Adhoc and Wireless Sensor Networks

Code: CS-545

By

Dr K P Sharma

Department of Computer Science and Engineering
Dr. B.R. Ambedkar National Institute of Technology
Jalandhar Punjab-144011

Course Syllabus

- **DEPARTMENT: COMPUTER SCIENCE AND ENGINEERING**
  COURSE CODE: CS-545
- **COURSE TITLE: Adhoc and Wireless Sensor Network**
- **COURSE DESIGNATION: ELECTIVE**
- **PRE-REQUISITES: Computer Network**
- **CONTACT HOURS/CREDIT SCHEME: (L-T-P-C: 3-0-0-0)**

• Course Contents

- **Introduction**: What is an Ad Hoc Network?, Types of Ad hoc Mobile Communications , Types of Mobile Host Movements, Challenges Facing Ad hoc Mobile Networks, Ad hoc wireless Internet, Issues in Designing a Routing Protocol for Ad Hoc Wireless Networks, Classifications of Routing Protocols: Table–Driven Routing Protocols, Destination Sequenced Distance Vector (DSDV), Wireless Routing Protocol (WRP), Cluster Switch Gateway Routing (CSGR), Source–Initiated On–Demand Approaches, Ad hoc On–Demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA), Signal Stability Routing (SSR), Location–Aided Routing (LAR), Power–Aware Routing (PAR), Zone Routing Protocol (ZRP).

TOPICS TO BE COVERED

- **Wireless Sensor Networks:** Introduction to Wireless sensor networks, Single-sink single-hop WSN, Single-sink multi-hop WSN, Multi-sink multi-hop WSN, Advantages of ad-hoc/sensor networks, Node and Network Architectures, Wireless Sensor Device Architecture, Network Architectures, Main features of WSANs, Current and future research on WSANs
- **Applications of WSNs:** Positioning and animals tracking, Entertainment, Logistics, Transportation, Industrial Control and Monitoring, Home Automation and Consumer Electronics, Security and Military Sensing, Asset Tracking and Supply Chain Management, Intelligent Agriculture and Environmental monitoring, Health Monitoring.
- **Technologies for WSNs:** ZigBee technology, Ultrawide bandwidth technology, Bluetooth technology, Comparison among technologies
- **The Physical Layer:** Introduction, Wireless Propagation Models: The Free Space Propagation Model, The Two-Ray Ground Model, The Log-Distance Path Model, Energy Dissipation Model, Error Models: The Independent Error Model, The Two-State Markov Error Model, Sensing Models: The Binary Sensing Model, The Probabilistic Sensing Model

Communication protocols for WSNs

- **MAC protocols:** Scheduled protocols, LEACH protocol, Guo protocol, TRAMA protocol, Contention-based protocols, Zhong protocol, DMAC protocol, PAMAS protocol, SMAC protocol

TOPICS COVERED

- **Routing protocols:** Issues in designing routing protocols, Classification of routing protocols, Flat routing, Flooding and gossiping, SPIN protocol, Directed diffusion protocol, Rumour routing, Gradient-based routing, Hierarchical routing, LEACH protocol, PEGASIS protocol, TEEN protocol, MECN protocol, SPAN protocol, Location-based routing protocols, GAF protocol, GEAR protocol, GeRaF protocol, Rugin protocol
- **Case Studies**: Simulation of a Sensor Network
- **Text/References:**
  - Akyildiz, Ian F., and Mehmet Can Vuran. *Wireless sensor networks*. Vol. 4. John Wiley & Sons, 2010.
  - Murthy, C. S. R., & Manoj, B. S. (2004). *Ad hoc wireless networks: Architectures and protocols, portable documents*. Pearson education.
  - Jochen H. Schiller. Mobile communications Addison-Wesley, 2003
  - Roberto Verdone, Davide Dardari, Gianluca Mazzini and Andrea Conti, “Wireless Sensor and Actuator Networks: Technologies, Analysis and Design”, Academic Press, 2008.
  - Azzedine Boukerche, “Handbook of Algorithms for Wireless Networking and Mobile Computing”, Chapman & Hall/CRC, 2005.

Wireless Networks

- Need: Access computing and communication services, on the move

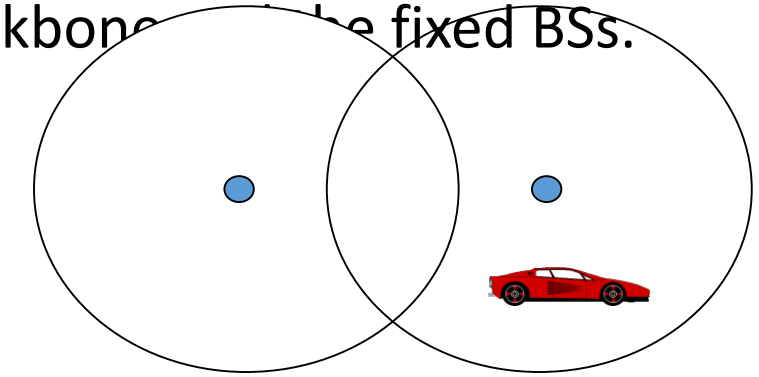
- Infrastructure-based Networks
  - traditional cellular systems (base station infrastructure)

- Wireless LANs
  - Infrared (IrDA) or radio links (Wavelan)
  - very flexible within the reception area; ad-hoc networks possible
  - low bandwidth compared to wired networks (1-10 Mbit/s)

