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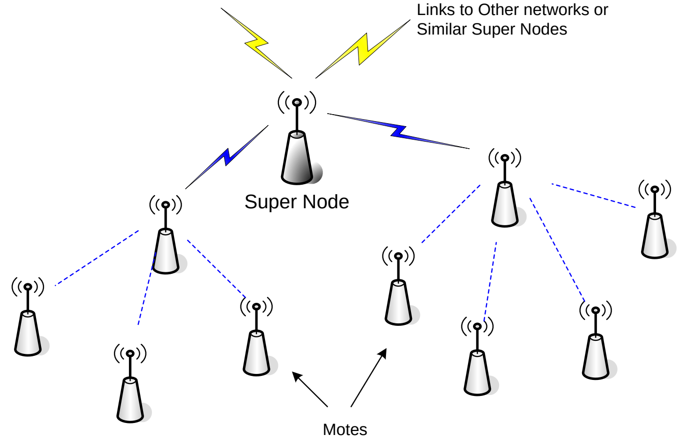
Wireless sensor networks: Introduction

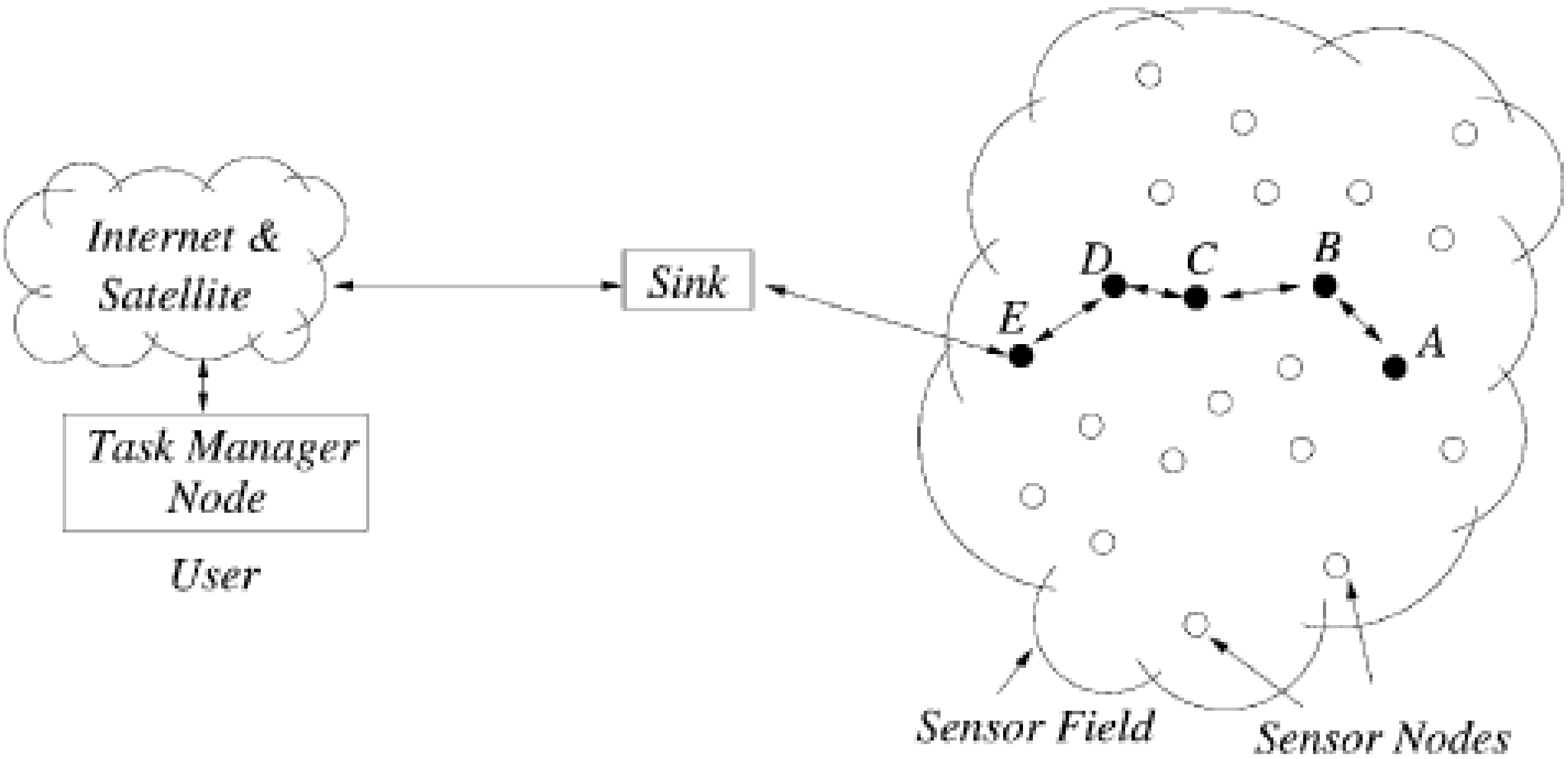
Wireless sensor networks

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

- Formed by hundreds or thousands of motes that communicate with each other and pass data along from one to another

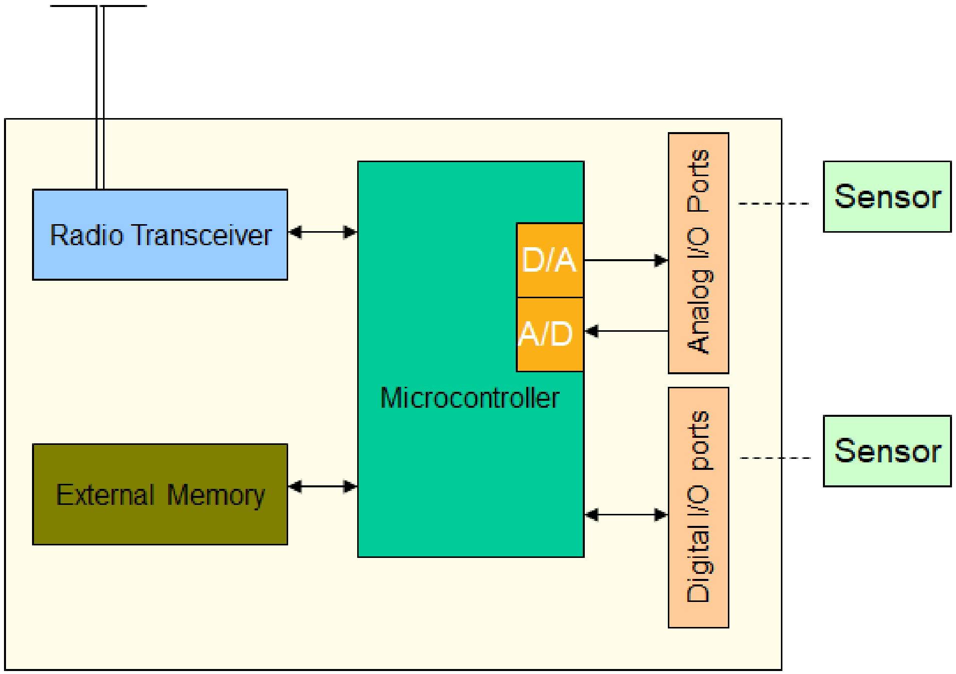


IOT context



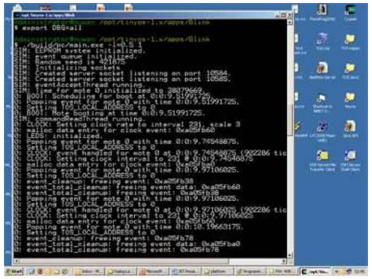
Internet &
Satellite
Sink
Task Manager
Node
User
D
C
B
E
A
Sensor Field
Sensor Nodes

Motes: the building blocks of WSN



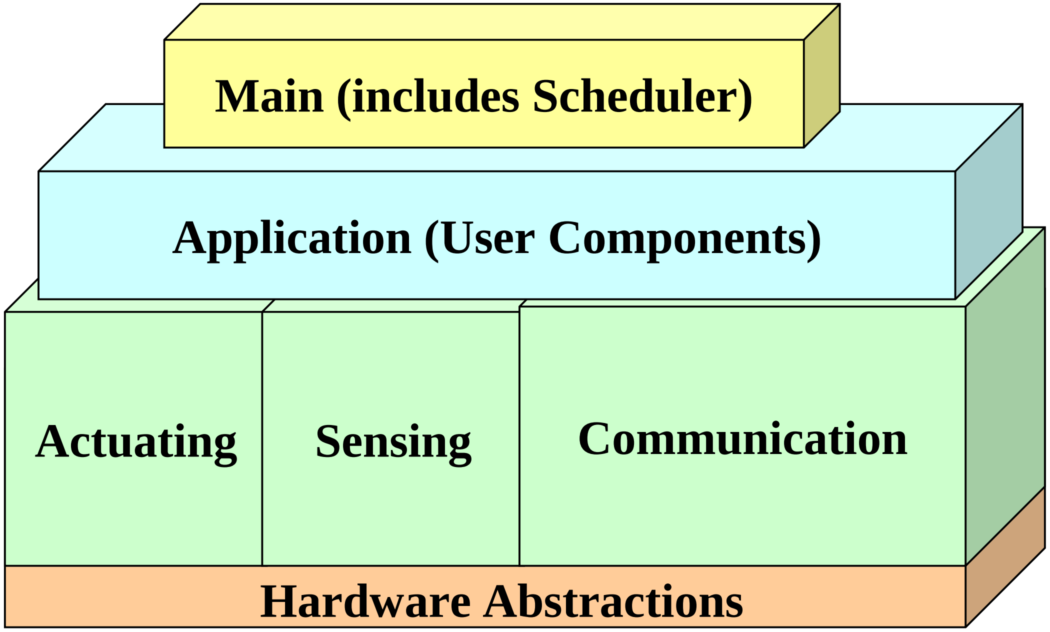
- A very low cost low power computer
- Monitors one or more sensors
- A Radio Link to the outside world
- Are the building blocks of Wireless Sensor Networks (WSN)

