Course Material

on

Wireless Sensor Networks (CS136)

for

Bachelor of Technology (RA15)

(IV Year I Semester)

Prepared by

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Innovation . Creativity . Entrepreneurship

Department of Computer Science and Engineering

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2019-20

Learning Resources:

1. Chalk and Talk
2. Activities

Required Resources:

Text Books:

1. C. Siva Ram Murthy and B. S. Manoj, "Ad-hoc Wireless Networks", Pearson Education, 2008.

References Text Books:

1. K. Sohraby Minoli and T. Zanti," Wireless Sensor Networks: Technology, Protocols, and Applications", John Wiley and Sons, March 2007.
2. H. Karl, and A. Willig, "Protocols and Architectures for Wireless Sensor Networks", John Wiley and Sons, October 2007.
3. C. S. Raghavendra, K.M. Sivalingam and T. Zanti," Wireless Sensor Networks", Springer Verlag, Sep. 2006.
4. E. H. Callaway, Jr. Auerbach," Wireless Sensor Networks: Architectures and Protocols", Aug. 2003.
5. Erdal Cayirci and Chunming Rong, "Security in Wireless Ad Hoc and Sensor Networks", John Wiley and Sons, 2009.
6. Charles E.Perkins, "Ad-hoc Networking", Pearson Education, 2001.
7. Shih-Lin Wu and Yu-Chee Tseng, "Wireless Ad-hoc Networking", Auerbach Publications, Taylor & Francis Group, 2007.
8. Carlos De Morais Cordeiro and Dharma Prakash Agrawal, "Ad-hoc and Sensor Networks: Theory and Applications", World Scientific Publishing Company, 2006.

Reading materials:

1. Lecture Notes soft copy will be provided to the students.
2. Online Video links will be provided**.**

Additional Resources:

1. https://www.intechopen.com/books/wireless-sensor-networks-technology-and-rotocols/overview-of-wireless-sensor-network
2. https://www.elprocus.com/architecture-of-wireless-sensor-network-and-applications/
3. https://www.wisdomjobs.com/e-university/wireless-sensor-networks-interview-questions.html
4. https://www.elprocus.com/architecture-of-wireless-sensor-network-and-applications/
5. https://www.wisdomjobs.com/e-university/wireless-sensor-networks-interview-questions.html

Assessment

- **Internal Exams**

Internal/ MID Examination	Marks
MID-I	20
MID-II	20

- **Exams and quizzes:** 5 exams/ MCQs online test

  - Slip –Tests (essay) are designed for every end of the unit with prior instruction.
  - If the assessment is through online, the results will be displayed to the students immediately.

- **Assignments/Course Activities:**

Assignment:

Two types of assignments are planned:

1) *Homework:* For every week students will be having an online assessment exam which is covered on that week only. Exam grading appeals in writing on the day the exam is returned with in 1 hour.
   - Homework assignments will be given approximately every week and each assignment will be worth approximately the same credit.
2) *Paper presentations*: Each student will be assigned a research paper selected by the instructor. A list of papers will be made available by the instructor and each student will be given the opportunity to pick a paper that matches his/her interest. The student is required to technically digest the assigned paper and present it in class. The goal is to make the students acquainted with research publications, stimulate class discussion and enrich the course coverage with example techniques from the literature. Grades will be based on the clarity of the oral presentation (30%), depth of understanding the technical material (40%), and the quality of the viewgraphs (30%).

Course Activity:

1. ***Topic Name:*** Adhoc /sensor networks Applications and design issues

   Name of the Activity: Group Grid

   Description of the Activity: Students can form a team and discuss on comparisons between cellular and adhoc networks and their applications. To design sensor network architecture for different applications within stipulated time.

2. ***Topic Name:*** Different MAC protocols in adhoc wireless networks & Sensor networks

   Name of the Activity: Fishbowl debate

   Description of the Activity: For example, the person on left takes one position on a topic for debate, the person on right takes the opposite position, and the person in the middle takes notes and decides which side is the most convincing and provides an argument for his or her choice.

   - Students can get an idea about the MAC protocols using this activity.

3. ***Topic Name:*** Routing Protocols in sensor networks

   Name of the Activity: Think-Pair-Share

   Description of the Activity: Routing can be done in different protocols in different approaches. Students write a response and then share it with a student nearby. Students clarify their positions and discuss points of agreement and disagreement. The instructor can use several answers to illustrate important points or facilitate a whole class discussion.

Grades/ Rubrics:

- Class participation and class assignments.

Course work	Grade distribution
Assignments ❖ Homework (15%) ❖ Paper presentation (15%)	30%
Mid Term Examination	20%
End semester Examination	50%

Final grade will computed as follow:

Course grade	Range
A	90% - 100%
B	80% - 89.9%
C	70% - 79.9%
D	60% - 69.9%
E	<60%

Late assignment = no assignment

- Exam grading appeals in writing on the day the exam is returned.
- Late homework is not accepted unless an extension is pre-approved by the instruction.

- If the Assessment is through offline (For eg, Group Activity, Concept test,etc.,) it takes 2-3 days to give the results.

How to Contact Instructor:

- **In-person office hours**:
  - Students can meet, whenever we have free schedule during the college hours.
  - Can meet 3:00 pm to 4:00 pm in working college hours.

- **Online office hours: time and how to access**
  - Email-ID (s): seena_naik@srecwarangal.ac.in, mahesh_d@srecwarangal.ac.in
  - Phone numbers: 9014995456, 9505663153
  - LMS : 8 pm to 9:30 pm

Pre-requisite:

- Prior courses - CS136
- Assumed knowledge: Basic knowledge in wireless Networks and computer networks.

Technology Requirements:

- Laptops for class work - To create an **Adhoc network** we need a laptop.
- Software - Nil
- Learning management system – NPTEL Lectures

Overview of the Course:

- **What is the course about its purpose?**

  Wireless communication technologies are undergoing rapid advancements. The last few years have experienced a steep growth in teaching and research in the areas of wireless ad hoc and sensor networks. The wireless sensor network is not only a fascinating research topic but has a growing future in terms of employment especially with the advent of technologies like the Internet of Things.

- **What are the general topics or focus?**

  a) Key definitions of adhoc/ sensor networks
  b) Sensor network architecture
  c) MAC protocols for sensor network
  d) Routing Protocols

e) need for energy management

- **How does it fit with other courses in the department or on campus?**

  Wireless Sensor Network is an active area of research with various applications. Some of the applications of WSNs includes homeland security, environmental monitoring, safety, health care system, monitoring of space assets for potential and human-made threats in space, ground-based monitoring of both land and water, intelligence gathering for defense, precision agriculture, civil structure monitoring, urban warfare, weather and climate analysis and prediction, battlefield monitoring and surveillance, exploration of the Solar System and beyond, monitoring of seismic acceleration, temperature, wind speed and GPS data. For each application area, there are different technical issues that researchers are currently resolving. Open research issues and challenges are identified to spark new interests and developments in this field. However, the design of wireless sensor networks introduces formidable challenges, since the required body of knowledge encompasses a wide range of topics in the field of electrical and computer engineering, as well as computer science.