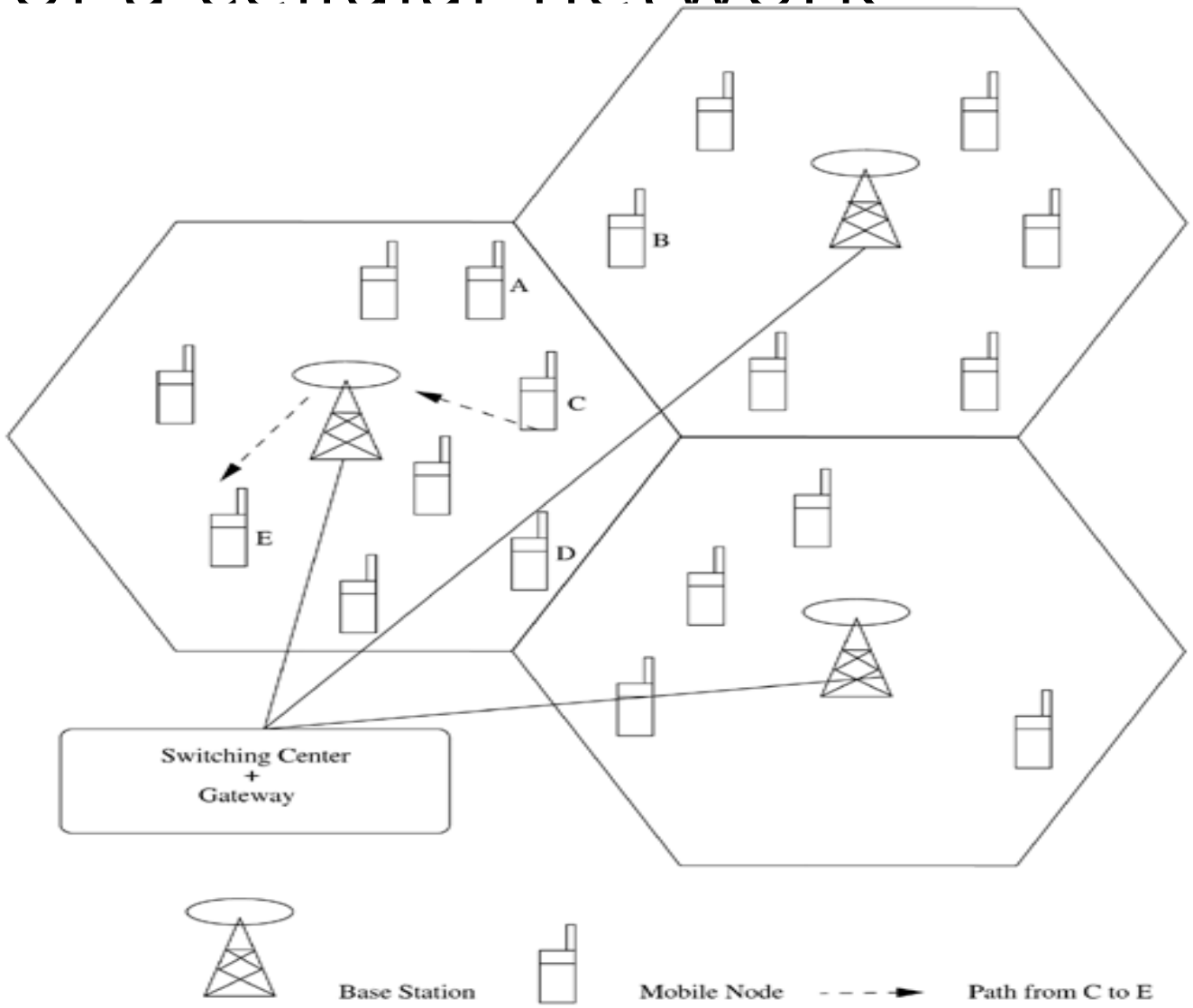
- Ad hoc Networks
  - useful when infrastructure not available, impractical, or expensive
  - military applications, rescue, home networking

Cellular Wireless

- Single hop wireless connectivity to the wired world
  - Space divided into cells
  - A base station (BS) is responsible to communicate with hosts in its cell
  - Mobile hosts can change cells while communicating
  - Hand-off occurs when a mobile host starts communicating via a new base station
  - In these cellular networks, communications between two mobile nodes completely rely on the wired backbone [illegible]e fixed BSs.

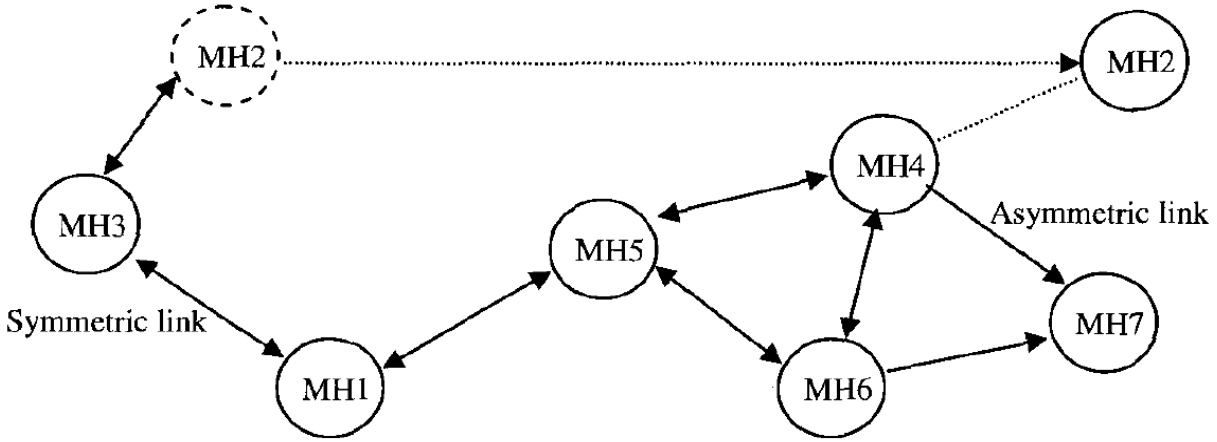


Example of a cellular network



Mobile Ad Hoc Networks (MANET)

- A Mobile Ad hoc NETwork (MANET) is one that comes together as needed, not necessarily with any support from the existing infrastructure or any other kind of fixed stations.
- Topology may dynamically change in an unpredictable manner since nodes are free to move.
- Peer-to peer multi-hop mobile wireless networks where information packets are transmitted in a store-and-forward manner from a source to an arbitrary destination, via intermediate nodes



Why Ad Hoc Networks ?

