RESEARCH ARTICLE OPEN ACCESS

Wireless Sensor Network (WSN) Architectural Design and Applications

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ABSTRACT
wireless Networks (WN's) eliminating the wires used in networks, where communication takes place via wireless media and provide access in a user friendly manner. WNs are connecting the world and providing communication to various users. WSN's are used in the areas, where transmission through wires is not possible. WSN's consist of sensor nodes (SN's) that are smaller, cheaper and intelligent. This paper discusses about the architecture design, applications and security of WSN.
Keywords **-** Wireless sensor networks, sensor nodes, Architecture design, Security issue.

I. INTRODUCTION

Wireless networks (WN's) are broadly categorized into Infrastructure Networks, Infrastructureless Networks and Hybrid Networks as given in figure 1.

Infrastructure Networks (structured network):

It consists of wireless nodes with wired gateways as network backbone. Cellular wireless networks falls under structured networks. A Mobile unit communicate through Base station (BP) to another mobile with in its communication range. In this BP are fixed. This network deploye some nodes in pre-planned manner. To provide coverage fewer nodes placed at specific locations and fewer nodes deployed with lower network maintenance and management cost.

Unstructured (Infrastructure-less Networks):

It consists of wireless nodes which are low power, task oriented, dynamic topology and distributed independently. This networks classified into i) AD-HOC and ii) WSN.

i) AD-HOC:

1. It is a distribute (decentralize) type of WN and does not rely on a pre-existing infrastructure such as routers in wired networks or Access Point (AP) in WSN(Managed WN's)
2. wireless nodes(devices) integrated and communicated to each other by making an on support dynamic wireless link.
3. After network deployed, the network left unattended for monitoring and reporting functions.
4. Intermediate nodes in the network between source and sink node only pass the data.
5. In AD-HOC network nodes are mobility and communication between nodes are point to point communication.

ii)WSN :

1. It is spatially distributed type of WN and rely on sink node or AP.
2. Nodes in the sensor field collects information from different nodes and finally send to sink node. Sink node removes redundant information for further processing.
3. Network maintenance such as managing connectivity and detecting failure is difficult because of many nodes.
4. Intermediate nodes in the networks between source and sink node process the receive packets and forward to the upper nodes.
5. In WSN network nodes are static and communication between nodes are broadcasting communication.

Hybrid Wireless Networks :

It adopts characteristics of both infrastructure and infrastructure-less networks.

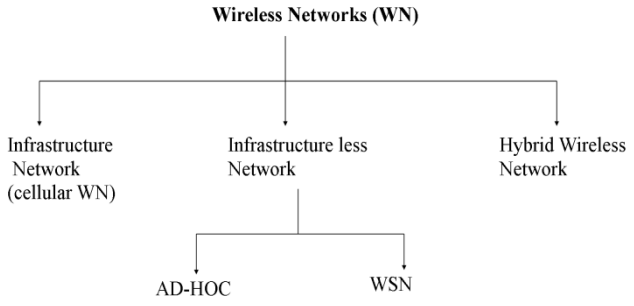

Fig 1: Classification of Wireless Networks

II. WSN COMMUNICATION

WSN deployed in the areas where transmission through wires are not reliable and possible. A WSN consist of huge number of small sensor nodes with senors for sensing,

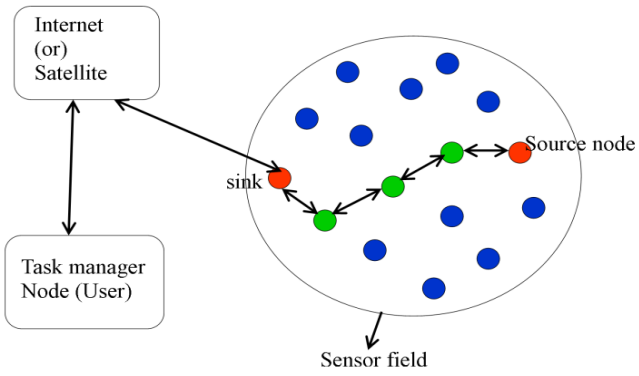

Fig 2: Communication architecture of WSN

processor for data processing and transceiver for communication capabilities. Sensor nodes in the network monitors the surrounding areas and gathers application specific parameters like pressure, humidity, chemical activity, mechanical stress level, temperature, light and other parameters

The sensor nodes periodically sense the data and process it to the neighbor nodes to form a communication network. Once the collected data send to the sink node in hop by hop transmission utilizing the minimum possible power. When data reach the sink, it is then routed to the task manager node or user via satellite or internet where users can have access to the data as shown in Fig 2. Sink node may be a static or mobile based on application. Communication over long distance drain power quickly so multihop communication is necessary for WSN. A long range single hop communication avoided by using intermediate nodes as relays this reduces total power required for data transmission from source to destination node(sink node).