Example of motes

mica	mica2	mica2dot	micaz
			
telos	telosb	rene2	pc
			

TinyOS

- Event-driven programming model instead of multithreading
- TinyOS and its programs written in nesC

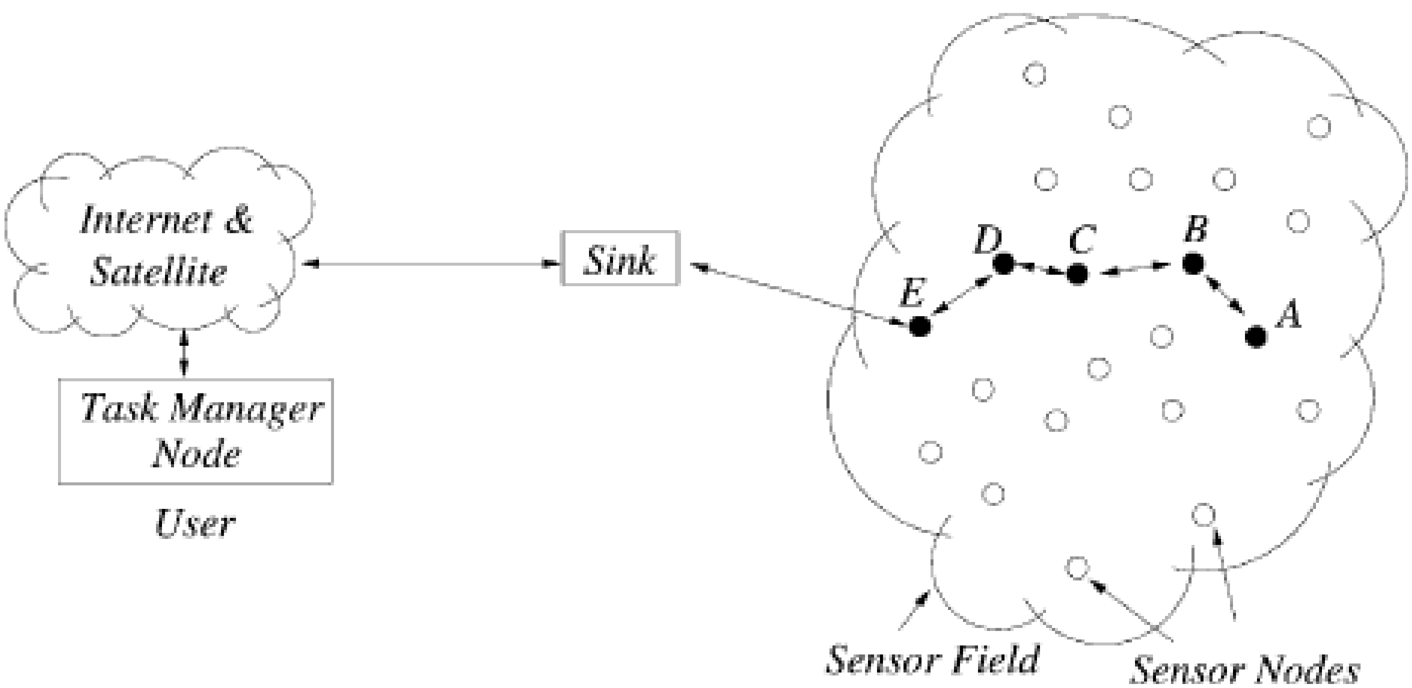


Characteristics of TinyOS

- Small memory footprint
  - non-pre emptable FIFO task scheduling
- Power Efficient
  - Puts microcontroller to sleep
  - Puts radio to sleep
- Concurrency-Intensive Operations
  - Event-driven architecture
  - Efficient Interrupts and event handling
- No Real-time guarantees

WSN Broad Applications

- Monitoring **Space**
- Monitoring **Objects**
- Monitoring **Interactions of Objects & Space**



Monitoring Space

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- Environmental and Habitat Monitoring
- Precision Agriculture
- Indoor Climate Control
- Military Surveillance
- Intelligent Alarms

Monitoring objects

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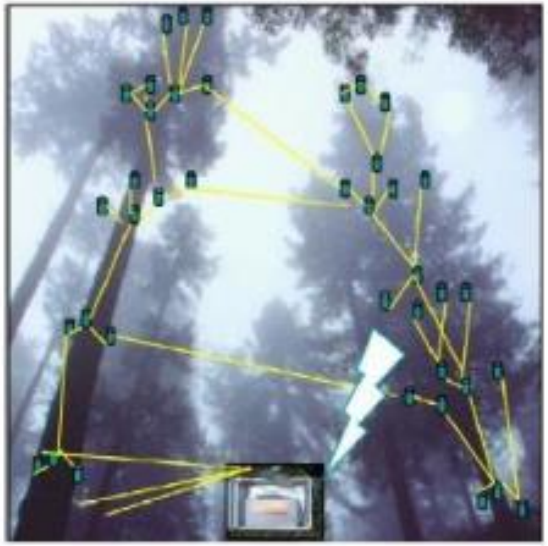
- Structural Monitoring
- Condition-based Maintenance
- Medical Diagnostics
- Urban terrain mapping

Monitoring Interactions of objects and space

- Wildlife Habitats
- Disaster Management
- Emergency Response
- Asset Tracking
- Health Care
- Manufacturing Process Flows



Environmental Monitoring

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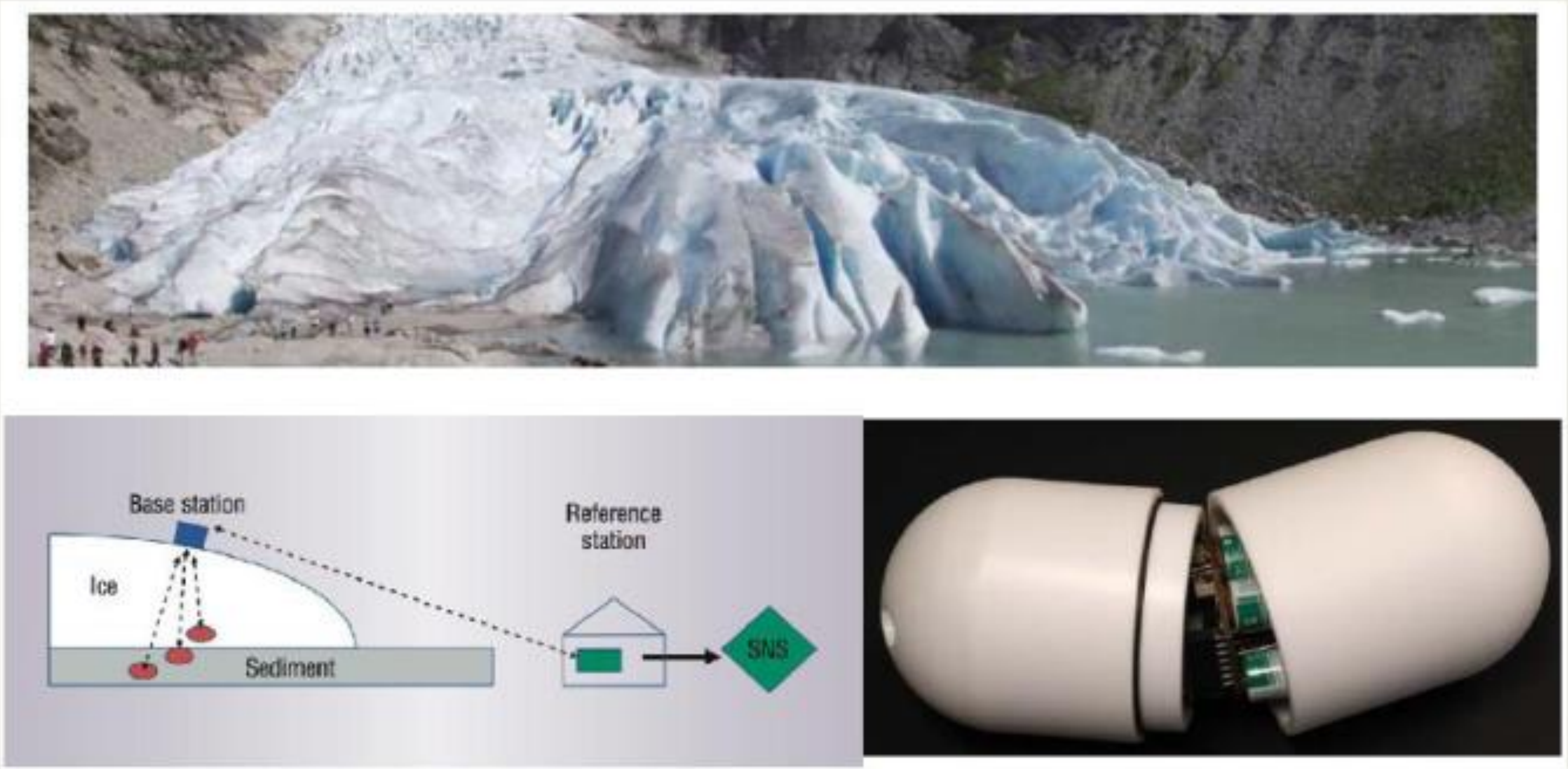