- **Why would students want to take this course and learn this material?**

  - The field of wireless sensor networks is growing quickly, and there is an increasing interest in providing students with a foundation in the area. It is crucial that the emerging field of wireless sensor networks be integrated into the computer engineering curriculum.

  - WSN future scope towards Security (confidentiality, Data integrity, Accountability), Target detection and tracking, Global contour detection.

Methods of instruction

- ***Discussion:***
  - Categorize various protocols of Adhoc network and issues and challenges in wireless adhoc network.
  - Discussion on issues and challenges in QoS of Adhoc network and energy management.
  - To comprehend the various methods in multi-casting routing protocols.
  -

- ***Group work:***
  - Understand the Senor Network architecure and its hardware components.
  - Comparative study on different routing protocols of sensor networks.

Workload

- Estimated amount of time to spend on course readings: **4 hours per week**
- Estimate amount of time to spend on course assignments and projects: **2-3 Hours per week.**

Key concepts

1. Issues in design of sensor network
2. Sensor network architecture
3. MAC protocols for sensor network
4. Need for energy management

Difficult Topics

1. Location discovery in WSN
2. Hierarchical routing protocols
3. System power management schemes
4. Routing Protocols

Lesson Plan:

Course Outcomes (COs):

At the end of the course the student should be able to:

1. Create a Sensor network environment for different type of applications.
2. Design ad-hoc and sensor network architectures using QoS and Congestion Control mechanisms.
3. Apply appropriate routing algorithms for different network environments.
4. Analyze the various applications of sensor networks and deploy security mechanisms.
5. Evaluate the QoS related performance measurements of ad hoc and sensor networks.

Course Articulation Matrix: Mapping of Course Outcomes (COs) with Program Outcomes (POs):

Course Outcomes (COs) / Program Outcomes (POs)	1	2	3	4	5	6	7	8	9	10	11	12	PSO1	PSO2
Create a Sensor network environment for different type of applications.	-	3	2	-	2	-	2	1	-	2	-	1	-	-
Design ad-hoc and sensor network architectures using QoS and Congestion Control mechanisms	-	-	3	-	-	-	-	2	-	1	-	2	1	-
Apply appropriate routing algorithms for different network environments.	3	-	-	-	2	1	-	2	-	1	2	1	-	1
Analyze the various applications of sensor networks and deploy security mechanisms.	2	2	-	3	-	-	-	1	-	2	-	1	-	-
Evaluate the QoS related performance measurements of ad hoc and sensor networks	-	2	-	2	-	-	-	1	2	1	-	2	-	-

UNIT WISE PLAN

UNIT-I: Introduction to wireless communication technology		**Planned Hours:** 7 Hrs	
S. No.	**Topic Learning Outcomes**	**COs**	**Blooms Levels**
1.	Students will get an overview of the modulation techniques and multiple access mechanisms.	CO1	L2
2.	Understand the medium access control protocols and address physical layer issues	CO1	L2
3.	To understand the state-of-the-art in network protocols, architectures and applications.	CO3	L2

1.0 Introduction

1.1 Fundamentals of Wireless communication technology

1.2 The Electromagnetic Spectrum

- 1.2.1 Spectrum Allocation

1.3 Radio Propagation Mechanisms

1.4 Characteristics of the Wireless Channel

1.5 Modulation Techniques

- 1.5.1 Analog Modulation
- 1.5.2 Digital Modulation

1.6 Multiple Access Techniques

- 1.6.1 Frequency Division Multiple Access
- 1.6.2 Time Division Multiple Access
- 1.6.3 Code Division Multiple Access
- 1.6.4 Space Division Multiple Access

1.7 Fundamentals of WLANs

- 1.7.1 Technical Issues
  - Differences Between Wireless and Wired Transmission
  - Use of WLANs
  - Design Goals
- 1.7.2 Network Architecture
  - Infrastructure Based Versus Ad Hoc LANs
  - Components in a TypicalIEEE802.11 Network
  - Services Offered by a TypicalIEEE802.11 Network
- 1.7.3 IEEE802.11 Standard
- 1.7.4 CSMA/CA Mechanism
- 1.7.5 HIPERLAN Standard

1.8 Wireless PANs

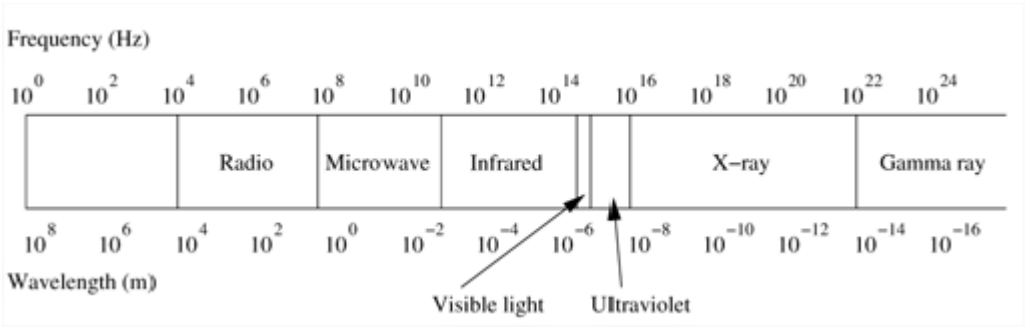
- 1.8.1 Bluetooth
- 1.8.2 Bluetooth Specifications

1.9 Wireless WANS
- 1.9.1 Introduction
- 1.9.2 Channel Allocation Algorithms
- 1.9.3 Handoffs

1.10 Wireless MANs
- 1.10.1 Cellular Architecture
- 1.10.2 IEEE 802.16 Standard
  - Differences between IEEE802.11 and IEEE 802.16

Solved Problems:

1) **Draw the pictographic view of Electro-magnetic spectrum.**



2) **List any four design goals of WLANs.**

1) Low power for battery use
2) No special permissions or licenses needed to use the LAN
3) Easy to use for everyone, simple management
4) Security, privacy, safety

3) **List out the differences between IEEE 802.11 and IEEE 802.16.**

While IEEE 802.11 has been a successful standard for WLANs, it is not suited for use in BWA. This fact can be appreciated when the differences between IEEE 802.11 and IEEE 802.16, listed below, are studied.

- IEEE 802.11 has been designed for mobile terminals, which is irrelevant in the context of MANs. IEEE 802.16 has been designed for broadband data such as digital video and telephony.
- The number of users and bandwidth usage per user is much higher in a typical IEEE 802.16 network when compared to a typical IEEE 802.11 basic service set.
- IEEE 802.16 is completely connection-oriented and QoS guarantees are made for all transmissions. Though IEEE 802.11 provides some QoS support for real-time data (in the PCF mode), it has not been designed for QoS support for broadband usage.

Review Questions (Levels I, II, III)

1) Compare the handoff procedures of the HIPERLAN/2 and the IEEE 802.11 standards.
2) Explain the IEEE 802.11 WLAN protocol.
3) Discuss in detail various modulation techniques.
4) Illustrate the major issues that are to be considered for Wireless Internet.
5) List the multiple access techniques and explain briefly.

