Wireless Sensor Networks (WSN)

Wireless Sensor Network

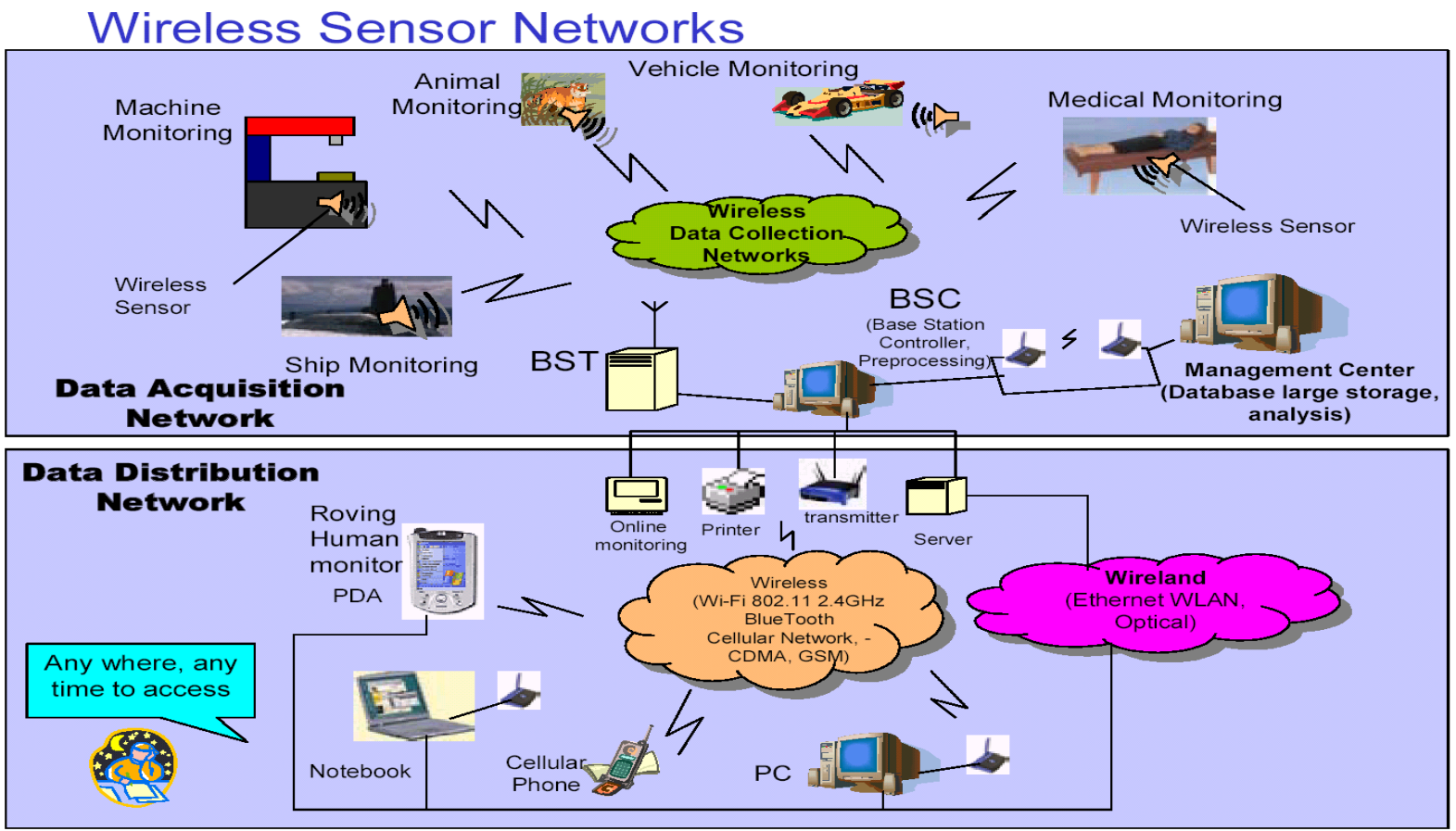
A **wireless sensor network** (WSN) is a wireless network consisting of spatially distributed autonomous devices using smart sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations.

Applications

1. Smart Buildings
2. Tree Monitoring
3. Glacier Monitoring
4. Aircraft, Spacecraft Monitoring
5. Environment Monitoring
6. Monitoring for intrusion at country borders
7. Industrial Process Monitoring
8. Habitat monitoring
9. Landslide Detection

etc.

Wireless Sensor Networks



Challenges in Designing WSN

1. Limited Hardware
2. Limited Support for Networking
3. Limited Support for Software Development
4. Limited Energy / Power Availability

Requirements for WSNs

1. Collaborative data processing- scalable, fault tolerant, flexible data access, intelligent data reduction
2. Constrained energy use- battery / solar
3. Large topology support- more than 1,00,000
4. Querying capabilities- event driven & query driven
5. Self organization – reconfigurable

Basic Types of WSNs

Event driven

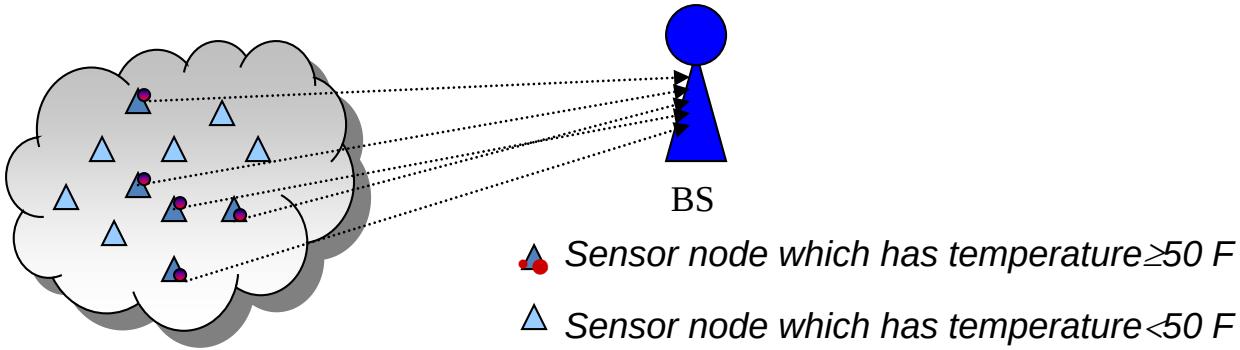
-- Transmitting all sensory data by individual nodes all the time wastes the wireless bandwidth and energy.

-- Therefore sensor network should respond to the changes in the environment automatically when event occurs

-- The sensors become active only when certain abnormal conditions are detected.

-- Sensors broadcast the results only when they meet the threshold.

Event Driven Approach



For instance, if application is *temperature monitoring*, it reports data when the Temperature of the area being monitored goes *above or below certain Thresholds.* Every sensor node which has temperature above 50 broadcasts to sink node.

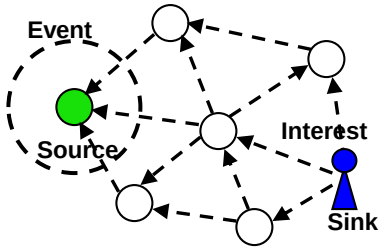
Query driven

The sensor is bought out of its sleep by the main controller only when it desires.

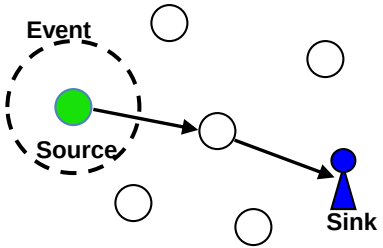
It searches for the result in the whole sensor network, whenever there are queries from the users.

Query Driven Approach

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



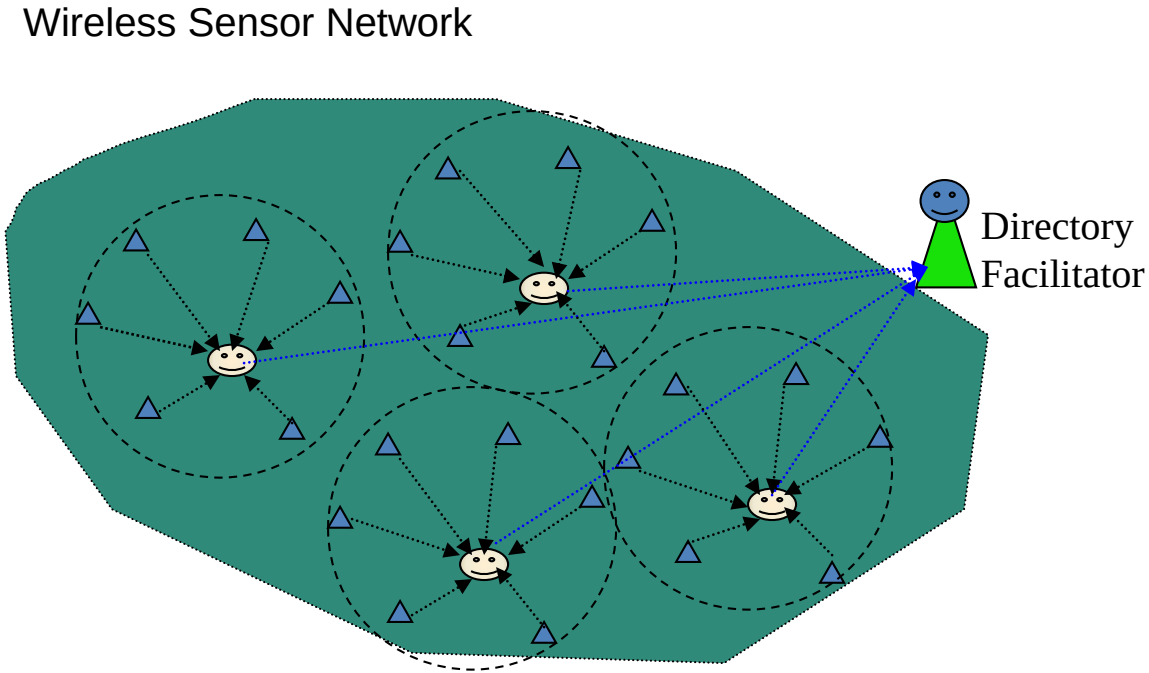
a) Interest Propagation



b) Data delivery

For 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.