Glacier Monitoring

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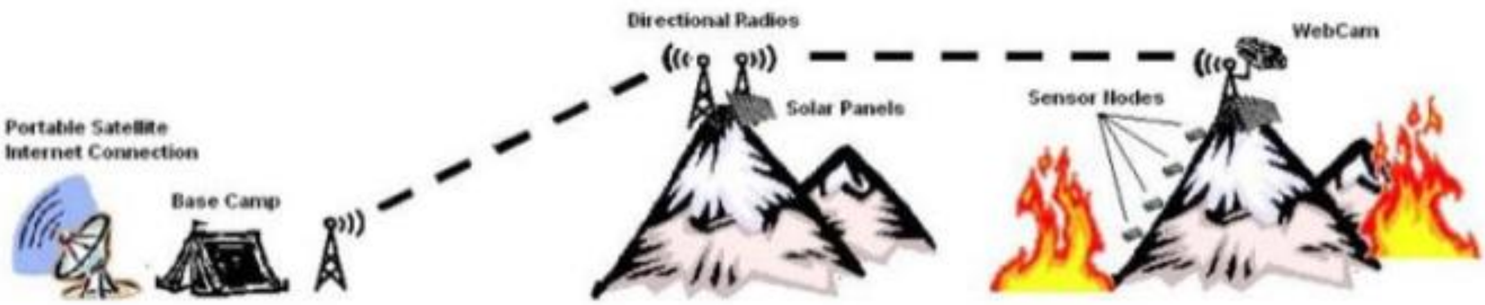
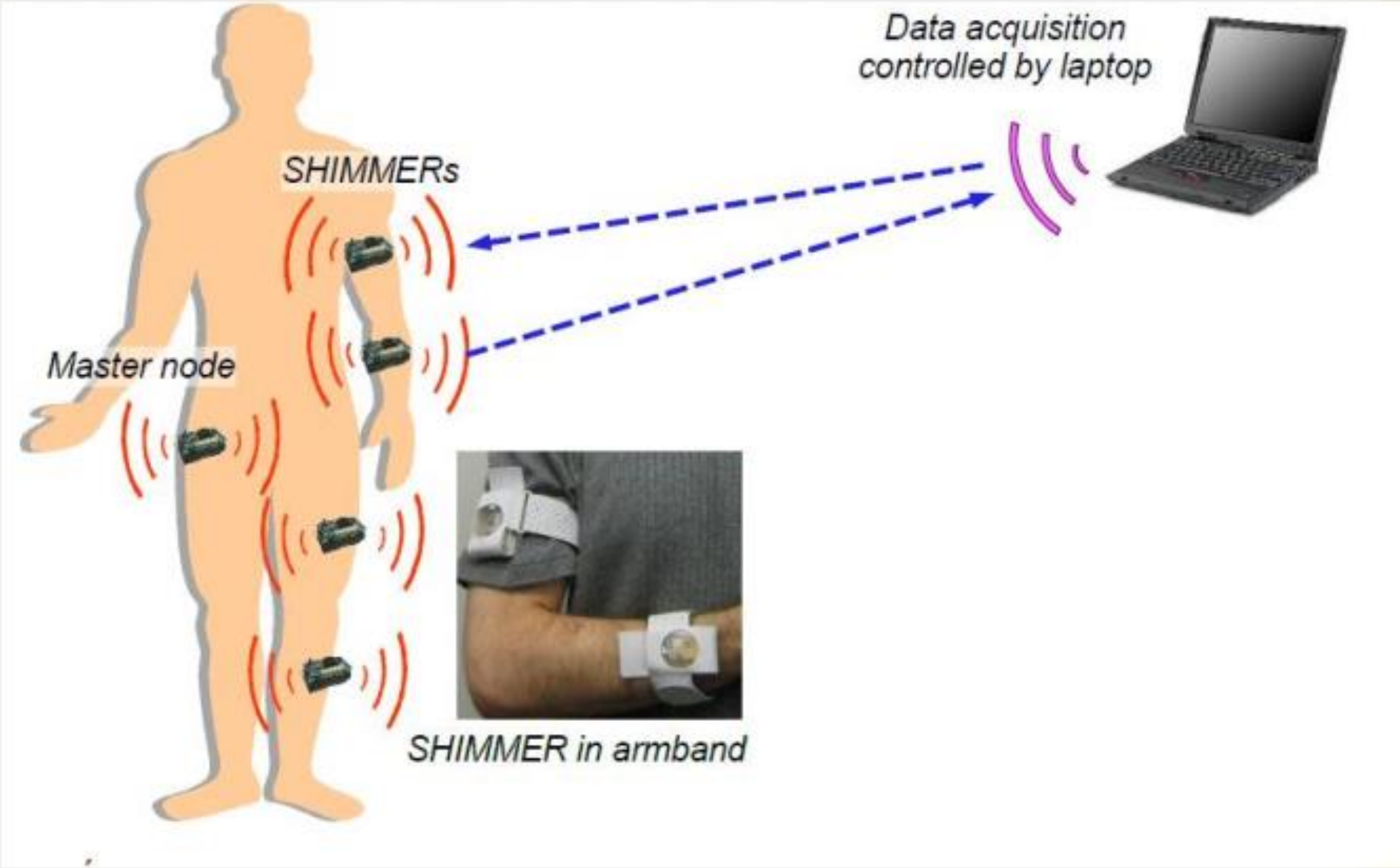


Forest Fire Monitoring



Nueromotor Disease Monitoring

Requirements for WSN

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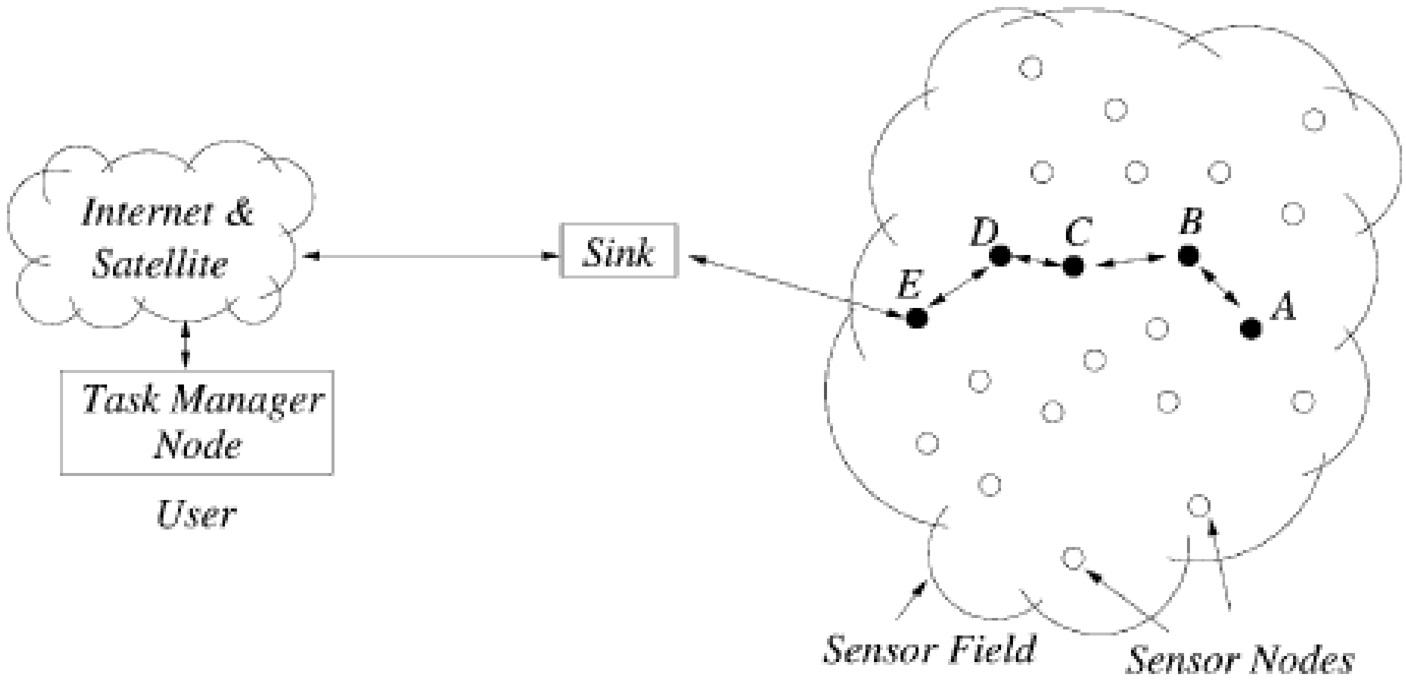
- Long Life
- Small Sized nodes
- Less cost



Constraints on locally available resources

- Limited Energy
- Limited Processing power
- Limited Memory
- Limited Bandwidth

Diversity of WSN nodes and dynamics

- Motes
- Sensors
- Nodes Deployed Randomly – Mobile
- Motes are subject to energy budget
- Motes may die
- Wireless Communication Media – dynamic

