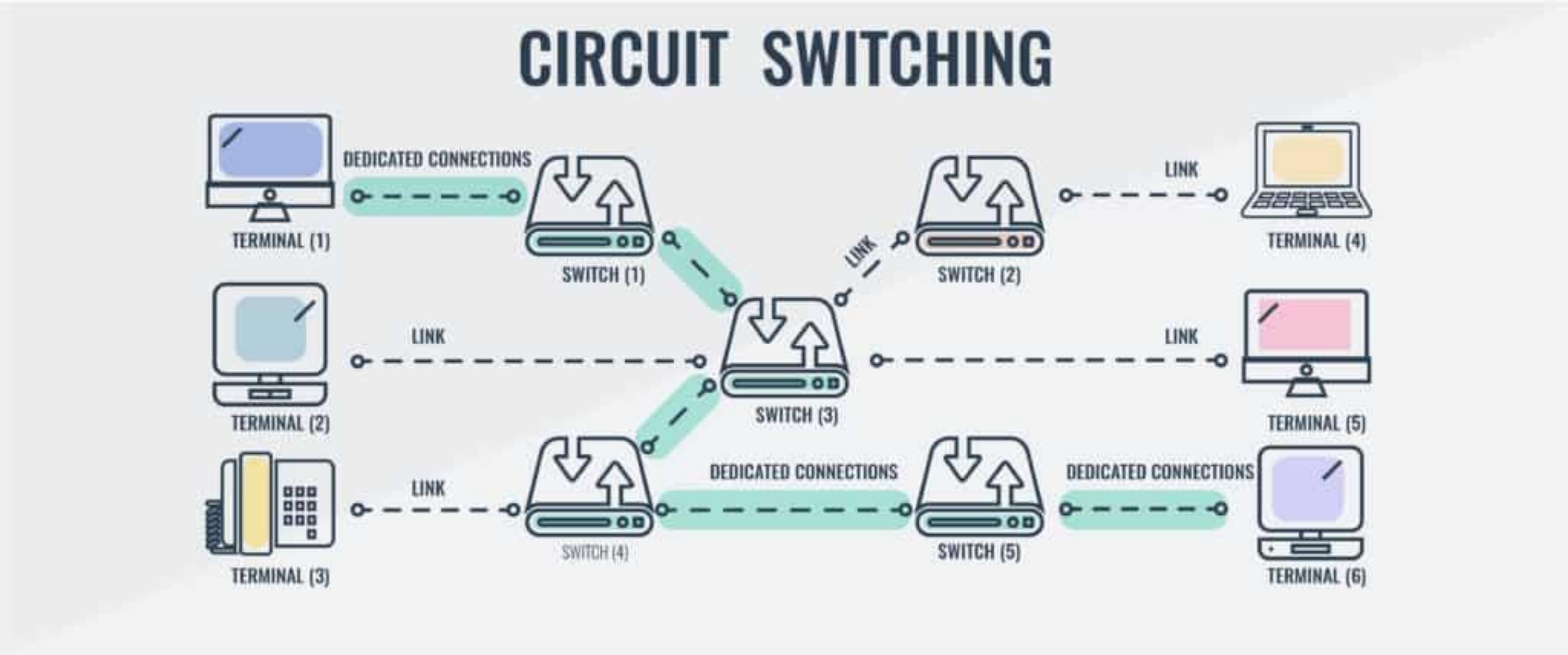
