UNIT 1

Introduction to Sensor Networks

Syllabus

Introduction to Sensor Networks, Unique Constraints and Challenges, Advantage of Sensor Networks, Applications of Sensor Networks, Types of Wireless Sensor Networks.

Learning Objectives

- ✓ Brief Introduction to Wireless Sensor Networks
- ✓ Various Features of Wireless Sensor Networks
- ✓ Various Subsystems of Sensor Nodes
- ✓ Various Challenges in Designing WSNs
- ✓ Advantages of Sensor Networks
- ✓ Various Applications of WSN
- ✓ Various Types of WSNs.

Introduction

A wireless sensor network refers to a network of devices (sensors) that collect the information from environments and communicate through wireless links. This data is forwarded through multiple nodes with a gateway. These sensors are involved in various sensing tasks such as temperature, sound and vibration and so on. However, wireless sensor networks can be used for various applications that deal with monitoring, control and surveillance.

Wireless sensor network is used in wide area of applications such as disaster relief management, habitat and environmental monitoring. The major issue of wireless sensor network is security because of certain restrictions such as limited battery power, size of memory at node level and limited adhoc networking, irregular connectivity at network level.

PART-B ESSAY QUESTIONS WITH SOLUTIONS

1.1 INTRODUCTION TO SENSOR NETWORKS

Q9. What is sensor network? Explain in detail about wireless sensor network.

Model Paper-I, Q2(a)

Answer :

Sensor Network

A sensor network refers to the infrastructure capable of sensing the environment so that the administrator can respond to the events accordingly. Typically, it consists of large number of sensors which can monitor the environment. Here, environment can be physical world, a biological system or an information technology framework. The output of the sensor network is usually electrical signal that can be further processed.

Wireless Sensor Network (WSN)

A wireless sensor network refers to a network of devices (sensors) that collect the information from environments and communicate through wireless links. This data is forwarded through multiple nodes with a gateway.

The sensors are involved in various sensing tasks such as temperature, sound, vibration and so on. Hence, Wireless sensor networks are used in applications that deal with monitoring, control and surveillance.

Each node of the sensor network consists of three subsystems,

1. **Sensor Subsystem**

   It senses the environment.

2. **Processing Subsystem**

   It processes the data i.e., performs the computations on the sensed data.

3. **Communication Subsystems**

   It is responsible for communication among the nodes i.e., it helps in exchange of messages between the neighboring nodes.

The following figure depicts the wireless sensor networks.

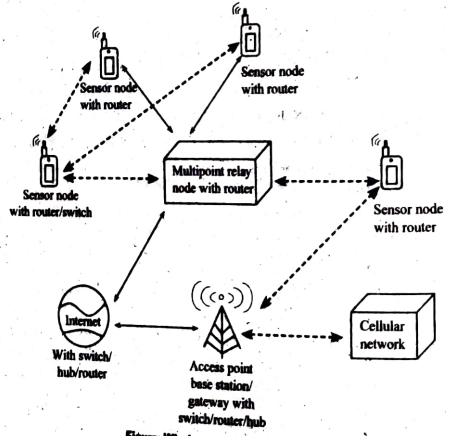

Figure: Wireless Sensor Networks

Q10. Outline the features of wireless sensor networks.

Answer :

Features of Wireless Sensor Networks

Model Paper-II, Q2(a)

The design features of wireless sensor network are as follows,

1. Energy limitations
2. Resistance to node failure
3. Scalability
4. Deployment
5. Quality of Service (QoS).

1. **Energy Limitations**

The energy is one of the major concerns in the wireless sensor networks. The sensor nodes uses chip devices that runs on batteries which are the common means to acquire energy. However, at times the batteries may not facilitate the required amount of power for longer sustenance. So, therefore, mechanism is necessary for efficient utilization of energy resources for long term use.

