Switching Techniques

In large networks there might be multiple paths linking sender and receiver. Information may be switched as it travels through various communication channels.

There are three typical switching techniques available for digital traffic.

- Circuit Switching
- Message Switching
- Packet Switching

Circuit Switching

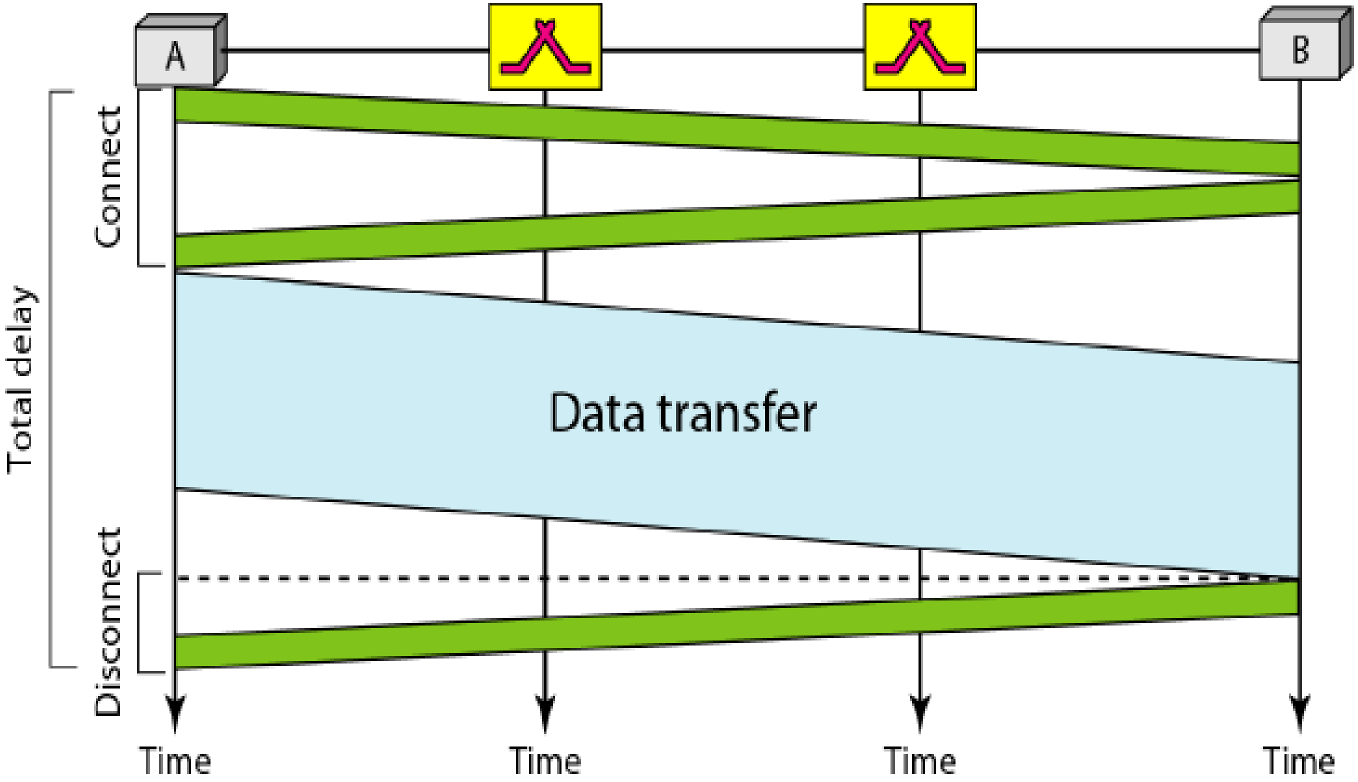
- *sender and the receiver connected directly in an unbroken path.*