Characteristic features

- The large density of nodes - sensors that are **cheap to manufacture and ready to deploy**
- The **application diversity**, which requires different kinds of **application specific sensor** devices
- The **tight limitations in energy, processing power and memory**, which call for highly optimized and lightweight protocols
- The **collaborative objective** for which all the sensor nodes cooperate with one another

Challenges

- Sensor networks are prone to **frequent topology changes** due to several reason hardware failure
- **depleted batteries**
- intermittent **radio interference**
- **environmental factors**
- addition of sensor nodes
- applications require a degree of inherent **fault tolerance** and the ability to reconfigure themselves as the network topology evolves

Advantages

- Due to the dense deployment of a greater number of nodes - higher level of **fault tolerance** is achievable in WSN

- **Coverage of a large area is possible** through the union of coverage of several small sensors

- Coverage of a particular area and terrain shaped as needed to overcome any potential barriers or holes in the area under observation

- It is **possible to incrementally extend coverage** of the observed area & density by deploying additional sensor nodes within the region of interest

Advantages/ Considerations

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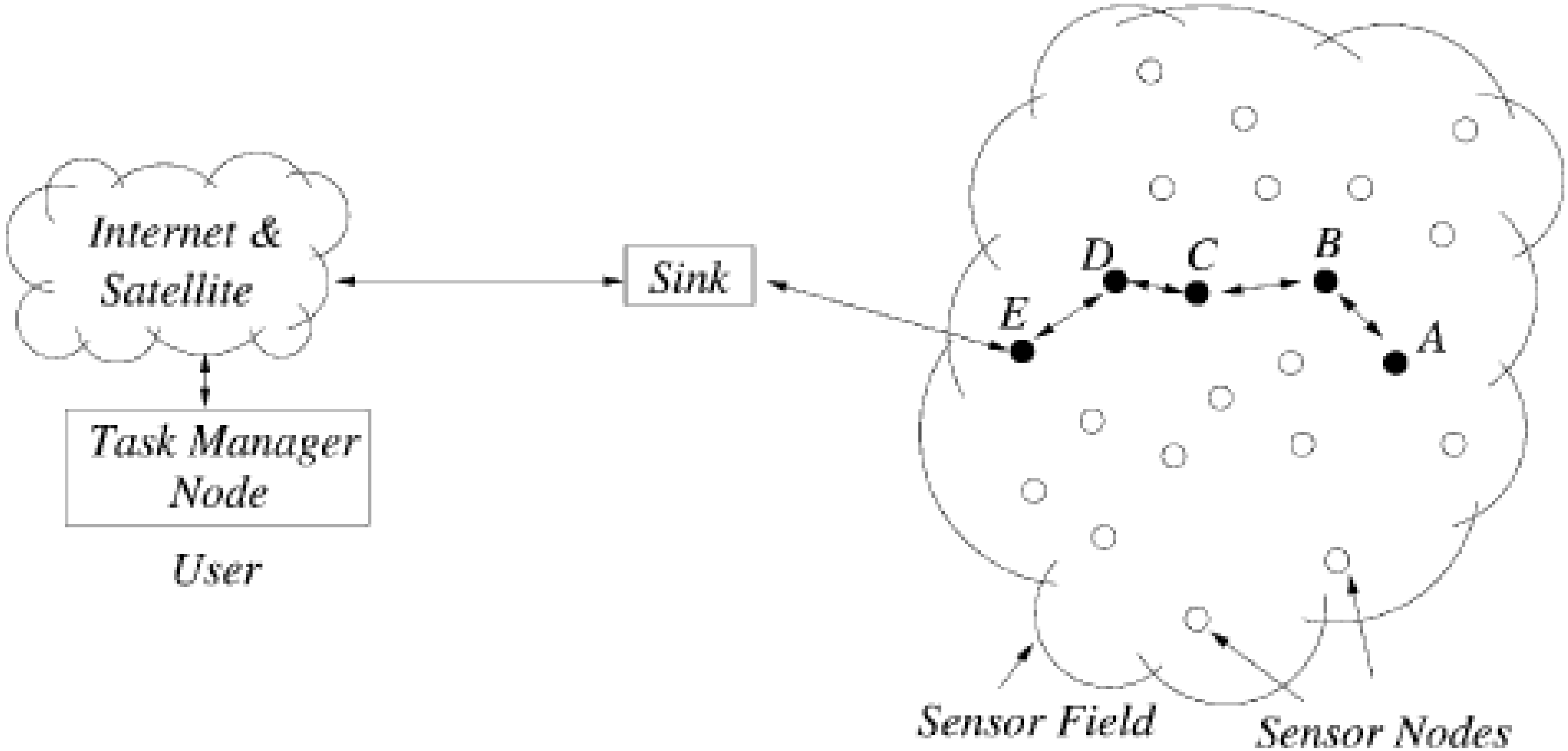
- An improvement in sensing quality is achieved by combining multiple, independent sensor readings.

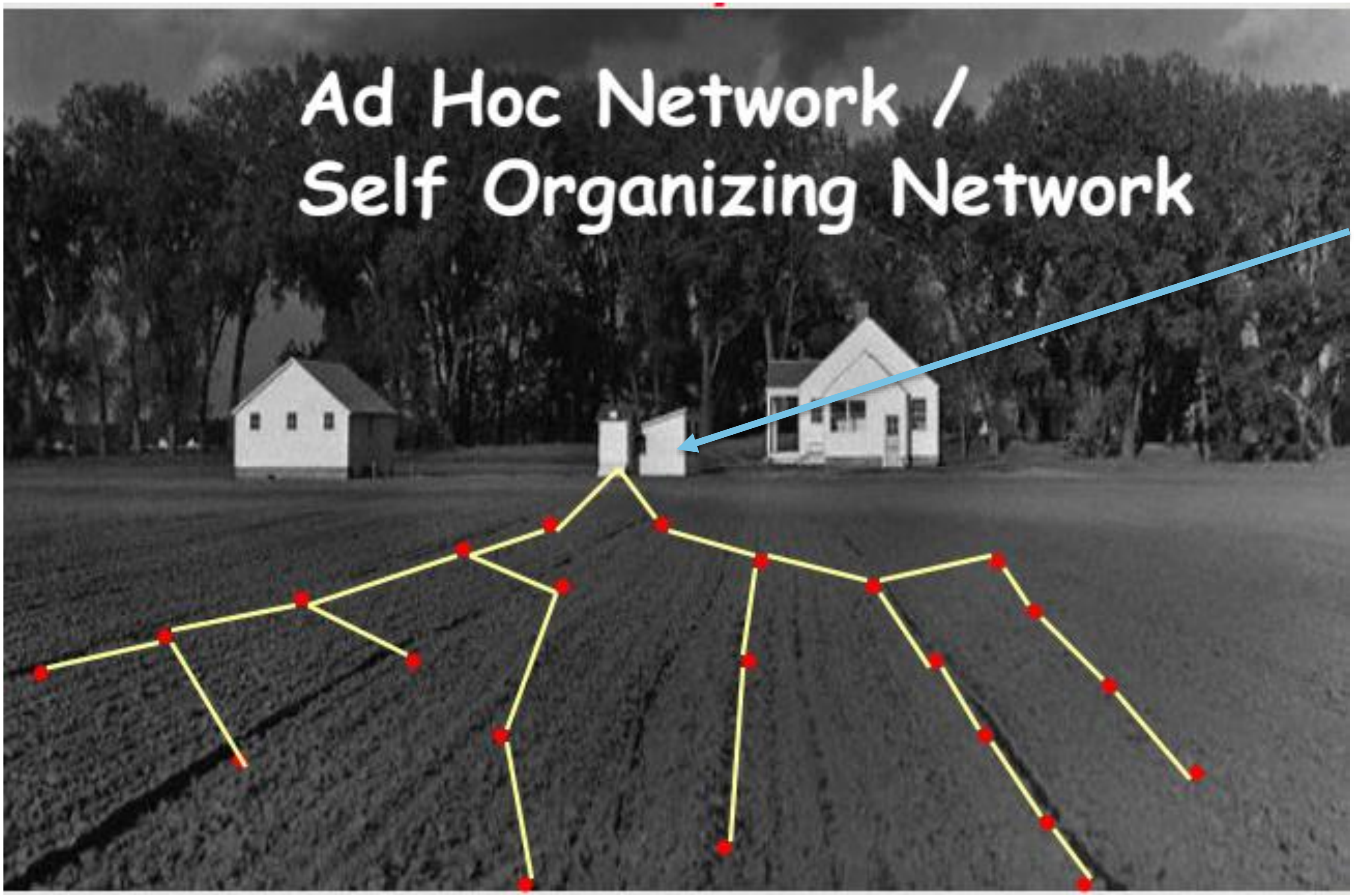
- **Local collaboration** between nearby sensor nodes achieves a higher level of confidence in observed phenomena.

