

In the OSI Model Layer-3 is called as network layer. Network layer manages options pertaining to host and network addressing. managing sub-networks and inter networking.

Network layer takes the responsibility to route packets from source to destination either in or outside a subnet. Two different subnets have different addressing schemes or non-compatible addressing types. same with protocols two different subnets may be operating on different protocols which are not compatible with each other. Network layer has the responsibility to route the packets from source to destination, mapping different addressing scheme and protocol.

Addressing, packetizing, Routing,  
Switching  
Inter-networking

- Design Issues
- ① Store-and-forward packets switch
  - ② Services provided to the transport layer

## Functionalities:-

Devices which work on network layer mainly focus on Routing. Routing may include various tasks aimed to achieve a single goal.

- addressing devices and networks
- populating routing tables or static routes
- queueing incoming & outgoing data and then forwarding them according to quality of service constraints set for those packets.
- Internetworking between two different subnets
- Delivering packets to destination with best efforts
- Provide connection oriented and connection less mechanism.

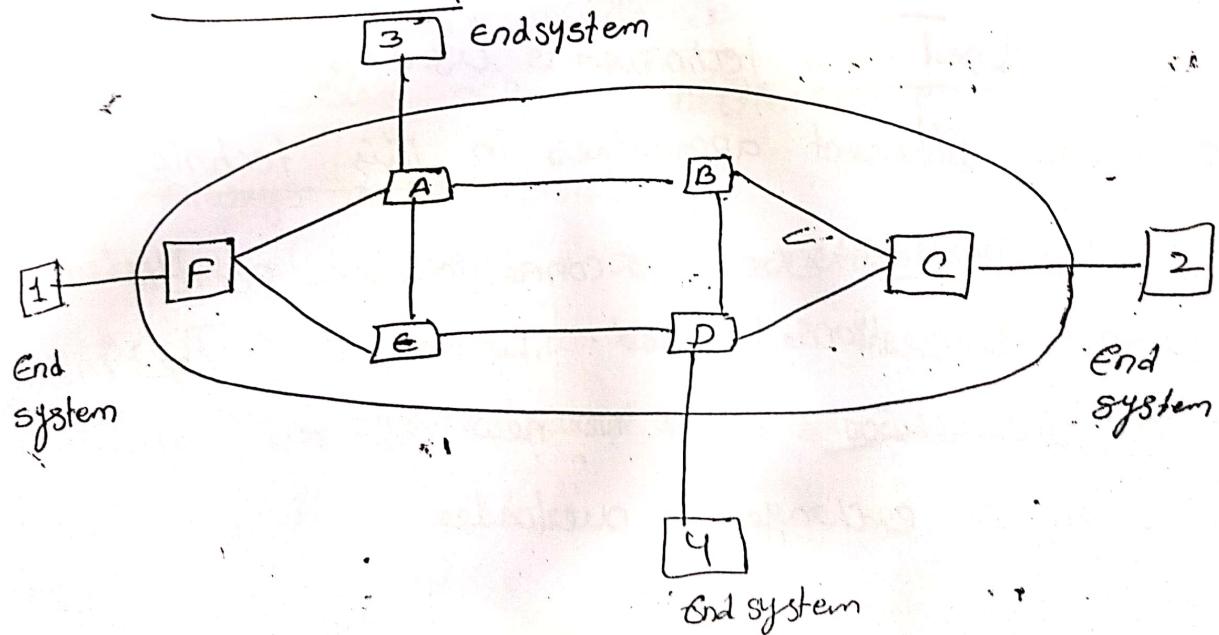
## Network Layer Features:

- Quality of service management
- Load balancing and link management
- Security
- Interrelation of different protocols and subnets with different schema.
- Different logical network design over the physical network means

## Virtual Circuit & Datagram Circuit:

Virtual Circuit is the connection oriented service in which there is an implementation of resources like buffers, CPU, bandwidth, etc. used by virtual circuit for a data transfer session. On other hand Datagram is the connection less service where no such resources are required for the data transmission.

Virtual Circuit is the computer network providing connection oriented service. It is a connection oriented network. In virtual circuit resources are reserved for the time interval of data transmission between two nodes. This network is highly reliable medium of transfer. Virtual circuits are costly to implement.



## Working of virtual circuit :-

Part

- In the first step a medium is set up between the two end nodes
- Resources are reserved for the transmission of packets
- Then a signal is sent to sender to tell the medium is set up and transmission can be started.
- It ensures the transmission of all packets
- A global header is used in the first packet of the connection.
- Whenever data is to be transmitted a new connection is setup.

## Congestion control in virtual circuits :-

Once the congestion is detected in virtual circuit network, closed-loop technique is used. There are different approaches in this technique:

No new connection: No new connections are established when the congestion is detected. This approach is used in telephone networks where no new calls are established when the exchange is overloaded.

## Participation of Congested route invalid :-

Another approach to control congestion is allow all new connections but route these new connections in such a way that congested router is not part of this route.

## Negotiation :-

To negotiate different parameters between sender and receiver of the network when the connection is established. During the set up host specifies the shape and volume of the traffic, quality of service and other parameters.

## Advantages of virtual circuit :-

1. Packets are delivered to the receiver in the same order sent by the sender
2. It provides only connection-oriented service.
3. Always a new connection
2. virtual circuit is a reliable network circuit
3. There is no need for overhead in each packet
4. single global packet overhead is used in virtual circuit

## Disadvantages:

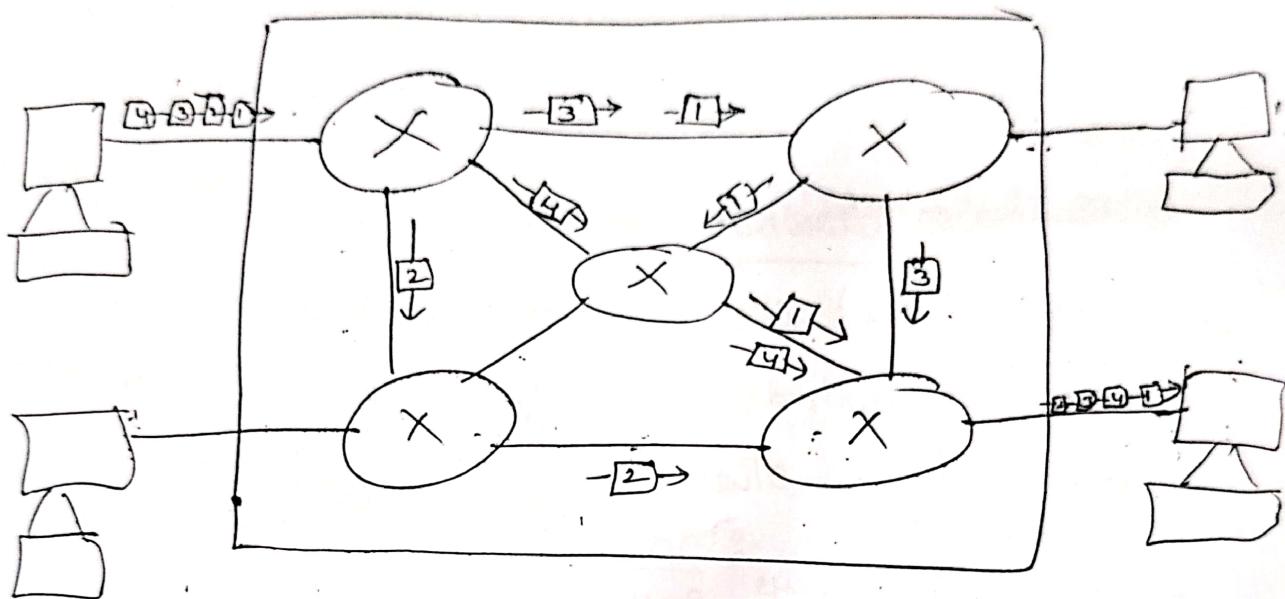
1. Virtual circuit is costly to implement
2. It provides only connection-oriented service.
3. Always a new connection set up is required for transmission.