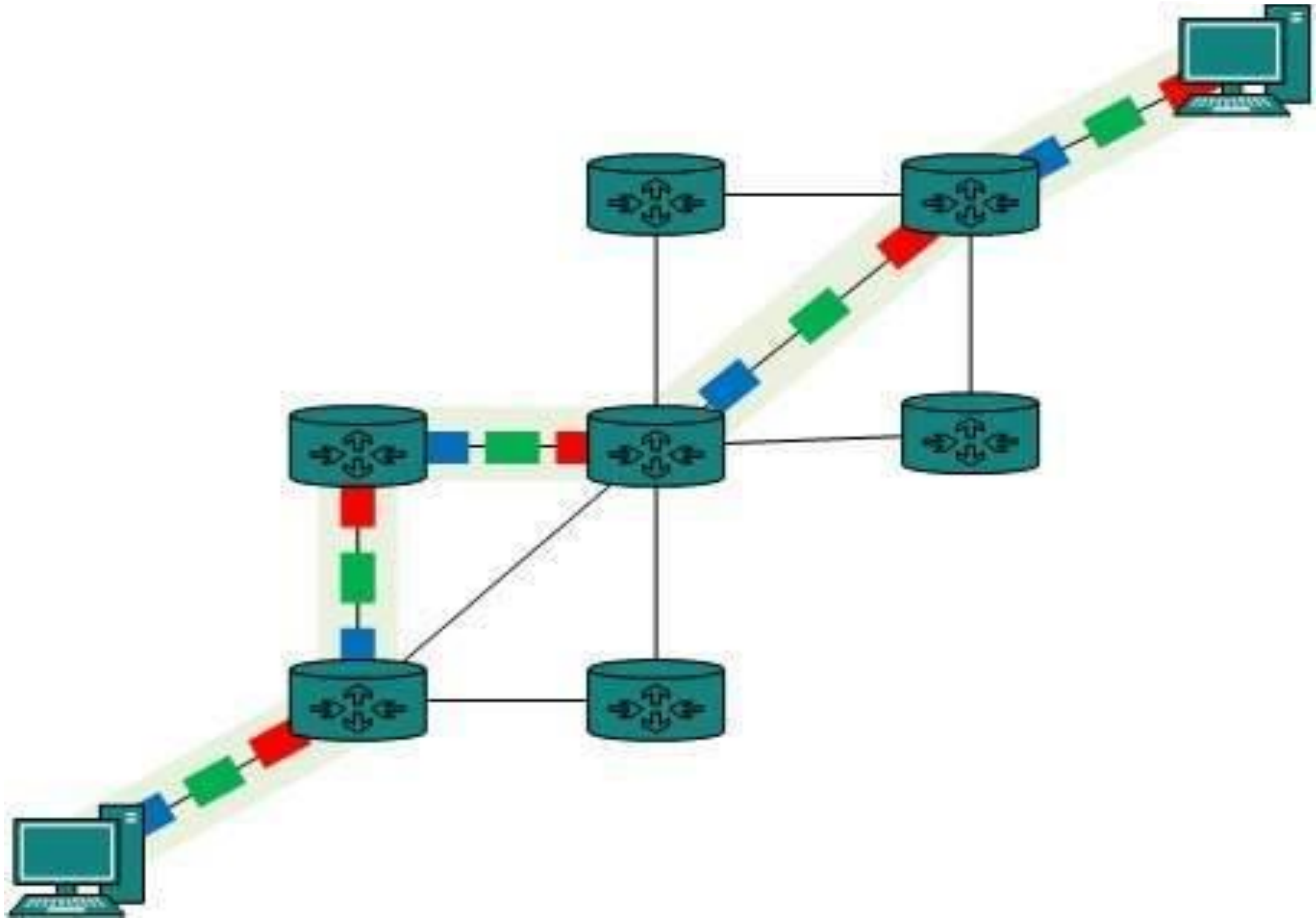
- Telephone switching equipment, for example, establishes a path that connects the caller's telephone to the receiver's telephone by making a physical connection.
- With this type of switching technique, once a connection is established, a dedicated path exists between both ends until the connection is terminated.
- Routing decisions must be made when the circuit is first established, but there are no decisions made after that time.

Circuit Switching

- **Circuit switching** in a network operates almost the same way as the telephone system works.
- A complete end-to-end path must exist before communication can take place.
- The computer initiating the data transfer must ask for a connection to the destination.
- Once the connection has been initiated and completed to the destination device, the destination device must acknowledge that it is ready and willing to carry on a transfer.

Three Phases of Circuit Switching





Advantages:

- The communication channel (once established) is dedicated.
- It has fixed bandwidth
- The data transmission delay is negligible. No waiting time is involved in switches.

