* Internet Based Mobile Ad-hoc Networking :-

→ A mobile Adhoc network (MANET) is an autonomous system of mobile nodes connected by wireless links.

→ A MANET does not necessarily need support from any existing n/w infrastructure like an Internet gateway or others fixed station.

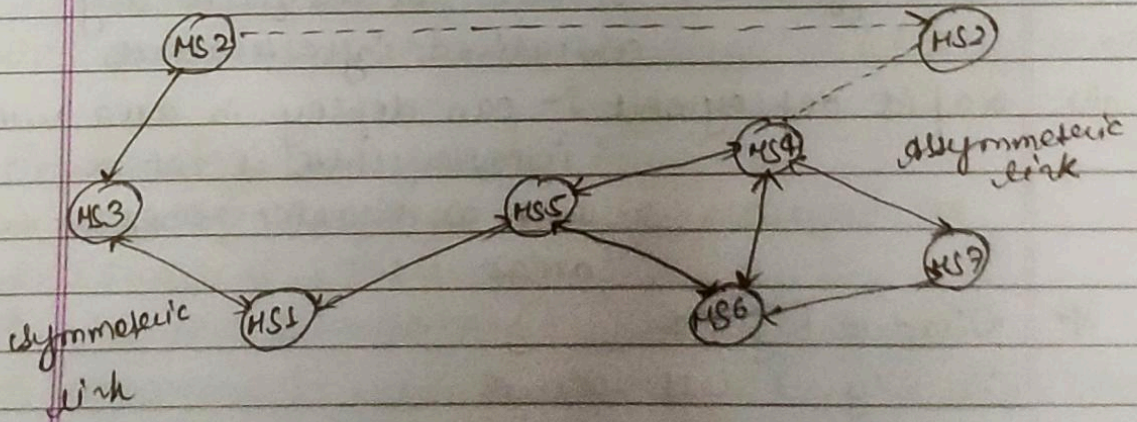
→ The n/w's wireless topology may dynamically change in an unpredictable manner since nodes are free to move.

→ Info. is transmitted in a store and forward manner using multi-hop routing.

→ Each node is equipped with a wireless transmitter and a receiver with an appropriate antenna.

→ It is not possible to have all nodes within each other's radio ~~range~~ range when the nodes are close by i.e., within radio range, there is no routing issue.

→ Each node behaves as a router as they forward traffic to other specified nodes in the n/w.



* Characteristics of Ad-Hoc N/Ws :-

(i) Dynamic Topologies :- N/w topology may change dynamically as nodes are free to move.

(ii) Bandwidth constrait, variable capacity links & Wireless links usually have lower reliability, efficiency, stability and capacity as compared to wired n/w.

(iii) Autonomous behaviour :- Each node act as a host and router.

(iv) Limited security :- more prone to security threats.

(v) Less human intervention :- requires less human intervention, ∴ dynamically autonomous in nature.

* Advantages :-

(i) Flexibility :- highly flexible and can deploy in diff. environment

(ii) Scalability :- easily accomodate large no. of nodes.

(iii) cost-effective :- ∵ does not require any centralized infrastructure

(iv) Rapid deployment :- can deploy in area where infrastructure is not available, such as disaster zones or rural areas.

* Disadvantages :-

(i) Security → less secure

(ii) Reliability → less reliable and diff. factors affect the quality of connection.

(iii) Bandwidth :- limited bandwidth
(iv) Routing :- complex Routing
(v) Power consumption is high.

* Appln :-
(i) Virtual Navigation
(ii) Tele-medicine
(iii) Tele-geo processing
(iv) Crisis management
(v) Education via internet

* Routing in MANETS :-
(i) Provides max^m reliability → uses alternative routes if an intermediate node fails
(ii) Choose a route with least cost metric.
(iii) Route computation must be distributed. Centralized routing is usually very expensive.
(iv) Every node must have quick access to routes on demand.
(v) Each node must be only concerned about the routes to its destination.
(vi) Broadcasts should be avoided (highly unreliable)

* Routing classification :-
→ Routing Protocols can be classified as
(i) Proactive (Table-driven)
(ii) Reactive (on-demand)
(i) Proactive :- when a packet needs to be forwarded route is already known
(ii) Reactive :- Determine route on demand

	Proactive	Reactive
(i)	level of delay is low because routes are pre-determined	High
(ii)	Period update is always required	does not require
(iii)	Routes are always available	Compute on demand
(iv)	Structure of Route is flat / hierarchial	Flat

* Routing protocols may also be categorized as,
  - Table Driven Protocols
  - Source Initiated (on-demand) Protocols

* Table-Driven Routing protocols :-
→ Each node maintains routing info. to all other nodes in the n/w.
→ when topology changes, updates are propagated throughout the n/w.
→ Examples are :-
  - Destination Sequenced Distance Vector Routing (DSDV)
  - Cluster-Head Gateway Switch Routing (CGSR)
  - Wireless Routing Protocol (WRP)

(DSDV)

* Destination Sequenced Distance Vector Routing :-

→ DSDV is a hop-by-hop vector Routing algo. requiring each node to periodically broadcast routing updates.

→ It uses proactive protocol and is based on Bellman-Ford routing mechanism.

→ Each node maintains a routing Table with entries as no. of hops to each destination, sequence no. which helps to distinguish stale (already visited) routes from new ones thereby avoiding loops.

→ To minimize routes variable sized update packets are used depending on the no. of topological changes.

→ Routing tables updates in DSDV are distributed by 2-different types of update packets :-

(i) Full-Dump :- this type of update packet contains all the routing info. available at a node.

