Sistemas de Computação Móvel e Ubíqua

2021/2022

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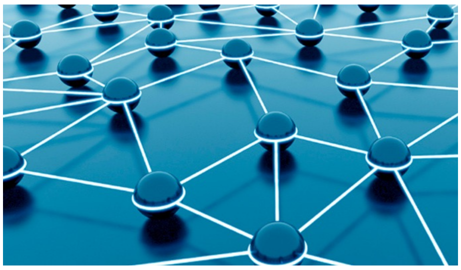
Wireless Sensor Networks

2021/2022



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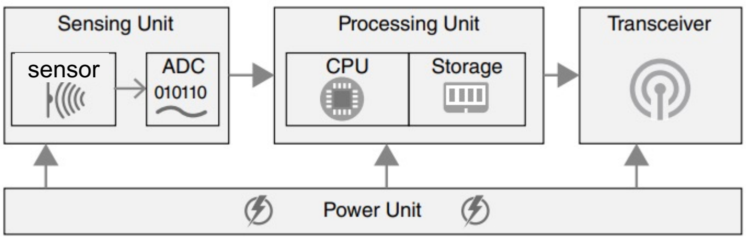
Smart sensors

Usually, can processes data, by performing predefined operations and functions and then pass it on.

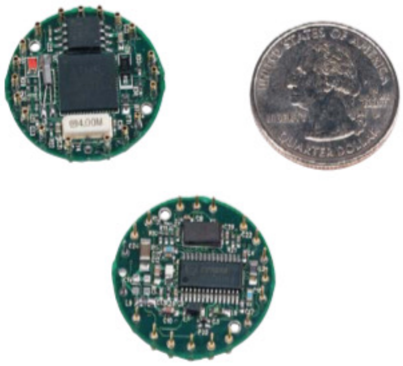
Enable more accurate and automated collection of environmental data with less erroneous noise.

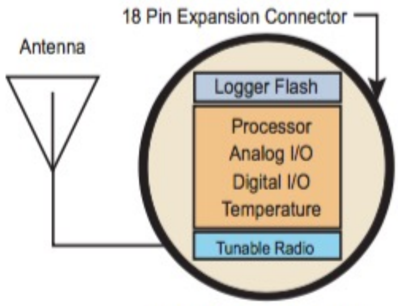
Allow the detection of status and key performance metrics, that can be handled immediately to improve the efficiency.

Smart sensor



Example Mica2dot mote





MPR500CA Block Diagram

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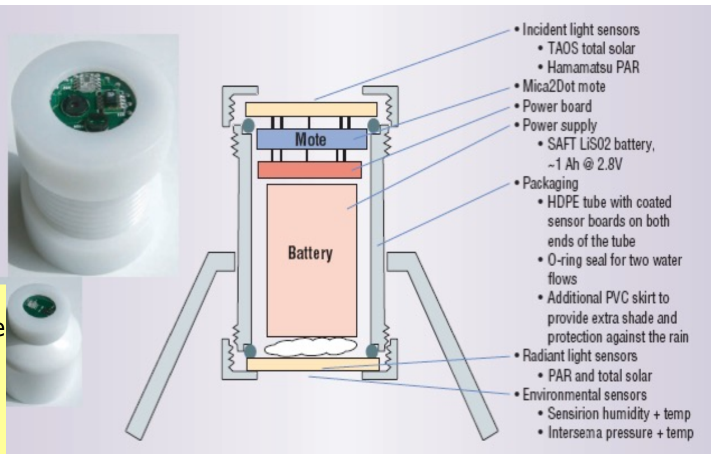
Small smart sensor - example



Sensor nodes include:
- Computing device
- Radio
- Sensors
- Battery

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Wireless Sensor Network

A data acquisition system having several smart sensors, which transmit data wirelessly

A **wireless sensor network** (WSN) is a wireless network consisting of spatially distributed autonomous devices using dedicated smart sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion, etc.. at different locations.