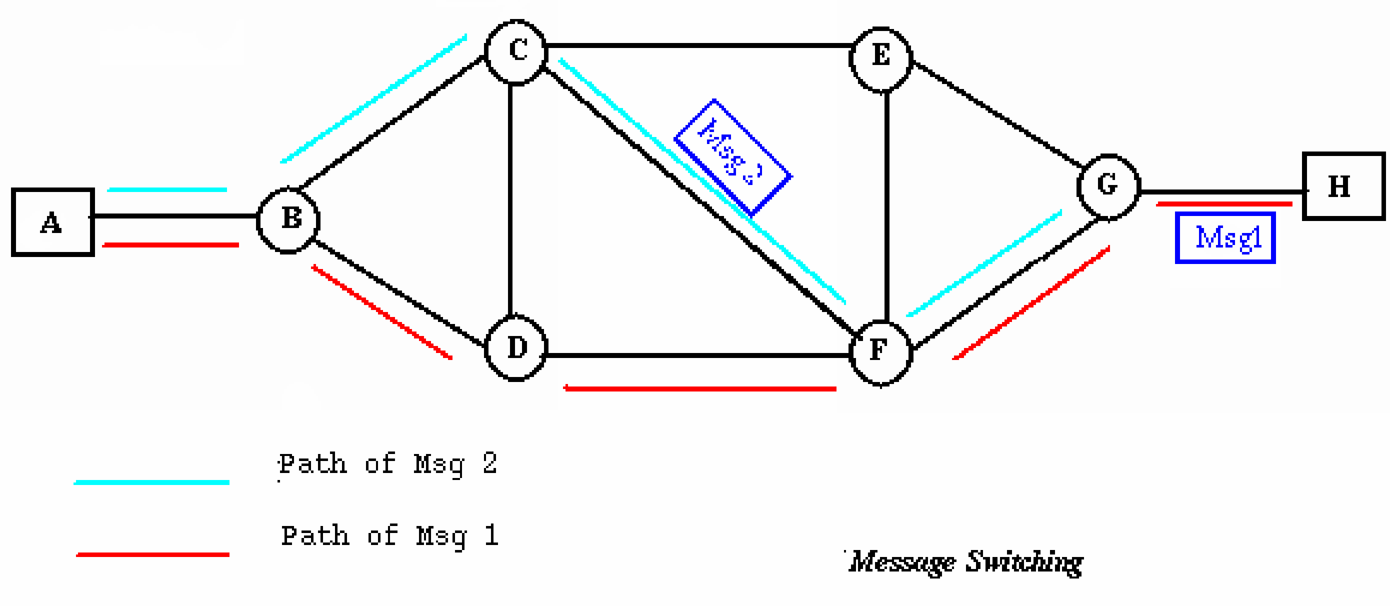
Disadvantages:

- Possible long wait to establish a connection, (10 seconds, more on long- distance or international calls.) during which no data can be transmitted.
- More expensive than any other switching techniques, because a dedicated path is required for each connection.
- Inefficient use of the communication channel, because the channel is not used when the connected systems are not using it.

