UNIT I

INTRODUCTION TO MOBILE AD HOC NETWORKS

Network Deployment - Structured Versus Randomized Deployment - Network Topology - Topology Control - Connectivity in Geometric Random Graphs - Connectivity using Power Control - Mobility Models.

INTRODUCTION TO MOBILE AD HOC NETWORKS

Networking

Interfacing or interconnecting two or more Communicating Devices for the purpose of sharing data

Modes of Networking

- Infrastructure Mode or Cellular Network
- Infrastructure-less Mode or Ad Hoc Network

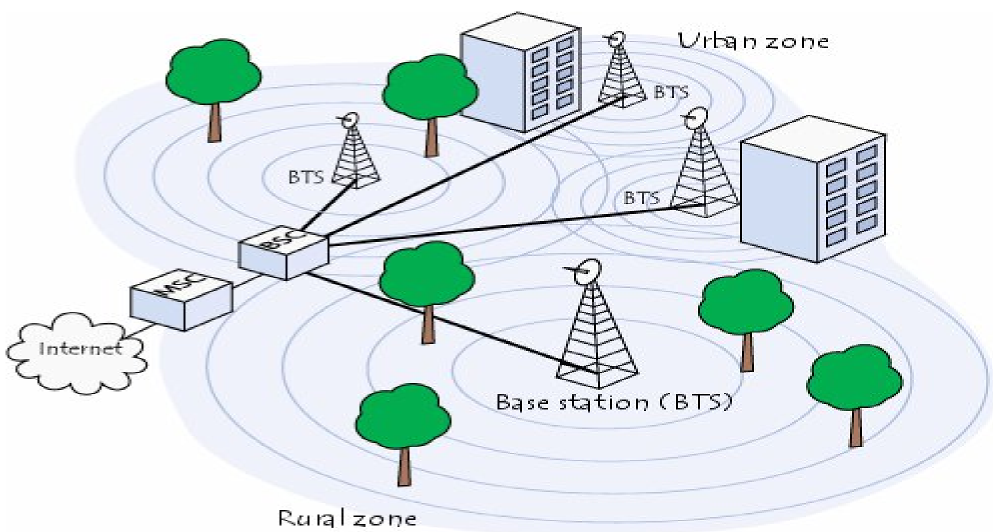


Fig 1.1: Cellular Network

Mobile Adhoc Network

Collection of wireless mobile nodes (devices) dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration

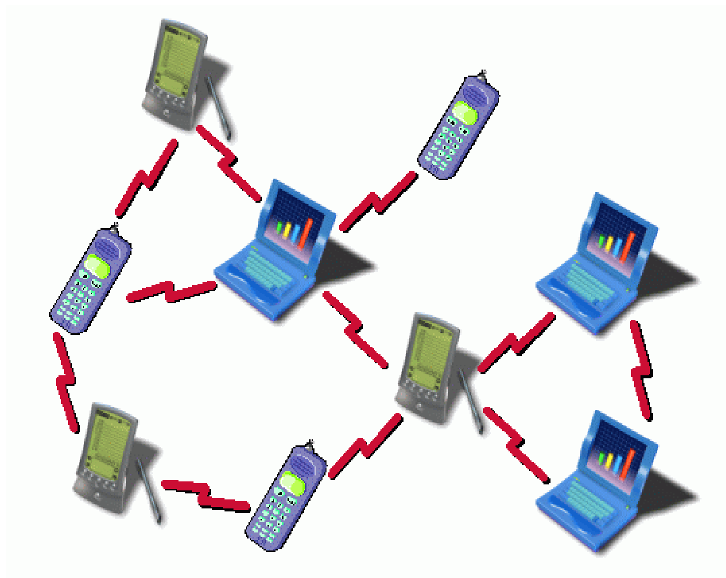


Fig 1.2: Mobile Adhoc Network

Wireless Sensor Network

Recent technological advances allow us to envision a future where large numbers of low-power; inexpensive sensor devices are densely embedded in the physical environment, operating together in a wireless network.

