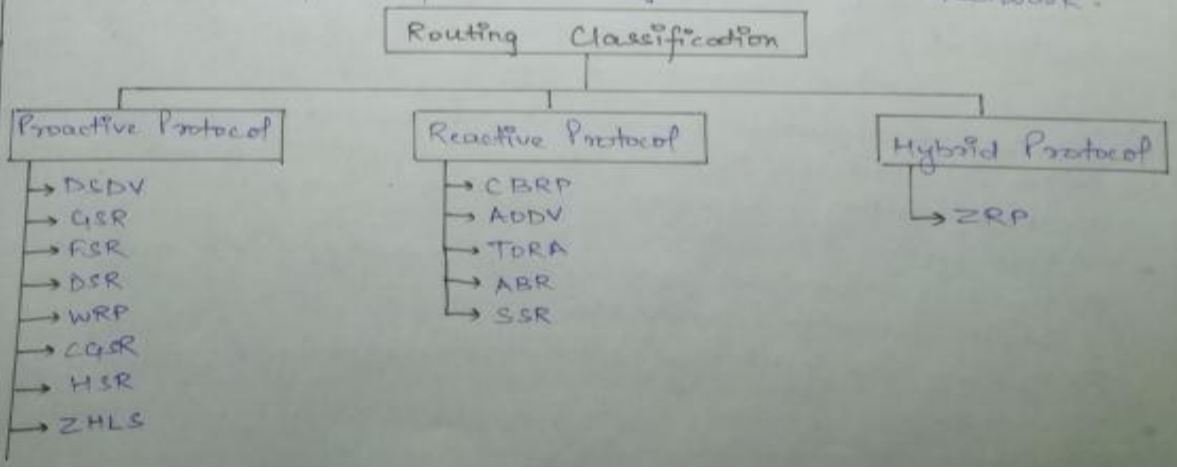
Q.1) Explain Routing protocols with example.

Ans) Routing is the process of finding the best path for traffic in a network, or across multiple networks. The role of routing is similar to the road map for a hotel. In both cases, we need to deliver messages at proper location and in an appropriate way.

Routing in a mobile ad-hoc network depends on many factors such as:

- Modeling of the topology
- Selection of routers
- Initiation of a route request,
- And specific underlying characteristics that could serve as heuristics in finding the path effectively.

In a MANET, each node or device is expected to reserve as a router, and each router is indistinguishable from another in the sense that all routers execute the same routing algorithm to compute paths through the entire network.



(1) Proactive Protocols:-

- These protocols attempt to evaluate continuously the routes within the network. It means proactive protocol continuously maintain the routing information, so that when a packet needs to be forwarded, the path is known already and can be immediately used. The family of distance vector protocols is an example of proactive scheme.
- The advantage of this is that whenever a route is needed, there is negligible delay in determining the route.
- Unfortunately, it is a big overhead to maintain routing tables in the MANET environment. Therefore, this type of protocol has following common disadvantages:
  - (*) Requires more amounts of data for maintaining routing info.
  - (*) Low reaction on re-structuring network and failures of individual nodes.

(2) Reactive Protocols:

- They do not maintain routes but invoke a route determination procedure only on demand or we can say reactive protocols build the routes only on demand. Thus, when a route is required, some sort of global search procedure is initiated. The family of classical flooding algo belongs to the reactive protocol group.
- Examples of reactive ad-hoc network routing protocols include adhoc on demand distance vector (ADOV) and temporarily ordered routing algorithm (TORA).
- Advantages:
  - (*) No large overhead for global routing table maintenance as in proactive protocols.
  - (*) Reaction is quick for n/w restructure and node failure.
- Disadvantages:
  - (*) Latency time is high in route finding.

* Excessive flooding can lead to n/w clogging.

③ Hybrid Protocols :

- It attempt to take advantage of best of reactive and proactive schemes. The basic idea behind such protocols is to initiate route discovery on demand but at a limited search cost.
- Example : One of the popular hybrid protocols is Zone Routing Protocol (ZRP).
- Disadvantages :
  The main disadvantages of such algorithms are :
  * Advantage depends on amount of nodes activated.
  * Reaction to traffic demand depends on gradient of traffic volume.

