BCA-603
Mobile Computing
Unit IV

Mobile Agents in Mobile Computing

In Mobile Computing, Mobile Agents are the composition of computer software and data that can autonomously move from one computer to another computer and continue its execution on the destination computer.

In other words, you can say that An Mobile Agent is an autonomous program that is capable of moving from host to host in a network and interact with resources and other agents. In this process, the chance of data loss is scarce because the state of the running program is saved and then transported to the new host. It allows the program to continue execution from where it left off before migration. The most significant advantage of mobile agents is the possibility of moving complex processing functions to the location where you have enormous amounts of data and that have to be processed.

Mobile Agents are also called as transportable agents. They are classified into two types:

- **Mobile Agents with pre-defined path:** They have a static migration path.
- **Mobile Agents with undefined path i.e., Roamer:** They have dynamic migration paths. The mobile agents choose their path according to the present network condition.

Features of Mobile Agents

The mobile agents are autonomous with intelligence, social ability, learning, and the most important feature is their mobility. They are independent in nature, self-driven and do not require a corresponding node for communication. They can work efficiently even after the user gets disconnected from the network.

Intelligence

Mobile Agents are capable of learning and searching for knowledge about their domain. That's why they are called intelligent agents because they possess a degree of domain knowledge. They can also transport their state from one environment to another without disturbing the previous holding data and be capable of performing appropriately in the new environment.

Autonomous

The Mobile Agents are Autonomous. It means the agents are not only motivated by the outside actions initiated by the users or system but also they have internal events that decided their performance and behavior. The mobile agents can also take an autonomous decision while selecting a node.

Mobility

Mobile Agents contain some degree of mobility. The agent is not limited to its home node only. They can migrate from one node to another and can carry out tasks along with them. This feature distributes the processing and balancing of the load. Another benefit of this capability is that when the user goes offline, the agents will still keep functioning.