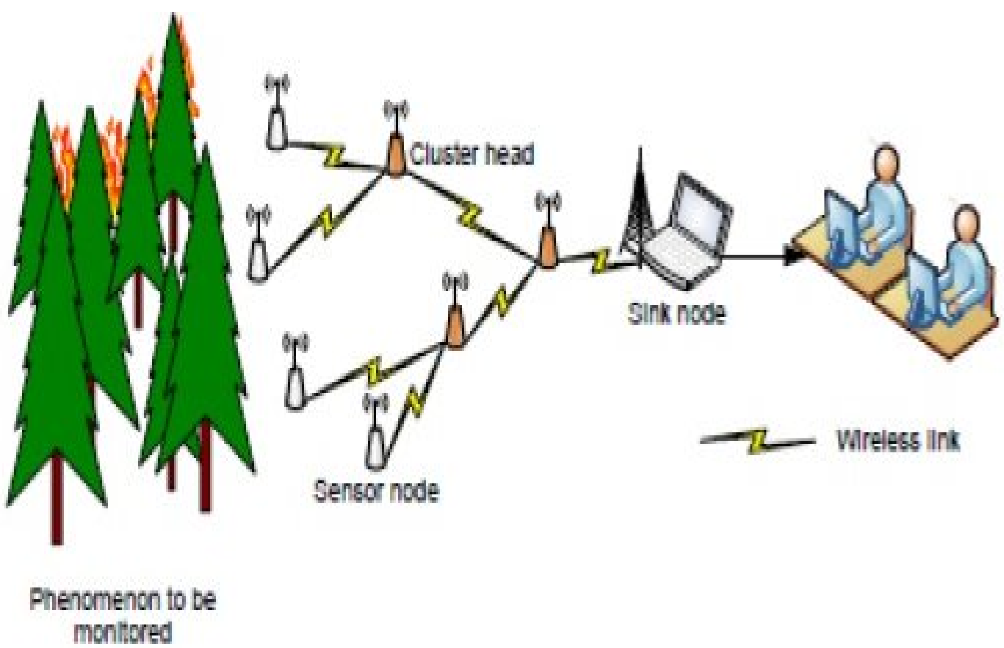


Fig 1.3: Architecture of WSN

There are several key components that make up a typical wireless sensor network (WSN) device

Low-power embedded processor: The embedded processors are often significantly constrained in terms of computational power (e.g., many of the devices used currently in research and development have only an eight-bit 16-MHz processor).

Memory/storage: Storage in the form of random access and read-only memory includes both program memory (from which instructions are executed by the processor), and data memory (for storing raw and processed sensor measurements and other local information).

Radio transceiver: Radio communication is often the most power intensive operation in a WSN device, and hence the radio must incorporate energy-efficient sleep and wake-up modes.

Sensors: Due to bandwidth and power constraints, WSN devices primarily support only low-data-rate sensing. The specific sensors used are highly dependent on the application; for example, they may include temperature sensors, light sensors, humidity sensors, pressure sensors, accelerometers, magnetometers, chemical sensors, acoustic sensors, or even low-resolution imagers.

Power source: For flexible deployment the WSN device is likely to be battery powered (e.g. using LiMH AA batteries). While some of the nodes may be wired to a continuous power source in some applications, and energy harvesting techniques may provide a degree of energy renewal in some cases, the finite battery energy is likely to be the most critical resource bottleneck in most WSN applications.

Applications:

1. Military:
   - Monitoring equipment and ammunition
   - Battlefield surveillance and damage assessment
   - Nuclear, biological, chemical attack detection and reconnaissance

2. Environmental:
   - Forest fire / flood detection
3. Health:
   - Tracking and monitoring doctors and patients inside a hospital
   - Drug administration in hospitals

Network Deployment

The network must be deployed keeping in mind two main objectives: coverage and connectivity

- *Coverage* pertains to the application-specific quality of information obtained from the environment by the networked sensor devices.

Connectivity pertains to the network topology over which information routing can take place.

Sensor deployment is a critical issue because it affects the *cost* and *detection capability* of a wireless sensor network .A good sensor deployment should consider both *coverage* and *connectivity*

- Node deployment in WSNs is application dependent and affects the performance of the routing protocol.
- The deployment can be either structured or randomized.
- In structured deployment, the sensors are manually placed and data is routed through pre-determined paths.
- In random node deployment, the sensor nodes are scattered randomly creating an infrastructure in an ad hoc manner.

Structured versus randomized deployment

The randomized deployment approach is appealing for futuristic applications of a large scale, where nodes are dropped from aircraft or mixed into concrete before being embedded in a smart structure. We can illustrate these issues by considering in detail one possible methodology for structured placement

1. Place sink/gateway device at a location that provides the desired wired network and power connectivity.
2. Place sensor nodes in a prioritized manner at locations of the operational area where sensor measurements are needed.
3. If necessary, add additional nodes to provide requisite network connectivity.

