African University of Science and Technology

Wireless Sensor Networks and Applications

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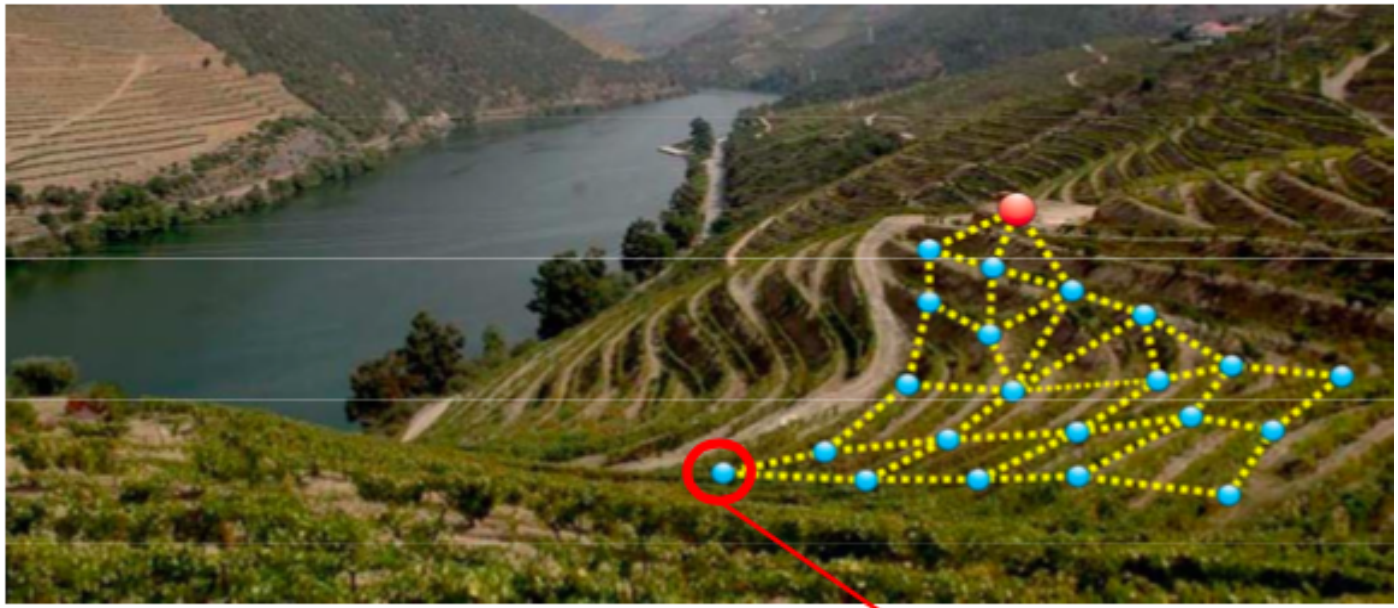
Outline

What is WSN



Wireless Sensor Networks (WSNs) consist of multiple unassisted embedded devices (nodes) which process and transmit data collected from different on-board physical sensors (temperature, humidity, pressure, etc.)

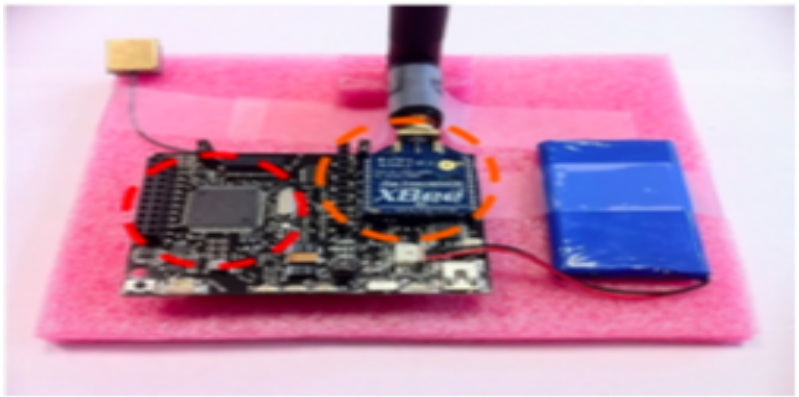
What are the WSNs?

- Low Cost
- Low Power Consumption
- Small Size
- Wireless communications ranging 100 meters
- Resource-constrained nodes (memory and processing)
- Energy constrained!!

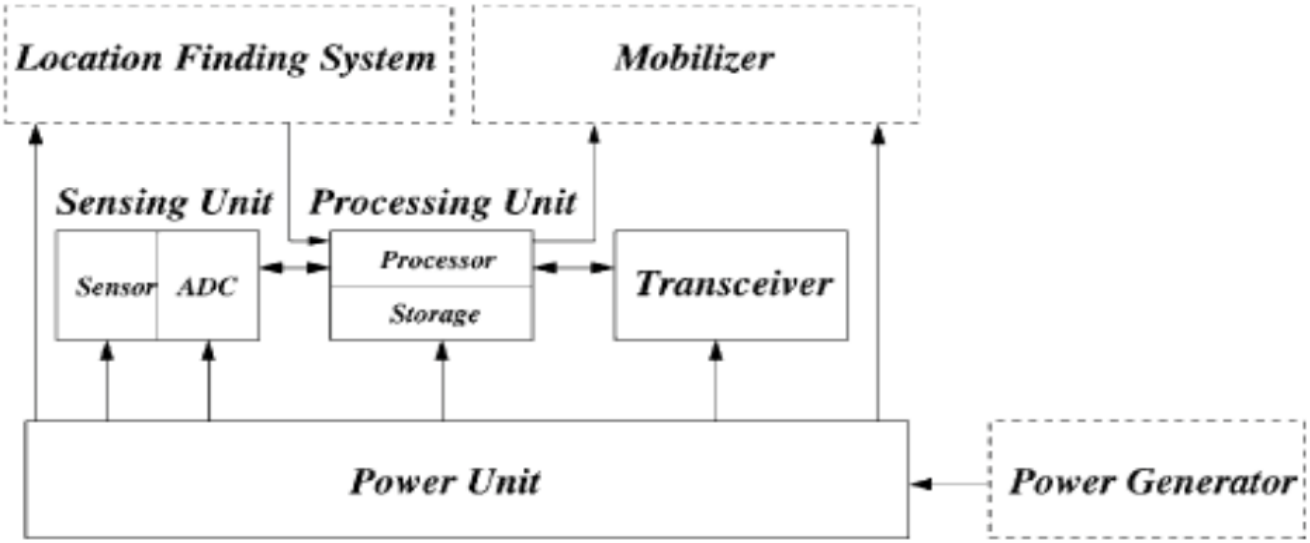
- sensor
  - A transducer
  - converts physical phenomenon e.g. heat, light, motion, vibration, and sound into electrical signals
- sensor node
  - basic unit in sensor network
  - contains on-board sensors, processor, memory, transceiver, and power supply
- sensor network
  - consists of a large number of sensor nodes
  - nodes deployed either inside or very close to the sensed phenomenon

