Introduction to CN

cont...

End-devices: A source or destination device in a networked system.

- Computers, laptops, file servers, web servers.
- Network printers
- VoIP phones
- Security cameras
- Mobile handheld devices

A **network interface card (NIC)** is a hardware component without which a computer cannot be connected over a network. It is a circuit board installed in a computer that provides a dedicated network connection to the computer.

Internal NIC

External NIC

- **Scalability** is the property of a system to handle a growing amount of work by adding resources to the system. scalability is a characteristic of computers, networks, algorithms, networking protocols, programs and applications. An example is a search engine, which must support increasing numbers of users, and the number of topics it indexes.
- **Robustness** is the ability of a computer system to cope with errors during execution and cope with erroneous input.
- **Efficiency** of a network is a measure of how efficiently it exchanges information.
- Efficiency = 100% * (transferred - retransmitted) / transferred

- Packets can get lost within a computer network. For example, a packet can overflow a buffer in a router, or can be discarded by a host or router after having some of its bits corrupted. For many applications – such as electronic mail, file transfer, remote host access, web document transfers, and financial applications – data loss can have devastating consequences.If a protocol provides such a guaranteed data delivery service, it is said to provide **reliable data transfer** .
- A transport protocol can provide an application with one or more **security** services. For example, in the sending host, a transport protocol can encrypt all data transmitted by the sending process, and in the receiving host, the transport-layer protocol can decrypt the data before delivering the data to the receiving processes.

- **Latency** is a measure of delay. In a network, latency measures the time it takes for some data to get to its destination across the network. It is usually measured as a round trip delay - the time taken for information to get to its destination and back again with ack.
- For network performance measurement, **throughput** is defined in terms of the amount of data or number of data packets that can be delivered in a pre-defined time frame over a specific communications link. **Maximum network throughput equals the TCP window size divided by the round-trip time of communications data packets.**

Example:

- 64 KB is the default TCP window size for computers running the Windows operating system. To convert the window size to bits, multiply the number of bytes by eight. 64 KB x 8 = 524,288 bits.
- Divide the TCP window size in bits by the network path latency. For this example, use a latency of 60 milliseconds.
- Then 524,288 bits / .060 seconds = 8,738,133 bits per second = 8.738 Mbps.

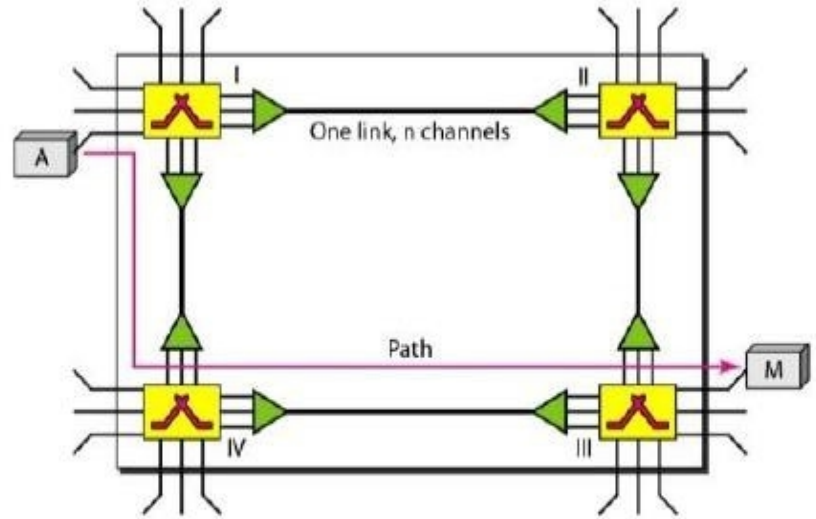
Circuit Switching & Packet Switching

Switching

- Traditionally, three methods of switching have been important: ***circuit switching***, ***message switching***, and ***packet switching***.
- The first and last are commonly used today, the middle one has been phased out in general communications but still has networking applications.
- We can then divide today's networks into three broad categories: ***circuit-switched networks***, ***message-switched networks***, and ***packet-switched networks***.
- Packet-switched networks can further be divided into two subcategories datagram networks and virtual-circuit networks.

Circuit-Switched Networks

A trivial circuit-switched network



- It is made of a set of switches connected by physical links, in which each link is divided into n channels.
- In the **circuit-switched network,** there are 4 switches and 4 links.
- Each link is divided into *n (n=3, here)* channels by using FDM or TDM.
- In circuit switching, the resources need to be reserved during the setup phase; the resources remain dedicated for the entire duration of data transfer until the teardown phase.

