# CSE2029: Data Communication & Computer Networks

## Lecture-2: Introduction to networking cont'd…

**Faculty: Dr. Sandeep Kumar**

# Outline

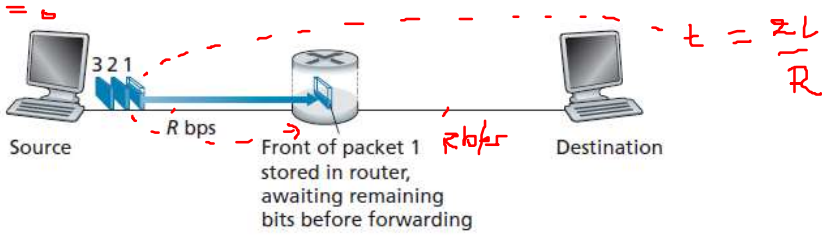
- Packet Switching
- Packet Switching: Store-and-Forward Transmission
- Packet Switching: Queuing Delays and Packet Loss
- Packet Switching: Forwarding Tables and Routing Protocols
- Circuit Switching
- Delay in Packet-Switched Networks
  - Nodal processing delay,
  - queuing delay,
  - transmission delay, and
  - propagation delay.

# Packet Switching

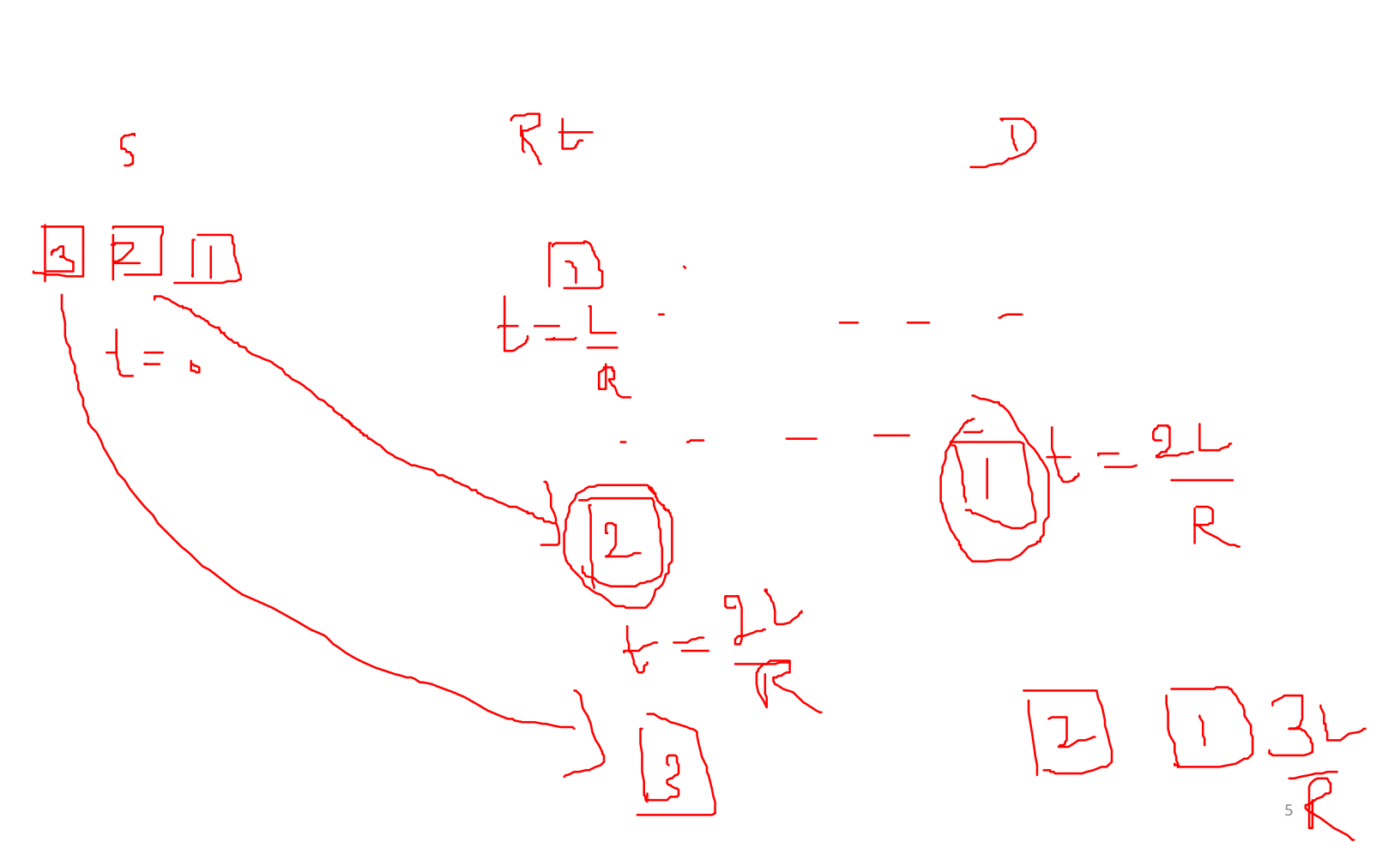
- In a network application, end systems exchange messages with each other. Messages can contain anything the application designer wants. Messages may perform a control signal or can contain data, such as an e-mail message, a JPEG image, or an MP3 audio file.
- To send a message from a source end system to a destination end system, the source breaks long messages into smaller chunks of data known as **packets**. Between source and destination, each packet travels through communication links and packet switches (routers and link-layer switches).
- Packets are transmitted over each communication link at a rate equal to the full transmission rate of the link. So, if a source end system or a packet switch is sending a packet of L bits over a link with transmission rate R bits/sec, then the time to transmit the packet is L / R seconds.