## Datagram Networks :-

A datagram is a basic transfer unit associated with a packet switched network. Data grams provide a connectionless communication service across a packet-switched network. The delivery, arrival time, and order of arrival of datagrams need not be guaranteed by the network.

Datagram Packet-switching is a packet switching technology by which each packet - now called a datagram is treated as a separate entity. Each packet is routed independently through the network. The individual packets which form a data stream may follow different paths between the source and the destination.

Each Packet is treated independently of all others  
All Packets belonging to the same message may travel different paths to reach their destination.



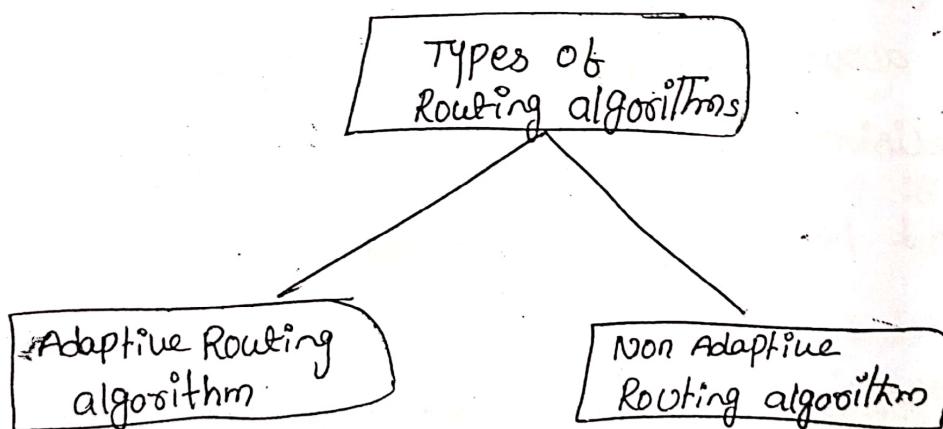
1. it is a connection-less service. There is no need for reservation of resources as there is no dedicated path for a connection session.
2. All packets are free to use any available path. As a result intermediate routers calculate routes. Calculate routes on the go due to dynamically changing routing algorithms tables on routers.
3. Since every packet is free to choose any path, all packets must be associated with a header with proper information about the source and the upper layer data.

- Q10
4. The connection less property makes data packets reach the destination in any order, which means that they can potentially be received out of order at the receiver end.
  5. Datagram networks not as reliable as virtual circuits
  6. The major drawback of datagram packets switching is that a packet can only be forwarded if resources such as the buffer, CPU and bandwidth are available. otherwise packet will be discarded.
  7. But it is always easy and cost-efficient to implement datagram networks as there is no extra headache of reserving resources and making a dedicated each time. an application has to communicate
  8. It is generally used by the IP network, which is used for Data services like Internet.

## Routing algorithms

Routing is process of establishing the routes that data packets must follow to reach the destination. In this process, a routing table is created which contains information regarding routes which data packets follow. Various Routing algorithms are used for the purpose of deciding which route an incoming data packet needs to be transmitted to reach admission destination efficiently.

## Classification of Routing algorithms



## Adaptive Routing algorithm :-

These are the algorithms which change their routing decisions when ever network topology or traffic load changes. The changes in routing decision are reflected in the topology as well as traffic of the network. It is also known as dynamic Routing, These use of dynamic information such as current topology, load, delay etc. to select ~~routes~~ Routes optimization parameters are distance, number of hops and estimated transit time.

### a) Centralized

Isolated :-

In this method a centralized node has entire information about the network and makes all the routing decision. Advantages of this is only one node is required to keep the information of entire network.

disadvantage is that if control node goes down entire network ~~and is~~ goes down.

### b) Isolated :-

In this method each node makes its routing decisions using the information it has without seeking information from others. The sending nodes does not have information about status of particular link.

C-distributed :- In this method, the node receives information from its neighbours and then takes the decision about the routing packets. disadvantage is that the packet may be delayed if there is change in between interval in which it receives information and sends packet. It is also known as decentralized algorithm as it computes the least-cost path between source and destination.

## 2. Non-adaptive algorithms :-

These are the algorithms which do not change their routing decisions once they have been selected. This is also known as static routing as route to be taken is computed in advance and downloaded to routers when router is booted.

Flooding :- This adopts the technique in which every incoming packet is sent on every outgoing line except from which it arrived.

Random walk :- In this method, packets are sent host by host or node by node to one of its neighbours randomly.

## Shortest path Routing algorithm:

to bind

- The idea is to build a graph of the network with each node of the graph representing a router and edge of the graph representing communication link.
- Dijikstra's algorithm is used in shortest path first which is used in the routing protocol open shortest path first.
- To choose a route between a given pair of routers the algorithm just finds the shortest path between them on the graph.
- The basic shortest path computation from a given node to all other nodes is performed using dijkstra's algorithm.
- To find the shortest route we are having some functions between nodes.
  - cost
  - Distance
  - Traffic
  - Bandwidth
  - time.

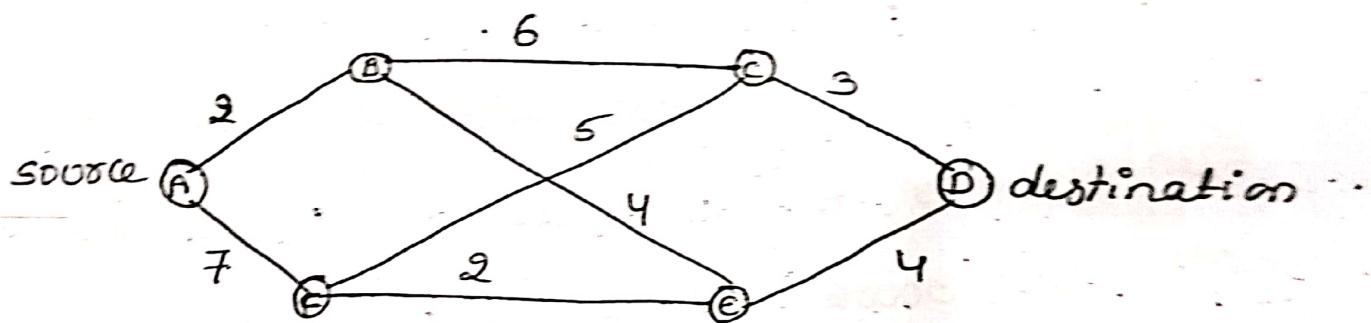
To find shortest path we are using two methods:

→ Tree Structure

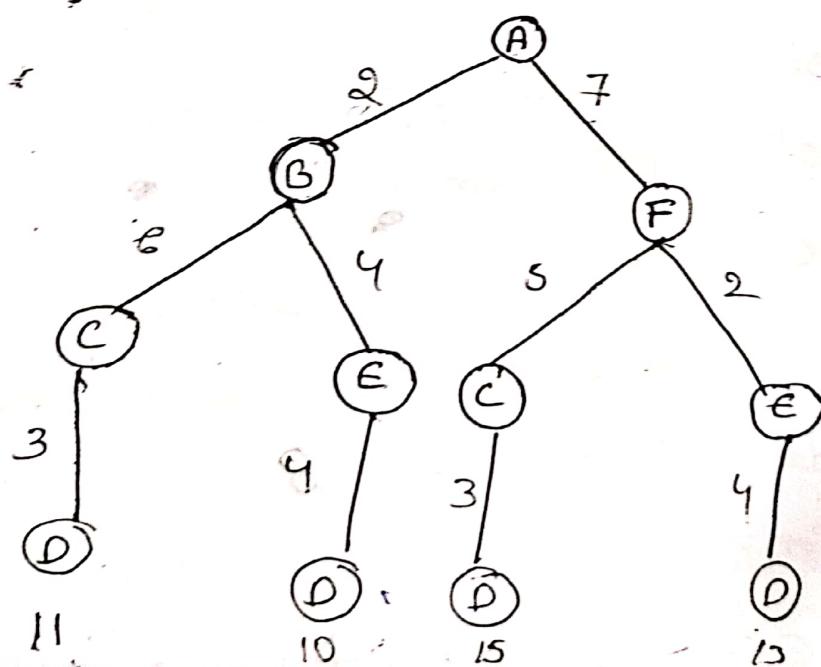
→ Dijksta's Algorithm

Tree structure :-

In the tree structure we start it from source node to destination node. what are the links connected with the source node. Then move to next nodes and their links.

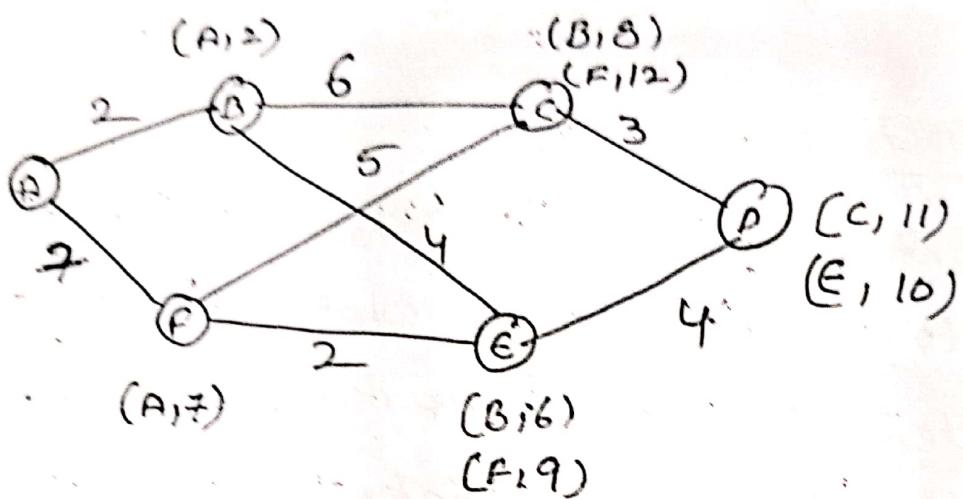


Tree :-



ABCD  
ABED → shortest path  
AFCD  
AFED

## Dijkstra's Algorithm



In the above circuit we have 4 nodes and 8 links. A is source node and D is destination node. From source node A we have two direct links B & F. From A to B cost 2. A to F cost 7. From B to C cost is 6. But our Route start from node B so the cost is 8. Like that we are going to calculate the total cost from source node to destination node and take the less cost from source to destination. Then we will get shortest Path  $A \leftarrow B \leftarrow E \leftarrow D$ .

## Flooding :- (static algo).

Flooding is a simple routing technique in computer networks where a source node sends packets through every outgoing link.

Flooding which is similar to broadcasting, occurs when source packets are transmitted to all attached network nodes. Because flooding uses every path in the network. The shortest path is also used. The flooding algorithm is easy to implement.

### Characteristics :-

- All possible routes between source and destination is tried. A packet will always get through if path exists.
- As all routes are tried, there will be at least one route which is the shortest.
- All nodes directly or indirectly connected are visited.

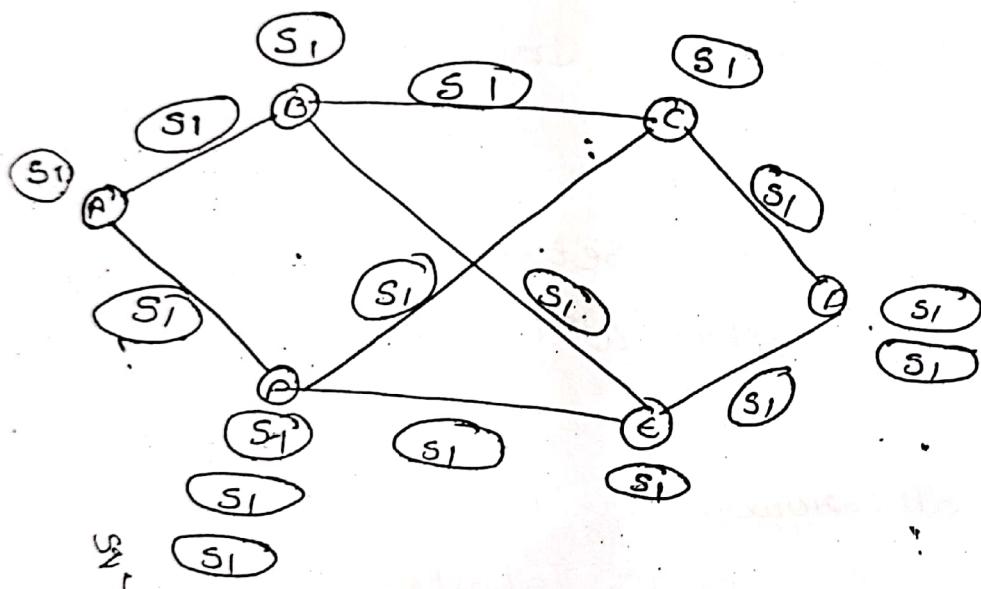
### Limitations :-

- Flooding generates vast no of duplicate packets.
- Suitable damping mechanism must be used.

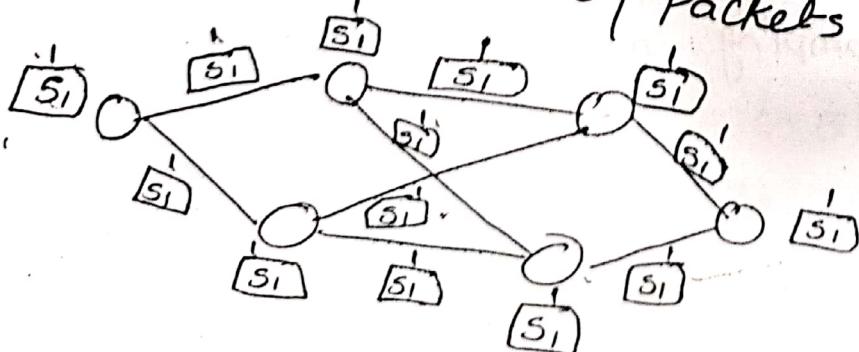
### Top - down :-

## Advantages of Flooding:-

- Highly Robust, emergency or immediate messages can be sent (military applications)
- Set up route in virtual circuits
- Flooding always chooses the shortest path
- Broadcast messages to all the nodes.



In the flooding we are getting duplicates at some numbers for the frames / packets. To avoid duplication use sequence numbers.

