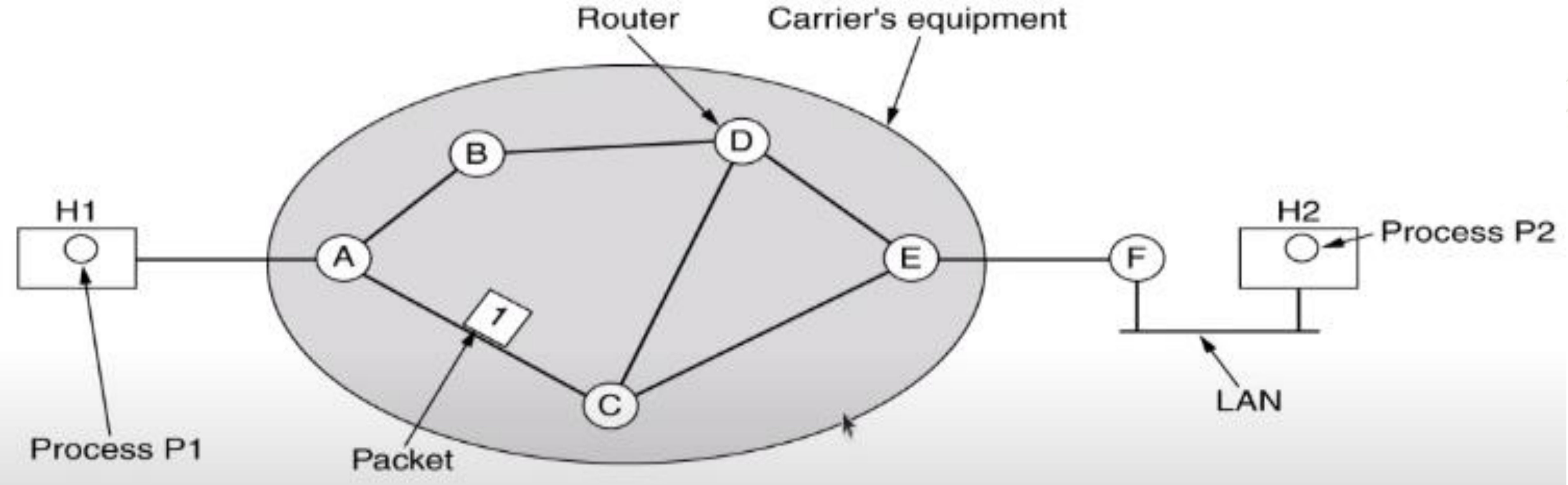
Network Layer Design Issues

- Store-and-Forward Packet Switching
- Services Provided to the Transport Layer
- Implementation of Connectionless Service
- Implementation of Connection-Oriented Service
- Comparison of Virtual-Circuit and Datagram Subnets

1- Store and Forward Packet Switching

The environment of the network layer protocols.



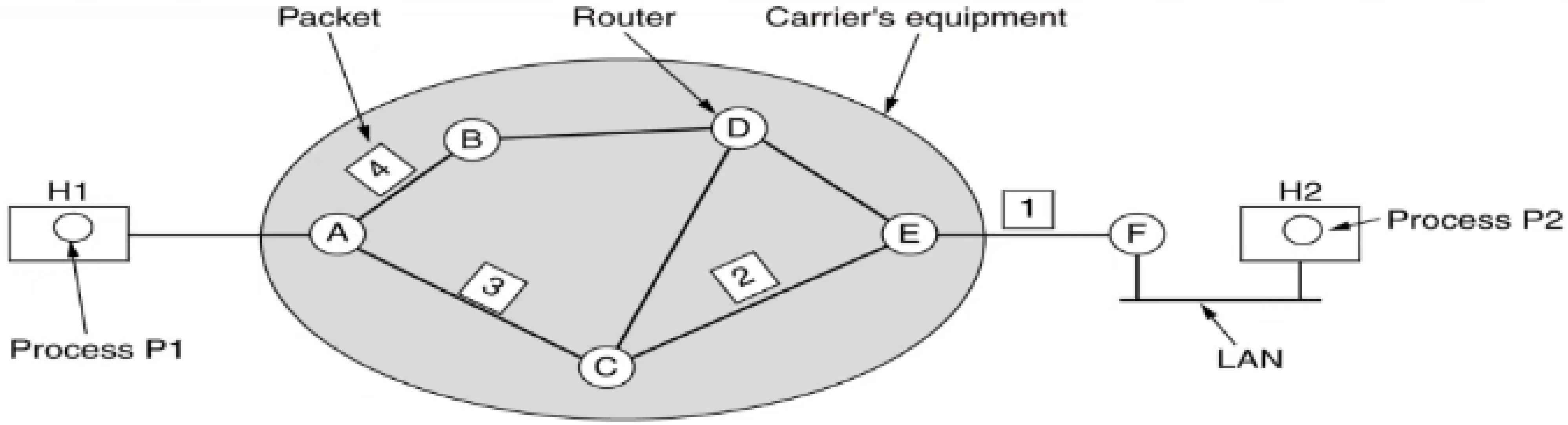
1- Store and Forward Packet Switching

- A host with a packet to send transmits it to the nearest router either on its own LAN or over a point-to-point link to the carr
- The packet is stored there until it has fully arrived so the checksum can be verified.
- Then it is forwarded to the next router along the path until it reaches the destination host, where it is delivered.
- This mechanism is store-and-forward packet switching.

2-Services to the Network Layer

- The services should be independent of the router technology.
- The transport layer should be shielded from the number, type, and topology of the routers present.
- The network addresses made available to the transport layer should use a uniform numbering plan, even across LANs and WANs.

3- Connectionless Service



A's table initially (Dest.)	A's table initially (Line)	A's table later (Dest.)	A's table later (Line)	C's table (Dest.)	C's table (Line)	E's table (Dest.)	E's table (Line)
A	–	A	–	A	A	A	C
B	B	B	B	B	A	B	D
C	C	C	C	C	–	C	C
D	B	D	B	D	D	D	D
E	C	E	B	E	E	E	–
F	C	F	B	F	E	F	F

Dest. Line

3- Connectionless Service

Assume that the message is four times longer than the maximum packet size, so the network layer has to break it into four packets, 1, 2, 3, and 4 and sends each of them in turn to router A using some point-to-point protocol.

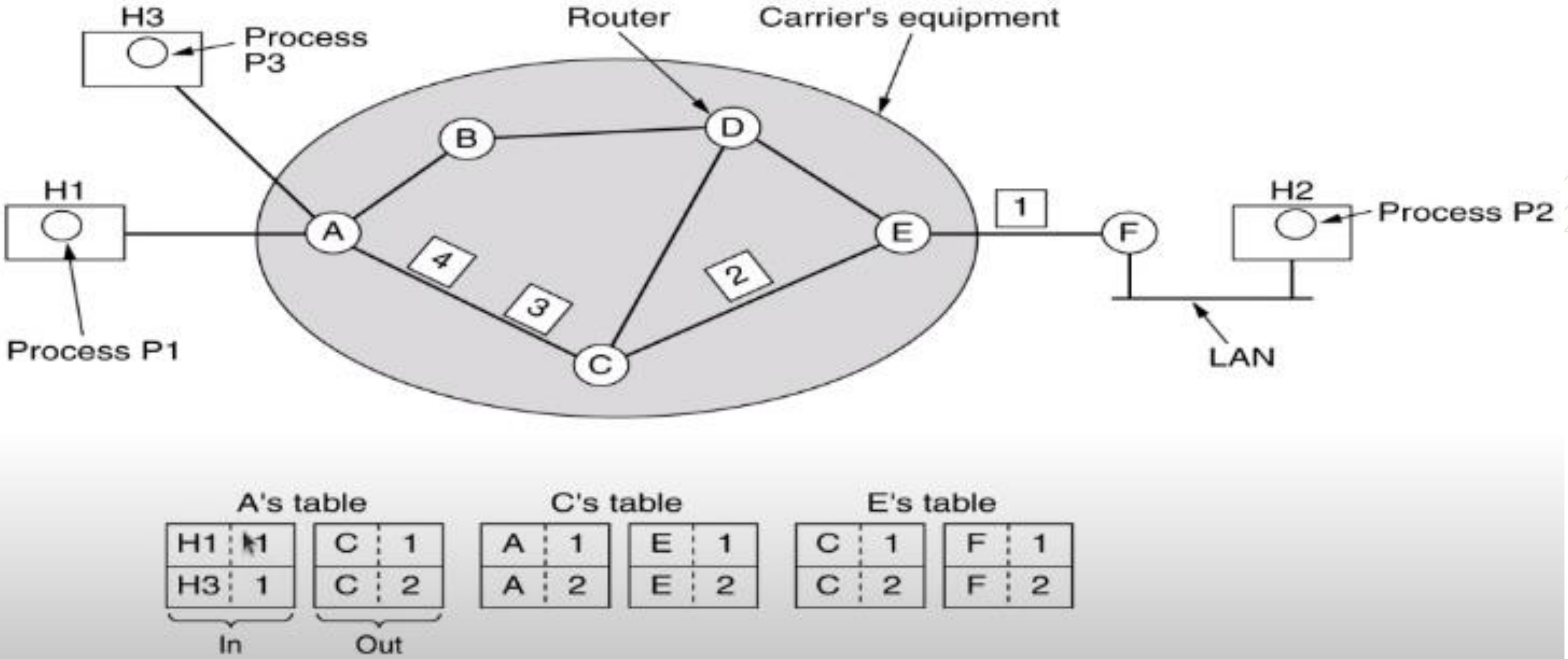
For example, PPP. At this point the carrier takes over. Every router has an internal table telling it where to send packets for each possible destination. Each table entry is a pair consisting of a destination and the outgoing line to use for that destination. Only directly- connected lines can be used.