Que.2) Explain GSR (Global State Routing Protocol) with example.

Ans) Global state Routing :

- Global Global State Routing is based upon the fundamental concepts of link state routing.
- In Link State Routing (LSR), one of the node floods out a single routing table information to its neighbours and these neighbours floods out that table to further nodes. This process continue to take place until the routing table is received by all the nodes throughout the n/w.
- But in case of Global State Routing, the routing table of a particular node is broadcast-ed to its immediate neighbours only. Then initial tables of those neighbouring nodes are updated. These updated tables are further broadcast one by one and this process continues to take place until all the nodes broadcasts their tables to each node in the network.

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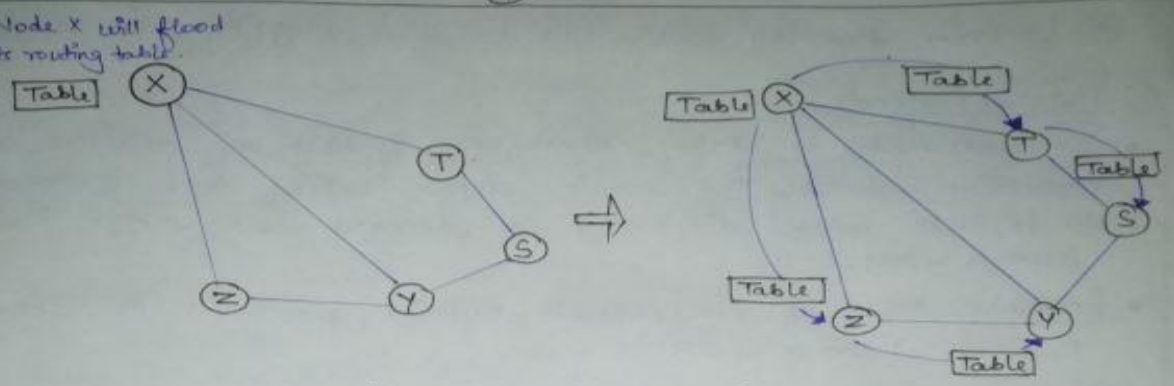

fig:> Concept: Link State Routing

- Concept: Global State Routing:
GSR Protocol uses and maintains three tables for every node individually. These tables are:

(1) Distance Table: This table contains the distance of a node from all the nodes in a network.

Format ⇒

Node	Distance

(GSR: Distance Table).

(2) Topology Table: This table contains the information of link state data along with the sequence number which can be used to determine when the information is updated last.

Format ⇒

Node	Link State	Sequence

(GSR: Topology Table)

(3) Next Hop Table: Next Hop table will contain the information about the immediate neighbour of a particular node.

Format ⇒

Node	Next Hop

(GSR: Next hop table)

* These tables are updated on every step and ensures that each node receives correct information about all the nodes including their distances.

- **Example:**

~~GSR is~~

Consider a n/w of 4 nodes having a distance of "1" on each of its edge. Below mentioned steps will let you know how GSR works and how its routing tables are updated.

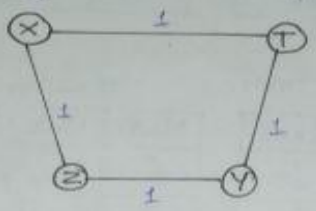

fig: GSR: Example N/w.

↳ **Steps:**

(1) **For Node "X":** Firstly three tables are mentioned above will be maintained which includes distance table, Topology table and Next hop tables. This same process will be done for the rest of the nodes too.

For "X"

Topology Table

Node	Link State	Sequence
X	{}	---
Y	{}	---
Z	{}	---
T	{}	---

Next Hop Table

Node	Link State
X	X
Y	-1
Z	-1
T	-1

Distance Table

Node	Distance
X	0
Y	Infinite
Z	Infinite
T	Infinite

(2) Secondly, broadcasting of all the tables will be done to all the immediate neighbours of "X" i.e. "Y" and "Z".

(3) These tables are updated at "X", "Y" & "T" nodes respectively.