# Packet Switching: Store-and-Forward Transmission

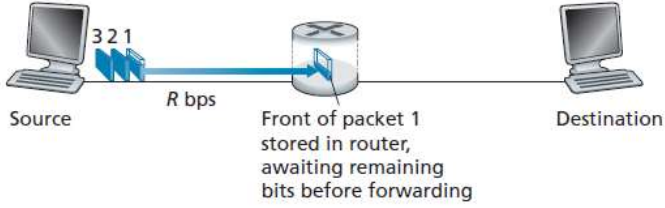
- Store-and-forward transmission means that the packet switch must receive the entire packet before it can begin to transmit the first bit of the packet onto the outbound link.




- Assuming link propagation delay = 0, packet length = L bits and link speed = R bits/s
- If source begins to transmit at t = 0; at time L/R seconds, the source has transmitted the entire packet, and the entire packet has been received and stored at the router.
- At time L/R seconds, since the router has just received the entire packet, it can begin to transmit the packet onto the outbound link towards the destination; at time 2L/R, the router has transmitted the entire packet, and the entire packet has been received by the destination. Thus, the total delay is 2L/R.


S
Rt
D
3
2
1
t = 0
1
t = L/R
2
t = 2L/R
1
t = 2L/R
3
2
1
3L/R

# Packet Switching: Store-and-Forward Transmission Cont'd…




- Now let's calculate the amount of time that elapses from when the source begins to send the first packet until the destination has received **all three packets**.
- At time L/R, the router begins to forward the first packet. But also at time L/R the source will begin to send the second packet.
- Thus, at time 2L/R, the destination has received the first packet and the router has received the second packet.
- Similarly, at time 3L/R, the destination has received the first two packets and the router has received the third packet.
- Finally, **at time 4L/R the destination has received all three packets**!