3- Connectionless Service

However, something different happened to packet 4. When it got to A it was sent to router B, even though it is also destined for F. For some reason, A decided to send packet 4 via a different route than that of the first three. Perhaps it learned of a traffic jam somewhere along the ACE path and updated its routing table, as shown under the label "later."

The algorithm that manages the tables and makes the routing decisions is called the routing algorithm.

4- Connection Oriented Services



4- Connection Oriented Services

The idea behind virtual circuits is to avoid having to choose a new route for every packet sent.

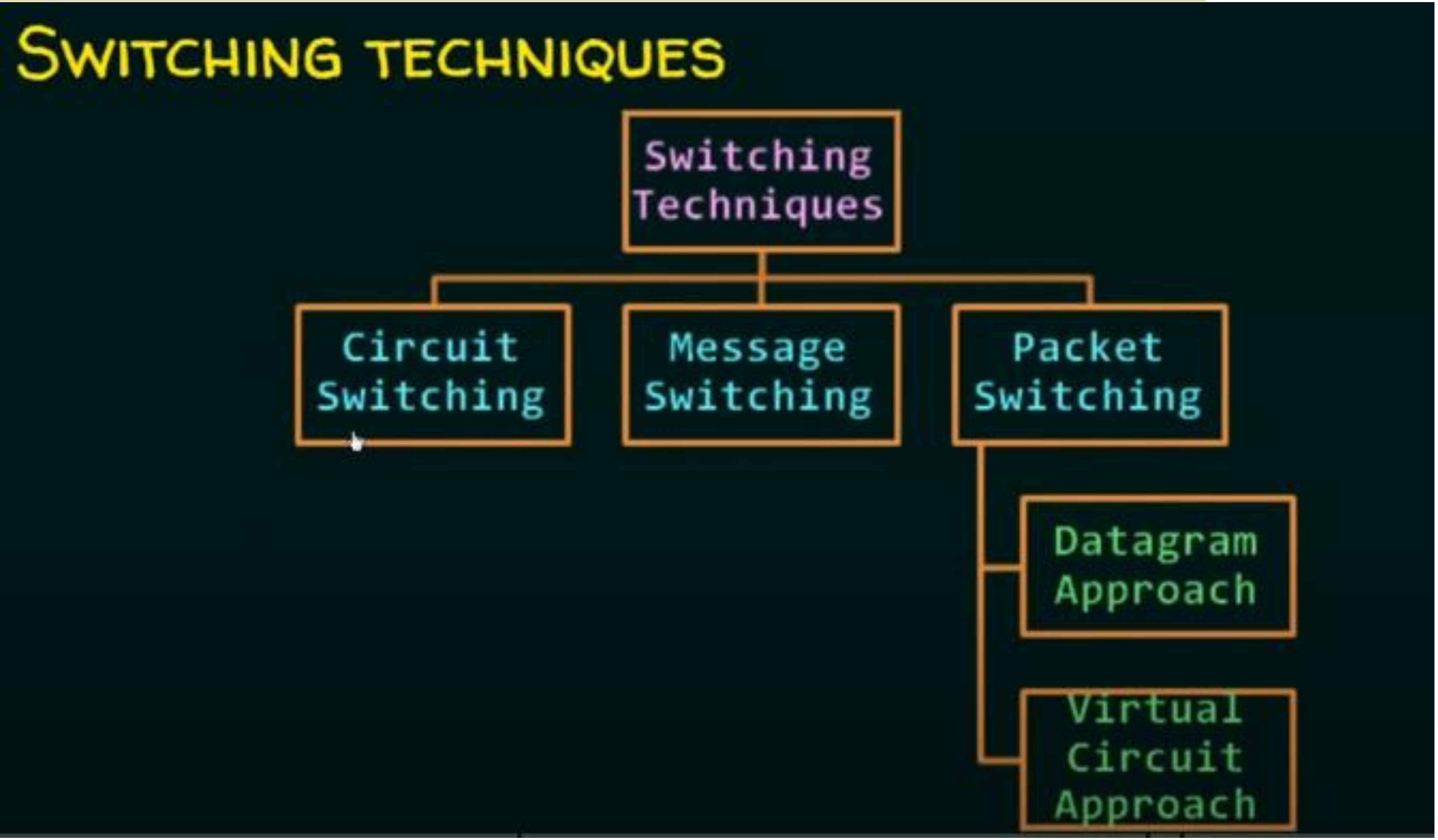
When a connection is established, a route from the source machine to the destination machine is chosen as part of the connection setup and stored in tables inside the routers.

That route is used for all traffic flowing over the connection, exactly the same way that the telephone system works.

Virtual Circuit Vs Datagram Subnets

Issue	Datagram subnet	Virtual-circuit subnet
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

Switching Techniques



Circuit Switching

★ A dedicated path is established between the sender and receiver.

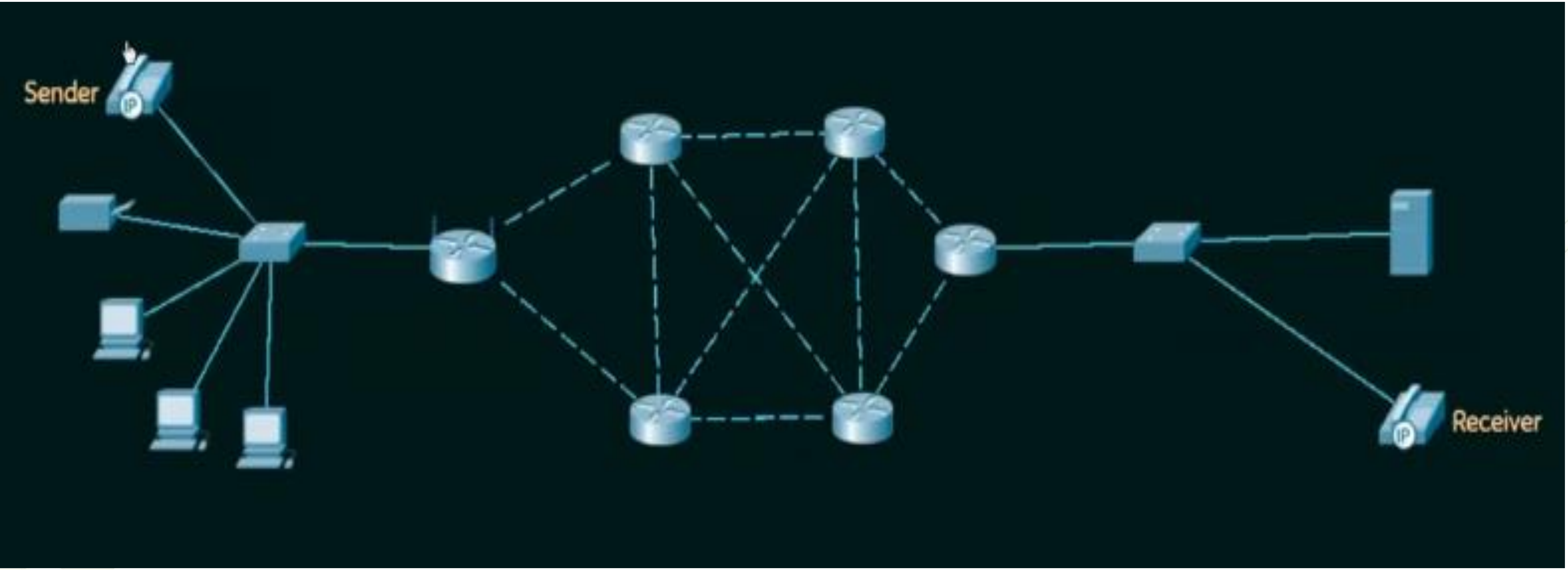
★ Before data transfer, connection will be established first.