Wireless Sensor Network

Is a collection of **nodes** organized into a cooperative network.

The size of the sensor nodes can range from the size of a shoe box to as small as the size of a grain of dust.

The prices also vary from a few pennies to hundreds of dollars

- depending on the functionality parameters of a sensor like energy consumption, computational speed rate, bandwidth, and memory.

Great Duck Island: Petrel Monitoring

Goal: build ecological models for breeding preferences of Leach's Storm Petrel
- Burrow (nest) occupancy during incubation
- Differences in the micro-climates of active vs. inactive burrows
- Environmental conditions during 7 month breeding season

Inconspicuous Operation
- Reduce the "observer effect"

Unattended, off-the-grid operation

Sensor network
- 26 burrow motes deployed
- 12 weather station motes deployed (+2 for monitoring the insides of the base station case)

http://ziyang.eecs.umich.edu/~dickrp/sensor-nets/papers/polastre-sensor-habitat.pdf

Burrow Occupancy Detector

Great Duck Island: Petrel Monitoring

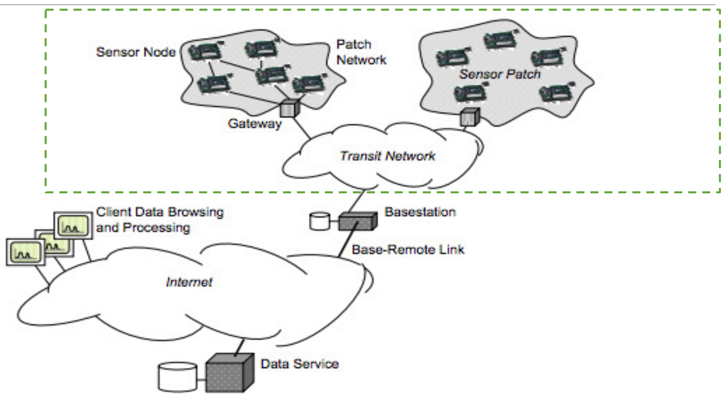


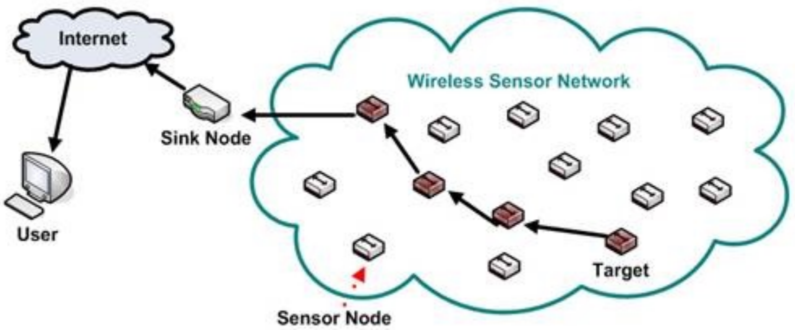
Figure 18.1. System architecture for habitat monitoring

Characteristics of WSN

The characteristics of WSN may include the following:

- Simple to deploy and use
- No network infrastructure
- Capacity to handle node failures and some mobility of nodes
- Heterogeneity or Homogeneity of nodes
- Scalability to large scale deployment
- Hardware limitations (resources, power for nodes with batteries)
- Capability to resist strict environmental conditions

Wireless Sensor **Network**



Wireless Sensor Network

Source node:

Sensor nodes which collect data and transmit it.

Sink node:

Base station which collects information from many sensor nodes.

A base station links the sensor network to another network (like a gateway) to disseminate the data sensed for further processing.

Base stations may need enhanced capabilities over simple sensor nodes since they can do more complex data processing.

