SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

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SITA1501
Wireless Sensor Networks and Architecture

Unit I

INTRODUCTION AND OVERVIEW OF WSN

- Introduction to WSN
- Historical Survey of WSN
- Background of Sensor Networks topology
- Ad-hoc Networks
- Applications of WSN

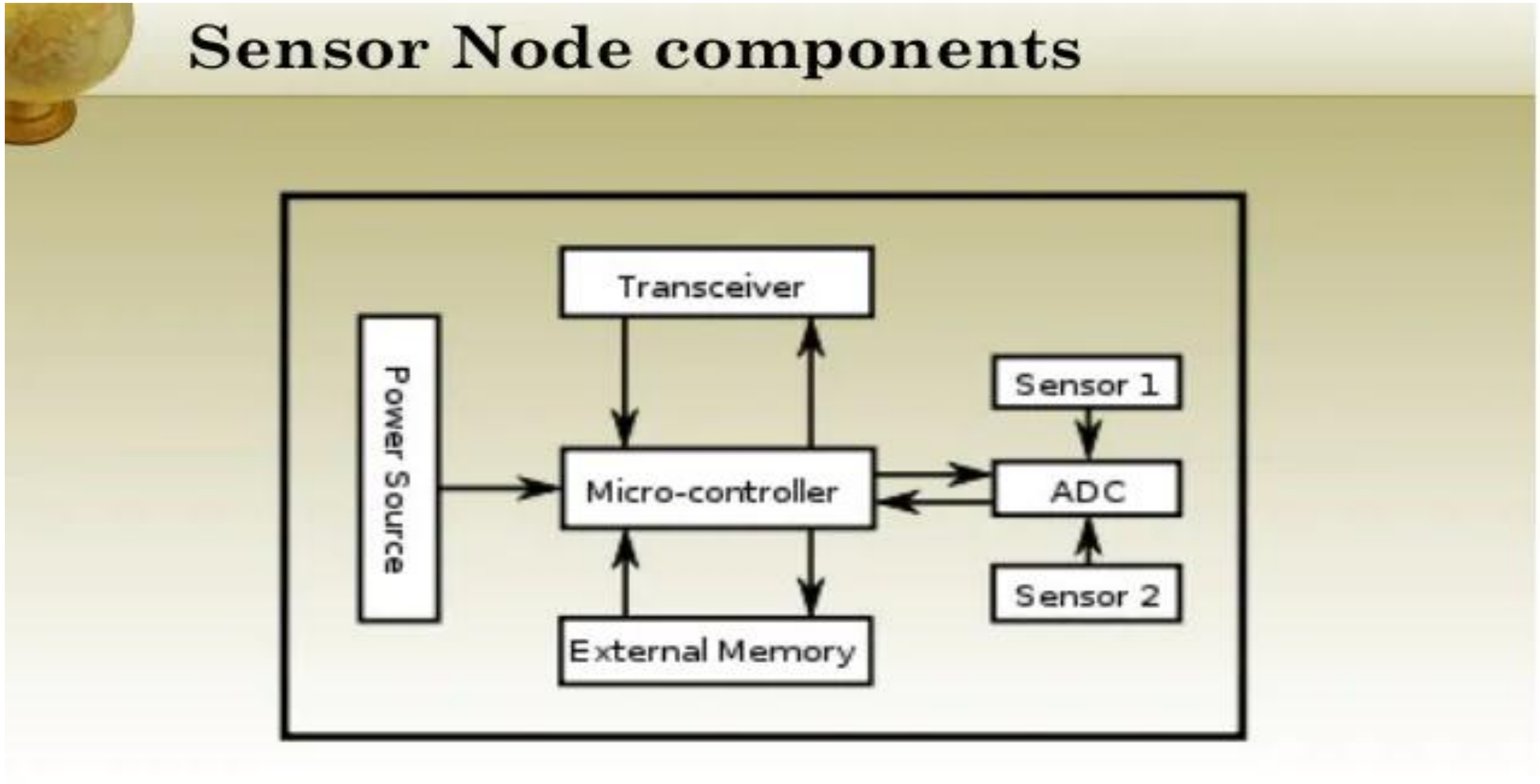
Unit - I

sensor and Sensor Node

- A **sensor** is a electronic device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.

- **Sensor Node** : Basic unit in Sensor Network

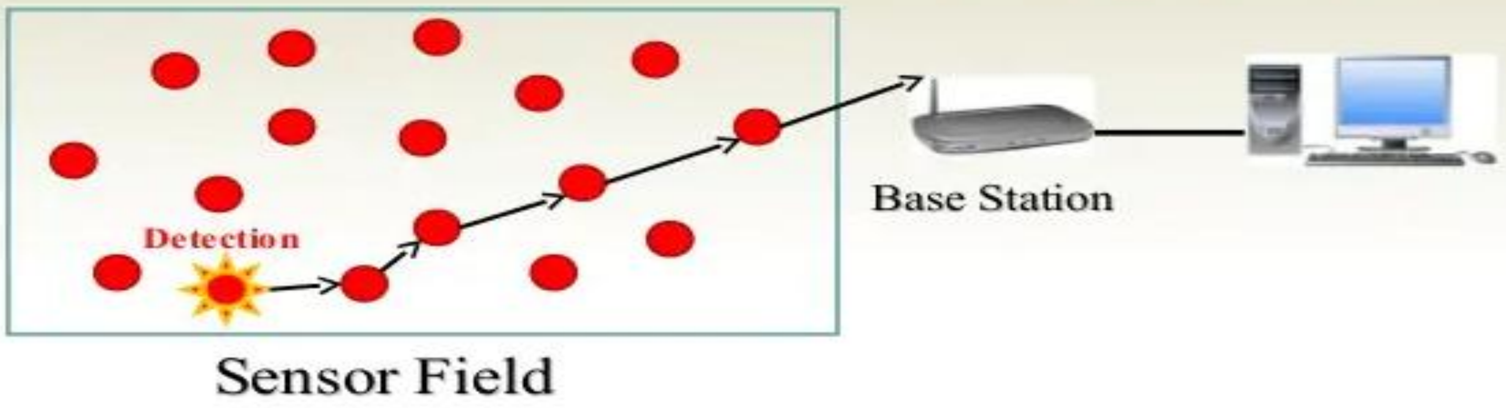
Unit I


Sensor Node components
Transceiver
Power Source
Micro-controller
Sensor 1
ADC
Sensor 2
External Memory