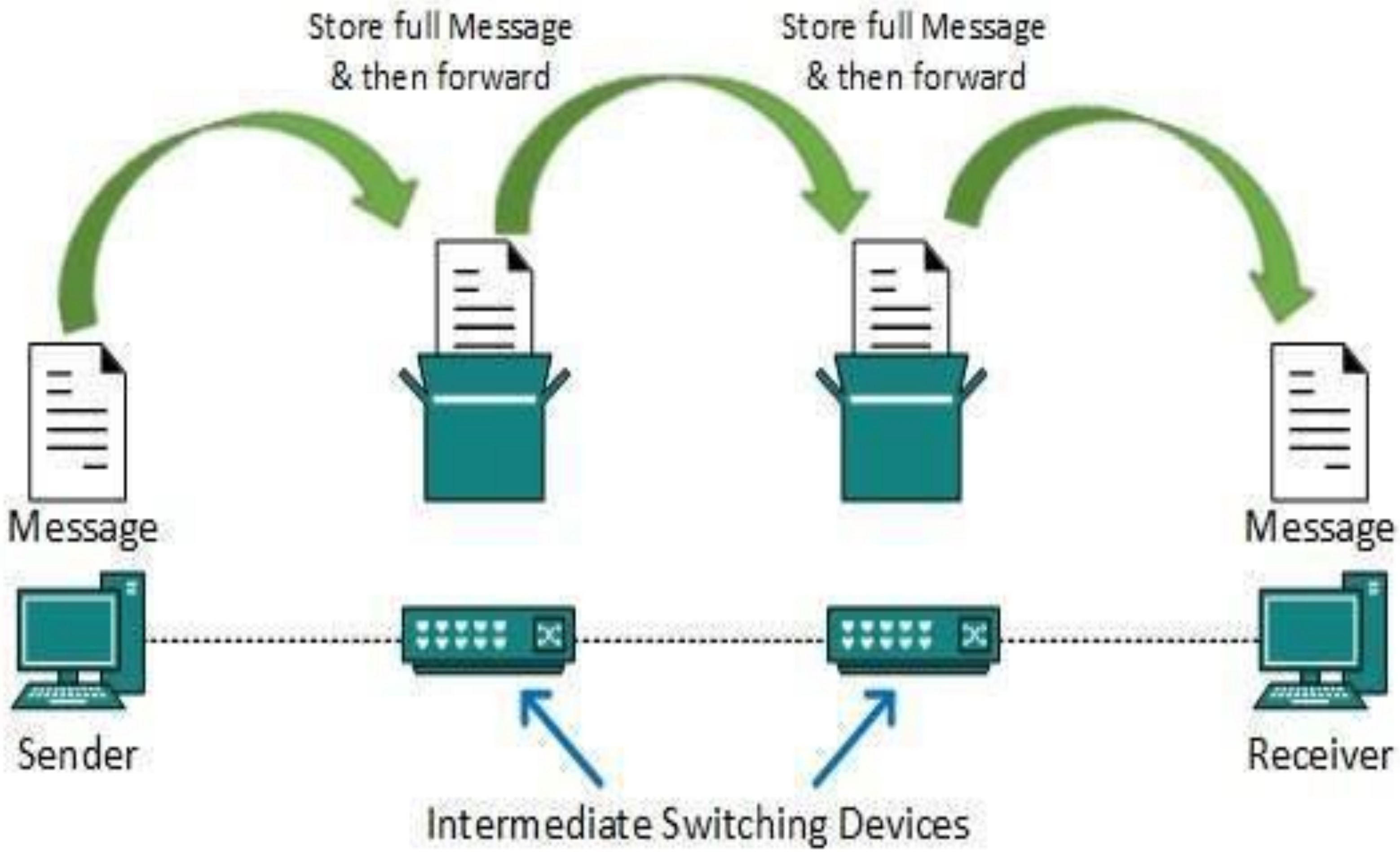
Message Switching

- With message switching there is no need to establish a dedicated path between two stations.
- When a station sends a message, the destination address is appended to the message.
- The message is then transmitted through the network, in its entirety, from node to node.
- Each node receives the entire message, stores it in its entirety on disk, and then transmits the message to the next node.
- This type of network is called a store-and-forward network.

Message Switching



A message-switching node is typically a general-purpose computer. The device needs sufficient secondary-storage capacity to store the incoming messages, which could be long. A time delay is introduced using this type of scheme due to store- and-forward time, plus the time required to find the next node in the transmission path.


Store full Message
& then forward
Store full Message
& then forward
Message
Message
Sender
Receiver
Intermediate Switching Devices

Advantages:

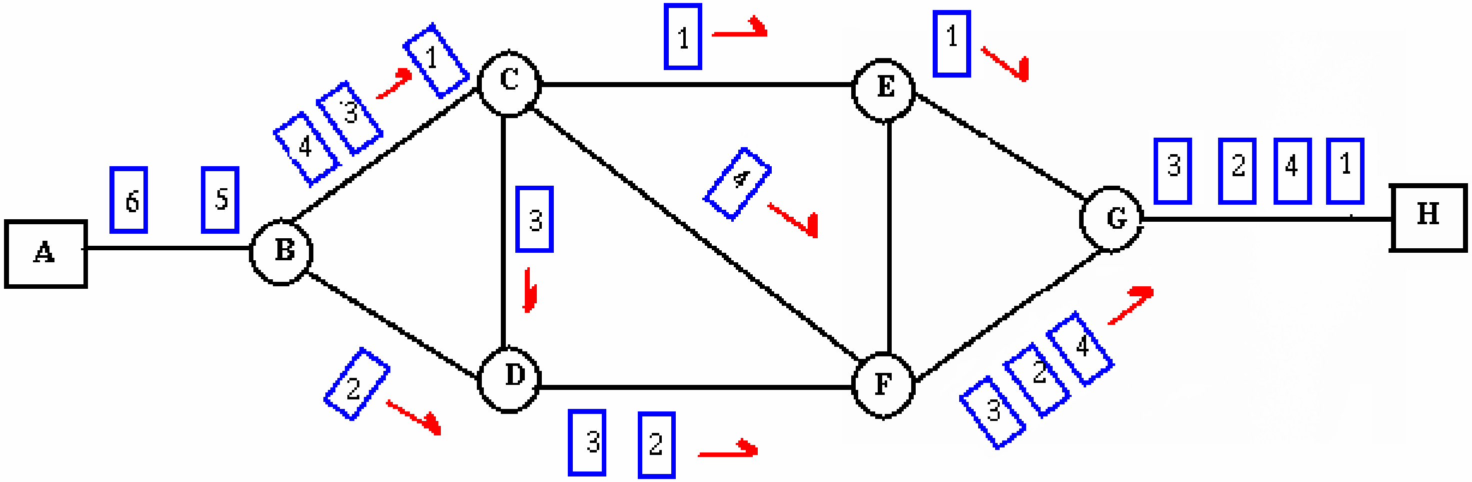
- Channel efficiency can be greater compared to circuit-switched systems, because more devices are sharing the channel.
- Traffic congestion can be reduced, because messages may be temporarily stored in route.
- Message priorities can be established due to store-and-forward technique.
- Message broadcasting can be achieved with the use of broadcast address appended in the message.

Disadvantages

- Message switching is not compatible with interactive applications.
- Store-and-forward devices are expensive, because they must have large disks to hold potentially long messages.