Advantages of WSNs

- Network arrangements can be carried out without immovable infrastructure
- It avoids plenty of wiring
- Applications for the non-reachable places like mountains, over the sea, rural areas and deep forests
- It might provide accommodations for the new devices at any time
- Execution pricing is inexpensive
- It can be opened by using a centralized monitoring

Sensor Network Challenges

- Improvement in Signal to Noise ratio
- Increased Energy Efficiency
- Data Aggregation
- Improved Robustness
- Improved Scalability

Requirements for WSNs

- **Collaborative data processing** - scalable, fault tolerant, flexible data access, intelligent data reduction;
- **Constrained energy use** - battery / solar;
- **Querying capabilities** - event driven and query driven;
- **Self organizing, Self healing** - reconfigurable
- **Large topology support** - could be more than 100000;

Factors influencing sensor network design

- Fault Tolerance
- Scalability
- Productivity Costs
- Hardware Constrains
- Sensor Network Topology
- Environment
- Transmission Media
- Power Consumption

Fault tolerance

Fault tolerance is the ability to sustain sensor network functionalities without any interruption due to sensor node failures.

The fault tolerance level depends on the application of the sensor networks.

Productivity costs

The cost of a single node is very important to justify the overall cost of the networks.

The cost of a sensor node is a very challenging issue given the amount of functionalities needed.

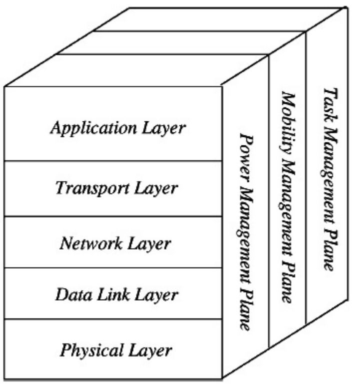
WSN Architecture

Wireless sensor networks follows most common architecture OSI model with five layers:

- application, transport, network, data link and physical.

Three cross layers planes monitor the power, movement, and task distribution among the sensor nodes.

These planes help the sensor nodes coordinate the sensing task and lower the overall power consumption



Wireless Sensor Network Architecture

Ad Hoc Wireless Networks

- Large number of self-organizing static or mobile nodes that are possibly randomly deployed
- Near(est)-neighbor communication
  - With multi-hoop (intermediate nodes as routers)
- Wireless connections
  - Links are fragile, possibly asymmetric
  - Connectivity depends on power levels and fading
  - Interference is high for omnidirectional antennas
  - → Specific network protocols

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Ad Hoc Wireless Networks (dif.)

- Sensing and data processing are essential
- WSNs have many more nodes and are more densely deployed
- Hardware must be cheap: nodes are more prone to failures
- WSNs operate under very strict energy constraints
- WSN nodes are typically static
- The communication scheme is many-to-one (data collected at a base station) rather than peer-to-peer

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WSN – Centralized formation

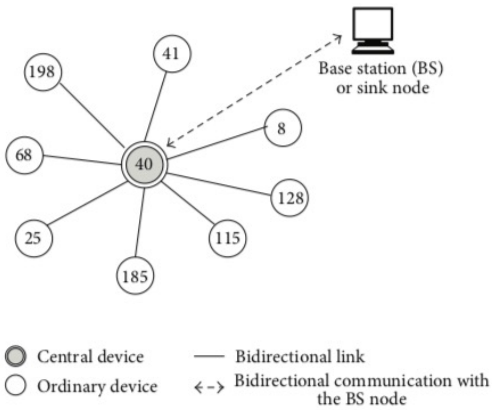

Figure 1: Centralized strategy.

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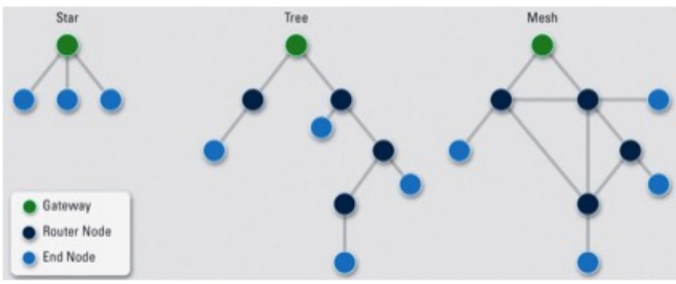
Network Topologies



Wireless Sensor Network Topologies

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Transmission media

In a multi-hop sensor network, communicating nodes are linked by a wireless medium. To enable global operation, the chosen transmission medium must be available worldwide.