2. **Resistance to Node Failure**

The failure of nodes is also another concerns of energy losses in WSN. The wireless sensor networks are dynamic in nature and exhibits tolerance to node failures. The causes of the node failures can be depleted batteries, intruder attacks and environmental factors such as fire, flood etc. Therefore, such factors can effect the topology of the networks. Hence, the nodes must be tolerant and robust in nature.

3. **Scalability**

It is defined as the ability of a network to retain its performance irrespective of its size. A wireless sensor network comprises of a very large number of nodes and therefore scalability is a very important aspect. Scalability is affected generally by address or routine table entries and these information should be restricted by limiting the resource of sensor nodes. It is observed that number of nodes compared to large number of nodes, resulting in considerable efficiency.

4. **Deployment**

The sensor nodes can be deployed in distinct ways, which is characterized by requirement, application and environmental factors. The sensor nodes can be set up randomly across the monitoring field or sensor field, which then remain stationary in most of the applications. To substantiate the WSN functionality, various deployment strategies and necessary communication protocols are incorporated depending upon the existing network topology.

5. **Quality of Service (QoS)**

The QoS is one of the major factors in WSN. It is mainly concern with the reliability of the networks. Therefore, ensuring the quality service is the basic requirements in achieving any application goals.

Q11. Explain the difference between cellular networks and ad hoc wireless networks.

Answer :

	Cellular Networks		Ad Hoc Wireless Networks
1.	Cellular networks are infrastructure dependent networks.	1.	Ad Hoc wireless networks are infrastructure independent networks.
2.	They are based on centralized routing.	2.	They are based on distributed routing.
3.	They use circuit switching.	3.	They use packet switching.
4.	The aim is to increase the call acceptance ratio and to decrease the call drop ratio.	4.	The aim is to find paths with minimum overhead and also quick reconfiguration of broken paths.
5.	They seek more time for deployment.	5.	They seek less time for deployment.

6.	The volume of call drops is low.	6.	The volume of call drops is very high.
7.	They utilize single hop links.	7.	They utilize multihop links.
8.	They are very expensive.	8.	They are cost-effective.
9.	Bandwidth can be easily reserved.	9.	Bandwidth cannot be easily reserved.
10.	Time can be easily synchronized.	10.	Time cannot be easily synchronized.
11.	Mobile hosts are relatively less complex.	11.	Mobile hosts are highly complex.
12.	They are primarily used for civil and commercial purposes.	12.	They are primarily used in military, emergency, battle field and rescue operations.
13.	Maintenance is very expensive.	13.	Maintenance properties are built into the network.
14.	Frequency is reused through geographical channel mechanism.	14.	Frequency is reused dynamically through carrier sense mechanism.

Q12. Differentiate between wireless sensor network and Ad hoc network.

Model Paper-I, Q2(b)

Answer :

Features	Wireless Sensor Network	Ad hoc Wireless Network
Number of nodes	Large in magnitude (quantity)	Medium in magnitude (quantity)
Failure rate	More	Less
Energy drain	More	Less
Battery	Non replaceable/non rechargeable	Replaceable/ rechargeable
Identifier used	Not unique	Unique
Centric mode	Data centric (queries are addressed based on the nodes satisfying data condition)	Address centric (queries are addressed based on the unique address of the nodes)
Fusion/Aggregation	Possible	Not possible
Bandwidth consumption	Limited	High
Media access delay	Limited	High
Processing capabity and memory requirement	Limited	Not limited
Redundancy	High	Low

Q13. Define some of the key terms and concepts of wireless sensor networks. Also, discuss various subsystems of sensor nodes.

Answer :

Concepts of WSN

There are several concepts that are used while developing the techniques for sensor nodes. Some of them are as follows,

(i) Sensor

The conversion of physical matter such as sound, light and heat to any other signal or electrical signal is referred as sensor. These signals can be handled using an apparatus in the future.

(ii) Sensor Node

Sensor node is referred as a basic unit of a sensor network comprising of memory, processor, wireless modem power supply and on-board sensors.

(iii) Routing

Routing refers to discovering of routes for a source node to reach its destination node present in the network.