- ***Circuit switching*** is a technique that directly connects the sender and the receiver 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.
- Three phases in circuit switching are Establish, Transfer, Disconnect.
- Routing decisions must be made when the circuit is first established, but there are no decisions made after that time.
- Ex: It is used in telephone networks.
- ***Advantages:*** The communication channel (once established) is dedicated.
- ***Disadvantages:***
  - Possible long wait to establish a connection, 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.

Packet Switching

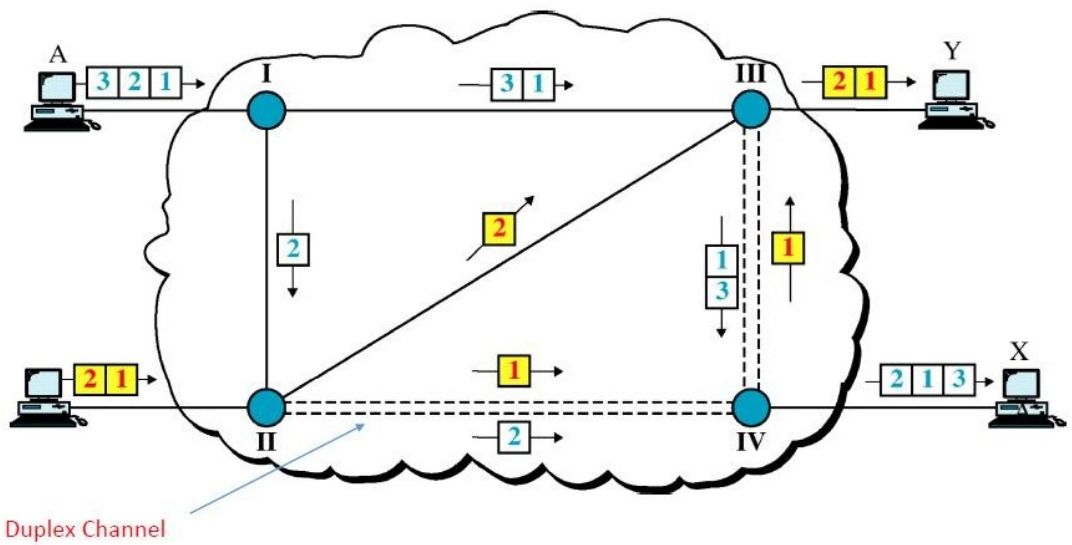
- ***Packet switching*** can be seen as a solution that tries to combine the advantages of message and circuit switching and to minimize the disadvantages of both.
- There are two methods of packet switching: **Datagram** and **virtual circuit.**
- In both packet switching methods, a message is broken into small parts(fixed or variable), 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 header contains routing information

Intermediate nodes(routers) store the packet, decide the route, and forward the packet: processing delay

Packet Switching: Datagram Service

- In a datagram network, each packet is treated independently of all others, even if they belong to the same message.
- It is generally done at network layer.
- For each packet, each node makes its own decision as to how to forward it so that it eventually reaches its destination.
- Different packets may take different paths to reach to the same destination.
- Thus, reordering may required but at the destination only.
- 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.
- It is called ***connection less*** bcz setup or teardown phases are not required



Datagram Switching: Key points

- Each packet contains a full destination address.
- Packets can take any practical route.
- Each packet is treated independently.
- Packets may arrive out of order (so receiver may require re-ordering)
- Packets may ***be omitted*** (end node handles recovery of missing packets)
- *It is best effort network.*
- Store and forward operation required at each node for each packet
- Connection less protocol: Ethernet, IP, UDP
- Ex: Internet using IP, voice and video communication and notifying message to alert a user that he/she has received a new e-mail(using UDP)

In this type of network, each switch has a **routing table** based on destination address. The routing tables are dynamic and updated periodically.

Packet Switching: Virtual-Circuit

- In this, a pre-planned route is established before any data packets are sent.
- A logical(virtual) connection is established when
  - A sender sends a “call request packet” to the receiver.
  - The receiver sends back an acknowledgement packet “call accepted packet” to the sender the receiver agrees on conversational parameters.
- The conversational parameter can be maximum packet size, path to be taken, and other variables necessary to establish and maintain the conversation.
- In virtual circuit, the route between stations does not mean that this is a dedicated path, as in circuit switching.
- In virtual circuit approach, routing decision is not made every time for all packets.