Wireless autonomous sensor!

- In general: low cost, low power (the battery may not be replaceable), small size, prone to failure, possibly disposable!
- Role: sensing, data processing, communication!



Sensor node components



Sensor node components

- Sensing unit: composed of two subunits, a physical capture device which takes the information of the local environment and an analog/digital converter called ADC ("Analog to Digital Converter"). The sensor is responsible for providing analog signals. And the ADC converts these signals into a signal understandable by the digital processing unit.
- Processing unit: this is the main unit of the sensor, usually a processor coupled to a memory. Its role is to control the operation of the other units. On some sensors it can carry an operating system to operate the sensor. It may also be coupled to a storage unit which serve for example to record the information transmitted by the capture unit.

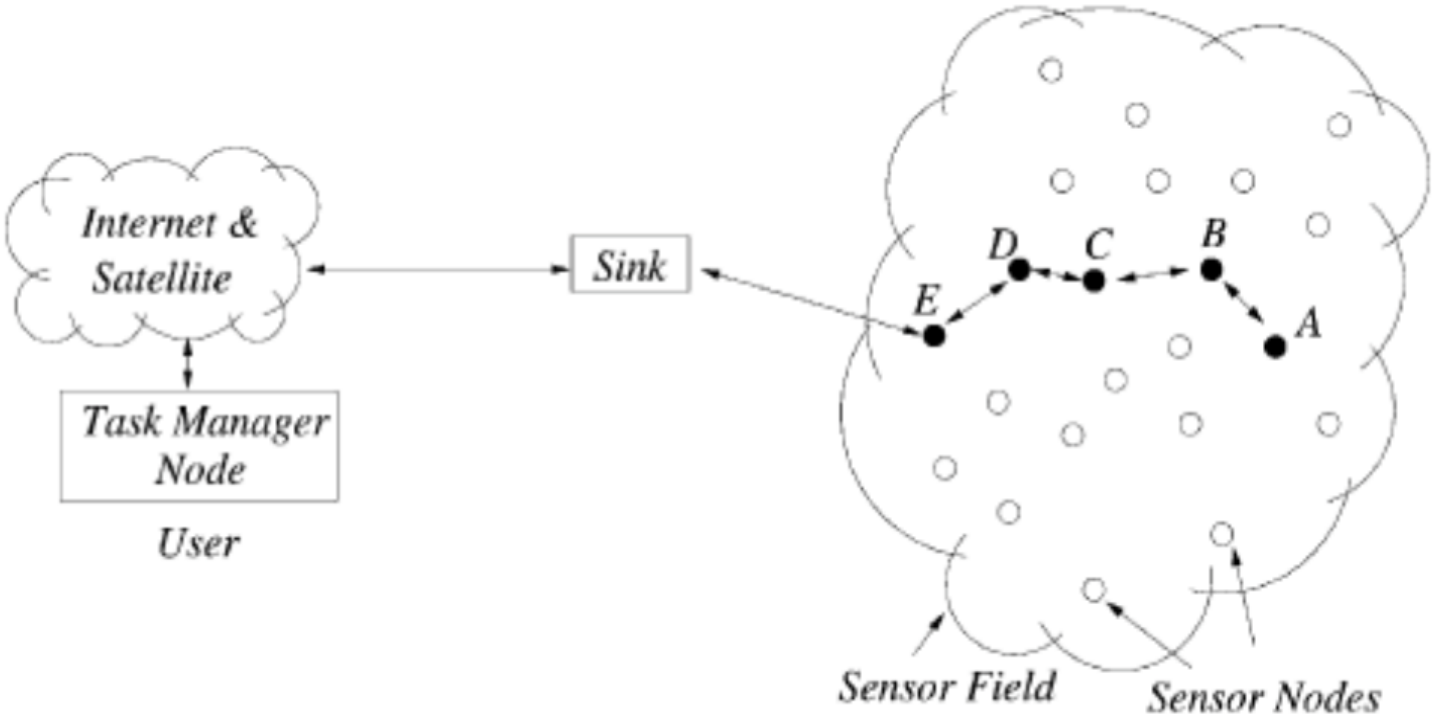
Sensor node components

- Transceiver unit: performs all transmission and reception of data on a "wireless" medium. It may be optical type, or radio frequency type. Optical type communications are robust. Nevertheless, that can not establish connections through obstacles, they have the disadvantage of requiring a permanent line of sight between the communicating entities. Radio frequency type transmission units include modulation circuits, demodulation, filtering and multiplexing; this implies an increase in the complexity and cost of production of the micro-sensor.