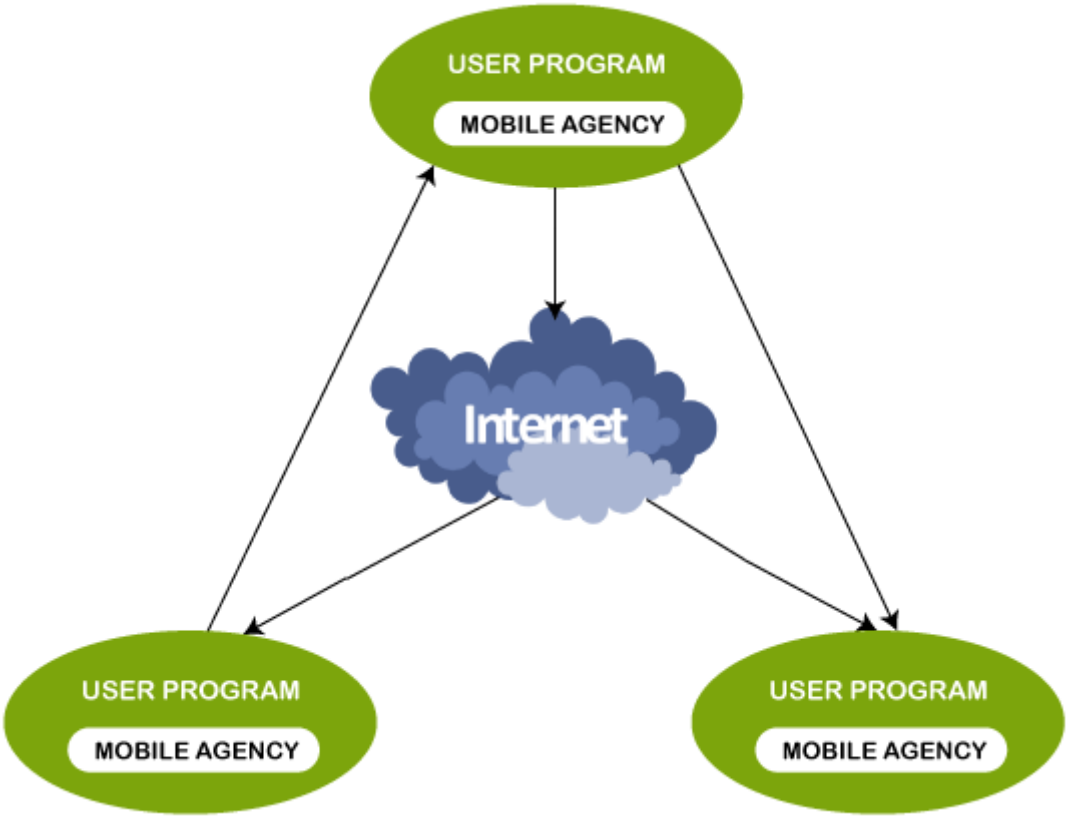
Communicative

Mobile Agents can communicate effectively with other agents, users and systems. The mobile agents use a communication language for inter-agent communication.

Life Cycle of Mobile Agents

The life cycle of mobile agents ensures the following conditions:

- They can adapt to the environment. For example, either home or foreign environment.
- They are capable of switching among the positions of one node to another.
- They are autonomous and focused on the final output.



Advantages of Mobile Agents

The following are some advantages of mobile agents over conventional agents:

- Mobile Agents are autonomous and self-driven in nature.
- They are maintenance-friendly or easily maintainable.

- They are Fault-tolerant. It means they are able to operate without an active connection between client and server.
- They reduce the compilation time.
- They provide less delay in the network.
- They provide fewer loads on the network.
- They facilitate parallel processing. It means they can be asynchronously executed on multiple heterogeneous network hosts.
- They provide dynamic adaptation in which their actions are dependent on the state of the host environment.

Disadvantages of Mobile Agents

The following are some disadvantages of mobile agents:

- The most significant disadvantage of mobile agents is their security. They are less secured

Applications of Mobile Agents

Mobile agents are used in the following applications:

- Mobile Agents are applied in a wide range of domains such as E-commerce, traffic control, network management, robotics, data-intensive applications etc.
- They are also used in grid computing, parallel computing, distributed computing and mobile computing etc.

Security and fault tolerance in mobile agent

Mobile agent systems, security focuses on protecting agents and the data they handle from malicious attacks and unauthorized access, while fault tolerance ensures the system can continue functioning despite failures, like host crashes or network issues.

Security in Mobile Agent Systems:

- **Threats:**

  Mobile agents are vulnerable to various attacks, including data breaches, code manipulation, and denial of service.
- **Security Measures:**
- **Encryption:** Protecting agent code and data during transit and at rest.
- **Access Control:** Restricting agent access to specific resources and functionalities.
- **Authentication:** Verifying the identity of agents and hosts.
- **Sandboxing:** Isolating agents to prevent them from harming the host system.
- **Trust Management:** Establishing trust relationships between agents and hosts.

- **Secure Communication:** Using secure protocols to ensure the integrity and confidentiality of agent communication.
- **Examples:**
- Using secure protocols like SSL/TLS for agent communication.
- Implementing access control lists to restrict agent access to specific resources.
- Employing digital signatures to verify the authenticity of agent code.

Fault Tolerance in Mobile Agent Systems:

- **Importance:**

Fault tolerance is crucial for ensuring the reliability and availability of mobile agent systems.

Fault Tolerance Techniques:

- **Checkpointing:** Regularly saving the agent's state to allow for recovery from failures.
- **Replication:** Creating multiple copies of the agent to ensure that if one fails, others can take over.
- **Redundancy:** Using redundant components or resources to ensure that if one fails, another can take over.
- **Error Detection and Recovery:** Implementing mechanisms to detect errors and automatically recover from them.
- **Fault-Tolerant Protocols:** Designing protocols that can tolerate failures and continue to function.
- **Examples:**
- Using checkpointing to save the agent's state periodically.
- Replicating agents to ensure that if one fails, another can take over.
- Implementing error detection and recovery mechanisms to automatically recover from failures.
- Using fault-tolerant protocols to ensure that the system can continue to function despite failures.