The System Overview



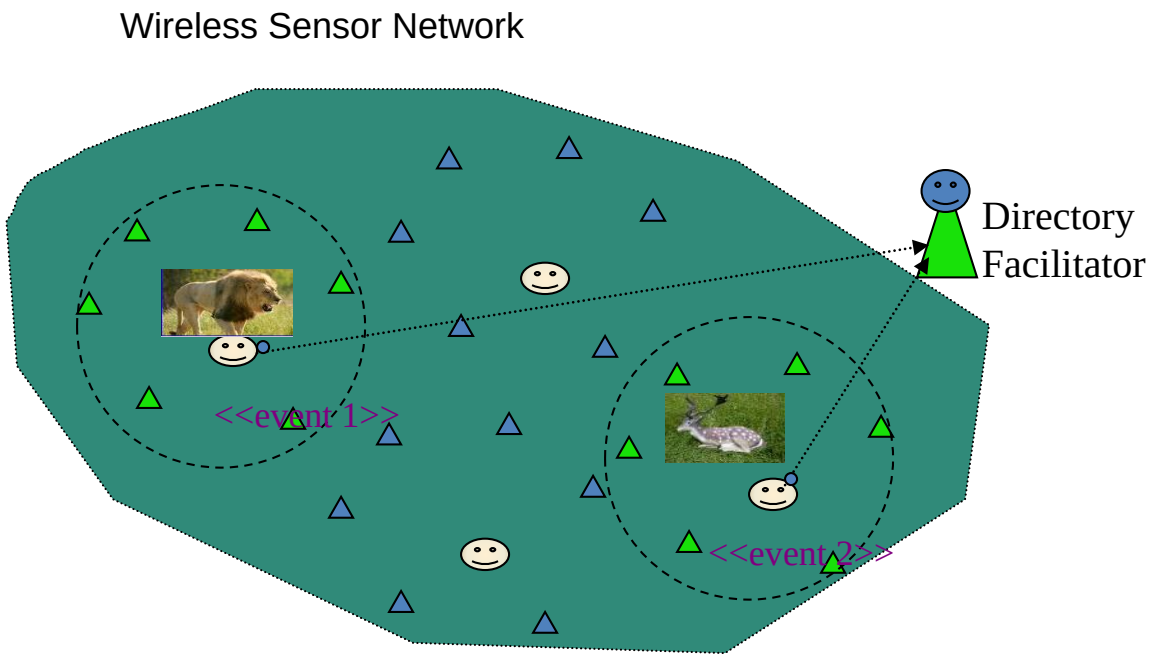
1. First, intelligent sensor nodes and their associated data centric nodes must register to the directory facilitator (DF).

Data centric sensor node

Intelligent sensor node

Mobile agent

The System Overview



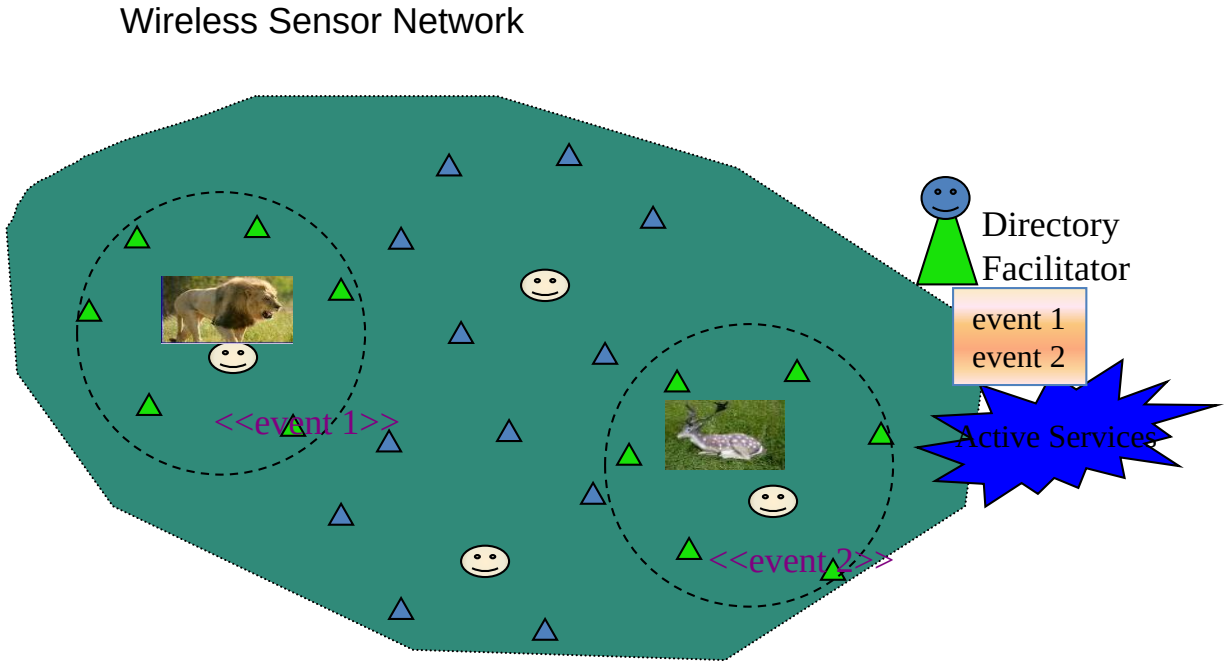
2. When event occurs, the intelligent sensor node, which detects the event, announce to the directory facilitator.

Data centric sensor node

Intelligent sensor node

Mobile agent

The System Overview



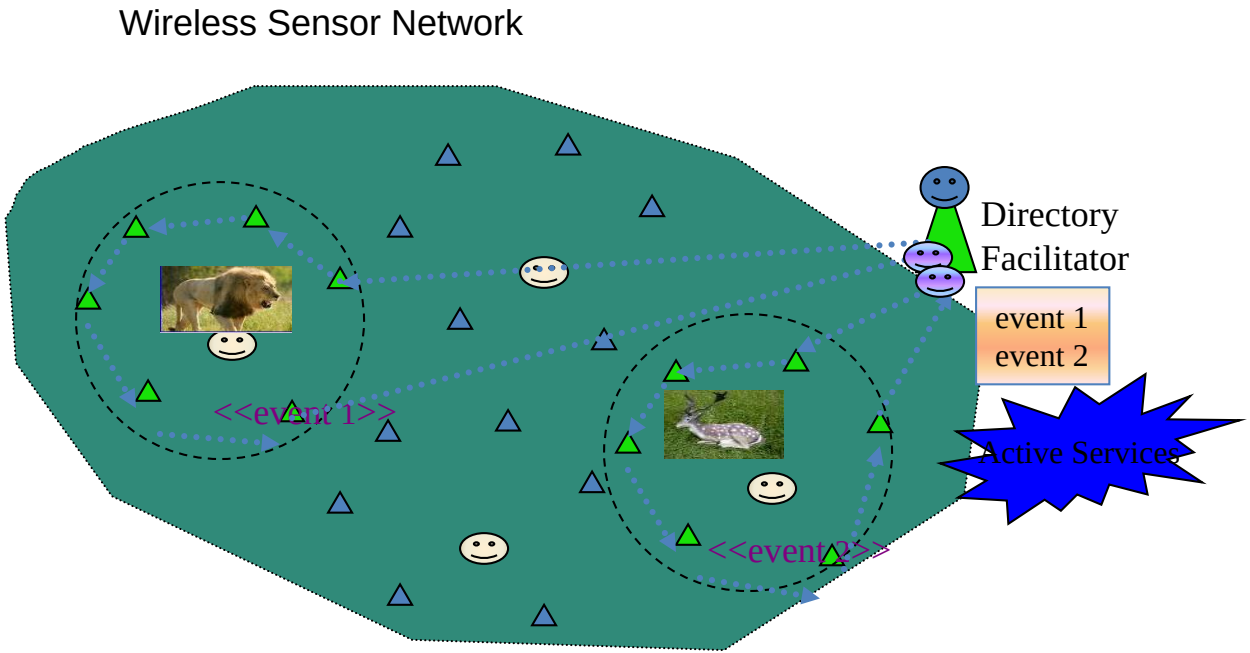
3. When directory facilitator receives the announcement from the intelligent sensors, it keeps the announcement as an active service

Data centric sensor node

Intelligent sensor node

Mobile agent

The System Overview



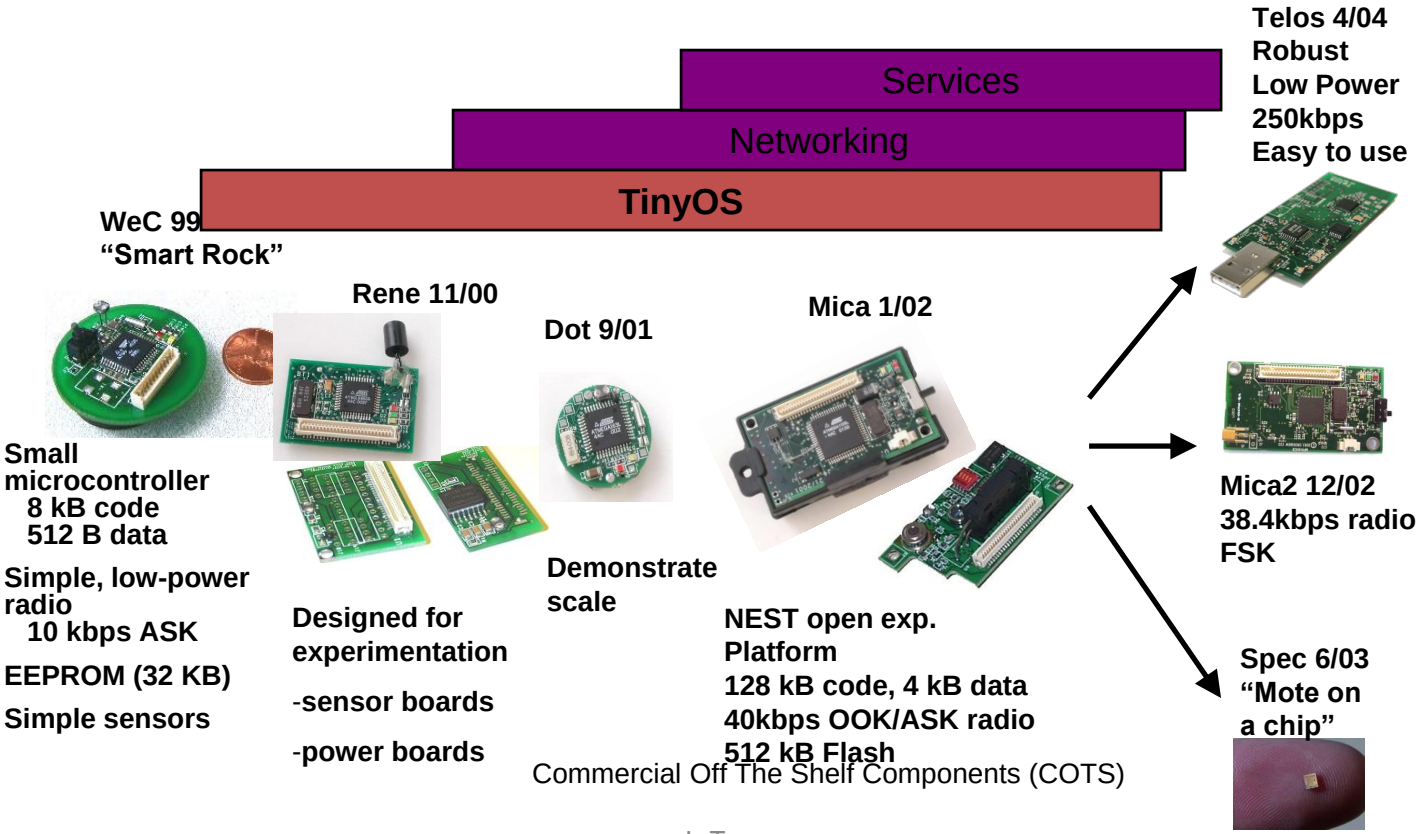
4. DF retrieves the identities of data centric nodes which are associated to intelligent sensor and performs the data collection task by using mobile agents.