- Setting up of fixed access points and backbone infrastructure is not always viable
  - Infrastructure may not be present in a disaster area or war zone
  - Infrastructure may not be practical for short-range radios; Bluetooth (range ~ 10m)

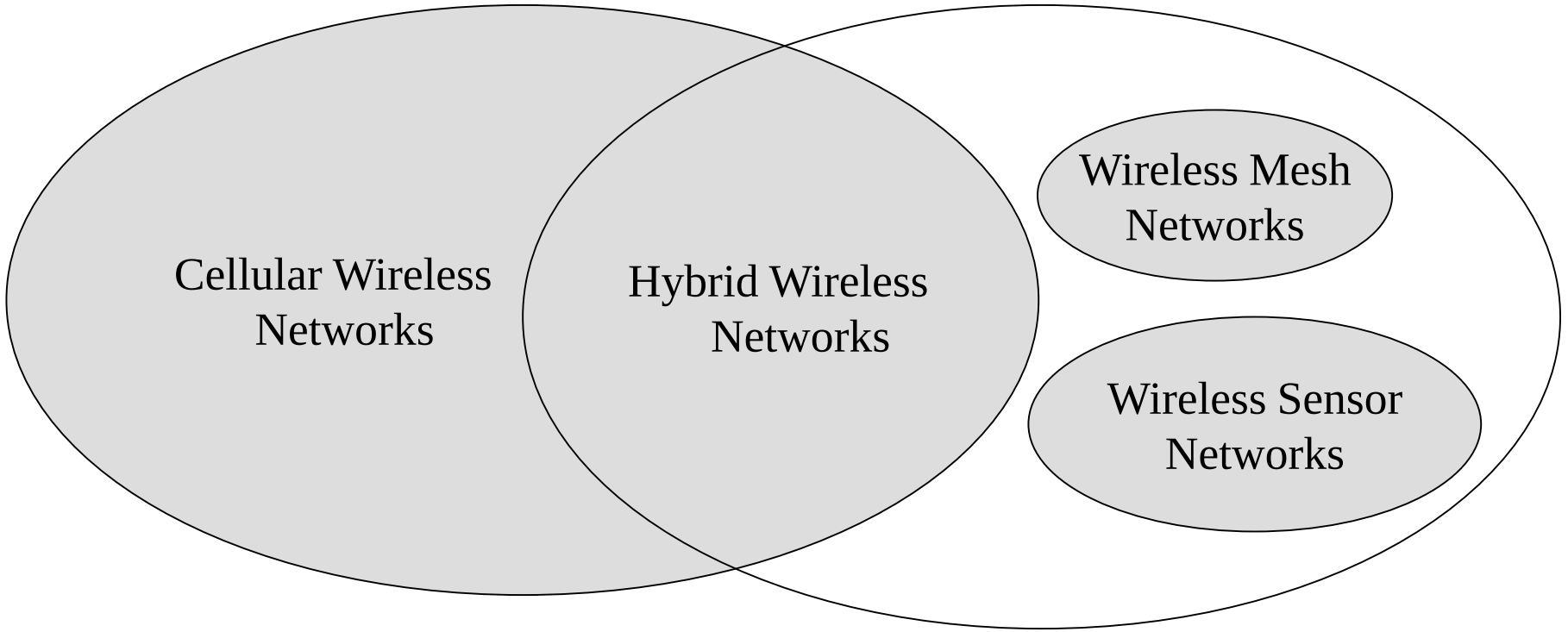
- Ad hoc networks:
  - Do not need backbone infrastructure support
  - Are easy to deploy
  - Useful when infrastructure is absent, destroyed or impractical

Characteristics of Ad Hoc Networks

- Dynamic Topology
  - Nodes are free to move arbitrarily
- Energy Constrained Operations
  - Some or all nodes may rely on battery power
- Limited Bandwidth
  - Multiple access, Fading, noise, and interference conditions etc.
- Security Threats
  - Denial of services, eavesdropping, spoofing, etc.

Cellular and Ad Hoc Wireless Networks

- The following figure represents different wireless networks.
  - Infrastructure: cellular wireless networks
  - Ad hoc: wireless sensor networks
  - Hybrid: mesh networks



Comparisons between Cellular and Ad Hoc Wireless Networks (I)

Cellular Networks	**Ad Hoc Wireless Networks**
Fixed infrastructure-based	Infrastructureless
Guaranteed bandwidth (designed for voice traffic)	Shared radio channel (more suitable for best-effort data traffic)
Centralized routing	Distributed routing
Circuit-switched (evolving toward packet switching)	Packet-switched (evolving toward emulation of circuit switching)
Seamless connectivity (low call drops during handoffs)	Frequent path breaks due to mobility
High cost and time of deployment	Quick and cost-effective deployment
Reuse of frequency spectrum through geographical channel reuse	Dynamic frequency reuse based on carrier sense mechanism
Easier to employ bandwidth reservation	Bandwidth reservation requires complex medium access control protocols

Comparisons between Cellular and Ad Hoc Wireless Networks (II)

Cellular Networks	**Ad Hoc Wireless Networks**
Application domains include mainly civilian and commercial sectors	Application domains include battlefields, emergency search and rescue operations, and collaborative computing
High cost of network maintenance (backup power source, staffing, etc.)	Self-organization and maintenance properties are built into the network
Mobile hosts are of relatively low complexity	Mobile hosts require more intelligence (should have a transceiver as well as routing/switching capability)
Major goals of routing and call admission are to maximize the call acceptance ratio and minimize the call drop ratio	Main aim of routing is to find paths with minimum overhead and also quick reconfiguration of broken paths