Adding nodes for ensuring sufficient wireless network connectivity can also be a non-trivial challenge, particularly when there are location constraints in a given environment that dictate where nodes can or cannot be placed. If the number of available nodes is small with respect to the size of the operational area and required coverage, a delicate balance has to be struck between how many nodes can be allocated for sensor measurements and how many nodes are needed for routing connectivity.

Randomized sensor deployment can be even more challenging in some respects, since there is no way to configure *a priori* the exact location of each position. In case of a uniform random deployment, the only parameters that can be controlled *a priori* are the numbers of nodes and some related settings on these nodes, such as their transmission range.

Network topology

- Single-hop star
- Multi-hop mesh and grid
- Two-tier hierarchical cluster

Single-hop star

Every node in this topology communicates its measurements directly to the gateway. The limitation of this topology is its poor scalability and robustness properties. Wherever feasible, this approach can significantly simplify design, as the networking concerns are reduced to a minimum. However, the limitation of this topology is its poor scalability and robustness properties. For instance, in larger areas, nodes that are distant from the gateway will have poor-quality wireless links.

Multi-hop mesh and grid

For larger areas and networks, multi-hop routing is necessary. Depending on how they are placed, the nodes could form an arbitrary mesh graph as in Figure 2.1(b) or they could form a more structured communication graph such as the 2D grid structure shown in Figure 2.1(c).

Two-tier hierarchical cluster

Perhaps the most compelling architecture for WSN is a deployment architecture where multiple nodes within each local region report to different cluster heads.