Data centric sensor node

Intelligent sensor node

Mobile agent

Open Experimental Platform



Commercial Off The Shelf Components (COTS)

Possible WSN Protocol Stack

Upper layer (Communication)	In-network applications, including application processing, data aggregation, external querying query processing, and external database
Layer 4	Transport, including data dissemination and accumulation, caching and storage
Layer 3	Networking, including adaptive topology management and topological routing
Layer 2	Link layer (contention); channel sharing (MAC), timing & locality
Layer 1	Physical medium; communication channel, sensing, actuation and signal processing

Traditional Wired Networks Vs Wireless Sensor Networks

Sr. No	Wired Network	Wireless Sensor Network
1.	Users can update and maintain devices (e.g., each computer maintained by a human)	May be impossible to update or maintain sensor nodes, due to sheer numbers as well as deployment locations
2.	Communication between two specific end users	Communication data-centric →End-user does not care that the data came from node X, only what the data describes
3.	Goal: providing high QoS bandwidth efficiency	Goal: prolonging lifetime of the network → Requires energy conservation → Willing to give up performance in terms of QoS or bandwidth efficiency

Traditional Wired Networks Vs Wireless Sensor Networks

Sr. No	Wired Network	Wireless Sensor Network
4.	Data is important	End user does not require all the data → Data from neighboring nodes are highly correlated, making the data redundant → End user typically cares about a higher-level description of events occurring in the environment nodes are monitoring → Network quality often based on quality of aggregate data set rather than individual signals
5.	Intermediate nodes do not care what the data is	Application-specific routing to improve performance

Traditional Wired Networks Vs Wireless Sensor Networks

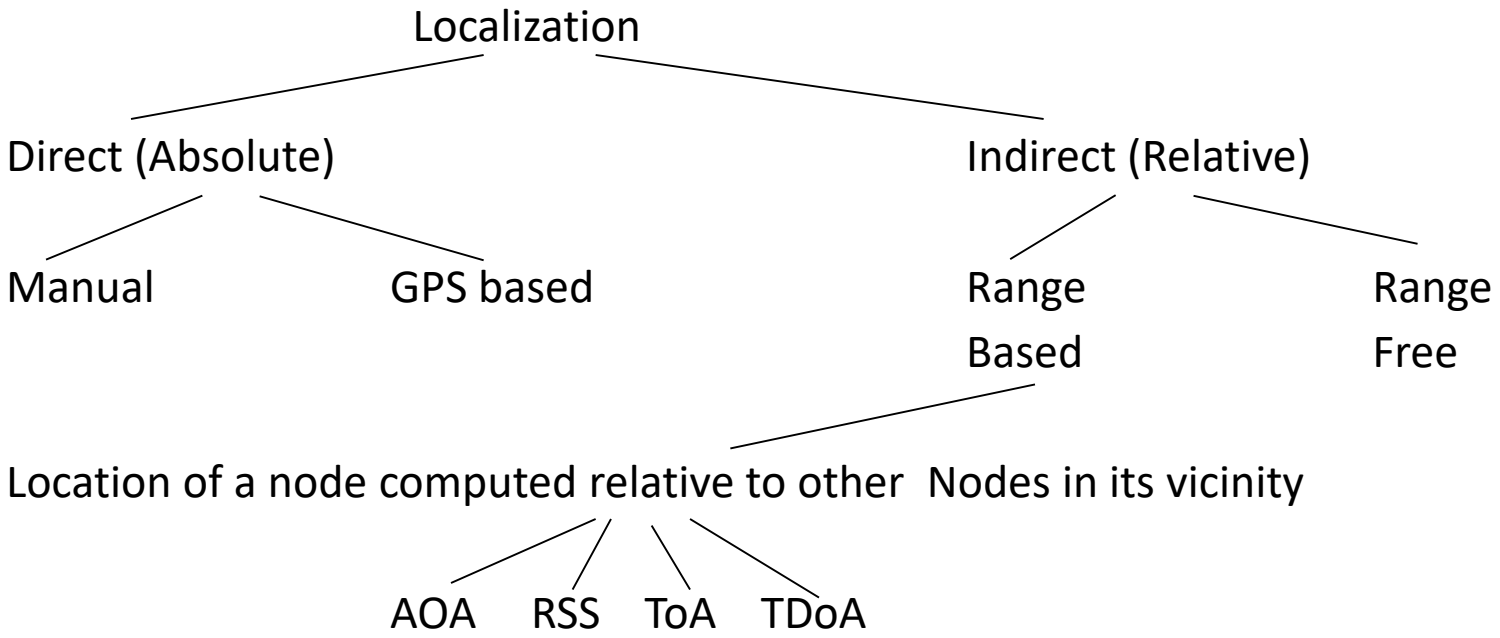
Sr. No	Wired Network	Wireless Sensor Network
6.	Nodes operating (mostly) independently	Sensor network application computation → May need to be distributed throughout network (e.g., localized algorithms that achieve desired global result) → May require hierarchical structure → Enables computation / communication tradeoff → Three processing levels: node, local, and global
7.	Operate in (mostly) benign environments	May be deployed in hostile or dangerous territory

Localization

- To dynamically define & form sensor groups based on task requirements & resource availability.
- A form of collaborative signal & information processing. (CSIP)
- Information sharing & group management is necessary.
- The above work has to be done in a dynamically evolving environment.

Localization

Localization gives the spatial relation between the different sensor nodes in a network.



Absolute point to point distance between sensor nodes is not estimated

Time Synchronization

- Nodes in a sensor network operate independently. Hence their clocks may not be, or stay, synchronized with one another.
- Estimating time differences across nodes accurately is important during node localization. (TDOA, time-of-flight)
- For nodes to be able to synchronize, they must have for a period a communication channel where message delays can be reliably estimated.

Time Synchronization

- **External** synchronization
  - clocks are synchronized with external source of time (reference clock)
  - reference clock is accurate real-time standard (e.g., UTC)
- **Internal** synchronization
  - clocks are synchronized with each other (no support of reference clock)
  - goal is to obtain consistent view of time across all nodes in network
  - network-wide time may differ from external real-time standards.

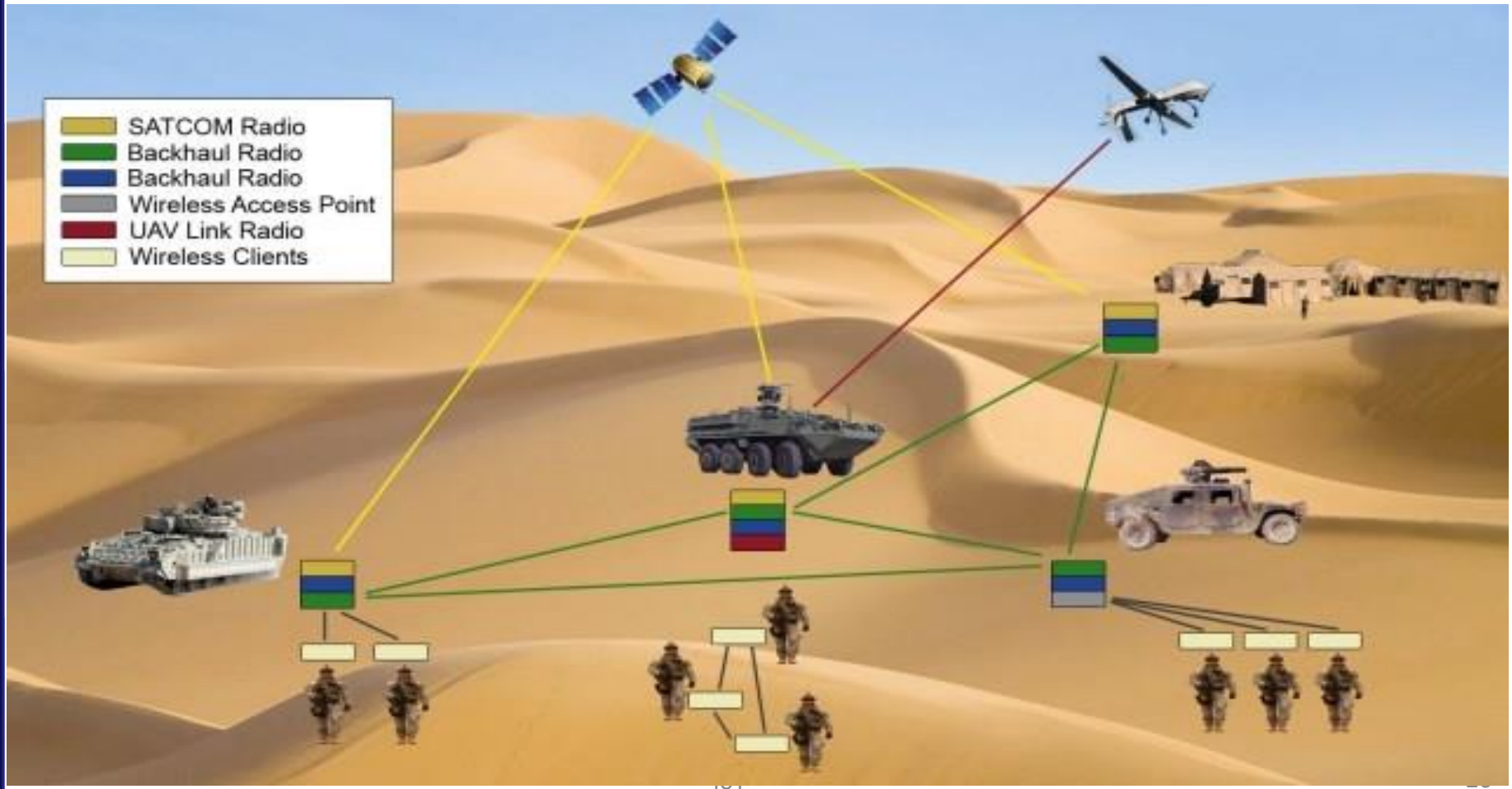
Types of WSNs

Depending on the environment, the types of networks are decided so that those can be deployed underwater, underground, on land, and so on. Different types of WSNs include:

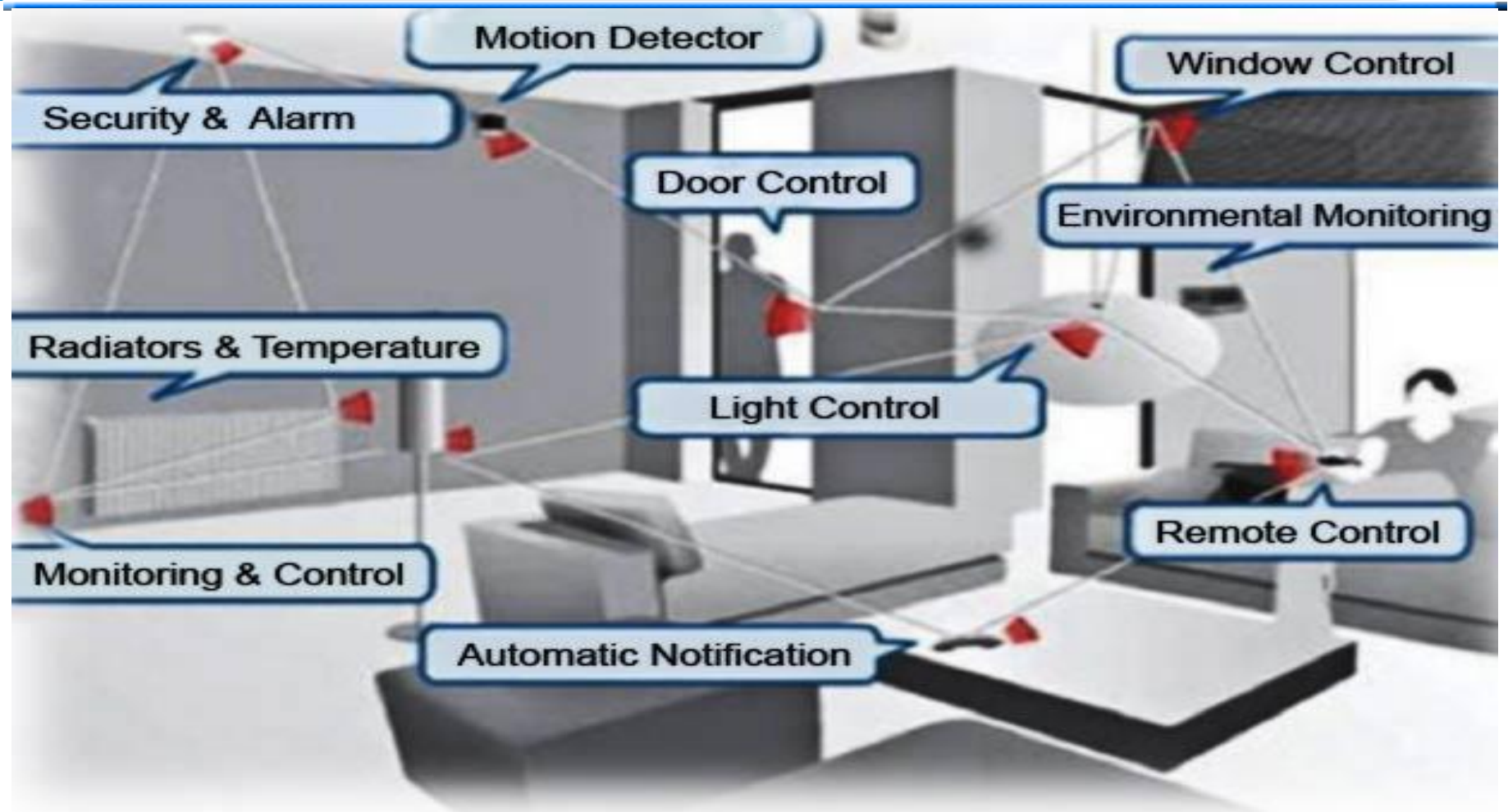
- Terrestrial WSNs
- Underground WSNs
- Underwater WSNs
- Multimedia and mobile WSNs

Terrestrial WSN

Terrestrial WSN

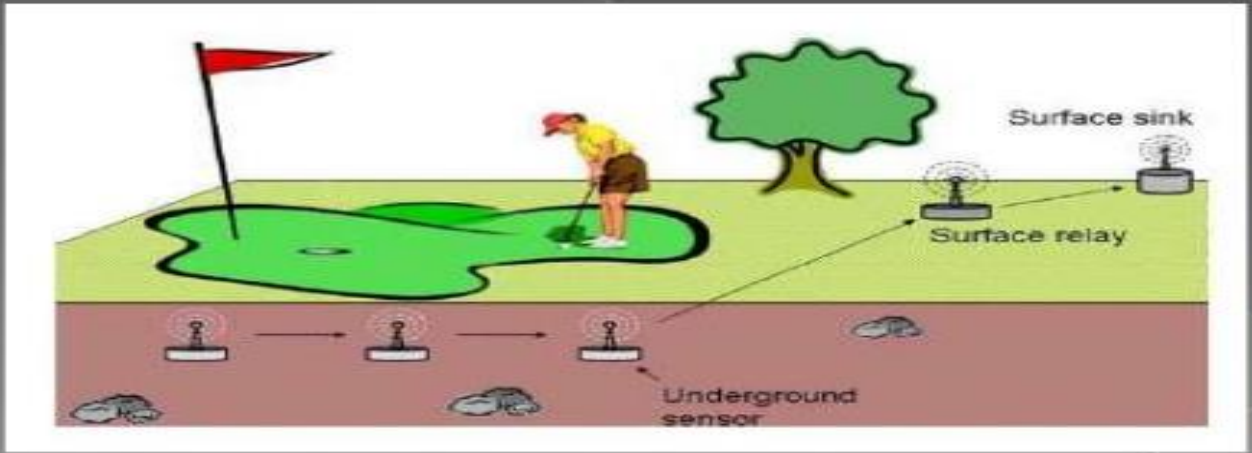


Terrestrial WSN

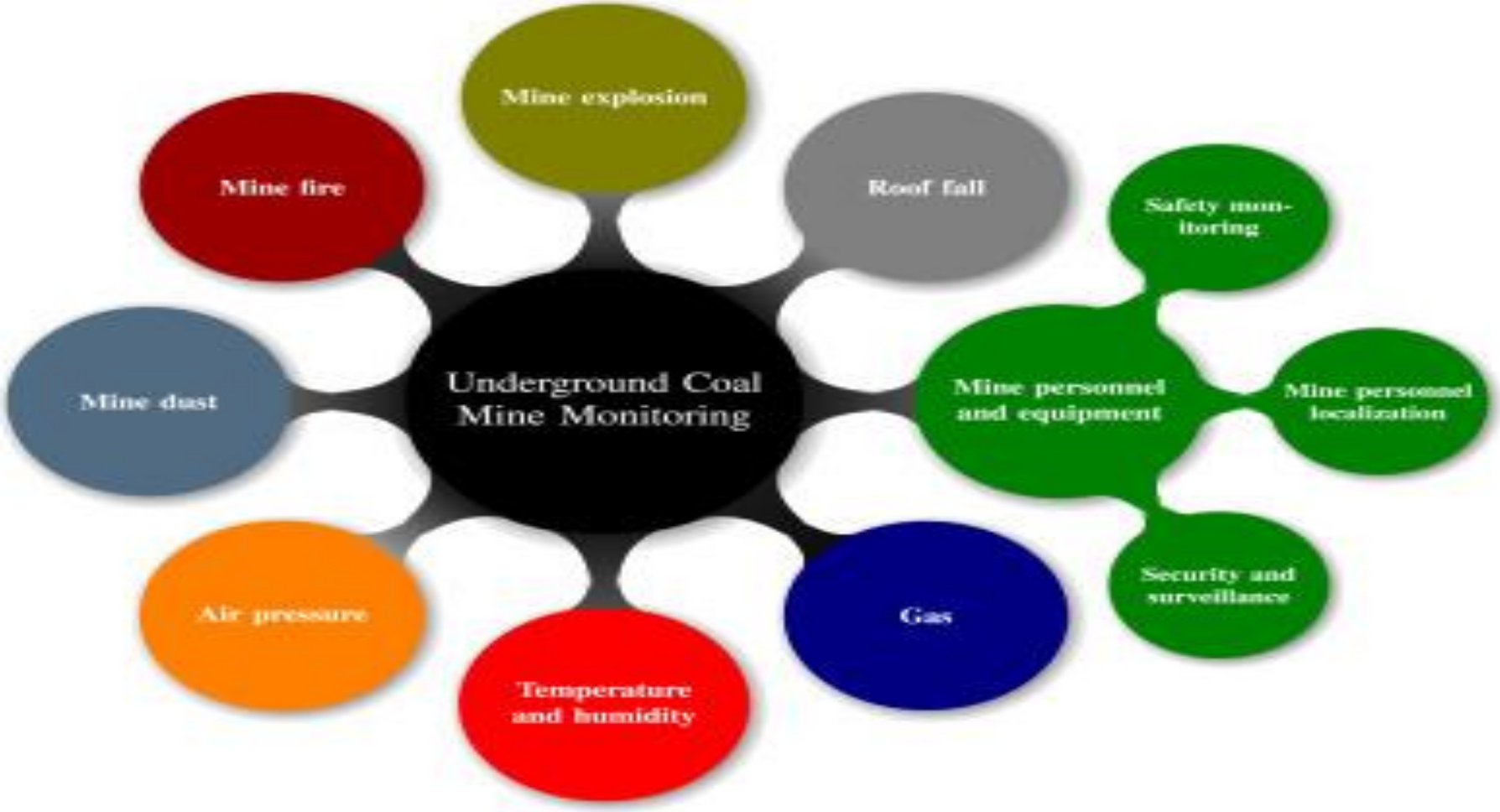


Underground WSN (WUSN)