Ad hoc Networks

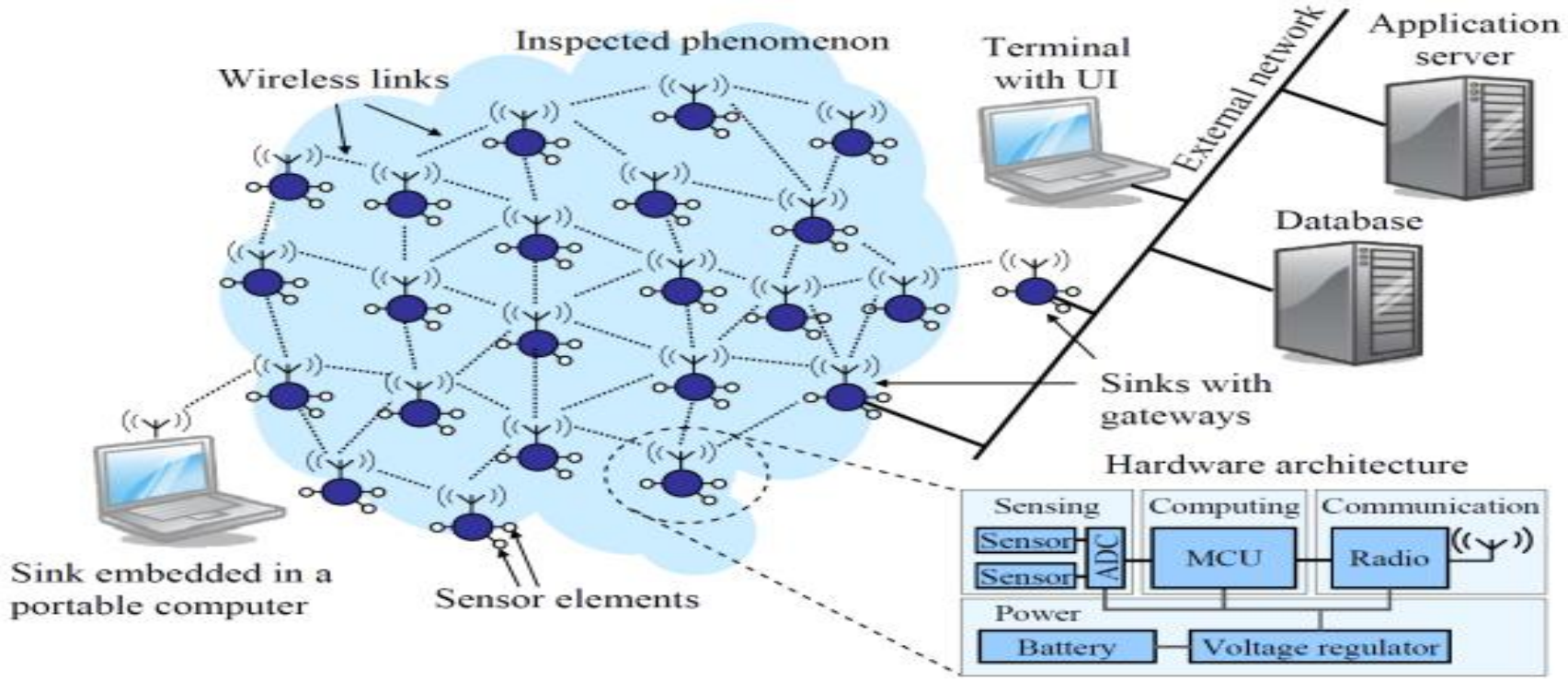
- A wireless ad hoc network (WANET) or MANET (Mobile ad hoc network) is a decentralised type of wireless network.
- The network is ad hoc because it does not rely on a pre-existing infrastructure, such as routers in wired networks or access points in managed (infrastructure) wireless networks.
- In the Windows operating system, ad-hoc is a communication mode (setting) that allows computers to directly communicate with each other without a router.
- Wireless mobile ad hoc networks are self-configuring, dynamic networks in which nodes are free to move.
- In early 1970s, the Mobile Ad hoc Network (MANET) was called packet radio network, which was sponsored by Defence Advanced Research Projects Agency (DARPA).

Applications of Ad hoc Wireless Networks

- Military applications
  - Ad hoc wireless networks is useful in establishing communication in a battle field.
- Collaborative and Distributed Computing
  - A group of people in a conference can share data in ad hoc networks.
  - Streaming of multimedia objects among the participating nodes.
- Emergency Operations
  - Ad hoc wireless networks are useful in emergency operations such as search and rescue, and crowd control.
- Wireless Sensor Networks
  - Network of sensor nodes forms for monitoring environmental and physical parameters for some decision making

Wireless Sensor Networks (WSNs)

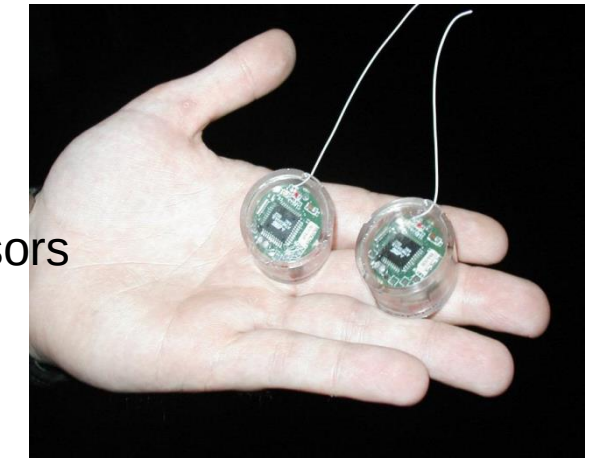
- A **wireless sensor network** (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors (sensor nodes), to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations.