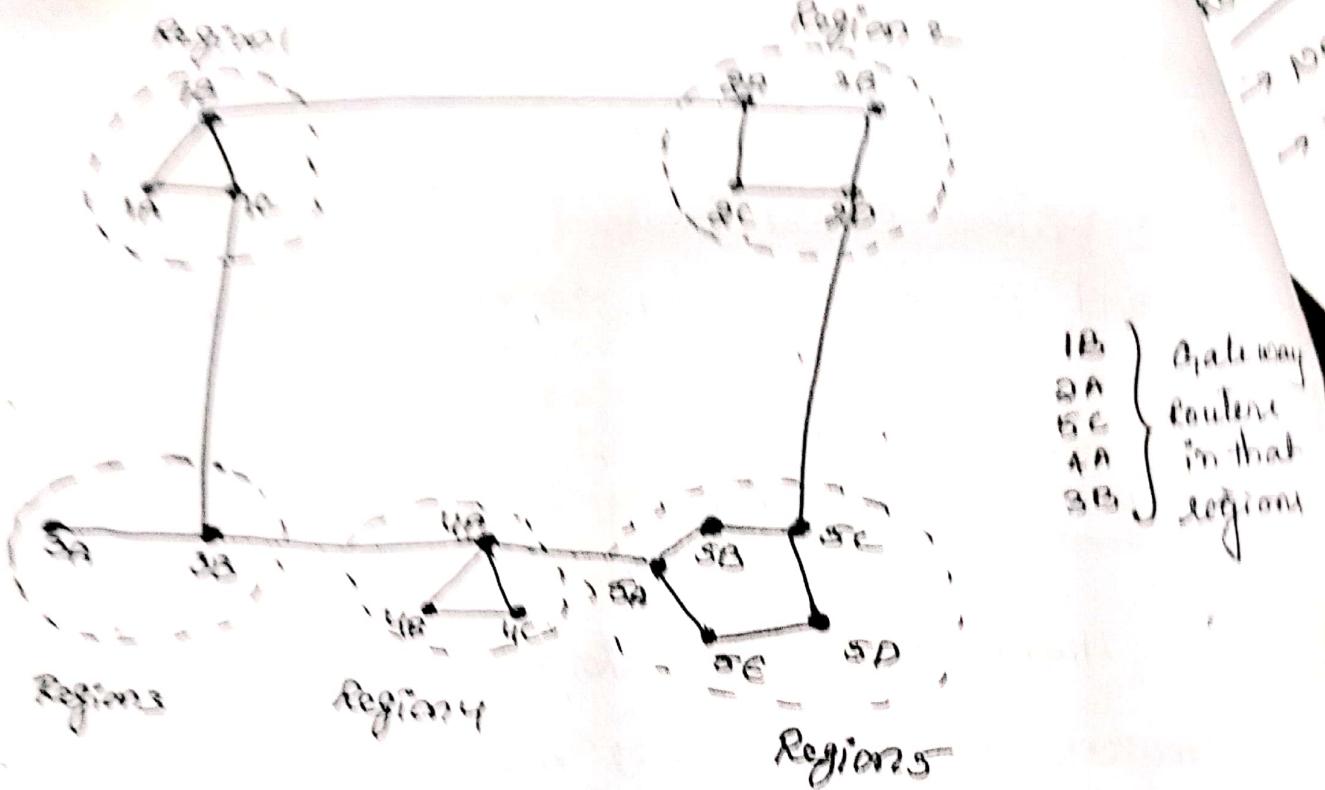


If we use sequence numbers if the same sequence number will come to the node it will check the packets is there any same packet is there if the same sequence packet present at that node it will discard the packet which is coming from the other node.

## Hierarchical Routing :-

Hierarchical Routing is the procedure of arranging routers in a hierarchical manner. It decreases the complexity of network topology, increases routing efficiency, and causes much less congestion because of fewer routing advertisements.

- Addresses the growth of routing tables
- Routers are divided into regions
- Routers know the routes for their own regions only
- works like telephone routing.
- possible hierarchy
  - city, state, country, continent.
- Gateway Router in one region will contain information of other regions gateways. (Routing process of other regions).



Full table for 1A

Dest	Line	Hope
1A	-	-
1B	1	
1C	1	
2A		
2B	2	
2C	3	
2D	3	
3A	1B	4
3B	1C	3
4A	1C	2
4B	1C	3
4C	1C	4
5A	1C	4
5B	1C	5
5C	1IB	5
5D	1C	6
5E	1C	5

Hierarchical table for 1A

Dest	Line	Hope
1A	-	-
1B	1	
1C	1	
2	1B	2
3	1C	2
4	1C	3
5	1C	4

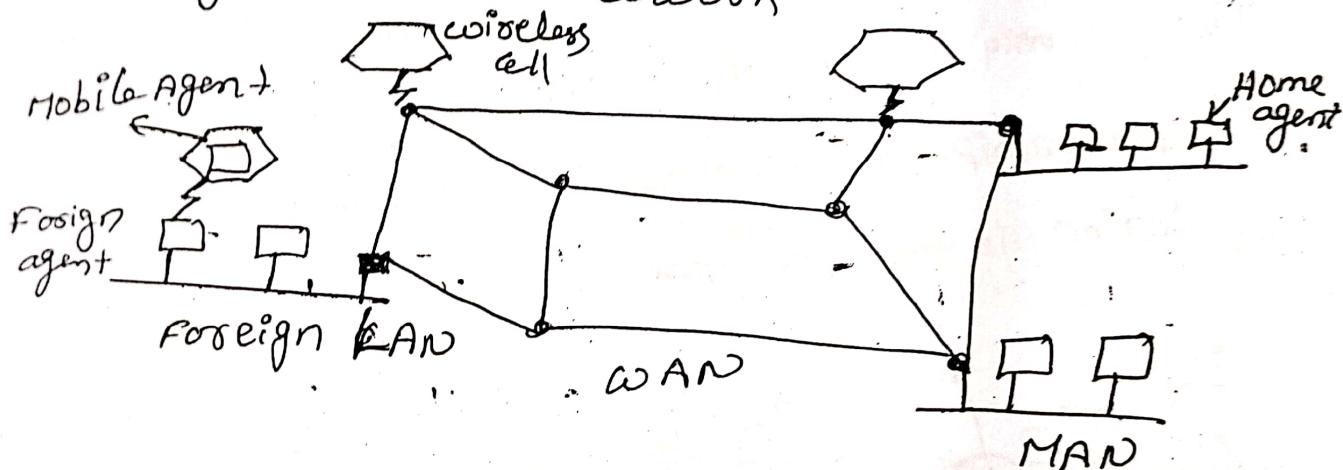
→ calculation  
only no. of  
Hope to  
reach the  
gateway  
in that  
particular  
region

Once msg enters the  
gateway routes  
it transfers to the  
destination in that  
region

## Routing Mobile Hosts:-

- Networking portable computers
- Nonmobile agents are assumed to have a permanent home location
- When a portable computer is attached to a remote network it contacts a process that acts as the local foreign agent.
- Each home location has a process that acts as the home agent.