Sensor node components

- Power unit: a sensor node is equipped with an energy source (battery). Given its small size, this energy resource is limited. This often made energy the most valuable resource of a sensor, because it directly affects its life span.
- mobilizer: mobility is sometimes necessary to allow a node to move to perform its tasks. Mobility support requires extensive energy resources that should be provided effectively. The mobility system may also operate in close interaction with the detection unit and the processor to control the movement.

WSN Communication Architecture



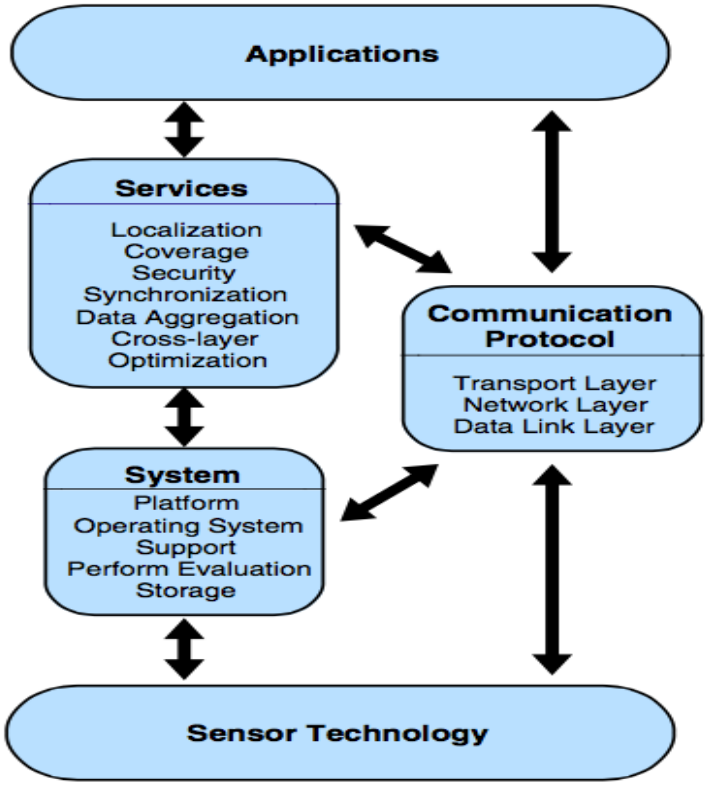
WSN Communication Architecture

- The Sensor nodes that form the sensor network. Their main objectives are making discrete, local measurement about phenomenon surrounding these sensors, forming a wireless network by communicating over a wireless medium, and collect date and rout data back to the user via sink (Base Station).
- The sink (Base Station) communicates with the user via internet or satellite communication. It is located near the sensor field or well-equipped nodes of the sensor network. Collected data from the sensor field routed back to the sink by a multi-hop infrastructureless architecture through the sink.

WSN Communication Architecture

- Phenomenon which is an entity of interest to the user to collect measurements about. This phenomenon sensed and analyzed by the sensor nodes.
- The user who is interested in obtaining information about specific phenomenon to measure/monitor its behavior.

Broad classification of various issues in a WSN



- Based on flexible and autonomous concept of wireless sensor networks, opportunities have been created for exciting application areas requiring remote sensing and actuation for optimized results. However, wireless sensor network technology poses many issues that need to be handled for long term viability of developed systems.
- Issues like energy consumption for autonomous operation of sensor nodes, dictate design and development issues including communication, protocols and deployment.

Energy consumption

- Each sensor node placed in a wireless sensor networks has the responsibility of event detection, data processing and transmission. In case of multi-hop network, a node has the additional responsibility of data routing also.
- Each of the above actions requires energy to be consumed. A node is usually equipped with a limited and finite energy source e.g. alkaline batteries or lithium cells.
- Therefore, a sensor node life time greatly depends upon battery life time. By applying proper energy management strategy in hardware and software, battery life may be extended to several more months.
- Alternatively, the use of renewable energy sources such as solar power or kinetic energy could be adopted where a slight expensive solution could be traded off in favor of longer life of sensor nodes.

Data acquisition, sampling and transmission

- With each data sampled, processed and transmitted, energy is spent. An efficient and optimized data collection and sample rate is needed to be programmed so as not only the relevant and useful data is captured but energy is also not wastefully spent.
- A data transmission strategy could also be strategized so that lesser transmissions are made, thus conserving the energy.

Fault tolerance

- Sensor nodes being placed in open harsh environment are prone to physical damage, blockage and interference.
- In order to maintain the reliability of a WSN, the failure of a sensor node should not affect the overall task of the network.
- Redundant use of sensor nodes, reorganization of sensor network, and overlapped sensing regions etc. are few of the techniques employed to increase the fault tolerance or reliability of the network.

Sensor placement

- Sensor Node Placement is an important issue regarding the design of the network, algorithms, topologies used, and the parameters being sensed. It needs to be carefully designed and smartly implemented so that a WSN could be established that may work reliably and autonomously.
- Placement of sensors should be such that the whole area under the concern is covered and sensors are placed in position and altitudes so as to measure the parameters without hindrance. For example, light sensors must be placed at heights so as to avoid blockage from plant leaves.
- Water level and moisture sensors, on the other hand, must be placed close enough to the ground necessary for accurate measurements. Strong winds and water currents may dislocate the sensors from desired positions, so proper fixtures need to be mounted to support the nodes.