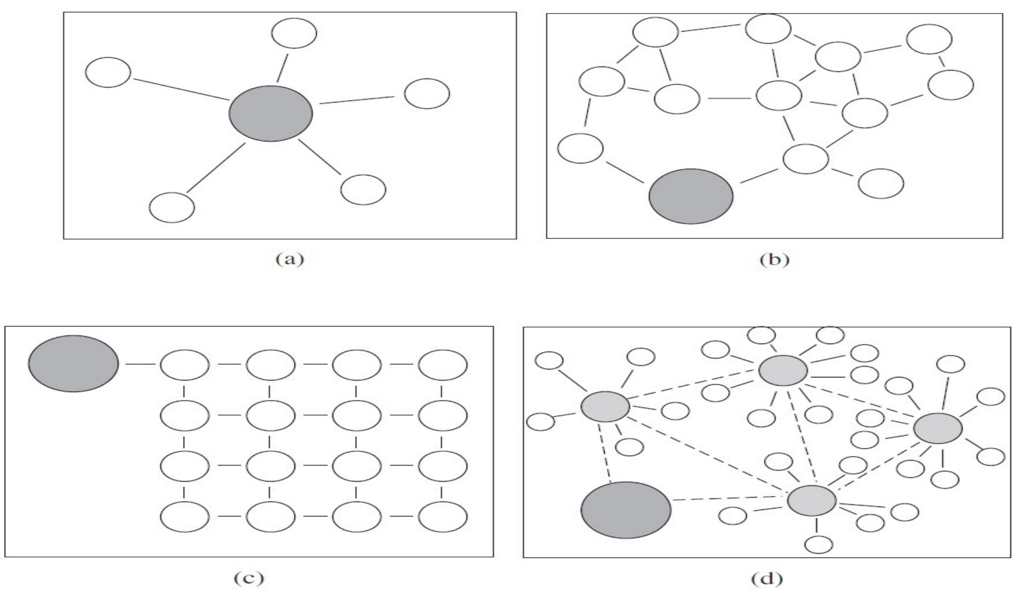


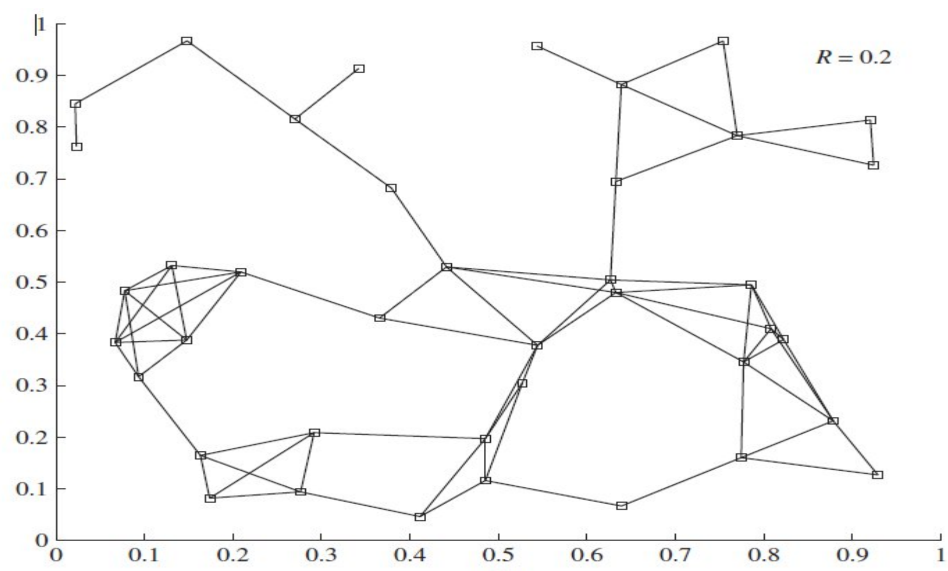
Fig 1.4: Different deployment topologies: (a) a star-connected single-hop topology,(b) flat multi-hop mesh, (c) structured grid, and (d) two-tier hierarchical cluster topology

The advantage of the hierarchical cluster based approach is that it naturally decomposes a large network into separate zones within which data processing and aggregation can be performed locally. Within each cluster there could be either single-hop or multi-hop communication. Once data reach a cluster-head they would then be routed through the second-tier network formed by cluster-heads to another cluster-head or a gateway. The second-tier network may utilize a higher bandwidth radio or it could even be a wired network if the second-tier nodes can all be connected to the wired infrastructure. Having a wired network for the second tier is relatively easy in building-like environments, but not for random deployments in remote locations. In random deployments there may be no designated cluster-heads; these may have to be determined by some process of self-election.

Connectivity in geometric random graphs

A *random graph model* is essentially a systematic description of some random experiment that can be used to generate graph instances. These models usually contain a tuning parameter that varies the average density of the constructed random graph. The Bernoulli random graphs G (n, p), studied in traditional Random Graph Theory, are formed by taking n vertices and placing random edges between each pair of vertices independently with probability p.

A random graph model that more closely represents wireless multi-hop networks is the geometric random graph G(n, R). In a G(n, R) geometric random graph, n nodes are placed at random with uniform distribution in a square area of unit size (more generally, a d-dimensional cube). There is an edge (u, v) between any pair of nodes u and v, if the Euclidean distance between them is less than R.



(a)