MCQs

1) They can even use other services such as location tracking using the __.
   (a) GPS (b) VPS (c) GPRS (d) GSM
2) W-CDMA is ____.
   (a) Wireless Code Division Multiple Access
   (b) Wideband code division multiple access
   (c) Wide code division multiple access
   (d) Web band code division multiple access
3) Wireless networks are computer networks that use radio frequency channels as their __ for communication.
   (a) Physical Medium (b) Medium Access Control (c) TDMA (d) CDMA
4) Match the following pairs:

1. association	A. improves speed during roaming
2. authentication	B. is necessary for roaming
3. reassociation	C. is needed for STA-AP mapping
4. preauthentication	D. makes the transmission secure

5) Which of the following is a collection of many separate networks?
   (a) LAN (b) MAN (c) WAN (d) PAN

Short Questions

1) What are the responsibilities of physical layer in Wireless LAN?
2) How is secure routing done on wireless channels?
3) Explain about topologies of PANs.
4) What is the function of transport layer?
5) What is Data-Centric Network?

Long Questions

1) Discuss in detail about various multiple access techniques.
2) Illustrate the basics of Wireless WAN & Wireless MAN.
3) Explain the physical layer and transceiver design considerations in wireless networks.
4) Illustrate modulation techniques in a wireless channel.

Problems

1) Based on your understanding of the Bluetooth protocol stack, suggest a possible implementation of FTP over Bluetooth without using TCP/IP.
2) What is the wavelength of a signal with a frequency of 150 Mhz?

GATE/Competitive Exams Questions

1) Explain the physical layer and transceiver design considerations in wireless networks.
2) Explain major issues that are to be considered for Wireless Internet.
3) Discuss in detail various modulation techniques.
4) The portion of the electromagnetic spectrum occupied by a signal is called _____
   (a) Signal spectrum (b) Bandwidth (c) Frequency width (d) Signal strength
5) You have 5 information signals and only one transmitter. What technique will help in transmitting all the 5 signals?
   (a) Frequency modulation (b) Multiplexing
   (c) Amplification (d) Amplitude modulation
6) What networking structure do the 802.11 standards define?
   (a) WLAN (b)BSS (c)WPAN (d)WMAN
7) Which one of the IEEE 802 committees is tasked with the development of security standards?
   (a) 802.10 (b) 802.16 (c) 802.15 (d) 802.11
8) Which Bluetooth protocol performs link setup, authentication, link configuration, and the discovery of other Bluetooth devices?
   (a) LMP (b) L2CAP (c) Radio (d) SIG
9) The use of Ultra wideband (UWB) technology for WPANs is specified under the _____ standards.
   (a) 802.15.3 (b) 802.15.1 (c) 802.15.4 (d) 802.15.2

UNIT-II: Introduction to Ad-hoc / Sensor Networks		**Planned Hours:** 9 Hrs	
S. No.	**Topic Learning Outcomes**	**COs**	**Blooms Levels**
1.	To understand the state-of-the-art in network protocols, architectures and applications.	CO2	L2
2.	Students will be introduced to elements of distributed computing and network protocol design and will learn to apply these principles in the context of wireless sensor networks	CO3	L3
3.	With scientific precision to define wireless sensor networks	CO4	L6
4.	Students will learn the various hardware, software platforms that exist for sensor networks	CO2	L2

2.0 Introduction

2.1 Cellular and Ad Hoc Wireless Networks

2.2 Applications of Ad Hoc Wireless Networks

2.3 Issues in Ad Hoc Wireless Networks

- 2.3.1 Medium Access Scheme
- 2.3.2 Routing
- 2.3.3 Multicasting
- 2.3.4 Transport Layer Protocols
- 2.3.5 Pricing Scheme

2.4 Ad Hoc Wireless Internet

2.5 Introduction to Sensor Networks

- 2.5.1 Applications of Sensor Networks
- 2.5.2 Issues and Challenges in Designing a Sensor Network
- 2.5.3 Comparison with Ad Hoc Wireless Networks

2.6 Sensor Network Architecture

- 2.6.1 Layered Architecture
  - Unified Network Protocol Framework (UNPF)
- 2.6.2 Clustered Architecture
  - Low-Energy Adaptive Clustering Hierarchy (LEACH)

2.7 Data Dissemination

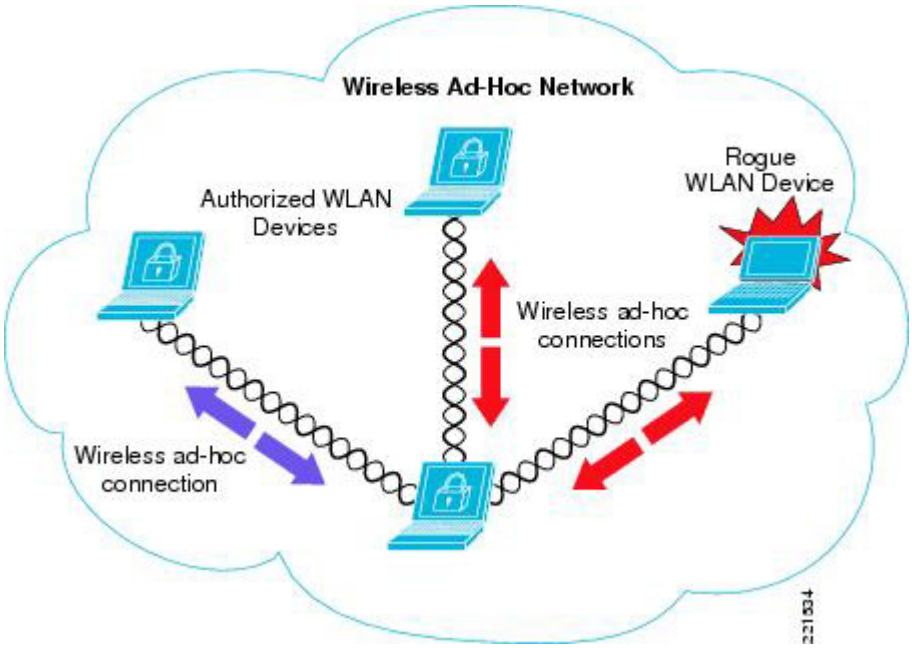
2.8 Data Gathering

Solved Problems

1) Explain about mobile adhoc network with a neat diagram?

An ad hoc network is a network that is composed of individual devices communicating with each other directly. Many ad hoc networks are local area networks where computers or other devices are enabled to send data directly to one another rather than going through a centralized access point.

One of the main advantages of an ad-hoc network is the ability to file share without having to rely on an active network connection. An ad-hoc network will only be useful if the plan is to transfer files between multiple devices regularly.



2) Discuss on Issues and Challenges in Designing a Sensor Networks?