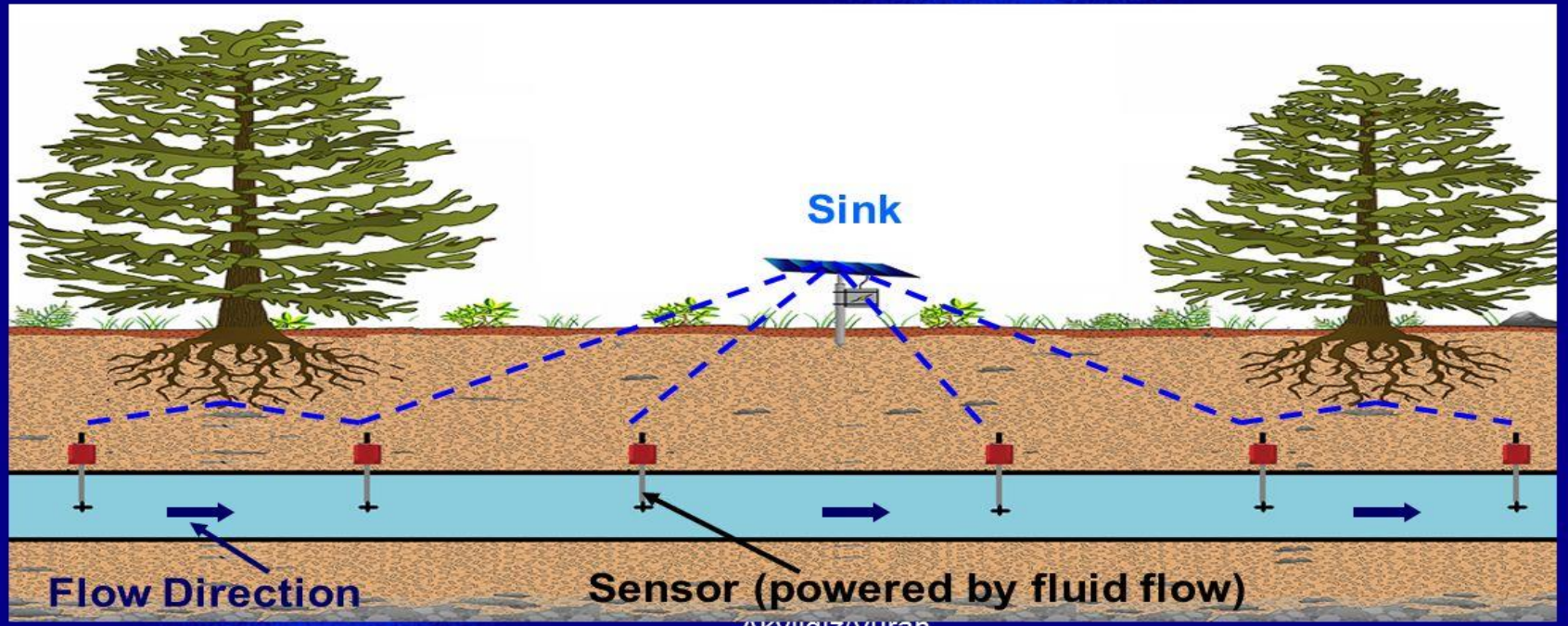
- A WUSN deployed for monitoring a golf course.
- Underground sensors can be used to monitor soil salinity, water content, and temperature.
- Surface relays and sinks, which can be placed away from playing areas, are used to forward WUSN sensor data to a central receiving point



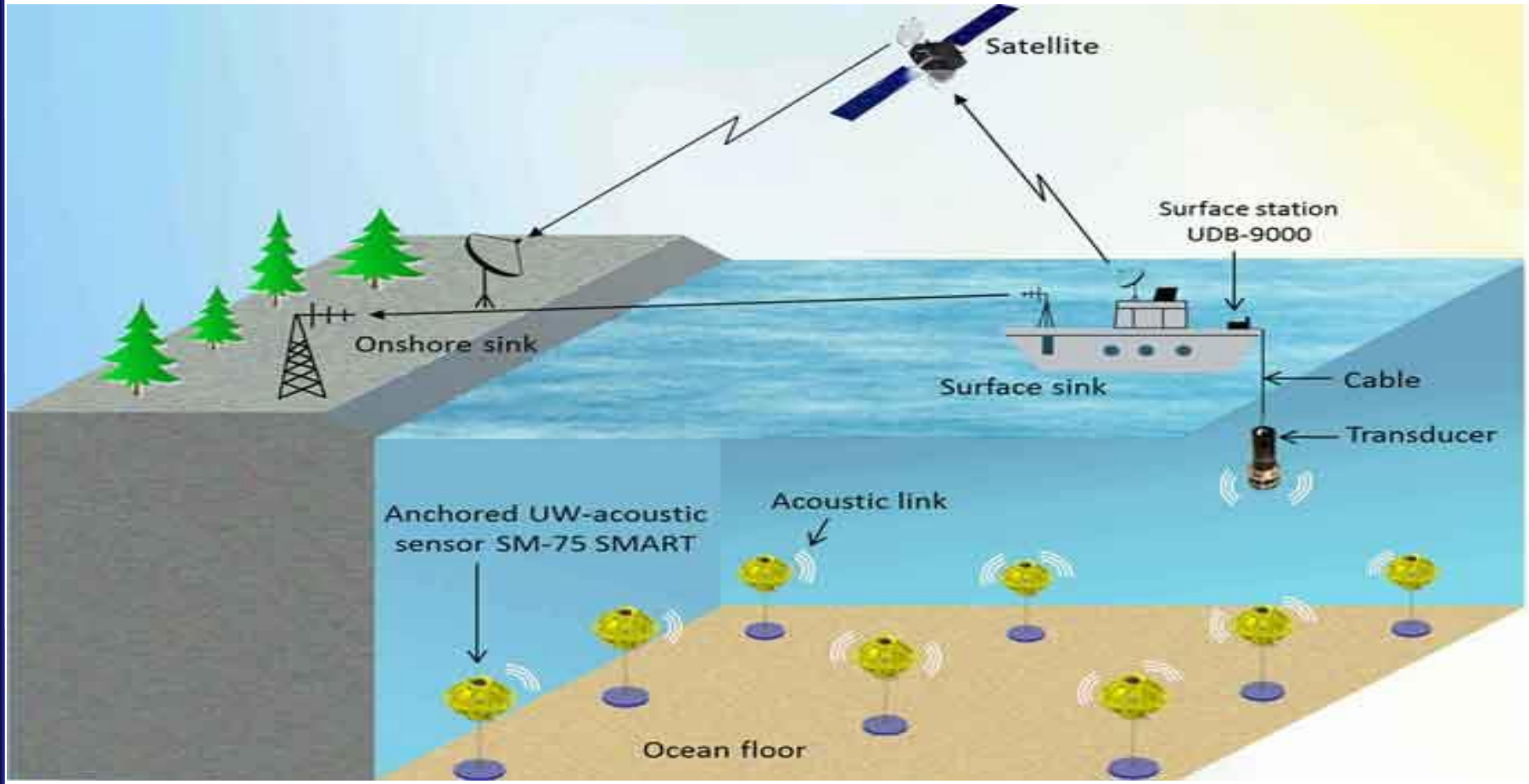
Underground WSN (WUSN)



Underground Pipeline Monitoring



Underwater WSN (UWSN)



Underwater WSN (UWSN)