Transaction Processing in Mobile Environment

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Computing Technologies are the technologies that are used to manage, process, and communicate data. In this article, we will learn about Transaction Processing

in Mobile Computing. A transaction processing system allows application programmers to concentrate on writing code that will allow users to perform transactions simultaneously without bothering about what other users may be doing with their transactions at the same time:

- It manages the concurrent processing of transactions.
- It enables the sharing of data.
- It ensures the integrity of data.

Issues in Transaction Processing

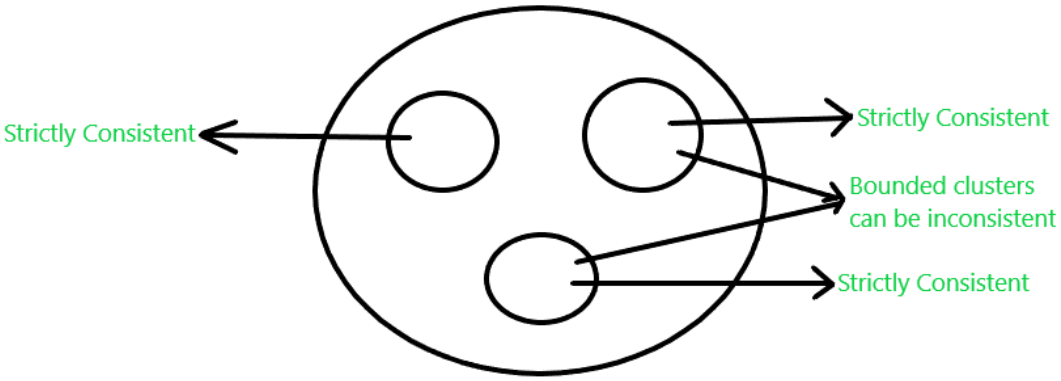
Database applications are normally structured into transactions. The transaction is a type of operation that makes sure that database does not change into an inconsistent state to disrupt the transactions.

One important aim in the design of any database system is to maximize the number of transactions that can be active at a time. DBMS ensures serializability using ACID constraints:

- Atomicity
- Consistency
- Isolation
- Durability

ACID properties have been redefined to support transactions in the mobile environment are:

Atomicity Relaxation: Mobile Host is allowed to submit pieces of the transaction from different cells according to the movement. It requires the ability to break a transaction into many sub-transactions that can be concurrently executed.
Consistency Relaxation: The database is logically partitioned into "clusters" based on some attributes. Data in the same cluster must be strictly consistent. Although the bounded degree of inconsistency is tolerated among the clusters.



The above figure describes three clusters inside a bounded region.

Isolation Relaxation: The intermediate results of a transaction can be observed by other concurrent transactions. For example, if T1 is a transaction process and T2 is another transaction process then T1 should not be visible to T2.

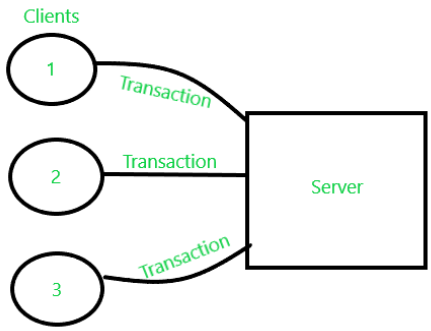
T1	
	T2

T1 and T2 are two transaction processes where the operation of T1 is not seen by T2.

Durability Relaxation: A disconnected Mobile Host can only commit a transaction locally if this transaction does not conflict with other transactions executed on the same HOST while HOST was disconnected.

Transaction Processing Environment

1. Centralized Environment: Single user system executes all the transactions.
2. Client Server Environment: Transaction and transaction initiation are done by the server and client respectively. Many clients can send transactions to servers simultaneously.



3. Distributed Environment: Data is distributed over a network. The transaction can occur fully on a node or partially on a different node.
4. Mobile Environment: Special type of distributed environment can accommodate user movements while processing transactions.

Issues in Mobile Environment

- **User Movement:** Tracking users, and data recovery are complicated. LOG location determination is complex.
- **Disconnections:** There may be temporary disconnections due to noise, fading of signal, handoff, etc. If there are planned disconnections, then the mobile user can perform some operations by downloading data beforehand. It can be referred to as data hoarding. Another way to deal with disconnection is by migrating transaction processing to a non-mobile computer. One more approach is maintaining proxy agents at MSS(Mobile Satellite Service). The process includes representing Mobile Host(MH) during its absence and participating in communication and finally handing over control to MH as it reappears.

