Chapter 2: Applications

CENX 534 : Sensor networks
Prof: Sami S Alwakeel

Military Applications:

Command, Control, Communications, Computing, Intelligence, Surveillance, Reconnaissance, Targeting (C4ISRT)

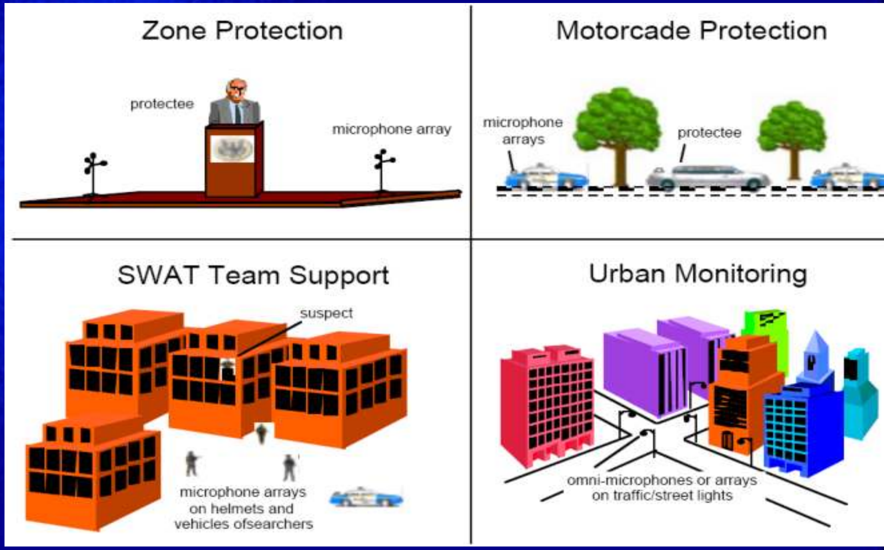
- Monitoring friendly forces, equipment and ammunition
- Battlefield surveillance
- Reconnaissance of opposing forces and terrain
- Targeting
- Battle damage assessment
- Nuclear, Biological and Chemical (NBC) attack detection and reconnaissance

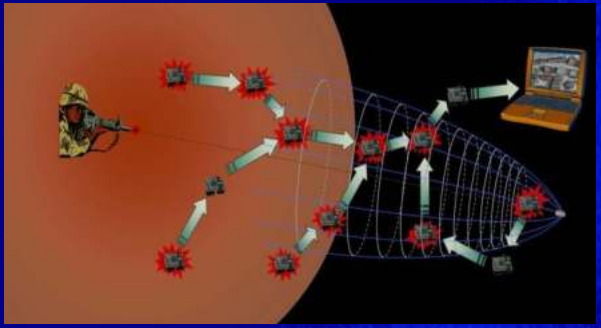
Sniper Detection

- BBN Boomerang
  - Currently deployed in Iraq
  - Humvee-mounted tetrahedral arrays to sense muzzle blast and shockwave

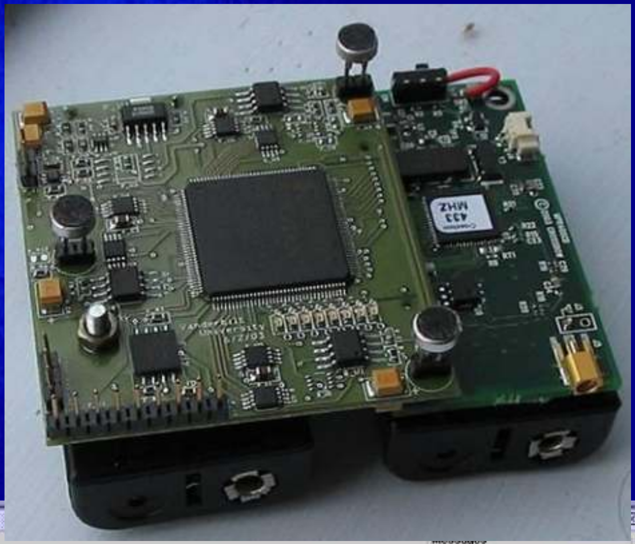
Sniper Detection via WSNs

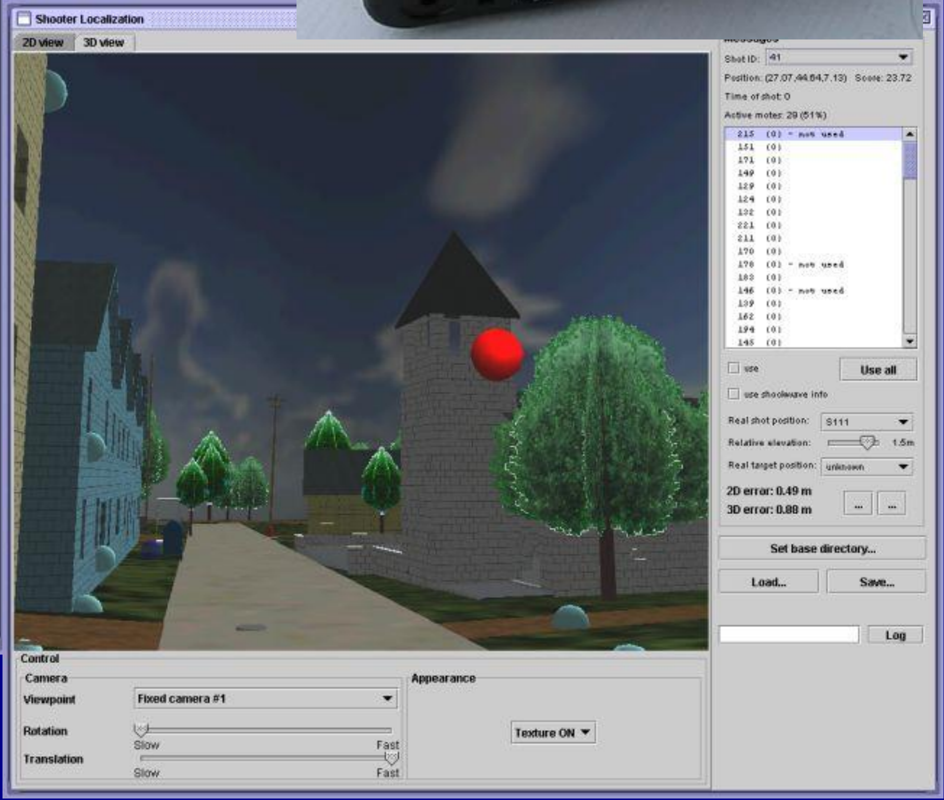
- Boomerang relies on a single point of detection
- Possible scenarios
- PinPtr
  - Use a spatially distributed WSN to detect snipers





PinPtr in Action





Further Military Applications

- Intrusion detection (mine fields)
- Chemical (biological) attack detection
- Targeting and target tracking systems
- Enhanced navigation systems
- Battle damage assessment system
- Enhanced logistics systems

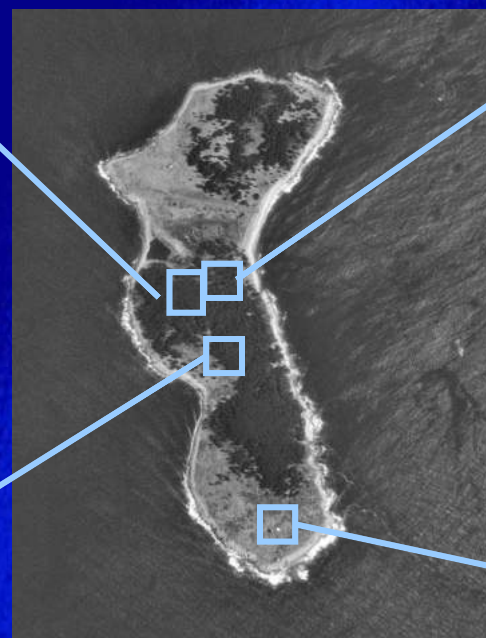
Environmental Applications

- Tracking the movements of birds, small animals, and insects
- Monitoring environmental conditions that affect crops and livestock
- Irrigation
- Earth monitoring and planetary exploration
- Chemical/biological detection
- Biological, Earth, and environmental monitoring in marine, soil, and atmospheric contexts

Environmental Applications

- Meteorological or geophysical research
- Pollution study
- Precision agriculture
- Biocomplexity mapping of the environment
- Flood detection, and Forest fire detection.

