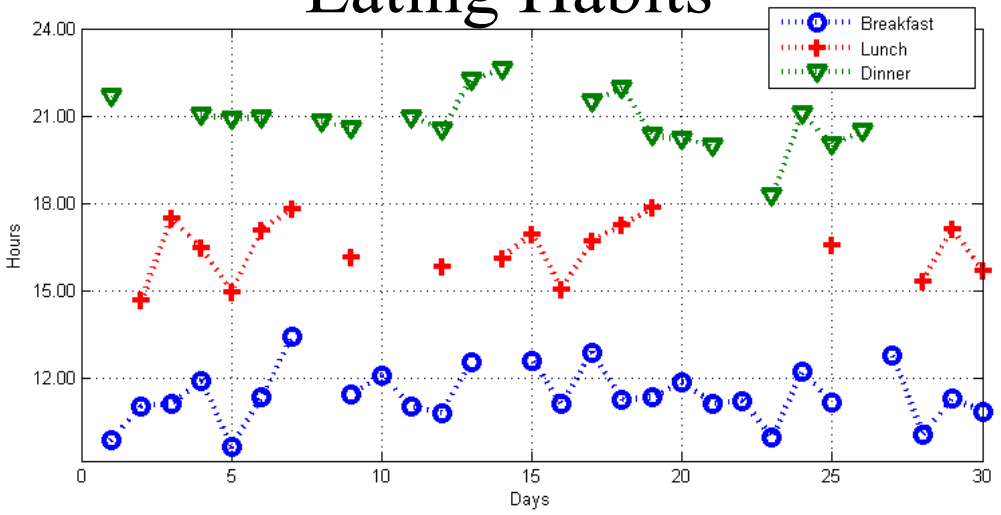
What can the data tell you?

- What is normal for an individual not necessarily living alone?
  - Long term monitoring with automatic recognition of the ADL

Sleeping Duration



Eating Habits



Smartphones as Sensor Nodes
Urban/Opportunistic/Participatory Sensing

Target Applications

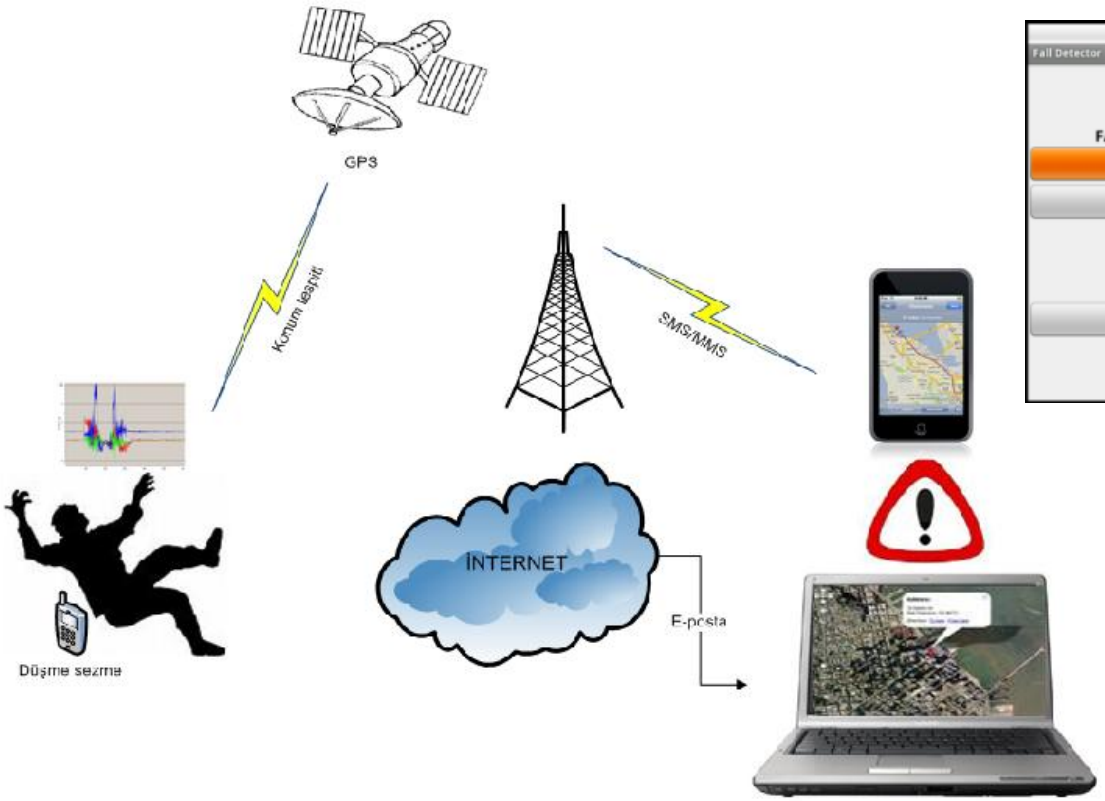
- *Medical Applications*
- *Home monitoring & Assisted Living*
- *Sports & Leisure Applications*

Urban participatory sensing examples:

- Noise map of the city
- Current weather (sky) in a country

Fall Detector Application on a Smartphone

Tracking of patients with neurodegenerative diseases, e.g. epilepsy



For Further Communications

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