- **Poor Communication Media-** Bandwidth allocated to mobile users could be very low. Interference from other traffic, noise, etc may corrupt data. MH tends to disconnect from the network whenever there is no data to send or receive in the near future.
- **Processing Power-** With a less powerful CPU, database server operation is difficult.
- **Memory-** Memory availability is limited.
- **Battery Power-** Like memory, battery power is also limited.
- **User Interface-** It should be designed keeping in mind resource restrictions.
- **Security-** Chances of data theft and unauthorized access increases while MH moves from one cell to another.

Introduction of Mobile Ad hoc Network (MANET)

- MANET stands for Mobile Adhoc Network also called a wireless adhoc network or Adhoc wireless network that usually has a routable networking environment on top of a Link Layer ad hoc network. They consist of a set of mobile nodes connected wirelessly in a self-configured, self-healing network without having a fixed infrastructure. MANET nodes are free to move randomly as the network topology changes frequently. Each node behaves as a router as it forwards traffic to other specified nodes in the network.

  What is MANET?

  A MANET is a decentralized wireless network consisting of mobile devices (nodes) that communicate with each other without relying on a fixed infrastructure. MANET forms a highly dynamic autonomous topology with the presence of one or multiple different transceivers between nodes. MANETs consist of a peer-to-peer, self-forming, self-healing network MANETs circa 2000-2015 typically communicate at radio frequencies (30MHz-5GHz). This can be used in road safety, ranging from sensors for the environment, home, health, disaster rescue operations, air/land/navy defense, weapons, robots, etc.