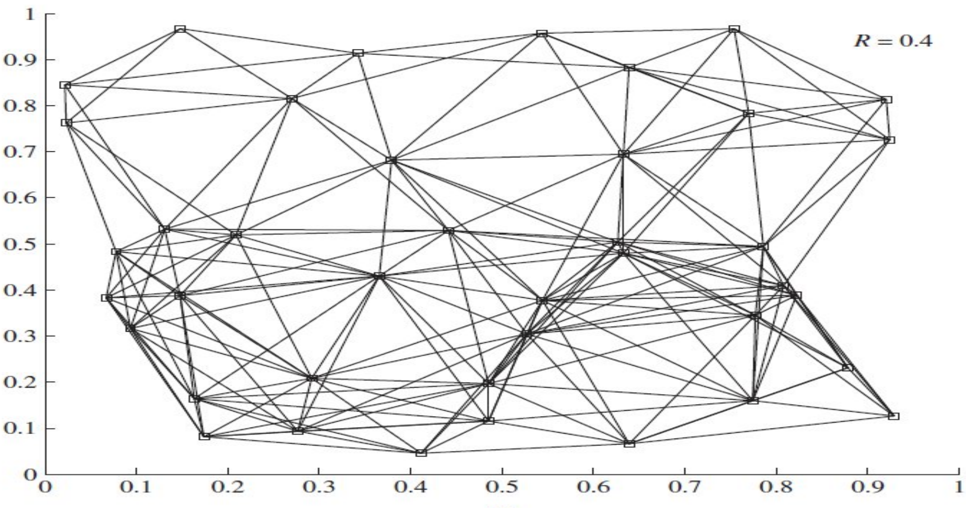
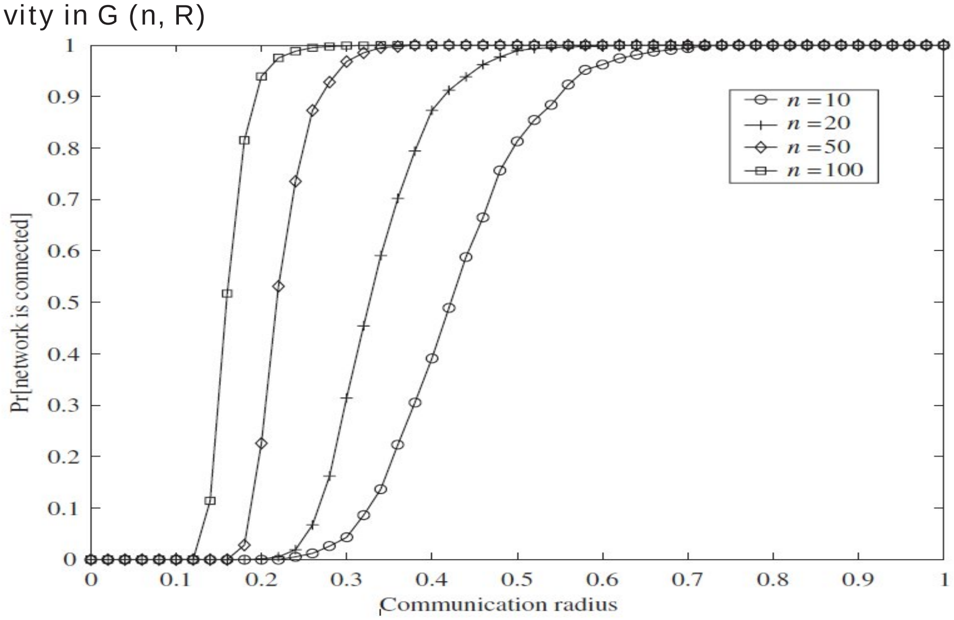


Fig 1.5: Illustration of G(n,R) geometric random graphs: (a) sparse (small R) and (b) dense (large R)

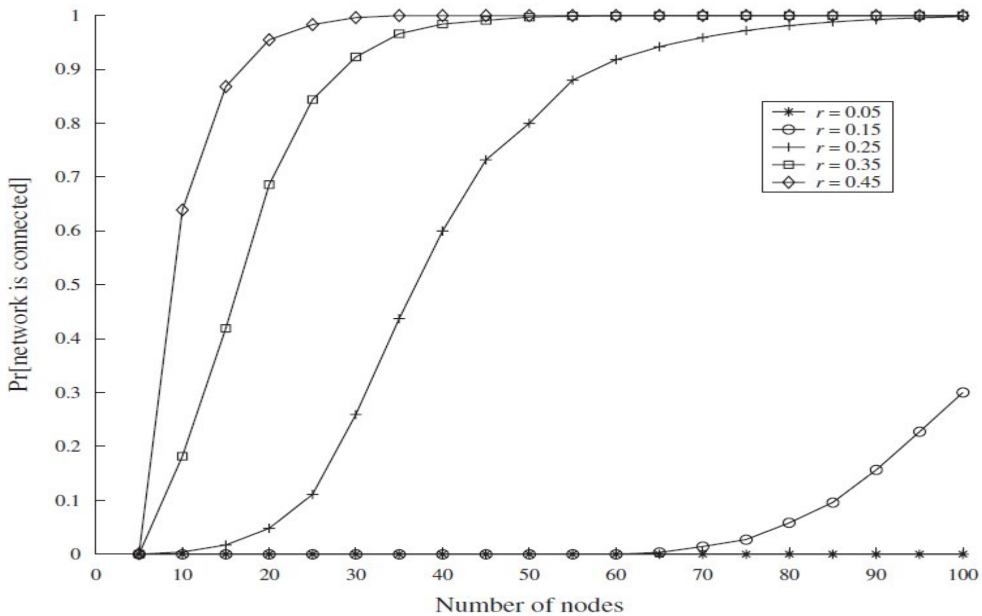
Figure a & b illustrates G(n,R) for n=40 at two different R values. When R is small, each node can connect only to other nodes that are close by, and the resulting graph is sparse; on the other hand, a large R allows longer links and results in a dense connectivity.