Outline

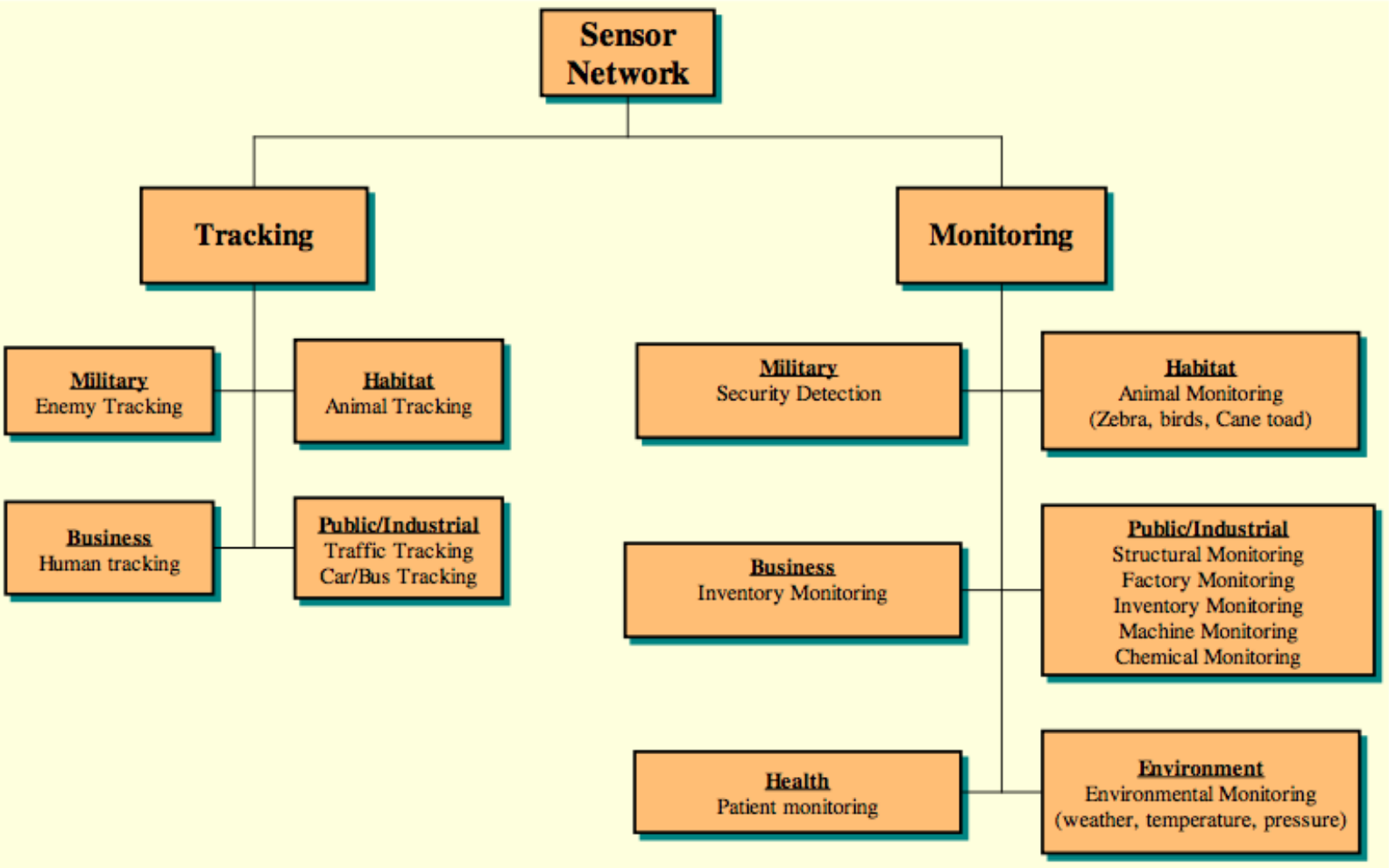
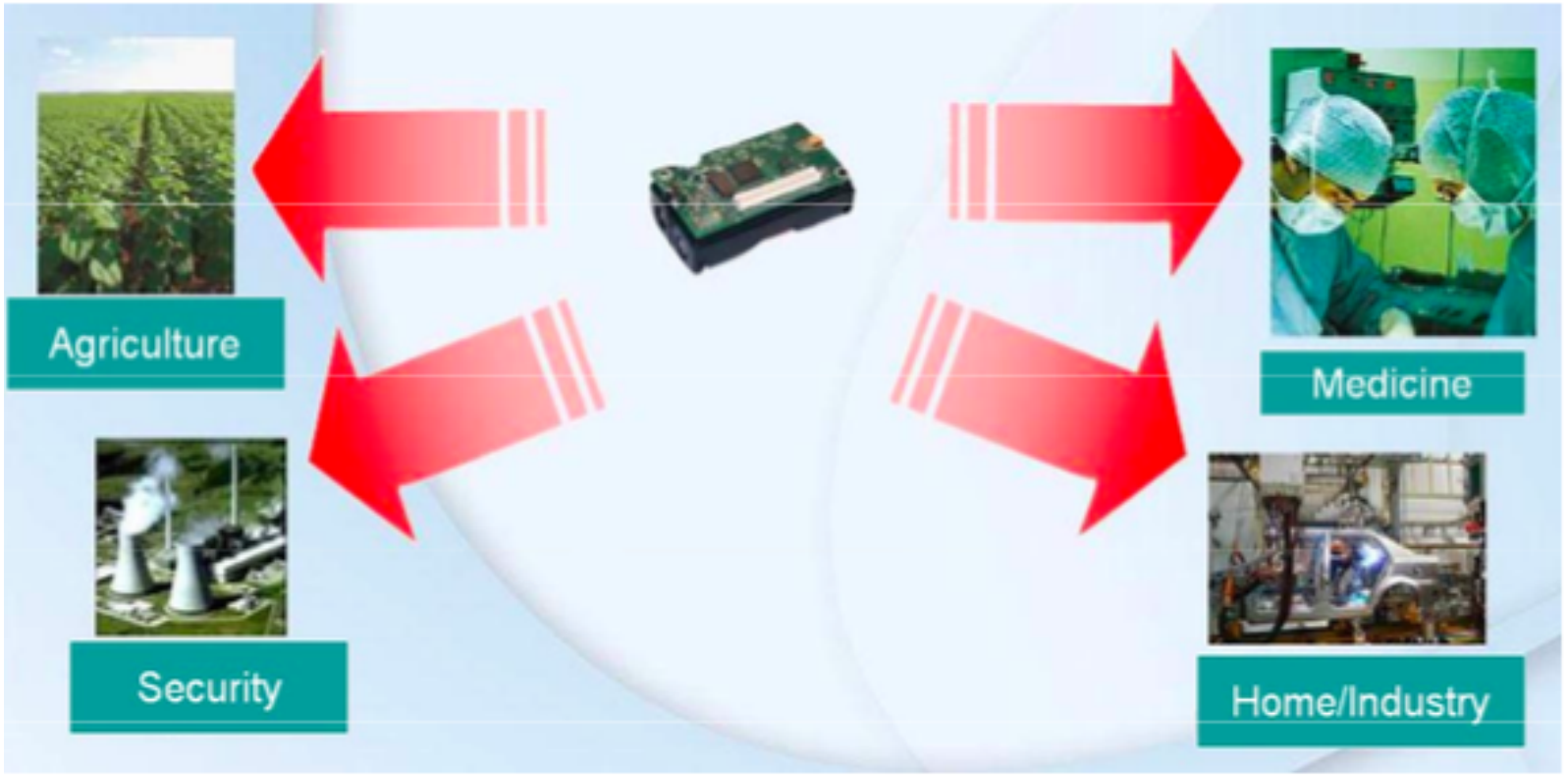