Habitat Monitoring
Great Duck Island in Maine



Habitat Monitoring

- Approx. 200 nodes including MICA, MICA2, burrow nodes (with IR) and weather station nodes
- Motes detect light, barometric pressure, relative humidity and temperature conditions.
- An infrared heat sensor detects whether the nest is occupied by a seabird, and whether the bird has company.

Habitat Monitoring

- Motes within the burrows send readings out to a single gateway sensor above ground, which then wirelessly relays collected information to a laptop computer at a lighthouse (~350 feet).
- The laptop, also powered by photovoltaic cells, connects to the Internet via satellite.
- Computer at base-station logs data and maintains database

ZebraNet

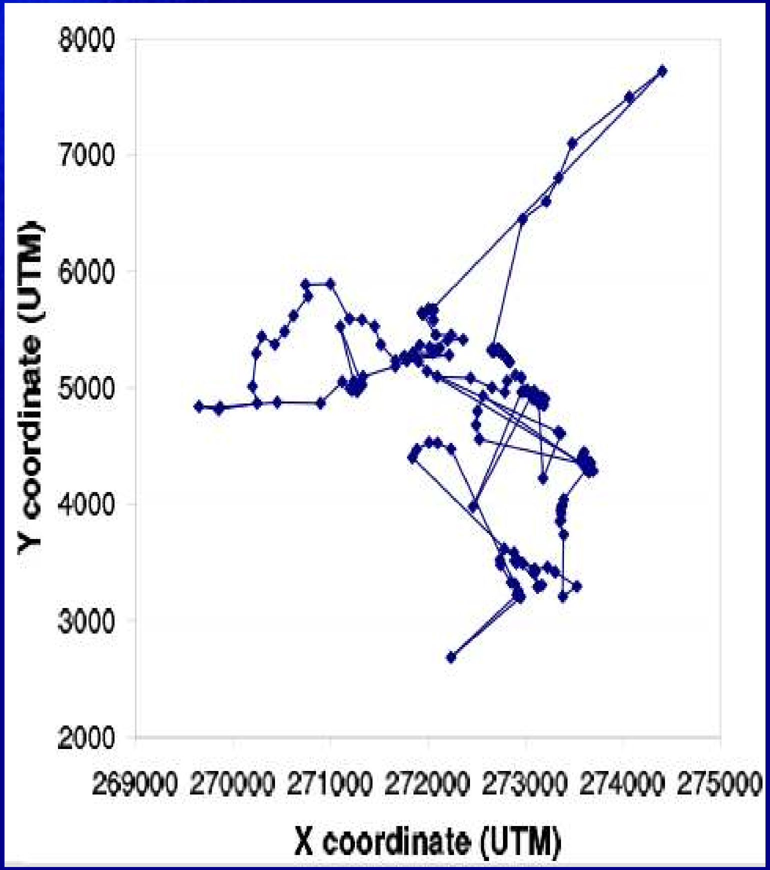
http://www.princeton.edu/~mrm/zebranet.html

- Animal Tracking – Use collars with GPS to monitor the walking patterns of zebras in Kenya
  - Collect detailed, accurate position logs of each zebra
  - Have a high data recovery rate
  - Autonomous Operation

ZebraNet

http://www.princeton.edu/~mrm/zebranet.html

- Nodes obtain GPS reading every 8 minutes
- Nodes send information over radio (multi-hop) every 2 hours
- All data logged to onboard flash (local and received)

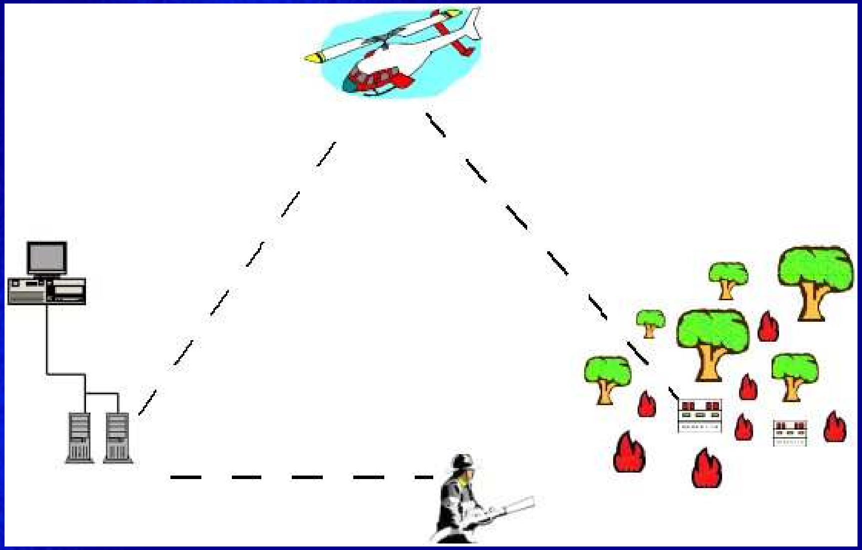


Forest Fire Detection: Firebug
http://firebug.sourceforge.net/

- Design and Construction of a Wildfire Instrumentation System using Networked Sensors
- Network of GPS-enabled, wireless thermal sensors
- FireBug network self-organizes into edge-hub configurations
- Hub motes act as base stations

Firebug

- Firebug - mote/fireboard pair
- Mote - Crossbow MICA board
- Fireboard - Crossbow MTS420CA
  - Temperature and humidity sensor.
  - Barometric pressure sensor.
  - GPS unit.
  - Accelerometer
  - Light Intensity Sensor



Firesensorsock

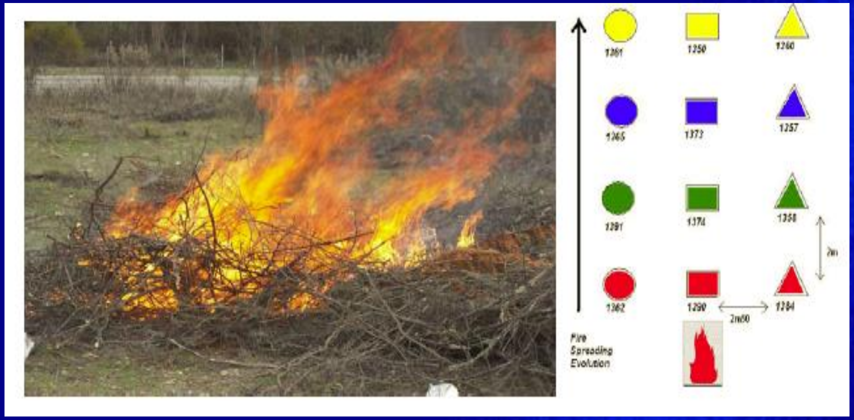
http://www.mdpi.com/1424-8220/9/8/5878/pdf

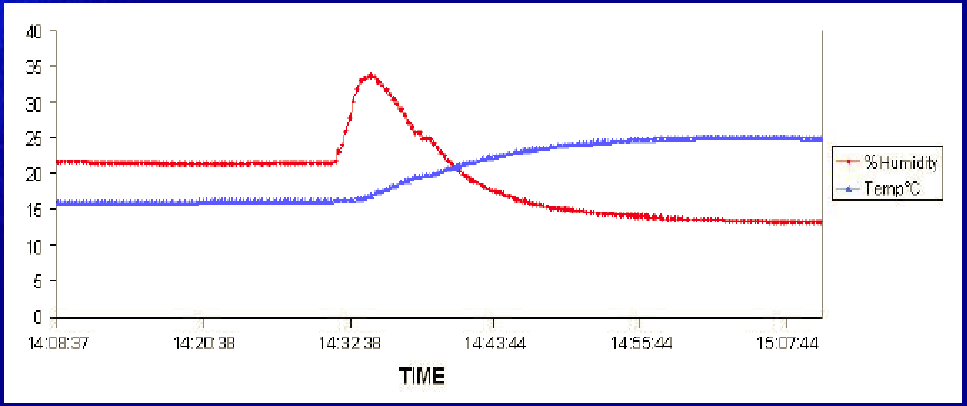
- Fire detection at the coast of France (U. of Corsica)
- 3 purposes
  - Sensing thermal data in the open
  - Detecting a fire i.e., the its spatial position
  - Tracking the fire spread during its spatial and temporal evolution
- Problem: How do you detect fire without being affected by it?
- Solution: Firesensorsock
  - Protection to dampen the thermal impact
  - Allow both a continuous emission of data and the temperature
  - Hygrometry inside the sock should vary on short time scales for locating the fire’s position