(ii) Incremental :- contains only the info. that has changed since the latest full dump was sent out by the node

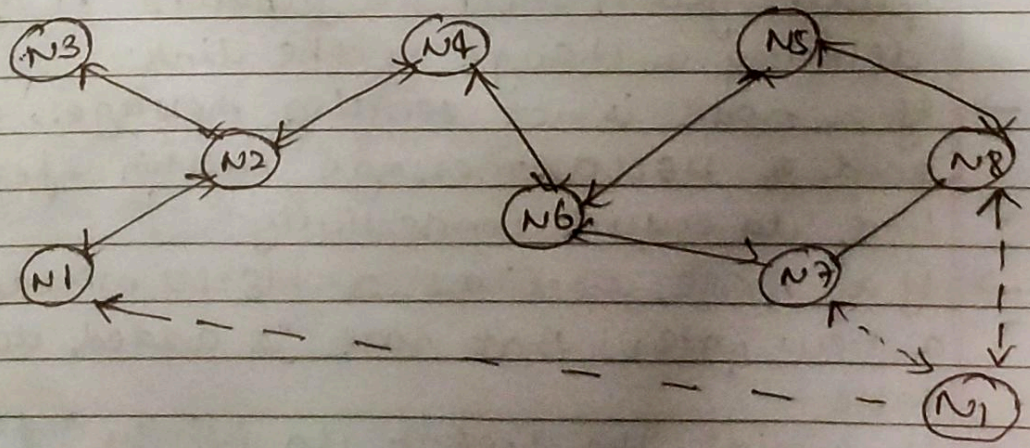


Table-1

Routing Table at Node 4

Dest.	Metric	Seq. no.
N1	2	S406-N2
N2	1	S128-N2
N3	2	S564-N2
N4	0	S710-N6
N5	2	S392-N6
N6	1	S076-N6
N7	2	S128-N6

Table-2

R.T. updated for node

Dest.	Metric	Seq. no.
N1	3	S816-N6
N2	1	S288-N2
N3	2	S674-N2
N4	0	S820-N4
N5	2	S502-N6
N6	1	S186-N6
N7	2	S238-N6

* The wireless routing Protocol :-

→ Each node maintains 4-tables.

① Distance table
② Routing table
③ Link cost table
④ Message Retransmission list Table (MRL)

→ Nodes inform each other of link changes using update messages.

→ Nodes send update messages after processing updates from their neighbours or after detecting a change in the link.

→ If a node is not sending messages, it must send a HELLO message within specified time to ensure connectivity.

→ If a node receives a HELLO message from a new node, that node is added to the table.

→ It avoids the "count to infinity" problem.

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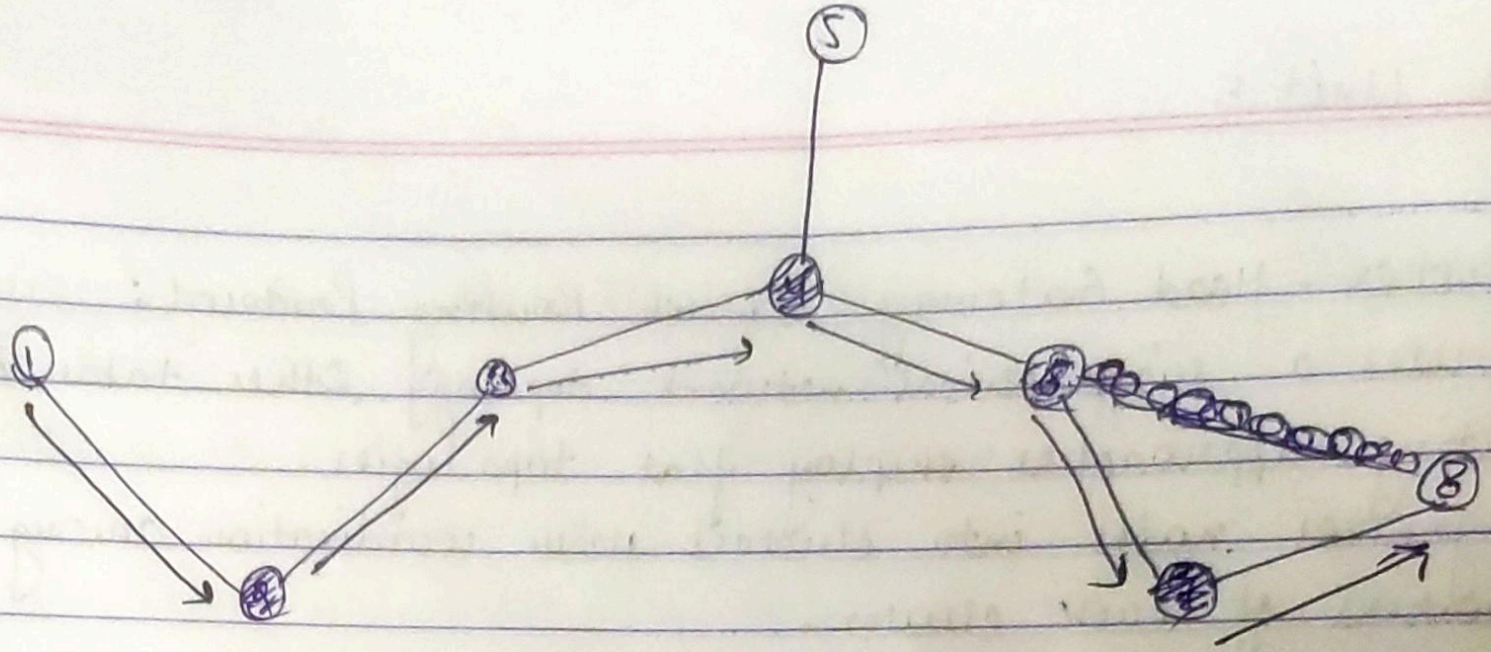
* On-Demand Routing Protocol :-

1. Ad-Hoc On-Demand Distance Vector (AODV)
2. Dynamic Source Routing (DSR)
3. Temperary ordered Routing Algo. (TORA)
4. Associativity Based Routing (ABR)
5. Signal Stability Routing (SSR)

NRA Unit 5

(x) Cluster - Head Gateway Switch Routing Protocol:

- It uses a hierarchical network topology. Other table driven routing approaches employ flat topologies.
- Organizes nodes into clusters with coordination among the members of each cluster.
- Cluster head is employed dynamically by using least Cluster Change (LCC) algorithm.
  - → According to LCC, a node ceases to be the cluster head only if it comes in the range of another cluster head.
  - → Clustering provides a method to allocate bandwidth.
  - → All the member nodes within a cluster can be reached by the cluster head within a single hop. This improves coordination among nodes.
  - → CGSR assumes that all communication passes through cluster-head.
  - → Communication b/w two clusters take place through the common members nodes.
  - → These nodes which are members of more than one cluster are called gateways.
  - → Performance of routing is influenced by token scheduling and code scheduling that are handled at cluster heads and gateways respectively.
  - → The routing protocol used in CGSR is an extension of DSDV.
  - → Every member node contains a routing table containing destination cluster head for every node.
  - → Every node maintains a cluster member table. Routing table also keeps the list of the next-hop nodes.
  - → When a node with packets is to be transmitted to a destination gets token from its cluster head, obtains destination cluster head and next hop node from cluster member table & routing table.
  - → Main disadvantages are increase in path length and instability in the system at high mobility.



1, 5, 8 → Node

3, 6 → Gateway

2, 4, 7 → Cluster head.

(*). Ad Hoc on demand Distance vector Routing Protocol (AODV)

→ Route is established only when it is required by a source node for transmitting data packets.

→ It employs destination sequence number to identify most recent path.

→ Source node and intermediate nodes contain the next hop information.

→ Destination Sequence Number is used to determine an up-to-date path to destination.

→ A Route Request carries: → Source Identifier, destination identifier, Source Sequence Number, Destination Sequence Number, Broadcast Identifier and Time to Live field.

→ When an Intermediate node receives a Route request, it either forwards it or prepares a Route Reply if there is a valid route to the Destination.

→ If a route request is received multiple times, then the duplicate copies are discarded.

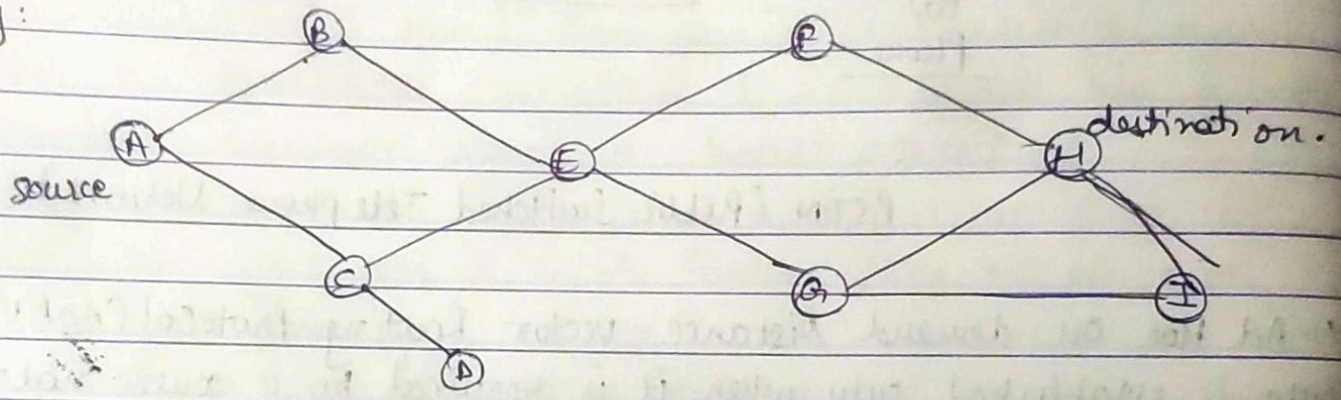
→ AODV does not repair a broken path locally. When a link breaks, the end nodes are notified. The Source Node re-establishes the route to destination if required.

Operations: → ① Route Discovery
↳ RREQ packet
↳ RREP packet

② Route Maintenance
↳ RERR packet.

→ The source node will not carry the complete path.
→ Each node knows the previous & the next hop.

Eg:



3 possible routes:

① A → B → E → F → H } Hop count = 4
② A → C → E → G → H } Hop count = 4
③ A → C → E → G → J → H } Hop count = 5 ✗ Max Hop count. Discard.

In this way we can find the best route by calculating Hop Count.

Advantages: ① Connection setup delay is less.
② Routes are established on demand.

Disadvantages: ① Intermediate nodes can lead to inconsistent routes.
② Multiple Route Reply packets to single Route Request packet can lead to heavy control overhead.

(*). Dynamic Source Routing Protocol (DSR)

→ Designed to restrict bandwidth consumed by eliminating the periodic table update messages.

→ Does not require periodic Hello packet transmissions.

→ Basic approach is to establish a Route by flooding Route Request packets in the n/w.

→ Destination node responds by sending a Route Reply Packet back to the source.

→ Each Route Request carries a sequence no. generated by source node.

→ The packet is forwarded only if it is not a duplicate Route Request.

→ The sequence number on the packet is used to prevent loop formations and multiple transmissions.

→ This protocol uses a route cache that stores all the possible information extracted from the source route.

→ for optimization, the intermediate nodes are also allowed to originate Route Reply packets.

→ The source node selects the best route from multiple replies and then uses that for sending data packets.

→ Each data packet carries complete path to its destination.