(iv) In-network

In-network is a type of processing which processes the data and integrates it with the data from where it has been produced.

(v) State

State represents the snapshot of the physical environment or a system. Physical environment refers to locations, speed at which the source is moving and number of signal sources whereas system itself refers to the network state.

(vi) Task

Tasks can be of various types either high level tasks or application tasks. High level system task are sensing, communication, processing and resource allocation. Whereas, application tasks refers to detection, classification, localization and tracking of the data.

(vii) Detéction

Detection is a process of checking the availability of a physical phenomenon. It is done by using threshold based detector which sets a flag as soon as it detects the presence of physical phenomenon more than required.

(viii) Resource

Resources are nothing but sensors, processors, node energy reserves, communication links and on-board memory which will be allocated to the tasks, in order to make best use of it and to enhance the performance.

(ix) Sensor Tasking

Sensor tasking is the process of assigning the sensors to a specific task. It also assigns sensors to control of sensor state which control them using the buttons ON/OFF, PAN/TILT in order to perform the task.

(x) Geographic Routing

Geographic routing is the process of routing the data depending upon the geographical attributes which includes locations or regions.

Subsystems of Sensor Node

The different subsystems of sensor node are as follows,

1. Sensing unit
2. Processing unit
3. Communication unit
4. Power unit.

1. Sensing Unit

The combination of sensor and ADC forms the sensing unit, which is used for converting analog to digital signals. It contains two components.

(i) Sensor

(ii) ADC.

2. Processing Unit

Processing unit is responsible for performing the assigned sensing tasks. It contains two components.

(i) Memory

(ii) Microcontroller.

Communication Unit

Communication unit behaves as a communication channel between the sensor node and network. It consists of radio transceiver.

4. **Power Unit**

Power unit acts as source for power. It makes use of batteries.

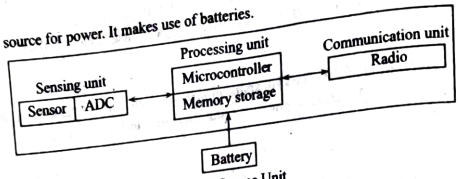

Figure: Different Subsystems of a Sensor Node

1.2 UNIQUE CONSTRAINTS AND CHALLENGES

Q14. What are the unique constraints of sensor networks? Model Paper-II, Q2(a)

Answer :

The constraints of the sensor networks are categorized into node constraints and network constraints.

1. **Node Constraints**

The security solutions need certain constraints such as high computation, storage, memory and energy resources which make the process of dealing the tiny sensor nodes complicated.

(a) **Limited Memory**

Sensor nodes are very tiny devices which possess limited memory and have less storage capacity. For example, Berkeley's MICA2 have 4-8 MHz, 4 kB of RAM, 128 kB flash and 916 MHz of radio frequency.

(b) **Limited Energy**

Energy is a significant factor that needs to be considered while designing the security measures for sensor nodes. Energy consumption need to be limited in the sensor network topology where accessing them is impracticable once they are deployed. It however gets reduced when security measures are added.

2. **Network Constraints**

Mobile adhoc network constraints such as insufficient physical infrastructure, unreliable network communication and problems relevant to collision are acquired by the sensor network.

(a) **Unreliable Communication**

Wireless communication is unreliable which causes damage to the packets or they get dropped in the middle of the transfer.

(b) **Collisions and Latency**

Sensor networks make use of dense arrangement of nodes by deploying thousands of nodes in one application. This leads to packet collision and latency. In such cases, packet resending becomes impractical.

Q15. Define wireless sensor networks. Explain in brief about the challenges in designing wireless sensor networks.

Answer : Model Paper-II, Q3(b)

Wireless Sensor Networks

For answer refer Unit-I, Q9, Topic: Wireless Sensor Network (WSN).

Challenges in Designing a Wireless Sensor Network

The challenges faced while designing the sensor network systems and applications are as follows,

1. **Limited Hardware**

The storage, processing, communication capabilities, energy supply and bandwidth of a node are limited to a specific range.