(4) Same will be done for node "Y". After first updation from "X", node "Y" will broadcast the tables to its immediate neighbour i.e. "X" & "T" and these will be updated accordingly. This will be done for "T" & "Z" also.

(5) Once done, all the nodes "X", "Y", "Z" & "T" will be having the updated routing tables containing distances from each, with the help of which an optimal path can be chosen if data needs to be transferred from one node to other.

distances.

P.T.O.

For X:

Distance Table

Node	Distance
X	0
Y	1
Z	1
T	∞

Next Hop Table

Node	Next
X	X
Y	Y
Z	Z
T	-1

Topology Table

Node	Link State	SEQ Number
X	{Y, Z}	1
Y	{}	---
Z	{X, T}	---
T	{}	---

For Y:

Distance Table

Node	Distance
X	1
Y	0
Z	∞
T	1

Next Hop Table

Node	Next
X	X
Y	Y
Z	-1
T	T

Topology Table

Node	Link State	SEQ Number
X	{}	----
Y	{X, T}	1
Z	{}	----
T	{}	----

For Z:

Distance Table

Node	Distance
X	1
Y	∞
Z	0
T	1

Next Hop Table

Node	Next
X	X
Y	-1
Z	-Z
T	T

Topology Table

Node	Link State	SEQ Number
X	{}	---
Y	{}	---
Z	{X, T}	1
T	{}	---

(6) Now, broadcasting of topology tables of "X" will take place to its neighbour i.e. "Y" & "Z" and updated tables will be like as mentioned below.

For Y:

Distance Table

Node	Distance
X	1
Y	0
Z	2
T	1

Next Hop Table

Node	Next
X	X
Y	Y
Z	X
T	T

Topology Table

Node	Link State	SEQ Number
X	{Y, Z}	1
Y	{X, T}	1
Z	{}	---
T	{}	---

For Z:

Distance Table

Node	Distance
X	1
Y	2
Z	0
T	1

Next Hop Table

Node	Next
X	X
Y	Y
Z	Z
T	T

Topology Table

Node	Link State	SEQ Number
X	{Y, Z}	1
Y	{}	---
Z	{X, T}	1
T	{}	---

(7) Similarly, these tables are further updated with topology tables of "Y", "Z" & "T" as done in case of "X".

- **Advantages:**
  - Higher accuracy of GSR in generating optimal path as compared to LSR.
  - Broadcasting reduces error rate as compare to flooding used in LSR.
- **Disadvantages:**
  - Large bandwidth consumption.
  - Higher operational cost.
  - Large Message size resulting in more time consumption.

Q.3.) Explain DSDV Protocol with example.

Ans) **Destination Sequenced Distance Vector Routing:**

- DSDV Routing Protocol is a modified version of Bellman Ford Algorithm and is based upon the concepts of Distance Vector Routing.
- In Distance Vector Routing (DVR), each node broadcast a table containing its distance from nodes which are directly connected and based upon this, other nodes broadcasts the updated routing. Those nodes which are unreachable directly are labelled as "infinite".
- But, this updation of routing tables keeps on happening and an infinite loop is generated which is commonly known as Count-To-Infinity Problem.
- To overcome this problem of count to infinity by generating sequence number in the routing table, every time the routing table is updated. The process of DSDV is same as that of DVR but an extra attribute of sequence no. is added.
- **DSDV Concept:**
  - DSDV Protocol uses and maintains a single table only, for every node individually. The table contains the following attributes.
    - ⇒ **Routing Table:** It contains the distance of a node from all the neighbouring nodes along with the sequence number (SEQ No. means the time at which table is updated).

Format:

Node	Destination	Next Hop	Distance	SEQ No.

(*) This table is updated on every step and ensures that each node broadcast as well as receives correct information about all the nodes including their distance and sequence number.

- **Example :**

Consider a n/w of 3 nodes having distances of "1" on each of the edges respectively. Below mentioned steps will let you know how DSDV works and routing tables are updated.

fig: DSDV Example N/w.

↳ **Step(1):** Draw seperate tables for all the nodes "X", "Y" & "Z" along with the distance and sequence number.