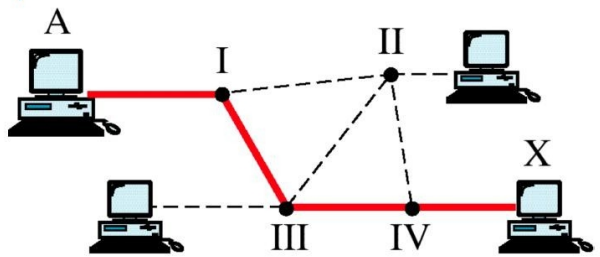
Routing decision is made only once for all packets using that virtual circuit.

Packets transfer involves basically three steps:

- Connection establishment
- Data transfer
- Connection release

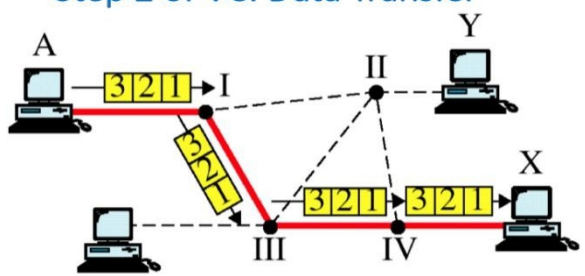
- A packet is still buffered at each node and queued for output over line
- VC's offer guarantee that
  - The packets sent arrive in order at the destinations
  - No duplication of the packets or omission
  - No error
- **Routing decision is made only once** for all packets using that virtual circuit.
- Packets are forwarded more quickly as no routing decision to make every time.
- Intermediate nodes need to do store and forward in both the cases.