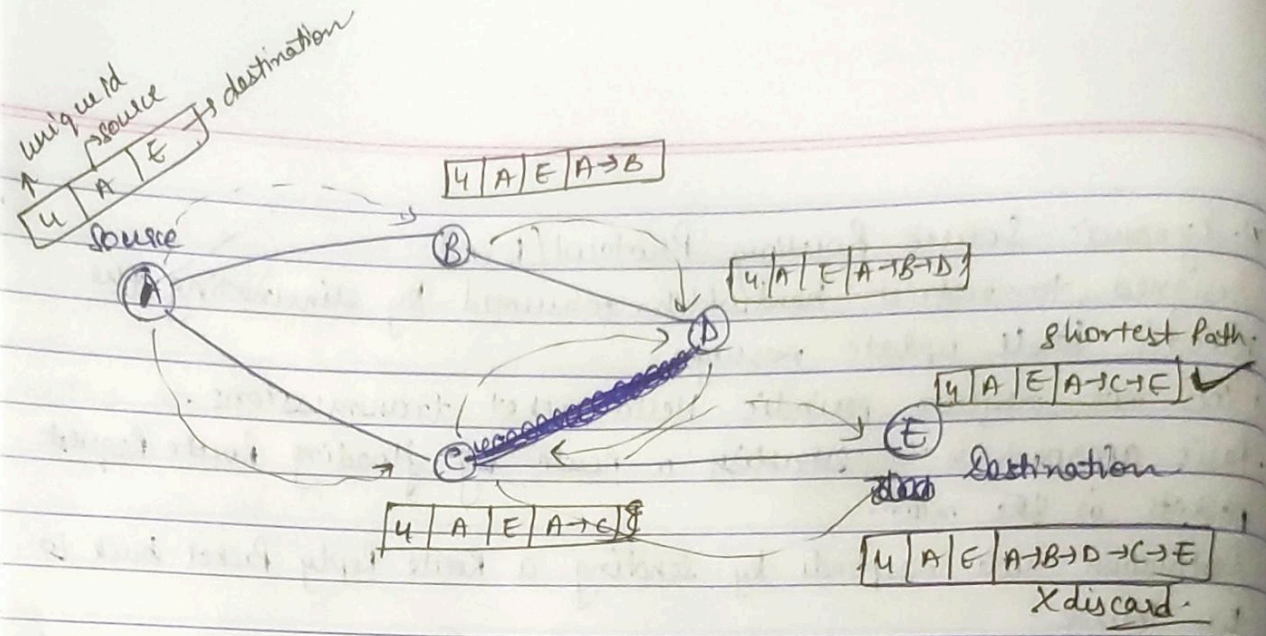
→ If a link breaks, source node again initiates the route discovery process.

→ Phases: Route Discovery — Route Maintenance

↳ RREQ packet (broadcast) ↳ RERR message

↙ Source Node ID ↘ Destination node ID

↳ RREP packet (unicast)



We find the shortest path that is A→C→E.
Now E will reply to C with complete packet and C will reply to A with complete packet.
Now A will have complete information about the path.

(*) Hybrid Routing Protocols:

(*) Core Extraction Distributed Ad Hoc Routing Protocol (CEDAR):
→ CEDAR integrates routing and support for QoS.
→ Based on extracting Core Nodes (also called Dominator Nodes) in the Network.
→ Core nodes together approximate the Minimum Dominating Set.
→ There exists atleast one core node within every three hops.
→ The nodes that choose the core node as their dominating node are called core member nodes of the core node concerned.
→ The path between two core nodes is termed as a virtual link.
→ CEDAR employs a distributed Algo. to select core nodes.
→ Selection of core nodes represent the core extraction phase.
→ CEDAR uses core broadcast mechanism to transmit any packet throughout the network in the unicast mode.
→ Transmission involves minimum no. of nodes possible.

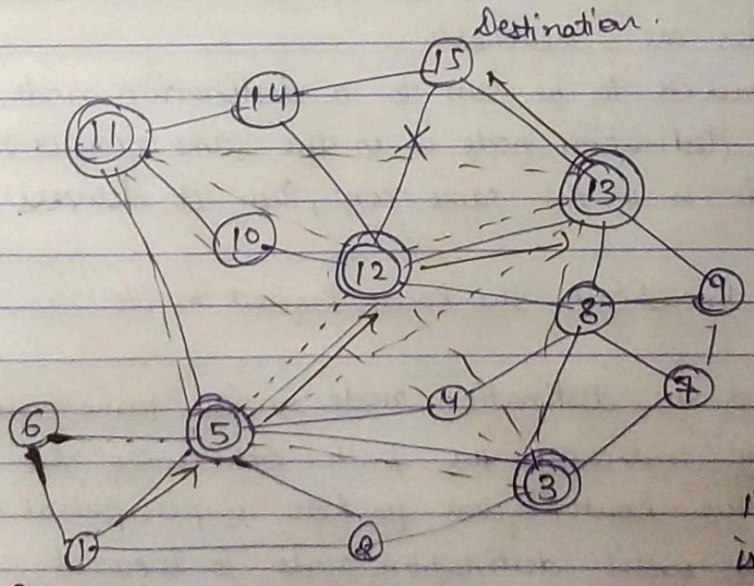
→ Route establishment in CEDAR is done in two phases:
(i) First Phase finds a core path from source to destination.
(ii) In the second phase, the QoS feasible path is found over the core path.

→ A node initiates a Route Request if the destination is not in the local topology table of its core node. Otherwise the path is established immediately.

→ A core node which has destination node as its core member replies to the source core.

→ A node after which break occured: → Sends the notification of failure.
→ Begins to find a new path from it to destination.
→ Rejects every received packet till it finds the new path to destination.

→ Meanwhile, as the source receives the notification message:
→ It stops to transmit.
→ It tries to find a new path to destination.



---- Virtual link
○ → Normal Node
◎ → Core node

Final path: 1 → 5 → 12 → 13 → 15

13 is chosen because it is the nearest core node from the destination.