- Radio
- Infrared
- Optical media

Power Consumption

Main power consumption causes:

- Communication
- Sensing
- Data processing

To save energy:

- Sleep as much as possible
- Transmit and receive only if necessary
  - Usually more costly than sensing and data processing
- Acquire data only if indispensable
- Use data fusion and compression

In-network data processing

Constant transmission of all sensory data by individual nodes all the time wastes the wireless bandwidth and energy.

Event driven

- Therefore, sensor network should respond to the changes in the environment, depending on the application interest
- The sensors are programmed to become active only on certain conditions and may do some data fusion and compression
- Sensors broadcast the results only when they meet some other conditions.

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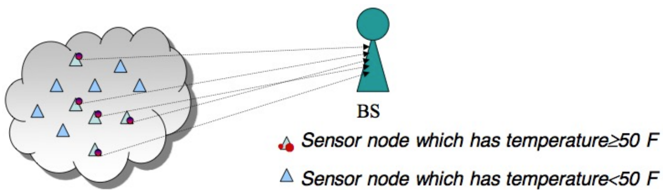
Event driven

Sensors broadcast the data whenever they meet the specific condition



For instance, if application is *temperature monitoring*, it reports data when the **temperature** of the area being monitored goes above or below certain thresholds.

Example: Every sensor node which has temperature above 50F broadcasts to sink node.

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In-network data processing

Constant transmission of all sensory data by individual nodes all the time wastes the wireless bandwidth and energy.

Query driven

- Application searches for some data in the whole sensor network, only when it needs.
- The sink node broadcasts the query to the whole sensor network
- The sensor is bought out of its sleep to answer the query
- Some data fusion and compression can be carried out

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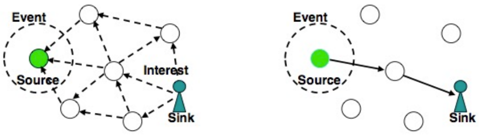
Query driven

Sink node broadcasts the request to the whole sensor network whenever there are queries from users



a) Interest Propagation b) Data delivery

Example: If the query is "Type=four-legged animal", the user wants to query the four legged animal from the environment. If there are no such kind of animals at the environment or the events have not occurred yet at that time, the query may be costly.

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Tradeoff between Energy Efficiency and Reliability/Performance

Improved reliability ⟷ energy consumption

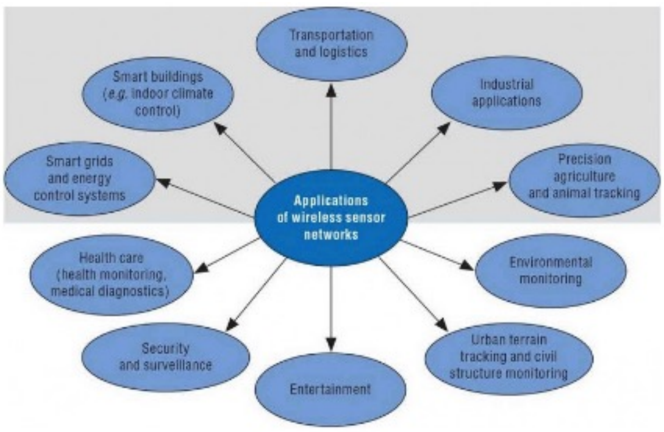
Aggregating sensor readings ⟷ loss of information

Energy-efficient protocols often involve increased delay, loss of accuracy, reduced reliability and/or other performance penalties

Sensor readings with path and source redundancy

Achieving application requirements while extend lifetime is a major challenge

WSN Applications - examples



WSN Application

WSN Applications - examples

- Smart Buildings
- Tree Monitoring
- Glacier Monitoring
- Aircraft, Spacecraft Monitoring
- Environment Monitoring
- Monitoring for intrusion at country borders
- Industrial Process Monitoring
- Habitat monitoring
- Landslide Detection

WSN Applications

Many sensor networks applications are for monitoring and possibly for actuating on the monitored environment.