### The Agents on the Network

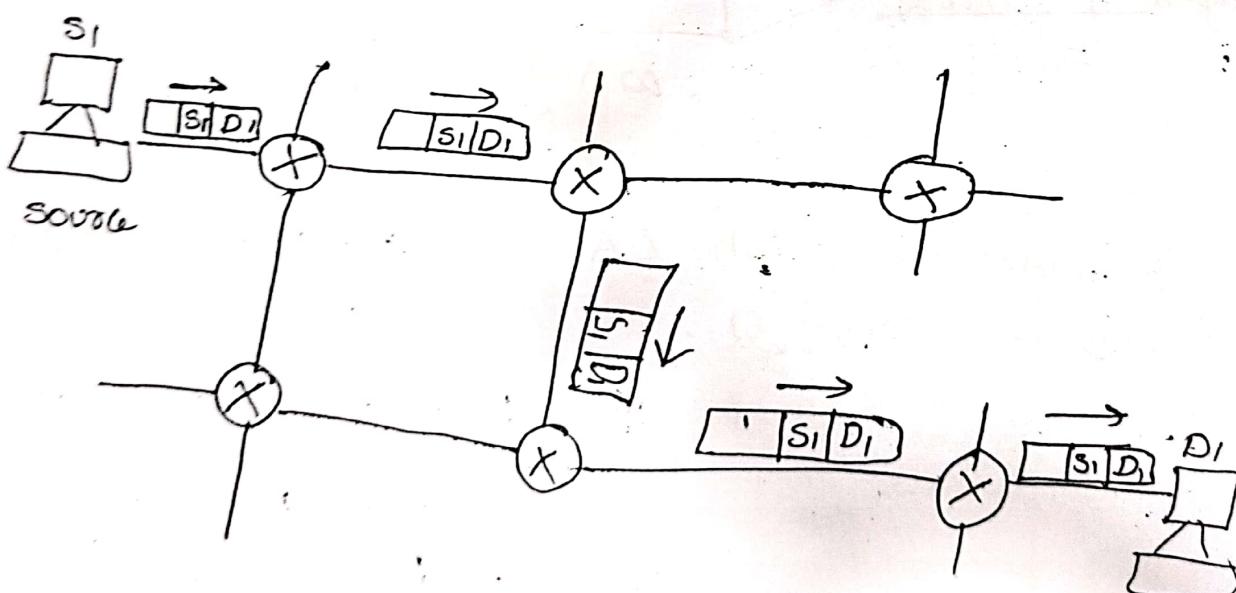


A WAN to which LANs, MANs and wireless cells are attached.

## Unicast Routing:-

Unicast Routing is the process of forwarding unicasted traffic from a source to a destination on an internetwork. Unicasted traffic is destined to a unique address. The Internet Protocol (IP) and the Internetwork Packet Exchange (IPX) Protocols are used as the example protocols where appropriate.

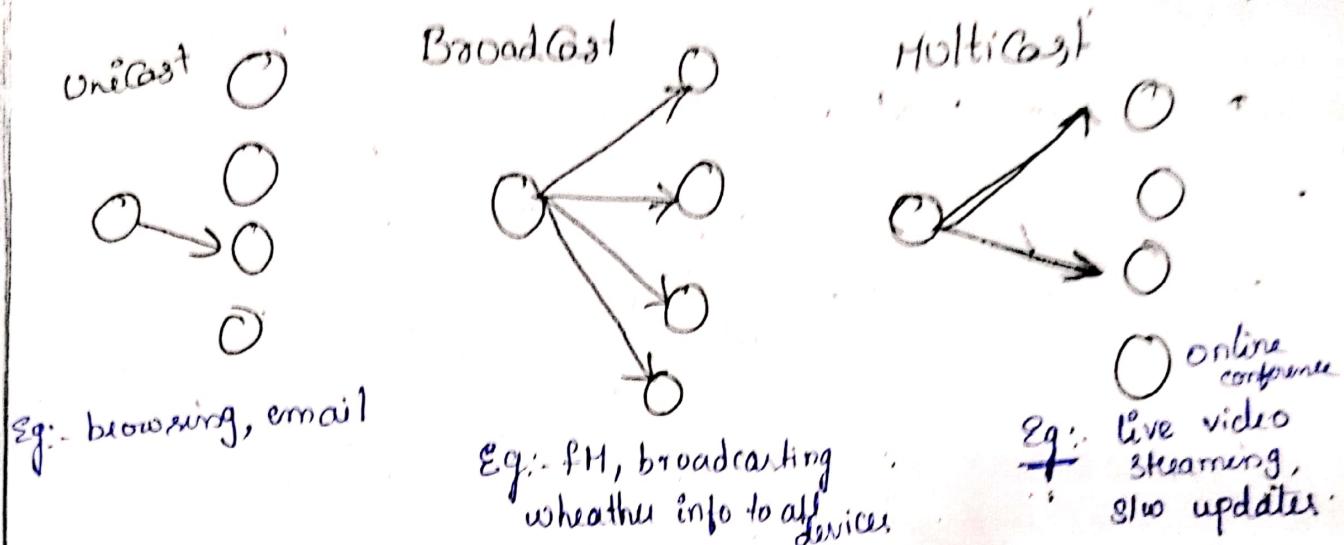
In unicasting, the Router forwards the received packet through only one of its interfaces. The relationship between the source and the destination is one-to-one.



## Unicasting

## Multicasting:-

→ Multicast Communications refers to one-to-many communications.



IP multicasting refers to the implementation of multicast communication in the Internet.

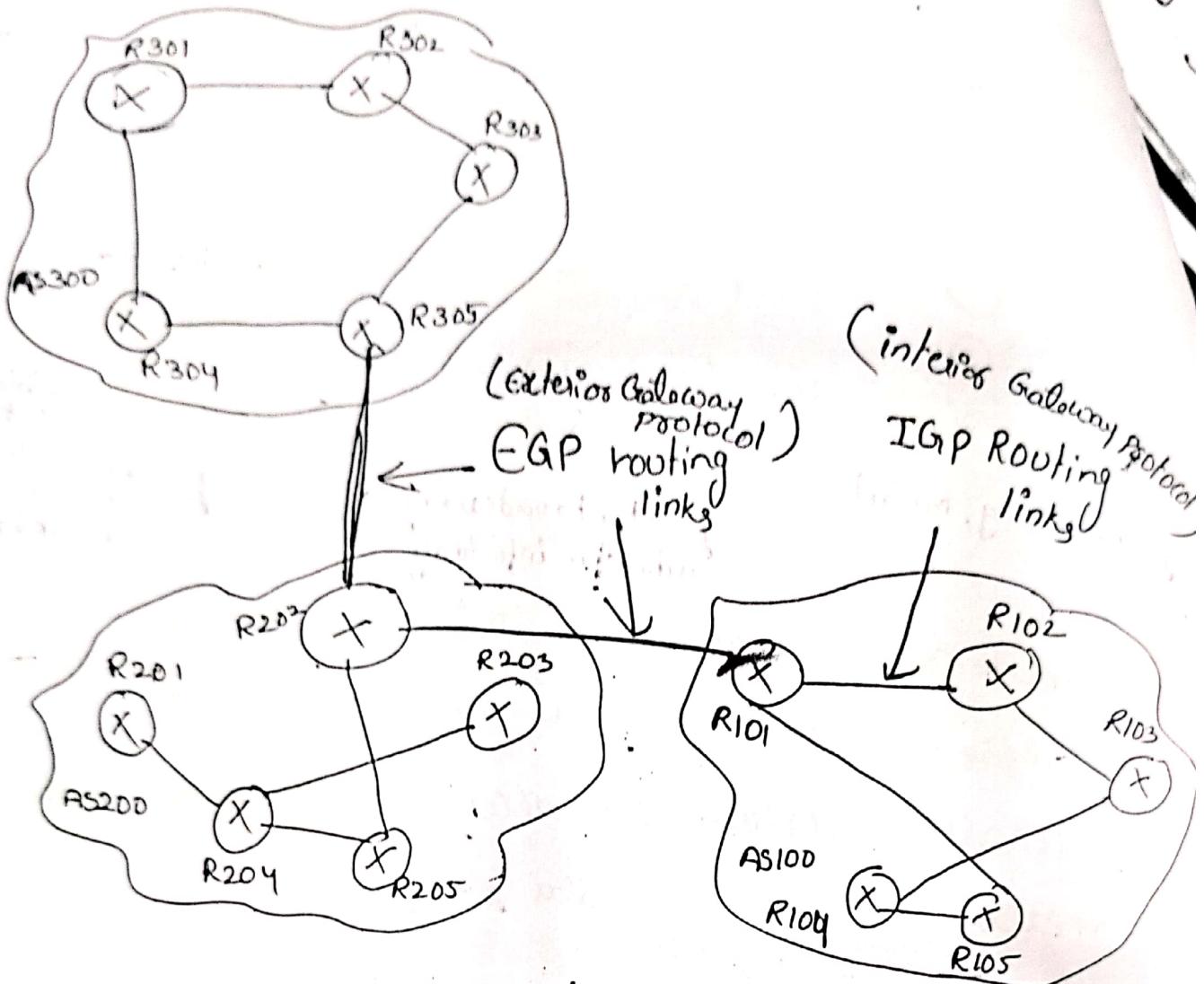
multicast is driven by receivers: Receivers indicate interest in receiving data.