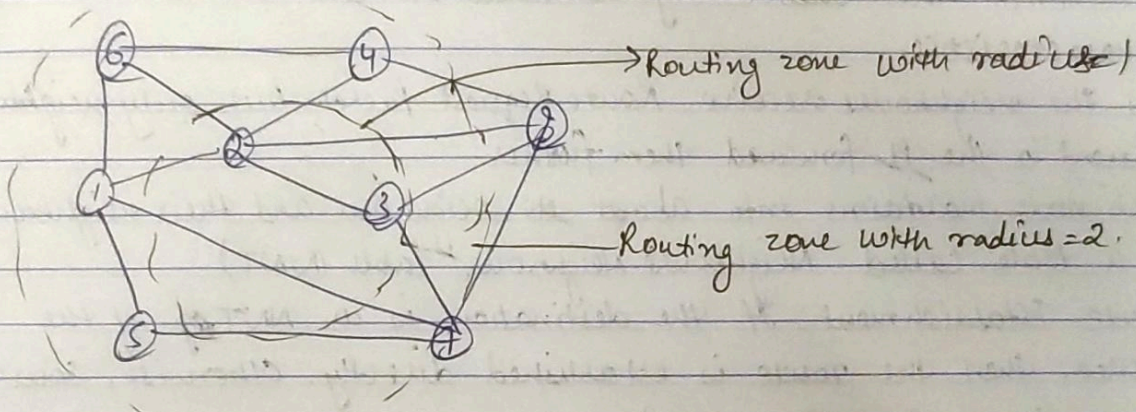
(*). Advantages: (i). Performs both Routing & QoS path computation efficiently with the help of core nodes.
(ii). Utilization of core nodes reduces traffic overhead.
(iii). Reliable mechanism for establishing paths.

(*). Disadvantages: (i). Movement of core nodes adversely affects the performance of protocol.
(ii). Core node update information causes control overhead.

(*). Zone Routing Protocol:
→ Combines the best features of both Proactive and Reactive routing protocols.
→ Uses the proactive scheme within a limited zone in the r-hop neighbourhood of every node.
→ Uses the Reactive scheme for nodes beyond this.
→ Intra zone (IARP) Routing Protocol is used for Proactive scheme.
→ Inter zone (IERP) Routing Protocol is used for Active scheme.
→ Routing zone of a given node is the subset of the n/w within which all nodes are reachable.
→ When a node has packets to be sent to a destination node, it checks whether the destination node is in the same zone or not.
→ If the destination node is in the same zone, then it delivers the packet directly.
→ Otherwise, source node broadcasts the Route Request to its Peripheral nodes.
→ If peripheral nodes find the destination node in the same zone, they send a RouteReply indicating the path. Otherwise the node rebordercasts the RouteRequest packets to peripheral nodes.
→ This process continues until destination node is located.
→ Every node that forwards RouteRequest appends its address to it.

→ This info is used for delivering the RouteReply packet back to the source.

→ When an intermediate node detects a broken link, it performs a local path reconfiguration by means of a short alternate path connecting the ends of the broken link.



→ Advantage: Reduce control overhead by combining best features of Proactive and Reactive Protocols.

→ Disadvantage: Control overhead may increase due to the large overlapping of nodes routing zones.

(*). Routing Protocols with efficient flooding Mechanisms:

→ Many protocols flood the nlw with RouteRequest packets in order to obtain a path to the destination.

→ Flooding of control packets results in → Wastage of bandwidth.
→ Increase in no. of collisions.

→ Protocols with efficient flooding mechanisms:

① Preferred link-based Routing Protocol (PLBR)

② Optimized Link State Routing Protocol (OLSR)

(*) - Preferred Link Based Routing Protocol:

→ Uses the preferred link approach by processing a Route Request Packet only if it is achieved through a strong link.

→ A Node selects the subset of nodes from its Neighbours List (NL). This subset is referred to as the Preferred List (PL).

→ Selection of this subset may be based on link or node characteristics.

→ All the neighbours receive Route Request Packet but only neighbours present in the PL forward them further.

→ Each node maintains info about its neighbour and their neighbours in a table called Neighbours Neighbour Table (NNT)

→ Route Establishment: If the destination is in NNT of the source, then the route is established directly. Otherwise, source transmits a Route Request Packet.

→ A node is eligible for forwarding Route Request only if:

(a). It should be present in PL. ✓

(b). RREQ packet must not have been already forwarded by the node and the TTL on the packet must be greater than zero.

→ If dest is in the eligible node's NNT, the Route Request is forwarded as a unicast packet to the neighbours.

→ If the RREQ packet reaches the destination, then the route selection is done.

→ When multiple RREQ packets reach dest, the best path is selected.

→ Criteria can be shortest path, or least delay path or most stable path.

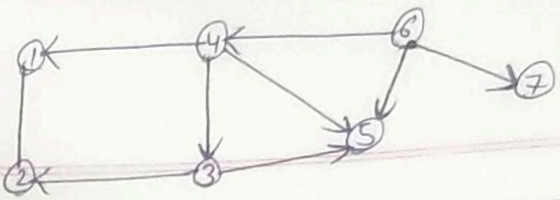
→ Destination starts a timer after receiving 1st RREQ packet. After a particular time, no RREQ packets are accepted.

→ Algorithms for preferred links computation:

(a) - NBPL (Neighbour-degree - Based Preferred Link Algorithm)

(b) - WBPL (Weight Based Preferred Link Algorithm).

Disadvantage → Computationally more complex.



(*) - Optimized link state Routing (OLSR):

→ Proactive Routing Protocol that employs an efficient link state packet forwarding mechanism called Multipoint Relaying (MPR).

→ This protocol optimizes the pure link state Routing Protocol.

→ Optimizations are done in two ways:

(a) - By reducing size of control packets.

(b) - By reducing the no. of links that are used to forward the link state packets.

→ The subset of links or neighbours that are designated for link state updates and are assigned the responsibility of packet forwarding are called multipoint Relays.

→ The set consisting of nodes that are multipoint Relays is referred to as MPR set.

→ Each node in the n/w selects the MPR set that processes and forwards every link state packet that the node originates.

→ The neighbour nodes that do not belong to MPR set process the packets but do not forward them.

→ In order to decide on the membership of the nodes in the MPR set, a node periodically sends Hello messages which contains:

(a) List of neighbours with which the node has bidirectional link.

(b) - List of neighbours whose transmission was received in recent past but with whom bidirectional links have not yet been confirmed.

→ The nodes that receive this Hello packet update their own two-hop topology tables.

→ The Neighbour table is used to store the lists of neighbours, the two hop neighbours and the status of neighbour nodes.

Advantages: (a) - Reduces Routing Overhead.

(b) Reduces the no. of broadcasts done.

(c) - Low connection setup time.