Figure: overview of sensor applications


Agriculture
Medicine
Security
Home/Industry

- Many WSN applications process the sensed event before sending the data, this processing tries to reduce the information to send.
- WSNs may contain different kind of sensors that help monitor metrics related to: temperature, humidity, pressure, speed, direction, movement, light, soil makeup, noise levels, presence or absence of certain kinds of objects, mechanical stress and vibration.

Military Applications

- One of the first appli- cations of WSNs
- The main advantages in this area are the fact that the deployment of low cost sensors (that are subject to destruction in a battlefield) proposes a cheaper approach to sensing different types of metrics, which in turn brings new challenges to WSN applications (increased power and processing constraints).
- Some of the applications are related to: monitoring the movement of troops, equipment and ammunition, battle- field surveillance, terrain reconnaissance, damage assessments, snipper detection and threat detection, as in the case of biological, radiological or chemical attacks.

Military Applications

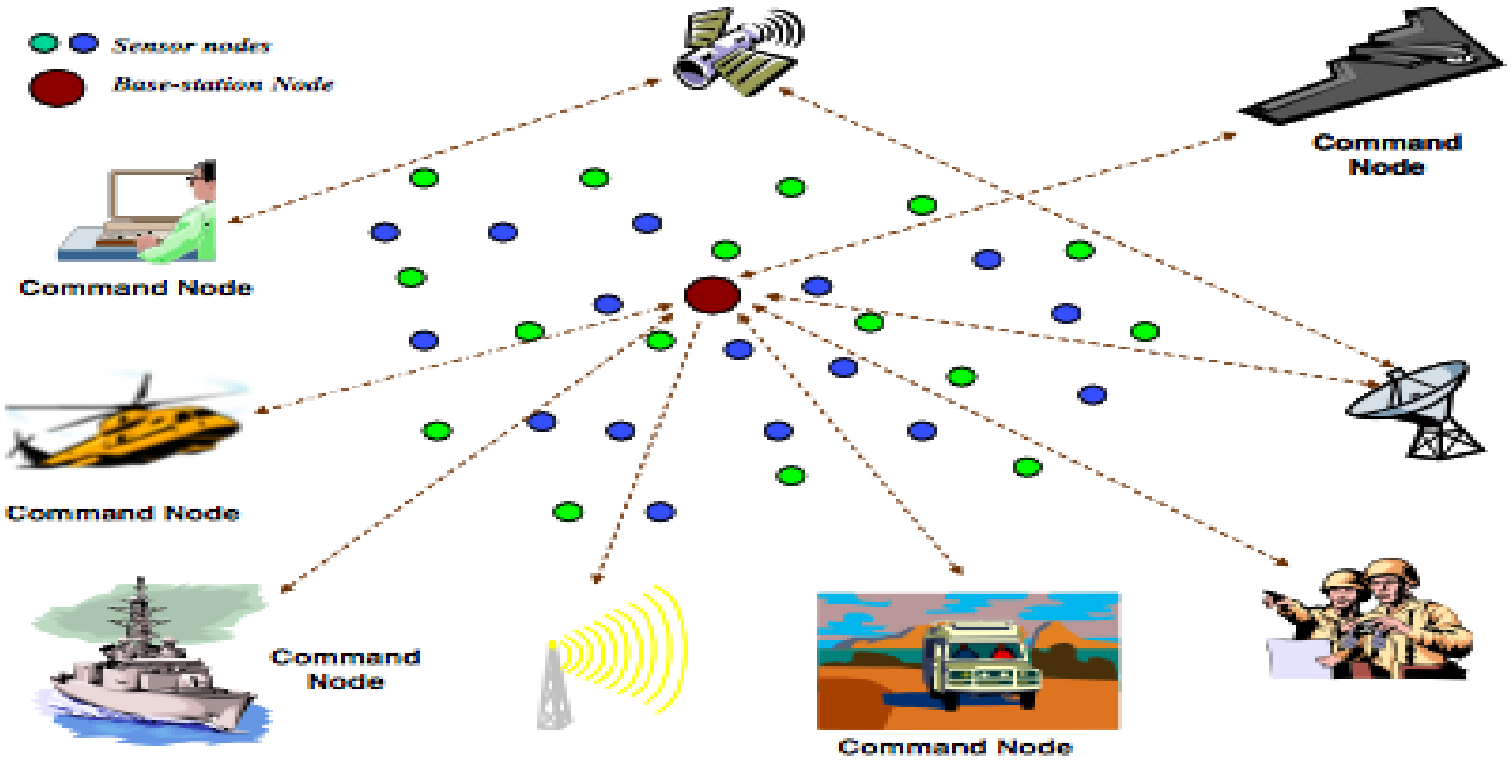


Figure: A sensor network for a combat filed surveillance application

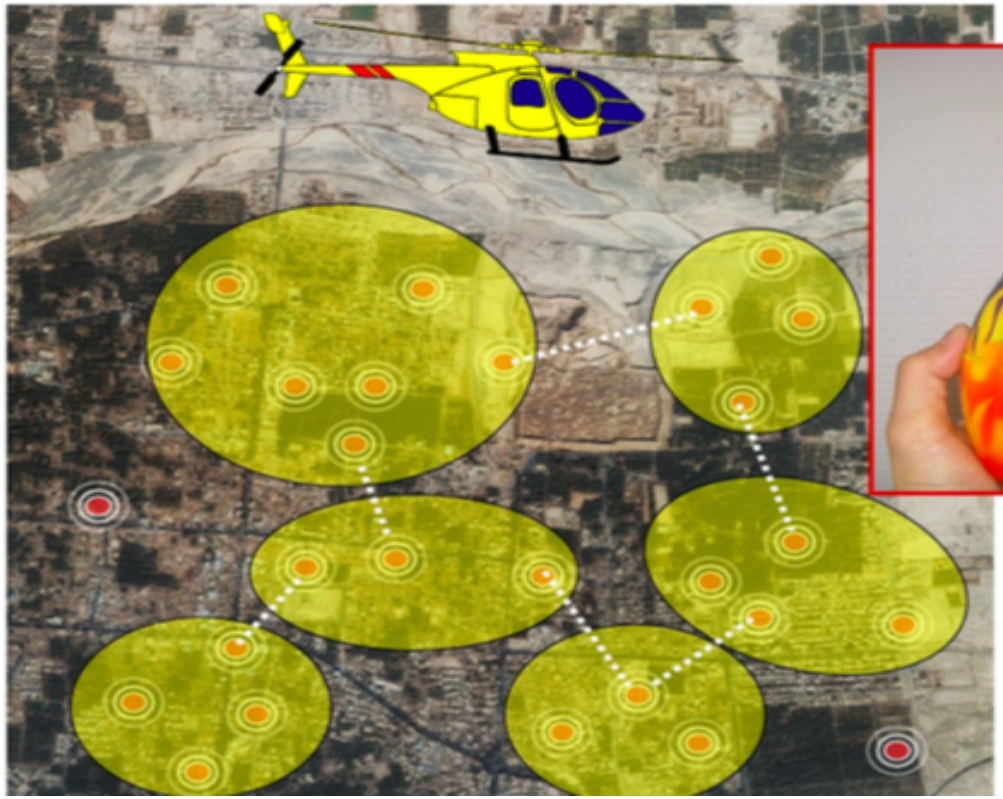
Environmental Applications

- Most of these applications are related to animal tracking, weather conditions and threat contention.

Environmental Applications

Imote2!

Multimedia " board!



Environmental Applications

Figure: Air quality monitoring

Health Applications

- A great deal of these applications are dedicated to monitor patients inside hospitals and provide them with better care.
- This is achieved by tracking the patients vitals or other information of interest and making it available to doctors at any time from anywhere securely through the Internet.

Home Applications

- Technology is making its way inside our homes from various fronts, and WSN are no exception.
- Sensor nodes inside domestic devices will result in an increased interaction among them and allow access via the Internet.
- Theses applications are of great importance in fields like domotics towards a smart home/work environment.
- Home surveillance and multimedia WSNs for home environments are also a growing field of research.

Home Applications

Figure: Smart electricity networks

Industrial Applications

- Historically the monitoring of material fatigue was made by experts introducing the observed situation in- side PDA devices to be collected on a central site for processing.
- Further sensing tech- niques were developed on the form of wired sensors; nevertheless its implementation was slow and expensive due the necessary wiring. WSNs bring the best of both methods by sensing the events without the need of expert personal and the cost of wiring.

Other Applications

- Inventory management
- Product quality monitoring
- Smart offices/houses
- Vehicle tracking and detection
- Guidance in automatic manufacturing environments
- Spectrum sensing for cognitive radio networks
- Underground and underwater monitoring.
- Precision agriculture