# Packet Switching: Store-and-Forward Transmission Cont'd…

- Let's now consider the general case of sending **one packet** from source to destination over a path consisting of N links (***There will be N-1 routers between source and destination***).
- Again, assuming link propagation delay = 0, packet length = L bits and each link speed = R bits/s
- Applying the same logic as above, we see that the end-to-end delay is:

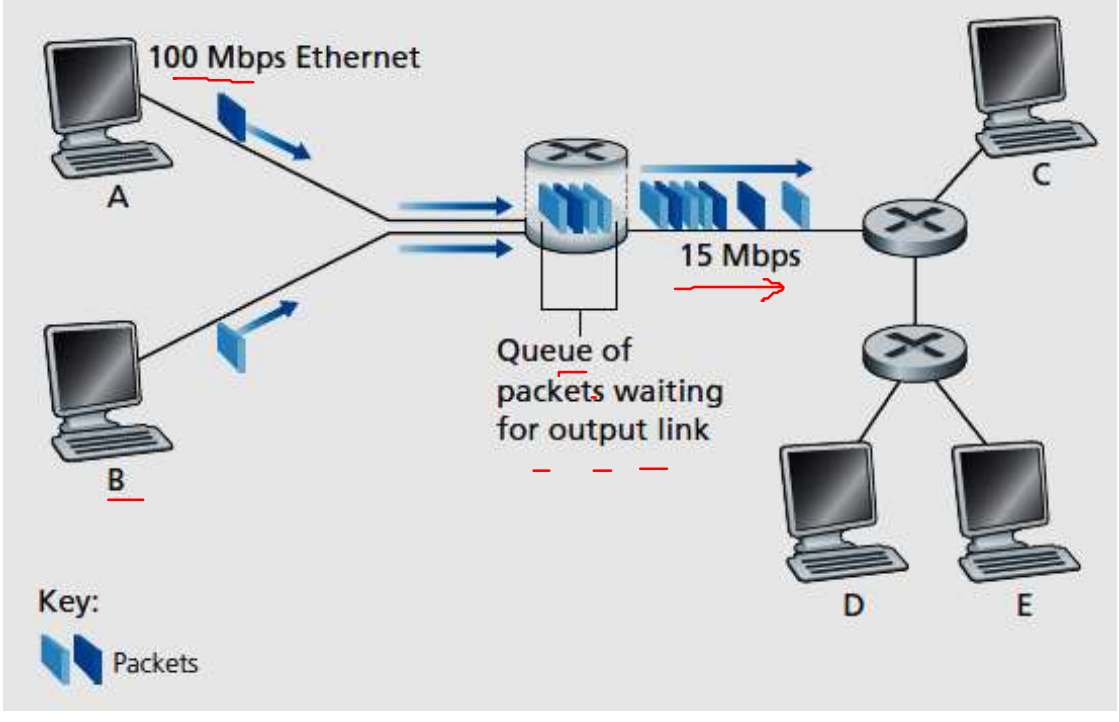
$$d_{\text{end-to-end}} = N\frac{L}{R}$$

- **What will be the delay would be for P packets sent over a series of N links. (Think yourself…)**

# Packet Switching: Queuing Delays and Packet Loss

- Each packet switch has multiple links attached to it. For each attached link, the **packet switch has an output buffer** (also called an output queue), which stores packets that the router is about to send into that link. The output buffers play a key role in packet switching.
- If an arriving packet needs to be transmitted onto a link but finds the link busy with the transmission of another packet, the arriving packet must wait in the output buffer.
- **Thus, in addition to the store-and-forward delays, packets suffer output buffer queuing delays.**
- These delays are variable and depend on the level of congestion in the network.
- Since the amount of buffer space is finite, an arriving packet may find that the buffer is completely full with other packets waiting for transmission. In this case, **packet loss** will occur—either the arriving packet or one of the already-queued packets will be dropped.