Step 1 of VC: Connection establishment



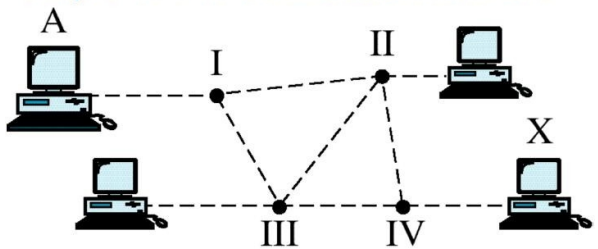
Connection establishment

Step 2 of VC: Data Transfer



Data transfer

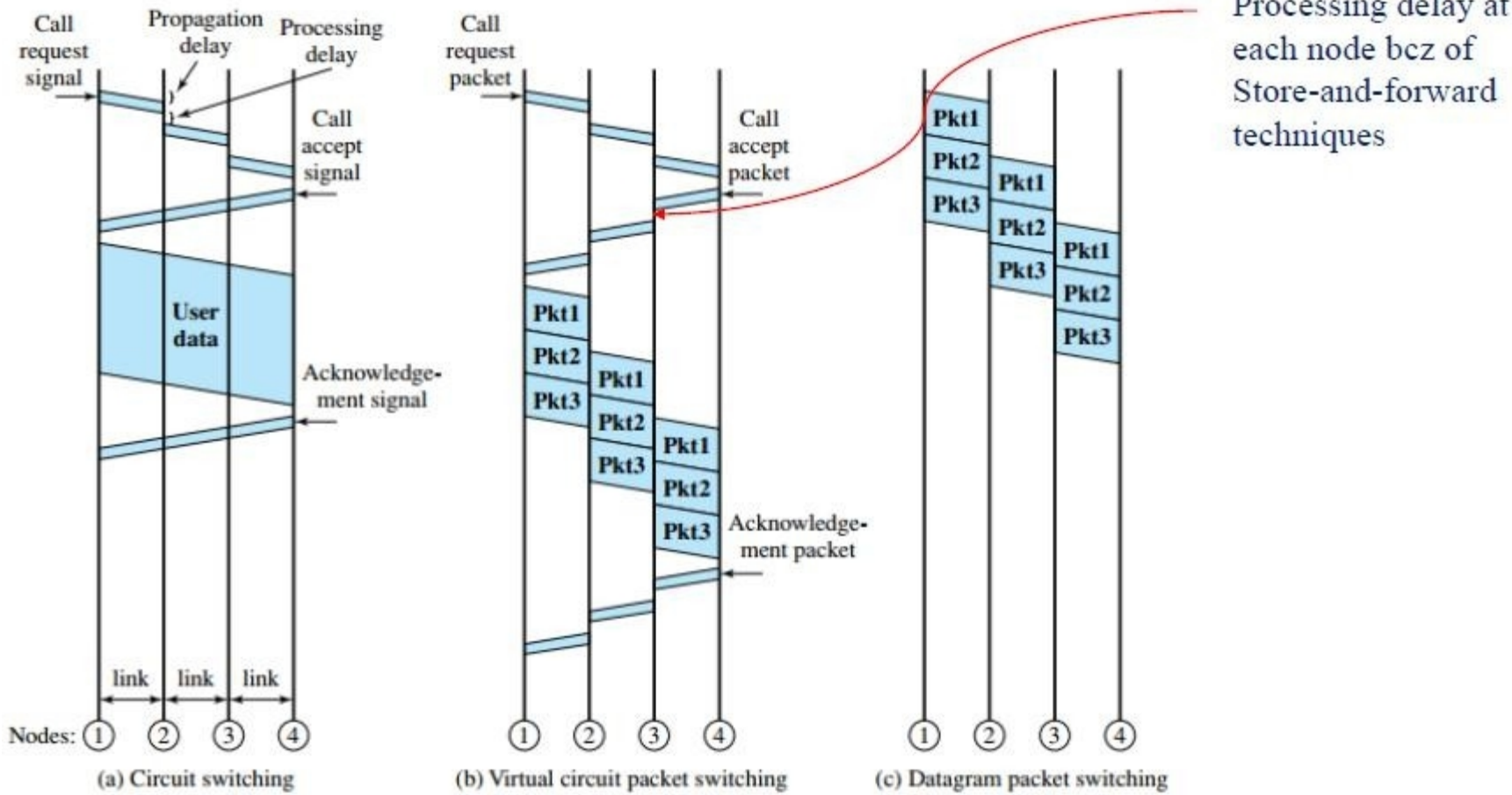
Step 3 of VC: Connection Release



Connection release

- **Advantages of Packet Switching**
  - Line efficiency: maximize link efficiency by making optimal use of link bandwidth
  - Data rate conversion: Nodes buffer the data if required to equalize rates
  - Packets are accepted even when network is busy
  - Priority can be used
  - Cost effective
  - Robust against link and node failure
- **Disadvantages of Packet Switching**
  - Protocols for packet switching are typically more complex
  - If packet is lost, sender needs to retransmit the data.
  - Packet switched system still can't deliver the same quality as delivered by circuit switched system.
  - It can add some initial cost in implementation.

Event Timing for Circuit Switching and Packet Switching



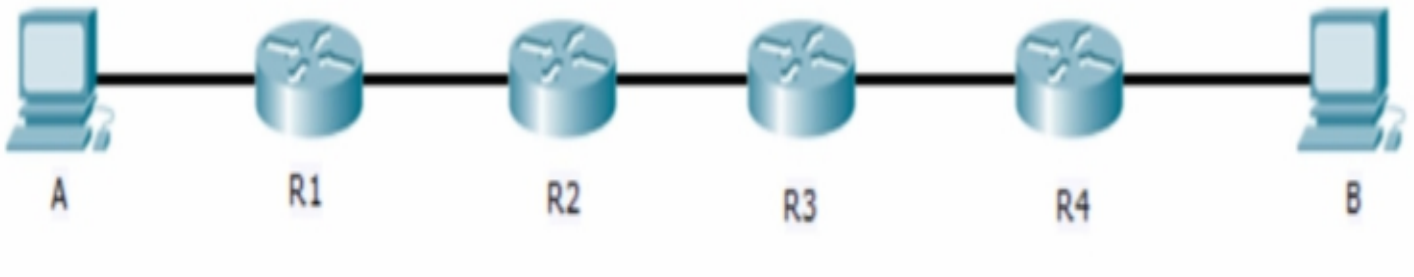
Processing delay at each node bcz of Store-and-forward techniques

A comparison of circuit switched and packet switched(connection less) system

Item	Circuit-switched	Packet-switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
When can congestion occur	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

Example:

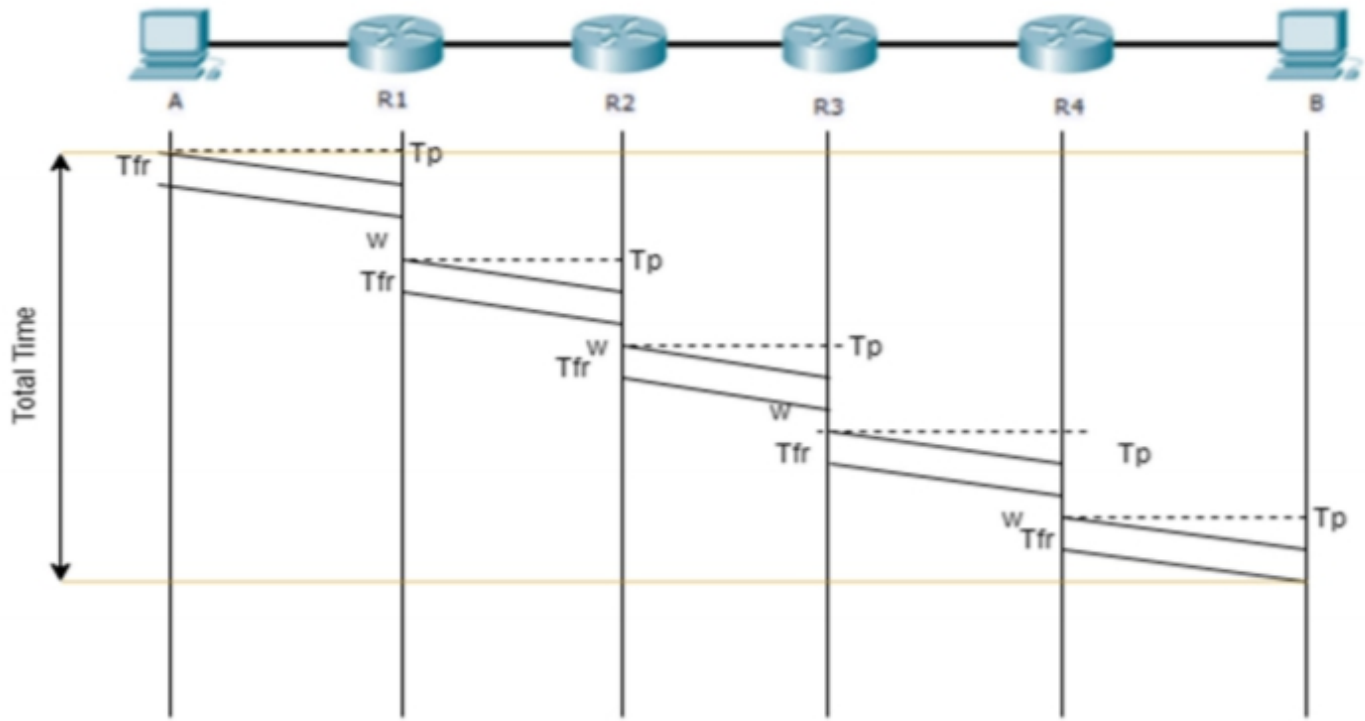
In a packet switched network, a 1024 byte Packet is sent over a link of speed 100Mbps. R1, R2, R3 and R4 are four intermediate routers between Source ‘A’ and destination ‘B’ machines. If the waiting time in each intermediate router is 1 msec. Draw the data flow diagram and calculate What is the total time required for the packet to reach from ‘A’ to ‘B’. Given that: All devices are placed at a distance of 500 kilometer apart from each of its neighboring devices. Consider the speed of electrical signal in guided media as 2/3 of speed of light in free space due to impedance. (figure given below)



Note: Here processing time/delay is not given.

Answer:

Packet Switched Network Numerical:



Where,
Tfr = Frame Transmission time
Tp = Propagation delay
W= Waiting time in each intermediate device

Total Time = 5 Tfr + 5 Tp + 4 W

Tfr= Size of Frame / Data rate = 1024 bytes/ 100 Mbps = (1024 x 8) / (100 x 10^6) sec. = 81.92 µsec.
Tp = Distance / Speed = 500 km/ (2/3 x c) = (500 x 10^3)/ (2 x 10^8) sec. = 2.5 millisec.
w = waiting time in each intermediate node = 1 millisec.

Putting all calculated value into formula derived from data flow diagram above:
Total time = (5 x 81.92 µsec.) + (5 x 2.5 millisec.) + (4 x 1 millisec.) = **16.9096 millisec. = 16.91 millisec.**

Total Time required for the packet to reach from Source 'A' to destination 'B' is 16.91 millisec.