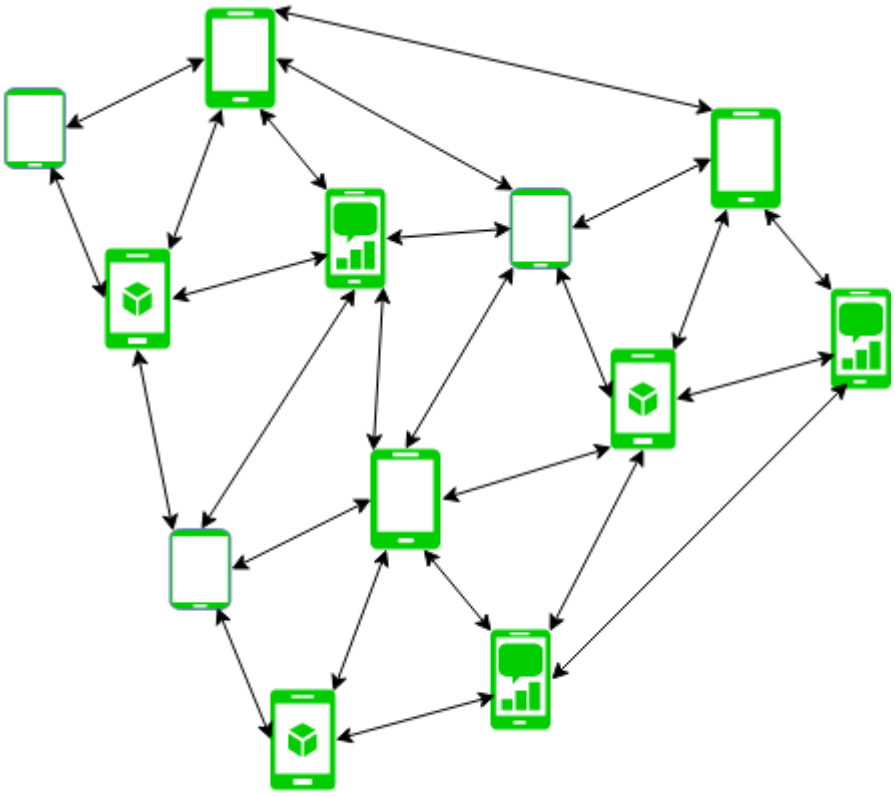


Figure - Mobile Ad Hoc Network

Characteristics of MANET

- **Dynamic Topologies:** Network topology which is typically multihop may change randomly and rapidly with time, it can form unidirectional or bi-directional links.
- **Bandwidth constrained, variable capacity links:** Wireless links usually have lower reliability, efficiency, stability, and capacity as compared to a wired network
- **Autonomous Behavior:** Each node can act as a host and router, which shows its autonomous behavior.
- **Energy Constrained Operation:** As some or all the nodes rely on batteries or other exhaustible means for their energy. Mobile nodes are characterized by less memory, power, and lightweight features.
- **Limited Security:** Wireless networks are more prone to security threats. A centralized firewall is absent due to the distributed nature of the operation for security, routing, and host configuration.
- **Less Human Intervention:** They require minimum human intervention to configure the network, therefore they are dynamically autonomous in nature.

Advantages of MANET

- Separation from central network administration.
- Each node can play both the roles ie. of router and host showing autonomous nature.

- Self-configuring and self-healing nodes do not require human intervention.
- Highly scalable and suits the expansion of more network hub.

Disadvantages of MANET

- Resources are limited due to various constraints like noise, interference conditions, etc.
- Lack of authorization facilities.
- More prone to attacks due to limited physical security.
- High latency i.e. There is a huge delay in the transfer of data between two sleeping nodes.

Improvement in MANET

- **Quality of Service (QoS):** Researchers are working to improve the quality of service of MANET by developing efficient routing protocols that provide better bandwidth, throughput, and latency.
- **Security:** To ensure the security of the MANET, researchers are developing efficient security mechanisms that provide encryption, authentication, and authorization facilities.
- **Power management:** To enhance the lifetime of MANET nodes, researchers are working on developing efficient power management techniques that reduce the energy consumption of nodes.
- **Multimedia support:** Researchers are working to provide multimedia support to MANET by developing efficient routing protocols that can handle multimedia traffic efficiently.
- **Standardization:** To ensure the interoperability of different MANET devices, researchers are working on developing standard protocols and interfaces that can be used by different MANET devices.

Applications of MANET

- Military and Defense Operations
- Healthcare
- Sensor Networks
- Wireless Sensor Networks
- Internet of Things (IoT)