Firesensorsock

http://www.mdpi.com/1424-8220/9/8/5878/pdf

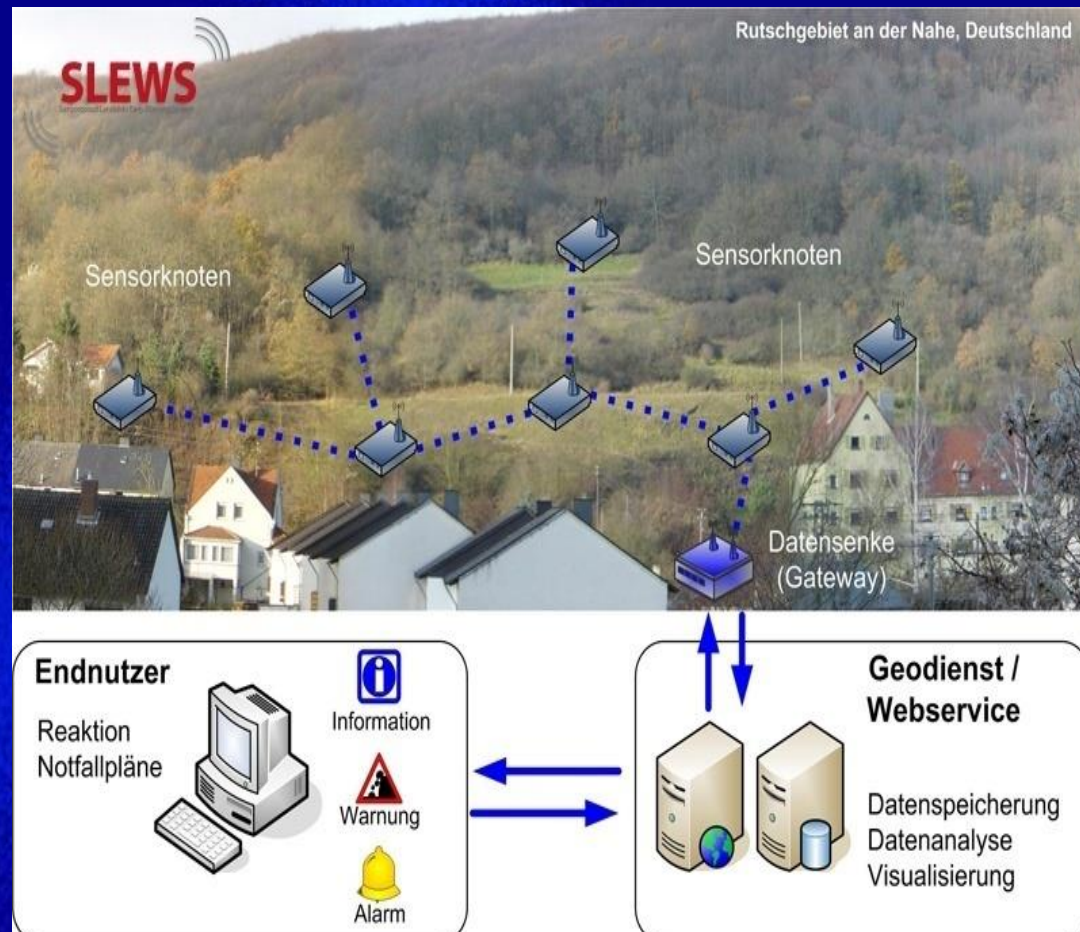
- Use MICA motes and MTS420 GPS enabled sensors





A Sensor-based Landslide Early Warning System (SLEWS)

http://www.slews.de/



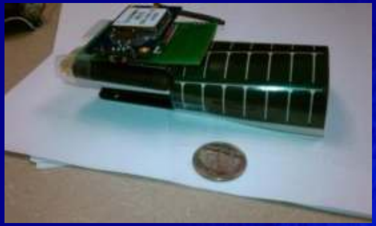
A Sensor-based Landslide Early Warning System (SLEWS)

http://www.slews.de/

Monitoring Environment Behavior

http://cpn.unl.edu

Combining Sensor Networks with Advanced Monitoring techniques



Disaster Relief / Rescue Operations

- Drop sensor nodes over unknown area
- Measure parameters (temperature, gas, radiation...)
- Determine precise situation on ground

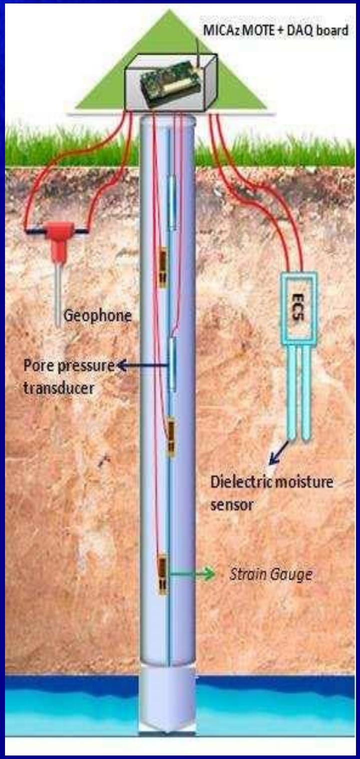
Disaster Relief / Rescue Operations

- Drop nodes during rescue, extend transmission range, forward health status of helpers
  - Monitor pressure, temperature, gas
  - Non-invasive monitoring of body temperature to determine the Physiological Stress Index
  - All parameters transmitted via ad-hoc deployed WSN

AMRITA WSN System for Landslide Detection

http://www.amrita.edu/Winsoc/Amritawsnsl.html

- Landslide detection system using WSN at Munnar, Idukki, Kerala, India
- WSN in combination with Wi-Fi and satellite technology
- Multiple sets of geophysical sensors inside a column
  - 5 -6 m buried in the earth



AMRITA WSN System for Landslide Detection

http://www.amrita.edu/Winsoc/Amritawsnsl.html

- Data retrieved using spatially distributed WSN
- Wireless sensor nodes forward data on to a Gateway
- Gateway sends data via a directional Wi-Fi link to a Field Data Management Center (FMC)
- Finally collected at a Data Management Center (DMC) through a satellite link 252 km away from the deployment field

Preventive Maintenance on an Oil Tanker in the North Sea: The BP Experiment

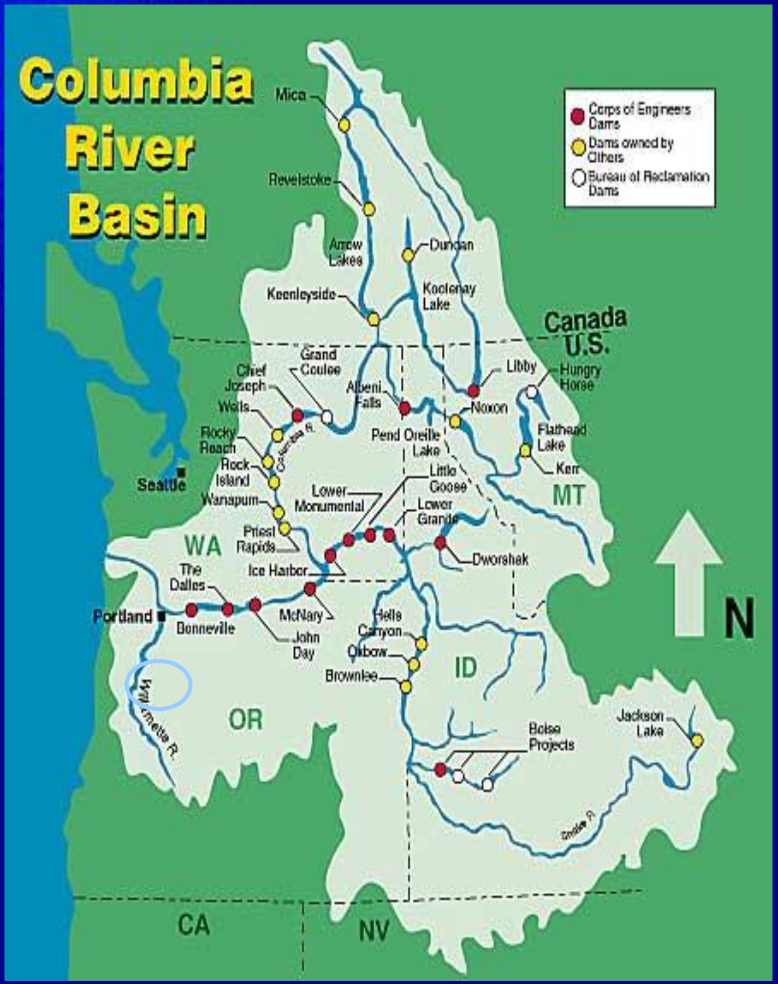
- Collaboration of Intel & BP
- Use of sensor networks to support preventive maintenance on board an oil tanker in the North Sea.
- A sensor network deployment onboard the ship
- System gathered data reliably and recovered from errors when they occurred.
- The project was recognized by InfoWorld as one of the top 100 IT projects in 2004