Packet Switching

- combine the advantages of message and circuit switching and to minimize the disadvantages of both.
- There are two methods of packet switching:
- **Datagram**
- **virtual circuit.**



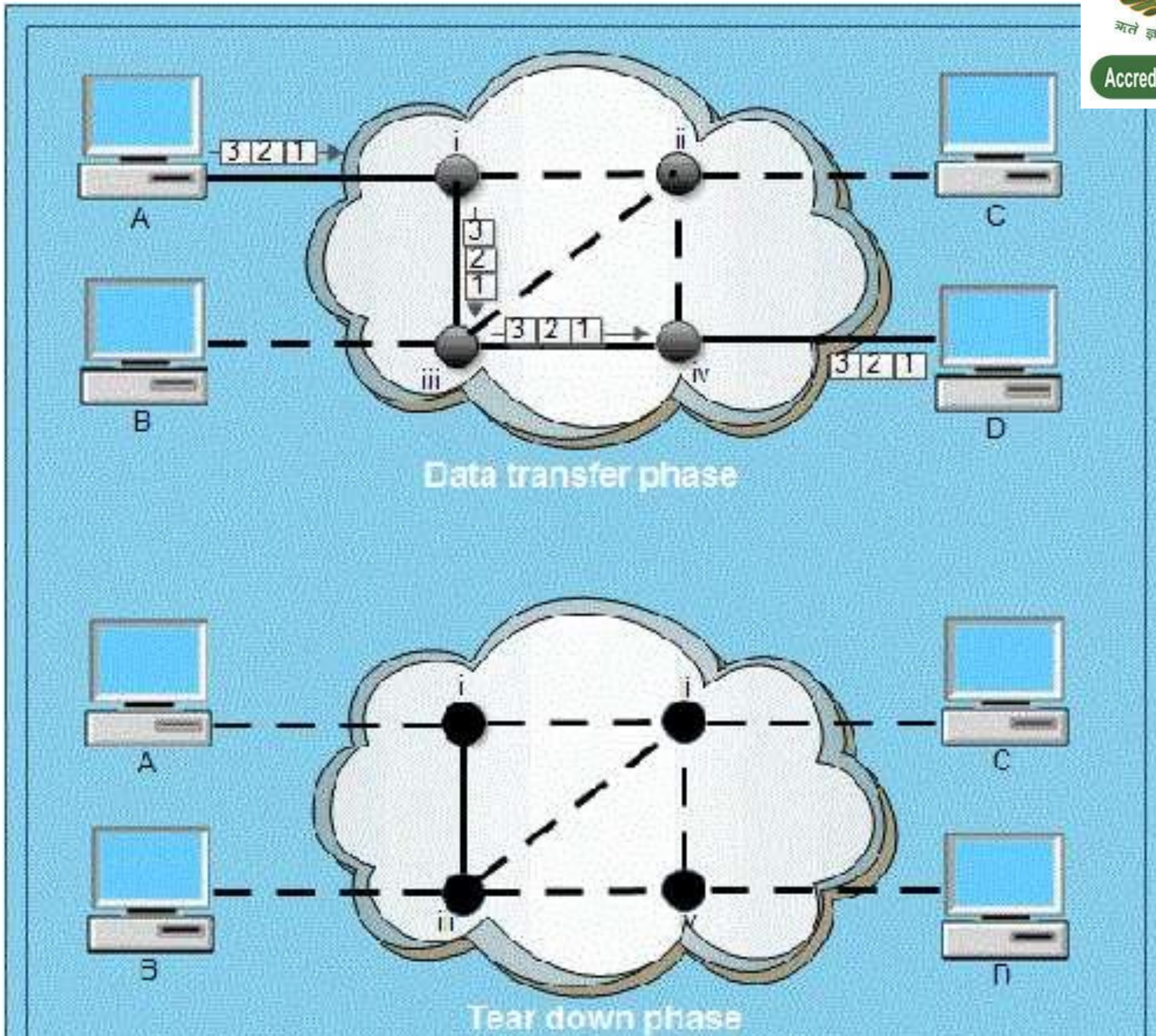
Packet Switching

Packet Switching

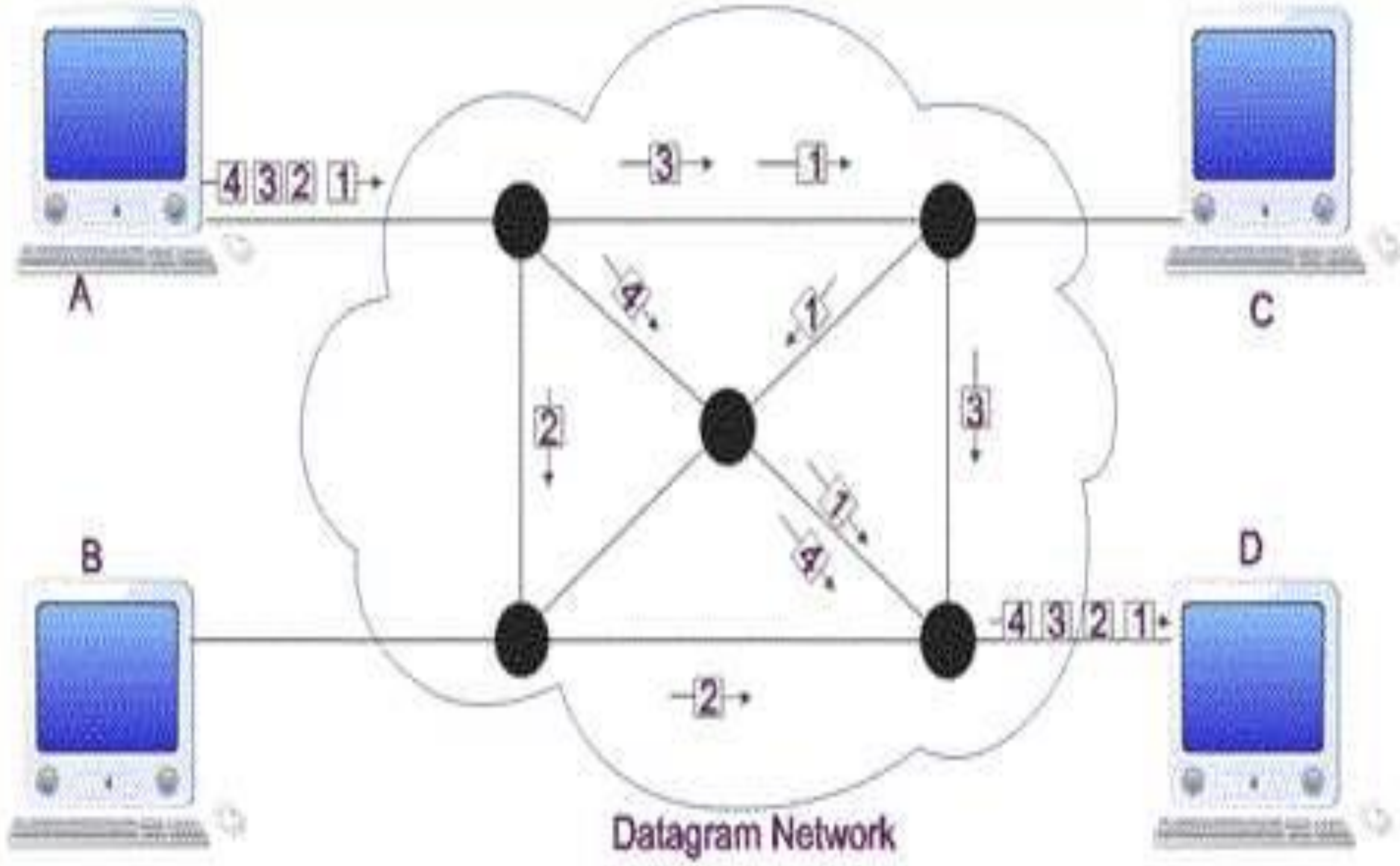
- In both packet switching methods, a message is broken into small parts, called packets.
- Each packet is tagged with appropriate source and destination addresses.
- Since packets have a strictly defined maximum length, they can be stored in main memory instead of disk, therefore access delay and cost are minimized.
- Also the transmission speeds, between nodes, are optimized.
- With current technology, packets are generally accepted onto the network on a first-come, first-served basis. If the network becomes overloaded, packets are delayed or discarded (``dropped'').

Packet switching

- In packet switching, the analog signal from your phone is converted into a digital data stream. That series of digital bits is then divided into relatively tiny clusters of bits, called packets. Each packet has at its beginning the digital address -- a long number -- to which it is being sent. The system blasts out all those tiny packets, as fast as it can, and they travel across the nation's digital backbone systems to their destination: the telephone, or rather the telephone system, of the person you're calling.
- They do not necessarily travel together; they do not travel sequentially. They don't even all travel via the same route. But eventually they arrive at the right point -- that digital address added to the front of each string of digital data -- and at their destination are reassembled into the correct order, then converted to analog form, so your friend can understand what you're saying.



Phases in virtual circuit packet switching