# Packet Switching: Queuing Delays and Packet Loss cont'd…

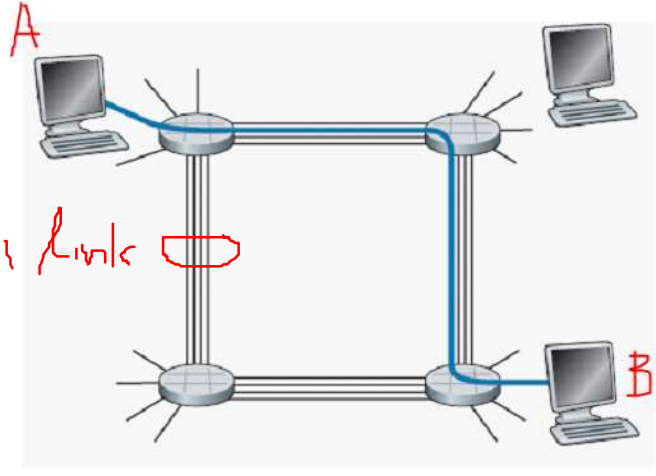


# Packet Switching: Forwarding Tables and Routing Protocols

- A router takes a packet arriving on one of its attached communication links and forwards that packet onto another one of the attached communication links.
- **But how does the router determine which link it should forward the packet onto?**
- In the Internet, every end system has an address called an **IP address**. When a source end system wants to send a packet to a destination end system, the source includes the **destination's IP address** in the packet's header.
- Each router has a **forwarding table** that maps **destination IP address** (or portions of destination address) to it's outbound links. The router examines the IP address and uses this forwarding table to find the appropriate outbound link and then it directs the packet to that outbound link.
- **How do forwarding tables get set? Are they configured by hand in each and every router, or does the Internet use a more automated procedure?**
- **ANS: Internet has a number of special routing protocols that are used to automatically set the forwarding tables. A routing protocol may, for example, determine the shortest path from each router to each destination and use the shortest path results to configure the forwarding tables in the routers.**

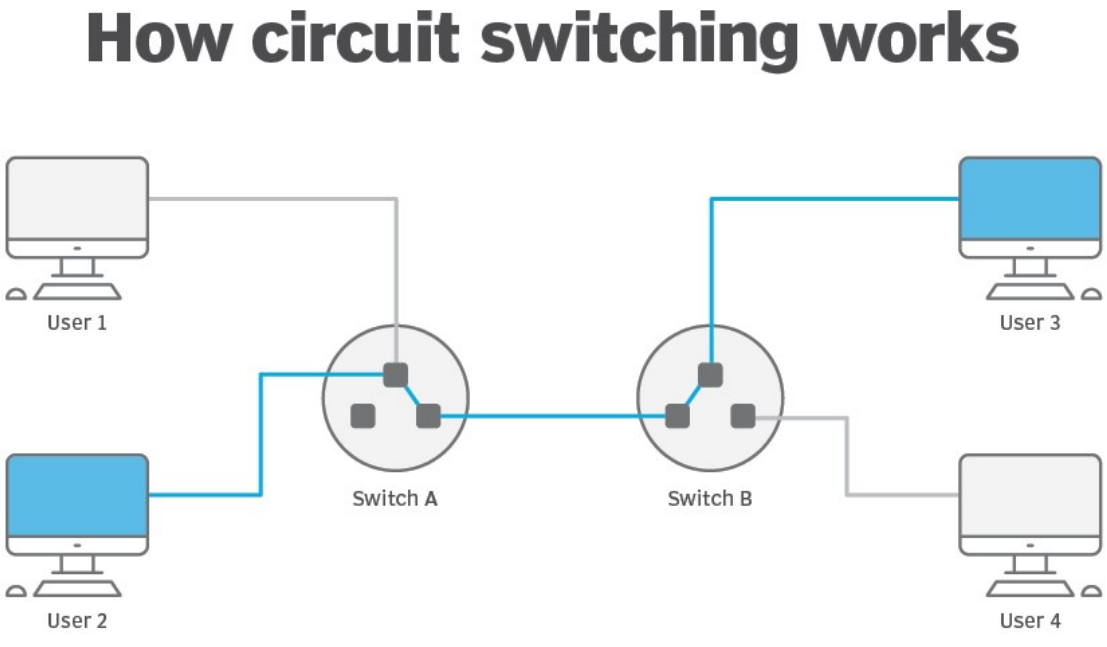
# Circuit Switching

- There are two fundamental approaches to moving data through a **network** of links and switches: packet switching and **circuit switching.**
- In circuit-switched networks, the resources needed along a path (link, transmission rate) are reserved to provide communication between the end for the duration of the communication session. The figure below illustrates a circuit switched network:




- In this network, the **four switches are interconnected by four links.**
- The hosts (PCs) are directly connected to one of the switches.
- When two hosts want to communicate, the network establishes a dedicated end-to-end connection between the two hosts.
- Thus, in order for **host-A** to communicate with **host-B**, the network must first reserve one **circuit (connection)** on each of two links.
- Because **each link has four connection lines**, the connection gets one fourth of the link's total transmission capacity (rate) for the duration of the connection.

## Circuit Switching: Another example

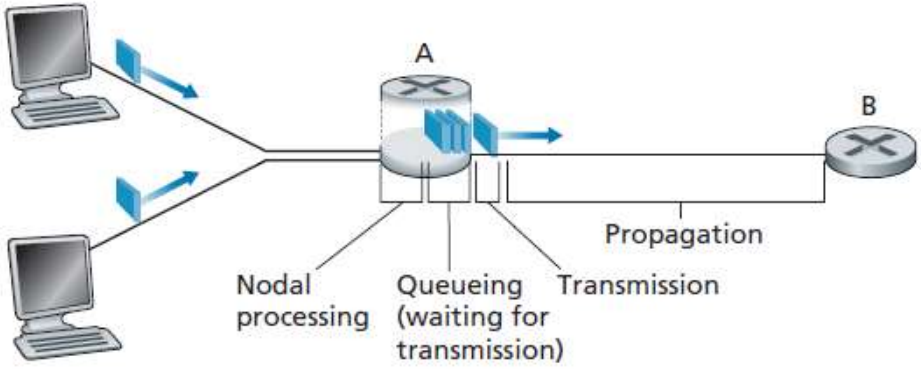


# Delay, Loss, and Throughput in Packet-Switched Networks…

## Overview of Delay in Packet-Switched Networks

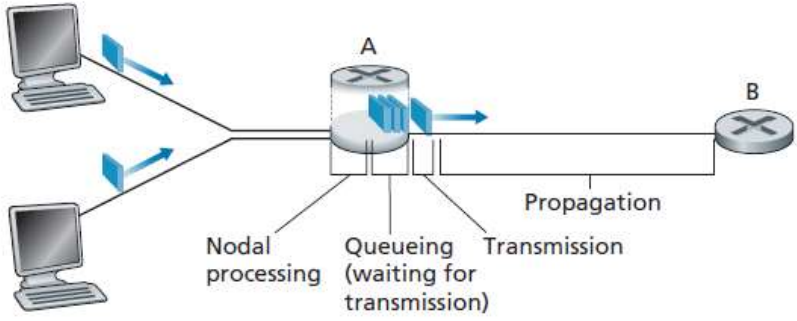
- As a packet travels from one node (host or router) to the subsequent node (host or router) along this path, the packet suffers from several types of delays at each node.
- The most important of these delays are the **nodal processing delay**, **queuing delay**, **transmission delay**, and **propagation delay**.
- Altogether, these delays accumulate to give a total nodal delay.
- The performance of many Internet applications—such as search, Web browsing, e-mail, maps, instant messaging, and voice-over-IP—are greatly affected by network delays.