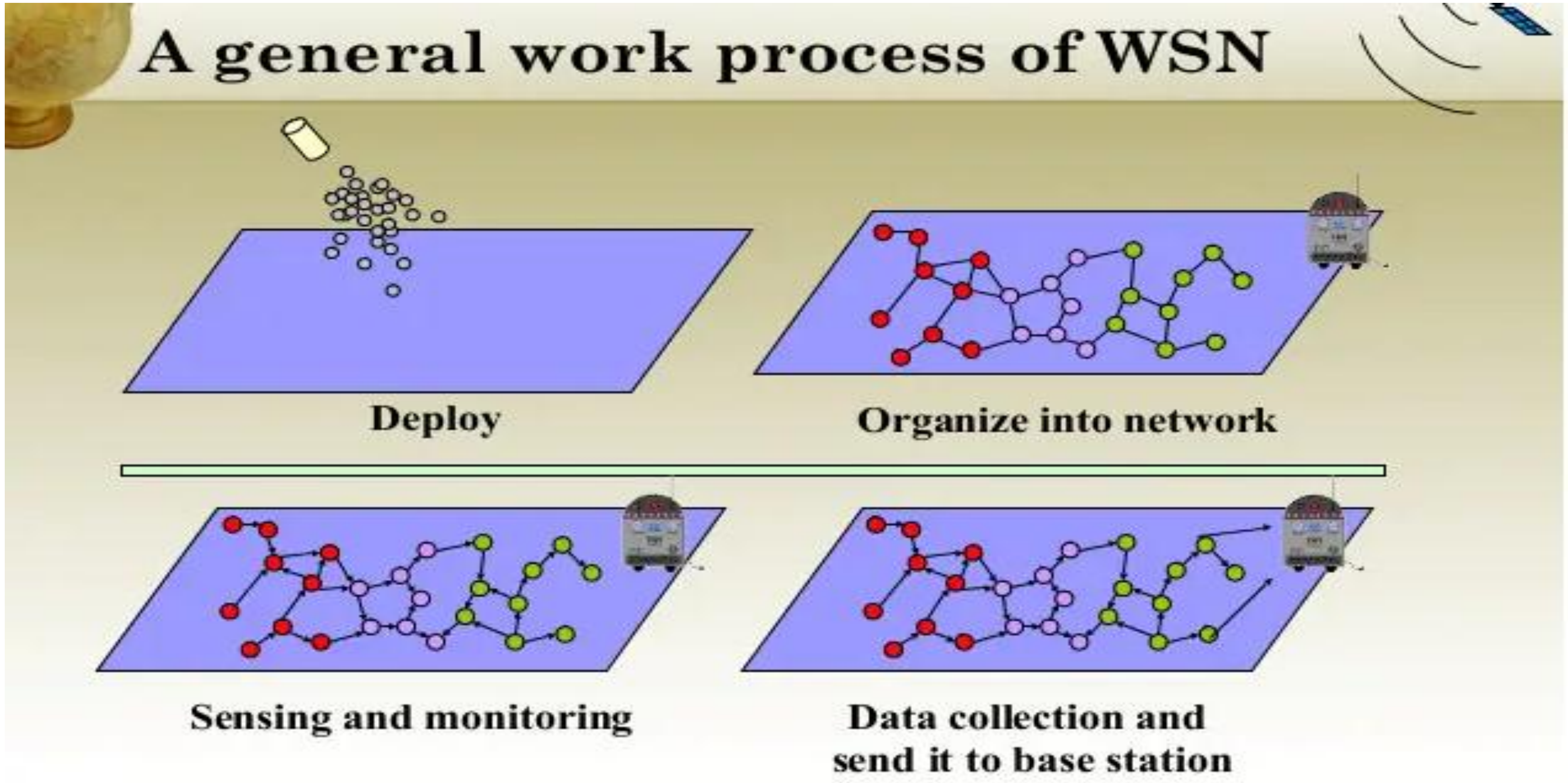
Unit I

Wireless sensor Network (WSN)

A wireless sensor network is a collection of nodes "sensors" organized into a cooperative network. The nodes communicate wirelessly and often self-organize after being deployed.



Unit I



A general work process of WSN
Deploy
Organize into network
Sensing and monitoring
Data collection and send it to base station

Unit I

Wireless sensor Network (WSN)

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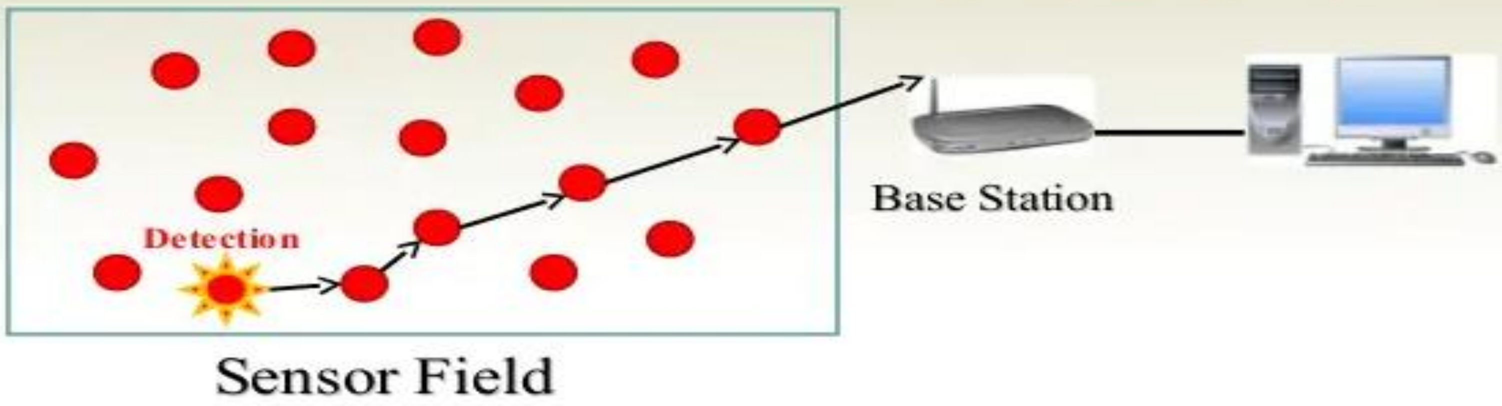


Unit I

Goal of the sensor node

The goal from the sensor node is to collect the data at regular intervals, then transform the data into an electrical signal and finally send the signal to the sink or the base node.

Unit I

Sensor Networks Operating Systems

- Sensor Network uses TinyOS.
- It is a free open source operating system designed for wireless sensor networks.
- It is an embedded operating system written in NesC programming language, developed in 1999.

TinyOS

Unit I

Need of TinyOS

- Problems with traditional OS
  - Multithreaded Architecture not useful
  - Large Memory Footprint
  - Does not help to conserve energy and power
- Requirements for Wireless Sensor Networks
  - Efficient utilization of energy and power
  - Small Footprint
  - Should support diversity in design and usage
  - More emphasis on Concurrent execution

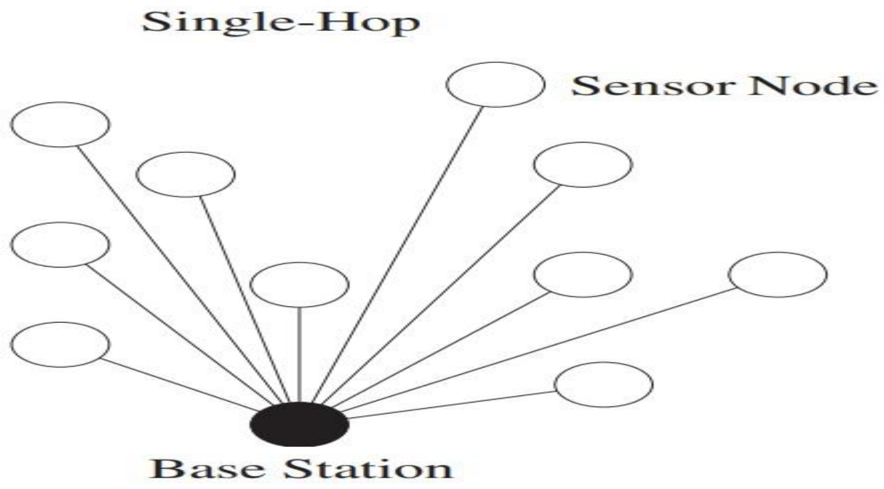
Unit I

TinyOS Features

- Component based architecture allows frequent changes while still keeping the size of code minimum.
- Event based execution model means no user/kernel boundary and hence supports high concurrency.
- It is power efficient as it makes the sensors sleep as soon as possible.
- Has small footprint as it uses a non-preemtable FIFO task scheduling.

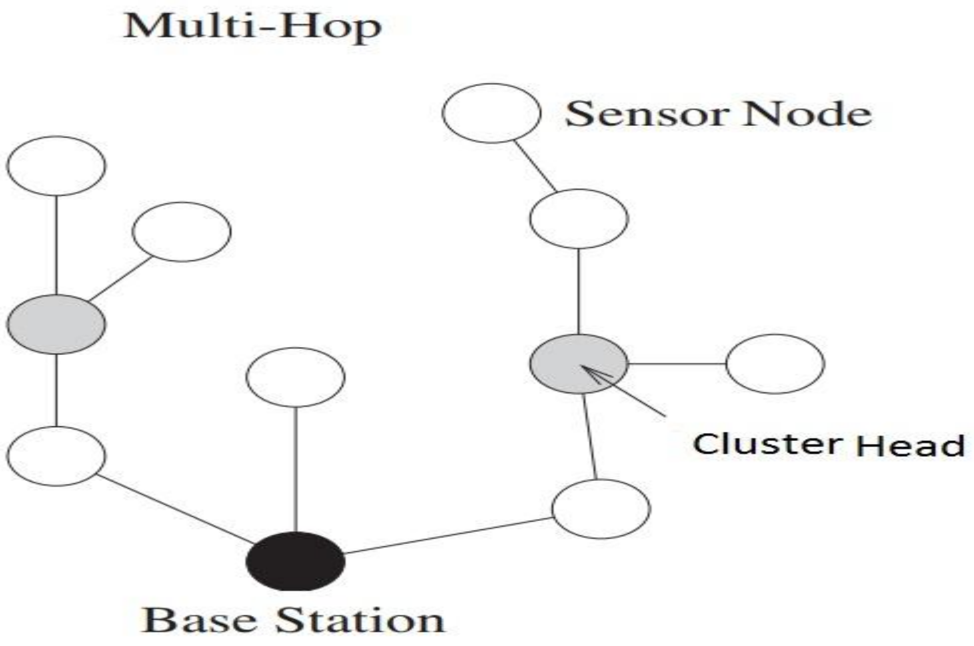
Single Hop network

If each sensor node is connected to the base station, it is known as Single-hop network architecture. Although long distance transmission is possible, the energy consumption for communication will be significantly higher than data collection and computation.