Sensor networks pose certain design challenges due to the following reasons:

- Sensor nodes are randomly deployed and hence do not fit into any regular topology.
- Sensor networks are infrastructure-less. Therefore, all routing and maintenance algorithms need to be distributed.
- An important bottleneck in the operation of sensor nodes is the available energy. Sensors usually rely only on their battery for power, which in many cases cannot be recharged or replaced.
- Hardware design for sensor nodes should also consider energy efficiency as a primary requirement. The micro-controller, operating system, and application software should be designed to conserve power.
- Sensor nodes should be able to synchronize with each other in a completely distributed manner, so that TDMA schedules can be imposed and temporal ordering of detected events can be performed without ambiguity.

- Real-time communication over sensor networks must be supported through provision of guarantees on maximum delay, minimum bandwidth, or other QoS parameters.
- Provisions must be made for secure communication over sensor networks, especially for military applications which carry sensitive data.

3) What are the characteristics of an ideal routing-protocol for Adhoc networks?

a. The protocol must be fully distributed as centralized routing involves high control-overhead and hence is not scalable.

b. It must be adaptive to frequent topology changes caused by mobility of nodes.

c. Route-computation & maintenance must involve a minimum no. of nodes.

d. It must be localized, as global state maintenance involves a huge state propagation control-overhead.

e. It must be loop-free and free from state routes.

f. It must converge to optimal routes once network-topology becomes stable.

g. It must optimally use scarce resources such as bandwidth, computing power, memory, and battery-power.

h. It should be able to provide a certain level of quality of service (QoS) as demanded by the applications.

i. The number of packet collisions must be kept to a minimum by limiting the number of broadcasts made by each node.

j. Every node in the network should try to store information regarding the stable local topology only.

Review Questions (Levels I, II, III)

1) Why multihop wireless communication is required for WSN?
2) Explain their Challenges, Applications and Advantages of Ad-hoc Sensor Networks?
3) Explain in detail main sensor node hardware components with neat diagram.
4) Write about optimization goal and Figure of Merits of WSN.

MCQs

1) Ad hoc wireless networks can be very useful in establishing ____ among a group of soldiers for tactical operations. ( )
   (a) Communication (b) Information (c) Network channel (d) DCN
2) MANET does not face the challenge of ( )
   (a) Security (b) Node cooperation (c) QoS (d) Quick network setup
3) This mode of wireless network allows devices to communicate directly with each other.
   (a) Ad-hoc (b) Digital (c) Physical (d) Infrastructure
4) A _____ is self-created when roaming wireless devices are connected over a wireless link.
   (a) MANET (b) WPAN (c) DARPA (d) NTDR

Short Questions

1) Compare MANET and WSN.
2) Discuss the characteristic requirements of WSN.
3) State the fundamental tasks of Address Management in WSN.
4) Differentiate between active and passive sensors.
5) What is a gateway?

Long Questions

1) Discuss in detail the design principles for WSN
2) Write about the operational states of a sensor node.
3) Briefly discuss various issues in Ad-hoc wireless networks.
4) Write a short note on ADHOC wireless internet.

GATE/Competitive Exams Questions

1) Write in detail about the communication device in a WSN.
2) Discuss the potential applications of WSN.

UNIT-III: MAC Protocols		**Planned Hours:** 8 Hrs	
S. No.	**Topic Learning Outcomes**	**COs**	**Blooms Levels**
1.	Be able to demonstrate deeper methodological knowledge in wireless sensor networks.	CO1	L1
2.	Be able to describe the current research and development issues in wireless sensor networks.	CO5	L3
3.	Be able to carry out simple analysis and planning of WSNs.	CO4	L2
4.	To Managing the information generated with a adhoc networks/ Sensor Networks.	CO5	L3

3.0 Introduction

3.1 MAC Protocols For Ad Hoc Wireless Networks

3.2 Issues in Designing a MAC Protocol for Ad Hoc Wireless Networks

- 3.2.1 Bandwidth Efficiency
- 3.2.2 Quality of Service Support
- 3.2.3 Synchronization
- 3.2.4 Hidden and Exposed Terminal Problems
- 3.2.5 Error-Prone Shared Broadcast Channel

3.3 Design Goals of a MAC protocol for Ad Hoc Wireless Networks

3.4 Classifications of MAC Protocols

- 3.4.1 Contention-based protocols
- 3.4.2 Contention-based protocols with reservation mechanisms
- 3.4.3 Contention-based protocols with scheduling mechanisms
- 3.4.4 Other Protocols

3.5 MAC Protocols for Sensor Networks

- 3.5.1 Self-Organizing MAC for Sensor Networks and Eavesdrop and Register
- 3.5.2 Hybrid TDMA/FDMA
- 3.5.3 CSMA-Based MAC Protocols

3.6 Location Discovery

- 3.6.1 Indoor Localization
- 3.6.2 Sensor Network Localization

3.7 Quality of a Sensor Network

- 3.7.1 Coverage
- 3.7.2 Exposure

3.8 Other Issues

- 3.8.1 Energy-Efficient Design
- 3.8.2 Synchronization

3.9 S-MAC

3.10 IEEE 802.15.4.Standard

Solved Problems

1) Discuss issues in designing MAC protocol for adhoc-networks.

1. Bandwidth Efficiency

- It is defined as the ratio of the bandwidth utilized for data transmission to the total available bandwidth.
- Bandwidth must be utilized in efficient manner.
- Control-overhead must be kept as minimal as possible.

2. Quality of Service support

- This is essential for supporting time-critical traffic-sessions.
- The protocol should have resource reservation mechanism that takes into considerations.

1) Nature of wireless-channel and

2) Mobility of nodes

3. Synchronization

- This is very important for bandwidth (time-slot) reservation by nodes.
- The protocol must consider synchronization between nodes in the network.
- Exchange of control-packets may be required for achieving time-synchronization among nodes.

4. Hidden and Exposed Terminal Problems

- The hidden-terminal problem refers to the collision of packets at a receiving-node due to the simultaneous transmission of those nodes that are not within the direct transmission-range of the sender but are within the transmission-range of the receiver.
- Collision occurs when both nodes transmit packets at the same time without knowing about the transmission of each other.

- In figure, S1 and S2 are hidden from each other & they transmit simultaneously to R1 which leads to collision.
- The exposed-terminal problem refers to the inability of a node, which is blocked due to transmission by a nearby transmitting node, to transmit to another node.
- If S1 is already transmitting to R1, then S3 cannot interfere with on-going transmission & it cannot transmit to R2.
- Hidden & exposed-terminal problems reduce the throughput of a network when traffic load is high.

5. Error-prone Shared Broadcast Channel

- When a node is receiving data, no other node in its neighborhood (apart from the sender) should transmit.
- A node should get access to the shared medium only when its transmission do not affect any ongoing session.
- The protocol should grant channel access to nodes in such a manner that collisions are minimized.
- Protocol should ensure fair bandwidth allocation.