# Overview of Delay in Packet-Switched Networks: Types of Delay



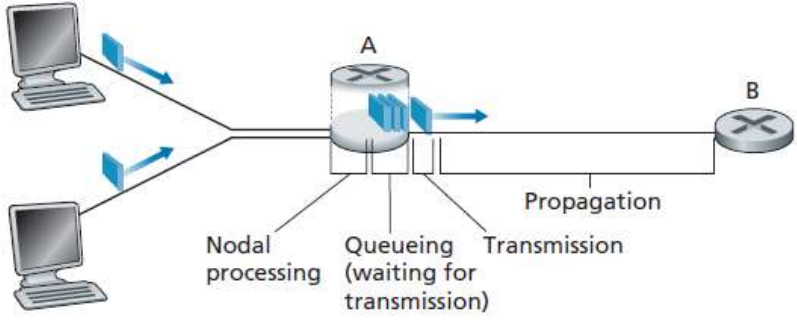

- **Processing Delay:** The time required to examine the packet's header and determine where to direct the packet is part of the processing delay. The processing delay can also include other factors, such as the time needed to check for bit-level errors in the packet that occurred in transmitting the packet's bits from the upstream node to router-A. Processing delays in high-speed routers are typically on the order of microseconds or less. After this nodal processing, the router directs the packet to the queue.

# Overview of Delay in Packet-Switched Networks: Types of Delay Cont'd…



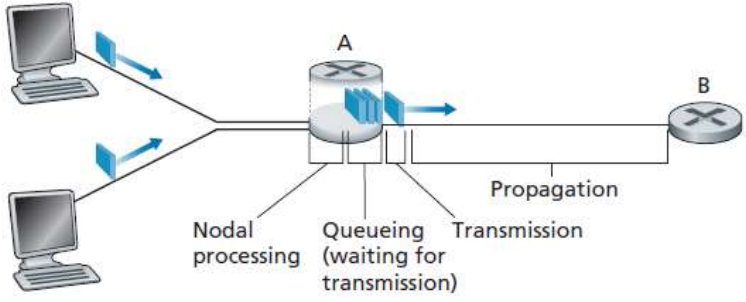

- **Queuing Delay:** At the queue, the packet experiences a queuing delay as it waits to be transmitted onto the link. The length of the queuing delay of a specific packet will depend on the number of earlier-arriving packets that are queued and waiting for transmission onto the link. If the queue is empty and no other packet is currently being transmitted, then our packet's queuing delay will be zero. On the other hand, if the traffic is heavy and many other packets are also waiting to be transmitted, the queuing delay will be long. We will see shortly that the number of packets that an arriving packet might expect to find is a function of the intensity and nature of the traffic arriving at the queue. Queuing delays can be on the order of microseconds to milliseconds in practice.

# Overview of Delay in Packet-Switched Networks: Types of Delay Cont'd…




- **Transmission Delay:** Denote the length of the packet by L bits, and denote the transmission rate of the link from router-A to router-B by R bits/sec. **The transmission delay is L/R**. This is the amount of time required to push (transmit) all bits of the packet into the link. Transmission delays are typically on the order of microseconds to milliseconds in practice.

# Overview of Delay in Packet-Switched Networks: Types of Delay Cont'd…




- **Propagation Delay:** Once a bit is pushed into the link, it needs to propagate to router B. The time required to propagate from the beginning of the link (after router-A) to router B is the propagation delay. The bit propagates at the propagation speed of the link.
- In wide-area networks, propagation delays are on the order of milliseconds.

## Packet Loss

- Because the queue capacity is finite, packet delays do not really approach infinity as the traffic intensity approaches 1 (continuous occupancy).
- Instead, a packet can arrive to find a full queue. With no place to store such a packet, a router will drop that packet; that is, the packet will be lost.
- From an end-system viewpoint, a packet loss will look like a packet having been transmitted into the network core but never emerging from the network at the destination.
- The fraction of lost packets increases as the traffic intensity increases.
- Therefore, performance at a node is often measured not only in terms of delay, but also in terms of the probability of packet loss.
- **Note:** a lost packet may be retransmitted on an end-to-end basis in order to ensure that all data are eventually transferred from source to destination.

**Throughput in Packet-Switched Networks… to be discussed in the next lecture.**

***Thank you.***