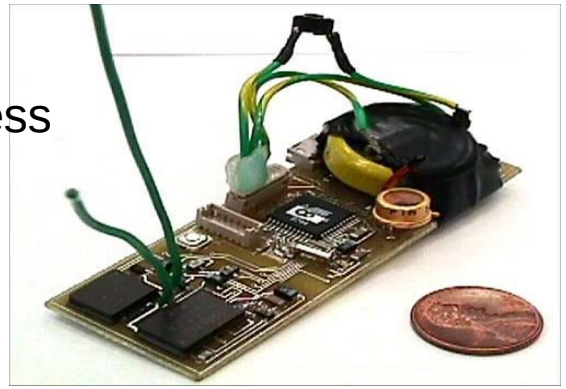
Wireless Sensor Networks (WSNs)

- A typical sensor node consist sensing, communicating, processing, memory and power unit

Sensors



Wireless Radio



Benefits:

- No need of fixed infrastructure.
- Capable of surviving harsh environments (heat, humidity, corrosion, pollution, radiation, etc)
- Implementation cost is cheap.
- A Large range of sensors are available like- Pressure, Temperature , Light , Biological , Chemical , Strain, fatigue ,Tilt , and many others.

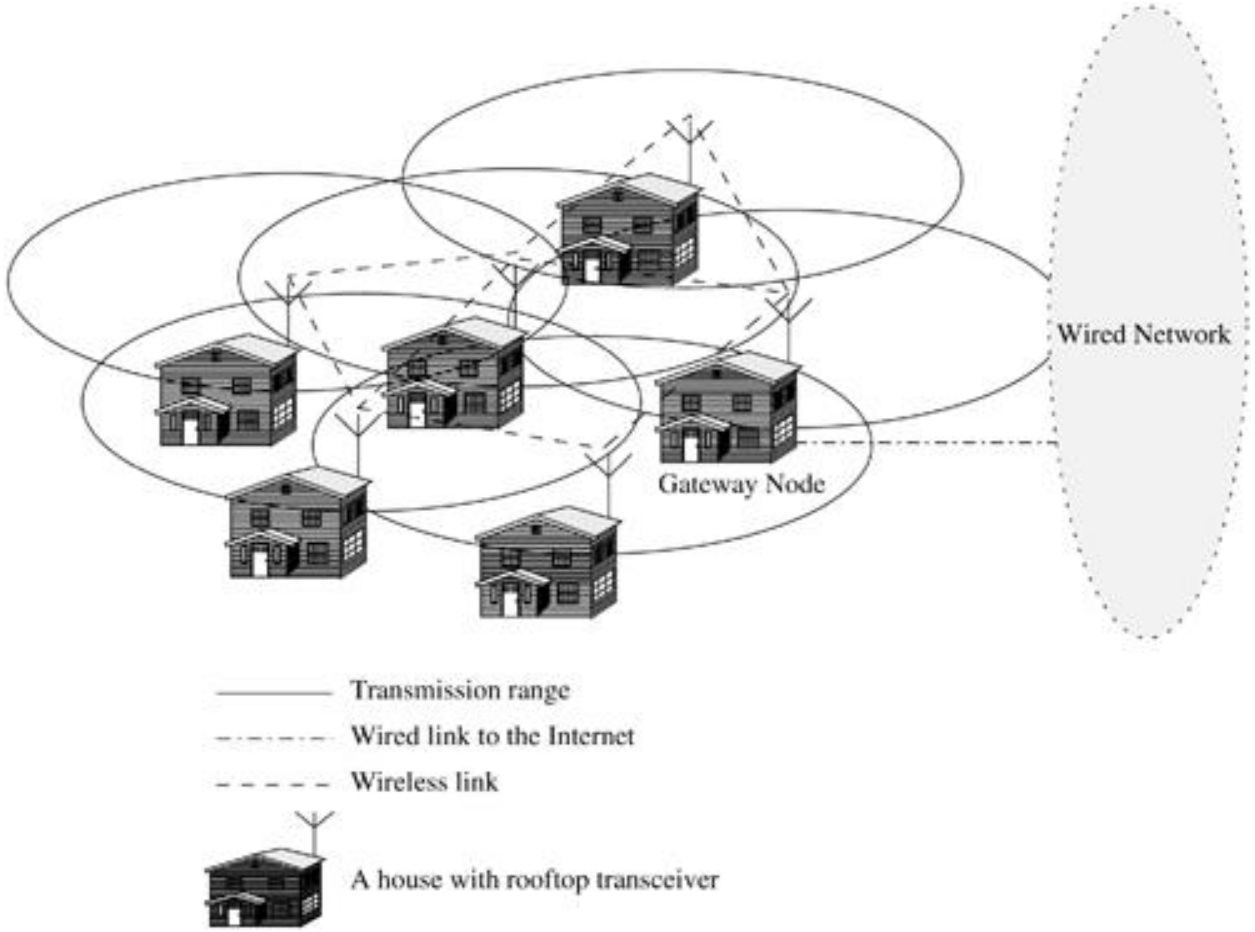
Wireless Sensor Networks

- Distinct properties of wireless sensor networks:
  - Mobility of nodes are not needed in all cases in wireless sensor networks.
  - The size of the network is much larger than that in a typical ad hoc wireless network.
  - The density of nodes in a sensor network varies with the domain of application.
  - The power constraints in sensor networks are much more stringent than those in ad hoc wireless networks.
  - The power source can be classified into three categories:
    - Replenishable power resource
    - Non- Replenishable power source
    - Regenerative power source