III. SENSOR NODES ARCHITECTURE

Each sensor node consists of following four units:

1. Sensing unit:
   It senses the environment, collects information and data conversion
2. Processing unit:
   It performs local computations on the sensed data.
3. Communication unit:
   It is responsible for message exchange between the nodes.
4. Power unit:
   It provides energy for working sensor node.

1. Sensing unit:

- ***A/D converter (ADC)***:
  Converts the analog signal from a sensor node into digital signal and gives to the microcontroller.

- ***Sensor*:**
  WSN consists of a large number of sensor nodes, depending upon the application each node contains more than one sensor. In fig 4 sensors are a device which senses physical phenomenon like pressure, temperature, light, speed, motion etc and transfer it into an analog signal. The analog signal processed to ADC and converted as digital signal and that signal processed to the MCU (Microcontroller Unit) [1].

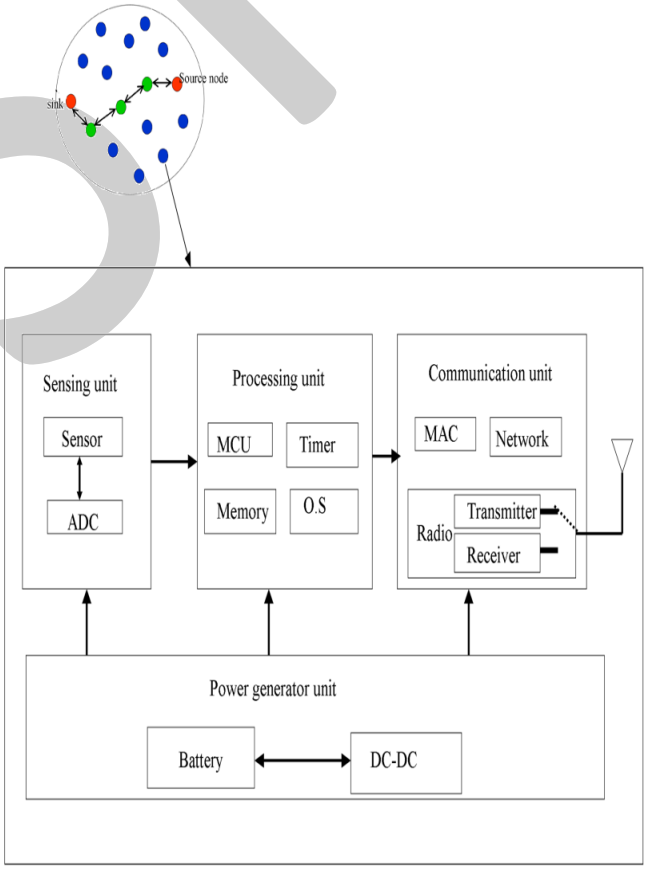

Fig 3: Sensor node architecture

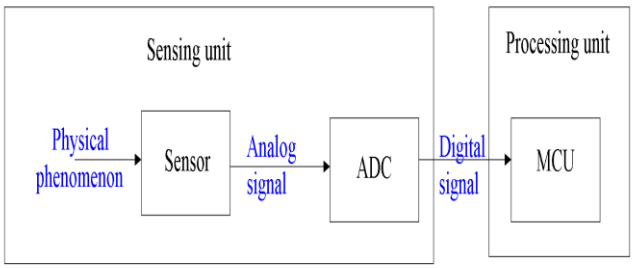

Fig 4: signal processed in sensing unit

Sensor node may be active sensor or passive sensor. An **active sensor** emits radiation towards the target and the radiation reflected from the target is detected and energy measured by active sensor. A **passive sensor** only used to detect available naturally occurring energy.