★ Example: Telephone network.

3 phases in circuit switching:

1. Connection establishment.
2. Data transfer
3. Connection Disconnection.

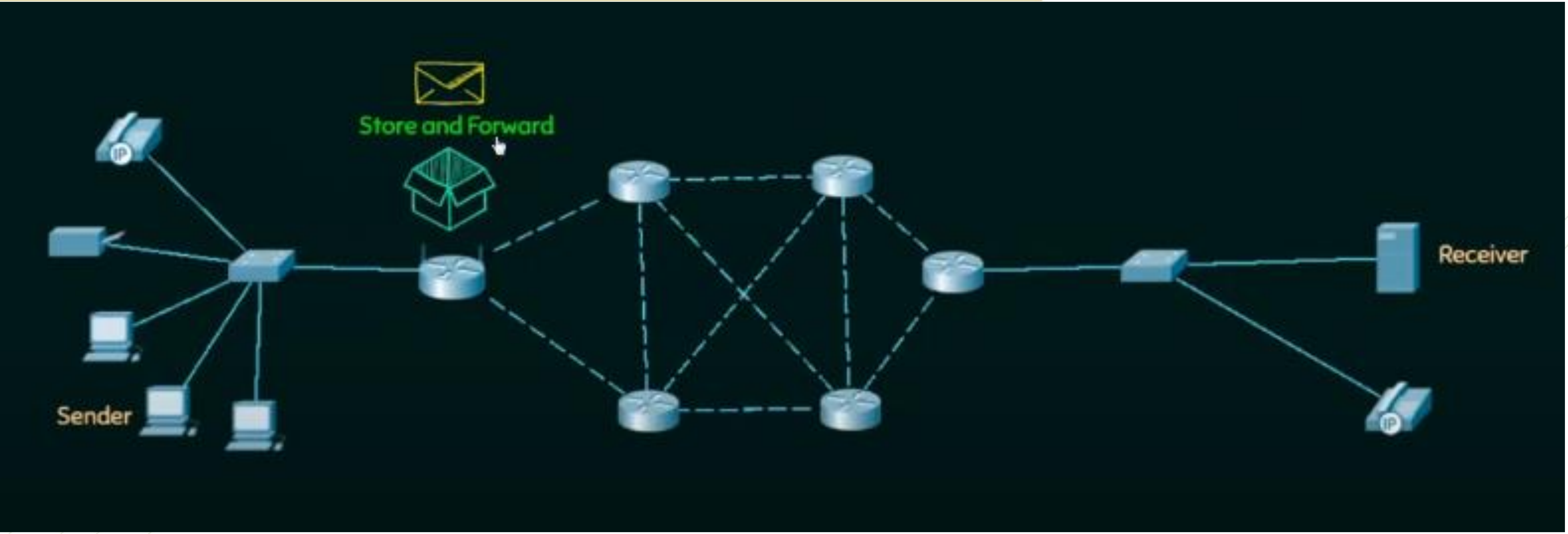
Example- Circuit Switching



Message Switching

- ★ Store and forward mechanism.
- ★ Message is transferred as a complete unit and forwarded using store and forward mechanism at the intermediary node.
- ★ Not suited for streaming media and real-time applications.

Example- Message Switching



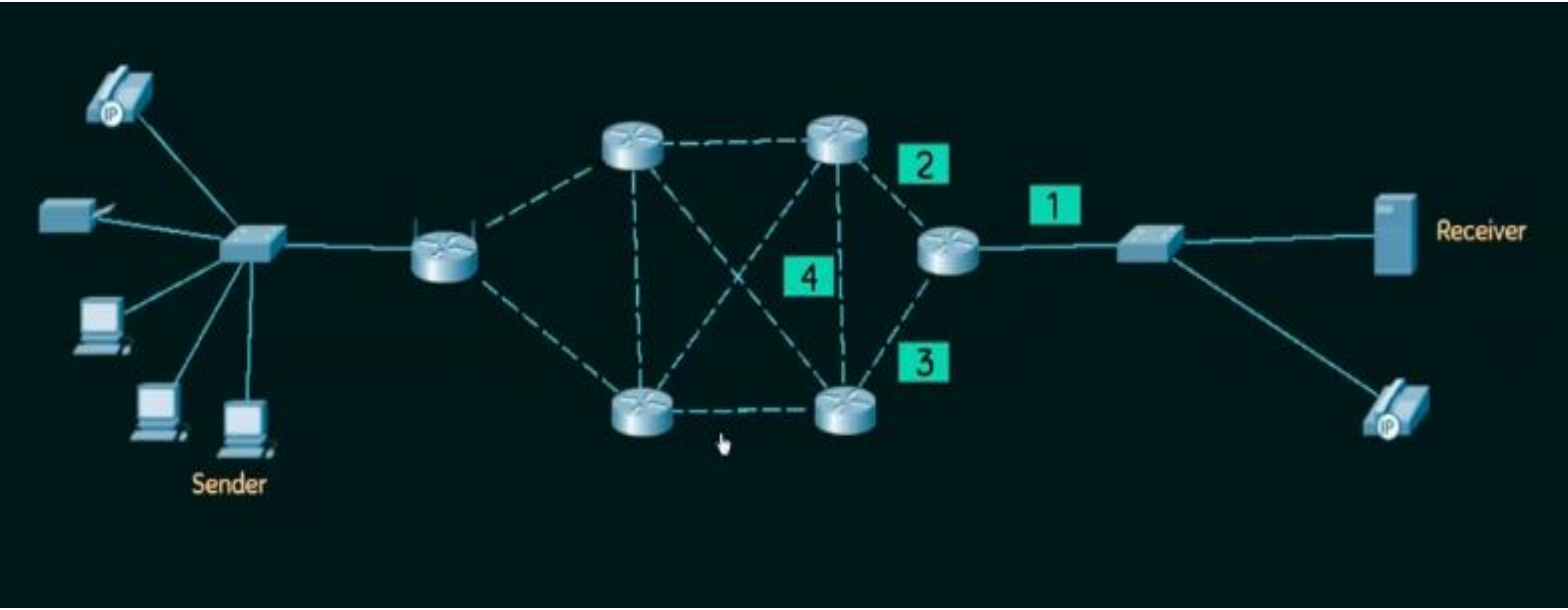
Packet Switching

- ★ The internet is a packet switched network.
- ★ Message is broken into individual chunks called as packets.
- ★ Each packet is sent individually.
- ★ Each packet will have source and destination IP address with sequence number.
- ★ Sequence numbers will help the receiver to
    - ○ Reorder the packets.
    - ○ Detect missing packets and
    - ○ Send acknowledgments.

Packet Switching- Datagram approach

- ★ Datagram Packet Switching is also known as connectionless switching.
- ★ Each independent entity is called as datagram.
- ★ Datagrams contain destination information and the intermediary devices uses this information to forward datagrams to right destination.
- ★ In Datagram Packet Switching approach, the path is not fixed.
- ★ Intermediate nodes take the routing decisions to forward the packets.