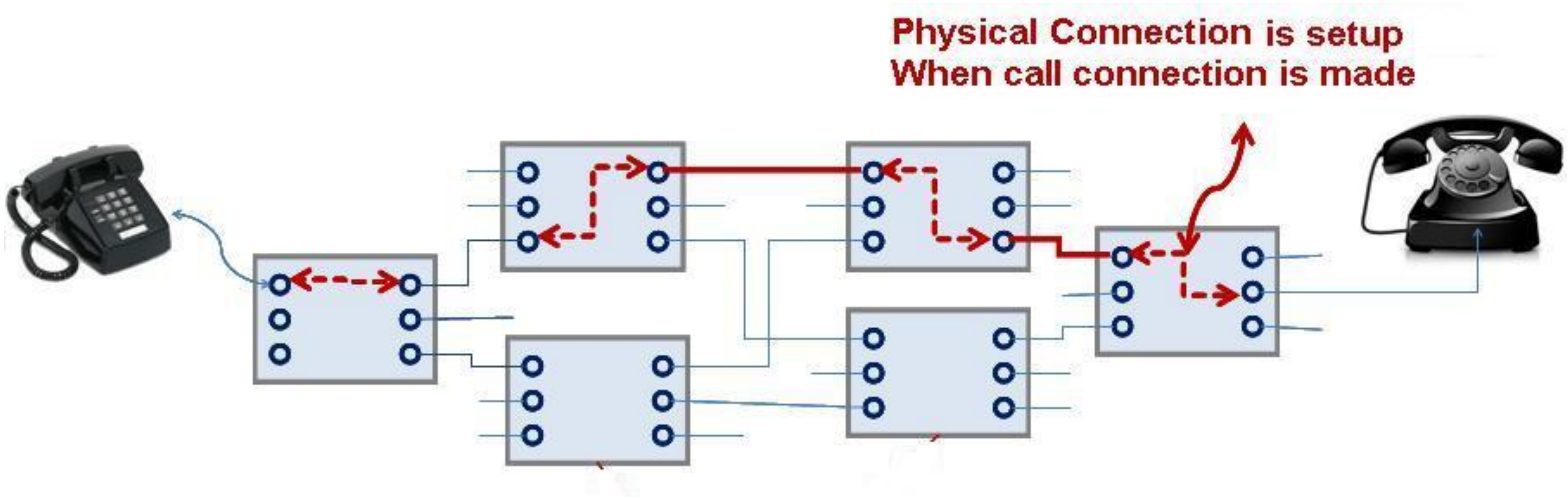