Other Applications

Figure: Application in agriculture

Other Applications

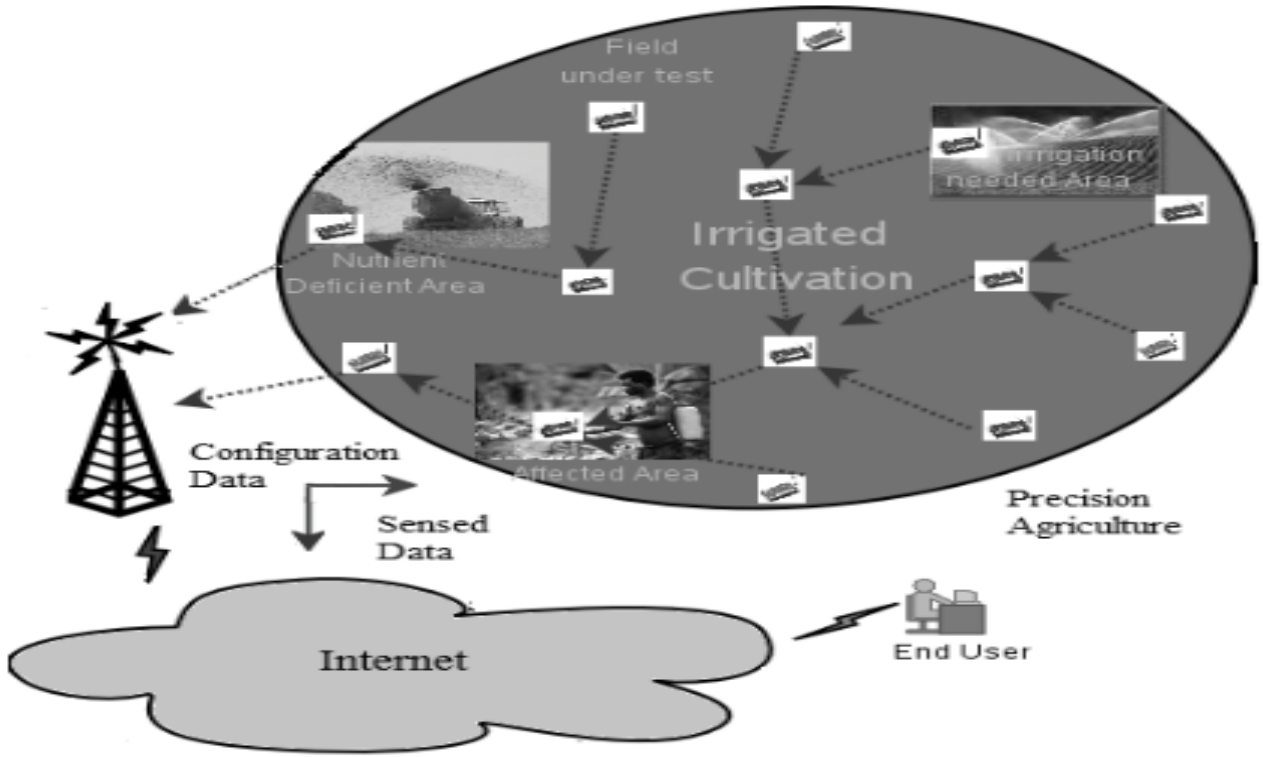


Figure: A typical WSN deployment for agricultural applications

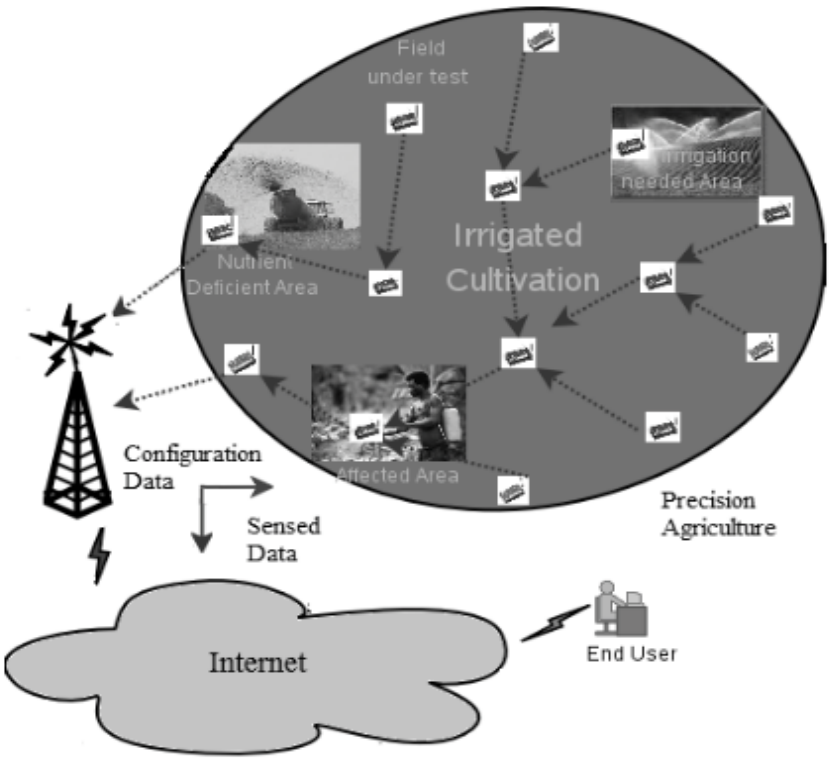


Figure: A typical WSN deployment for agricultural applications

- The use of WSN technology in agriculture has positively impacted the environment and therefore the humanity, because the controlled irrigation and proper use of fertilizer can save drinking water levels and prevent water pollution.
- On the contrary, if irrigation and fertilization is performed in an uncontrollable fashion, it may have terrible and immediate consequences in underwater life.