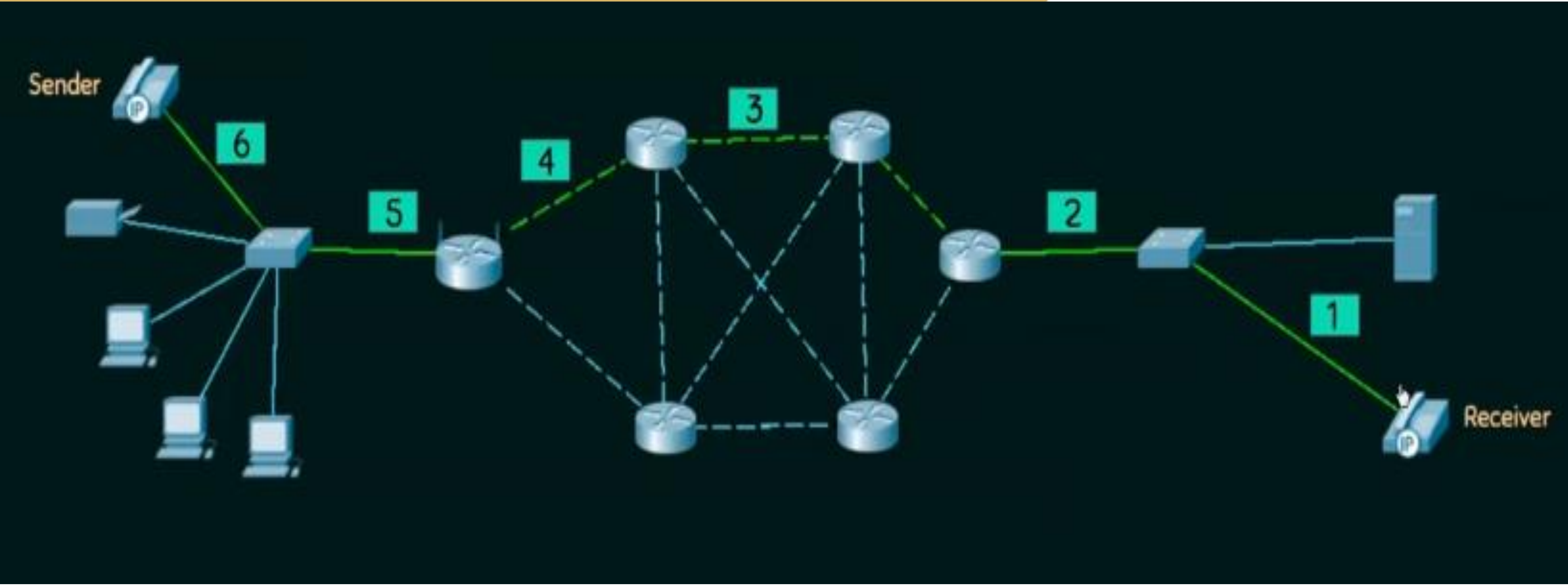
Example- Packet Switching- Datagram approach



Packet Switching- Virtual Circuit approach

- Virtual Circuit Switching is also known as connection-oriented switching.
- In the case of Virtual circuit switching, a preplanned route is established before the messages are sent.
- Call request and call accept packets are used to establish the connection between sender and receiver.
- In this approach, the path is fixed for the duration of a logical connection.

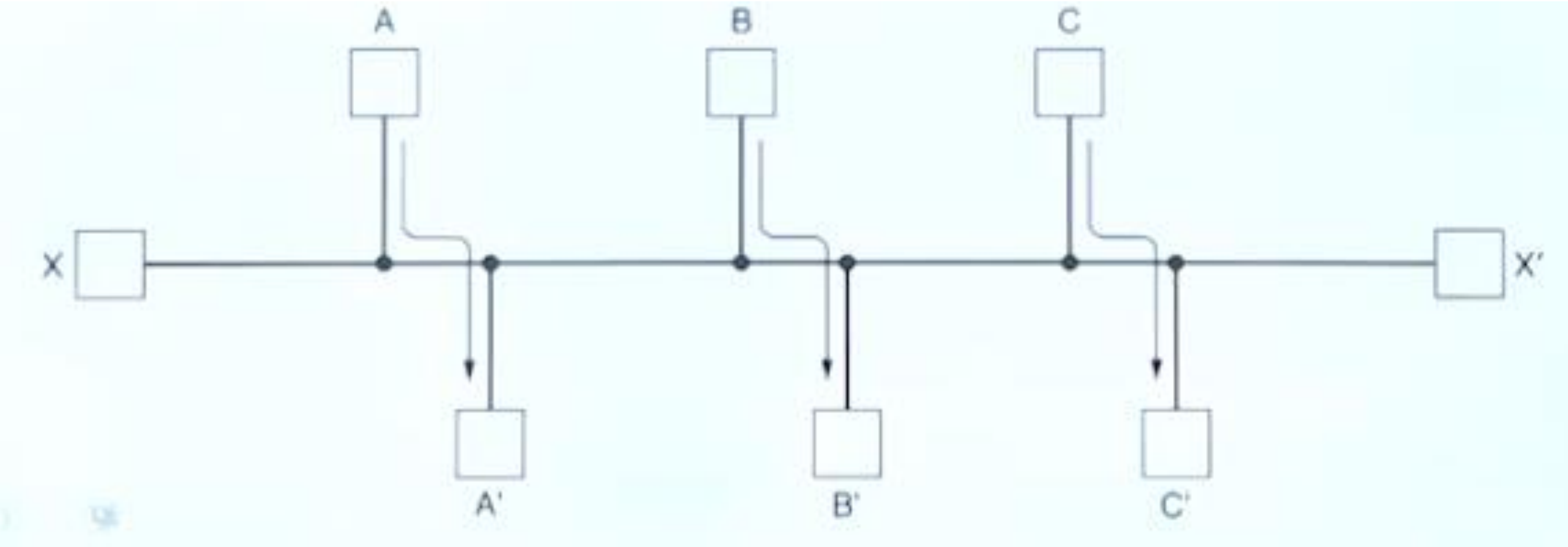
Example- Packet Switching- Virtual Circuit approach



Routing Algorithms

- Network Layer Functions:
  - forwarding: move packets from router's input to appropriate router output.
  - routing: determine route taken by packets from source to destination (routing algorithms).
- Properties of Routing algorithms:
  - Correctness
  - Simplicity
  - Robustness
  - Stability
  - Fairness
  - Optimality

Fairness Vs Optimality



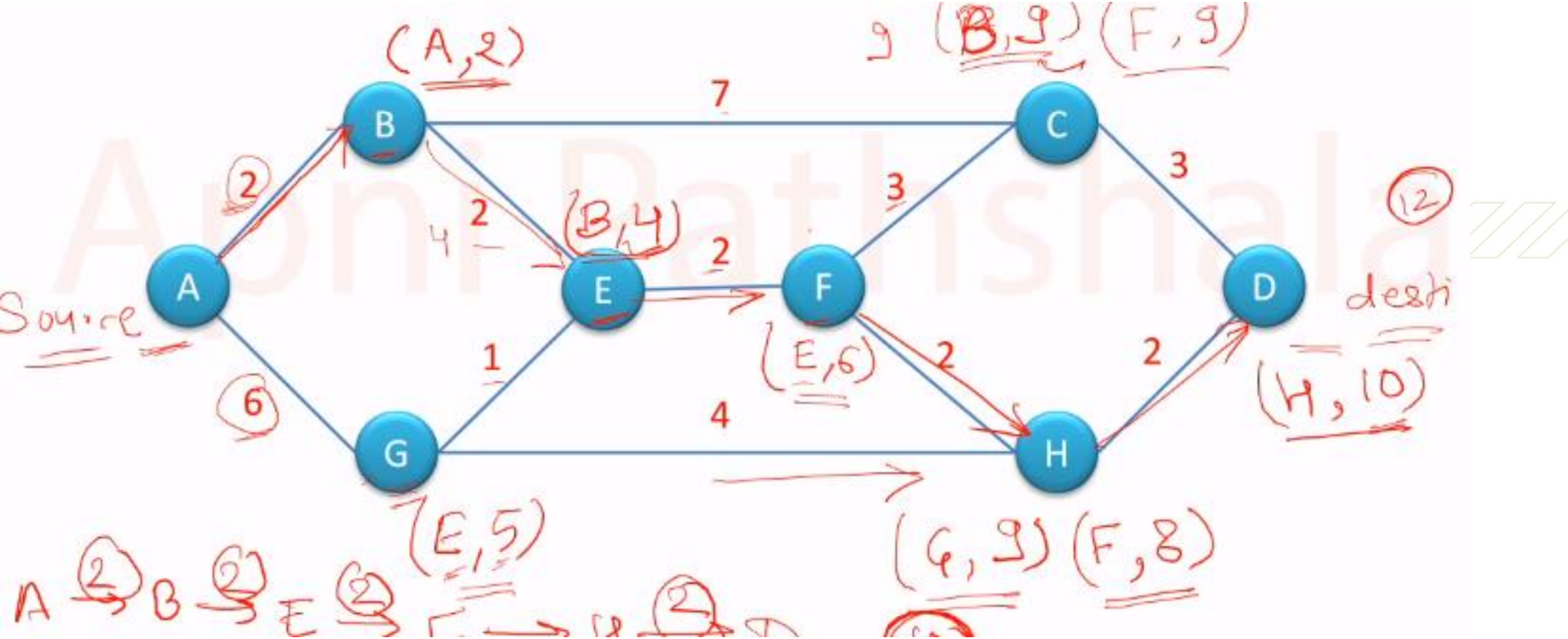
Categories of Algorithms

- 2 Categories namely nonadaptive and adaptive.
- Nonadaptive:
  - do not base their routing decisions on measurements or estimates of the current traffic and topology. Instead, the choice of the route to use to get from I to J is computed in advance offline, and downloaded to the routers when the network is booted. This procedure is sometimes called Static routing.
- Adaptive:
  - Adaptive algorithms, in contrast, change their routing decisions to reflect changes in the topology, and usually the traffic as well.
  - This procedure is sometimes called dynamic routing.