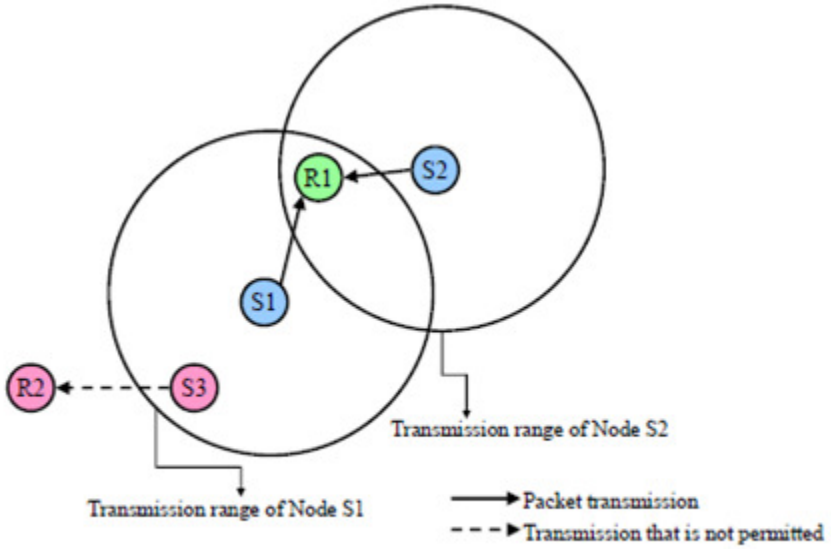


Figure . Hidden and exposed terminal problems

6. Error-prone Shared Broadcast Channel

- When a node is receiving data, no other node in its neighborhood (apart from the sender) should transmit.
- A node should get access to the shared medium only when its transmission do not affect any ongoing session.
- The protocol should grant channel access to nodes in such a manner that collisions are minimized.
- Protocol should ensure fair bandwidth allocation.

7. Distributed Nature

- There is no central point of coordination due to the mobility of the nodes.
- Nodes must be scheduled in a distributed fashion for gaining access to the channel.

8. Mobility of Nodes

- Nodes are mobile most of the time.
- The protocol design must take this mobility factor into consideration so that the performance of the system is not affected due to node mobility.

2) Explain directional busy-tone-based MAC protocol in detail.

Directional Busy Tone based MAC Protocol:

The nodes use directional-antennas for transmitting & receiving data-packets, thereby reducing their interference to other neighbor-nodes. This leads to an increase in the throughput of the system.

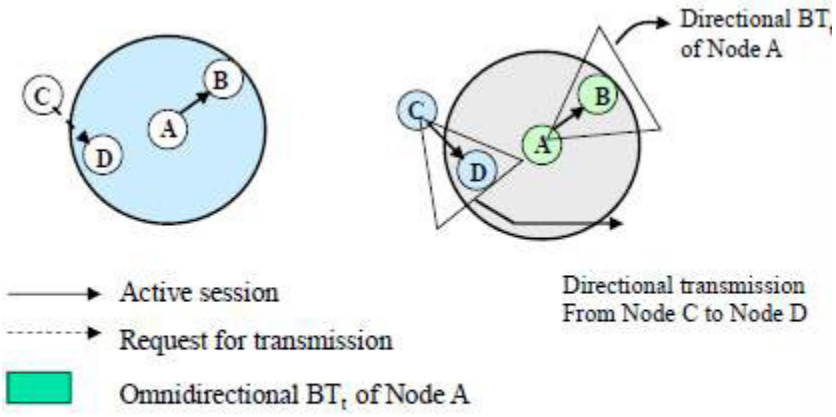
The purpose of the busy-tones (BTs) is as follows:

1) Before transmitting an RTS, the source makes sure that the BTr tone is not active in its neighborhood, so that its transmissions do not interfere with packets being received at a neighboring receiver. Similarly, a receiver, before transmitting CTS, verifies that a BTt is not active in its neighborhood.

2) The directional busy-tones can permit simultaneous transmissions in the neighborhood of a source or a receiver.

The protocol works as follows (Figure):

1) A source transmits an RTS addressed to the receiver on all its antennas (omni-directional transmission).
2) On receiving this RTS, the receiver determines the antenna-element on which the RTS is received with maximum gain.
3) The receiver then sends back a directional-CTS (DCTS) to the source using the selected antenna-element. It also turns on busy-tone BTr in the direction towards source.
4) On receiving the CTS, the source turns on busy-tone BTt in the direction towards receiver.
5) Once the packet transmission is over, the source turns off the BTt signal.
6) After receiving the Data-packet, the receiver turns off the BTr signal.
(For a uni-cast transmission, only a single antenna element is used. For broadcast transmission, all the N antenna elements transmit simultaneously).



Figure, Directional DBTMA :

Review Questions (Levels I, II, III)

1) Describe about optimization goals of a WSN and figures of merit in detail.
2) Elaborate on the requirements of MAC protocols for WSNs.
3) Explain in detail the programming challenges and state-centric programming in sensor networks.
4) What are the advantages of reservation-based MAC protocols over contention based MAC protocols?
5) What are the disadvantages of the BTMA protocol? How are they overcome in the DBTMA protocol?

MCQs

1) RTS/CTS period is called ( )

   (a) Waiting period (b) Contention period

   (c) Running period (d) none of these

2) Existing MAC protocols cannot be used in MANETs because of ( )

   (a) Resource constrained nodes (b) Limited bandwidth

   (c) Lack of centralized control (d) All of the above

3) MARCH exploits the properties of _____ antennas and overhearing properties of MANETs. ( )

   (a) Single directional (b) Bi-directional (c) Omnidirectional (d) None of these

Short Questions

1) What is localization and what is the advantage of localization?
2) Explain how clustering solves the issue of scalability on WSN.
3) List various services offered by localization.
4) Which protocol is more bandwidth efficient, RTMAC or MACA/PR? Explain.

Long Questions

1) Describe in detail about SMAC.
2) What are the advantages and disadvantages of MAC protocols using directional antennas?
3) Explain Wireless Sensor Network Taxonomy and Trends in Details.
4) Explain WSN Design Issues for MAC protocols, Routing protocols and Transport protocols in detail.
5) Discuss different types of MAC protocols.
6) Discuss about the Contention Based MAC Protocols with Scheduling Mechanisms.

GATE/Competitive Exams Questions

1) Which is not a variant of S-MAC?

   (a) Timeout MAC (TMAC) (b) Dynamic sensor MAC (DSMAC)

   (c) Input-Output MAC (IOMAC) (d) Data gathering (DMAC)

2) Why is implementation of MAC protocols important in context of WSNs?
   a) Supports multi-hop communication, alongside single-hop
   b) Special design for energy-constrained environments
   c) Support for Ad-hoc node deployment
   d) All of the above
3) Which are the Performance Metrics that are used for evaluating the Performance of WSN? Explain each of them briefly.
4) Discuss following main issues of designing a MAC protocol.
   i) Quality of services (QoS)
   ii) Hidden and exposed node problem.
5) Explain in detail CSMA-Based MAC Protocols in Wireless Ad Hoc networks.
6) Define the concept of localization and positioning in detail.