Other Applications

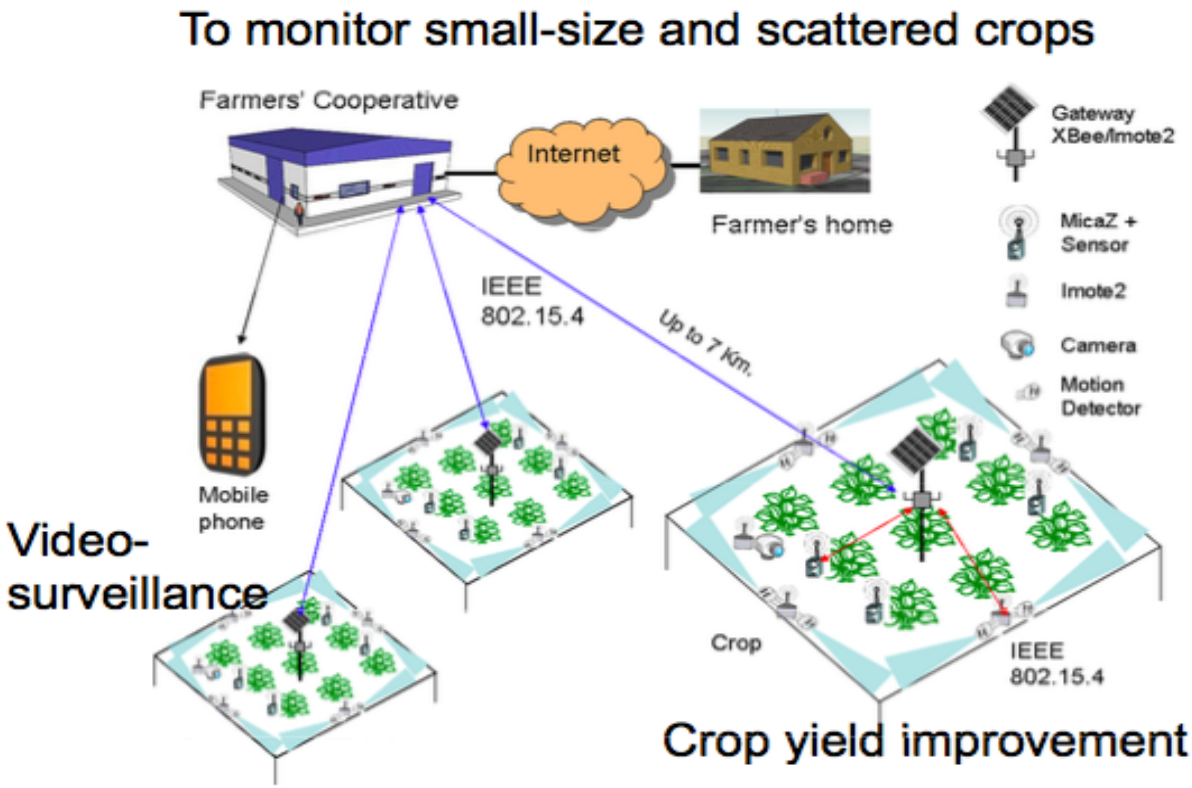


Figure: WSN for precision agriculture

Other Applications

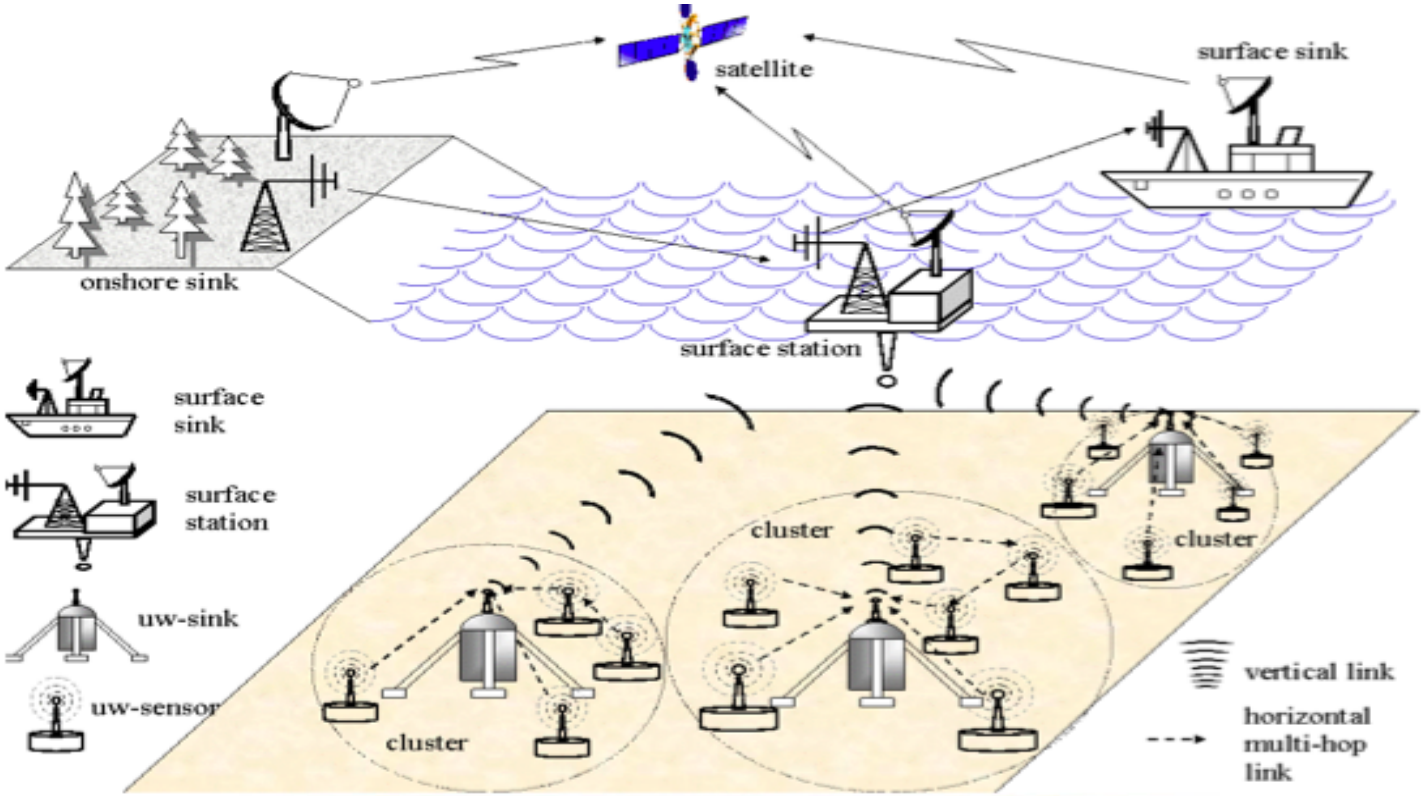


Figure: Underwater acoustic sensor networks