- Since **nodes are deployed in close proximity to the sensed event**- this overcomes any ambient environmental factors that might otherwise interfere with observation of the desired phenomenon

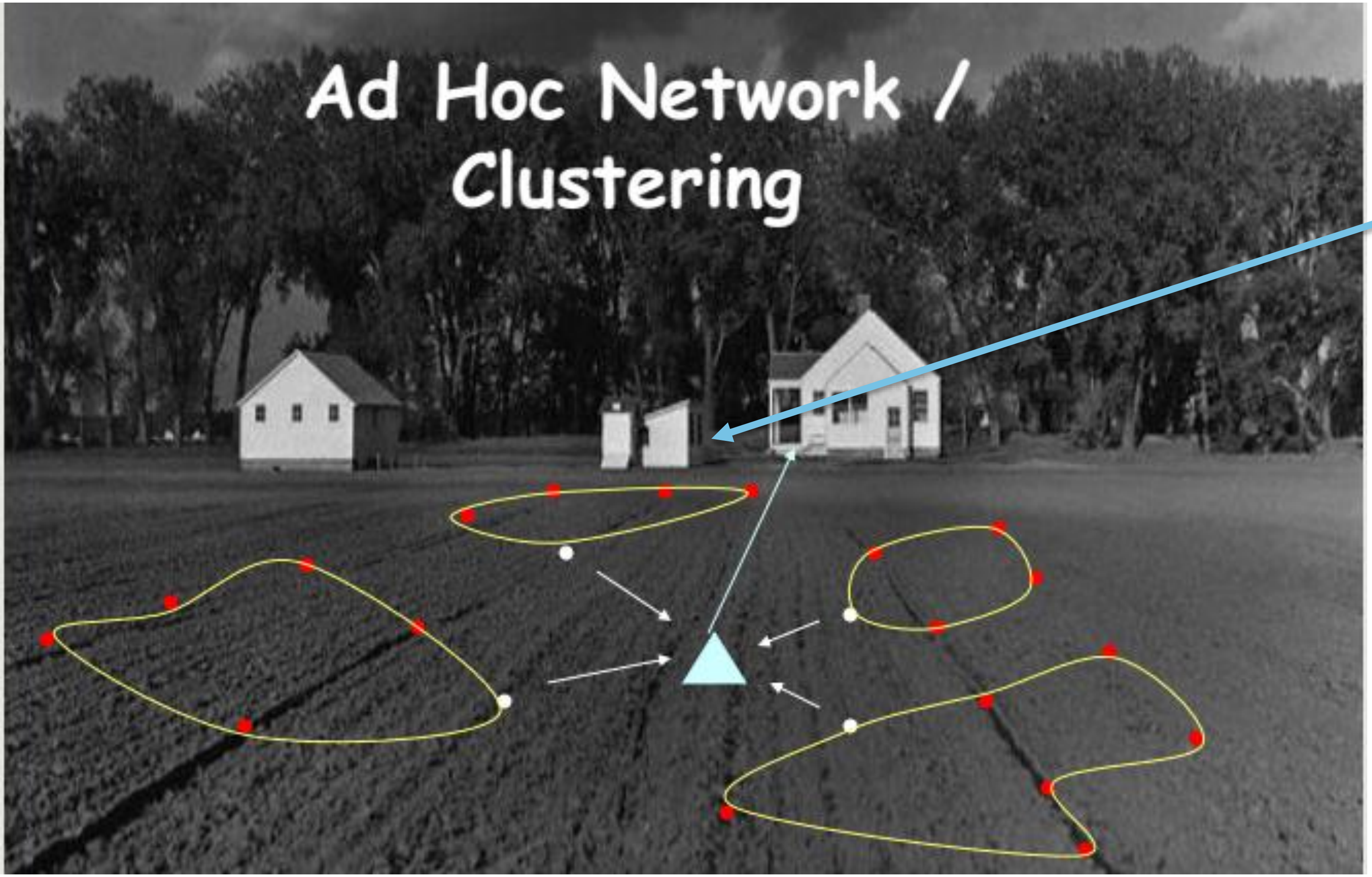
Network architectures in WSN

- How are the sensor nodes teamed up





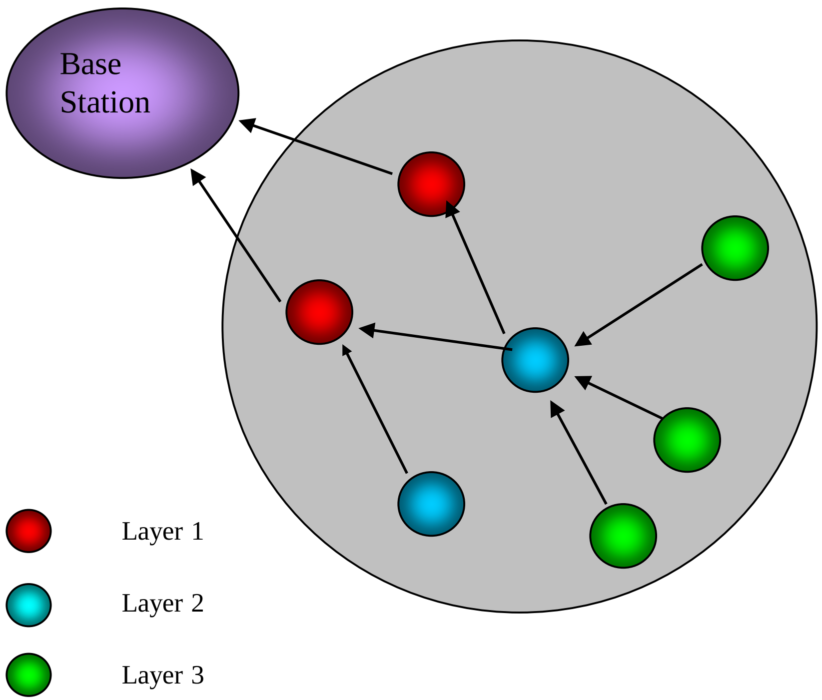
SINK/ Base station/ Gateway



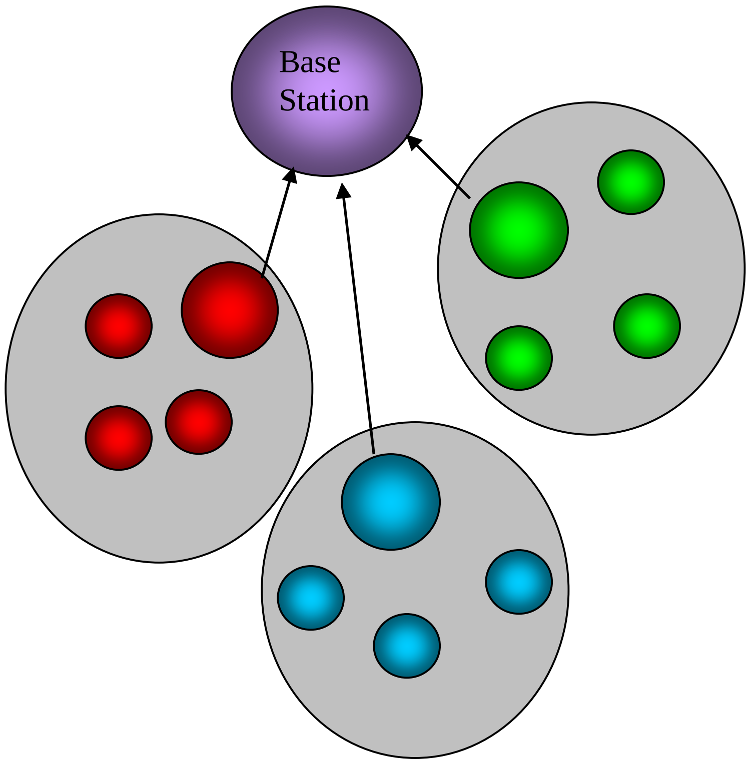
SINK

Network Architectures: Layered vs Clustered

Layered Architecture



Clustered Architecture



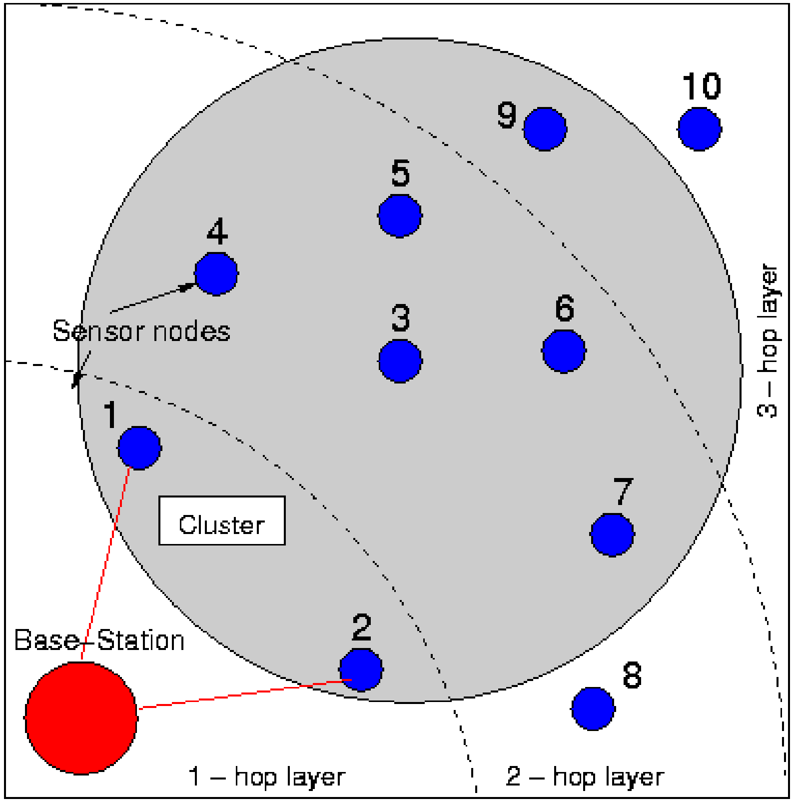
Larger Nodes denote Cluster Heads

Layered network architecture

A few hundred sensor nodes (half/full duplex)