Energy Monitoring Pilot

- Honeywell Service: monitor, analyze and reduce power consumption
- Problem: >> $100/sensor wiring cost
- Solution: WSN
  - Entire network installed in 3 hours (vs. 3-4 days)
  - 9 min/sensor
  - Software developed in 2 weeks (XML interface)
  - 12 months, 99.99%

Observation and Forecasting System for the Columbia River

http://www.ccalmr.ogi.edu/CORIE/



Health Applications

- Providing interfaces for the disabled
- Integrated patient monitoring
- Diagnostics
- Telemonitoring of human physiological data
- Tracking and monitoring doctors and patients inside a hospital and drug administration in hospitals

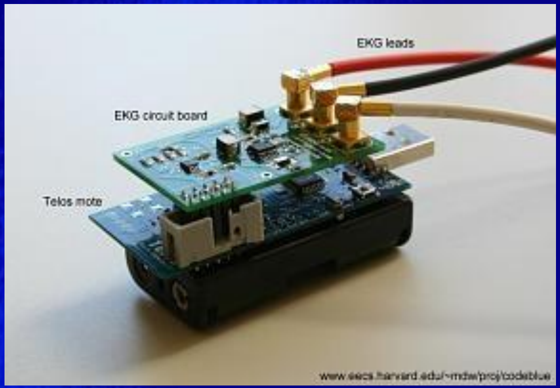
CodeBlue: WSNs for Medical Care

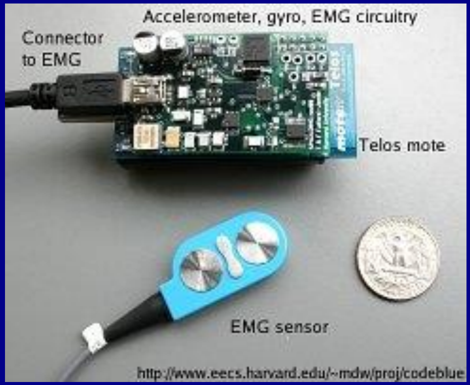
http://fiji.eecs.harvard.edu/CodeBlue /

- 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





CodeBlue: WSNs for Medical Care

- Pluto mote
  - Scaled-down version of the Telos
  - Rechargeable Li-ion battery
  - Small USB connector
  - 3-axis accelerometer

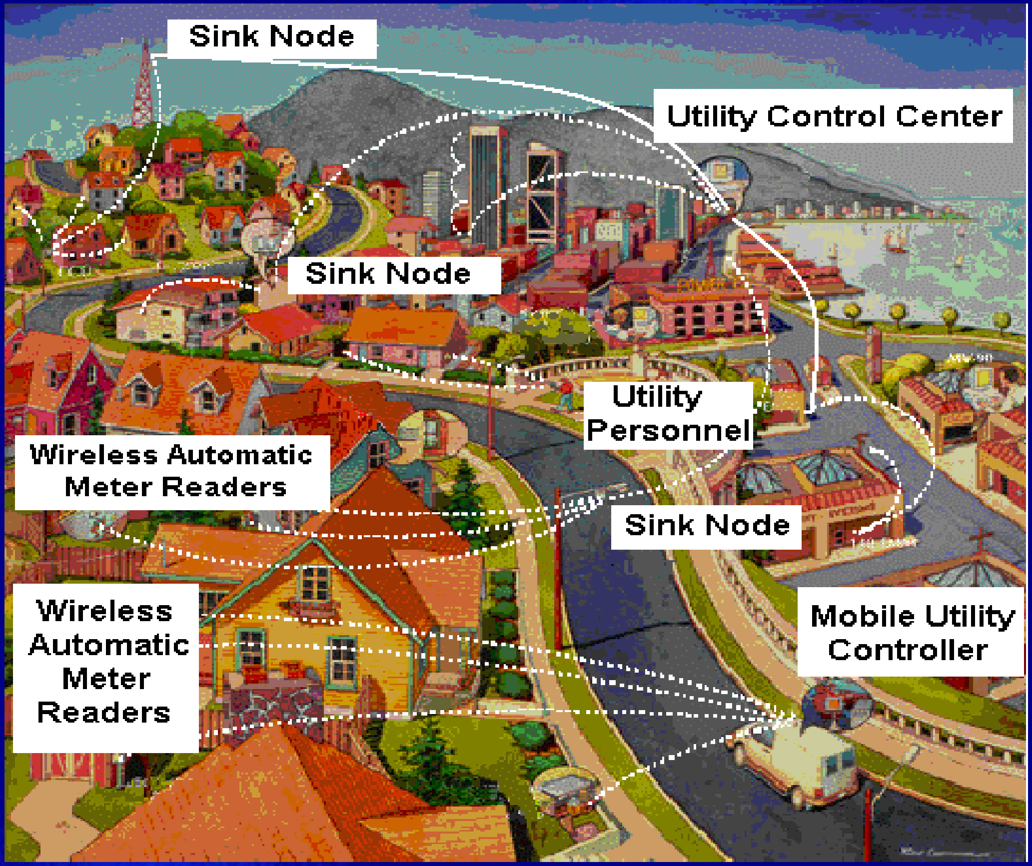
CodeBlue: WSNs for Medical Care

- Intel SHIMMER mote
  - CC2420 IEEE 802.15.4 radio
  - Rechargeable Li-polymer battery
  - MicroSD slot supporting up to 2 GBytes (More than 80 days of data)
  - Optional Bluetooth radio

CodeBlue: WSNs for Medical Care

- CodeBlue - scalable software infrastructure for wireless medical devices
- Heart rate (HR), oxygen saturation (SpO2), EKG data monitored
- Relayed over a short-range (100m)
- Receiving devices - PDAs, laptops, or ambulance-based terminals
- Data can be displayed in real time and integrated into the developing pre-hospital patient care record
- Can be programmed to process the vital sign data (and provide alerts)

Wireless Automatic Meter Reading (WAMR) Systems for Power Utilities

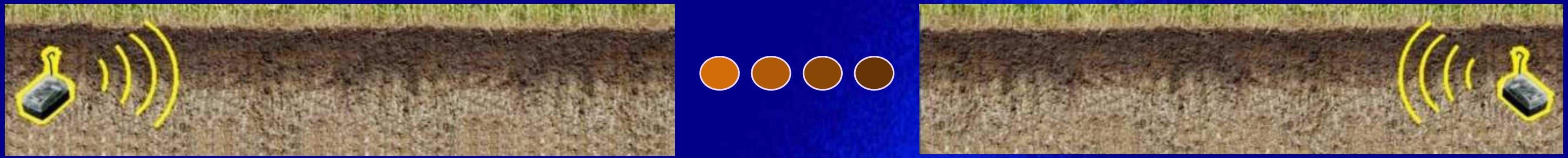


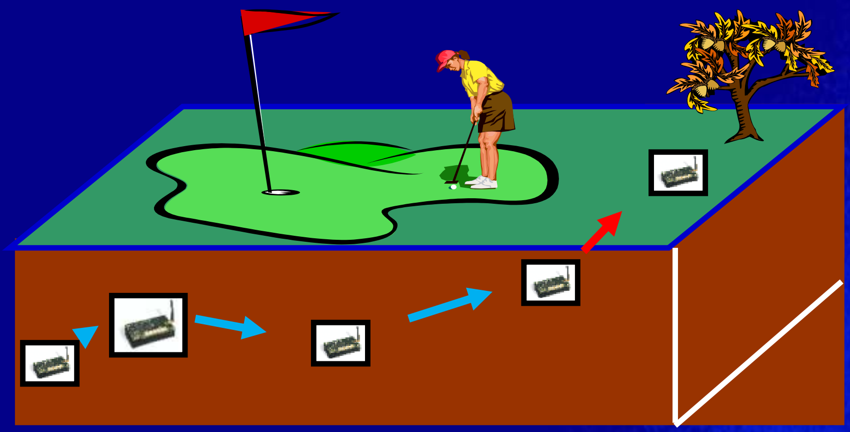
Wireless Automatic Meter Reading (WAMR) Systems