UNIT-IV: Routing Protocols		**Planned Hours:** 10 Hrs	
S. No.	**Topic Learning Outcomes**	**COs**	**Blooms Levels**
1.	To Select the appropriate technology to implement a WSN.	CO1	L1
2.	Students will read and present seminal papers on various issues in sensor networks, opening a path to research in this area.	CO5	L3
3.	Be able to evaluate the routing protocols in wireless sensor networks	CO2	L2
4.	Students will be able to orally and in writing present and discuss their conclusions in relation to routing mechanisms knowledge and arguments that form the basis.	CO3	L3

4.0 Introduction

4.1 Issues in Designing a Routing Protocol for Ad Hoc Wireless Networks

4.2 Classifications of Routing Protocols

- 4.2.1 Proactive or table-driven routing protocols
- 4.2.2 Reactive or on-demand routing protocols
- 4.2.3 Hybrid routing protocols

4.3 Table-Driven Routing Protocols

4.4 On-Demand Routing Protocols

4.5 Hybrid Routing Protocols

4.6 Routing Protocols With Efficient Flooding Mechanisms

4.7 Hierarchical Routing Protocols

- 4.7.1 Hierarchical State Routing Protocol
- 4.7.2 Fisheye State Routing Protocol

4.8 Power-Aware Routing Protocols

- 4.8.1 Power-Aware Routing Metrics

Solved Problems

1) Characteristics of an Ideal Routing Protocol for Ad Hoc Wireless Networks?

A routing protocol for ad hoc wireless networks should have the following characteristics:

a. It must be fully distributed, as centralized routing involves high control overhead and hence is not scalable. Distributed routing is more fault tolerant than centralized routing, which involves the risk of single point of failure.
b. It must be adaptive to frequent topology changes caused by the mobility of nodes.
c. Route computation and maintenance must involve a minimum number of nodes. Each node in the network must have quick access to routes, that is, minimum connection setup time is desired.

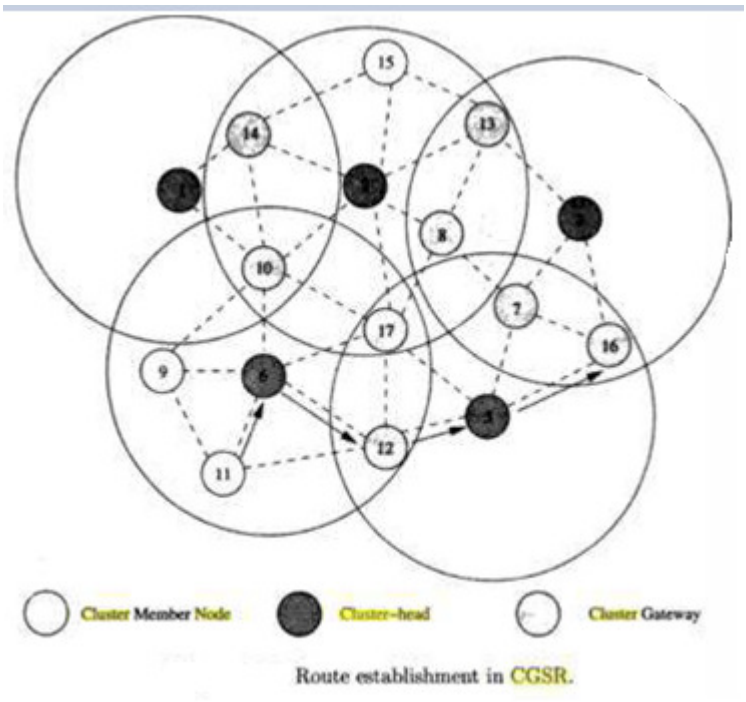
d. It must be localized, as global state maintenance involves a huge state propagation control overhead.
e. It must be loop-free and free from stale routes.
f. The number of packet collisions must be kept to a minimum by limiting the number of broadcasts made by each node. The transmissions should be reliable to reduce message loss and to prevent the occurrence of stale routes.
g. It must converge to optimal routes once the network topology becomes stable. The convergence must be quick.
h. It must optimally use scarce resources such as bandwidth, computing power, memory, and battery power.
i. Every node in the network should try to store information regarding the stable local topology only. Frequent changes in local topology, and changes in the topology of parts of the network with which the node does not have any traffic correspondence, must not in any way affect the node, that is, changes in remote parts of the network must not cause updates in the topology information maintained by the node.
j. It should be able to provide a certain level of quality of service (QoS) as demanded by the applications, and should also offer support for time- sensitive traffic.

2) Explain in detail CGSR protocol?

Cluster-head Gateway Switching Routing protocol (CGSR)

- It uses a hierarchical network-topology (Figure). It organizes nodes into clusters, with coordination among the members of each cluster.
- The cluster-head is elected dynamically by employing a least cluster change (LCC) algorithm.
- LCC algorithm states that A node ceases to be a cluster-head only if it comes under the range of another cluster-head, where the tie is broken either using the lowest ID or highest connectivity algorithm.
- A token-based scheduling is used within a cluster for sharing the bandwidth among the members of the cluster.
- All communication passes through the cluster-head. Communication between 2 clusters takes place through the gateways.
- The gateways are common member-nodes that are members of both the cluster.
- A gateway is expected to be able to listen to multiple spreading-codes that are currently in operation in the clusters.
- A gateway-conflict is said to occur when a cluster-head issues a token to a gateway over spreading-code while the gateway is tuned to another code.
- The performance of routing is influenced by
  → token-scheduling at cluster-heads
  → code-scheduling at gateways
- Every member-node maintains a routing-table containing the destination clusterhead for every node in the network.

In addition, each node maintains a routing-table which keeps the list of next-hop nodes for reaching every destination cluster.



Route establishment in CGSR.

Advantages

a. It enables partial coordination between nodes by electing cluster-heads. Hence, better bandwidth utilization is possible.
b. It is easy to implement priority scheduling schemes with token-scheduling and gateway code-scheduling.

Disadvantages

- It increases in path-length and instability in the system at high mobility when the rate of change of cluster-heads is high.
- To avoid gateway conflicts, more resources are required.

Review Questions (Levels I, II, III)

1) List the cons and pros of routing protocols proposed for Ad Hoc Networks such as DSR, TORA, and AODV.
2) Explain Zone Routing-protocol (ZRP).
3) Discuss the power-aware routing-metrics for adhoc-networks.
4) Give the classification of routing-protocols for Adhoc-networks, based on the routing information update mechanism.
5) Discuss the differences in topology reorganization in DSDV and CGSR routing protocols.
6) How is the cluster-head selected in the CGSR protocol? In the CGSR protocol, the resources of the node chosen as the cluster-head get drained very quickly, more rapidly than the other nodes in the cluster. How can this problem be overcome?
7) What are the key differences between the LAR1 and the LAR2 algorithms?

MCQs

1) Battery-driven systems are those systems which are designed taking into consideration mainly _____ ( )
   (a) Battery and its internal characteristics
   (b) An electrolyte medium
   (c) Environmental impact
   (d) None of the above

2) _____ effect is concerned with the recovery of charges under idle conditions.