Circuit switching is when a **dedicated channel** or circuit needs to be established before users can speak to each other on a call. A channel used in circuit switching is **kept reserved at all times** and is used once the two users communicate.



Circuit switching phases:

- <u>Call setup phase</u> is used to establish communication path between the source and the sink.
- <u>Data transfer phase</u> is used to transmit the data after the path has been established.
- <u>Call teardown phase</u> is used to clear, tear down, or delete the communication path after the communication

Total time taken to transmit a message in **circuit switched** network

= Connection set up time + Transmission delay + Propagation delay + Tear down time

where-

Transmission delay = Message size / Data rate
Propagation delay = (Number of hops on way x Distance between 2 hops) / Propagation speed

4 hops (point-to-point links) between two terminals nodes;

Transmission rate 9600 bps on all links;
24 overhead bits [Header + Trailer] for each packet;
1ms per-hop signal propagation delay.
1 sec. Call set-up time for circuit switched connection across 4 hops.

Message size 5000 bits

Transmission delay = 5000 bits at 9600 bps = 521 m sec
Total propagation delay 4x1m sec = 4 m sec

Total time for message is 521 + 4 + 1000 = 1525m sec sec.

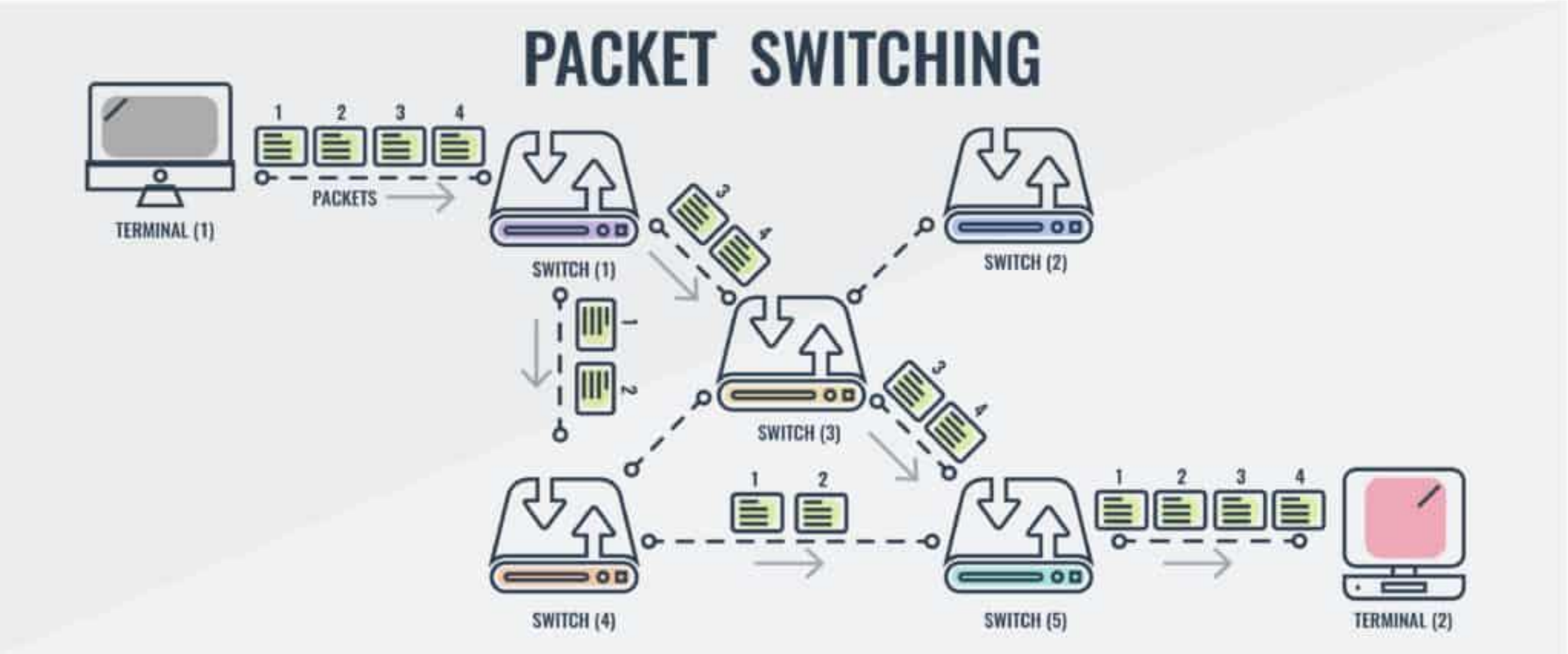
Consider all links in the network use TDM with 24 slots and have a data rate of 1.536 Mbps. Assume that host A takes 500 msec to establish an end to end circuit with host B before begin to transmit the file. If the file is 512 kilobytes, then how much time will it take to send the file from host A to host B?

Total **bandwidth** = 1.536 Mbps
Bandwidth is shared among 24 slots
Connection set up time = 500 msec
File size = 512 KB

Bandwidth Per User = Total **bandwidth** / Number of users = 1.536 Mbps / 24 = 0.064 Mbps = 64 Kbps

Transmission Delay = File size / Bandwidth = 512 KB / 64 Kbps = (512 x 1024 x 8 bits) / (64 x 1000 bits per sec)
= 65.536 sec = 65536 msec

Time Required To Send File = Connection set up time + Transmission delay
= 500 msec + 65536 msec = 66036 sec
= 66.036 msec



Packet Switching, The entire message to be sent is divided into multiple smaller size packets. This process of dividing a single message into smaller size packets is called as packetization. These smaller packets are sent after the other. It gives the advantage of pipelining and reduces the total time taken to transmit the message.