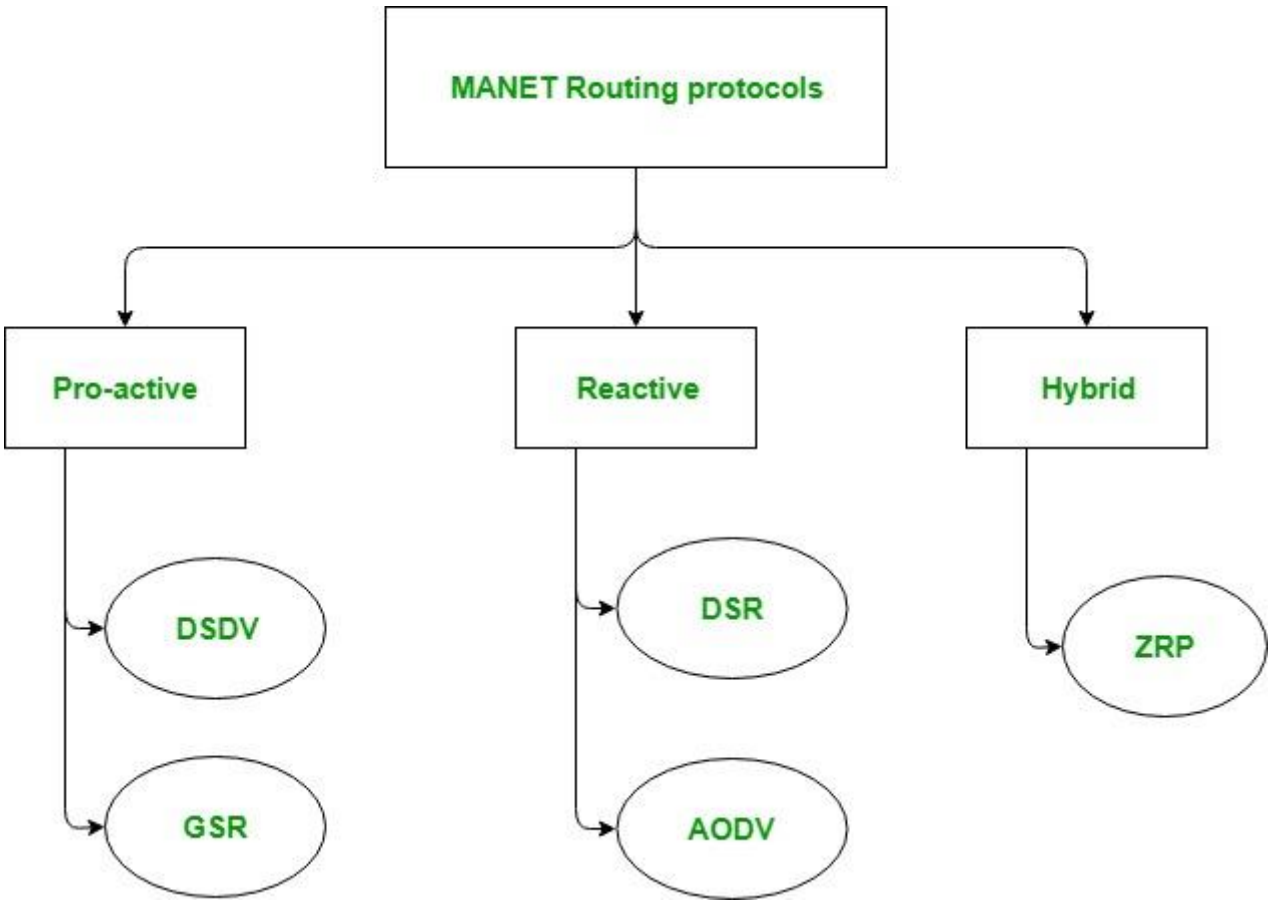
Conclusion

Mobile Ad hoc Networks (MANETs) are decentralized, self-configuring, and self-healing wireless networks made up of mobile nodes. They provide flexibility, scalability, and independence from fixed infrastructure, making them ideal for a wide range of applications, including military operations, disaster recovery, healthcare, sensor networks, and the Internet of Things (IoT). With limitations such as limited resources and security concerns, continuous research strives to

improve their quality of service, security, power management, and multimedia support, increasing their dependability and efficiency across multiple domains.

MANET Routing Protocols

In Mobile Ad hoc Network (MANET), nodes do not know the topology of their network, instead they have to discover it by their own as the topology in the ad-hoc network is dynamic topology. The basic rules is that a new node whenever enters into an ad-hoc network, must announce its arrival and presence and should also listen to similar announcement broadcasts made by other mobile nodes.



1. Pro-active routing protocols: These are also known as table-driven routing protocols. Each mobile node maintains a separate routing table which contains the information of the routes to all the possible destination mobile nodes.
Since the topology in the mobile ad-hoc network is dynamic, these routing tables are updated periodically as and when the network topology changes. It has a limitation that it doesn't work well for the large networks as the entries in the routing table becomes too large since they need to maintain the route information to all possible nodes.

1. **Destination Sequenced Distance Vector Routing Protocol (DSDV):** It is a pro-active/table driven routing protocol. It actually extends the distance vector routing protocol of the wired networks as the name suggests. It is based on the Bellman-ford routing algorithm. Distance vector routing protocol was not suited for mobile ad-hoc networks due to count-to-infinity problem. Hence, as a solution Destination Sequenced Distance Vector Routing Protocol (DSDV) came into picture.
   Destination sequence number is added with every routing entry in the routing table maintained by each node. A node will include the new update in the table only if the entry consists of the new updated route to the destination with higher sequence number.
2. **Global State Routing (GSR):** It is a pro-active/table driven routing protocol. It actually extends the link state routing of the wired networks. It is based on the Dijkstra's routing algorithm. Link state routing protocol was not suited for mobile ad-hoc networks because in it, each node floods the link state routing information directly into the whole network i.e. Global flooding which may lead to the congestion of control packets in the network. Hence, as a solution Global State Routing Protocol (GSR) came into the picture. Global state routing doesn't flood the link state routing packets globally into the network. In GSR, each of the mobile node maintains one list and three tables namely, adjacency list, topology table, next hop table and distance table.
3. **Reactive routing protocols:** These are also known as on-demand routing protocol. In this type of routing, the route is discovered only when it is required/needed. The process of route discovery occurs by flooding the route request packets throughout the mobile network. It consists of two major phases namely, route discovery and route maintenance.