## Broadcast Routing:-

In Broadcast routing, packets are sent to all nodes even if they do not want it.

→ Routers creates broadcast domains. But it can be configured to forward broadcast message if destined to all network devices.

→ A router creates a data packet and then sends it to each host one by one.. In this case the router creates multiple copies of single data packet with different destination addresses.



## Distance vector Routing

A Distance - vector Routing protocol requires that a router information changes periodically. Historically known as The old ARPANET routing

### Bellman Ford Basics

Each router maintains a distance vector table containing the distance between itself and ALL possible destinations.

Distances based on a chosen metric, are computed using information from the neighbour's distance vectors.

1. A router transmits its distance vector to each of its neighbours in a routing packet
2. Each Router receives and saves, the most recently received distance vectors from each of its neighbours.
3. A Router recalculate its distance vectors when:
  - it receives a distance vector from a neighbour containing different information than before.
  - It discover that a link to a neighbor has gone down.

The Distance Vector Calculation is based on minimizing the cost to each destination.

when a node  $X$  receives new distance vector estimates from any neighbor, it saves  $v$ 's distance

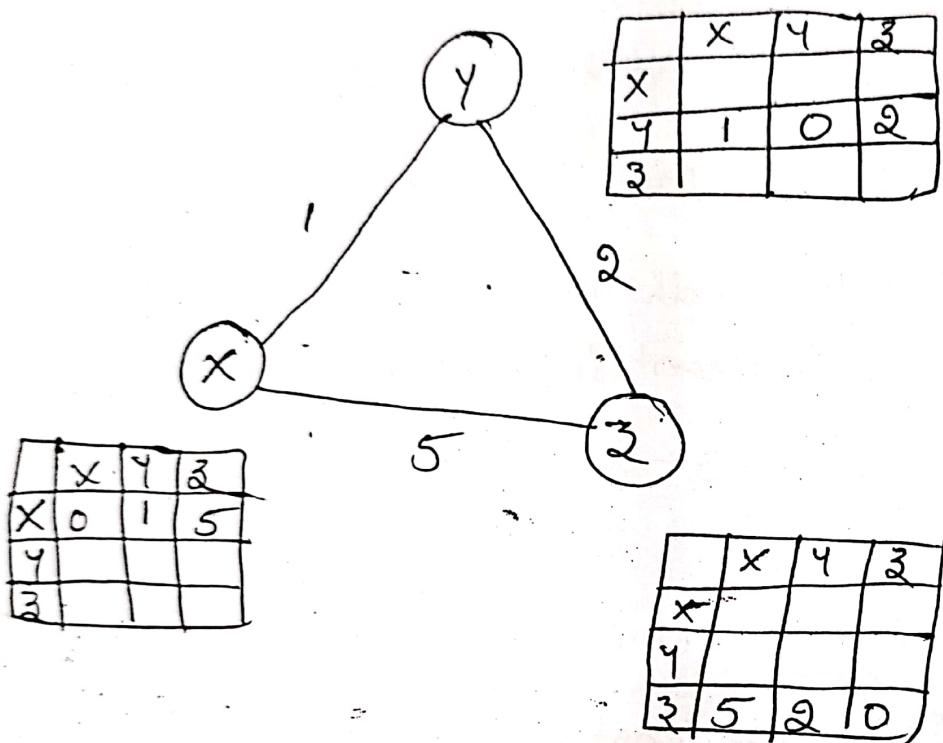
- \* vector and it updates its own distance vector using Bellman Ford equation.

$$D_X(Y) = \min \{ C(x, v) + D_V(Y); D_X(Y) \} \text{ for.}$$

Each node  $y \in N$

### Example :-

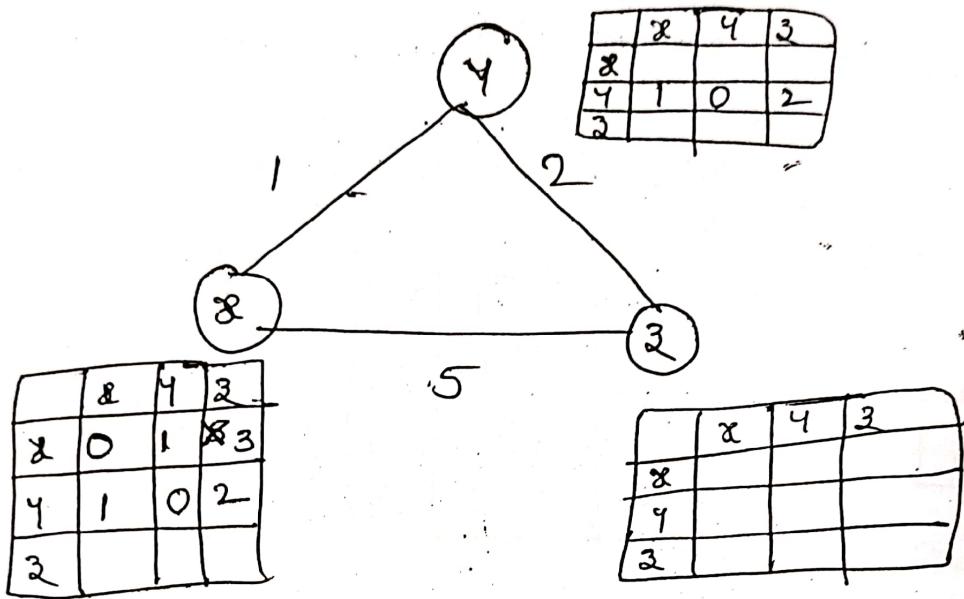
Consider 3 routers X, Y, Z. Each Router has their own Routing table. Every Routing table will contain distance to the destination nodes.



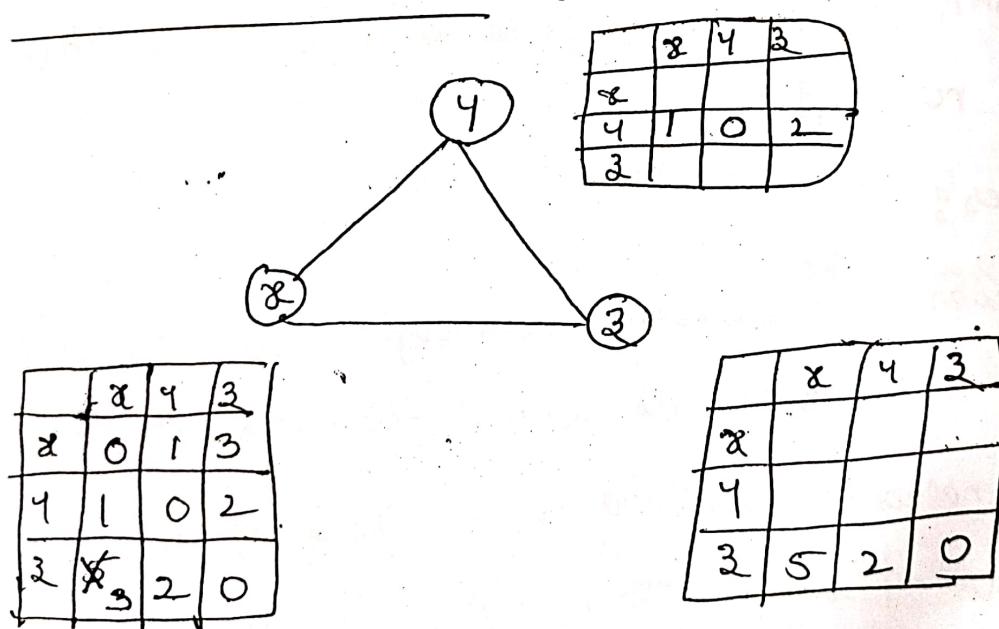
Consider router X, X will share its routing table to neighbours and neighbours will share its routing table to it. To X and destination will be calculated using Bellman-Ford equation.