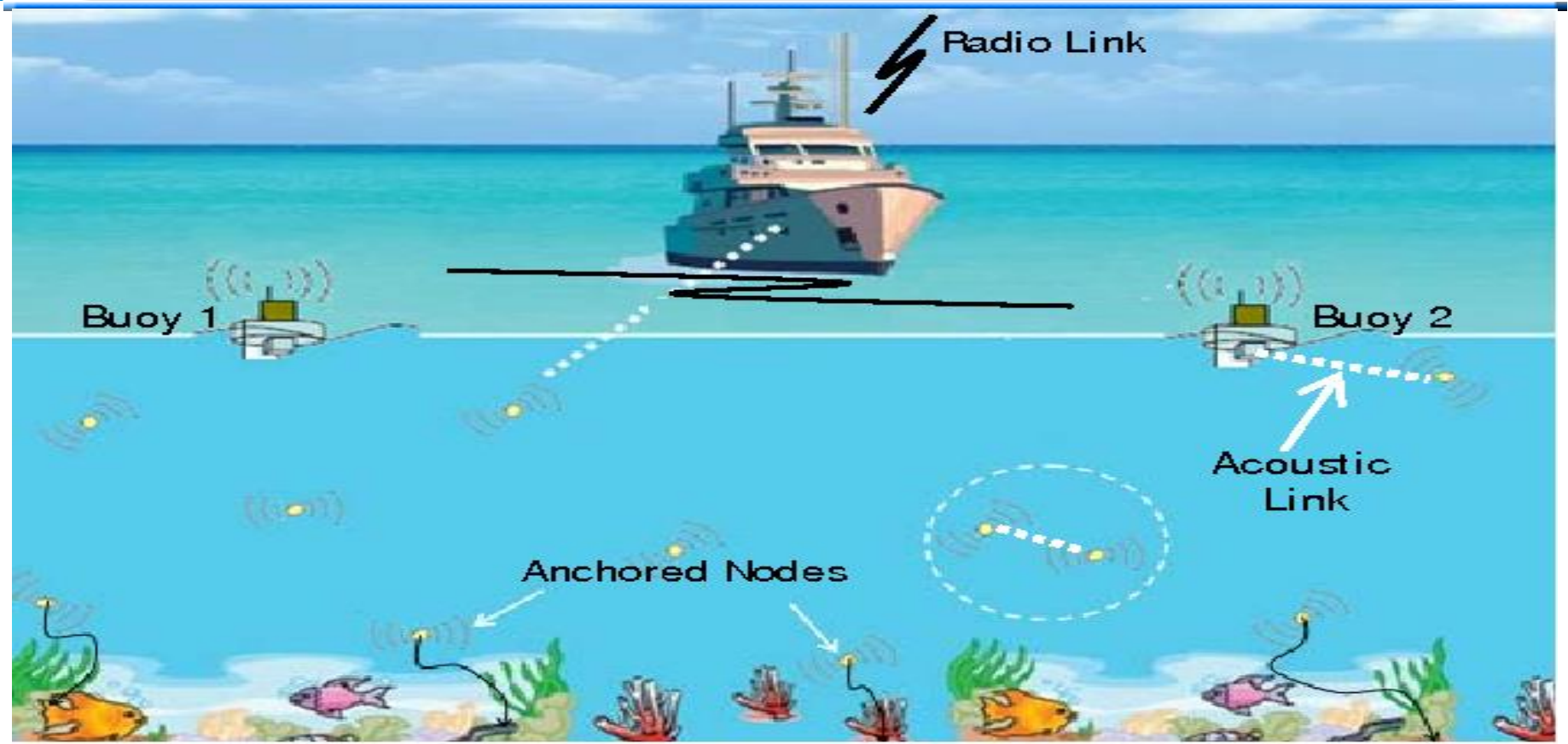
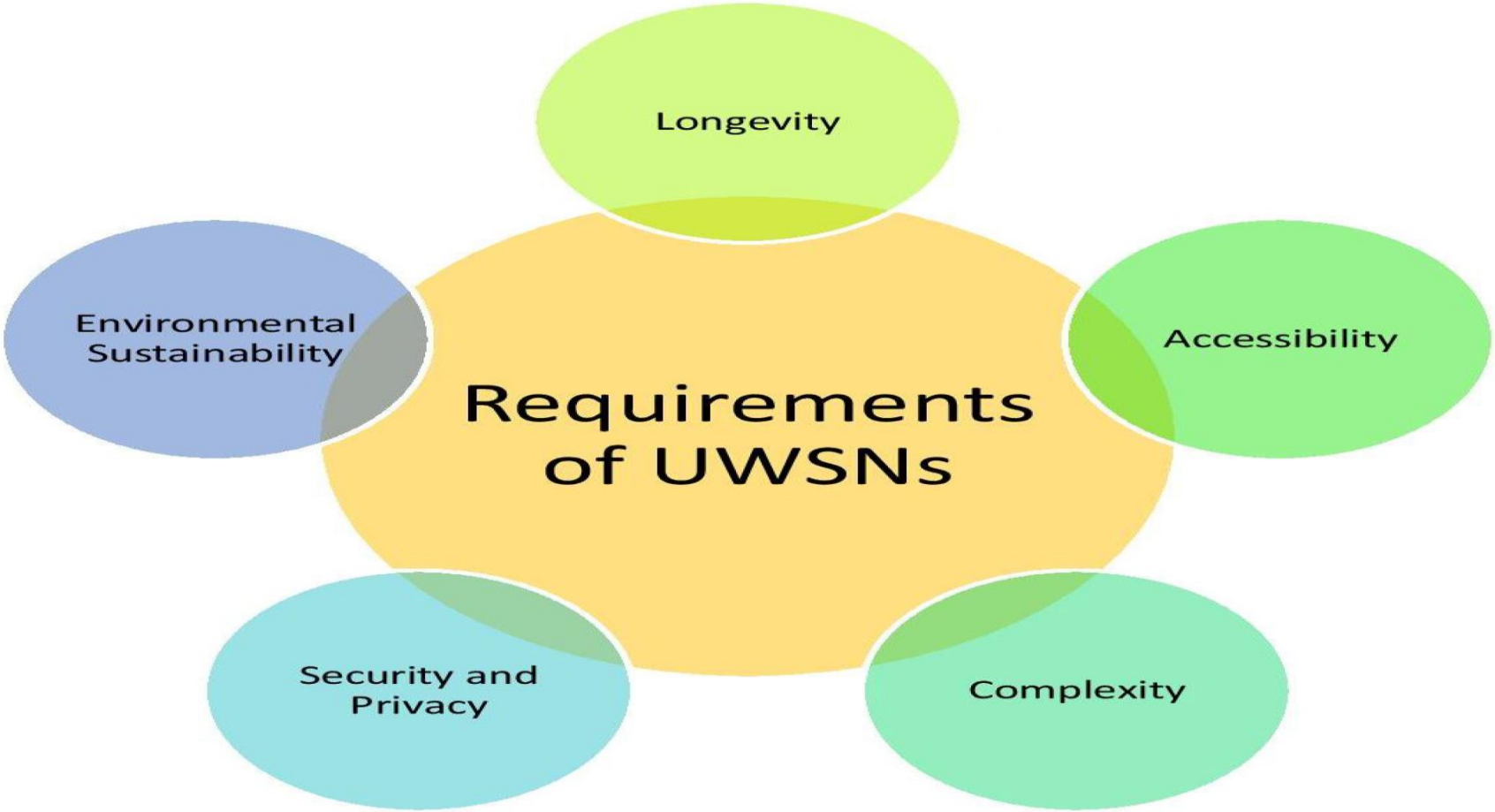
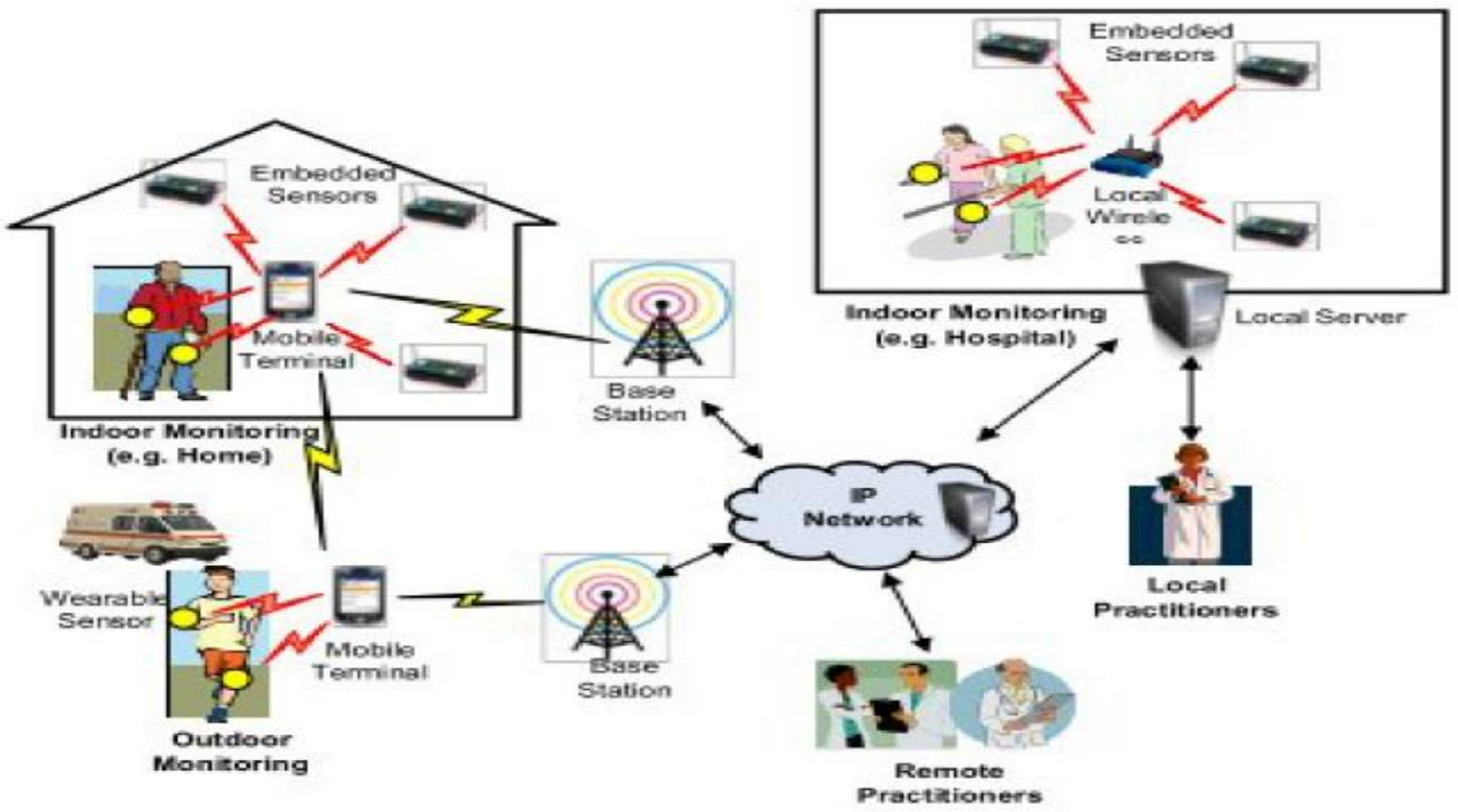