Shortest Path Algorithm

- For any Router at initial level of forwarding a packet, all router's distance is by default set to unknown.
- This algorithm basically works on distance between two Routers.
- Selects shortest distance after comparing with others.
- Forward packet to the next Router with minimum distance.
- A path between source to destination with minimum distance is selected.

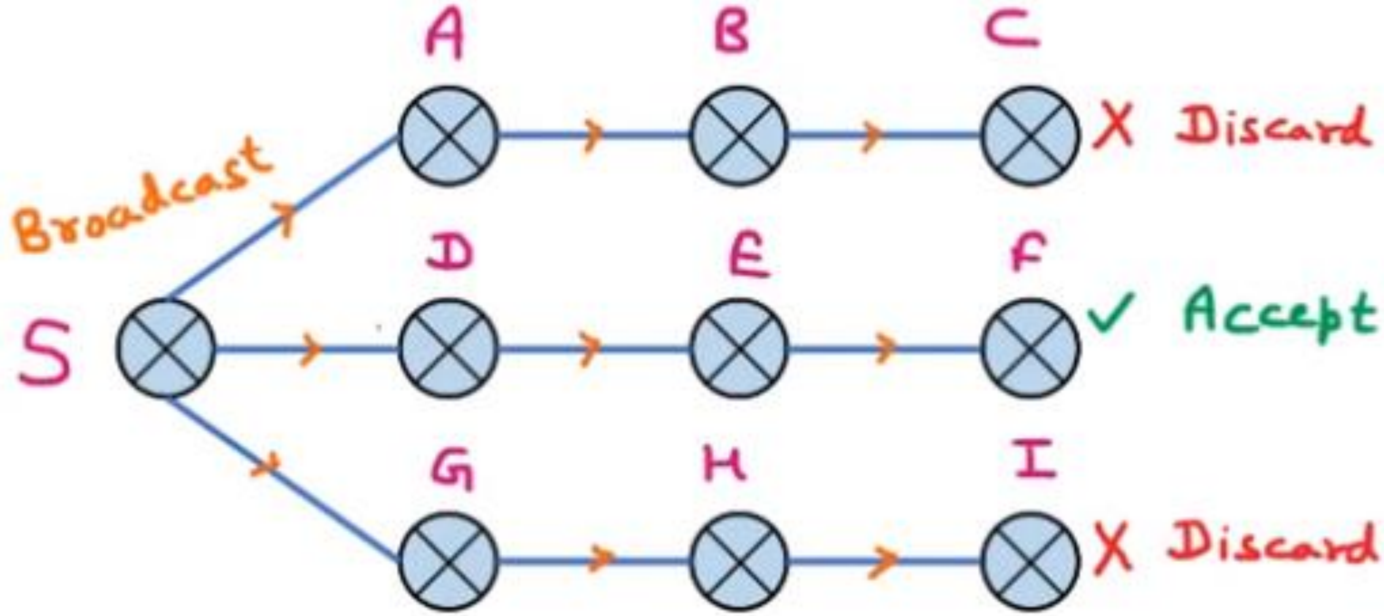
Example- Shortest Path Algorithm



Flooding and Broadcast

Flooding

- Source do not having idea about destination
- Every incoming packet is sent out on every outgoing line except the one it arrived on



Disadvantage

- Duplicate Packet

Applications

- Militery, Distributed Database

Flooding and Broadcast

- Each router must have the details of its adjacent routers.
- Sends data packets to all router expect the one from where the data packet came.
- Too many Duplicate Packets will be received to the destination end.
- To eliminate these duplicate packets counters can be used at hops, with a logic to decrement counter by one when packet arrives.

Distance Vector Routing

- Each Router's Table has one entry for one router.
- This entry has two parts
  - Preferred out going Line for each Router.
  - Estimated distance to destination Router.
- Distance is basically considered by no's of Hops.
- Delays basically measured by sending ECHO packets to another Routers.

Distance Vector Routing

Distance vector routing algorithms operate by having each router maintain a table giving the best known distance to each destination and which line to use to get there. These tables are updated by exchanging information with the neighbours.

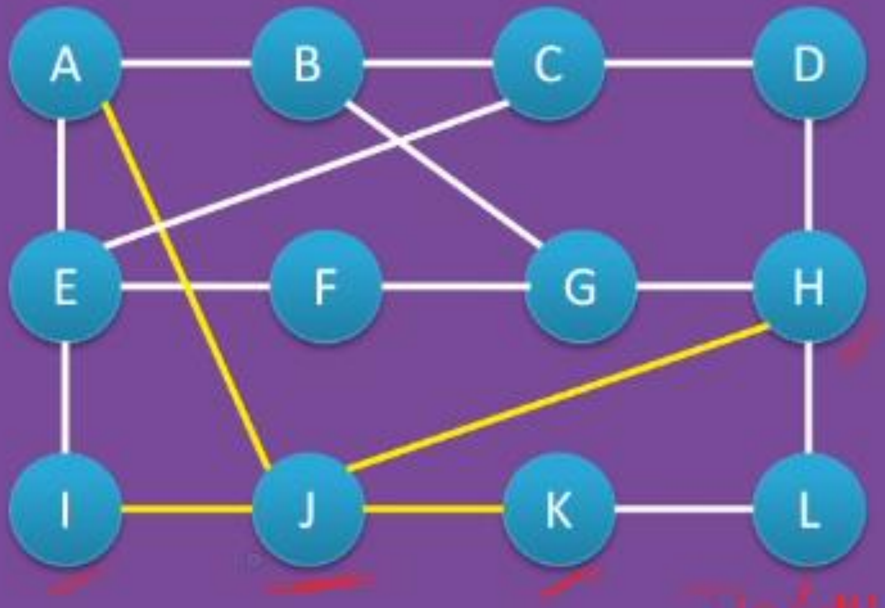
Distance vector routing algorithm uses Bellman-Ford routing algorithm and Ford-Fulkerson. It was originally ARPANET routing algorithm.

Distance Vector Routing

In distance vector routing, each router maintain a routing table which contains one entry for each router. This entry contains 2 parts:

- The preferred outgoing line to use for that destination.
- An estimate of the time or distance to that destination.
    - number of hops
    - time delay in msec
    - Total number of packets queued along the path

Example-Distance Vector Routing



JA Delay is 8
JI Delay is 10
JH Delay is 12
JK Delay is 6

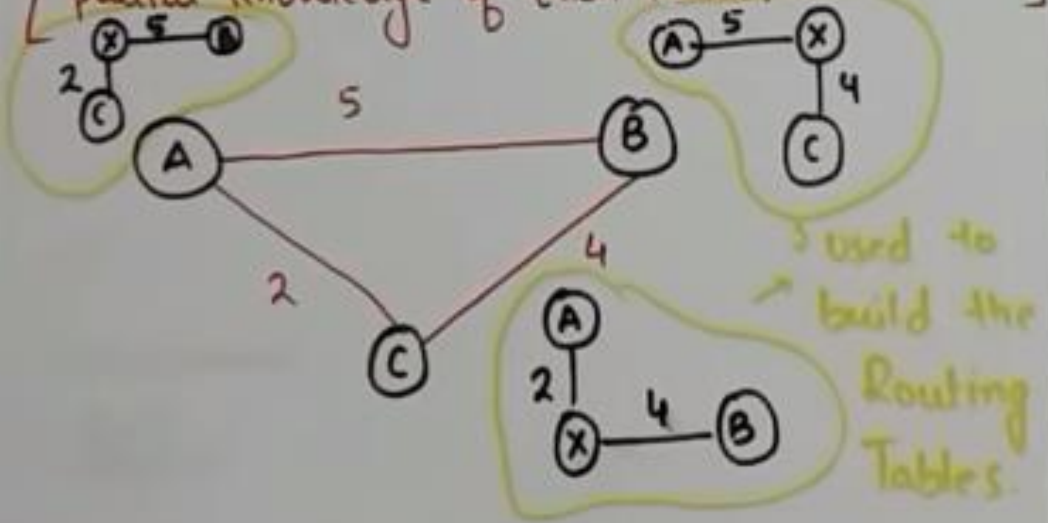
	A	I	H	K
A	0	24	20	21
B	12	36	31	28
C	25	18	19	36
D	40	27	8	24
E	14	7	30	22
F	23	20	19	40
G	18	31	6	31
H	17	20	0	19
I	21	0	14	22
J	9	11	7	10
K	24	22	22	0
L	29	33	9	9