Classification of sensors:

i. Environmental sensors:

- Pressure sensor → Measure pressure, altitude, flow, depth and leak testing of liquid or gas.
  Types:
  Absolute pressure sensor
  Vacuum pressure sensor
  Gauge pressure sensor
  Sealed pressure sensor
  Differential pressure sensor
- Temperature sensor → Measure temperature of a medium.
  Types:
  Contact sensor → Measure the temperature of the object to which the sensor is in contact
  Non-contact sensor → Measure the thermal radiant power of the Infrared or Optical radiation received
- Soil moisture sensor → Measure the water content in soil
- Humidity sensor → Measure the humidity of air or gas.
  Types:
  Capacitive humidity sensors
  Hygrometric humidity sensors
  Gravimetric humidity sensors
  Optical humidity sensors
- Wind sensor → Measure the speed and direction of wind.
- pH sensor → Measure the pH of liquid contain the acidity and alkalinity

ii. Physical sensors:

- Water sensor → Shows whether the sensors are dry, wet or completely dip in water by measuring conductivity
- Ultrasound sensor → uses sound waves to detect a target for detecting liquids, clear objects or irregular objects.
- Sound sensor → Used to detect sound strength of the environment. The Sound sensor picks up sound that the human ear cannot.
- Accelerometer sensor → Measure acceleration in one, two, or three orthogonal axes.
- Presence sensor → Detect the location of objects or personnel near hazardous areas.
- Vibration sensor → Measure and analyze displacement, linear velocity, and acceleration (motion).
- Bend sensor → Measure the amount of deflection caused by bending the sensor
- Flex sensor → Measure change in resistance depending on the amount of bend on the sensor.
- Strain sensor → Measure strain (internal resistance forces) of an object.
- Stress sensor → Measure stress(displacement and deformation) of an object
- Power sensor

iii. Gas sensors:

- CO_2 sensor → Measure CO_2 (carbon dioxide) gas
- CO sensor → Measure the presence of CO (Carbon monoxide) gas in order to prevent CO poisoning. Types:
  Opto-chemical sensor
  Biomimetic sensor
  Electrochemical sensor
- CH4 sensor → Detect CH_4 (Methane) gas it is a harmful gas used in CH4 detectors in industrial settings.
- $O2_{sensor}$ → Measure the proportion of O_2 in the gas or liquid being analyzed.
- NH3 sensor → Detecting NH3 (ammonia) leaks in almost any environment
- SH2 sensor
- NO2 sensor

iv. Optical sensors:

- Color sensor → Detect the color present in a surface.
- Ultraviolet sensor → Measures UV light from the Sun.
- Infrared sensor → Detect infrared radiation, measure the heat of an object and detect motion.
- Sunlight sensor → Detect sunlight
- Radiation sensor → Measure the solar radiation flux density.

v. Biological sensors:

- Pulse sensor → Heart rate per minute for Arduino,
- Oximetry sensor → Measure the oxygen level in the blood.
- Fall sensor → Detect falls, stumbles, trips or recovered falls.
- Sweat sensor
- Electrocardiogram ECG sensor

2. Processing unit:

- ***Microcontroller unit (MCU)*** – It consists of memory, processor, interfaces and non-volatile memory. It is a general purpose processor which reduces the need of wiring, circuit board space, extra hardware and energy consumption. Microcontroller has three states: active, sleep, idle state.
- ***Memory*** – Used for storing information in MCU. RAM is used as internal memory. EEPROM or flash memory (Electrically erasable and reprogrammable in blocks) is used for storing program code. Size of memory depends upon the application and size of memory can affect power consumption and cost.
- ***Timer*** – Timer is a special type of clock. Different types of timers are digital, electronic, mechanical and electromechanical.
- ***Operating Systems (O.S)*** – some of the WSN O.S are contiki, BTnut, MANTIS, TinyOS and SOS etc. WSN uses less complex O.S consist of few thousands of lines of coding whereas general purpose O.S consists of millions of coding lines [1].

3. Communication unit:

- ***Transceiver:*** It consists of a transmitter and receiver which sharing same circuitry on a single board. It receives instruction from processing unit and passes it to another node via antenna. Three types of communication and their frequency ranges are
  i. RF communication – 3KHz to 300GHz
  ii. Infrared communication – 300GHz to 120THz
  iii. Optical communication – 385THz

  RF (Radio Frequency) based communication is best for the requirements of WSN. RF is based on electromagnetic waves. WSN uses communication frequency between 433 MHz and 2.4 GHz
- ***Network protocol:*** In WSN communication takes place through communication channels. To perform the communication this unit provides a protocol layer as shown in fig 5.