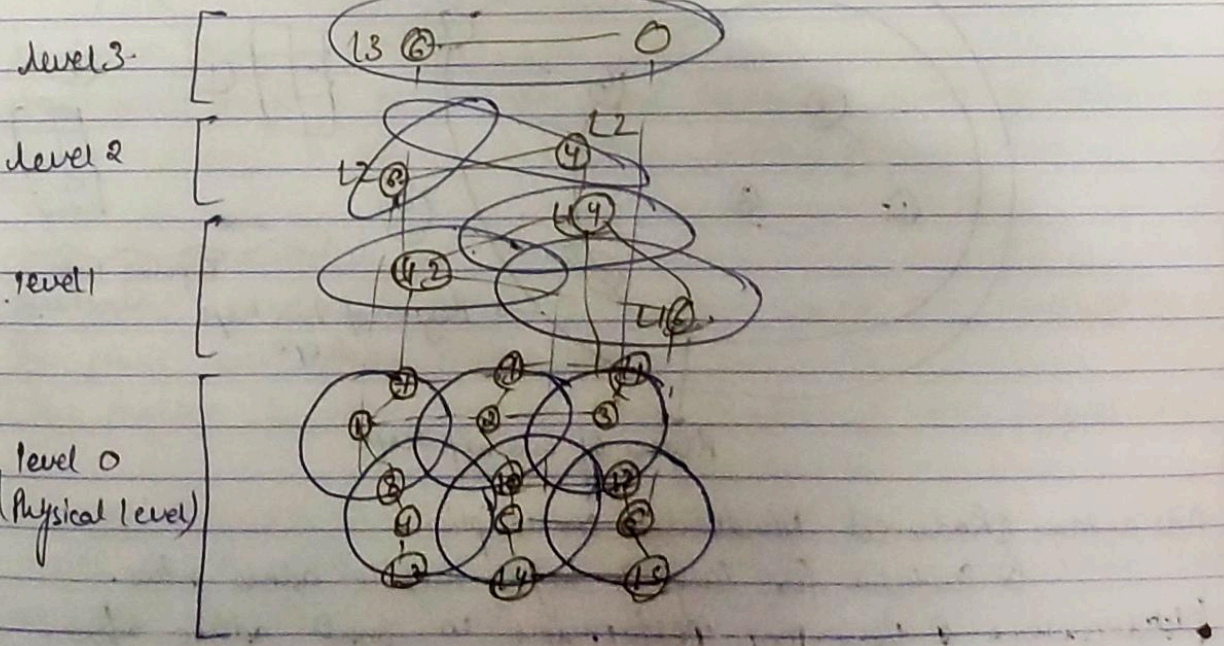
Unit 5 - (NRA)

(*). Hierarchical Routing Protocols:

→ Advantages in use of routing Hierarchy: (a) Better Scalability
(b). Reduction in size of Routing Tables.

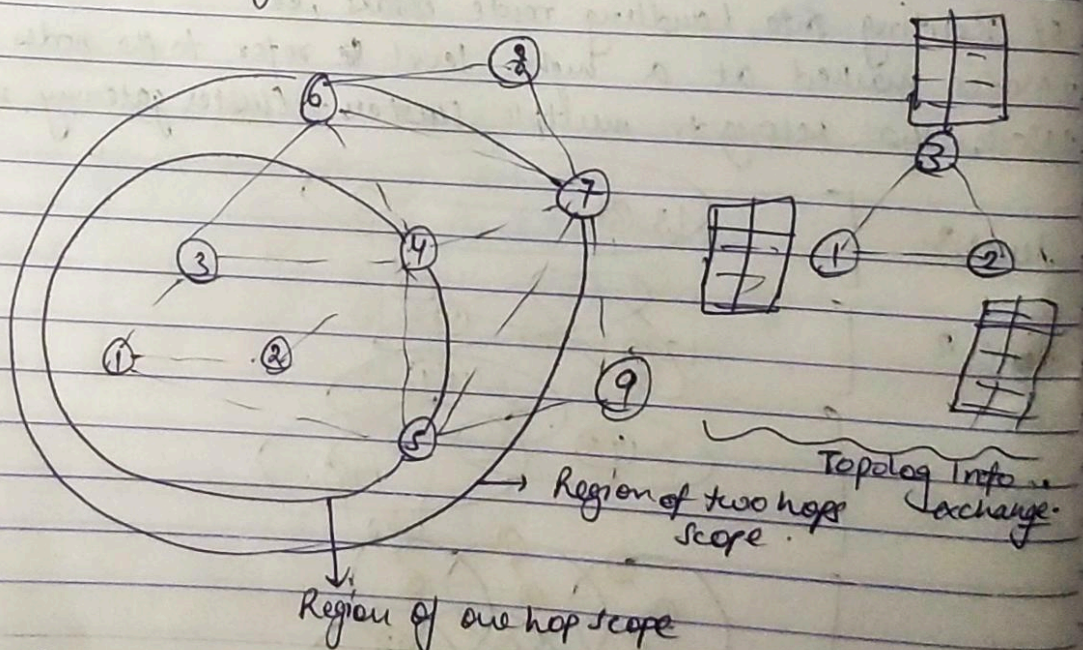
(*) Hierarchical State Routing Protocol:

→ Distributed multi-level hierarchical Routing Protocol. ✓
→ Employs clustering at different levels.
→ Each cluster has its leader.
→ Levels of Clustering:
(a). Physical: b/w Nodes that have physical wireless one-hop link b/w them.
(b). Logical: based on certain relations.
→ Cluster leader is entrusted with responsibilities such as exchange of Routing info, handling route breaks, etc.
→ Nodes marked at a higher level refer to the nodes of lower level.
→ Nodes that belong to multiple clusters → Cluster gateway nodes.



Disadvantage: ① Process of exchanging info at all levels of hierarchy is difficult.
② Process of electing leader for all clusters is difficult.