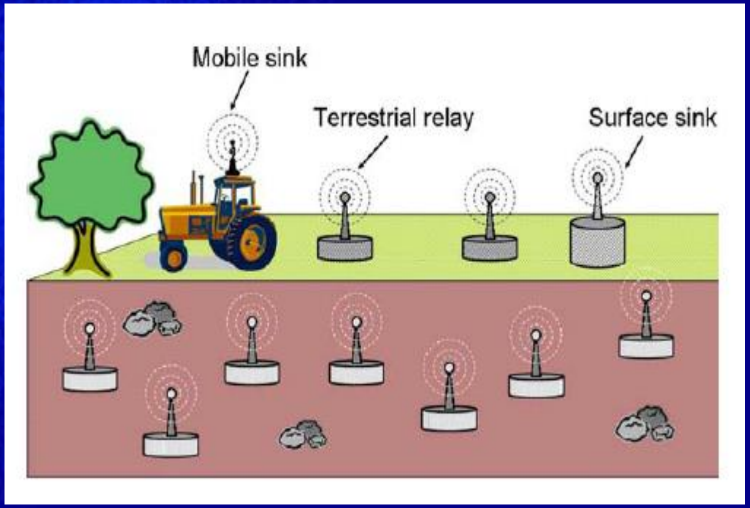
- Automatic meter reading functionalities:
  - Real-time energy consumption statistics
  - Effective billing management
- Telemetry functionalities:
  - Remote control of equipment
- Dynamic configuration functionality:
  - Self-configuration of the network in case of route failures
- Status monitoring functionality:
  - Monitoring the status of the metering devices

Wireless Underground Sensor Networks

I.F. Akyildiz, E.P. Stuntebeck. "Wireless underground sensor networks: Research challenges," *Ad Hoc Networks (Elsevier)*, November 2006.

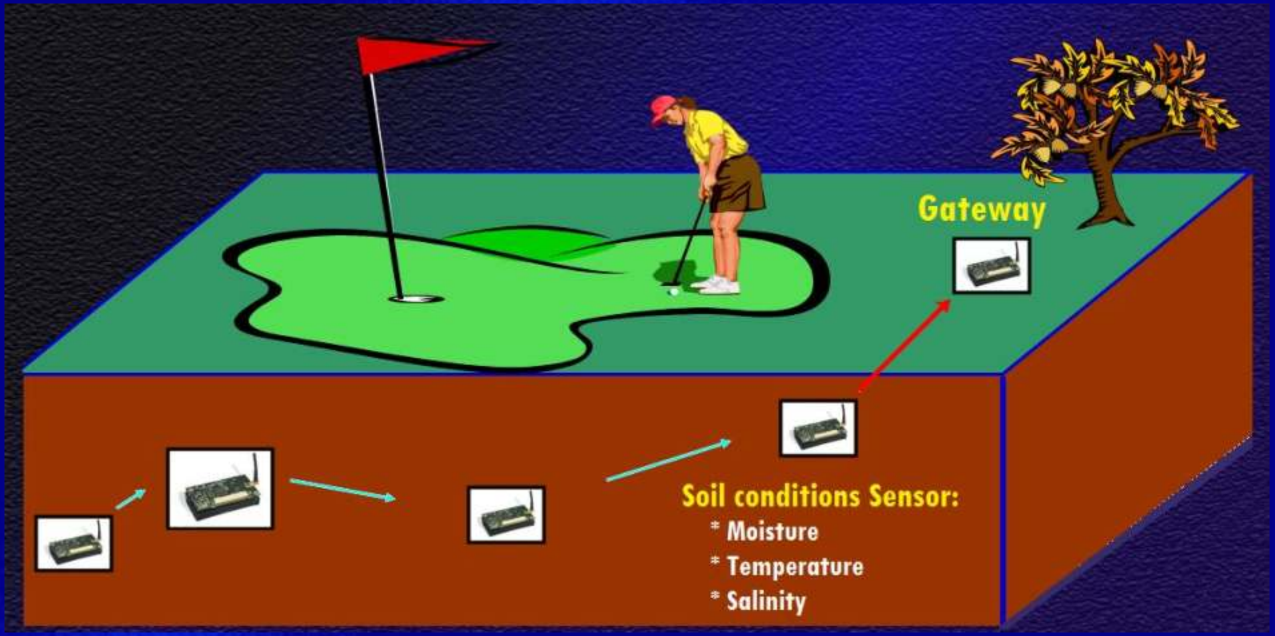






- **Tiny computers capable of wireless communication**
- **On-board sensing capabilities (soil moisture, temperature, salinity, etc…)**
- **Communication through soil**