Packet switching is a method of transferring the data to a network in form of packets. In order to transfer the file fast and efficiently manner over the network and minimize the transmission latency, the data is broken into small pieces of variable length, called Packet. At the destination, all these small parts (packets) have to be reassembled, belonging to the same file. A packet composes of payload and various control information. No pre-setup or reservation of resources is needed.

Packet Switching uses Store and Forward technique while switching the packets; while forwarding the packet each hop first stores that packet then forward. This technique is very beneficial because packets may get discarded at any hop due to some reason. More than one path is possible between a pair of sources and destinations. Each packet contains Source and destination address using which they independently travel through the network. In other words, packets belonging to the same file may or may not travel through the same path. If there is congestion at some path, packets are allowed to choose different paths possible over an existing network.

Packet-Switched networks were designed to overcome the weaknesses of Circuit-Switched networks since circuit-switched networks were not very effective for small messages.

Advantage of Packet Switching over Circuit Switching :

- More efficient in terms of bandwidth, since the concept of reserving circuit is not there.
- Minimal transmission latency.
- More reliable as a destination can detect the missing packet.
- More fault tolerant because packets may follow a different path in case any link is down, Unlike Circuit Switching.
- Cost-effective and comparatively cheaper to implement.

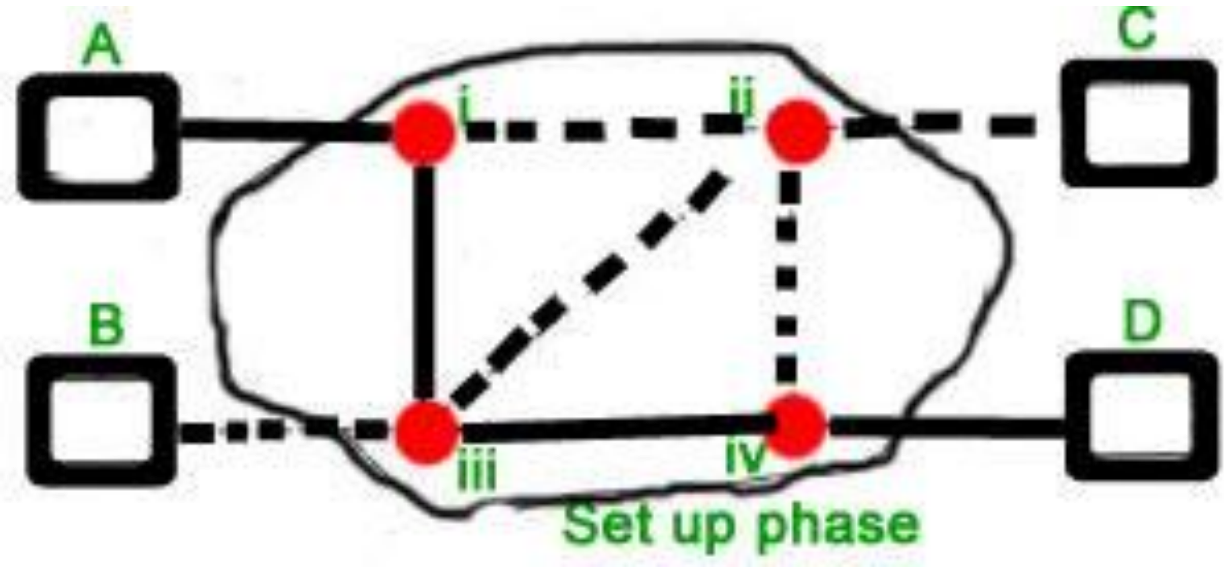
The disadvantage of Packet Switching over Circuit Switching :

- Packet Switching doesn’t give packets in order, whereas Circuit Switching provides ordered delivery of packets because all the packets follow the same path.
- Since the packets are unordered, we need to provide sequence numbers for each packet.
- Complexity is more at each node because of the facility to follow multiple paths.
- Transmission delay is more because of rerouting.
- Packet Switching is beneficial only for small messages, but for bursty data (large messages) Circuit Switching is better.