(2) Fish Eye State Routing Protocol (FSR)
→ Uses fish eye technique to reduce overhead.
→ Can capture pixel info with greater accuracy.
→ Thus accuracy decreases with increase in distance from center of focal point.
→ Each node maintains accurate info about near nodes.
→ Nodes exchange topology info only with their neighbours.
→ Link level info exchange of Distance Vector RP & complete topology info exchange of link state protocols.
→ FSR defines the set of nodes reachable in specific no. of hops.
→ Routing overhead is significantly reduced.



Advantages ① Reduced bandwidth consumption.
② Suitable for large & highly mobile adhoc nws.
Disadvantage: ① Very poor performance in small adhoc nws.

(*) Power Aware Routing Protocols:

→ Power Aware Routing Metrics:
(i) Limitation on the availability of Power is a significant bottleneck.
(ii) Use of Routing metrics contribute to efficient utilization of energy and increases lifetime of a nw.

→ Minimal Energy consumption per packet:
(i) This metric aims at minimizing the power consumed by a packet from traversing from source node to destination node.
(ii) Total Energy consumed is the sum of the energies required at every immediate hop.
(iii) This Metric doesnt balance load.
Disadvantages: → Selection of path with large hop length.
→ Inability to measure power consumption in advance.
→ Inability to prevent fast discharging of batteries at some nodes.

→ Maximize Nw connectivity:
(i) This metric helps to balance the load among the subset of nodes in Nw
(ii) It is difficult to achieve a uniform battery draining rate.

→ Maximum variance in Node Power levels:
(i) This metric proposes to distribute the load among all nodes in the Nw
(ii) The power consumption pattern remains uniform.
(iii) This problem is very complex when the size of data packets vary.

→ Minimum cost per packet:
(i) A node's cost decreases with an increase in its battery charge (vice-versa)
(ii) Cost can be easily computed.
(iii) Minimize the max. cost per node.
(iv) This delays the failure of a node.

(*) Quality of Service Routing for next Generation:

→ The upcoming high speed n/ws are expected to support a wide range of communication intensive real time applications.
→ One of the key issues is Quality of Service Routing.
→ It selects network routes with sufficient resources.
→ The goal is: (a) Satisfying QoS requirements for every connection.
(b) Achieving Global efficiency in resource Utilization.
→ The routing algorithms to achieve QoS Routing can be divided into:
(i) Source Routing Algorithms
(ii) Distributed Routing Algorithms.
(iii) Hierarchical Routing Algorithms.
→ QoS Routing is expected to direct n/w traffic in an efficient way that can maximize the total n/w throughput.
→ One common scheme is to always choose short path b/c longer path means using more n/w resources.

(*) Multiprotocol label Switching (MPLS)

→ MPLS is an IP packet Routing Technique that routes IP packets through paths via labels instead of looking at complex Routing tables of routers.
→ This feature helps in increasing the delivery Rate of IP packets.
→ It uses layer 3 service, i.e., Internet Protocol and uses router as a forwarding device.
→ The traffic of different customers is seperated from each other b/c MPLS works somewhat like VPN.
→ It does not encrypts but makes sure packet from one customer cannot be received by other customer.
→ MPLS header is added to packets that lie b/w layers 2 & 3.
→ Hence, it is also called layer 2.5 protocol.

→ MPLS Header: 32 bits long divided into 4 parts:

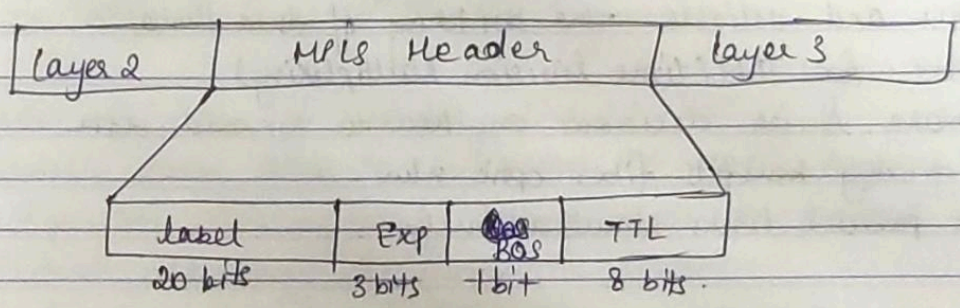
(i) Label : (20 bit)

(ii) Exp : 3bit (used for QoS)

(iii) Bottom of Stack (S): 1 Bit.

(iv) Time to live (TTL): 8 bit long. Value is decreased by 1 at every hop.

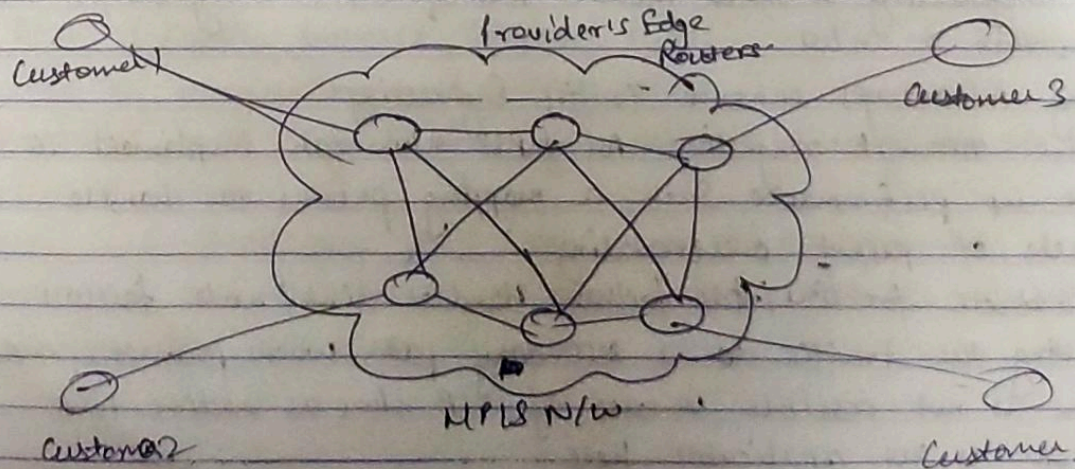
MPLS labels are stacked one over other. If there is only one label remained in MPLS header, then the value is 1 otherwise 0.