Potential Applications of WUSNs



Sports field irrigation

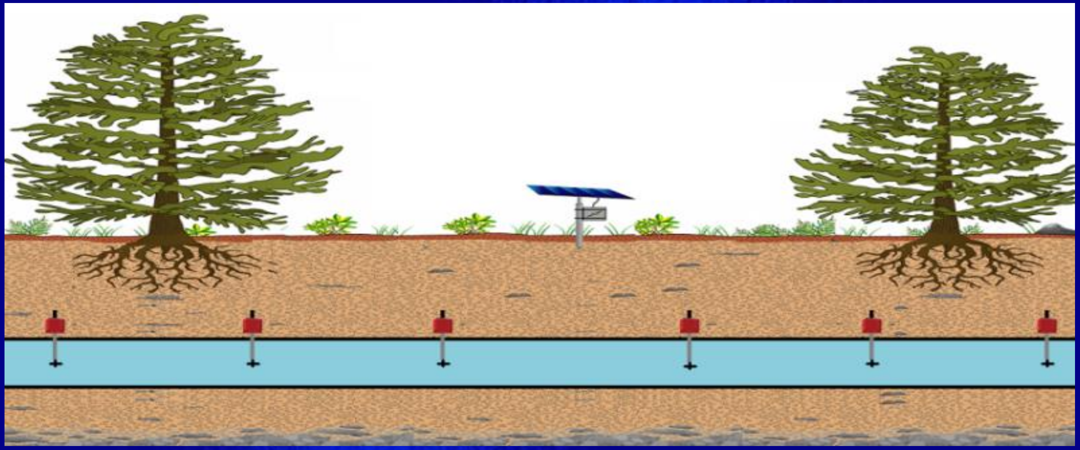
Precision agriculture

Potential Applications of WUSNs

Landslide monitoring

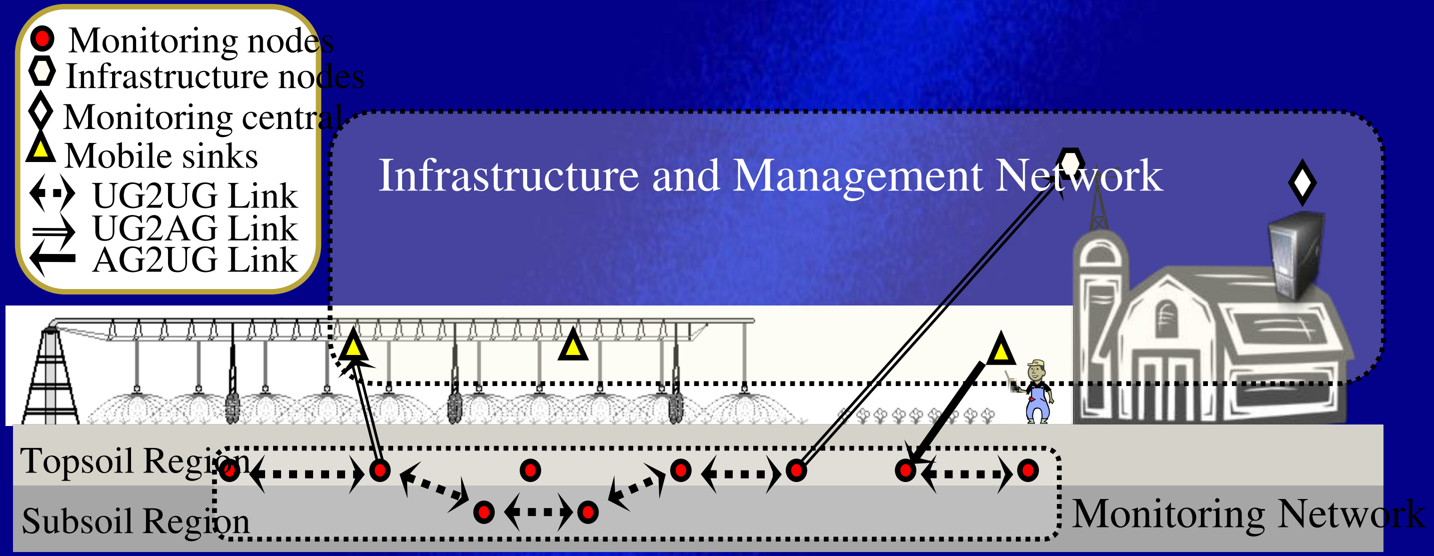
Potential Applications of WUSNs

Liquid leakage monitoring



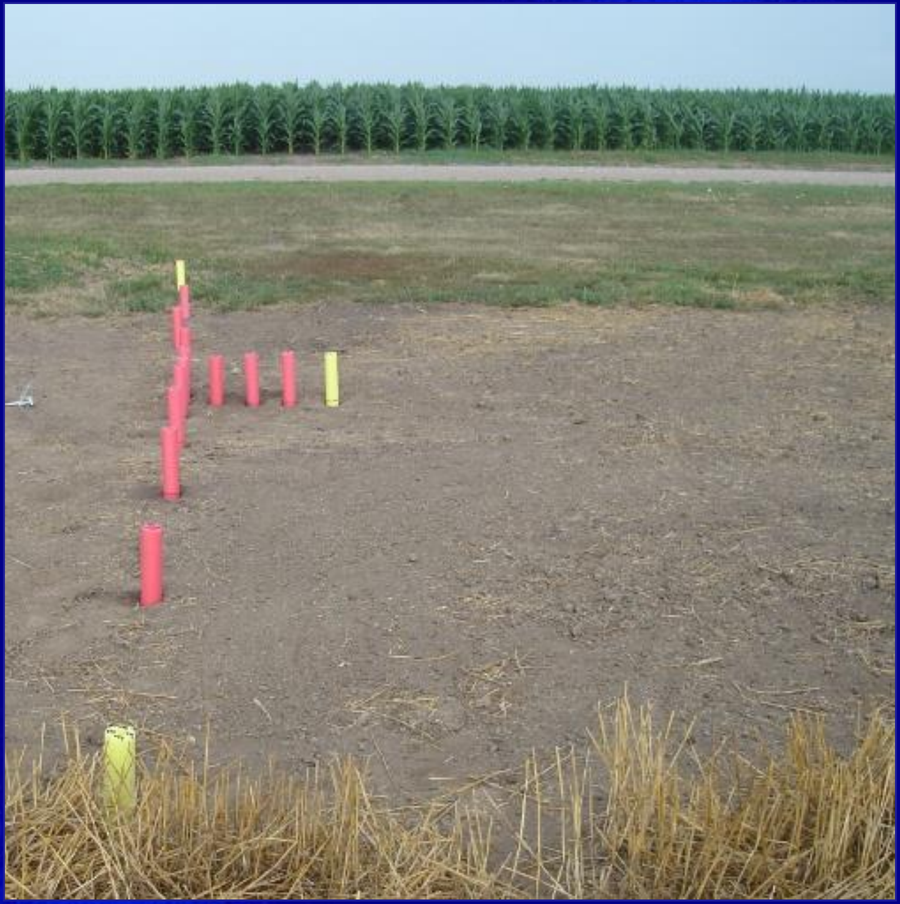
Agricultural Networks

http://cpn.unl.edu



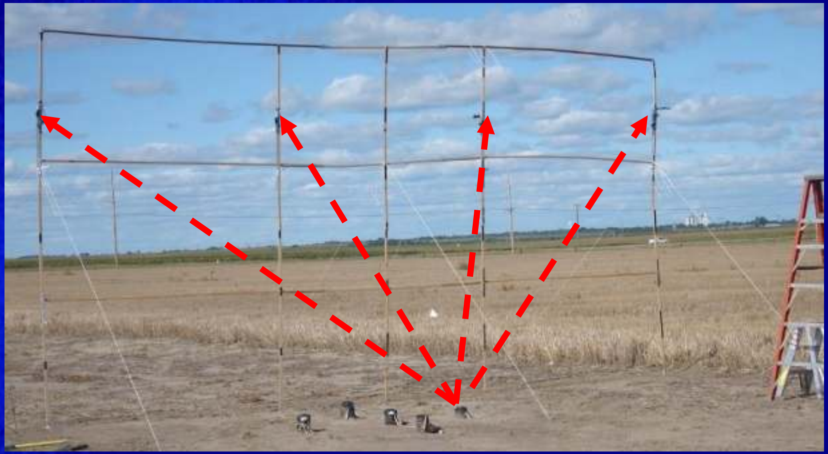
- Real-time information about soil and crop conditions
- Inter-connection of heterogeneous machinery with the management network
- Complete autonomy on the field