For X:

Source	Destination	Next Hop	Cost	SEQ No.
X	X	X	0	100 - X
X	Y	Y	1	200 - Y
X	Z	Y	2	300 - Z

For Y:

Source	Destination	Next Hop	Cost	SEQ No.
Y	X	X	1	100 - X
Y	Y	Y	0	200 - Y
Y	Z	Y	1	300 - Z

For Z:

Source	Destination	Next Hop	Cost	SEQ No.
Z	X	Y	2	100 - X
Z	Y	Y	1	200 - Y
Z	Z	Z	0	300 Z

↳ **Step(2):** If "Y" wants to broadcast the routing table. Then updated routing tables of all the nodes in the n/w will look like as depicted in the tables on the next page where the circle

marked cell denotes the change in sequence number.

For X:

Source	Destination	Next Hop	Cost	SEQ No.
X	X	X	0	100 - X
X	Y	Y	1	210 - Y
X	Z	Y	2	300 - Z

For Y:

Source	Destination	Next Hop	Cost	SEQ No.
Y	X	X	1	100 - X
Y	Y	Y	0	210 - Y
Y	Z	Z	1	300 - Z

For Z:

Source	Destination	Next Hop	Cost	SEQ No.
Z	X	Y	2	100 - X
Z	Y	Y	1	210 - Y
Z	Z	Z	0	300 - Z

- Advantages:
  - Can't be implemented commercially or on large scale.
  - Efficient results will be produced if applied on small networks.
- Disadvantages:
  - Slower protocol processing time.
  - Less bandwidth
  - Not suitable for large no. of networks which are dynamic in nature.

Que) 4) Explain DSR, AODV and TORA with example.

Ans) Dynamic Source Routing (DSR):

- DSR comes under the reactive routing protocol category, as it is capable of discovering the route from source to destination only when required and needed.
- Dynamic Source Routing protocol uses a process called "Route Discovery Mechanism" that is capable of discovering the route for data packets from source node to destination node using intermediate nodes.
- ~~As like proactive routing protocols like GSR, an~~
- The major change in DSR as compare to GSR and DSDV is, in

DSR, after asking a requirement of route from source to destination, path via intermediates nodes is checked for its length. Then a "Re-Request" packet is sent back from destination to source via the smallest route pauible in the whole n/w. The "Re-Request" packet does contains its unique ID also.

- This process of seperately sending a "Re-Request" packet from destination to source makes it easier for the sender to send the data packets on fixed path rather than sending it on multiple paths to check for total distance.

- Example:

In the following example, the route discovery procedure is shown where S1 is the source node and S7 is the destination node.

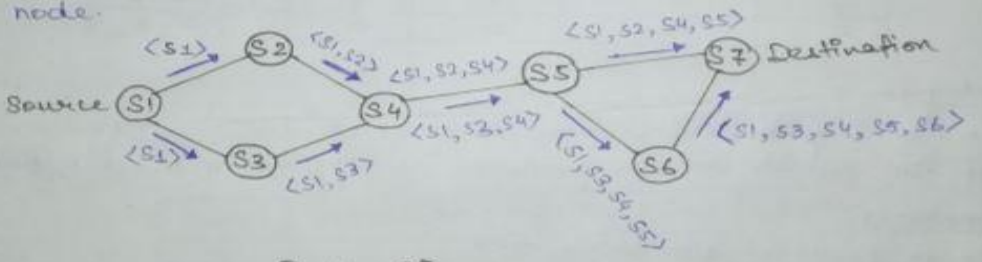

fig (a): Route Discovery

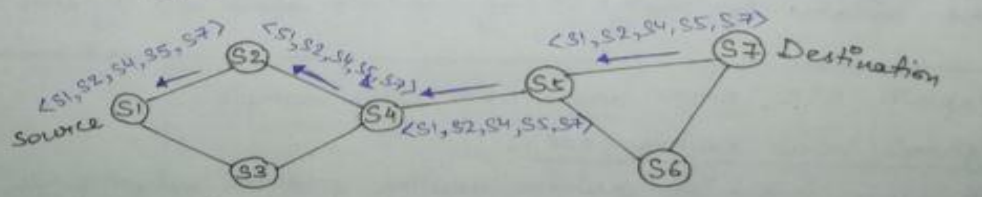

fig (b) Using route record to send the route reply

In this example, the destination S7, gets the request through two paths. It chooses one path based on the route records in the incoming packet and sends a reply using the reverse path to the source node. At each hop, the best route with minimum hop is stored. In this example, it is shown the route record status at each hop to reach the destination from the source node.
Here, the choosen route is <S1, S2, S4, S5, S7>.