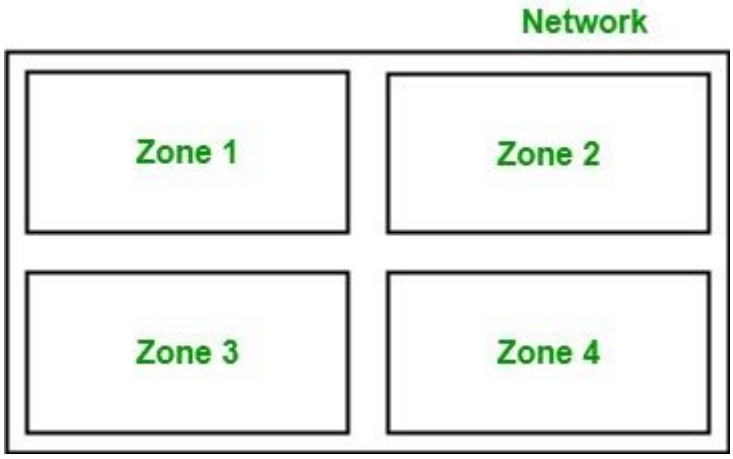
    1. **Dynamic Source Routing protocol (DSR):** It is a reactive/on-demand routing protocol. In this type of routing, the route is discovered only when it is required/needed. The process of route discovery occurs by flooding the route request packets throughout the mobile network. In this protocol, Source node stores the complete path information and intermediate nodes do not need to maintain routing information. It consists of two phases:
        - **Route Discovery:** This phase determines the most optimal path for the transmission of data packets between the source and the destination mobile nodes.
        - **Route Maintenance:** This phase performs the maintenance work of the route as the topology in the mobile ad-hoc network is dynamic in nature and hence, there are many cases of link breakage resulting in the network failure between the mobile nodes.

    2. **Ad-Hoc On Demand Vector Routing protocol (AODV):** It is a reactive/on-demand routing protocol. It is an extension of dynamic source routing protocol (DSR) and it helps to remove the disadvantage of dynamic source routing

protocol. In DSR, after route discovery, when the source mobile node sends the data packet to the destination mobile node, it also contains the complete path in its header. Hence, as the network size increases, the length of the complete path also increases and the data packet's header size also increases which makes the whole network slow.

Hence, Ad-Hoc On Demand Vector Routing protocol came as solution to it. The main difference lies in the way of storing the path, in AODV Sourcenode does not stores complete path information, instead of that each not stores information of its previous and next node. It also operates in two phases: Route discovery and Route maintenance.

3. Hybrid Routing protocol: It basically combines the advantages of both, reactive and pro-active routing protocols. These protocols are adaptive in nature and adapts according to the zone and position of the source and destination mobile nodes. One of the most popular hybrid routing protocol is **Zone Routing Protocol (ZRP)**.
The whole network is divided into different zones and then the position of source and destination mobile node is observed. If the source and destination mobile nodes are present in the same zone, then proactive routing is used for the transmission of the data packets between them. And if the source and destination mobile nodes are present in different zones, then reactive routing is used for the transmission of the data packets between them.



Characteristics of MANET Routing Protocol:
To avoid the problems with routing in MANET, routing protocols should have following characteristics:

- It should be widely distributed.
- It must be localized.
- Because of nodes mobility, it should be adjustable to frequent change in topology.
- It must be free of impermeable routes.
- The convergence of routes must be fast.
- Each node in the network should be required to store information about the network's stable local topology.
- It should be able to provide high-quality service.