Monitoring applications can be broadly classified into:

monitoring space,

monitoring things,

monitoring the interactions of things with each other and the encompassing space

WSN - Environment monitoring

Environmental monitoring consists in collecting readings over time across a volume of space large enough to exhibit significant internal variation.

Researchers are using WSNs to monitor nesting seabird habitats, to conduct studies of contaminant propagation, building comfort, and intrusion detection.

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WSN - Environment applications

- Busy intersections
- Interior of a large machinery
- Bottom of an ocean
- Surface of an ocean during a tornado
- Biologically or chemically contaminated field
- Battlefield beyond the enemy lines
- Home or a large building
- Large warehouse
- Animals control
- Fast moving vehicles
- Drain or river moving with current

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WSN Motion monitoring

Motion monitoring consists in collecting readings **over time** about motion of things.

- tracking animal migration
- tracking vehicles
- health monitoring
- tele-rehabilitation of patients ("body network systems")
- ocean movements

WSN - EXAMPLES

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Great Duck Island: Petrel Monitoring

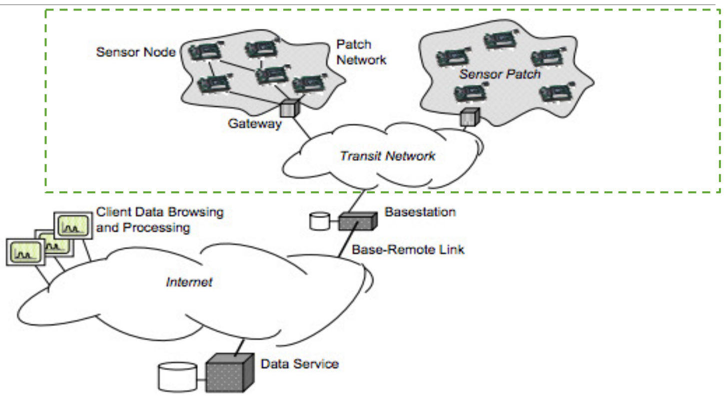

Figure 18.1. System architecture for habitat monitoring

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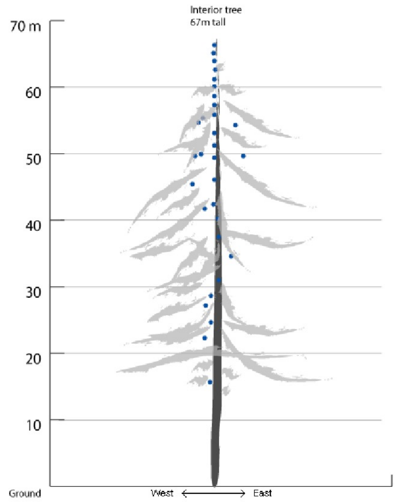
Redwood tree Microclim…

WSN recorded 44 days in the life of a 70-meter tall redwood tree, at a density of every 5 minutes in time and every 2 meters in space.

Each node measured air temperature, relative humidity, and photosynthetically active solar radiation.

The network captured a detailed picture of the complex spatial variation and temporal dynamics of the microclimate surrounding a coastal redwood tree.



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FireSensorSock

- 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

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

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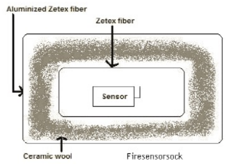
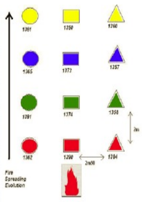
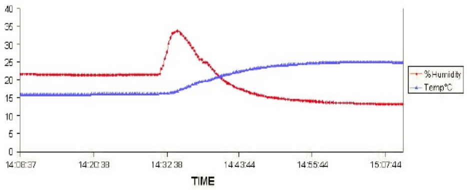
FireSensorSock

Use MICA motes and MTS420 GPS enabled sensors







Volcano Monitoring (Welsh, Harvard)

Motes with seismic sensors deployed on active volcano in Ecuador.

