

# Delays

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# Delays in Packet Switched Networks

- Packets travel from source to destination via intermediate routers/switches.
  - Processing delay
  - Queueing delay
  - Transmission delay
  - Propagation delay
- **Nodal delay** = Processing delay + Queueing delay + Transmission delay + Propagation delay

# Processing Delay

- Time required to **examine** the packets header
  - Determines where to direct the packet
  - Check for errors
- Order of microseconds

# Queuing Delay

- If a router is **busy** in processing and transmitting a packet, a freshly arrived packet has to wait in **queue** (buffer) for its turn.
- No queuing delay if the router is idle.
- Queuing delay varies with time and location. In general, it is a random variable.
- Order of microseconds to milliseconds.

# Transmission Delay

- Time required to **push** the packet into the link
- If the length of the packet is  $L$  bits and transmission rate of the link is  $R$  bps, then

$$\text{Transmission delay} = \frac{L}{R}$$

- Order of microseconds to milliseconds

# Propagation Delay

- Time required to **propagate** from one end of the link to the other end
- The propagation speed depends on the physical link between the routers
- In general, propagation speed  $s$ , is in the order of  $2 \times 10^8 - 3 \times 10^8 m/s$ .
- Propagation speed depends on the distance between the routers,  $d$
- Propagation delay  $= \frac{d}{s}$

# Traffic Intensity

- Queuing delays are **random** in nature
- Arrivals to a queue are also **random** in nature
- Traffic intensity is an indication of queuing delay
- Let  $a$  be the average number of packets arriving at a queue
- Each packet is of length  $L$  bits and transmission rate is  $R$  bps
- **Traffic intensity**  $= \frac{La}{R}$

# Traffic Intensity

- If traffic intensity  $> 1$ , the *queuelength* increases to  $\infty$
- It is desirable to have traffic intensity  $< 1$ .
- If traffic intensity **close to** 1, there will be a significant queuing delay



# Throughput

- Suppose Host A is sending data to Host B across a computer network
- **Instantaneous throughput** is the rate at which Host B is receiving data
- Suppose it takes  $T$  seconds to transfer  $F$  bits from Host A to Host B, then **average throughput**  $= \frac{F}{T}$  bps.

# Problems

- Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links of rates  $R_1 = 500\text{kbps}$ ,  $R_2 = 2\text{Mbps}$ ,  $R_3 = 1\text{Mbps}$ .
  - Assuming no other traffic, what is the throughput for the file transfer
  - Suppose the file size is 4 million bytes, how long will it take to transfer the file from A to B?
- How long does it take for a packet of length 1000 bytes to propagate over a link of propagation speed  $2.5 \times 10^8$  m/s. Length of the link is 2,500 Km and transmission rate is 2Mbps.

## Problem 3

Suppose  $N$  packets arrive simultaneously to a link at which no packets are currently being transmitted or queued. Each packet is of length  $L$  bits and the link has a transmission rate of  $R$  bits/sec. What is the average queueing delay for the  $N$  packets ?

# Problem 4

Suppose that  $x$  bits of user data has to be transmitted over a  $k$ -hop path in a packet switched network as a series of packets. Each packet contains  $p$  data bits and  $h$  header bits, with  $x \gg p + h$ . The bits rate of the links is  $b$  bps. Ignoring propagation delay and processing delay **find the value of  $p$  that minimizes total delay.**