Datagram Packet switching

Packet Switching: Datagram

- Datagram packet switching is similar to message switching in that each packet is a self-contained unit with complete addressing information attached.
- This fact allows packets to take a variety of possible paths through the network.
- So the packets, each with the same destination address, do not follow the same route, and they may arrive out of sequence at the exit point node (or the destination).
- Reordering is done at the destination point based on the sequence number of the packets.
- It is possible for a packet to be destroyed if one of the nodes on its way is crashed momentarily. Thus all its queued packets may be lost.

Virtual Circuit

- In the virtual circuit approach, a preplanned route is established before any data packets are sent.
- A logical connection is established when
  - a sender send a "call request packet" to the receiver and
  - the receiver send back an acknowledge packet "call accepted packet" to the sender if the receiver agrees on conversational parameters.
- The conversational parameters can be maximum packet sizes, path to be taken, and other variables necessary to establish and maintain the conversation.
- Virtual circuits imply acknowledgements, flow control, and error control, so virtual circuits are reliable.
- That is, they have the capability to inform upper-protocol layers if a transmission problem occurs.

Packet Switching:Virtual Circuit

- In virtual circuit, the route between stations does not mean that this is a dedicated path, as in circuit switching.
- A packet is still buffered at each node and queued for output over a line.
- The difference between virtual circuit and datagram approaches:

- With virtual circuit, the node does not need to make a routing decision for each packet.
- It is made only once for all packets using that virtual circuit.