2. **Limited Software Development Support**

The tasks have the following features,

(a) They are real time.

(b) They are distributed massively.

(c) Nodes are dynamically collaborated.

(d) They should be capable of handling multiple events that are competing with each other.

The global properties can be represented with the sue of local instructions. The software architecture need to be designed along with the information processing architecture, due to the coupling between the applications and system layers.

3. **Limited Networking Support**

This network has a peer to peer connectivity. It works on mesh topology and is dynamic in nature. In addition to this, it also substantiates mobile and unreliable connectivity. However there is no scope for implementing routing protocols or central registry services. Due to this, the node has to play the role of router as well as application host.

1.3 ADVANTAGE OF SENSOR NETWORKS

Q16. Define wireless sensor networks. Explain in brief about the advantages and disadvantages in wireless sensor networks.

Answer : Model Paper-I, Q3(a)

Wireless Sensor Networks

For answer refer Unit-I, Q9, Topic: Wireless Sensor Networks (WSN).

Advantages

Wireless sensor networks provide a unique range of advantages. The sensors of distributed computing such as dense networks have the capability of improving the ratio of signal-to-noise. This is done by reducing the average distance between the sensor and source of signal or target. The multihop topology of the network is responsible for increasing the energy efficiency in communications. While this is being done, the additional information which is relevant can also be aggregated from other sensors in the network. Some of the biggest advantages of networked sensing lies in the improved scalability and robustness. The decentralized sensing system is found to be more robust than the individual sensor node, and the decentralized algorithms are more scalable in practical deployment. The advantages of wireless sensor networks are as follows,

1. **Energy**

The multihop RF networks save the energy over single-hop network for almost the same distance, because RF signals have unique attenuation features. For example, consider an N-hop network for which the overall distance of transmission is *Nr*. The RF attenuation model at the ground is given as,

$$P_r \propto \frac{P_t}{r^{\alpha}}$$

Where,

r = Transmission distance

α = RF attenuation exponent ranging from 2 to 5.

P_r = Power to the node for a particular transmission error rate

P_t = Power at transmission node.

Similarly,

$$P_t \propto r^{\alpha} P_r$$

Thus, the power advantage of both the N-hop and single hop transmission for same distance of the same distance N_i is given as follows,

$$\eta_{rf} = \frac{P_s(Nr)}{N.P_s(r)} = \frac{(Nr)^{\alpha} P_r}{N.r^{\alpha} P_r} = \frac{N^{\alpha} r^{\alpha}}{Nr^{\alpha}} N^{\alpha-1}$$

2. Detection

All the sensors have a particular range of sensing that is specified by the sensor's noise floor. Any conflicts in detecting a signal source within the range are solved by the denser sensor field. An increase in the sensor density of a signal source within the range will decrease the average distance between the sensor and signal source. This will lead to an increase in the ratio of signal-to-noise. Consider an example of acoustic sensing in plane with two dimensions.

Here an acoustic power that is received at a distance of r is as follows,

$$P_{receive} \propto \frac{P_{source}}{r^2}$$

This will consider the inverse of distance squared attenuation. Signal-to-noise ratio is given as,

$$SNR_r = 10 \log \frac{P_{receive}}{P_{noise}} = 10 \log \frac{P_{source}/r^2}{P_{noise}}$$

$$= 10 \log P_{source} - 10 \log P_{noise} - 20 \log r$$

The average distance gets decreased by a factor of $\frac{1}{\sqrt{k}}$ with an increase in the sensor density by a factor of k.

Then, the advantage of signal-to-noise ratio with respect to denser sensor network will be,

$$\eta_{snr} = SNR_{\frac{r}{\sqrt{k}}} - SNR_r$$

$$= 20 \log \frac{r}{\frac{r}{\sqrt{k}}}$$

$$= 10 \log k$$

Thus, the signal to noise ratio increases by 10 log k dB with an increase in the sensor density by a factor of k.