Modes of Packet Switching

1. Connection-oriented Packet Switching (Virtual Circuit) :

Before starting the transmission, it establishes a logical path or virtual connection using signaling protocol, between sender and receiver and all packets belongs to this flow will follow this predefined route. Virtual Circuit ID is provided by switches/routers to uniquely identify this virtual connection. Data is divided into small units and all these small units are appended with help of sequence numbers. Overall, three phases take place here- The setup, data transfer and tear down phase.



All address information is only transferred during the setup phase. Once the route to a destination is discovered, entry is added to the switching table of each intermediate node. During data transfer, packet header (local header) may contain information such as length, timestamp, sequence number, etc.

Connection-oriented switching is very useful in switched WAN. Some popular protocols which use the Virtual Circuit Switching approach are X.25, Frame-Relay, ATM, and MPLS(Multi-Protocol Label Switching).

2. Connectionless Packet Switching (Datagram) :

Unlike Connection-oriented packet switching, In Connectionless Packet Switching each packet contains all necessary addressing information such as source address, destination address and port numbers, etc. In Datagram Packet Switching, each packet is treated independently. Packets belonging to one flow may take different routes because routing decisions are made dynamically, so the packets arrived at the destination might be out of order. It has no connection setup and teardown phase, like Virtual Circuits.

Packet delivery is not guaranteed in connectionless packet switching, so reliable delivery must be provided by end systems using additional protocols.

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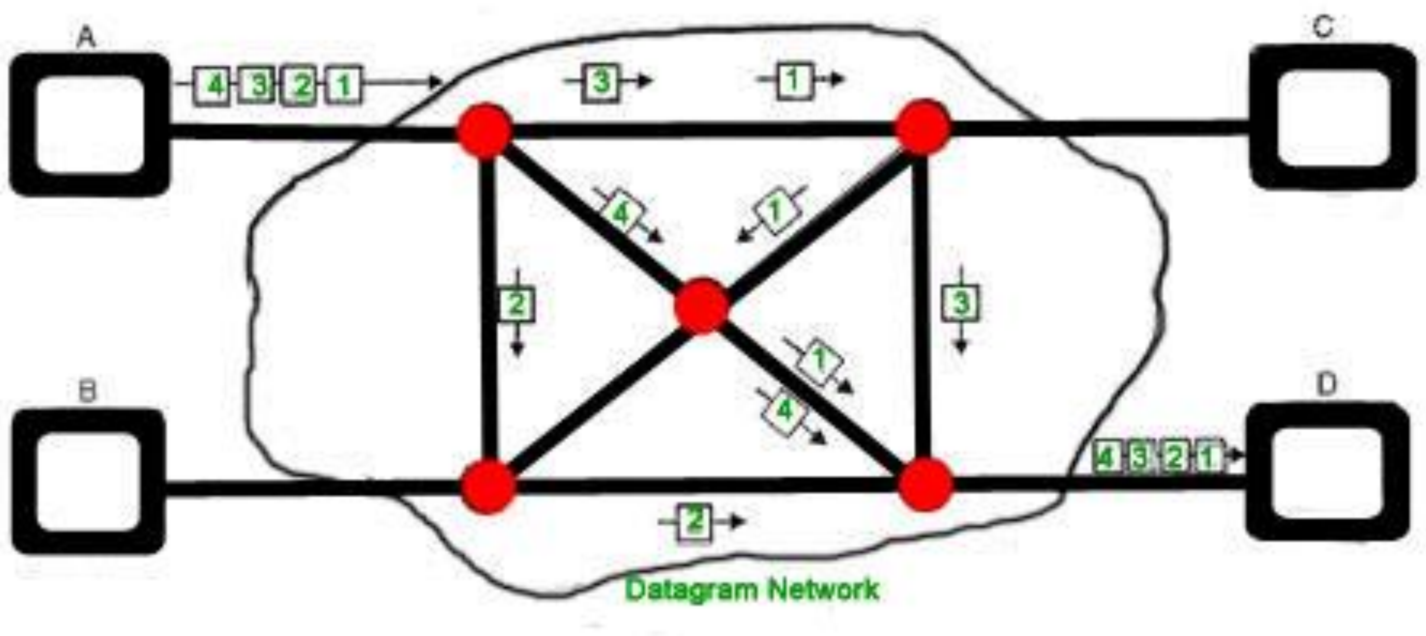