A single powerful base-station
Network nodes are organized into concentric ***Layers***

Layer: Set of nodes that have the same hop-count to the base-statior

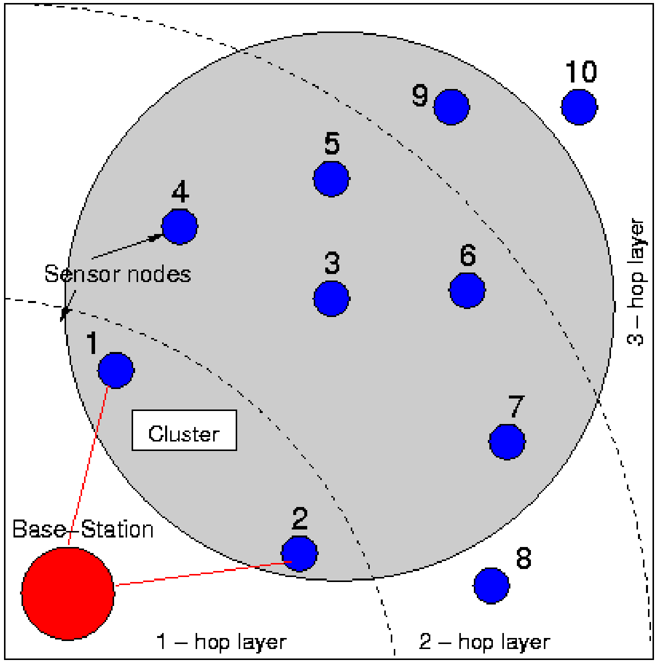


Layered network architecture (cont.)

- Set of wireless sensor nodes create an infrastructure – provide sensing and data forwarding functionality

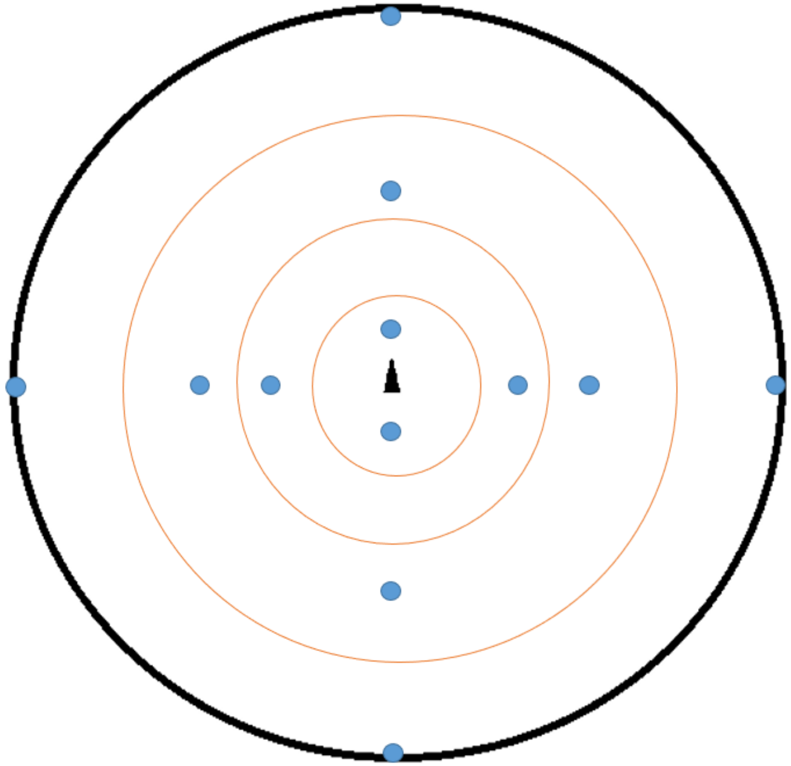
- BS is data gathering, processing entity and communication link to larger network

- Shorter-range, low-power transmissions preferred to conserve power



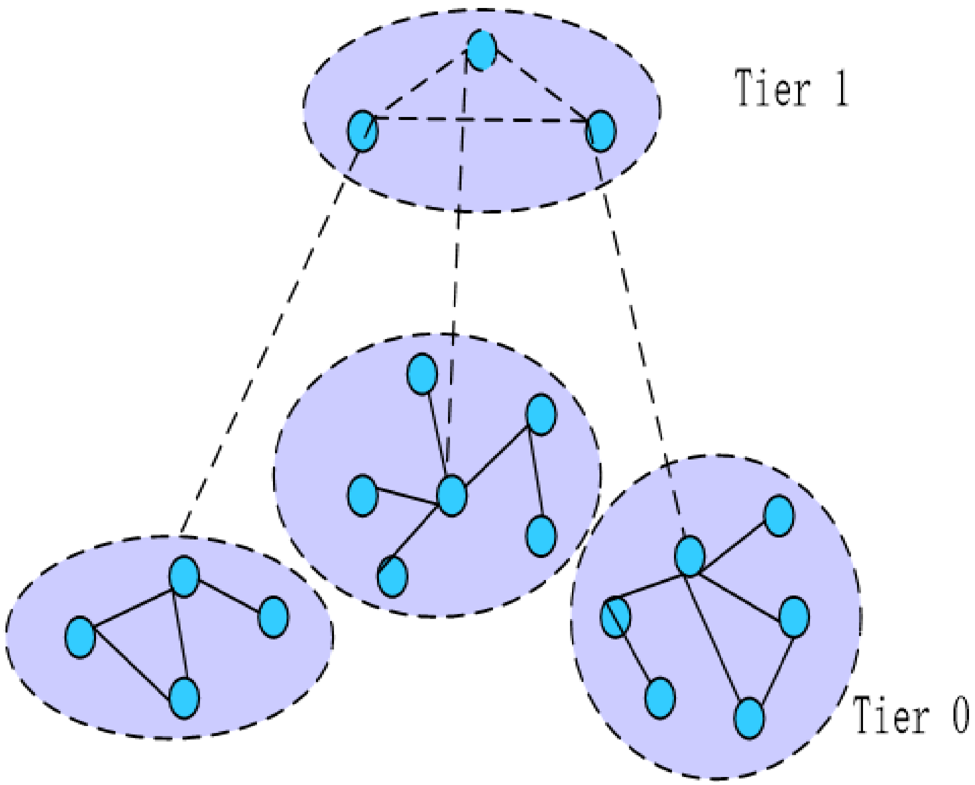
Case scenario

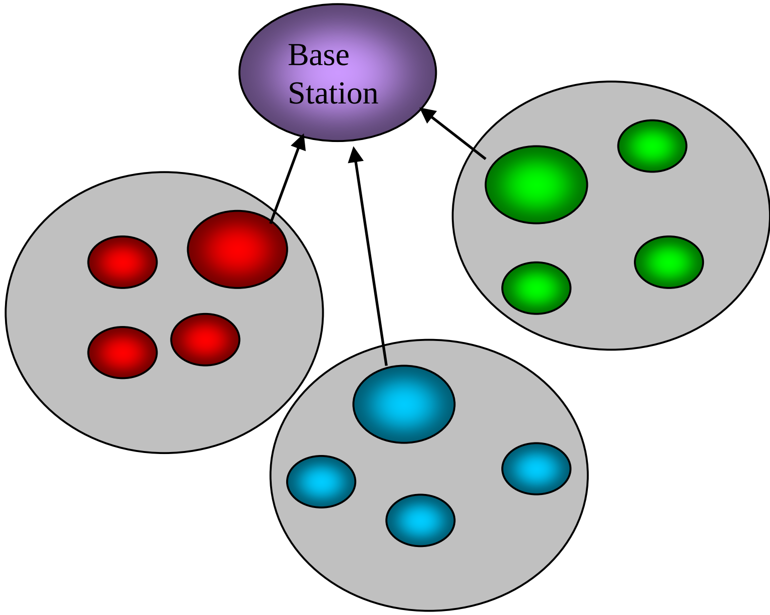
Assume that in the network shown below the transmission range of a mote is 2m. How many layers are there in the network given that the base station is in the center of the network and each consecutive red concentric circle is 1m apart from each other (thus leading to the outermost circle



Clustered Network architecture

- Sensor nodes autonomously form a group called **clusters**.
- The clustering process is applied recursively to form a hierarchy of clusters