J	Line
8	A
20	A
28	I
20	H
17	I
30	I
18	H
12	H
10	I
0	-
6	K
15	K

Link State Routing

Link State Routing Protocol:- In this, if each node in the domain has entire topolody of domain i.e., list of nodes and links, How they are connected, type, cost and condⁿ of link, then the node can use Dijkstra Algorithm to build Routing Table.

[In this whole topology can be compiled from partial knowledge of Each Node.]



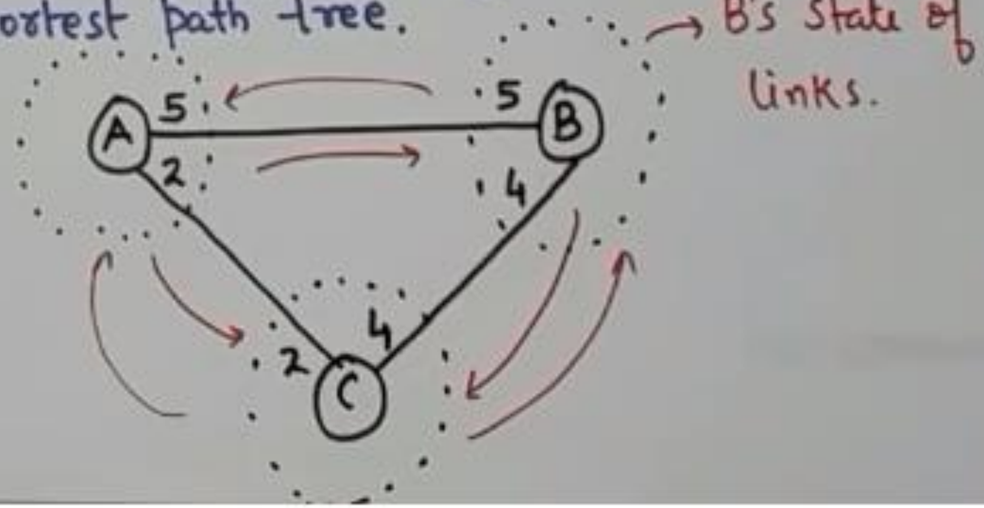
Building Routing Tables:- Following actions are required to ensure that each node has the routing table:-

i) Creation of the States of the links by each node, Called Link State Packet (LSP).

ii) Dissemination of LSPs to every router, Called Flooding.

iii) Formation of Shortest path tree for each node.

iv) Calculation of a routing table based on the Shortest path tree.



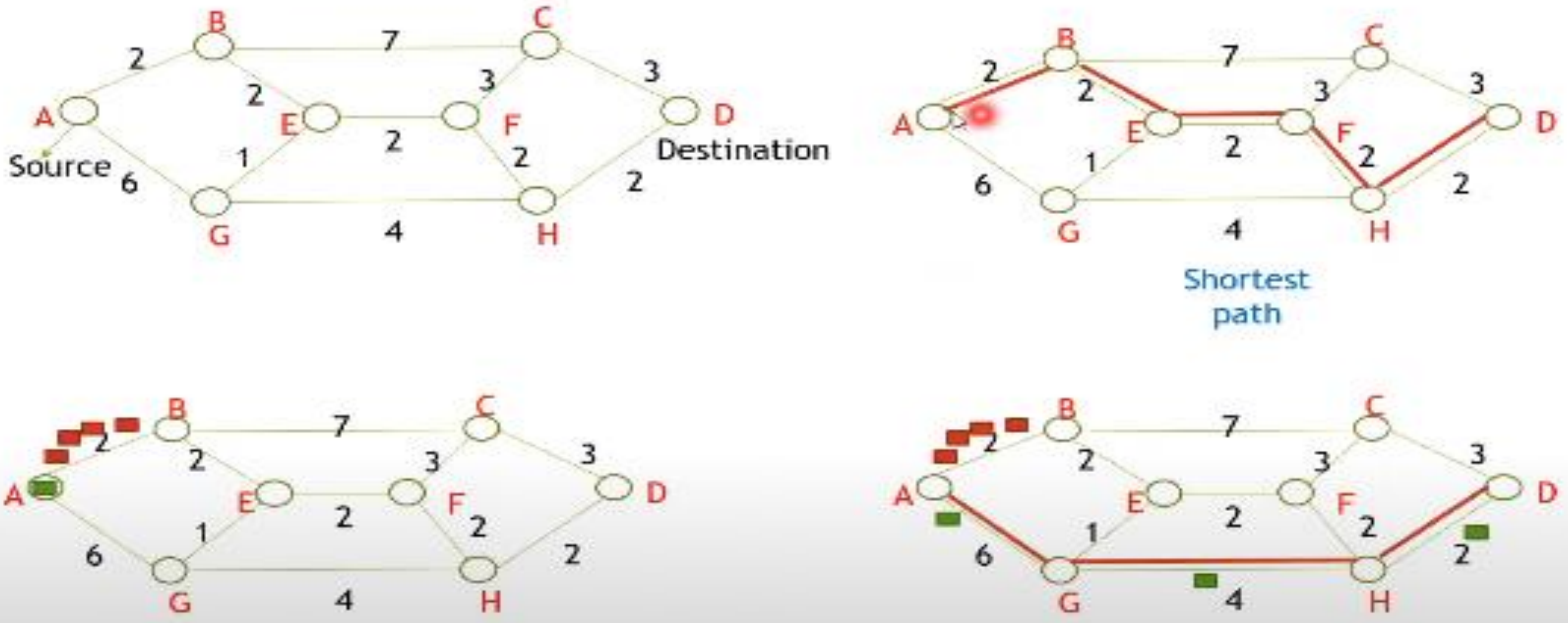
Flow based Routing

Flow routing is a static routing algorithm which uses topology and load conditions (traffic) for deciding a route. It takes variations in the flow of data into account to increase routing efficiency.

To use this technique the following should be known in advance -

- Subnet topology
- Traffic
- Line capacity (bandwidth)

Example- Flow based Routing



Let Traffic is more from A to B

Next shortest path it will choose i.e A - G - H - D

Multicast Routing

SCHOOL OF ENGINEERING AND TECHNOLOGY

VIPS Technical Campus

IN PURSUIT OF PERFECTION

– One Node to Many Node (Fixed Node) Group

- Some applications send packets to multiple receivers, such as multiplayer game or live video of a sports event streamed to many viewing locations.