Compared with Bernoulli random graphs, G (n,R) geometric random graphs need different analytical techniques. This is because geometric random graphs do not show independence between edges. For instance, the probability that edge (u, v) exists is not independent of the probability that edge (u, w) and edge (v, w) exist.

Connectivity in G (n, R)



The above Figure show how the probability of network connectivity varies as the radius parameter R of a geometric random graph is varied. Depending on the number of nodes n, there exist different critical radii beyond which the graph is connected with high probability. These transitions become sharper (shifting to lower radii) as the number of nodes increases



The above fig shows the probability that the network is connected with respect to the total number of nodes for different values of fixed transmission range in a fixed area for all nodes. It can be observed that, depending on the transmission

Monotone properties in G(n, R)

A monotonically increasing property is any graph property that continues to hold if additional edges are added to a graph that already has the property. A graph property is called *monotone* if the property or its inverse are monotonically increasing. Nearly all graph properties of interest from a networking perspective, such as K-connectivity, Hamiltonicity, K-colorability, etc., are monotone.

Connectivity in G(n, K)

Another geometric random graph model is G(n, K), where n nodes are placed at random in a unit area, and each node connects to its K nearest neighbors. This model potentially allows different nodes in the network to use different powers.

Connectivity and coverage in G grid (n, p, R)

In this model n nodes are placed on a square grid within a unit. area, p is the probability that a node is active (not failed), and R is the transmission range of each node.

Connectivity using power control

Power control is quite a complex and challenging cross-layer issue .Increasing radio transmission power has a number of interrelated consequences –some of these are positive, others negative:

- It can extend the communication range, increasing the number of communicating neighboring nodes and improving connectivity in the form of availability of end-to-end paths.
- For existing neighbors, it can improve link quality
- It can induce additional interference that reduces capacity and introduces congestion.
- It can cause an increase in the energy expended

Minimum energy connected network construction (MECN)

A graph topology is defined to be a *minimum power topology*, if for any pair of nodes there exists a path in the graph that consumes the least energy compared with any other possible path. The construction of such a topology is the goal of the MECN (minimum energy communication network) algorithm

Minimum common power setting (COMPOW)

The COMPOW protocol ensures that the lowest common power level that ensures maximum network connectivity is selected by all nodes.

(i) it makes the received signal power on all links symmetric in either direction (although SINR may vary in each direction);

(ii) it can provide for an asymptotic network capacity which is quite close to the best capacity achievable without common power levels;

(iii) a low common power level provides low-power routes; and

(iv) a low power level minimizes contention.

Mobile deployment

An incremental self-deployment algorithm is described, whereby a new location for placement is calculated at each step based on the current deployment, and the nodes are sequentially shifted so that a new deployment is created with a node moving into that new location and other nodes moving one by one accordingly to fill any gaps.

A bidding protocol for deployment of a mixture of mobile and static nodes is described, whereby, after an initial deployment of the static nodes, coverage holes are determined and the mobile nodes move to fill these holes based on bids placed by static nodes. A mutually helpful combination of static sensor nodes and mobile nodes is described, where a robotic node's mobile explorations help determine where static nodes are to be deployed, and the deployed static node then provides guidance to the robot's exploration. The deployment of static sensor nodes from an autonomous helicopter is described, where the sensor nodes are first dropped from the air and self-configure to determine their connectivity. If the network is found to be disconnected, the helicopter is informed about where to deploy additional nodes.

2 Mark Questions

1. Define ad-hoc network.
2. Explain geometric random graph
3. Define connectivity
4. Difference between Structured versus randomized deployment
5. List the applications of Adhoc Networks.
6. List the differences between Structured versus randomized deployment?
7. What is reply attack?
8. List out any four characteristics of an ideal routing protocol for Ad-Hoc networks
9. Define coverage
10. List any four differences between cellular & Adhoc networks.
11. Write briefly about random graphs.
12. List the techniques evolved to control power in mobile Adhoc networks.

12 Mark Questions

1. Explain in detail about different network topology in ad- hoc
2. List mobility models and explain how the mobility models influence the performance of the network protocols.
3. Explain TCP over ad hoc wireless networks.
4. Explain about structured and randomized deployment.
5. Explain the challenges and issues of Adhoc Networks
6. Differentiate Cellular network and Adhoc network
7. Explain the applications of mobile Adhoc networks.
8. Write short notes on power control algorithms.
9. Write short notes on geometric random graphs.