WSN Routing

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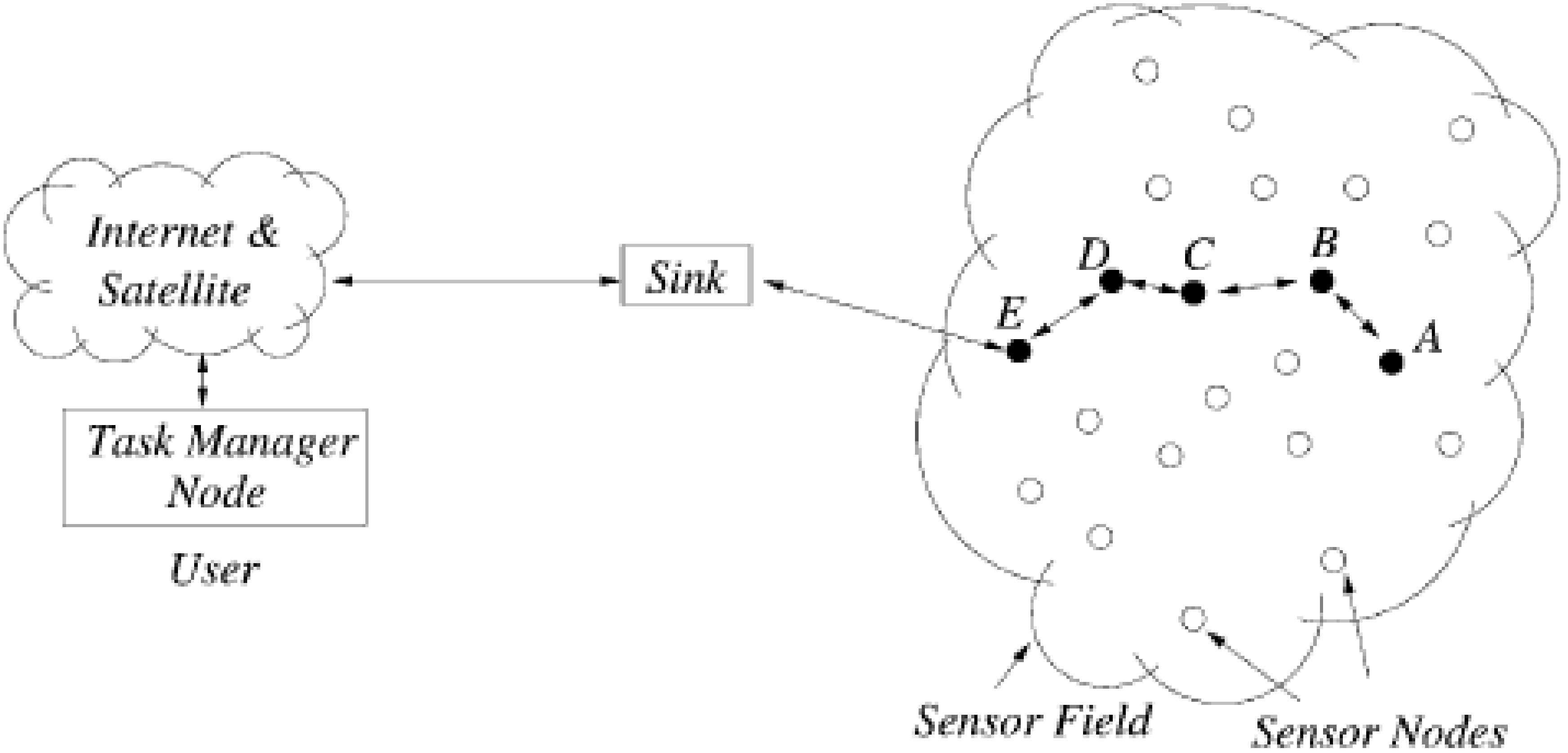
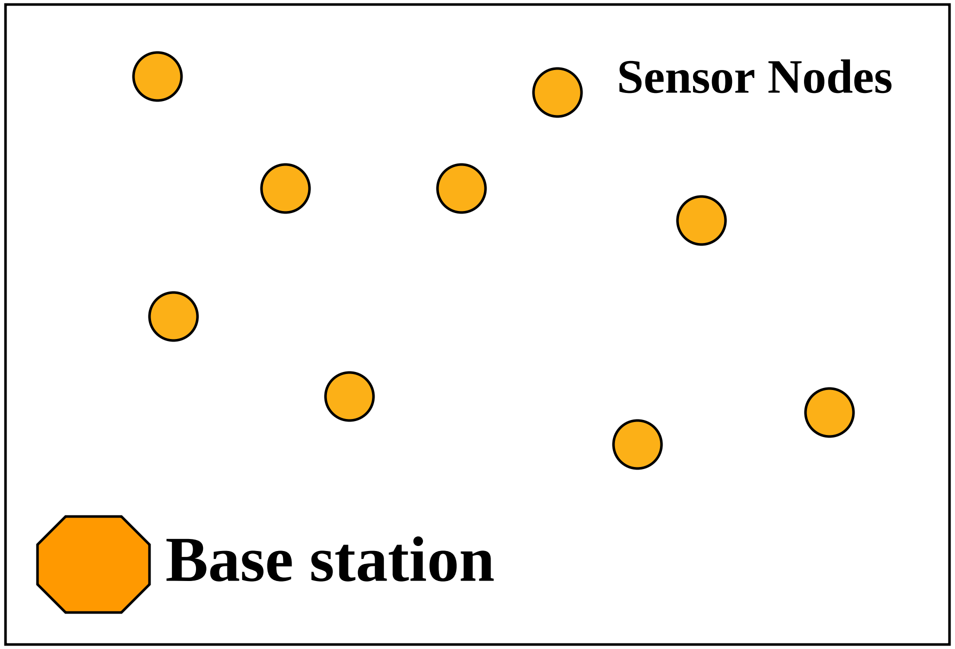
- Deals with details of : How does A send data to sink/user



Routing

- **Objective**: Transmit sensed data from each sensor node to a base station
  - One round = BS collecting data from all nodes
- Goal is to **maximize the number of rounds of communication** before nodes die and network is inoperable
- Minimize energy AND reduce delay
  - Conflicting requirements



Energy * Delay metric

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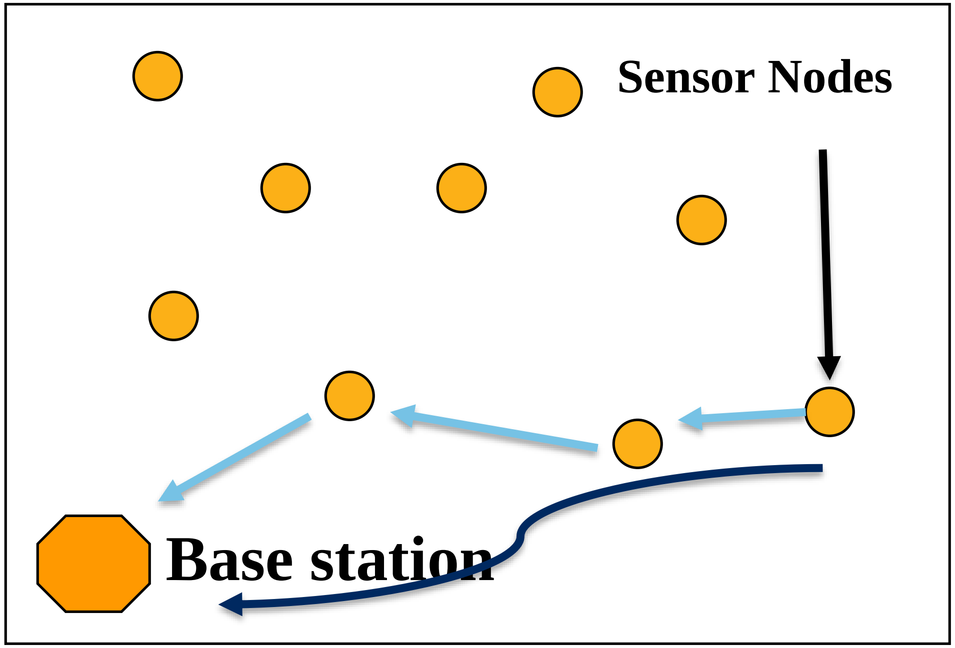
- Why **energy * delay** metric?
  - Find optimal balance to gather data quickly but in an energy efficient manner
  - Energy = Energy consumed per round
  - Delay = Delay per round (I.e. for all nodes to send packet to BS)

- Why is this metric important?
  - Time and energy critical applications



Direct transmission

- All nodes transmit to the base station (BS)
- Very expensive since BS may be located very far away and **nodes need more energy to transmit over longer distances**
- Farther the distance, greater the **propagation losses,** and hence higher the transmission power
- All **nodes must take turns** transmitting to the BS so delay is high (N units for a N-node network)
- Better scheme is to have fewer nodes transmit this far distance to lower energy costs and more simultaneous transmissions to lower delay

Routing protocols

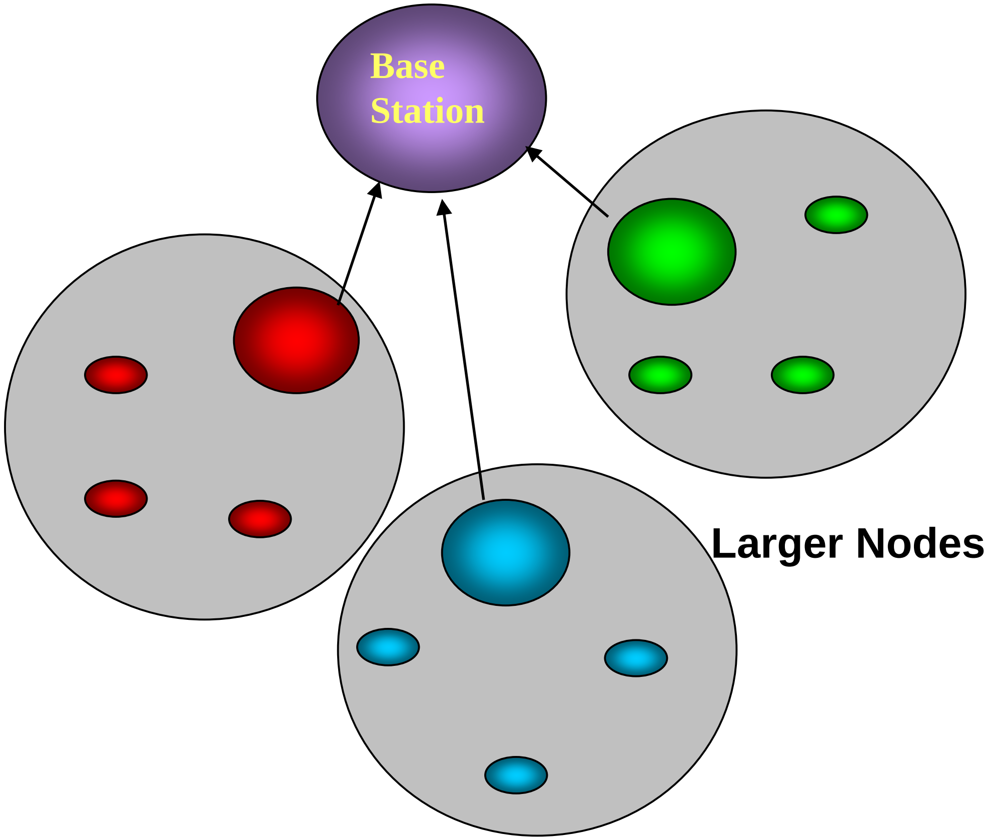
- LEACH
- PEGASIS
- Directed Diffusion
- TEEN
- APTEEN
- Etc…

- **Considerations:**

- Energy, network lifetime, accuracy, query response time etc.