Packet Switching: Virtual Circuit

VC's offer guarantees that

- the packets sent arrive in the order sent
- with no duplicates or omissions
- with no errors (with high probability)

regardless of how they are implemented internally.

Advantages of packet switching

Advantages:

- Packet switching is cost effective, because switching devices do not need massive amount of secondary storage.
- Packet switching offers improved delay characteristics, because there are no long messages in the queue (maximum packet size is fixed).
- Packet can be rerouted if there is any problem, such as, busy or disabled links.
- The advantage of packet switching is that many network users can share the same channel at the same time. Packet switching can maximize link efficiency by making optimal use of link bandwidth.

Disadvantages of packet switching

Disadvantages:

- Protocols for packet switching are typically more complex.
- It can add some initial costs in implementation.
- If packet is lost, sender needs to retransmit the data.
- Another disadvantage is that packet-switched systems still can’t deliver the same quality as dedicated circuits in applications requiring very little delay - like voice conversations or moving images.

I am Back

Consider the store and forward packet switched network given below. Assume that the bandwidth of each link is 10^6 bytes / sec. A user on host A sends a file of size 10^3 bytes to host B through routers R1 and R2 in three different ways. In the first case a single packet containing the complete file is transmitted from A to B. In the second case, the file is split into 10 equal parts, and these packets are transmitted from A to B. In the third case, the file is split into 20 equal parts and these packets are sent from A to B. Each packet contains 100 bytes of header information along with the user data. Consider only transmission time and ignore processing, queuing and propagation delays. Also assume that there are no errors during transmission. Let T1, T2 and T3 be the times taken to transmit the file in the first, second and third case respectively. Which one of the following is CORRECT?

(A) T1 < T2 < T3
(B) T1 > T2 > T3
(C) T2 = T3, T3 < T1
(D) T1 = T3, T3 > T2

- The important thing to note here is in first case, the whole packet is being transmitted, so no piplelining of packet happens. In second and third case, we have advantage of pipelining (While packet ‘i’ is being transmitted from R1 to R2,packet ‘i-1’ is being transmitted from A to R1 at the same time).

File Size = 1000 bytes Header Size = 100 bytes
Transmission Speed of all links = 10^6 bytes/sec
Ist Case:
Transmission time for one link = packetsize/bandwidth = (1000 + 100)/10^6 = 1100 micros
Total time = 3*1100 = 3300 microsec.

Second case:
Transmission time for one link and one part = (100 + 100)/10^6 = 200 microsec
While packet 'i' is being transmitted from R1 to R2,
packet 'i-1' is being transmitted from A to R1 at the same time]
Total time = 3*200 + 9*200
= 2400 micro sec
Third Case:
Transmission time for one link and one part
= (50+100)/10^6
= 150microsec
Total time = 3*150+19*150
= 3300 microsec

- Since it is a network that uses switch, every packet goes through two links, one from source to switch and other from switch to destination.
- Since there are 10000 bits and packet size is 5000, two packets are sent. Transmission time for each packet is 5000 / 10^7 microseconds.
- Two hosts are connected via a packet switch with 10^7 bits per second links. Each link has a propagation delay of 20 microseconds. The switch begins forwarding a packet 35 microseconds after it receives the same. If 10000 bits of data are to be transmitted between the two hosts using a packet size of 5000 bits, the time elapsed between the transmission of the first bit of data and the reception of the last bit of the data in microseconds is __________.
- **(A)** 1075
  (B) 1575
  (C) 2220
  (D) 2200

- Sender host transmits first packet to switch, the transmission time is $5000/10^7$ which is 500 microseconds. After 500 microseconds, the second packet is transmitted. The first packet reaches destination in 500 + 35 + 20 + 20 + 500 = 1075 microseconds. While the first packet is traveling to destination, the second packet starts its journey after 500 microseconds and rest of the time taken by second packet overlaps with first packet. So overall time is 1075 + 500 = 1575.