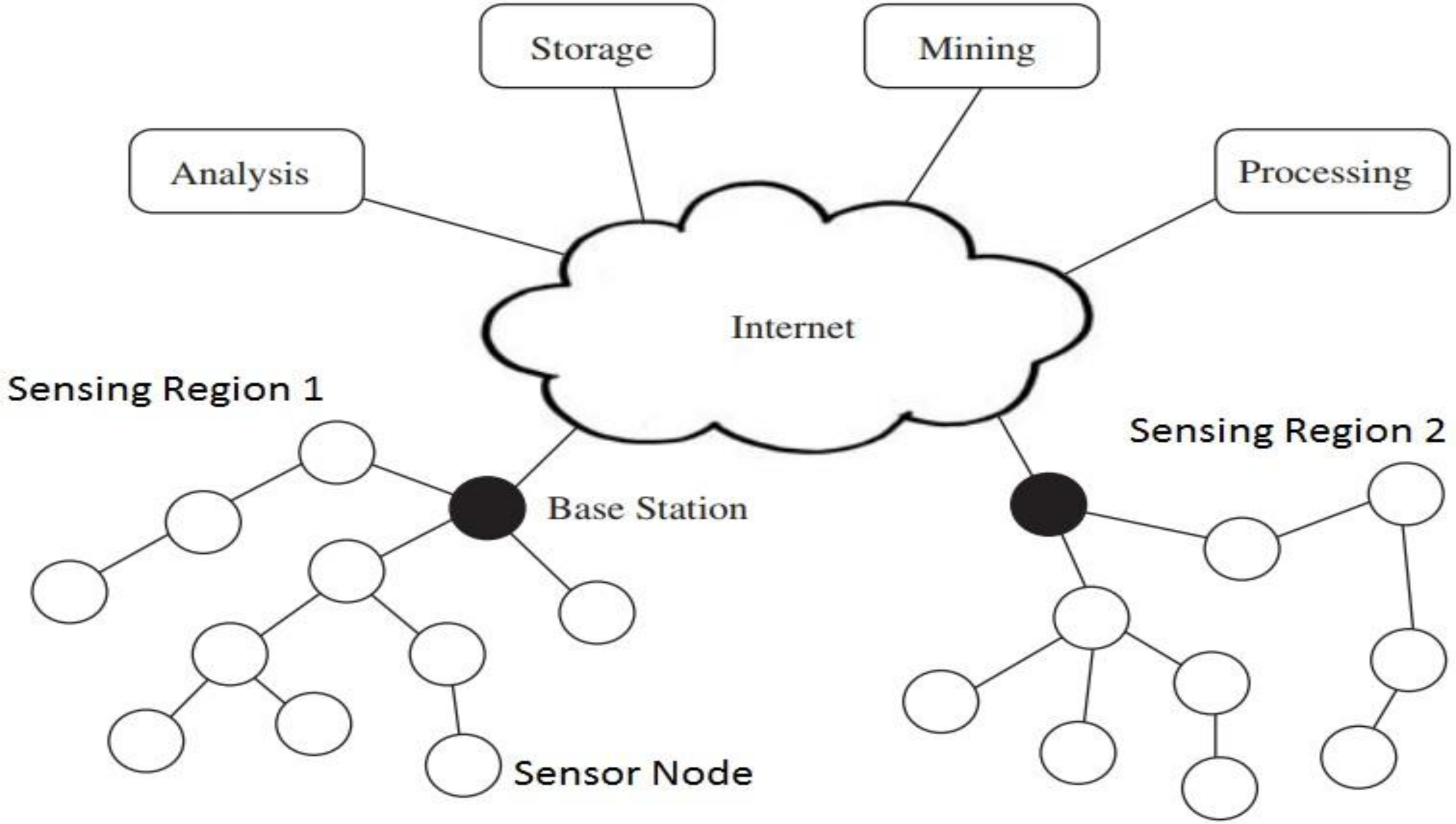


Multi-hop network

Instead of one single link between the sensor node and the base station, the data is transmitted through one or more intermediate node.

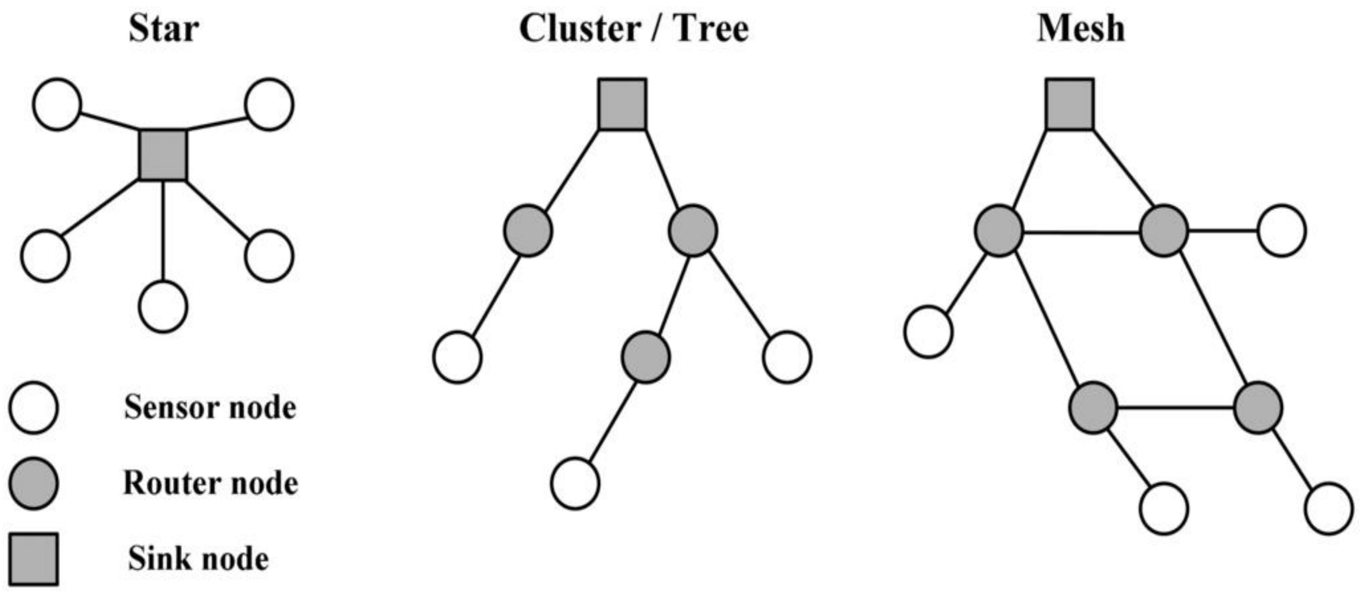


WSN network



Storage
Mining
Analysis
Processing
Internet
Sensing Region 1
Sensing Region 2
Base Station
Sensor Node

WSN network Topologies



Star Topologies

- Star topology is a communication topology, where each node connects directly to a gateway. A single gateway can send or receive a message to several remote nodes.
- In star topologies, the nodes are not permitted to send messages to each other. This allows low-latency communications between the remote node and the gateway (base station).
- Due to its dependency on a single node to manage the network, the gateway must be within the radio transmission range of all the individual nodes.
- The advantage includes the ability to keep the remote nodes’ power consumption to a minimum and simply under control. The size of the network depends on the number of connections made to the hub.

Tree Topologies

- Tree topology is also called as a cascaded star topology. In tree topologies, each node connects to a node that is placed higher in the tree, and then to the gateway.
- The main advantage of the tree topology is that the expansion of a network can be easily possible, and also error detection becomes easy.
- The disadvantage with this network is that it relies heavily on the bus cable; if it breaks, all the network will collapse.

Mesh Topologies

- The Mesh topologies allow transmission of data from one node to another, which is within its radio transmission range. If a node wants to send a message to another node, which is out of the radio communication range, it needs an intermediate node to forward the message to the desired node.