Datagram Packet Switching

The delays, here, means the time for which the processing of a particular packet takes place. The following types of delays in computer networks:

<u>1. Transmission Delay:</u>

The time taken to transmit a packet from the host to the transmission medium is called Transmission delay.

For example, if **bandwidth** is 1 bps (every second 1 bit can be transmitted onto the transmission medium) and data size is 20 bits then what is the transmission delay? If in one second, 1 bit can be transmitted. To transmit 20 bits, 20 seconds would be required.

Let B bps is the **bandwidth** and L bit is the size of the data then transmission delay is,

Tt = L/B

This delay depends upon the following factors:

If there are multiple active sessions, the delay will become significant.
Increasing **bandwidth** decreases transmission delay.
MAC protocol largely influences the delay if the link is shared among multiple devices.
Sending and receiving a packet involves a context switch in the operating system, which takes a finite time.

2. Propagation delay:

After the packet is transmitted to the transmission medium, it has to go through the medium to reach the destination. Hence the time taken by the last bit of the packet to reach the destination is called propagation delay.

Factors affecting propagation delay:

Distance – It takes more time to reach the destination if the distance of the medium is longer.
Velocity – If the velocity(speed) of the signal is higher, the packet will be received faster.
Tp = Distance / Velocity

Velocity =3 X 10^8 m/s (for air)
Velocity= 2 X 10^8 m/s (for optical fibre)

3. Queueing delay:

Let the packet is received by the destination, the packet will not be processed by the destination immediately. It has to wait in a queue in something called a buffer. So the amount of time it waits in queue before being processed is called queueing delay.

In general, we can’t calculate queueing delay because we don’t have any formula for that.

This delay depends upon the following factors:

If the size of the queue is large, the queuing delay will be huge. If the queue is empty there will be less or no delay. If more packets are arriving in a short or no time interval, queuing delay will be large. The less the number of servers/links, the greater is the queuing delay.

4. Processing delay:

Now the packet will be taken for the processing which is called processing delay.

Time is taken to process the data packet by the processor that is the time required by intermediate routers to decide where to forward the packet, update TTL, perform header checksum calculations.

It also doesn't have any formula since it depends upon the speed of the processor and the speed of the processor varies from computer to computer.

Both queueing delay and processing delay doesn't have any formula because they depend on the speed of the processor . This delay depends upon the following factors:

It depends on the speed of the processor.

$T_{total} = T_t + T_p + T_q + T_{pro}$

$T_{total} = T_t + T_p$

(when taking T_q and T_{pro} equals to 0)

4 hops (point-to-point links) between two terminals nodes;

Transmission rate 9600 bps on all links;
24 overhead bits [Header + Trailer] for each packet;
1ms per-hop signal propagation delay.
1 sec. Call set-up time for circuit switched connection across 4 hops.
Message size 5000 bits, packet size 1024 bits, all other parameters the same.

Packet switching

Number of packets = 5 (1024 - 24 = 1000 bits of message data, 5x1000=5000)
Packet duration = 1024/9600 = 107 m sec

Entire 1024-bit packet received by each node from preceding node in 1024/9600 + 0.001 = 108 m sec

Total message time is 4x0.108 + 4x0.107 = 968 m sec.
(There are 4 hops, and 4 packets in succession after the first complete packet is received at terminal node)

Transmission delay is 4x0.001 + (5-1)x0.107 = 0.432 sec.
By Transmission Delay we mean the delay between the sending out of a bit in the message and its reception at the other end.