LEACH

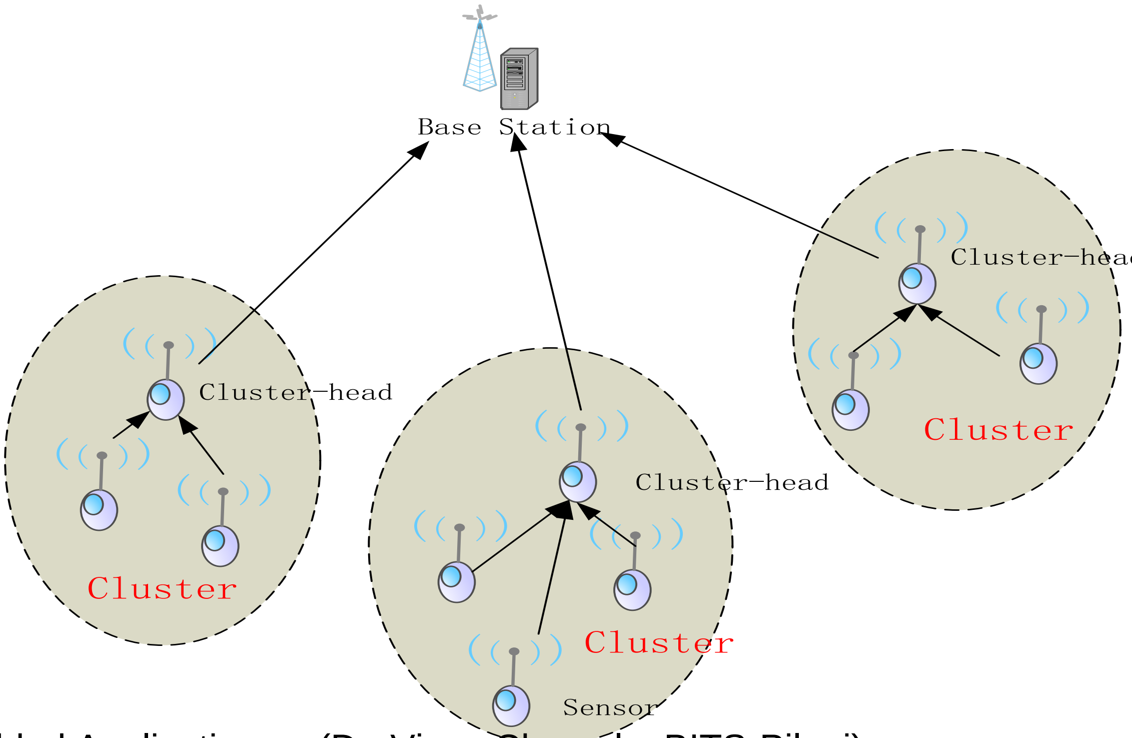
- Low Energy Adaptive Clustering Hierarchy
  - Two-level hierarchy



Larger Nodes denote Cluster Heads

Leach protocol

- It uses distributed algorithm to organize the sensor nodes into clusters.
- The cluster-head nodes create TDMA schedules.
- Nodes transmit data during their assigned slots.
- The energy efficiency of the LEACH is mainly due to data fusion.



Scheme: PEGASIS

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- Goals of PEGASIS (Power-Efficient GAthering for Sensor Information Systems)
  - ➢Minimize distant nodes transmitting directly
  - ➢Minimize number of leaders that transmit to BS
  - ➢Minimize broadcasting overhead
  - ➢Minimize number or messages leader needs to receive
  - ➢Distribute work more equally among all nodes

PEGASIS (cont.)

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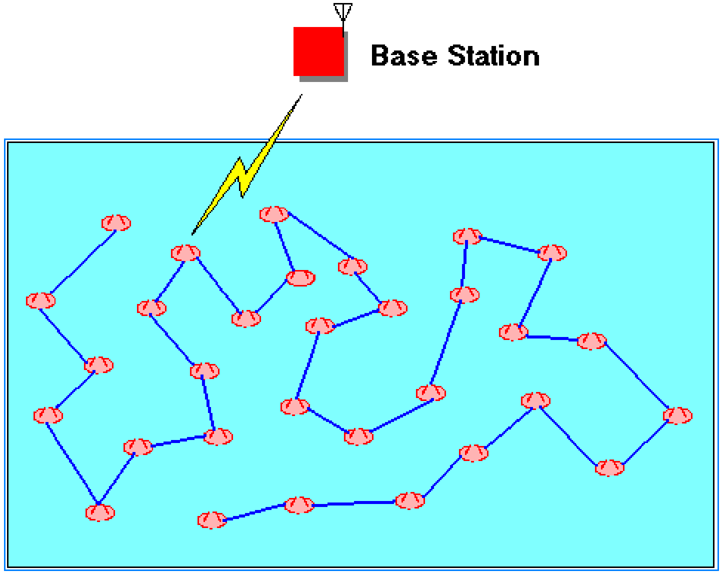
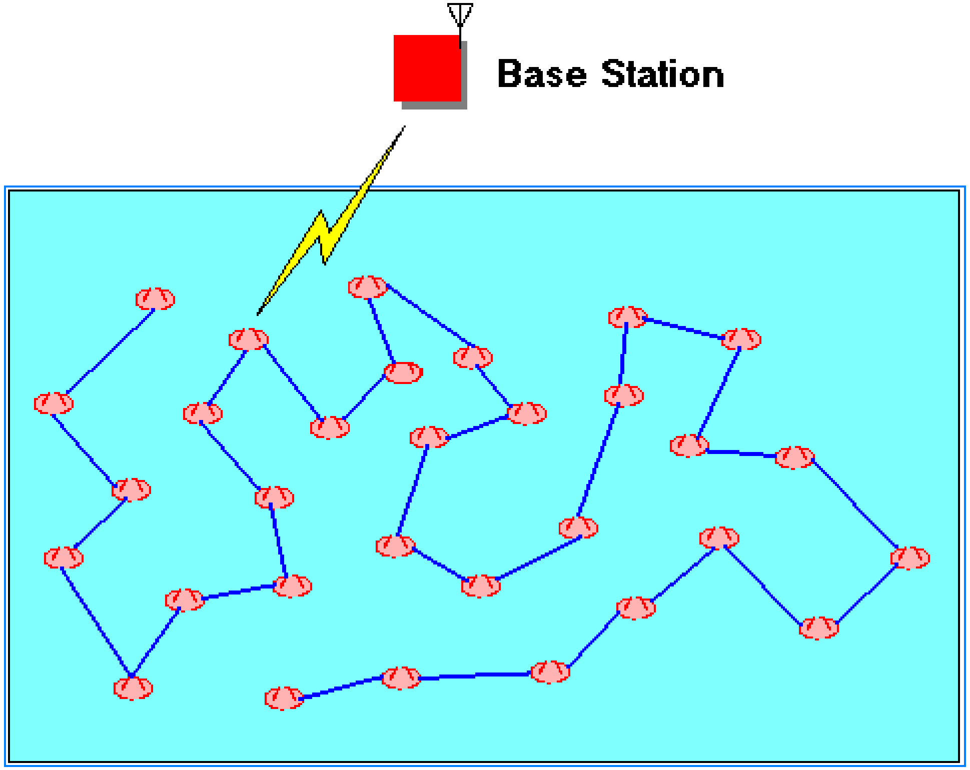
- Greedy Chain Algorithm
  - ➢Start with node furthest away from BS
  - ➢Add to chain closest neighbor to this node that has not been visited
  - ➢Repeat until all nodes have been added to chain
  - ➢Constructed before 1st round of communication and then reconstructed when nodes die



PEGASIS

- Data fusion at each node (except end nodes)
  - ➢Only one message is passed at every node
- Delay calculation: N units for an N-node network
  - ➢Sequential transmission is assumed



PEGASIS

- **Leader Selection**
  - Nodes become leaders in sequential order
  - Allows random deaths
  - Nodes will not become leader if the distance between neighbors is higher than a certain threshold
  - Token is passed so that all nodes will know who is leader and which direction to pass message