Applications

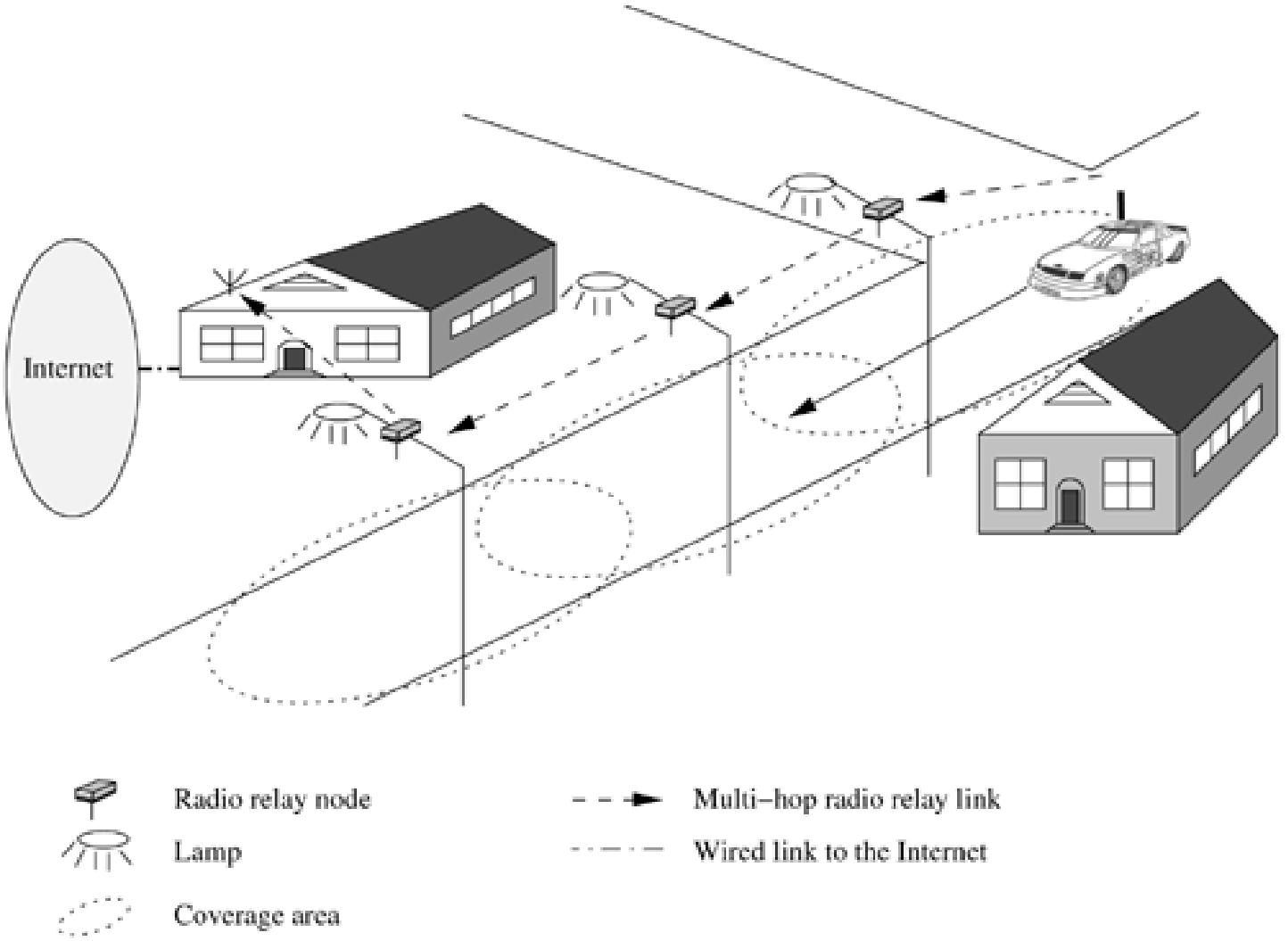
- Smart Home/offices
- Environmental Monitoring
- Battlefield Monitoring
- Underwater Activity Monitoring
- Precision Farming
- Environment Monitoring and Whether Forecasting
- Water Quality monitoring
- Health Care Monitoring

Wireless Mesh Networks



- Wireless mesh networks are ad hoc wireless networks that are formed to provide an alternate communication infrastructure for mobile or fixed nodes/users.

Wireless Mesh Networks



Wireless Mesh Networks

- The investment required in wireless mesh networks is much less than in the cellular network counterparts.
- Such networks are formed by placing wireless replaying equipment spread across the area to be covered by the network.
- The possible deployment scenarios include:
  - Residential zones (where broadband Internet connectivity is required)
  - Highways (where a communication facility for moving automobiles is required)
  - Business zones (where an alternate communication system to cellular networks is required)
  - Important civilian regions (where a high degree of service availability is required)
  - University campuses (where inexpensive campus-wide network coverage can be provided)

Vehicular Ad Hoc Network (VANET)

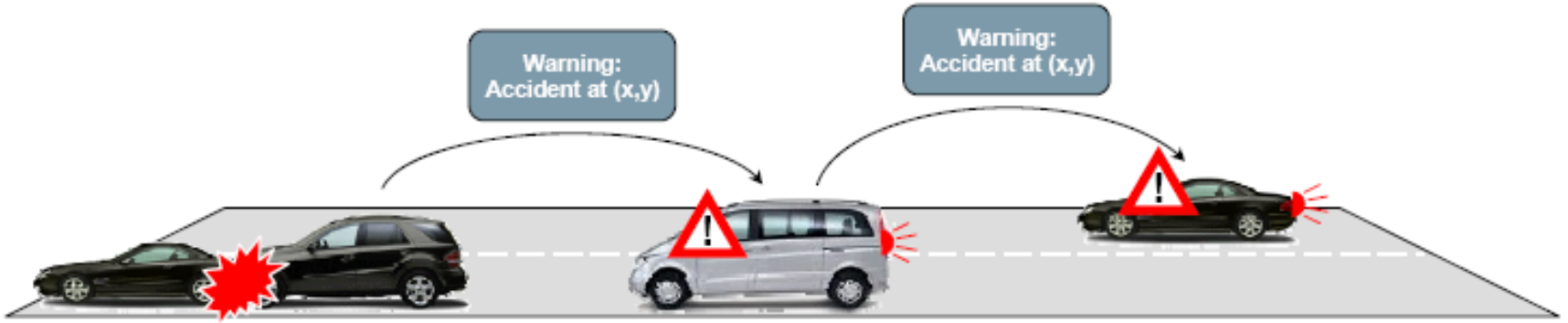
- Ad-Hoc Network:
  - A network with minimal or no infrastructure
  - Self-organizing
  - Each node can act as the source of data, the destination for data and a network router
- *Vehicular Ad Hoc network* (VANET)
  - Uses equipped vehicles as the network nodes
  - Nodes move at will relative to each other but within the constraints of the road infrastructure