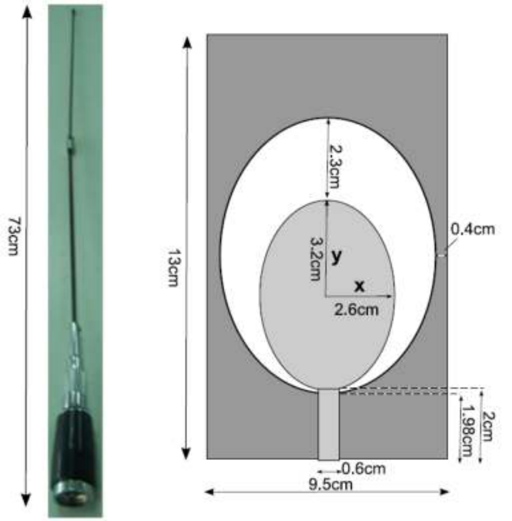
WUSN Testbed at UNL-SCAL



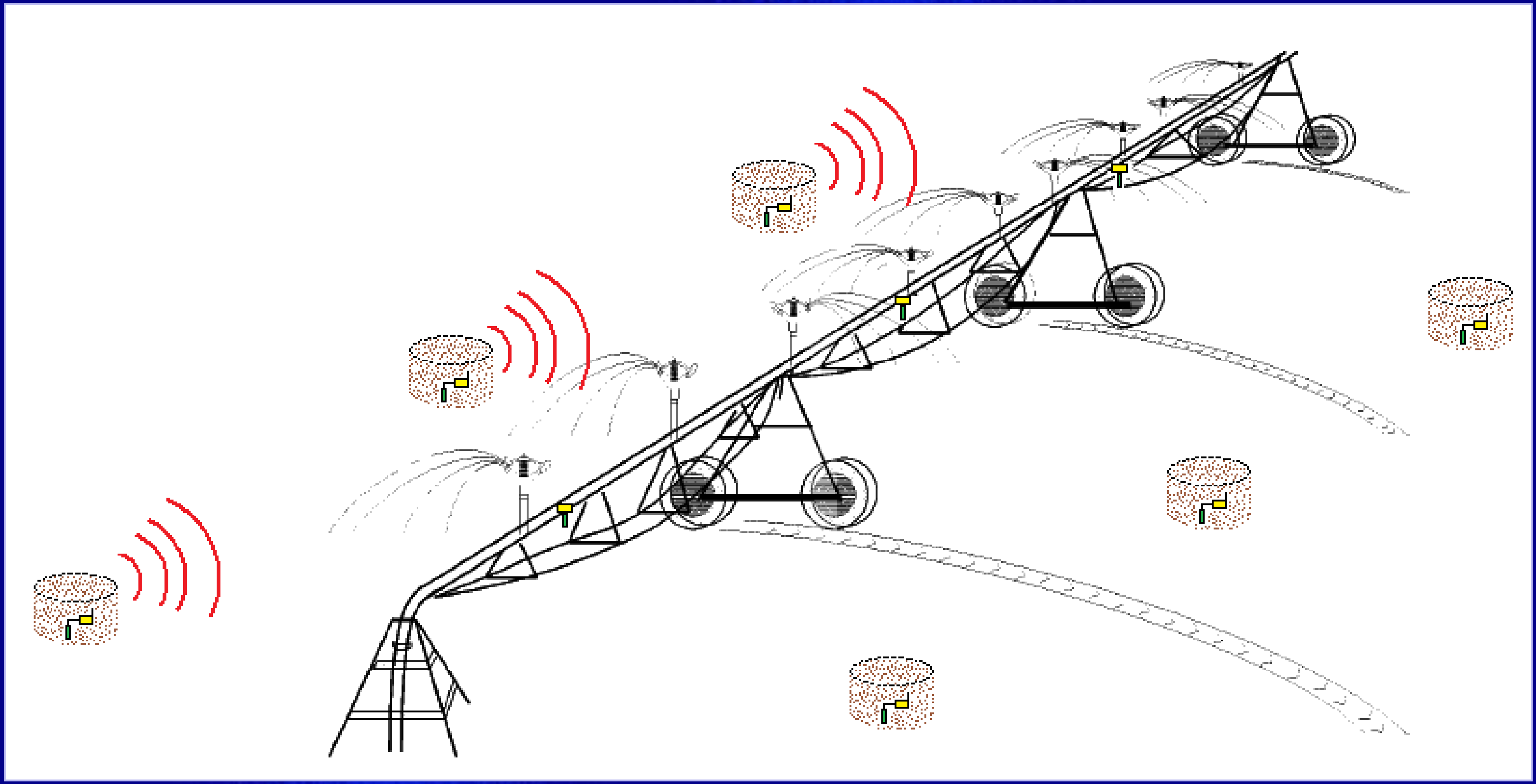
WUSN Experiments at UNL-SCAL

- UG2AG and AG2UG experiments using Mica2 at 433MHz



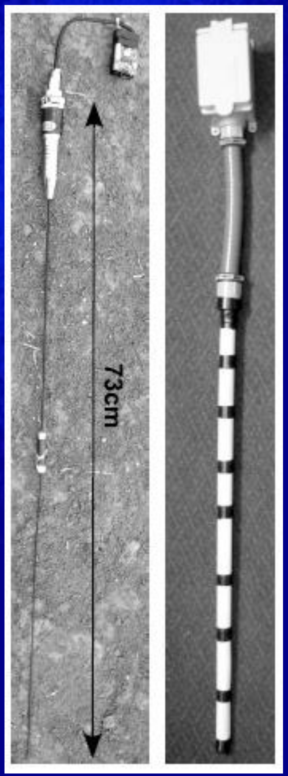


Extremely Efficient Irrigation Systems using Wireless Underground Sensor Networks

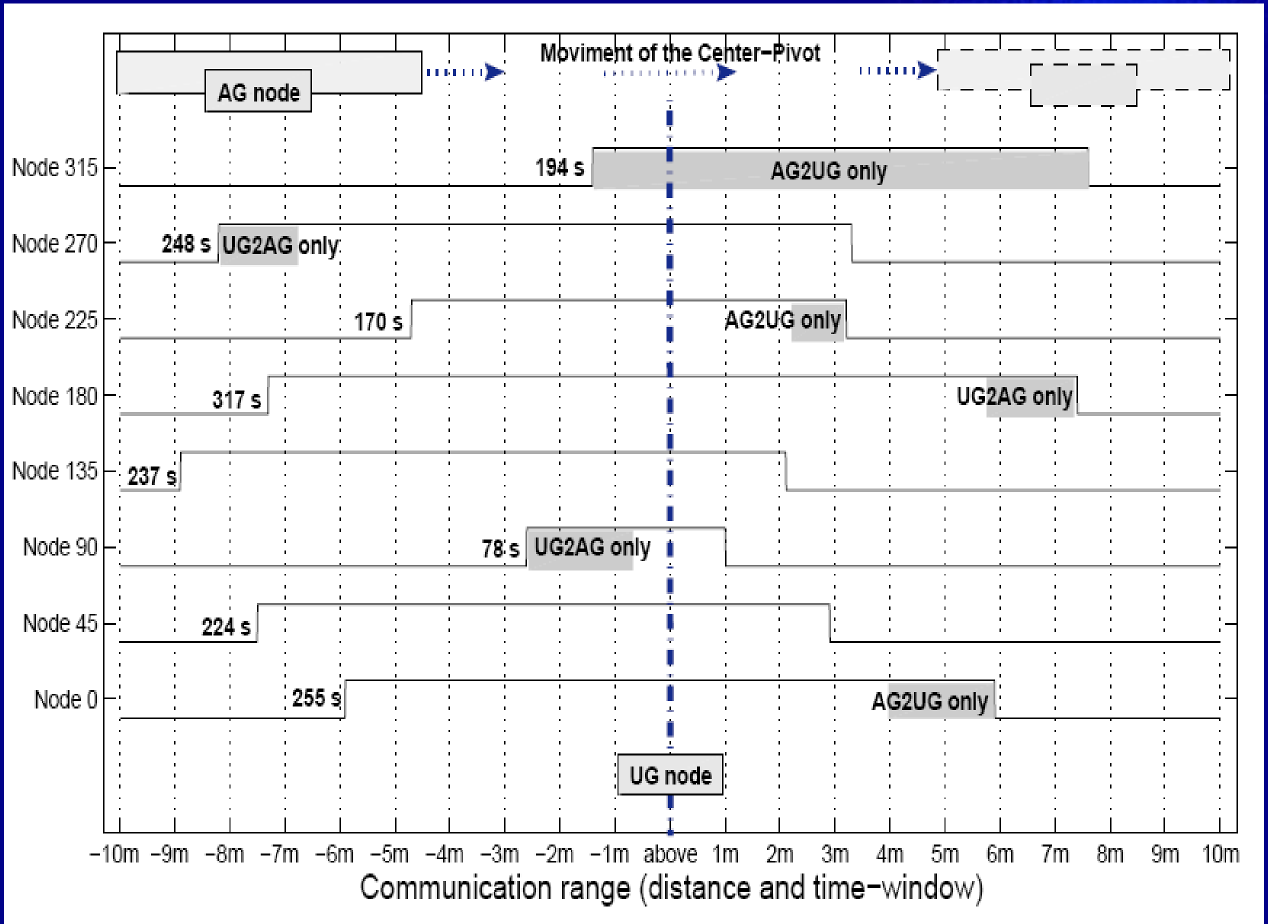


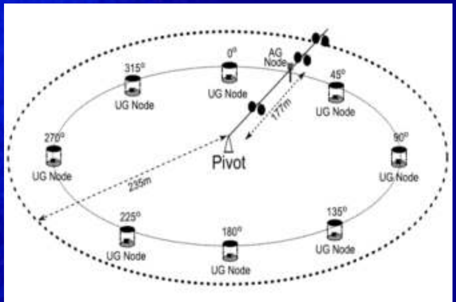
Center-Pivot Experiments

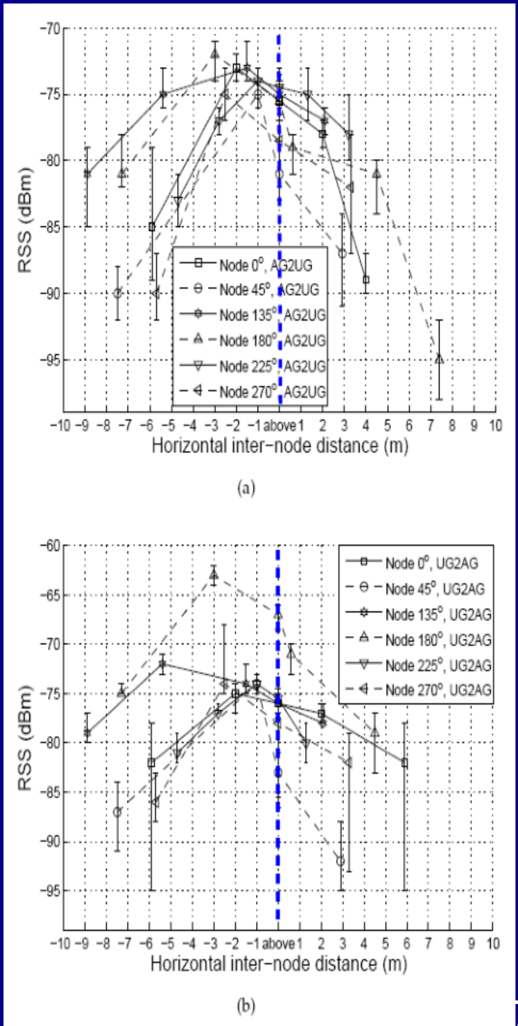
Experiment Setup



Experiments at UNL-SCAL Center-Pivot System







Research Challenges

- Extremely Lossy Environment
- Dynamic Channel Environment
- Power Constraints
- Low data rate