How much time will it take to send a packet of size L bits from A to B in given setup if Bandwidth is R bps, propagation speed is t meter/sec and distance b/w any two points is d meters (ignore processing and queuing delay) ?

A--------R1--------R2--------B

N = no. of links = no. of hops = no. of routers +1 = 3
File size = L bits
Bandwidth = R bps
Propagation speed = t meter/sec
Distance = d meters
Transmission delay = (N*L)/R = (3*L)/R sec
Propagation delay = N*(d/t) = (3*d)/t sec
Total time = 3*(L/R + d/t) sec

In a Packet switch network having Hops= 4, transfer 10 packets from A to B given packet size is L bits. Bandwidth to transfer data is R Mbps and speed of propagation is S meter/sec. Assume processing delay= P seconds and distance between two point is D meters. Find total time required for 10 packets to reach A from B.

A-------R1-------R2-------R3-------B

No. of hops= No. of links = M= 4
Here we send 10 packets, also since there is no acknowledgement of packet received required we perform parallel processing. When the 1st packet reaches R2, the second packet reaches R1.

R is in Mbps so convert to bps by multiplying 10^6.
Bandwidth=R*(10^6) bps
Packet size =L bits
Transmission delay= Packet size/Bandwidth =L/(R*(10^6))
Propagation Delay = Distance / Speed = D /S
Processing delay is in seconds no change
Delay can also be calculated as : Delay for 1st packet to reach + delay for (N-1) packets
Delay for 1st packet = M*(Propagation delay + Transmission delay) + (M-1)*(Processing delay + Queuing delay)
Delay for N-1 remaining packets = (N-1)*(Transmission delay)

Total delay = 4*(L/(R*(10^6) + D/S) + (4-1)*(P + 0) + (10-1)*(L/(R*(10^6))

Message size 5000 bits, packet size 512 bits

Packet switching

Number of packets = 11 (512 - 24 = 488 bits of message data for first 10 packets, the 11th packet has 120 bits of message data and 380 dummy bits)

Packet duration = 512/9600 = 0.0535 sec

Entire 512-bit packet received by each node from preceding node in 512/9600 + 0.001 = 0.0545 sec

Total message time is therefore 4x0.0545 + 10x0.0535 = 0.753sec.
(There are 4 hops, and 10 packets in succession after the first complete packet is received at terminal node)

Transmission delay is 4x0.001 + 3x0.0535 = 0.1645 sec.

Optimal Packet Size

If the packet size is not chosen wisely, then It may result in adverse effects.
It might increase the time taken to transmit the message.
So, it is very important to choose the packet size wisely.

Consider

There is a network having bandwidth of 1 MBps.
A message of size 1000 bytes has to be sent.
Packet switching technique is used.
Each packet contains a header of 100 bytes.

How many packets the message must be divided so that total time taken is minimum-

While calculating the total time, we often ignore the propagation delay.
The reason is in packet switching, transmission delay dominates over propagation delay.
This is because each packet is transmitted over the link at each hop.

Sending Message in 1 Packet = In this case, the entire message is sent in a single packet.

Size Of Packet = 1000 bytes of data + 100 bytes of header = 1100 bytes

Transmission Delay = Packet size / Bandwidth = 1100 bytes / 1 MBps = 1100 µsec = 1.1 msec

Total time taken to send the complete message from sender to receiver = 3 x Transmission delay = 3.3 msec

Sending Message in 5 Packets = In this case, The entire message is divided into total 5 packets.
These packets are then sent one after the other.