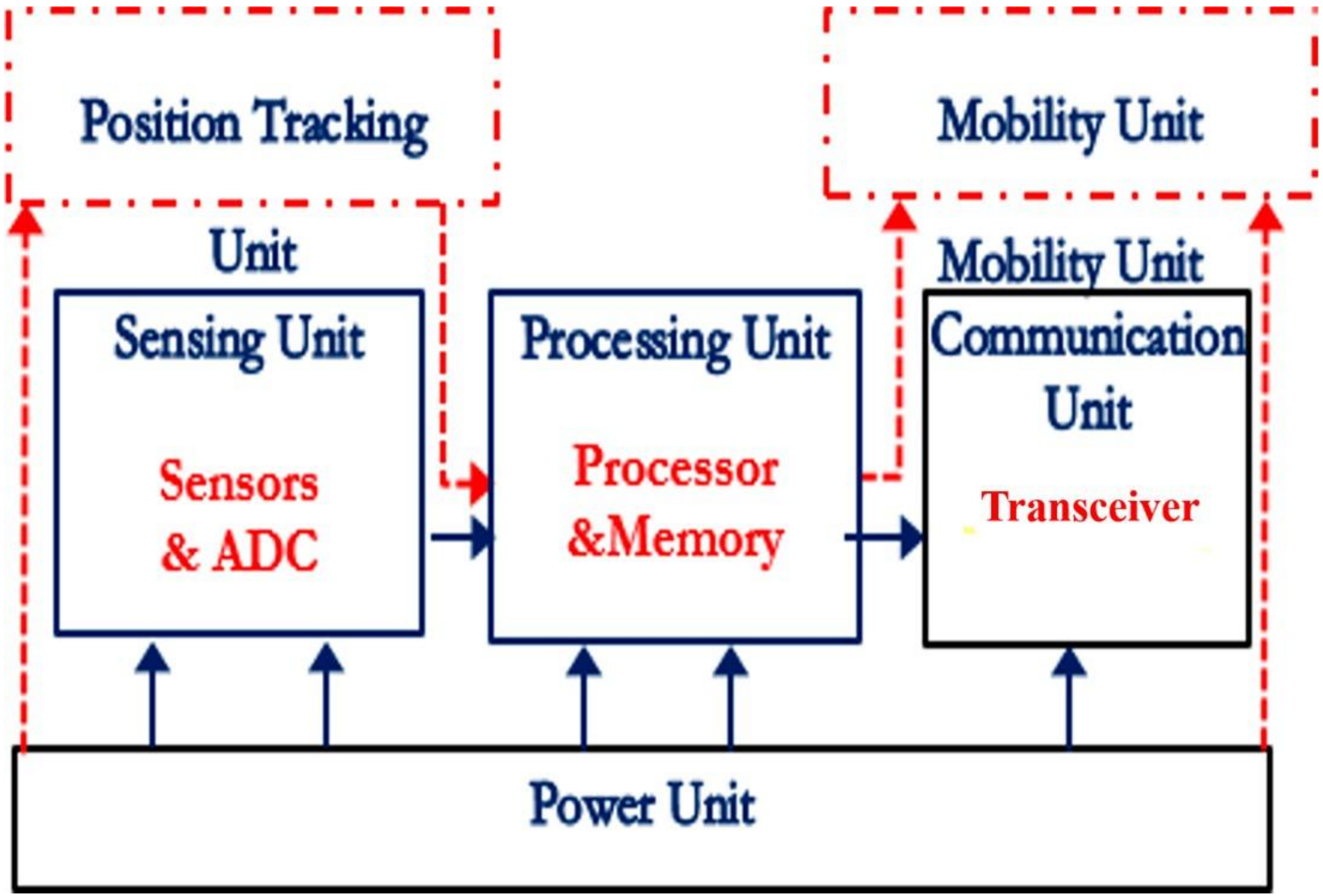
- The advantage of this mesh topology includes easy isolation and detection of faults in the network.

- The disadvantage is that the network is large and requires huge investment.

WSN

- A Wireless Sensor Network (WSN) is a group of spatially dispersed sensor nodes, which are interconnected by using wireless communication.
- A sensor node, also called mote, is an electronic device which consists of a processor along with a storage unit, a transceiver module, a single sensor or multiple sensors, along with an analog-to-digital converter (ADC), and a power source, which normally is a battery. It may optionally include a positioning unit and/or a mobilization unit.

Typical architecture of a sensor node used in WSNs



WSN Architecture

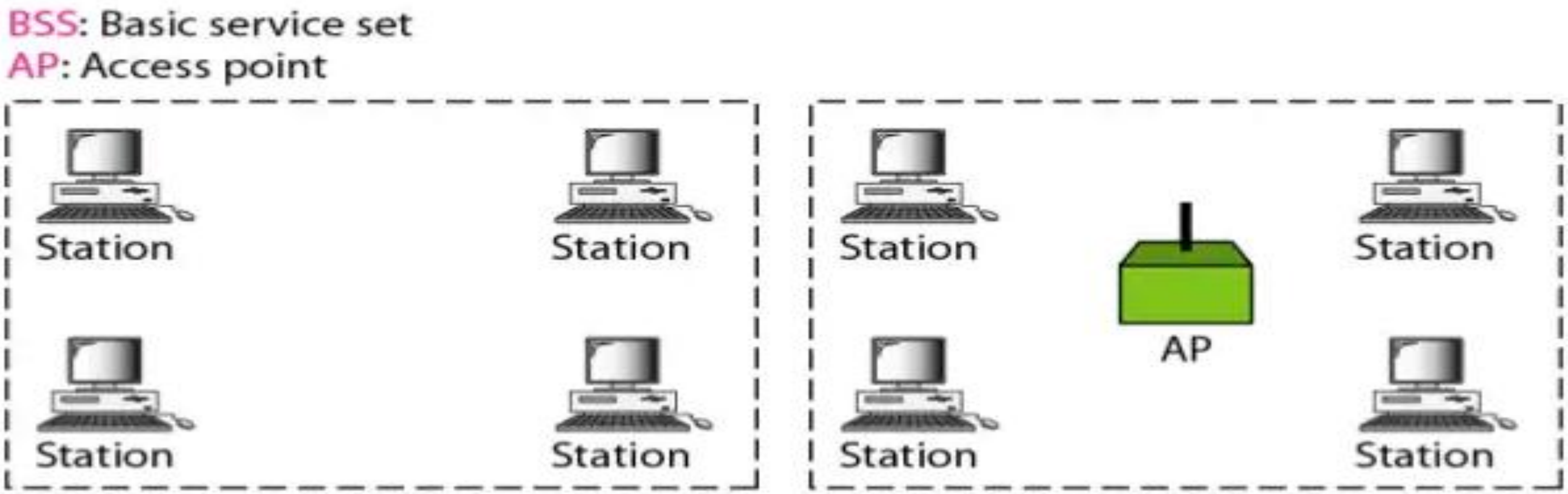
A sensor node uses its sensor(s) in order to measure the fluctuation of current conditions in its adjacent environment. These measurements are converted, via the ADC unit, into relative electric signals which are processed via the node's processor. Via its transceiver, the node can wirelessly transmit the data produced by its processor to other nodes or/and to a selected sink point, referred to as the Base Station

The typical architecture of a WSN

The Base Station, by using the data transmitted to itself, is able to both perform supervisory control over the WSN it belongs to and transmit the related information to human users or/and other networks

Ad Hoc Networks

A BSS without an AP is called an ad hoc network;
a BSS with an AP is called an infrastructure network.



Why Ad Hoc Networks ?

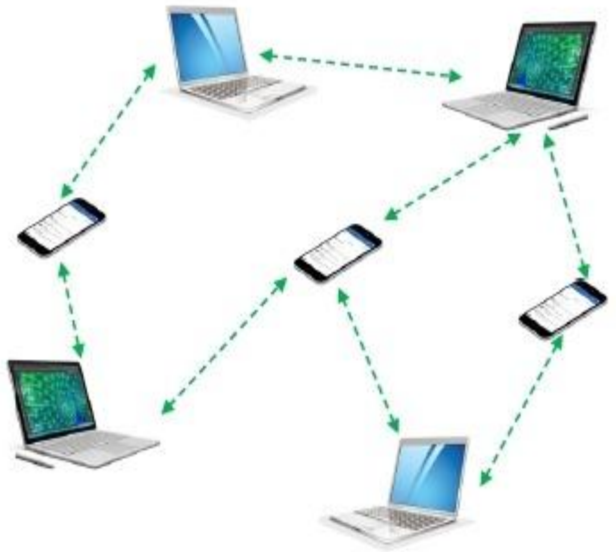
- Setting up of fixed access points and backbone infrastructure is not always viable
  - Infrastructure may not be present in a disaster area or war zone
  - Infrastructure may not be practical for short-range radios; Bluetooth (range ~ 10m)
- Ad hoc networks:
  - Do not need backbone infrastructure support
  - Are easy to deploy
  - Useful when infrastructure is absent, destroyed or impractical

Ad hoc Networks

An ad hoc network is one that is spontaneously formed when devices connect and communicate with each other.

Ad hoc networks are mostly wireless local area networks (LANs). The devices communicate with each other directly instead of relying on a base station or access points as in wireless LANs for data transfer co-ordination.

Each device participates in routing activity, by determining the route using the routing algorithm and forwarding data to other devices via this route.



Classification of Ad hoc Networks

Mobile ad hoc networks (MANETs)	• This is a self-configuring, self-organising, wireless network of mobile devices.
Vehicular ad hoc networks (VANETs)	• This is network formed by communication between moving vehicles and other roadside devices.
Wireless mesh networks	• The devices connected to these networks forms a wireless mesh, depending upon the mobility patterns, nature of devices and inter-device distances.
Smart phone Ad Hoc Networks (SPANs)	• These are peer - to - peer networks created by smartphones within range of each other without requiring any cellular carrier networks, wireless access points etc.
Wireless Sensor Networks (WSN)	• Sensors are portable devices that capture specific information from environment like temperature, humidity, traffic volume etc. WSNs form ad hoc networks to capture information on the fly.