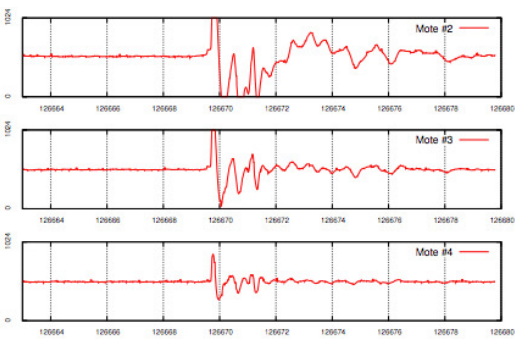


Figure 6: Volcán Tungurahua.

Requirements: high fidelity during events, large spatial separation, time synchronization.
Nature of the application allows triggered data collection rather than continuous.

Volcano Monitoring

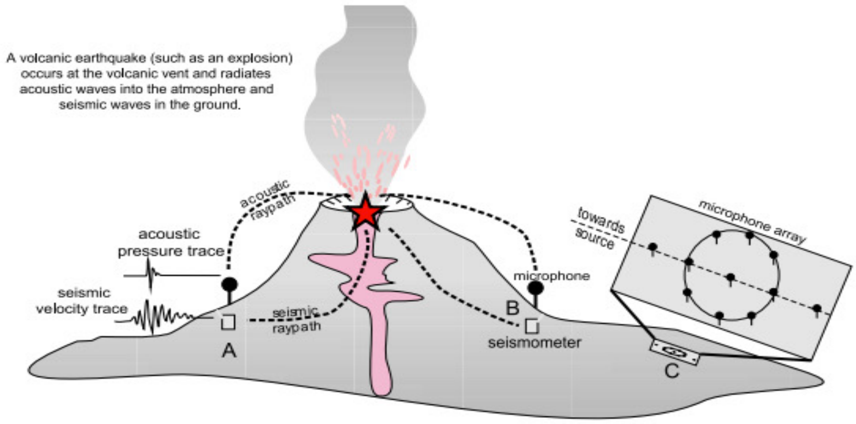


Figure 1: **Sensor arrays for volcanic monitoring.**

Volcano Monitoring

Prototype

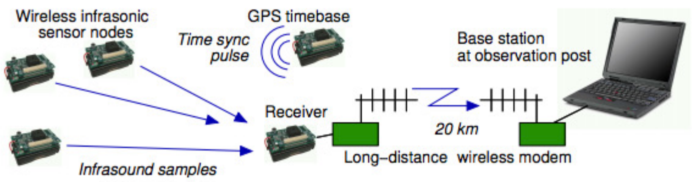
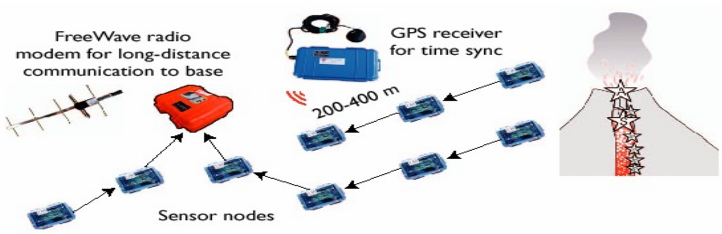