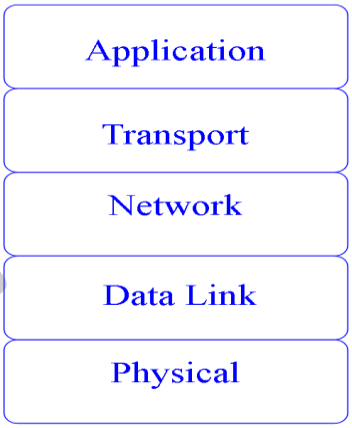

Fig 5: Protocol layers of a WSN

4. Power generator unit:

The power supply is essential for two aspects: first, storing energy and providing in the required form; second, consumed energy by scavenging.

- **Battery:** storing power is done using batteries. A battery is the power source of a sensor node; it may either non-rechargeable (primary batteries) or rechargeable (secondary batteries). Some other batteries are electro-chemical stores for energy.
- ***DC-DC converter:*** used to regulate the voltage delivered to the node's network. Even though the battery's voltage drops, the DC-DC converter ensure constant voltage and it draws higher current from battery directed to battery death.

IV. SENSOR NODES CHARACTERISTICS

- Sensor nodes are deployed closely.
- Due to a large number of sensors, sensor nodes aren't having a global identification (ID).
- Sensor nodes use broadcast communication.
- Sensor nodes easily adapt changes in topology.
- Energy for sensor nodes is limited and non-renewable.
- Limited capabilities of communication.
- Limited storage capacity and computation.

V. TYPES OF WSN

1. Mobile WSN → Movement of mobile nodes.
2. Multimedia WSN → About video, audio & images.
3. Underground WSN→ Nodes present in mines & caves.
4. Underwater WSN → Nodes in oceans for communication.

5. Terrestrial WSN → Nodes in land for various applications.

VI. WSN CHARACTERISTICS

Large scale network:

Coverage area of network increases by using a large number of nodes.

Self organizes network:

Sensor nodes place in an unreachable or dangerous area to human so nodes need self organize ability to automatically configure and manage through topology control mechanisms or through a network protocol.

Dynamic network:

Topology of the network may change due to joining a new node or environmental changes; this requires the network should adapt the change with the dynamic system reconfigure ability.

Reliable network:

The networks are deployed in cruel areas or in the areas where human cannot easily reach. So networks should deploy are well-built, hard to deploy and adjust environmental changes.

Application specific network:

The network has a variety of necessities depends upon different applications and network deployed based on that.

Factors affecting WSN Networks:

- Fault Tolerance
- Production cost
- Scalability
- Hardware constraints
- Operating environment
- Transmission media
- Sensor network topology
- Power consumption

VII. APPLICATIONS OF WSN

Military application:

Sensor nodes are deployed in the enemy's position using aircrafts, from a sensor network. Sensor network collects information and send to commanders on the battlefield. Biological and chemical weapons used by enemy detected, using biological and chemical sensors [6].

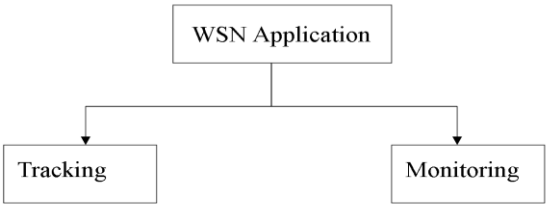

Fig 5. WSN application

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Environmental system:

Sensor networks used for monitoring flood, the amount of rainfall, water levels in Forest River, soil moisture and habitats of animals. Also used for tracking birds, small animals and insects [2].

Medical care:

Monitors human heart rate, blood pressure and various physiological data.

Smart Home:

Sensors embedded in the home connected to internet to control the appliances. Remote control cookers, telephones, computer, television and refrigerators are controlled by sensor networks [5].

Structural health monitoring (SHM):

The method of finding damage for civil constructions and engineering systems.

VIII. CONCLUSION

This paper elaborates an overview of the WSN, its characteristics and applications. The applications of WSN are not limited. It applies to various fields because of its low cost, the flexibility and rapid deployment of WSN. WSN becomes a part of human life now-a-days because of its performance, low cost, energy efficient techniques and variety of applications. This paper gives an overview and clear idea about WSN.

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