Disadvantages

The disadvantages of WSNs are as follows,

1. It is slow in terms of speed when compared to wired network.
2. It carries complex configurations.
3. It is less secure because information can be easily hacked by simply entering the accesspoint.
4. It is easily affected by surroundings.

1.4 APPLICATIONS OF SENSOR NETWORKS

Q17. Explain the applications of wireless sensor networks.

Model Paper-II, Q3(a)

Answer :

Applications of Wireless Sensor Networks

The sensors are used in the following wide area of applications,

1. Habitat Monitoring

Monitoring of habitat involves the following methods,

- Data reduction by adopting the technique of zero crossing rate.
- Localizing by adopting the technique of beam forming based on TDOA (Time difference of arrival).
- Classifying the target by adopting the technique of cross-correlation between the calculated reference and acoustic signal

2. Environmental Monitoring

Environmental monitoring involves the supervising of quality of air and landfill. The landfill in the area which is filled with the house held and industrial solid wastes.

3. Drinking Water Quality

To monitor and model the quality of water, a monitoring system, consisting of sensors that performs spatial-temporal data mining, using the technology called in situ sensing is developed.

4. Disaster Relief Management

An innovative sensor network has been introduced to deal with the attacks caused by terrorists, earthquakes, storms, floods and fires. All the sensors present in this network are deployed at homes, offices and other areas.

5. Soil Moisture Monitoring

Sensors are also used to monitor the various performance parameters of the soil moisture.

6. Health Care Monitoring

Health care monitoring tracks and inspects the doctors and patients in the hospital, manages drug administrators inspects the data belong to human physiology. All these functions can be performed using the sensors in different ways.

7. Building, Bridge and Structural Monitoring

The sensors are also used in inspecting and monitoring the health of bridges, highways and buildings. The stress, humidity, temperature and vibration of civil infrastructure can be analyzed by using the scatternet based on bluetooth. To inspect the cracks occurring in the bridge decks made by concrete and monitor the corrosion and strain of the reinforcement in the structures made by concrete, a sensor based on fiber optic has been introduced.

8. Smart Energy and Home/Office Applications

To enhance the efficiency of energy-provision chain, a network called societal-scale is used. It is an integration of three infrastructures i.e., energy generation, distribution and consumption.

9. Body Area Network

To measure the human body parameters, a new and special kind of sensors and transducers have been introduced. They sense the body characteristics parameters precisely and effectively in a non-invasive manner.

Q18. Explain how sensor helps in maintaining traffic and roads safer.

Answer :

Sensors are being used for the purpose of traffic monitoring by embedding them along the roads and highways. They measure the traffic flow and also look for traffic violations on the roads and street intersections when used in cameras. Sensors that are embedded in vehicles are responsible for monitoring the speed and other conditions. But they are not able to communicate with each other. There is possibility for the development of dynamic infrastructure for smart roads. By this, the roads become more safe and even the congestion gets minimized. In addition to this, it helps the drivers in locating the parking area which is nearer in an unknown city. This is possible only when the sensors are networked together for sharing the real-time information. For example, when the wireless sensors are equipped in cars and trucks, they gain the capability of doing the following things.

(a) They generate warnings about imminent collision or other road hazards further.

(b) They monitor themselves continuously and also transmit the data to a nearest service station by which just-in-time maintenance is enabled.

(c) They can also download movies and music through wireless connection while they are in waiting state such as at gas station.

(d) They can optimize the routes dynamically thereby avoiding the traffic hotspots.

1.5 TYPES OF WIRELESS SENSOR NETWORKS

Q19. Discuss in briefly about the different types of WSNs. Model Paper-I, Q19

Answer :

Types of WSNs

The different types of wireless sensor networks are as follows,

1. Proactive network
2. Reactive network
3. Hybrid network.

1. **Proactive Network**

In this network, the nodes periodically sense data using sensors and transmit it using transmitters. These networks are mostly suitable for applications that requires periodic data monitoring because they provide a brief view of required parameter at regular interval.