- **Advantages:**
  - (*) A perfect route is discovered always.
  - (*) Highly efficient
  - (*) Low bandwidth Consumption

- **Disadvantages:**
  - (*) If the route gets broke, data transmission cannot happen.
  - (*) Time taking algorithm — slow
  - (*) If n/w is large, then it is impossible for the data packets header to hold whole information of the routes.

Ad hoc On-Demand Distance Vector Routing (ADDV):

- ADDV is an improvement on the DSDV algorithm.
- ADDV minimizes the no. of broadcasts by creating routes on-demand as opposed to DSDV that maintains the list of all the routes.
- When the local connectivity of the mobile node is of interest, each mobile node can become aware of the other nodes in its neighbourhood by the use of several techniques including local broadcasts known as "hello" messages.
- The algorithm's primary objectives are:
  - (a) To broadcast discovery packets only when necessary.
  - (b) To distinguish b/w local connectivity management and general topology maintenance.
  - (c) To disseminate information about changes in local connectivity to those neighbouring mobile nodes that are likely to need the information.
- To find a path to the destination, the source broadcasts a route request packet.
- The neighbours in turn broadcast the packet to their neighbours that has a recent route information about the destination.
- A node discards a route request packet that it has already seen.

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- Example:

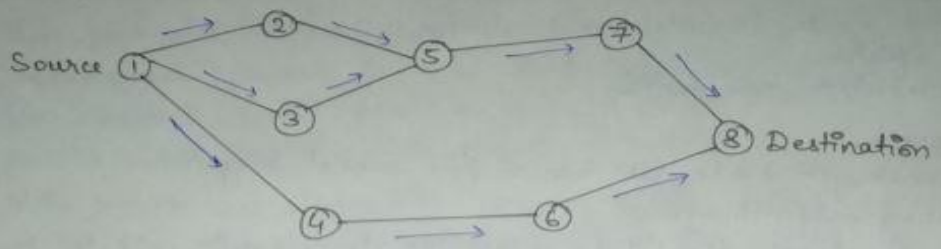

fig: Propagation of Route Request Packet (RREQ)

(*) The route request Packet uses sequence no. to ensure that the routes reply with the latest info. only.

(*) When a node forwards a route request packet to its neighbours it also records in its tables. This information is used to construct the reverse path for the route reply packet.

(*) The nodes along the path enter the forward route into their tables.

(*) If the source moves then it can reinitiate route discovery to the destination.

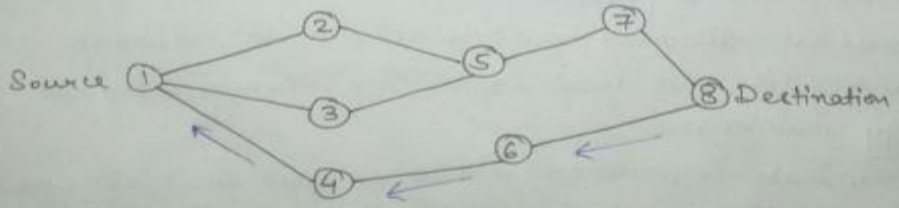

fig: Path taken by the route reply packet (RREP)

(*) Path Discovery: This process is initiated whenever a source node needs to communicate with another node for which it has no routing information in its table.