$$D_X(Y) = \min \{ c(x, v) + D_V(Y) \} \text{ for each node } Y \in N$$

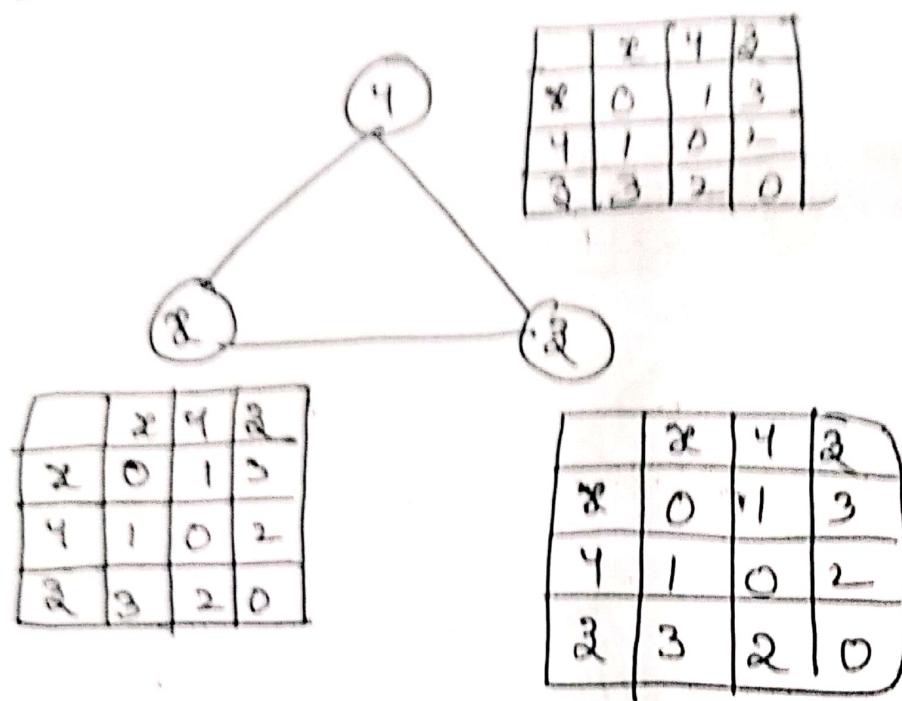
As we can see that distance will be less going from  $x$  to  $z$  when  $y$  is intermediate node so it will be updated in routing table  $x$ .



similarly for  $z$  also.



## Finally The Routing table For ALL :-



### Advantages For Distance Vector Routing:

It is simpler to configure and maintain than link state routing.

### Disadvantages:

- It is slower than link state routing.
- It is at risk from the count-to-infinity problem.
- For larger networks, distance vector routing results in larger routing tables than link state since each router must know about all other routers.

## Dynamic Routing :-

Dynamic routing is a technique in which a router learns about routing information without an administrator's help and adds the best route to its routing table. A router running a dynamic routing protocol adds the best route to its routing table and can also determine another path if the primary route goes down.

Dynamic Routing uses multiple algorithms and protocols. The most popular are Routing Information Protocol (RIP) and open shortest path first (OSPF).

Dynamic Routing protocols allow routers to share information about the network with other routers allowing them to select the best path to reach a destination.

RIP protocol is an old routing protocol, it suffers from scalability issues due to a relatively low maximum hop count of 15 routing devices.

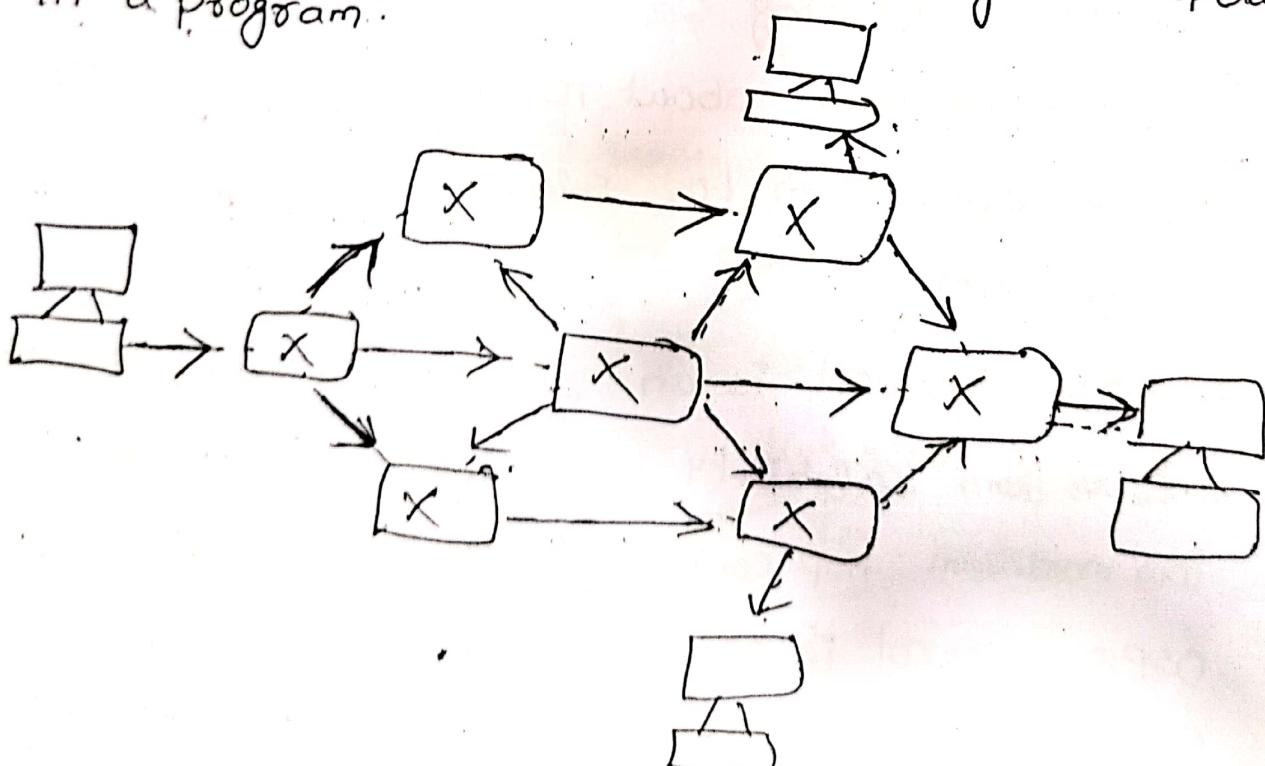
OSPF protocol is used in large to very large IP networks. The protocol uses a link-state database and link state advertisements to map the network topology.