Figure 2: **System architecture of the infrasonic sensor array.**



Underwater Sensor Networks

- 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

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

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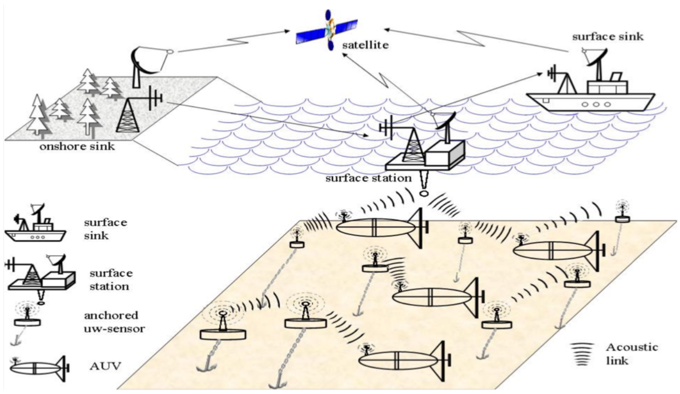
Underwater Sensor Networks

3D DYNAMIC Architecture using AUVs (Autonomous Underwater Vehicles)



Drifters, Gliders

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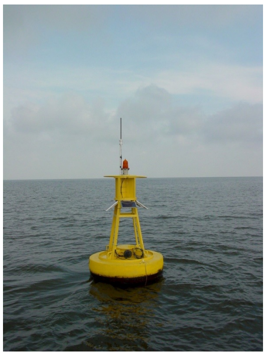
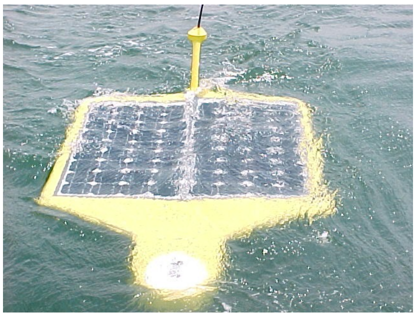
Ocean Sampling Sensors

Drift buoy: Path followed by surface currents
http://www.mbari.org/aosn/



Surface station
http://www.link-quest.com

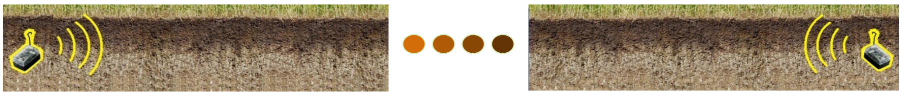
Autonomous Underwater Vehicles (AUVs)

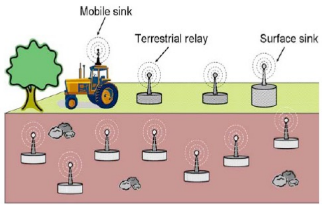


Solar recharged AUV
http://www.mbari.org/aosn

Phantom HD2 ROV
http://www.link-quest.com

Wireless Underground Sensors



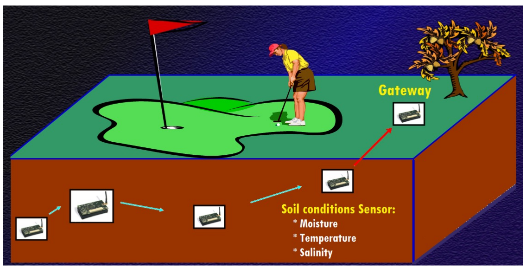


- Tiny computers capable of wireless communication
- On-board sensing capabilities (soil moisture, temperature, salinity, etc...)
- Communication through **soil**