The RREQ contains the following fields:

< Source addr ; Source Sequence # ; broadcast id ; dest addr ;
dest sequence # ; hop cnt >

- **Advantages:**
  - Dynamic networks can be handled easily.
  - No loop generation
- **Disadvantages:**
  - A delayed protocol b/c of the route discovery process
  - High bandwidth requirement

Temporally Ordered Routing Algorithm (TORA):

- TORA is a source initiated on-demand routing protocol
- TORA is highly adaptive, efficient, loop-free and scalable routing protocol based on link reversal algorithm.
- The main objective of TORA is to limit message propogation in the highly dynamic mobile computing environment. It means, it is designed to reduce communication overhead by adapting local topological changes in ad hoc n/w
- Another main feature of TORA routing protocol is the localization of control packets to a small region (set of nodes) near the occurance of a topological changes due to route break.
- TORA support multiple routes to transmit data packet b/w source and destination nodes of ad-hoc n/w. In short, TORA exhibits multipath routing capability.
- TORA works in three main phases:
  - Route Creation
  - Route Maintenance
  - Route Erasure

Route Creation: Route Creation is done using QRY and UPD packets

→ The route creation algo starts with the height of destination set to 0 and all other node's height set to null (undefined)

→ The source broadcasts a QRY packet with the destination node's id in it. Node with a non-NULL height responds with a UPD packet that has its height in it

➡ A node with higher height is considered upstream and a node with lower height downstream.

* **Route Maintenance:** When a node moves the DAG route is broken and route maintenance is needed to re-establish a DAG (Directed Acyclic Graph) for the same destination. When the last downstream link of a node fails, it generates a new reference level. This results in the propogation of that reference level by neighbouring nodes.

* **Routing Erasure:** In this phase, TORA floods a broadcast clear packet (CLR) throughout the n/w to erase invalid routes. In TORA, there is a potential for oscillations to occur, especially when multiple set of coording nodes are concurrently detecting partitions, erasing routes, and building new routes based on each other.

- TORA contains a quintuple metric which consists of:
  * Logical time of link failure.
  * Unique ID of the node that defines the new reference level.
  * A reflection indicator bit.
  * A propagation ordering parameter.
  * Unique ID of the node.

- **Example:**
  The TORA's operation can be compared to that of water flowing downhill toward a sink node through a grid of tubes that model the routes in the real world n/w. The tube junctions represent the nodes, the tube themselves represent the route links b/w the nodes, the tube's water represents the packets flowing b/w nodes through the route links toward the destination, as shown in the given figure:

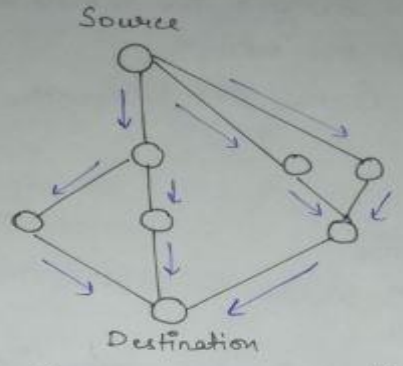

fig: TORA height metric

Considering the data flow to be downhill, each node has a height with respect to the destination node. The analogy also makes it easy to correct routes in case of link failure or error.

- **Advantages**
  - (*) It can operate smoothly in a highly dynamic mobile environment.
  - (*) It provides multiple paths for any source-destination pair.

Que.5) Explain QoS in Ad hoc network with application and example.

Ans:) QoS can be defined as the ability of the n/w to provide different services to various types of network traffic. It means goal of QoS is to achieve a more deterministic network behaviour so that data carried by the n/w can be better utilized.

When QoS (Quality of Service) model for MANETs was designed, these specific features of mobile ad hoc network had to have been considered. Especially features like dynamic network topology, bandwidth constraint and limited power of nodes which make MANET's really specific.

Some QoS models designed for mobile ad hoc networks are:

(i) Flexible QoS Model for MANETs
(ii) Integrated Mobile Ad hoc QoS framework
(iii) SWAN

- Applications:
  - Military Applications.
    - → Ad hoc n/w 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 n/w.
    - → Streaming of multimedia objects among the participating nodes.
  - Emergency Operations
    - → These are useful in emergency operations such as search and rescue, and crowd control.

- Example:

Delay, bandwidth, packet loss, delay jitter, includes pressure, temperature, toxics, pollution, etc.

An ad hoc n/w is a collection of wireless mobile hosts forming a temporary n/w without the aid of any stand alone infrastructure aid any stand or centralized administration.