10 → 1 → 5

~~5~~

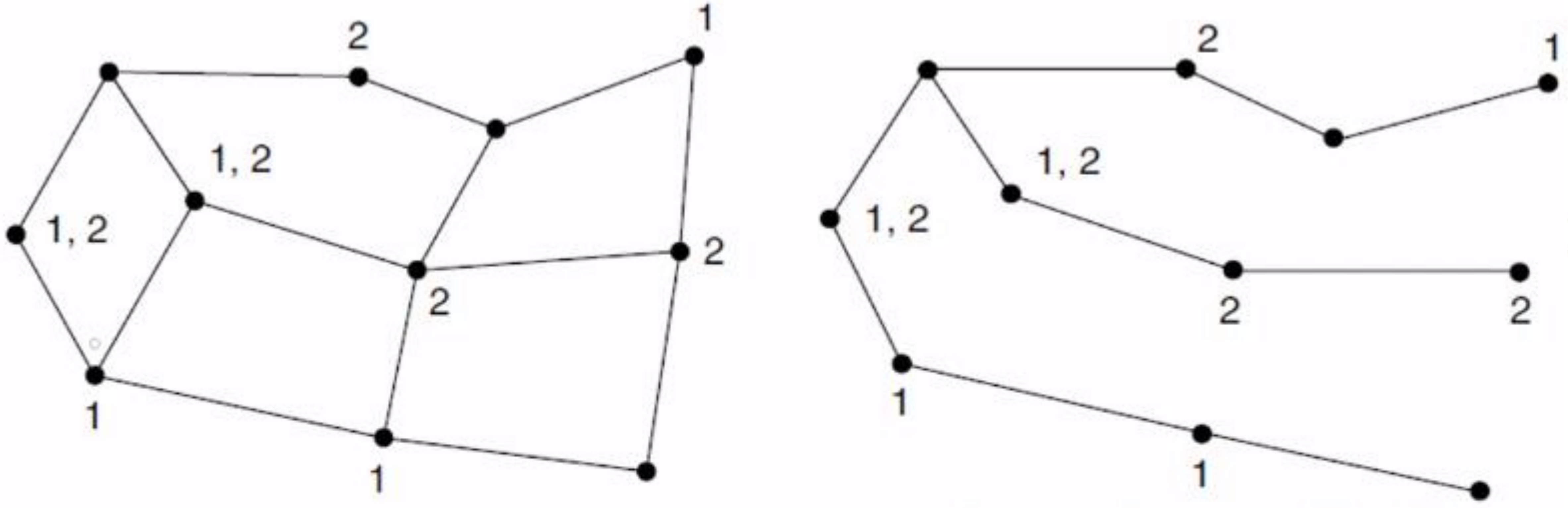
- Data Transmissions may be done as
  – Send packets to each receiver i.e. Expensive
  – Broadcasting the packets i.e. Wasteful

1–1

Multicast Routing

- Sending messages to well defined groups that are numerically large in size but small compared to the network as a whole, is called Multicasting.
- The routing algorithm used is called Multicast Rout
- A single router in a network can be part of two or more different groups.