(a) Recovery capacity effect
(b) Rate capacity effect
(c) Battery scheduling
(d) None of the above

Short Questions

1) What are the advantages of hierarchical topology-based protocols over protocols that use flat topologies?
2) Explain the differences between Proactive routing protocols and Reactive routing protocols.
3) Give the classification of routing protocol based on routing topology.
4) Describe about various types of hybrid routing protocols.

Long Questions

1) Discuss the differences in the maintenance of topology information in various protocols such as CGSR, HSR, SSA, ABR, PLBR, OLSR, and CEDAR.
2) Explain about Hierarchical routing protocols.
3) Explain about power-aware routing protocols.
4) What are the design issues in designing a routing protocol for ad hoc Wireless networks?

Problems

1) For the network shown in Figure 1, determine the fisheye routing table or nodes 7 and 5.

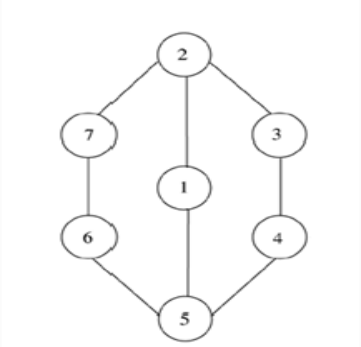


Fig. Topology for problem 1

2) Consider the topology given in Figure 2. Simulate DSR, SSA, and ABR protocols for path establishment from node 1 to node 10, find the paths found and the ratio of the number of *RouteRequest* packets sent in the network. (Links labeled "U" refer to unstable ones.)

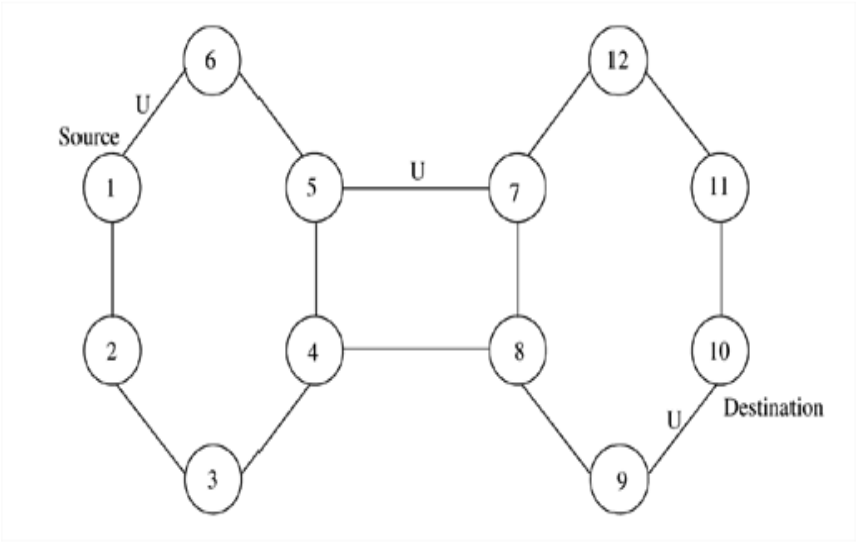


Fig. Topology for problem 2

GATE/Competitive Exams Questions

1) Let the maximum nominal and theoretical capacities *N* and *C* of a battery be equal to 25 units and 200 units, respectively, and let the current nominal and theoretical capacities of the battery be (a) *ni*= 23 and *ci* = 190, respectively. If the battery remains idle for three slots and then is subjected to two current pulses followed by three more idle slots, what will be the remaining capacities of the battery at the end of the idle slots when the binary pulsed discharge pattern is followed? Analyze and summarize your results. Repeat the same with (b) *ni* = 22 and *ci* = 1 and (c) *ni* = 2 and *ci* = 130. In case (c) assume one idle slot followed by transmission of five packets followed by five idle slots. Assume that the battery always transmits whenever it has a packet queued up for transmission and always gains one unit of charge when it idles for one time slot.

2) In the maximum-battery-cost-routing algorithm (MBCR), the cost of a node is a function of the remaining battery capacity of the node. Express the cost function of a node in terms of some parameters of the node other than battery capacity.

UNIT-V: QoS and Energy Management		**Planned Hours:** 10 Hrs	
S. No.	**Topic Learning Outcomes**	**COs**	**Blooms Levels**
1.	Students should able to learn various issues regarding energy management at the different layers of the protocol stack.	CO5	L3
2.	To develop battery-efficient system architecture that has low cost and complexity remains a crucial issue.	CO4	L2
3.	Developing battery aware MAC scheduling algorithms for the nodes that increase the lifetime of the nodes is an important issue.	CO3	L3

5.0 Introduction

5.1 Issues and challenges in providing QoS in ad hoc wireless networks

5.2 Classifications of QoS solutions

- 5.2.1 Classifications of QoS approaches
- 5.2.2 Layer-wise classification of existing QoS solutions

5.3 MAC layer solutions

- 5.3.1 Cluster TDMA
- 5.3.2 IEEE 802.11e

5.4 Network layer solutions

- 5.4.1 Qos routing protocols
- 5.4.2 Ticket-based qos routing protocol

5.5 QoS frameworks for ad hoc wireless networks

- 5.5.1 Qos models
- 5.5.2 Qos resource reservation signaling

5.6 Energy management in ad hoc wireless networks

- 5.6.1 Need for energy management in ad hoc wireless networks

5.7 Classification of energy management schemes

- 5.7.1 Battery management schemes
- 5.7.2 Transmission power management schemes
- 5.7.3 System power management schemes

Solved Problems

1) **Discuss on need for energy management schemes in ad hoc wireless networks.**

The energy efficiency of a node is defined as the ratio of the amount of data delivered by the node to the total energy expended. Higher energy efficiency implies that a greater number of packets can be transmitted by the node with a given amount of energy reserve. The main reasons for energy management in adhoc wireless networks are listed below:

- **Limited energy reserve:** The main reason for the development of ad hoc wireless networks is to provide a communication infrastructure in environments where the setting up of a fixed infrastructure is impossible. Ad hoc wireless networks have very limited energy resources.
- **Difficulties in replacing the batteries:** Sometimes it becomes very difficult to replace or recharge the batteries. In situations such as battlefields, this is almost impossible. Hence, energy conservation is essential in such scenarios.
- **Lack of central coordination:** The lack of a central coordinator, such as the base station in cellular networks, introduces multi-hop routing and necessitates that some of the intermediate nodes act as relay nodes.
- **Constraints on the battery source:** Batteries tend to increase the size and weight of a mobile node. Reducing the size of the battery results in less capacity which, in turn, decreases the active lifespan of the node.
- **Selection of optimal transmission power:** The transmission power selected determines the reachability of the nodes. The consumption of battery charge increases with an increase in the transmission power.

2) **Outline the issues related to transmission power management schemes.**

The components used in the communication module consume a major portion of the energy in ad hoc wireless networks. In this section, we investigate some of the means of achieving energy conservation through efficient utilization of transmission power such as selection of an optimal power for communication.