Characteristics of Ad hoc networks

Dynamic topologies

- Network topology may change dynamically as the nodes are free to move

Bandwidth-constrained, variable capacity links

- Wireless links have typically lower capacity than wired
- Realized throughput of wireless communication is lower than the radio's maximum transmission rate
- Link capacity is relatively low => congestion is common (collisions occurs frequently as application demand approaches link capacity)

Energy-constrained operation

- Nodes in ad hoc network may rely on batteries or other limited energy sources
  - Energy conservation may be a dominant design factor

Characteristics of Ad hoc networks

Limited physical security

More prone to physical security threats than wired networks

Incl. stealing mobile ad hoc devices

Many attacks, incl. Eavesdropping, spoofing, and DoS attacks are easier

Decentralized network control

Eliminates single points of failure (=> better reliability)

Scalability problems

As networks get large

WSN vs Ad hoc Networks

Feature	Wireless Sensor Network	Ad hoc Network
Number of sensor nodes or motes	Large in quantity	Medium in quantity
Deployment type	Very much dense	Scattered
Rate of failure	More	Very rare
Change in network topology	frequency	rare
Communication mode	Broadcast	point to point
Battery	Not replaceable / Not rechargeable	Replaceable
Identifiers (IDs) used in the network	No unique IDs	Unique IDs
Centric mode	based on data	based on address
Fusion/Aggregation	Possible	Not suitable
Computational capacities & memory requirement	Limited	Not limited
Data rate support provided	Lower	Higher
Redundancy	High	Low

WSN

- The collaborative use of a sufficient quantity of such sensor nodes, enables a WSN to perform simultaneous data acquirement of ambient information at several points of interest positioned over wide areas.

- The inexpensive production of sensor nodes of this kind, which despite their relatively small size, have exceptionally advanced sensing, processing, and communication abilities has become feasible due to continuous technological advances. For this reason, although WSNs were initially used mainly for military purposes, nowadays they support an ever-growing range of applications of different types

TYPES OF WIRELESS SENSOR NETWORKS

TERRESTRIAL WSNs

- These types of networks consist of hundreds or thousands of wireless sensor nodes. These nodes can be deployed in an unstructured or a structured manner. The nodes are distributed randomly in an unstructured mode, but they are kept within the target area.
- As these are the ‘terrestrial’ sensor networks therefore they are above ground and solar cells can be used to power up these networks. The energy can be conserved by minimizing delays and by using operations of low duty cycles etc.

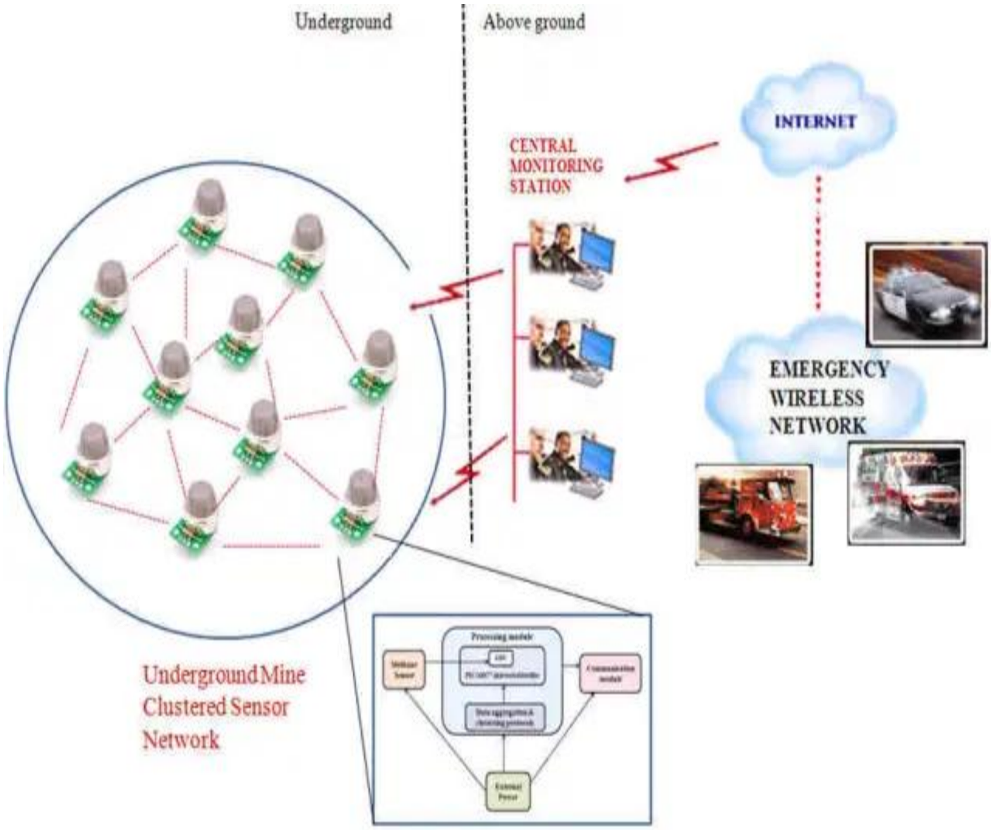
MOBILE WSNs

- The mobile network, as the name suggests, is not fixed rather the sensor nodes can move from one place to any other. They can be easily interfaced with the environment around them. Their main advantage is that they provide better coverage, superior channel capacity and enhanced coverage. These mobile WSNs are more versatile as compared to the other static sensor network systems.

UNDERGROUND WSNs

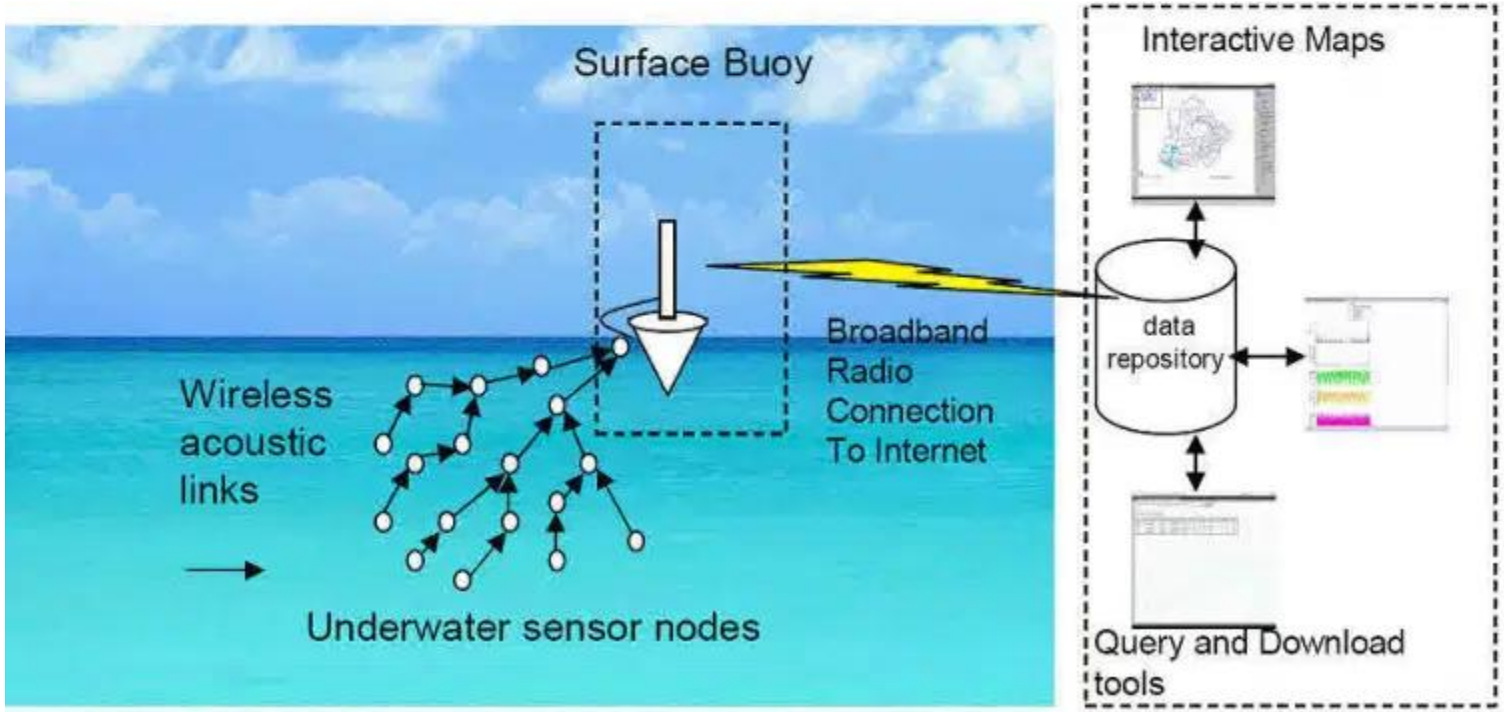
These sensor networks are more costly as compared to terrestrial networks. The equipments used are expensive and proper maintenance is needed. These are effectively used to monitor the underground conditions therefore their whole network is underground but to pass on the information to the base station, sink nodes are used which are present above the ground.

Problems are faced while recharging the batteries of the underground sensor networks and loss of signal can also occur due to high level of attenuation in the underground environment.