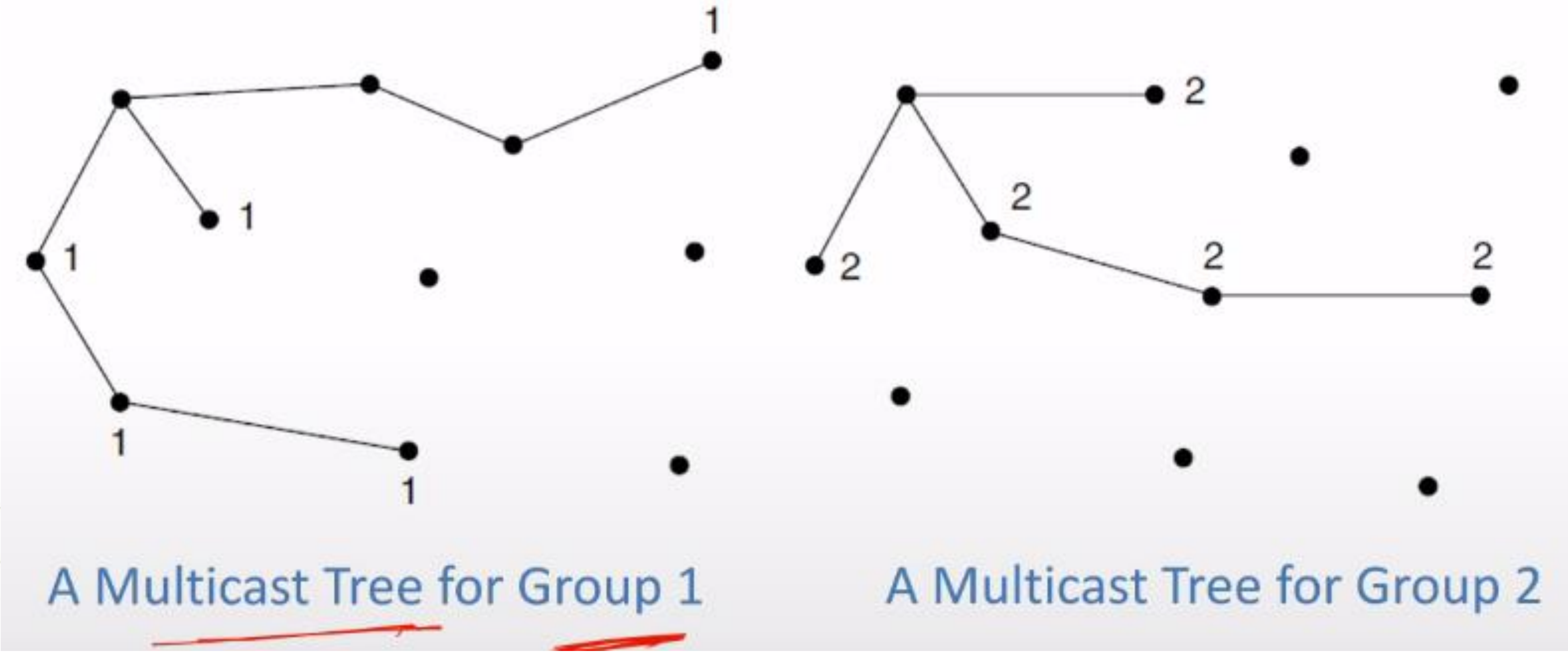
Example- Multicast Routing



A Network

A spanning tree for the leftmost router

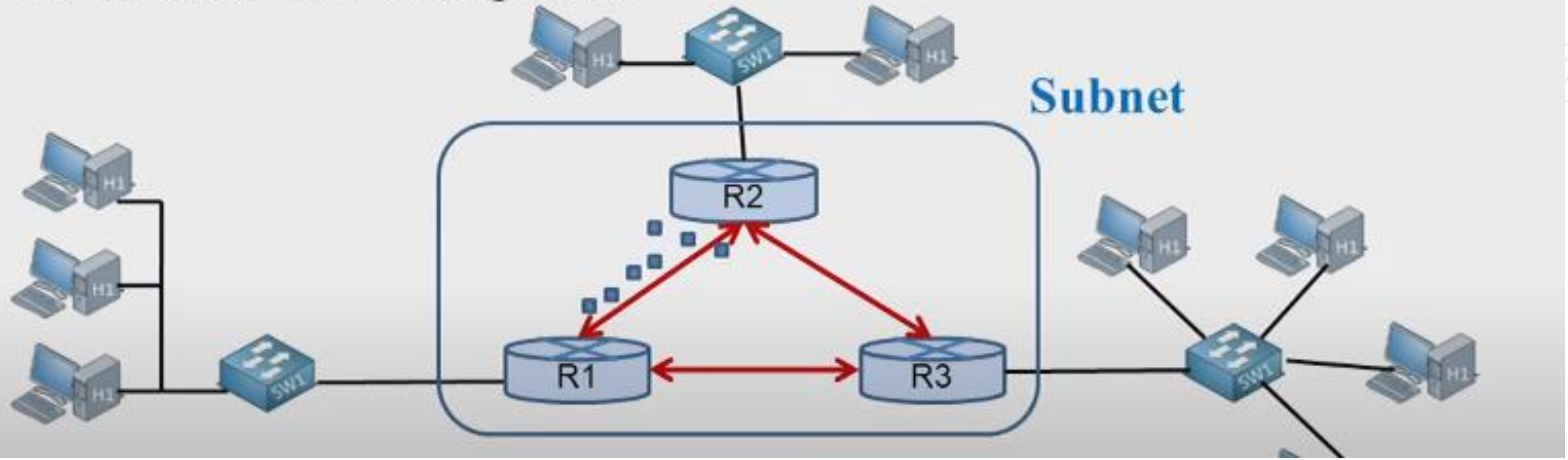
Example- Multicast Routing



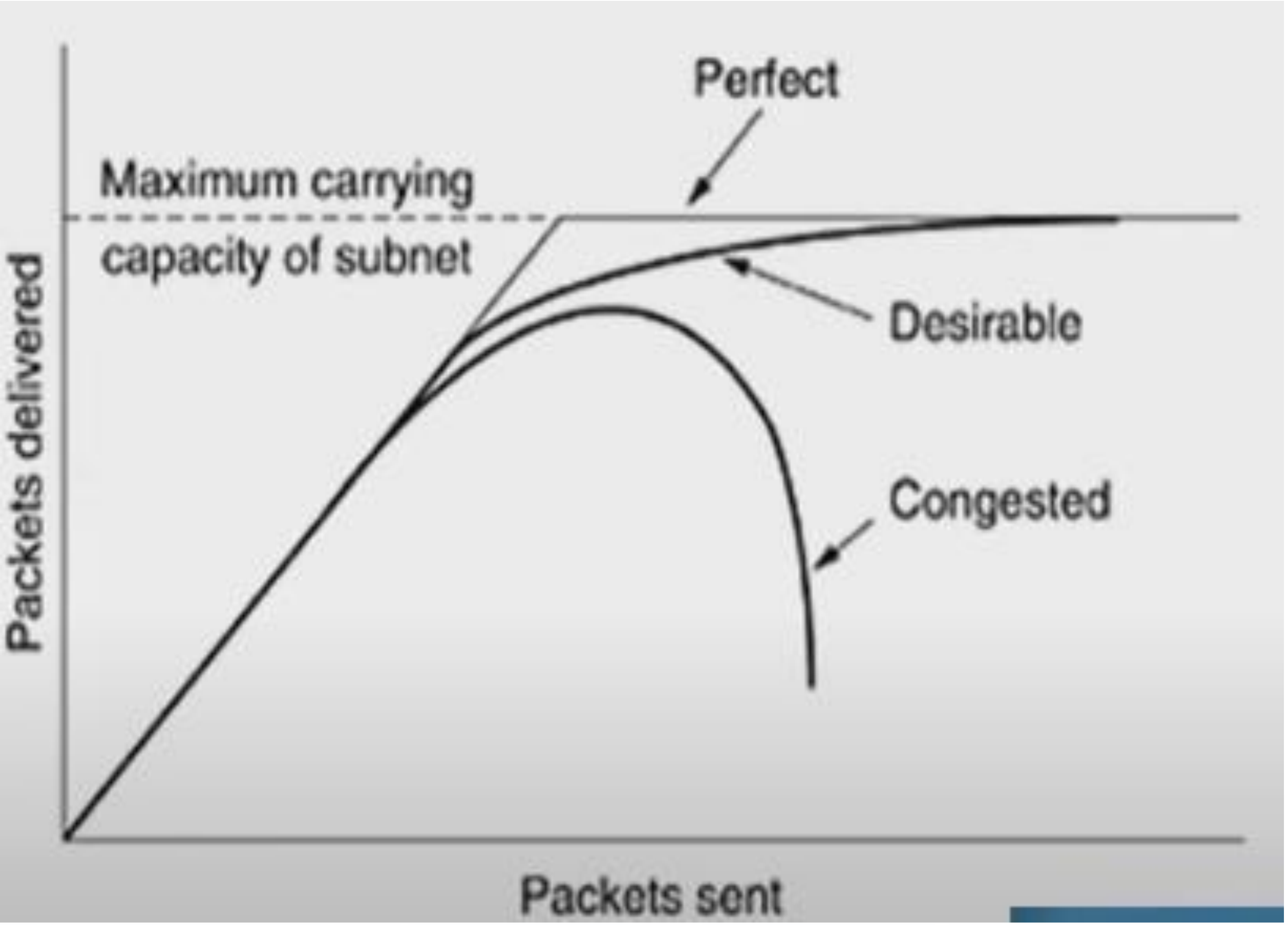
Congestion Control

Definition:

When too many packets are present in (a part of) the subnet, performance degrades. This situation is called **congestion.**



Congestion Control



Congestion Control

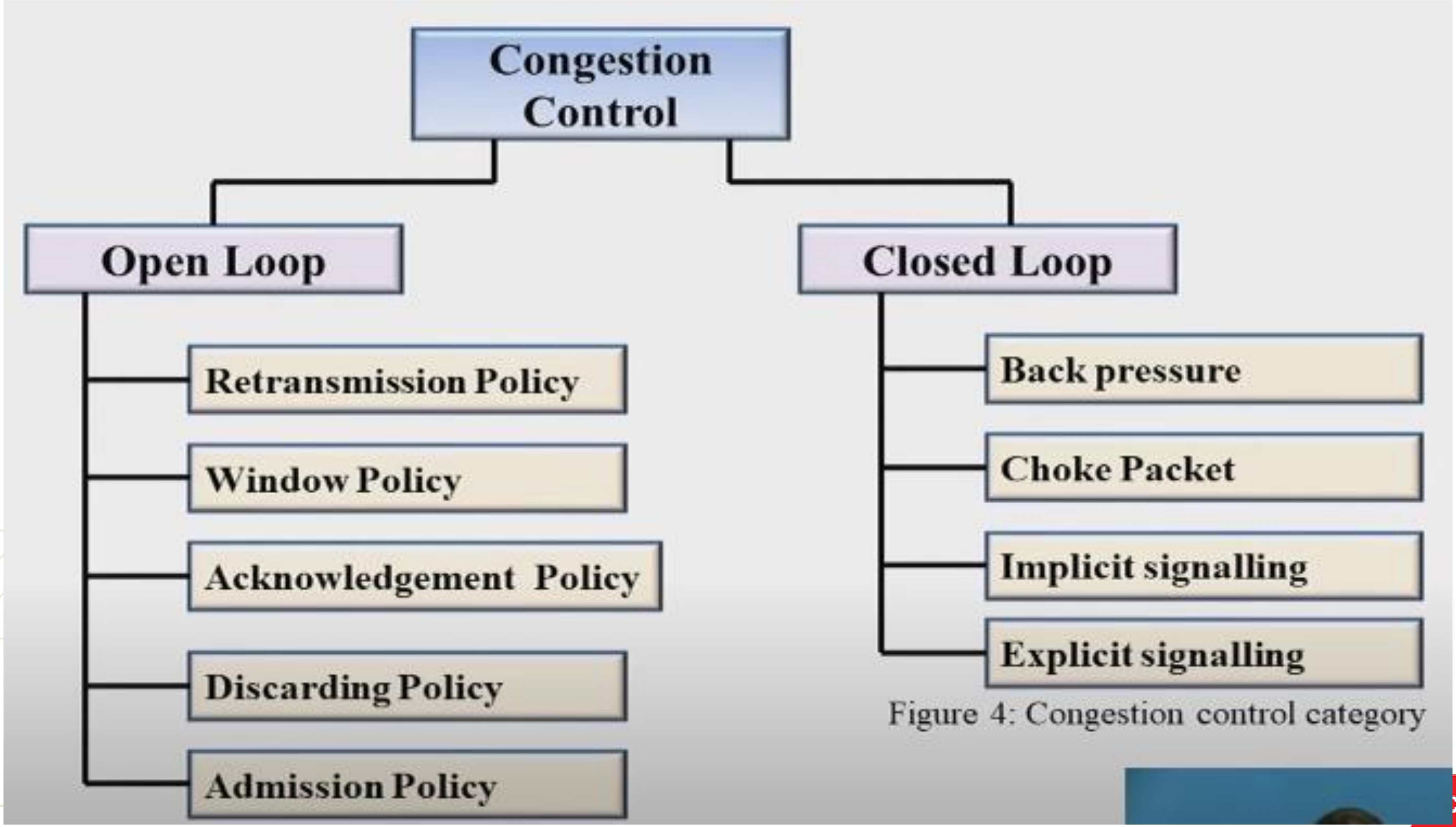


Figure 4: Congestion control category

Congestion Control

- Too many packets present in (a part of) the network causes packet delay and loss that degrades performance. This situation is called Congestion.
- The network and transport layers share the responsibility for handling congestion.
- Congestion occurs within the network, it is the network layer that directly experiences it and must ultimately determine what to do with the excess packets.

Example- Congestion and Flow Control

- Congestion Control and Flow Control ?
- Example 1 : Network with 100 Gbps line capacity and a Super Computer sends the data to Personal Computer continuously.
- Example 2 : Network of 1000 Computers with 1 Mbps line capacity, half computers want to send data to another half computers as 100 Kbps data rate.

Approaches to Congestion Control

- The presence of congestion means that the load is (temporarily) greater than the resources (in a part of the network) can handle.

Congestion = Load > Resources

- Two solutions come to mind:
  - Increase the resources.
  - Decrease the load.

Timescale of Approaches

- Solutions are usually applied on different time scales to either prevent congestion or react to it once it has occurred.