→ Label switch Router (LSR) receives an IP packet and adds MPLS header.

→ MPLS forwarding is based on label attached to IP packet.

→ This label attachment is regulated by a protocol called Label Distribution Protocol (LDP)



(*) Generalized Multi Protocol Label Switching:
→ Extending MPLS to manage further classes of switching technology other than Packet Switching.
→ Extends support to multiple types of switching such as TDM, wavelength
→ It is based on Generalized labels.
→ The MPLS label can represent: (a). a single fiber in a bundle.
(b). a single waveband within fiber.
(c). a single wavelength within a waveband.
(d). a set of time slots within a wavelength.
→ Enables fast and reliable nlw switching of data flows.
→ Adds support for TDM (Time Division Multiplexing).
→ Helps to make Quick decisions on how to forward data.
→ Its use greatly benefits fiber optic nlws.
→ It supports parallel links simultaneously.

(*). MPLS Traffic Engineering:
→ Traffic Engineering refers to selecting paths in order to balance load on various links, routers, switches, etc.
→ Goal of Traffic Engineering is to facilitate efficient IP nlws operations.
→ Traffic Engineering in MPLS involves technique of directing traffic that flows within a nlw.
→ following Advantages enhance Traffic Engineering:
(i) Minimize network congestion: An MPLS nlw can implement TE to boost up performance. Such a mapping process can handle bottlenecks of packet overcrowding.
(ii) Fast Reroute for link/node failure: Handles link/node failures by directing the traffic to a secondary path when primary one fails. This is not possible in case of IP nlws as redirecting mechanism is not applicable here.

(iii). Deployment flexibility: A TE system is efficient even when MPLS n/w is under-developed. It is flexible during situations when the overflowing packets from links are transferred to available links.

(iv). Class of service: 3 bit field. Based on this field, the traffic in its priority queue is used for transmission.

(v). Customer traffic identification: MPLS TE classifies the customer traffic based on the service provider used in MPLS N/w.

(*). Limitations of MPLS Traffic Engineering:

(i). Over-utilization of secondary links.

(ii). Manual path setup: To implement TE, paths require manual configuration. This manual setting needs professional solution providers.

(iii). Protocol dependency for automatic Rerouting:

(iv). Performance variation in MPLS fast reroute.

(v). Configuring intermediate nodes in MPLS is manually not achievable.

(vi). Lack of systematic Mapping System: The dynamic mapping of IP traffic on MPLS TE paths is not achievable.

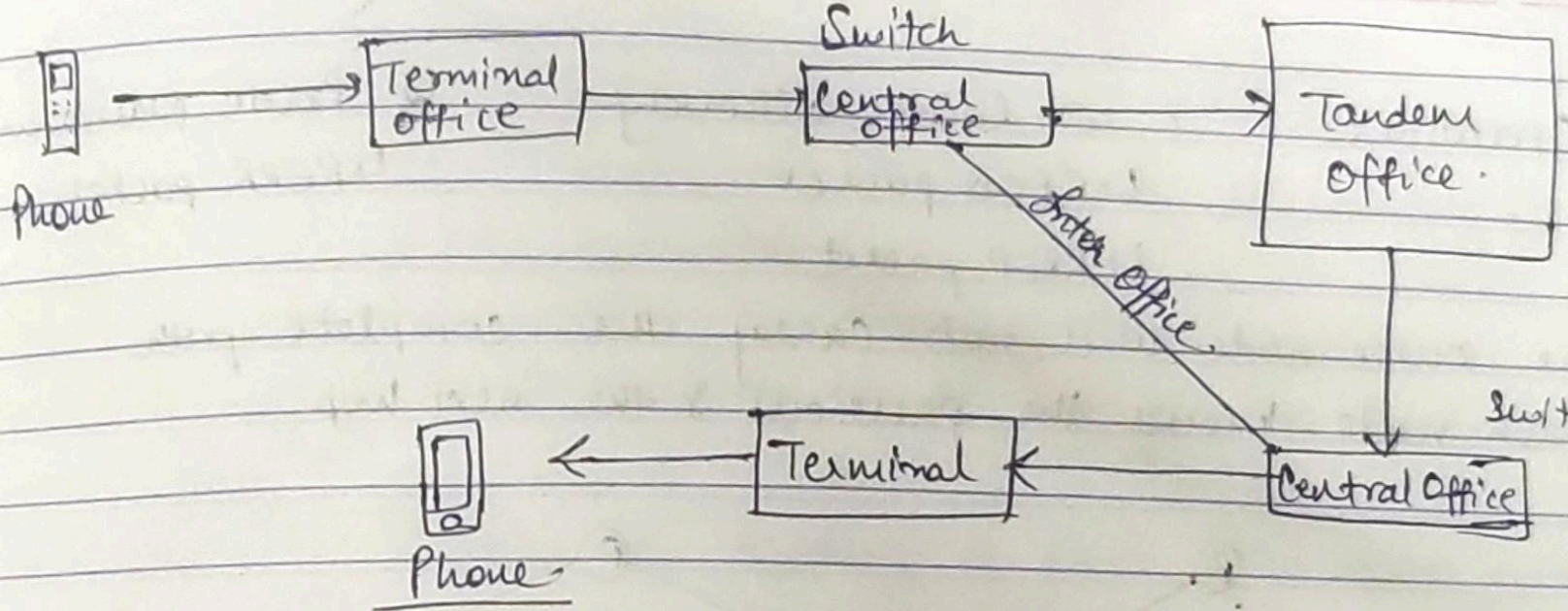
(*) PSTN (Public Switched Telephone N/w):

→ Works by using underground copper wires.

→ It carries voice signals from your telephone through the n/w to the recipients phone.

→ Costly and challenging. VoIP (Voice over IP) overcomes this.

→ VoIP sends and receives voice communication over the Internet rather than through old school PSTN.



PSTN (Public Switched Telephone Network).