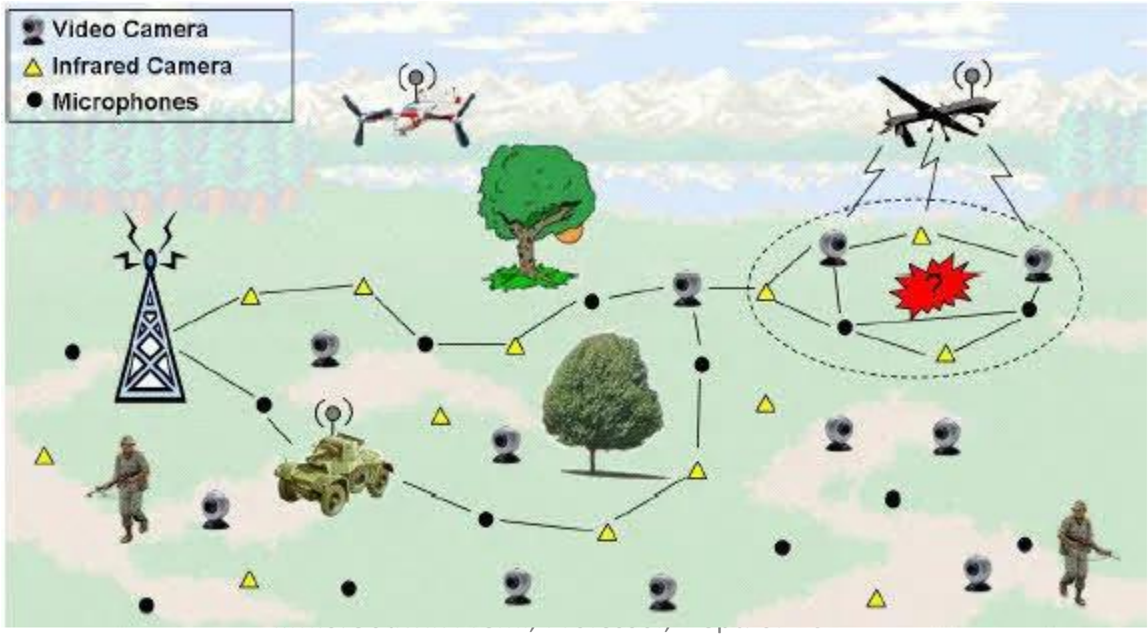
UNDERWATER WSNs

- Underwater wireless sensor network system comprises of sensor nodes and vehicles which are deployed under the water. To gather data from the sensor nodes, underwater vehicles are to be used. The long propagation delay and sensor failures are a big challenge to the underwater communication system. The battery of these WSNs is also limited and cannot be recharged; therefore, different techniques are being developed to solve this issue of energy usage and conservation.



MULTIMEDIA WSNs

- These sensor networks can gather information in the form of audio, video and imaging. The sensor nodes in these networks are connected with cameras and microphones. They can track and monitor different events occurring and can keep a visual display of the events also. For the purpose of data compression, retrieval and correlation, these nodes are also interconnected with one another through a wireless connection.



Applications of WSN

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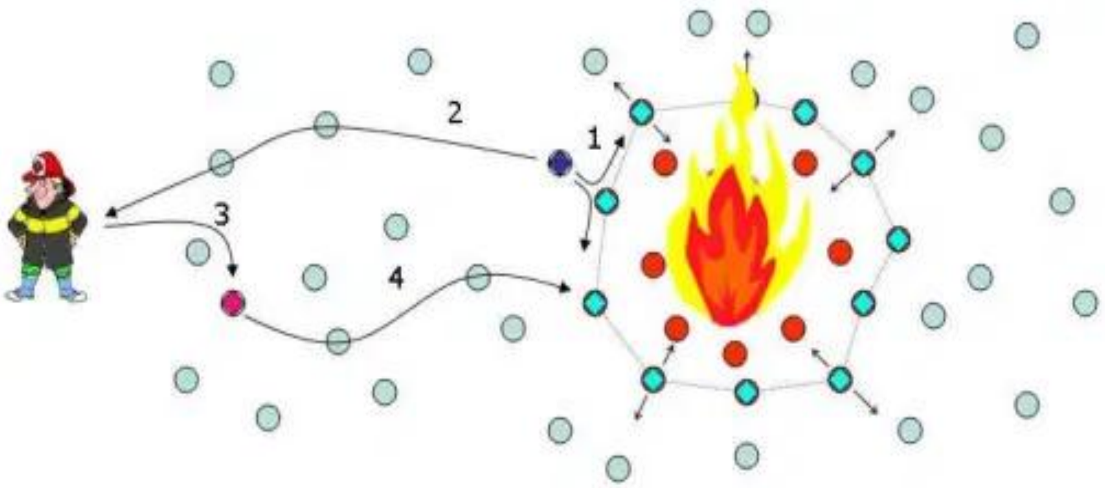
APPLICATIONS OF WIRELESS SENSOR NETWORKS

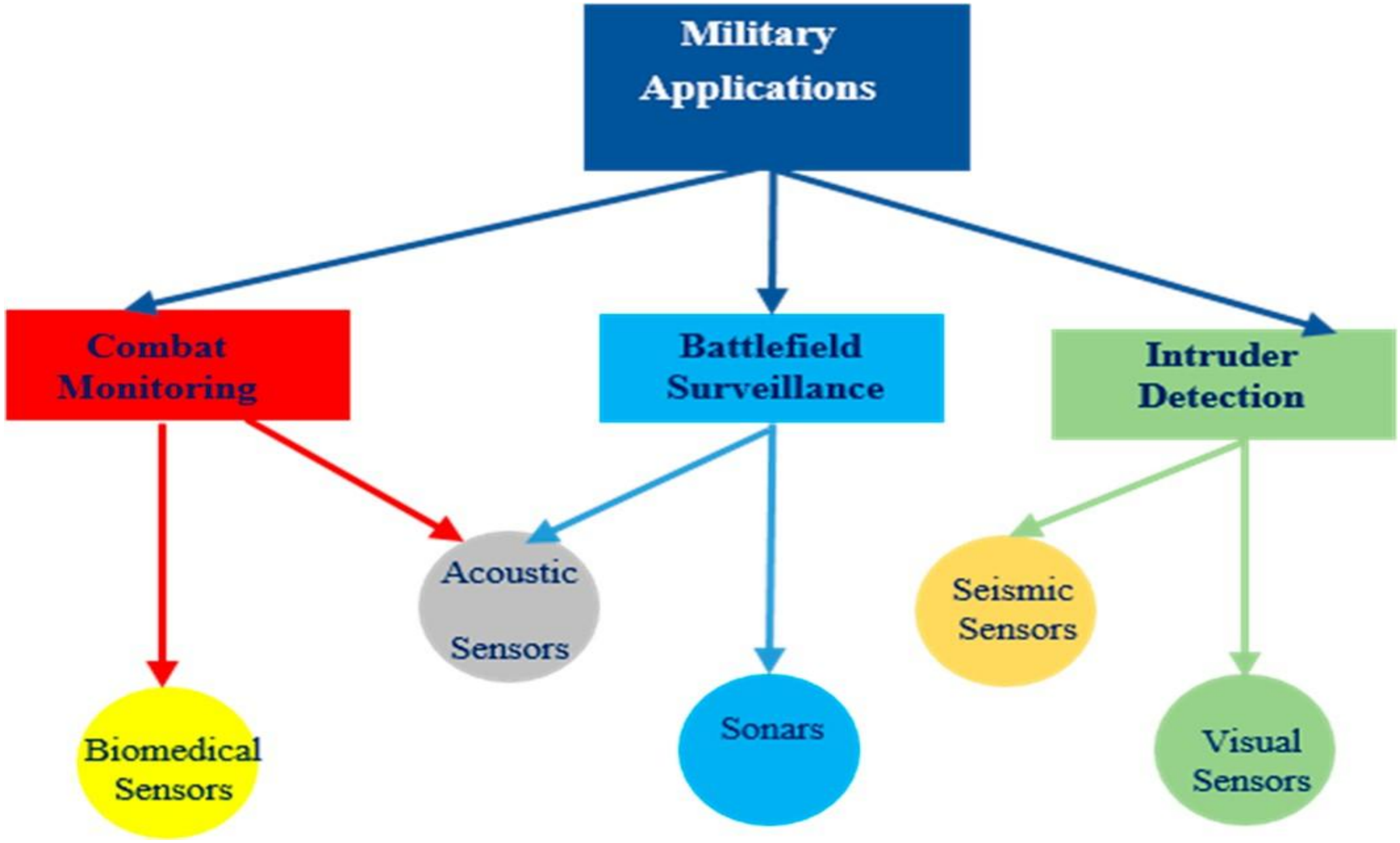
- There are numerous applications of WSNs in industrial automation, traffic monitoring and control, medical device monitoring and in many other areas.