2. **Reactive Network**

In this network, the nodes quickly responds to the sudden changes in sensed attribute values. These applications are mostly suitable for application that changes according to time.

3. **Hybrid Network**

This network is the integration of both reactive and proactive networks. As proactive network it periodically transmit the data and like reactive network it react to the sudden changes in value of sensed attributes.

Q20. Explain the architecture of wireless sensor networks.

Answer :

Architecture of Wireless Sensor Nodes

The following devices are present in the typical hardware platform of wireless sensor nodes,

1. Microcontroller
2. Radio transceivers
3. Batteries
4. Sensors
5. External memory
6. Operating system/run-time environment.

1. **Microcontroller**

Microcontrollers like atmel and MSP430 are used by wireless sensor nodes so as to process the data and to manage the functionalities of other component in sensor node. These controller where used due to the following characteristics,

(i) It is cost effective.

(ii) It provides flexibility while connecting with other devices.

(iii) It requires less power consumption.

(iv) It allow easy programming.

While designing the microcontroller inside the wireless nodes issues like operational mode, sleep modes (number of sleep nodes, cost of energy etc.,) must be considered. In addition to this chip size, computation power and on-chip memory should be considered.

2. **Radio Transceivers**

Radio transceivers like RFM TR1001, infineon and chipcon are used by wireless sensor nodes in order to transmit and receive the data across the network. They uses radio communication as transmission media. These transceivers basically follow wake up radio concept for transmission of data from one node to another. This concept not only wakes all the sensor nodes in range of sender but also wakes some directly address nodes. This type of transmission required only low-power detection circuit. Beside radio communication the other transmission media are optical communication, ultra sound for underwater application etc.

3. **Batteries**

Batteries are the major means of power supply in wireless sensor node. Since sensor node consumes high power for sensing, communicating and data processing. While designing the batteries issue like battery management, energy scavenging required for recharging battery, self discharge rates, self-recharge rate and lifetime of batteries should be considered.

4. **Sensors**

Sensors are used by wireless sensor node so as to monitor the physical data and to respond to changes in physical condition like temperature and pressure.

5. **External Memory**

External memory like on-chip memory and flash memory are used by wireless sensor network so as to store the data inside the wireless sensor node.

6. **Operating System/Run-time Environment**

Operating system and run-time environment are essential in wireless sensor nodes as they requires minimal memory footprint and less execution overhead. On the other hand run-time topology requires composition of different building blocks in order to work flexibly. While the use of black board, publish/ subscribe or tuple space indicates an initiative to different run-time environment.

IMPORTANT QUESTIONS

SHORT QUESTIONS

Q1. What is sensor network?

Ans: For answer refer Unit-I, Q1.

Q2. What are the disadvantages of WSNs?

Ans: For answer refer Unit-I, Q3.

Q3. List few characteristics of WSN.

Ans: For answer refer Unit-I, Q5.

Q4. What are the node constraints of sensor networks?

Ans: For answer refer Unit-I, Q6.

Q5. Contrast and compare single hop versus multi hop networks.

Ans: For answer refer Unit-I, Q8.

ESSAY QUESTIONS

Q6. What is sensor network? Explain in detail about wireless sensor network.

Ans: For answer refer Unit-I, Q9.

Q7. What are the unique constraints of sensor networks?

Ans: For answer refer Unit-I, Q14.

Q8. Define wireless sensor networks. Explain in brief about the challenges in designing wireless sensor networks.

Ans: For answer refer Unit-I, Q15.

Q9. Define wireless sensor networks. Explain in brief about the advantages and disadvantages in wireless sensor networks.

Ans: For answer refer Unit-I, Q16.

Q10. Explain the applications of wireless sensor networks.

Ans: For answer refer Unit-I, Q17.

Q11. Discuss in briefly about the different types of WSNs.

Ans: For answer refer Unit-I, Q19.