Data Sent in One Packet = Total data to be sent / Number of packets = 1000 bytes / 5 = 200 bytes

Size Of One Packet = 200 bytes of data + 100 bytes of header = 300 bytes

Transmission Delay = Packet size / Bandwidth = 300 bytes / 1 MBps = 300 µsec = 0.3 msec

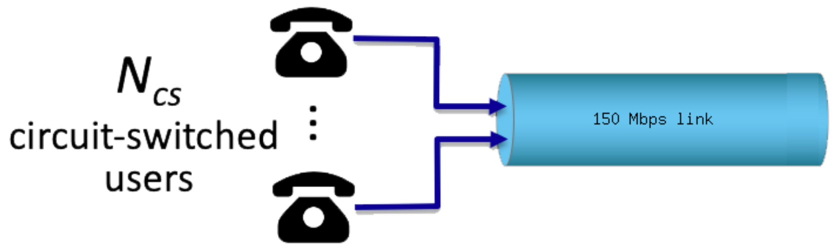
Time taken by the first packet to reach from sender to receiver = 3 x Transmission delay = 3 x 0.3 msec= 0.9 msec

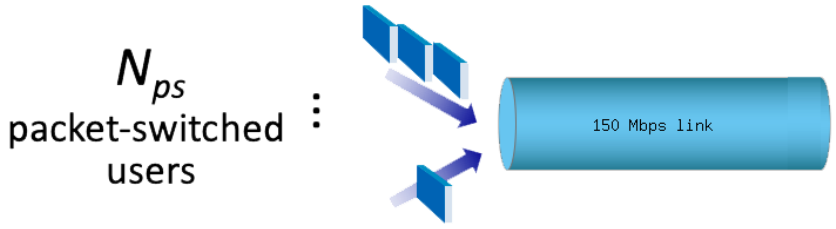
Time Taken By Remaining Packets = Number of remaining packets x Transmission delay = 4 x 0.3 msec = 1.2 msec

Total Time Taken = 0.9 msec + 1.2 msec = 2.1 msec

Sent in 1 packet, total time = 3.3 msec
Sent in 5 packets, total time = 2.1 msec
Sent in 10 packets, total time = 2.4 msec
Sent in 20 packets, total time = 3.3 msec

A circuit-switching scenario in which Ncs users, each requiring a bandwidth of 10 Mbps, must share a link of capacity 150 Mbps.
A packet-switching scenario with Nps users sharing a 150 Mbps link, where each user again requires 10 Mbps when transmitting, but only needs to transmit 20 percent of the time.

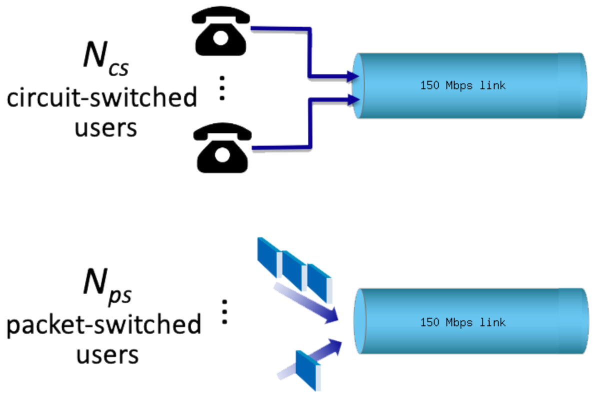




When circuit switching is used, what is the maximum number of users that can be supported?

When circuit switching is used, at most 15 users can be supported. This is because each circuit-switched user must be allocated its 10 Mbps bandwidth, and there is 150 Mbps of link capacity that can be allocated.

A circuit-switching scenario in which Ncs users, each requiring a bandwidth of 10 Mbps, must share a link of capacity 150 Mbps.
A packet-switching scenario with Nps users sharing a 150 Mbps link, where each user again requires 10 Mbps when transmitting, but only needs to transmit 20 percent of the time.



Suppose packet switching is used. If there are 29 packet-switching users, can this many users be supported under circuit-switching? Yes or No.

No. Under circuit switching, the 29 users would each need to be allocated 10 Mbps, for an aggregate of 290 Mbps - more than the 150 Mbps of link capacity available.