DISASTER RELIEF OPERATION

- If an area is reported to have been stricken from some sort of calamity such as wildfire, then drop the sensor nodes on the fire from an aircraft. Monitor the data of each node and construct a temperature map to devise proper ways and techniques to overcome the fire.

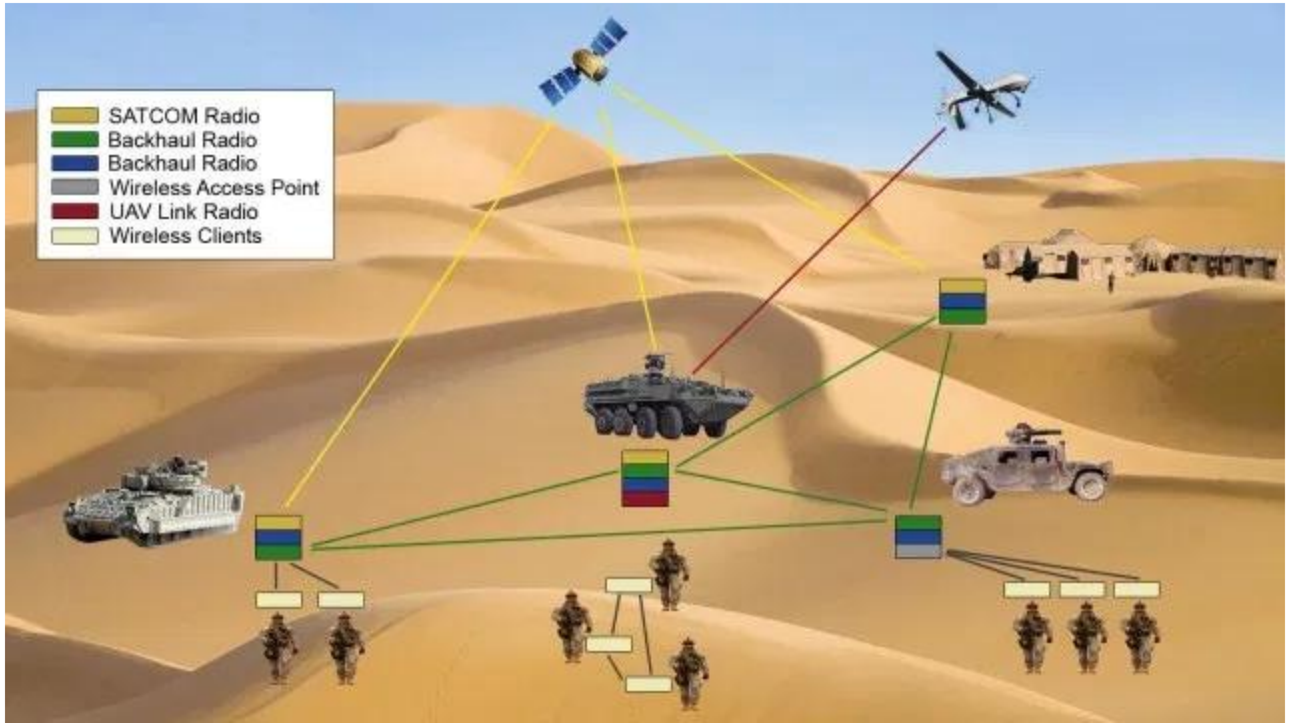


Military Applications



MILITARY APPLICATIONS

- As the WSNs can be deployed rapidly and are self organized therefore they are very useful in military operations for sensing and monitoring friendly or hostile motions. The battlefield surveillance can be done through the sensor nodes to keep a check on everything in case more equipment, forces or ammunitions are needed in the battlefield. The chemical, nuclear and biological attacks can also be detected through the sensor nodes.
- An **example** of this is the ‘sniper detection system’ which can detect the incoming fire through acoustic sensors and the position of the shooter can also be estimated by processing the detected audio from the microphone.



ENVIRONMENTAL APPLICATIONS

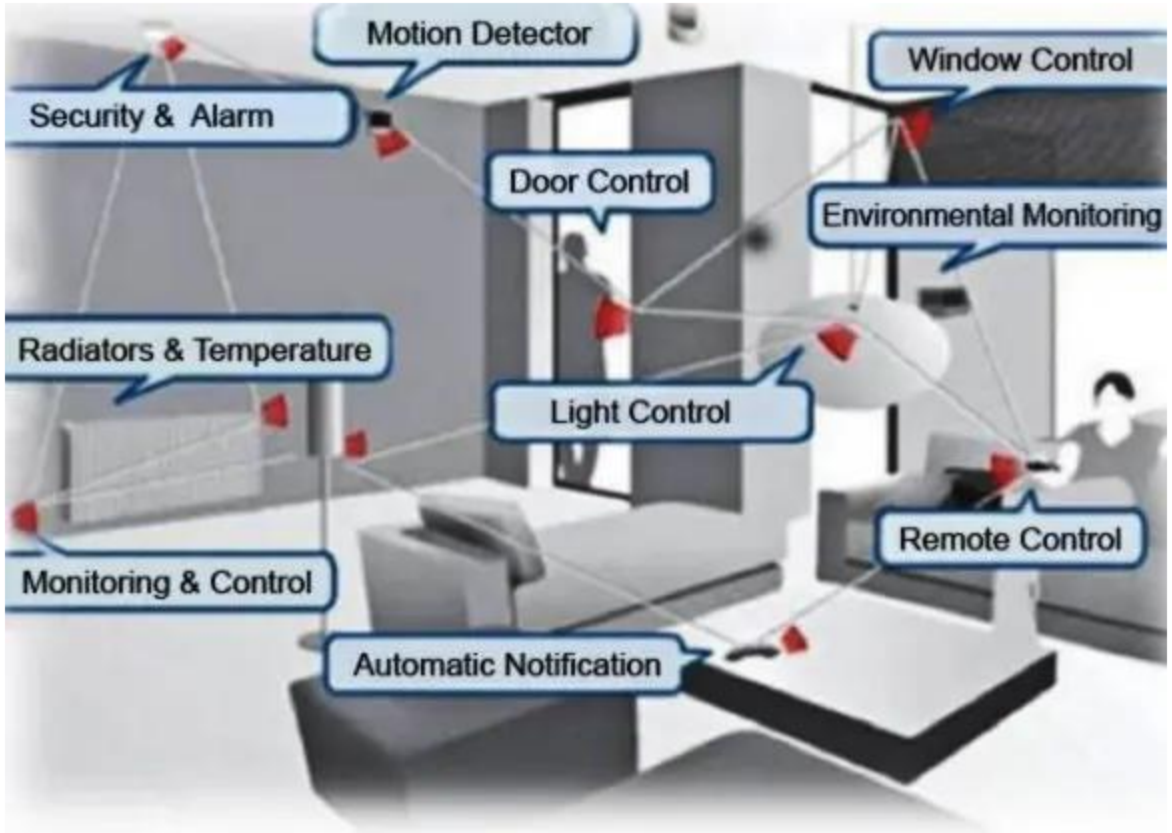
- These sensor networks have a huge number of applications in the environment. They can be used to track movement of animals, birds and record them. Monitoring of earth, soil, atmosphere context, irrigation and precision agriculture can be done through these sensors. They can also used for the detection of fire, flood, earthquakes, and chemical/biological outbreak etc.

MEDICAL APPLICATIONS

- In health applications, the integrated monitoring of a patient can be done by using WSNs. The internal processes and movements of animals can be monitored. Diagnostics can be done. They also help in keeping a check on drug administration in hospitals and in monitoring patients as well as doctors.
- An **example** of this is ‘artificial retina’ which helps the patient in detecting the presence of light and the movement of objects. They can also locate objects and count individual items.

MEDICAL APPLICATIONS

- As the technology is advancing, it is also making its way in our household appliances for their smooth running and satisfactory performance. These sensors can be found in refrigerators, microwave ovens, vacuum cleaners, security systems and also in water monitoring systems. The user can control devices locally as well as remotely with the help of the WSNs.



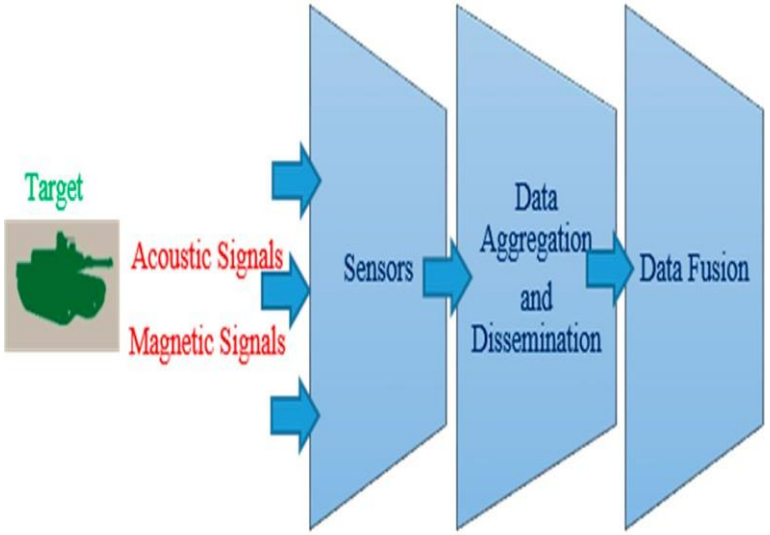
Military Applications

• Specifically, Chemical, Biological, Radiological, Nuclear and Explosive (CBRNE), and Toxic Industrial Material (TIM) sensors may be used to detect the presence of such substances.