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

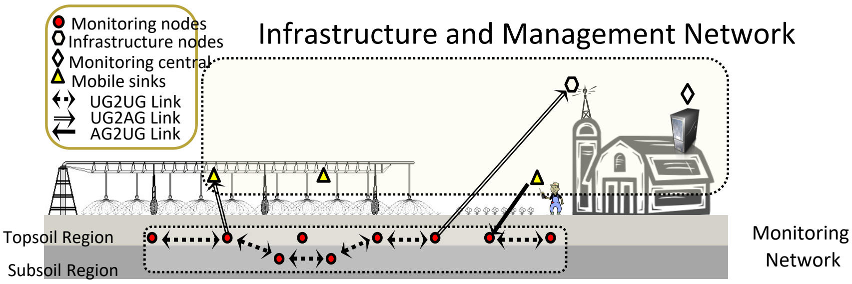
Potential Applications of WUSNs

Sports field irrigation



Precision agriculture

Agricultural Networks



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

http://cpn.unl.edu

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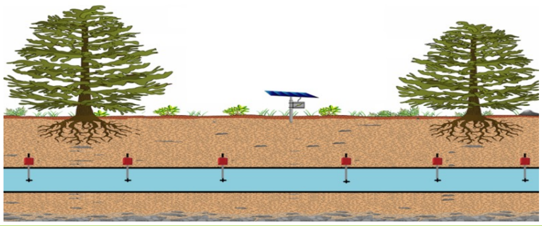
Potential Applications of WUSNs

Liquid leakage monitoring



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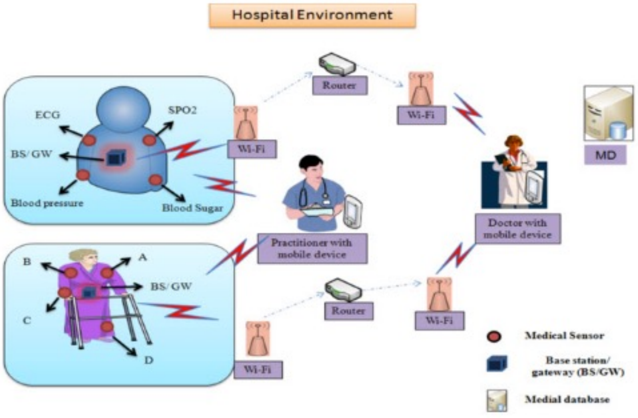
Wireless Health Monitoring System



Wireless Health Monitoring System

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ISMB Tele-monitoring Components

The wristwatch

Using suitable sensors, several parameters can be measured:

Personal parameters → skin temperature, heart beat rate, mobility

Environmental parameters → temperature, light

System parameters → removal from wrist, fault, radio coverage, battery level

Emergency Button

The base station

Data collected by the sensors are transmitted to a base station located up to 30 meters away. Transmission is currently based on a proprietary protocol over a 2.4 GHz channel. Future versions will be based on standard wireless sensor telecommunication protocols (Zigbee, IEEE 802.15.4). At any abnormal situation, automatically detection will be transmit to Services Operation Centre.

The Tele-monitoring Service Centre

The sensor data received by the service centre are checked against the patients' profiles. If a potentially dangerous situation is recognised , an alarm is sent to the operators.

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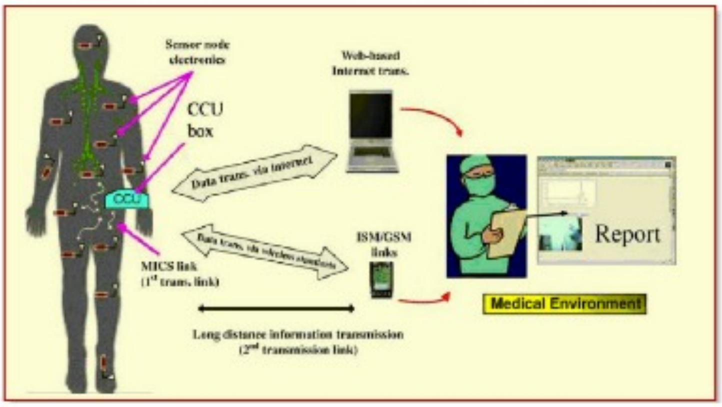
Wireless Health Monitoring System



Medical Applications Based on Wireless Sensor Networks

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- https://people.eecs.berkeley.edu/~culler/papers/sciam-near-final.pdf
- http://ftp.deas.harvard.edu/techreports/tr-27-04.pdf
- http://ziyang.eecs.umich.edu/~dickrp/sensor-nets/papers/polastre-sensor-habitat.pdf
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