Figure 1. Underwater sensor networks

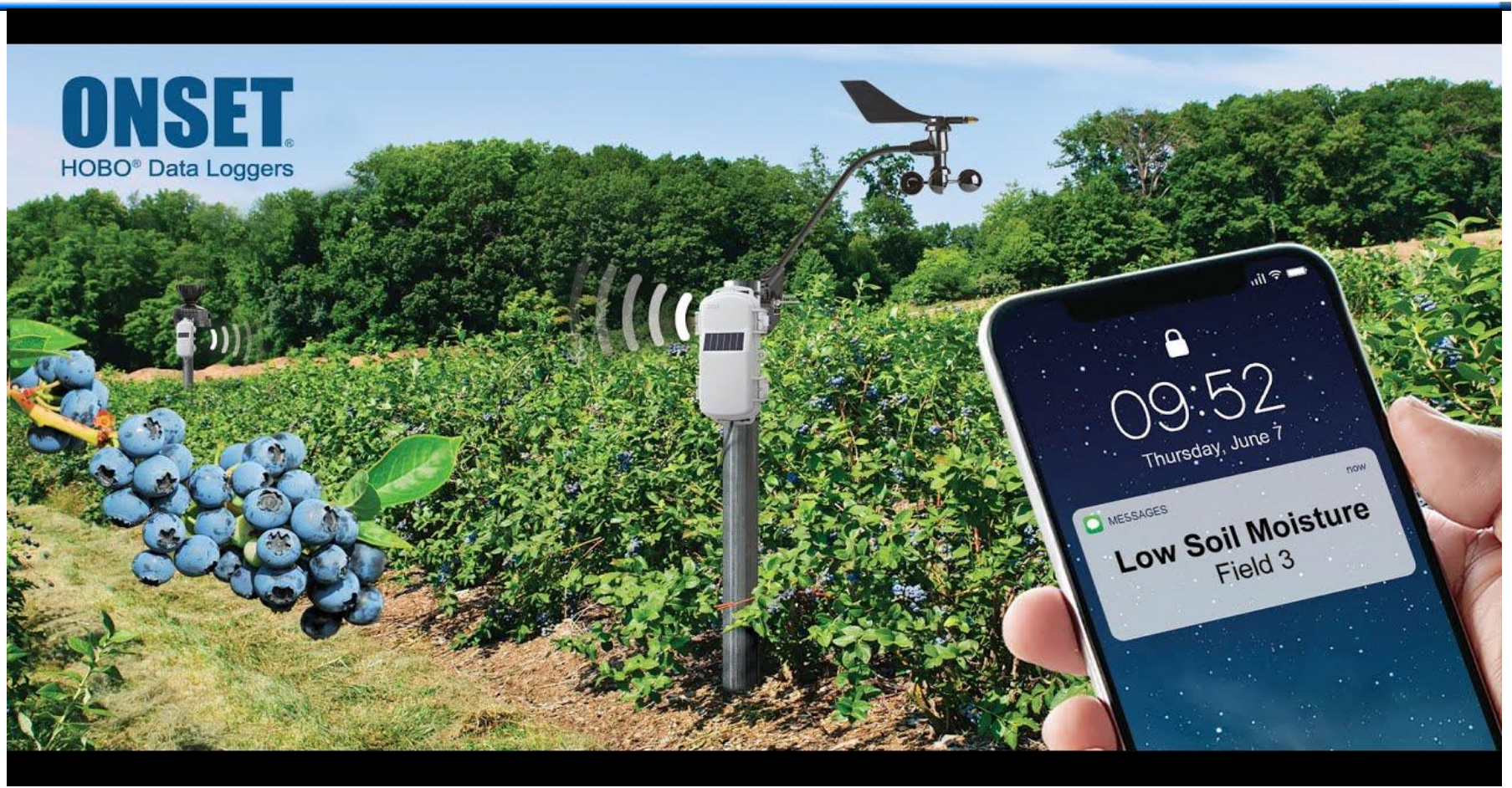
Underwater WSN (UWSN)



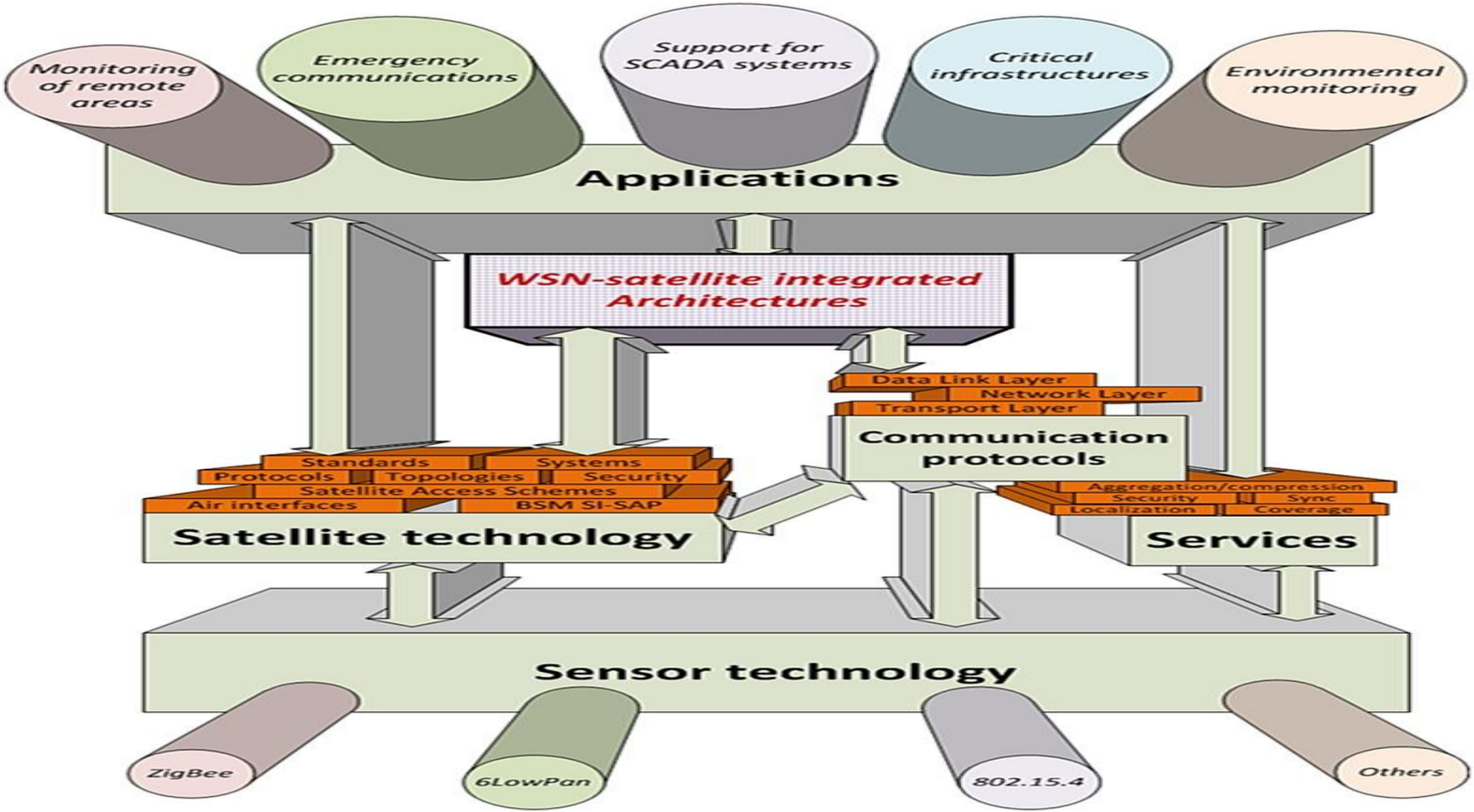
Multimedia and Mobile WSN



Multimedia and Mobile WSN



Other Applications-WSN in Satellites



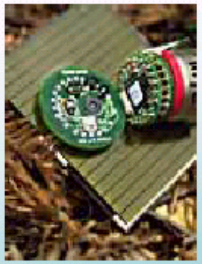
Redwood tree Microclimate Monitoring

Traditionally performed installing heavy equipment within the tree foliage, with cables connecting them to data logger installed at the bottom of the trees

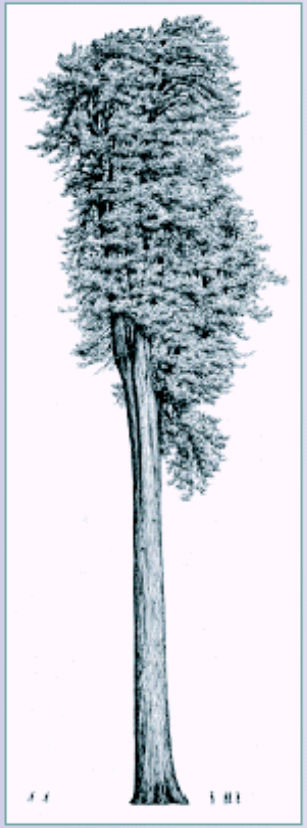
A few measurement sessions lasting few minutes each were possible, performed at different heights in the tree foliage.