• To detect intrusion, WSNs may use infrared (IR), photoelectric, laser, acoustic, and vibration sensors. Similarly, RAdio Detection And Ranging (RADAR), LIght Detection And Ranging (LIDAR), LAser Detection And Ranging (LADAR) and ultrasonic sensors are used by nodes in WSNs in order to detect the distance from objects of interest. Likewise, LADAR and infrared sensors are used for imaging purposes.

•Additionally, the flexibility that WSNs have in their structure enables them to adapt to various requirements. For instance, in battlefield operations large-scale WSNs consisting of many thousands of nodes, which are non-manually deployed, are used. In urban warfare and force protection operations, WSNs used consist of hundreds of manually deployed nodes. In other-than-war operations all scales of WSNs and deployment methods are used

Battlefield Surveillance



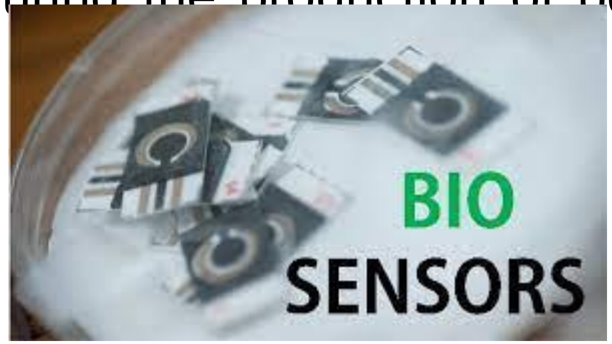
In applications of this type, the sensor nodes of the WSN may be deployed on a battlefield nearby of the paths that enemy forces may use.

The main advantage provided is that the WSN not only can be spontaneously positioned but also can function, without need for continuous attendance and maintenance.

The terrain of the battlefield in most cases is absolutely variable. This plays an important role for both the coverage and the energy consumption of the sensor nodes

Bio Sensors

- **Biosensors** can be defined as self-containing analytical devices comprised of a biological sensing element, or biorecognition element, responsible for specificity, and a physical transducer that converts the recognition phenomenon into a measurable signal.
- **Biosensors** are **used in** the food industry to measure carbohydrates, alcohols and acids, for example, during quality control processes. The devices may also be **used to** check fermentation during the production of beer, yoghurt and soft drinks



Acoustic Sensors

- **Acoustic** wave **sensors** are so named because their detection mechanism is a mechanical, or **acoustic**, wave. Piezoelectric **acoustic** wave **sensors** apply an oscillating electric field to create a mechanical wave, which propagates through the substrate and is then converted back to an electric field for measurement.
- **Acoustic sensors** is broader than detecting sound. In particular, they became increasingly popular for detecting mechanical vibrations in a solid for the fabrication of such **sensors** as microbalances and surface **acoustic**-wave (SAW) device

Seismic Sensors

A **seismic sensor** is an instrument to measure the ground motion when it is shaken by a perturbation. This motion is dynamic and the **seismic sensor** or seismometer also has to give a dynamic physical variable related to this motion.

A **seismic sensor** functions as a velocity **sensor** or an accelerometer that senses the ground vibration of the earth, which is widely used in the field of earthquake monitoring, resource exploration, and ocean bottom observation.

Seismic Sensors(Seismometers)and Vibration **Sensors** (Seismoscope) Usable for a wide range of applications such as shutting off fuel supply to plant and factory equipment when an **earthquake** is detected and for estimating physical damage to public facilities and transport.

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Vision/Visual Sensor

A **visual sensor** network or smart camera network or intelligent camera network is a network of spatially distributed smart camera devices capable of processing, exchanging data and fusing images of a scene from a variety of viewpoints into some form more useful than the individual images.

Vision sensors use images to determine the presence, orientation, and accuracy of surrounding objects. **Vision sensors use** a combination of both image acquisition and image processing, and multi-point inspections can be done using a single **sensor**.

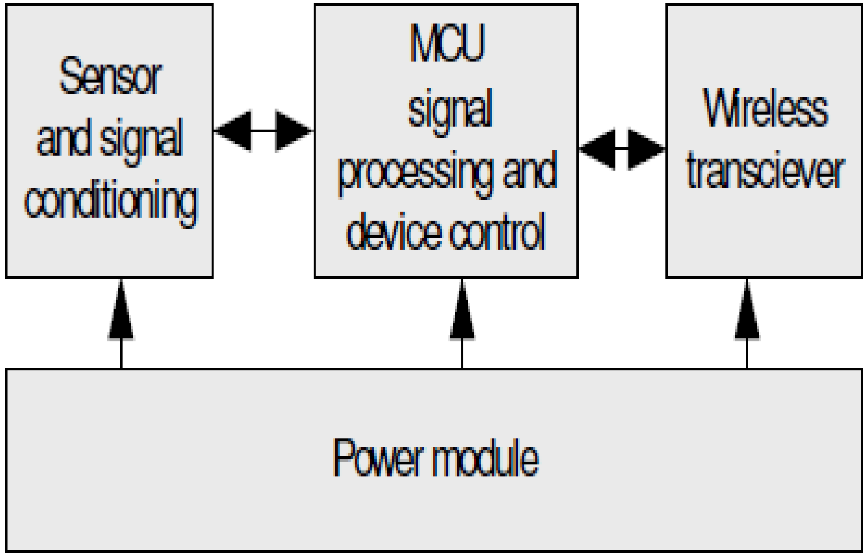
Applications of Ad hoc networks

- Personal area networking
  - cell phone, laptop, ear phone, wrist watch
- Military environments
  - soldiers, tanks, planes
- Civilian environments
  - taxi cab network
  - meeting rooms
  - sports stadiums
  - boats, small aircraft
- Emergency operations
  - search-and-rescue
  - policing and fire fighting

Challenges in Mobile Environments

- Limitations of the Wireless Network
  - packet loss due to transmission errors
  - variable capacity links
  - frequent disconnections/partitions
  - limited communication bandwidth
  - Broadcast nature of the communications
- Limitations Imposed by Mobility
  - dynamically changing topologies/routes
  - lack of mobility awareness by system/applications
- Limitations of the Mobile Computer
  - short battery lifetime
  - limited capacities

Node Hardware Equipment



Distance Measuring Sensors

The node is powered by batteries and DC/DC unit.

Capturing and pre-processing of the measured signal is made by 32-bit microcontroller AT91SAM7S64.
It has a build-in 8-channel, 10-bit AD converter.

Microcontroller’s clock frequency 48 MHz. Its core is built on the powerful ARM7 architecture, which allows engagement of the appropriate compression algorithms to increase wireless network throughput.

Wireless communication is based on XBee-PRO module. This module complies with IEEE 802.15.4 specification and is designed for low-cost, low-power mesh networks.

The module operates in the free 2.4 GHz ISM band. Transfer rate of the module is 250 kbps. The range is dependent on the type of environment, used antennas and the transmitter output power.

Measurements of the range under real world conditions. Data collection node is powered by USB. USB interface is compatible with USB 2.0 specifications. On the PC side, as a driver, freely available universal library libusb-win32 is used.
Maximum data transfer rate between the computer and the node is 8 Mb/s, which far exceeds the actual speed of wireless network. the nodes were used to transfer images from camera with serial output to PC. Other application involved transfer of audio signal in real time.

Distance Measuring Sensors

The principle of distance measuring sensor can be based on the reflection of either ultrasonic or infrared rays.

Ultrasonic distance measuring sensors have a relatively low refresh rate, which has an adverse impact on the quality of measured data.

Example ultrasonic sensor SRF02 has response time of 70 ms within range up to 6 m. voltage output that is updated approximately every 20 ms, corresponding to a maximum sampling frequency of 50 Hz. On a passenger car with an average length of 5 m and maximum moving speed of 50 km/h (maximum permitted speed in Slovak cities) then falls at least 18 samples, i.e. one sample on every 28 cm of car length. This number should be sufficient to reliably distinguish the type of passing vehicle.

Applications of WSN for Road Monitoring

Applications of WSN for Road Monitoring

The first measurement took 21 hours of the day With the sampling frequency of 50 Hz recorded 3 780 000 samples. Fig shows the output from the sensor while bus passes below it. At around 5:30 in the morning (after approximately 1 160 000 measured samples) it started raining. Rain caused the dispersion of the sensor's infrared beam and the signal became unstable . After the rain the situation has not improved much because the road was still wet. Another negative factor was rough road surface.