Data Link Layer Solutions:

As stated earlier, transmitter power greatly influences the reachability of the node and thus the range covered by it. Power control can be affected at the data link layer by means of topology control and constructing a power control loop. This section describes different power-based solutions at the data link layer. Some of the solutions proposed to Calculate the optimum transmission ranges are as follows:

- Dynamic power adjustment policies
- Distributed topology control algorithms
- Constructing distributed power control loop
- Centralized topology control algorithm

Dynamic Power Adjustment Based on the Link Affinity

Ad hoc wireless networks are prone to constant link failures due to node mobility, hence the stability of routes cannot be assured in such situations. But frequent link failures lead to reduced throughput.

Distributed Topology Control Mechanisms

Now we shall discuss the algorithm, which uses a distributed power control mechanism as opposed to the centralized one used and which is explained in the next section. According to this algorithm, each node of the ad hoc wireless network independently runs a localized algorithm and decides the appropriate power level to be used by that node.

Constructing Distributed Power Control Loop

The following is a distributed approach which tries to attain an optimal power level for the nodes in an ad hoc wireless network. The power control loop which increases the battery lifetime by 10-15% and the throughput by around 15%.

Review Questions (Levels I, II, III)

1) List at least two battery technologies that have the following properties.
   List your answers in the order of performance.
   a. Higher energy density
   b. Flat discharge characteristics
   c. Low cost
   d. Fast charging capability
   e. Higher lifetime
2) Describe about Energy consumption in wireless sensor networks?

MCQs

1) When the battery is actively involved in discharging, that is, at a non-zero current, the active materials move from the electrolyte solution to the electrodes and are consumed at the ____ ( )

   (a) Electrode (b) limiting current (c) Passivation process (d) Rate capacity

2) CTMDP stands for _____.

Short Questions

1) Suggest a few metrics that can be associated with battery-aware routing techniques.
2) Prove that the localized power-efficient routing algorithm in loop – free.

Long Questions

1) Mention the most relevant kinds of memory for sensor nodes from energy perspective.
2) Elaborate on the energy scavenging techniques for sensor nodes.
3) Write notes on Dynamic Energy and power management.

GATE/Competitive Exams Questions:

1) Which battery is being commonly used for portable mobile nodes such as laptops? Give a few reasons to support your answer.
2) What are the advantages of distributed power control algorithms in ad hoc wireless networks over the centralized power control algorithms?

Previous question papers or sample model papers

Code No.: CS136

IV B.TECH. I SEM. (RA15) REGULAR EXAMINATIONS, OCT/ NOV – 2018

WIRELESS SENSOR NETWORKS

(CSE)

Time: 3 Hours **Max. Marks: 70**

PART – A

Answer **ALL** questions

All questions carry equal marks

10 x 2

1. Explain various Radio propagation mechanisms.
2. List out the differences between wireless and wired transmission.
3. List any four applications of Sensor networks.
4. What do you know about Gossiping? Explain.
5. Write down hidden and exposed problems in Wireless Networks.
6. What is Delaunay triangulation technique?
7. Why the network topology in an Ad-hoc Wireless Network is dynamic? Explain.
8. Discuss the advantage of wireless routing protocol?
9. What is bandwidth routing protocol?
10. What is the need for energy management in Ad-hoc Wireless Networks?

PART – B

Answer any **FIVE** questions

All questions carry equal marks

5 x 10

1. Explain major issues that are to be considered for Wireless Internet.
2. Discuss in detail various modulation techniques.
3. Briefly discuss various issues in Ad-hoc wireless networks.
4. a) With relevant examples, explain any two MAC layer protocols in wireless Sensor Networks.
   b) Discuss various design goals of a MAC protocol for Ad-hoc Wireless Networks.
5. Explain Intrusion tolerant routing in wireless Sensor networks.
6. a) Discuss the characteristics of an ideal routing protocol for Ad-hoc Wireless Networks.
   b) Explain in brief about DSDV routing protocol.
7. Discuss in detail about routing protocols with efficient flooding mechanisms.
8. a) Write short notes on Ticket based QOS routing protocol.
   b) Write short notes on Processor Power management scheme.

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Code No.: CS136

IV B. TECH. I SEM. (RA15) SUPPLEMENTARY EXAMINATIONS, APRIL – 2019

WIRELESS SENSOR NETWORKS

(CSE)

Time: 3 Hours **Max. Marks: 70**

PART – A

Answer **ALL** questions

All questions carry equal marks

10 x 2

1. Draw the pictographic view of Electro-magnetic spectrum.
2. List any four design goals of WLANs.
3. Write down the challenges in designing a Sensor Network.
4. Explain the concept of Roumor routing.
5. What do you know about beacons? Explain.
6. What is the purpose of Voronoi diagram? Explain.
7. Explain the purpose of power aware routing metrics.
8. What is the advantage of CGSR routing? Explain.
9. Explain INORA framework.
10. What is battery scheduling?

PART – B

Answer any **FIVE** questions

All questions carry equal marks

5 x 10

1. a) Explain in brief about IEEE 802.16 protocols stack.
   b) List out the differences between IEEE 802.11 and IEEE 802.16
2. Discuss in detail about various multiple access techniques.
3. What do you know about Sensor network architecture? Explain.
4. Explain in brief about classification of MAC protocols.
5. Explain Localized encryption and Authentication protocol in detail.
6. What are the issues in designing a routing protocol for Ad-hoc Wireless Networks? Explain.
7. a) List out the differences between proactive and reactive routing protocols.
   b) Explain in brief about wireless routing protocol.
8. a) What is on-demand QOS routing protocol? Explain.
   b) Discuss device power management scheme.

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Code No.: 13CS431A/CS438

IV B.Tech. II Sem. (RA13/RA11) Regular Examinations, March/April – 2019

ADHOC & SENSOR NETWORKS

(CSE)

Time: 3 Hours **Max. Marks: 70**

PART – A

Answer **ALL** questions

All questions carry equal marks

10 x 2

1. List some applications of adhoc wireless networks.
2. List the major issues in MAC protocol for adhoc wireless networks.
3. What is multicasting?
4. Why normal TCP is not suitable for Adhoc networks.
5. Define a Wireless Senor Network.
6. What is Data Aggregation?
7. What are the three kinds of MAC protocols used in sensor networks?
8. Compare deterministic and random deployment in WSN.
9. Define Localization.
10. What is Split-TCP?

PART – B

Answer any **FIVE** questions

All questions carry equal marks

5 x 10

1. Explain the design issues in Adhoc networks.
2. Explain AoDV routing protocol in detail with an example.
3. Explain about the MAC protocols in WSN.
4. Explain about key management approaches of Adhoc Wireless Networks.
5. List and explain the different types of network layer attack possible in Adhoc wireless networks.
6. What is QoS? Discuss QoS in Wireless Sensor Networks.
7. Outline the issues related to routing in Wireless Sensor Networks.
8. What is range-based localization? Explain with an example how triangulation works.

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