Motivation

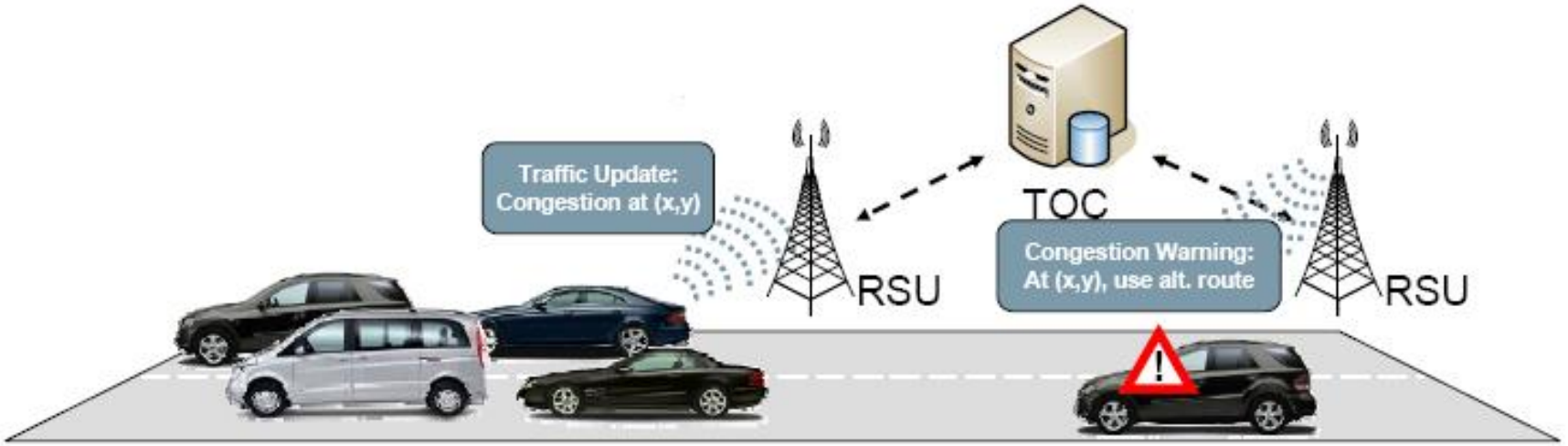
- Safety and transport efficiency
  - In Europe around 40,000 people die and more than 1.5 millions are injured every year on the roads
  - Traffic jams generate a tremendous waste of time and of fuel
- Most of these problems can be solved by providing appropriate ***information*** to the driver or to the vehicle

Vehicle Communication (VC)

- VC promises safer roads,

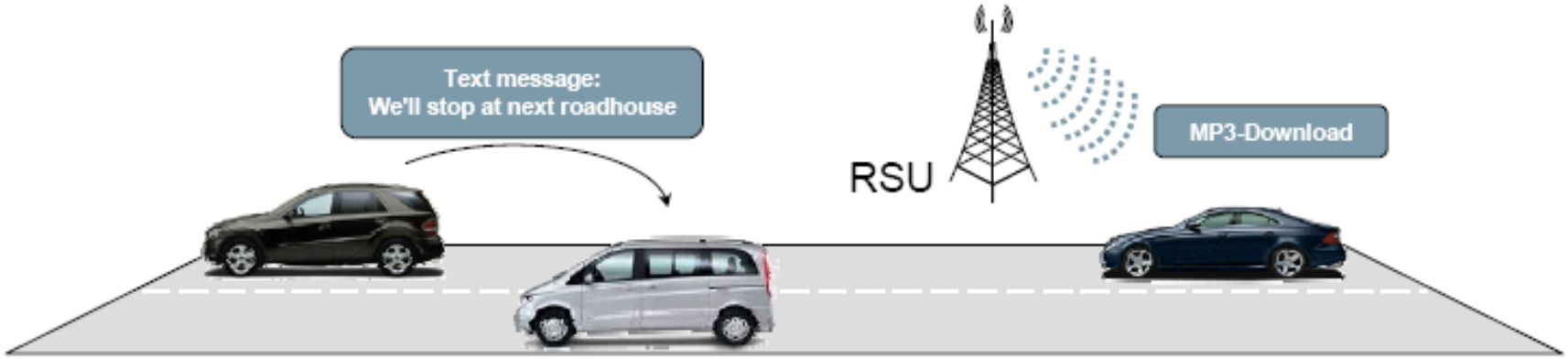


... more efficient driving,

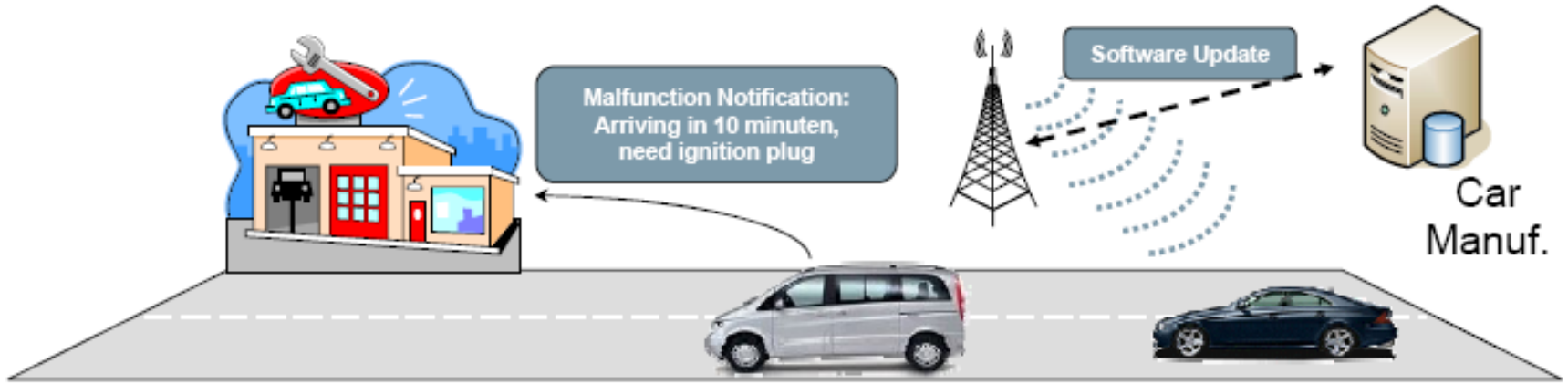


Vehicle Communication (VC)

- … more fun,



- … and easier maintenance.