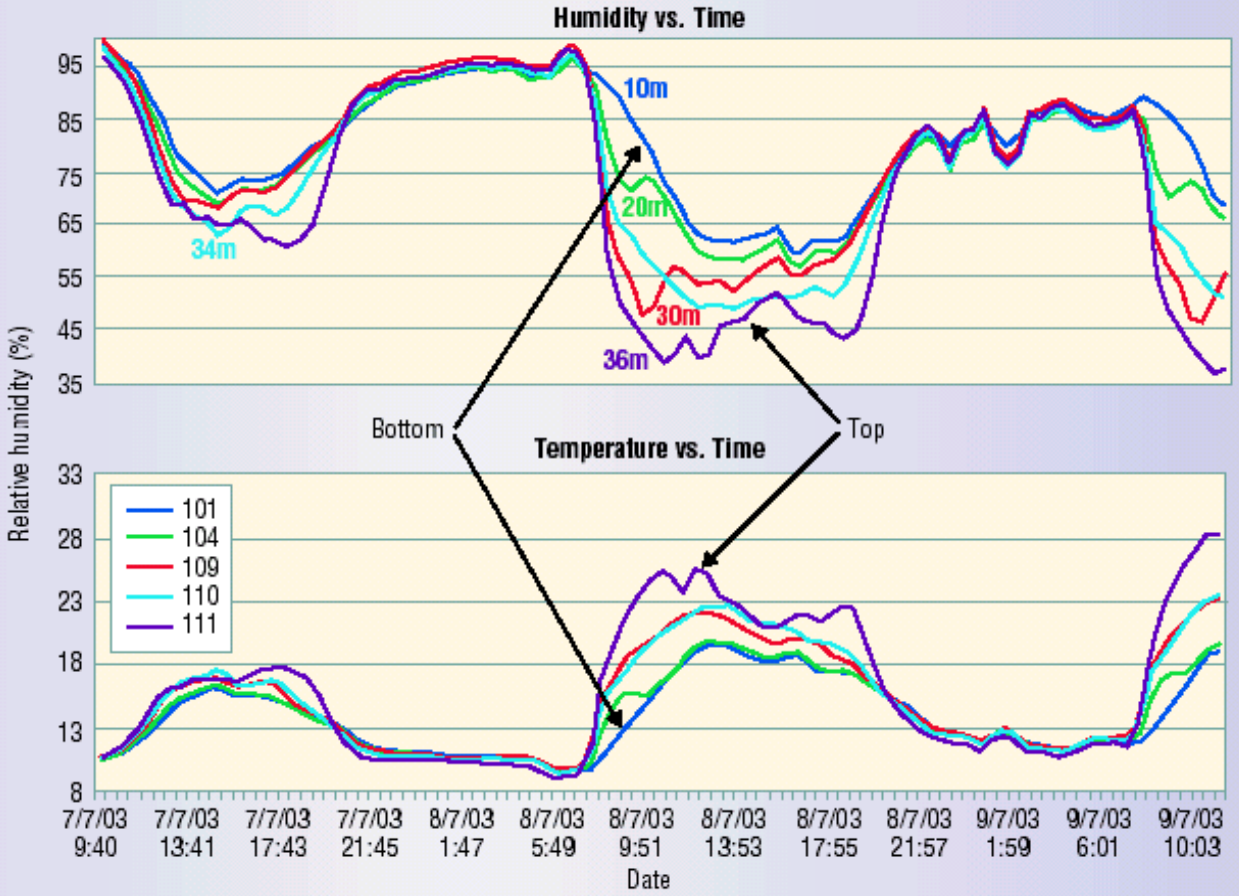
Redwood tree microclimate monitoring

- Aug 2003: David Culler's group helped Todd Dawson of UCB install a WSN to replace existing data logger system for redwood monitoring.
- 50 nodes were installed.
- ``This will really revolutionize our ability to collect high precision environmental data."

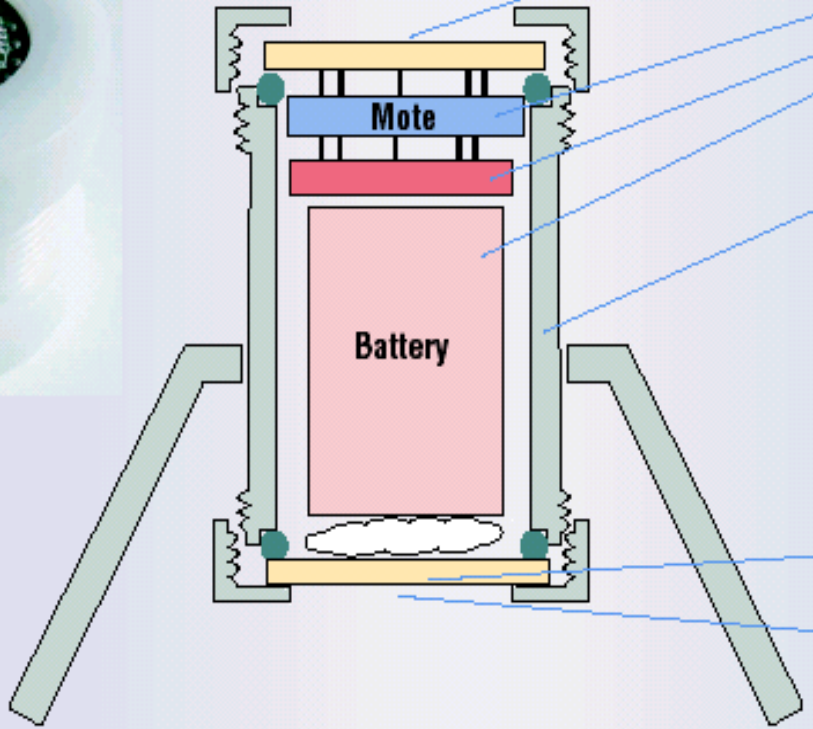


Redwood tree Microclimate Monitoring



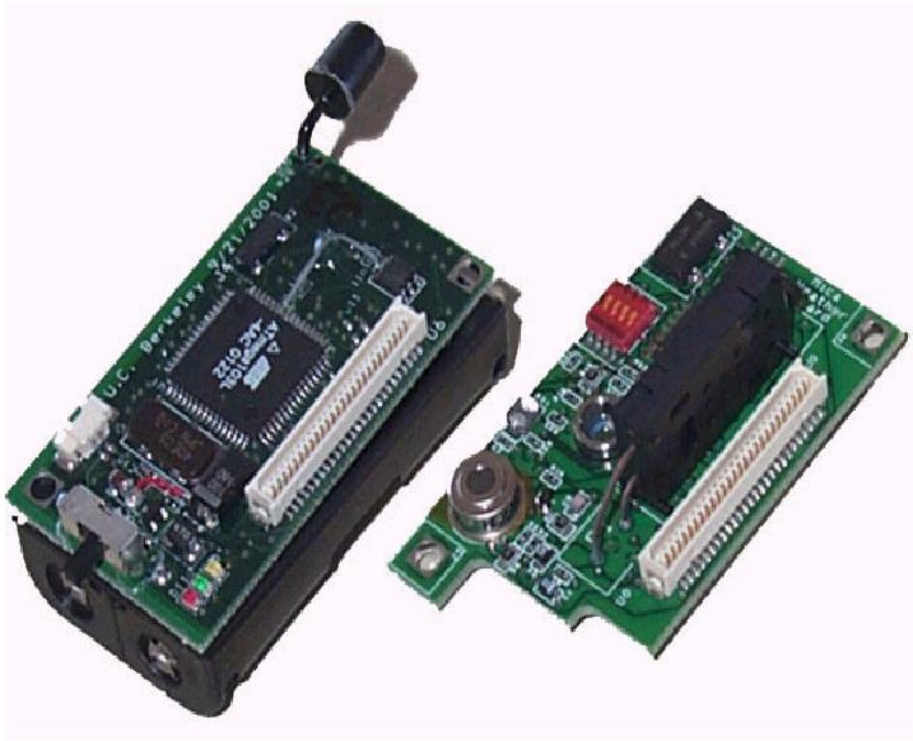


Redwood tree Microclimate Monitoring

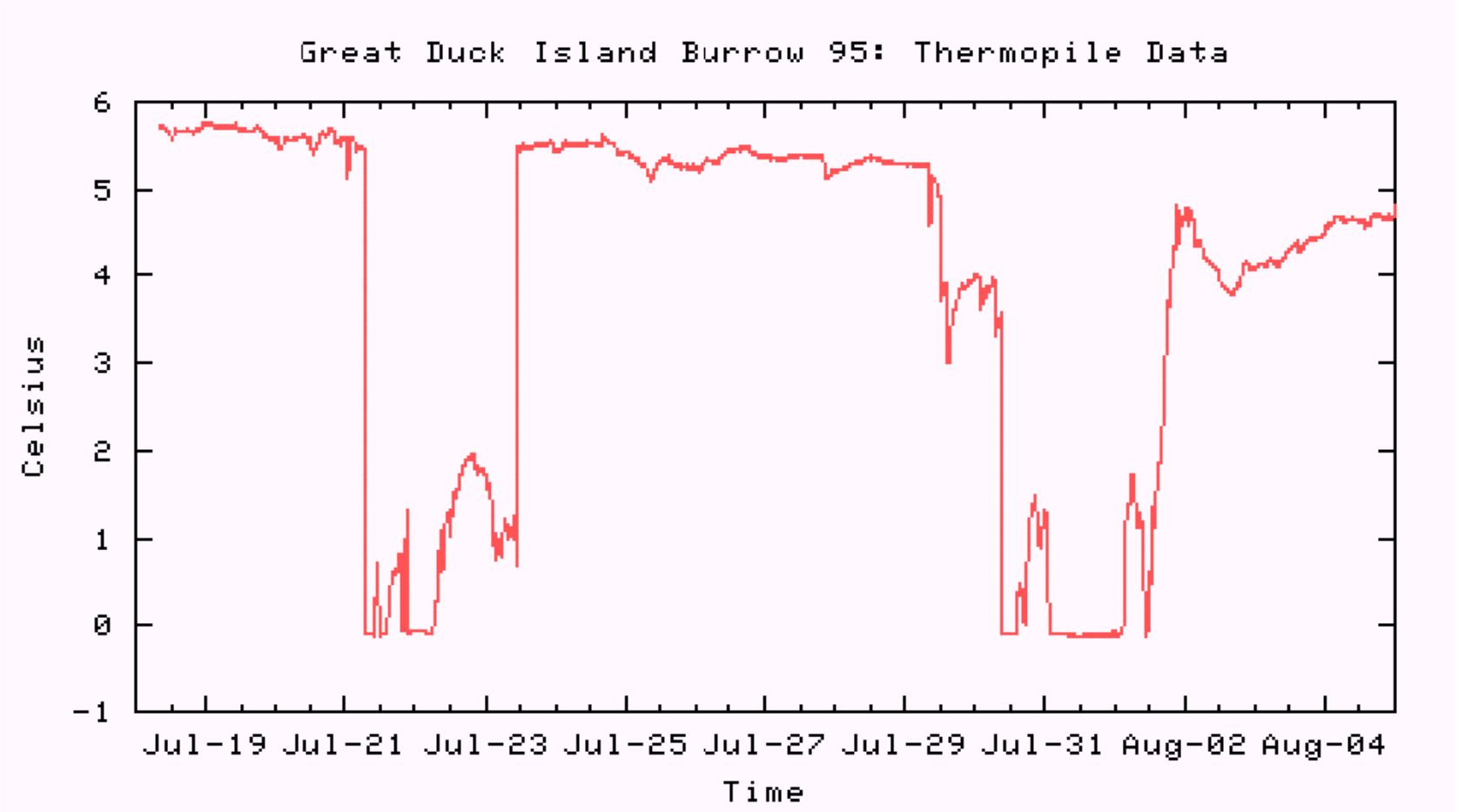


- Incident light sensors
  - TAOS total solar
  - Hamamatsu PAR
- Mica2Dot mote
- Power board
- Power supply
  - SAFT LiS02 battery, ~1 Ah @ 2.8V
- Packaging
  - HDPE tube with coated sensor boards on both ends of the tube
  - O-ring seal for two water flows
  - Additional PVC skirt to provide extra shade and protection against the rain
- Radiant light sensors
  - PAR and total solar
- Environmental sensors
  - Sensirion humidity + temp
  - Intersema pressure + temp

Habitat Monitoring- Great Duck Island



Habitat Monitoring- Great Duck Island



Thank You!