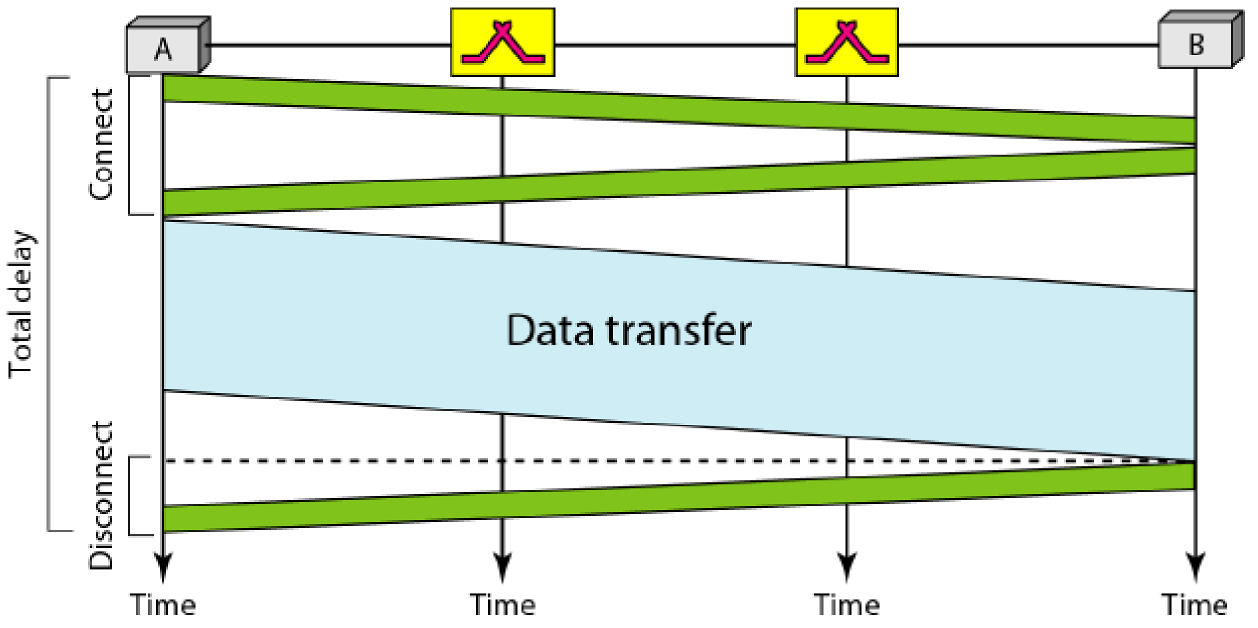
- A path in a digital circuit-switched network has a data rate of 1 Mbps. The exchange of 1000 bits is required for the setup and teardown phases. The distance between two parties is 3000 km. Answer the following questions if the propagataion speed is 2 × 108 m/s:

a. What is the total delay if 1000 bits of data are exchanged during the data transfer phase?

b. What is the total delay if 100,000 bits of data are exchanged during the data transfer phase?

c. What is the total delay if 1,000,000 bits of data are exchanged during the data transfer phase?

- Total delay (t) = delay of setup and tear down (d1) + delay of data transfer (d2)



- Delay of setup and tear down (d1) = (3 * propagation delay) + (3 * transmission delay)
- Delay of data transfer = propagation delay + transmission delay

1. Delay of setup and tear down (d1)

= (3 * propagation delay) + (3 * transmission delay)

$$= 3\left[\frac{3000\ km}{(2\times10^{8}\ m/s)}\right] + 3\left[\left(\frac{1000\ bits}{1\ Mbps}\right)\right]$$

$$= (3 \times 15)\ ms + (3 \times 1)\ ms$$

$$= 48\ ms$$

Lets assume, data transmission is in one direction

a. $Total\ delay\ (t) = d1 + d2$

$= 48\ ms + propagation\ delay + transmission\ delay\ = 48\ ms + 15\ ms + 1\ ms = 64\ ms$

b. $Total\ delay\ (t) = d1 + d2$

$= 48\ ms + propagation\ delay + transmission\ delay\ = 48\ ms + 15\ ms + 100\ ms = 163\ ms$

- Five equal-size datagrams belonging to the same message leave for the destination one after another. However, they travel through different paths as shown in the following table

Datagram	Path Length	Visited Switches
1	3200 Km	1,3,5
2	11,700 Km	1,2,5
3	12,200 Km	1,2,3,5
4	10,200 Km	1,4,5
5	10,700 Km	1,4,3,5

- We assume that the delay for each switch (including waiting and processing) is 3, 10, 20, 7, and 20 ms respectively. Assuming that the propagation speed is 2×108 m/s, find the order the datagrams arrive at the destination and the delay for each. Ignore any other delays in transmission.

2. Assuming that the transmission time is negligible (i.e., all datagrams start at time 0). The arrival times are calculated as

$$First: \left(\frac{3200\ Km}{2\times\ 10^8\ m/s}\right) + 3 + 20 + 20 = 59\ ms$$

$$Second: \left(\frac{11700\ Km}{2\times\ 10^8\ m/s}\right) + 3 + 10 + 20 = 91.5\ ms$$

$$Third: \left(\frac{12200\ Km}{2\times\ 10^8\ m/s}\right) + 3 + 10 + 20 + 20 = 114\ ms$$

$$Fourth: \left(\frac{10200\ Km}{2\times\ 10^8\ m/s}\right) + 3 + 7 + 20 = 81\ ms$$

$$Fifth: \left(\frac{10700\ Km}{2\times\ 10^8\ m/s}\right) + 3 + 7 + 20 + 20 = 103.5\ ms$$

Switch	Delay (ms)
1	3
2	10
3	20
4	7
5	20

The order of the arrival is $3 \rightarrow 5 \rightarrow 2 \rightarrow 4 \rightarrow 1$