## Advantages of Dynamic Routing :-

- Allow the exchange of routing information whenever the network experiences a change in topology.
- Since the routers do not have to be manually configured, there is less administrative overhead.
- Less error prone than static routing.
- Allow scalability since there is less administrative overhead involved.

## Broadcast Routing :-

In computer networking broadcasting is a method of transferring a message to all recipients simultaneously. Broadcasting can be performed as a high level operation in a program.



Broadcast Routing

By default, the broadcast packets are not flooded and forwarded by the routers on any network. Routers create broadcast domain. But it can be configured to forward broadcasts in some special cases. A broadcast message is destined to all network devices.

Broadcast Routing can be done in two ways:

→ A router creates a data packet and then sends it to each host one by one. In this case, the router creates multiple copies of single data packet with different destination addresses. All packets are sent as OneCast but because they are sent to all, it simulates as if router is broadcasting.

This method consumes lots of bandwidth and router must <sup>have</sup> destination address of each node.

→ Secondly when router receives a packet that is to be broadcasted, it simply floods those packets out of all interfaces. All routers are configured same way. This method is easy on routers' CPU but may cause the problem of duplicate packets received from peer routers.

Reverse path flooding is a technique, in which router knows in advance about its predecessor from where it should receive broadcast. This technique is used to detect and discard duplicates.

## Roaming for Mobility :-

Mobility in wireless networks basically refers to a node, Mobile Node (MN), or sometimes a subnet. Changing its point of attachment to the network while its communication to the network remains uninterrupted. A change in the MN's point of attachment to the network is called handover.

Mobile IP is a communication protocol that allows the users to move from one network to another with the same IP address. It ensures that the communication will continue without user's sessions or connections being dropped.

## Terminologies :-

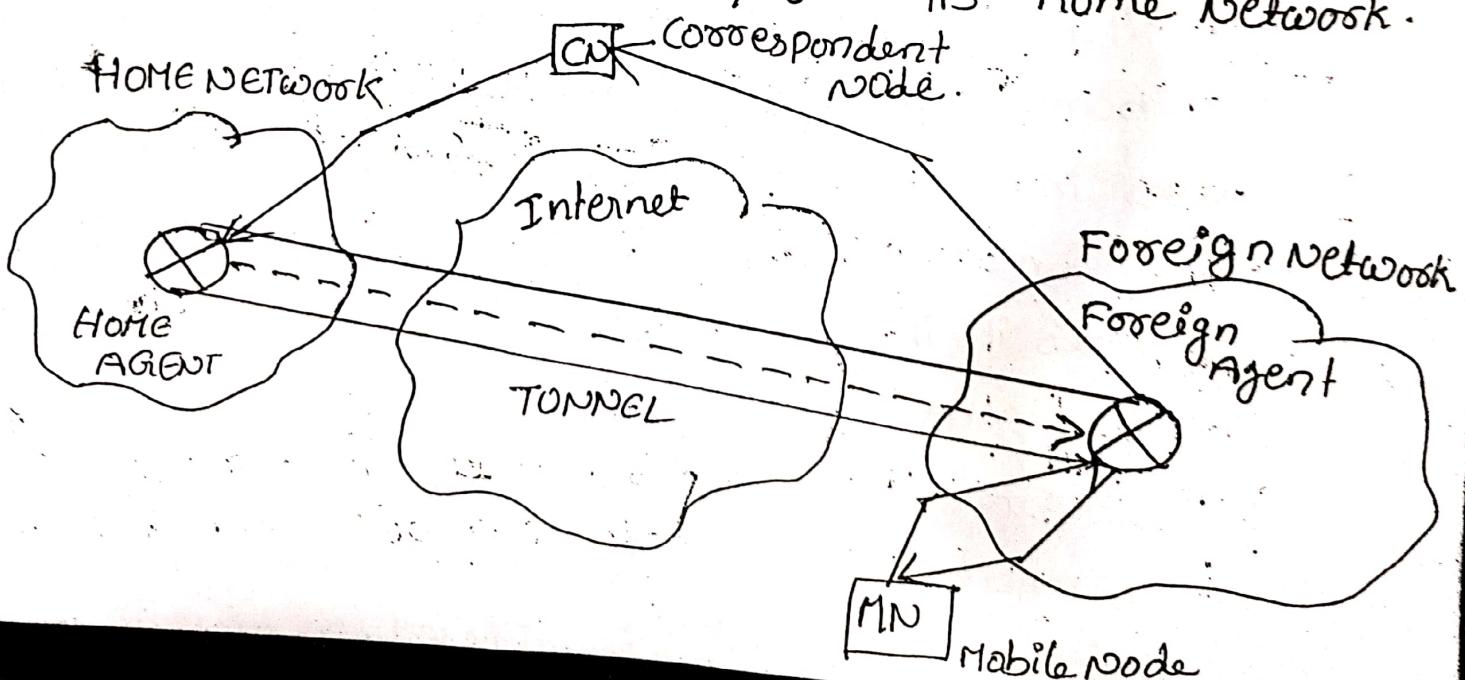
- Mobile Node (MN) :- It is the handheld communication device that the user carries e.g; Cell Phone
- Home network :- It is a network to which the mobile node originally belongs to as per its assigned IP addresses (home Address).
- Home Agent (HA) :- It is a router in home network to which the mobile node was originally connected.

- Home Address: It is the permanent IP address assigned to the mobile node (within its home network)
- Foreign Network: It is the current network to which the mobile node is visiting (away from its home network)
- Foreign Agent (FA): It is a router in foreign network to which mobile node is currently connected. The packets from the home agent are sent to the foreign agent which delivers it to the mobile node.

- Correspondent Node (CN): It is the device on the Internet communicating to the mobile node.

- Care of Address (COA):

It is the temporary address used by a mobile node while it is moving away from its home network.



### Working :-

Correspondent node sends the data to the mobile node. Data packet contains correspondent node's address (source) and home address (destination). Packets reaches to the home agent. But now mobile node is not in the home network, it has moved into the foreign network. Foreign agent sends the care-of address to the home agent to which all the packets should be sent. Now a tunnel will be established between the home agent and the foreign agent by the process of tunneling.

### Tunneling :-

Tunneling establishes a virtual pipe for the packets available between a tunnel entry and an endpoint. It is the process of sending a packet via a tunnel and it is achieved by a mechanism called encapsulation. Now home agent encapsulates the data packets into new packets in which the source address is the home address and destination is the care-of-address and sends it through the tunnel to the foreign agent. Foreign agent, on other side of the tunnel receives the data packets, de-encapsulates them and sends them to the mobile node. Mobile node in response to the data packets received, sends a replay in response to the foreign agent. Foreign agent directly sends the

## Key Mechanisms in Mobile IP:-

### 1. Agent discovery :-

Agents advertise their presence by periodically broadcasting their agent advertisement messages. The mobile node receiving the agent advertisement messages observes whether the message is from its own home agent and determines whether it is in the home network or foreign network.

### 2. Agent registration :-

Mobile node after discovering the foreign agent, sends registration request (RREQ) to the foreign agent. Foreign agent in turn, sends the registration request to the home agent with the Care-of-address. Home agent sends registration reply (RREP) to the foreign agent. Then it forwards the registration reply to the mobile node and completes the process of registration.

### 3. Tunneling :-

It establishes a virtual pipe for the packets available between a tunnel entry and an endpoint. It is the process of sending a packet via tunnel and it is achieved by a mechanism called encapsulation. It takes place to forward an IP datagram from the home agent to the correspondent node. Whenever home agent receives a packet from correspondent node, it encapsulates the packet with source address as care-of-address and destination as care-of-address.