Differences VANETs from MANETs

- Rapid Topology Changes
  - High relative speed of vehicles => short link life
- Frequent Fragmentation
  - Chunks of the net are unable to reach nodes in nearby regions
- Small Effective Network Diameter
  - A path may cease to exist almost as quickly as it was discovered (reactive routing)

Issues in Ad hoc Wireless Networks

- Medium access scheme
  - **Distributed operation** is required.
  - **Synchronization** is required in TDMA-based systems.
  - **Hidden terminals** are nodes hidden from a sender.
  - **Exposed terminals** are exposed nodes preventing a sender from sending.
  - **Throughput** needs to be maximized.
  - **Access delay** should be minimized.
  - **Fairness** refers to provide an equal share to all competing nodes.
  - **Real-time traffic support** is required for voice, video, and real-time data.
  - **Ability to measure resource availability**, helps in congestion control
  - **Capability for power control** reduces the energy consumption.
  - **Use of directional antennas** has advantages including increased spectrum reuse, reduced interference, and reduced power consumption.

Issues in Ad hoc Wireless Networks

- Routing
  - Mobility (path breaks, packet collision, transient loops, stale roots)
  - Bandwidth constraint
  - Error-prone and shared channel: wireless channel (10^{-5} to 10^{-3}), wired channel (10^{-12} to 10^{-9})
  - Location-dependent contention: (High contention should be avoided by balancing load)
  - Other resource constraints such as computing power, battery power
  - Minimum route acquisition delay
  - Quick route reconfiguration
  - Loop-free routing
  - Distributed routing approach
  - Minimum control overhead
  - Scalability
  - Provisioning of QoS (bandwidth, delay, jitter, packet delivery ration, throughput)
  - Support for time-sensitive traffic: hard real-time and soft real-time traffic
  - Security and privacy

Issues in Ad hoc Wireless Networks

- The objectives of the transport layer protocols include:
  - Setting up and maintaining end-to-end connections
  - Reliable end-to-end delivery of data packets
  - Flow control
  - Congestion control
  - UDP neither perform flow and congestion control nor reliable data transfer
  - Do not take into account the current network status like congestion at intermediate nodes, rate of collision or other factors.
  - Increase the load in the network blindly and degrade performance.
  - TCP faces the problem of dynamic topology, path breaks, stale routing information, high channel error rate, and frequent network partitioned
  - The process of finding an alternate path or reconfiguring the broken path might take longer than the retransmission timeout of the transport layer at the sender, resulting in retransmission of packets and execution of the congestion control algorithm with decreasing congestion window.
  - Due to error, lots of ACK packets and even ACK can loss which intern invoke congestion algorithm

Issues in Ad hoc Wireless Networks

Multicasting (Point to Multipoint and Multipoint to Multipoint)

- In emergency search-and-rescue operations and military communication applications nodes form groups to carry out certain tasks that require point-to-multipoint and multipoint-to-multipoint voice and data communication
- Wired network multicast protocols such as core based trees (CBT), protocol independent multicast (PIM), and distance vector multicast routing protocol (DVMRP) do not perform well in ad hoc wireless networks because a tree-based multicast structure is highly unstable and needs to be frequently readjusted to include broken links.
- Use of any global routing structure such as the link-state table results in high control overhead.
- Issues in designing multicast protocol
    - Robustness (recover and reconfigure quickly from link breaks)
    - Efficiency (Minimum number of message transfer to convey information to all)
    - Control overhead
    - Quality of service (Support of time sensitive data)
    - Efficient group management
    - Scalability
    - Security (Authentication of session members and preventing of unauthorized information)

Issues in Ad hoc Wireless Networks

- Pricing Schemes need to incorporate service compensation.
- Quality of Service Provisioning
  - QoS parameters based on different applications
    - multimedia applications, the bandwidth and delay are the key parameters, whereas military applications have the additional requirements of security and reliability
    - Emergency search-and-rescue operations, availability is the key parameter
    - For WSN battery life and energy conservation is the parameter
  - QoS-aware routing uses QoS parameters to find a path.
  - QoS framework is a complete system that aims at providing the promised services to each users.

Issues in Ad hoc Wireless Networks

- Self-Organization is required in ad hoc wireless networks:
  - Neighbor discovery (Building local topology)
  - Topology organization (Exchanging topology information)
  - Topology reorganization (Recovery from major topological changes)
  - Network partitioning and recovery
- Security
  - Denial of service
  - Resource consumption
    - Energy depletion: deplete the battery power of critical nodes
    - Buffer overflow: flooding the routing table or consuming the data packet buffer space
  - Host impersonation: A compromised node can act as another node.
  - Information disclosure: a compromised node can act as an informer.
  - Interference: jam wireless communication by creating a wide-spectrum noise.

Issues in Ad hoc Wireless Networks

- Energy Management
  - Transmission power management: The radio frequency (RF) hardware design should ensure minimum power consumption.
  - Battery energy management is aimed at extending the battery life.
  - Processor power management: The CPU can be put into different power saving modes.
- Scalability is expected in ad hoc wireless networks.
- There are issues related to wireless internet also.