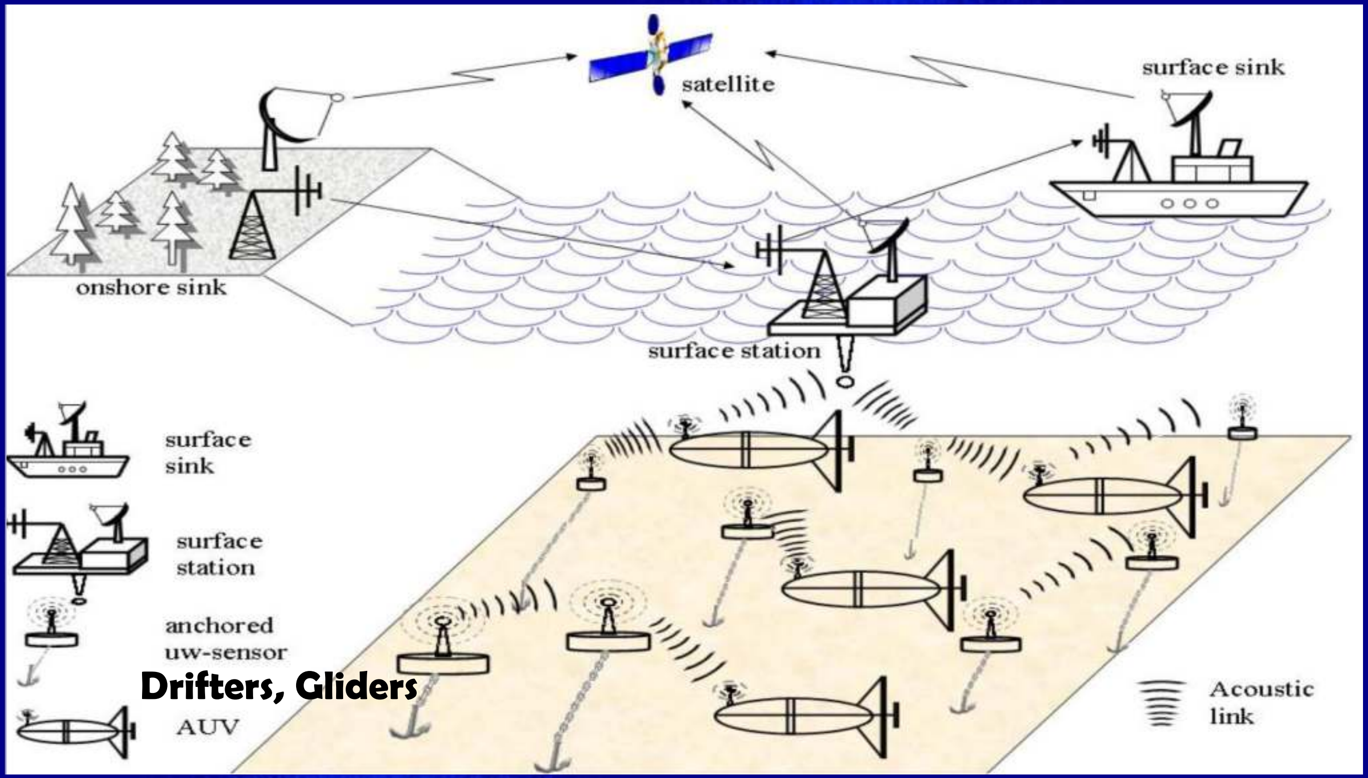
UNDERWATER SENSOR NETWORKS

I.F. Akyildiz, D. Pompili, T. Melodia, "Underwater Acoustic Sensor Networks: Research Challenges", Ad Hoc Networks (Elsevier) Journal, March 2005.

Applications:

- Ocean Sampling Networks
- Pollution Monitoring and other environmental monitoring (chemical, biological)
- Buoys alert swimmers to dangerous bacterial levels
- Disaster Prevention
- Assisted Navigation
- Distributed Tactical Surveillance
- Mine Reconnaissance

UNDERWATER SENSOR NETWORKS
3D DYNAMIC Architecture using AUVs



Ocean Sampling Sensors

Precision Marine Geodetic Systems

http://www.link-quest.com

Spread Spectrum Modem

http://www.dspcomm.com

Acoustic Transponders

http://www.link-quest.com

Terrestrial vs. Underwater Sensors

Terrestrial Wireless Sensor	Mica Mote MPR300CB
Speed	4 MHz
Flash	128K bytes
Radio Frequency	916MHz or 433MHz (ISM Bands)
Data Rate	40 kbits/s (max)
Transmit Power	0.75 mW
Radio Range	100 feet
Power	2 x AA batteries

Underwater Acoustic Modem	Short-range	Medium-range
Acoustic Frequency	27- 45 kHz	54-89 kHz
Data Rate	7 kbit/s	14 kbit/s
Transmit Power	1 W	6 W
Receive Power	0.75 W	1 W
Sleep Power	8 mW	12 mW
Radio Range	1000 feet	3000 feet

Ocean Sampling Sensors

Point measurements in upper water column 10 and 25 mi off Moss Landing

http://www.mbari.org/aosn/

Drift buoy: Path followed by surface currents

http://www.mbari.org/aosn/

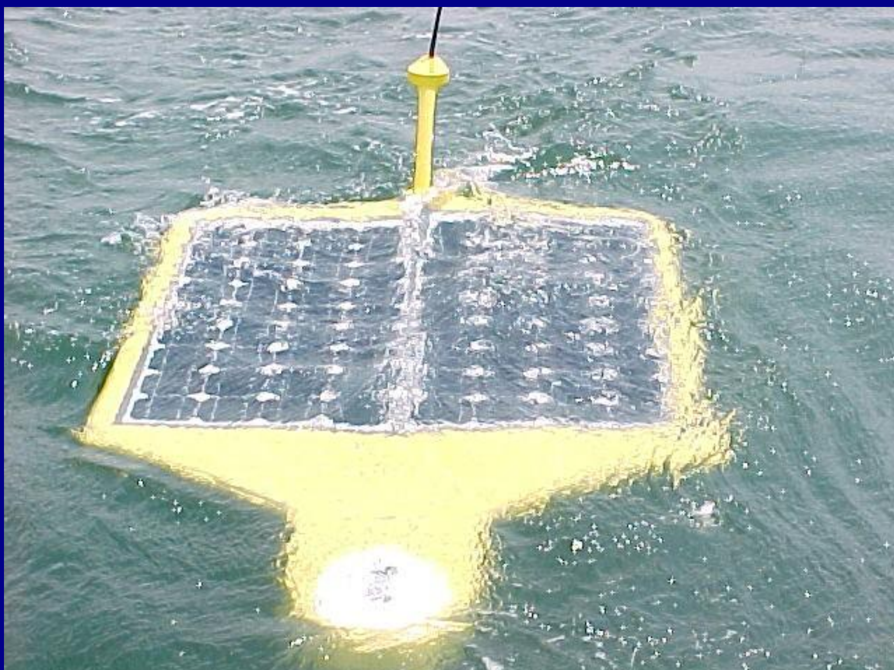
Surface station

http://www.link-quest.com

Autonomous Underwater Vehicles (AUVs)

- CARIBOU by Bluefin Robotics Corporation
- Equipped with state-of-the-art sensors (side-scan sonar and sub-bottom profiler), and can collect high-quality data for:
- Archaeological remote sensing
- Multi-static acoustic modeling
- Fisheries resource studies and
- Development of concurrent mapping and localization techniques

Autonomous Underwater Vehicles (AUVs)



Solar recharged AUV

http://www.mbari.org/aosn

Phantom HD2 ROV

http://www.link-quest.com

Research Challenges for UW Sensor Networks

- Available bandwidth is severely limited
- UW channel is severely impaired (in particular due to multi-path and fading)
- Very long (5 orders of magnitude higher than in RF terrestrial channels) and extremely variable propagation delays
- Very high bit error rates and temporary losses of connectivity (SHADOW ZONES)
- Battery power is limited and usually batteries cannot be recharged; no solar energy!!
- Very prone to failures because of fouling, corrosion, etc.