Delays in Packet Switched Networks

- A packet travels from source to destination through communication links and routers
  - Nodal processing delay
  - Queuing delay
  - Propagation delay
  - Transmission delay

Processing delay ($\approx \mu s$)

- Time required to examine the packet's header
- Determine where to direct the packet
- Time needed to check for bit-level errors.

Queuing delay (≈ μs – ms)

- If a router is busy in serving a packet, the freshly arrived packet has to wait in queue for its turn
- If there are no packets the buffer of a router, then freshly arrived packet may have '0' queuing delay

Transmission delay

- Amount of time required to push all of the packet's bits into the link.
- If length of the packet is L bits and transmission rate of the link is R,

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

Transmission delay

For a 10 Mbps link, transmission rate is $R = 10^7$ bits per sec

Transmission delay is in the order of μs – ms.

Propagation delay

- The time required to propagate from the beginning of the link to a router

- The propagation speed depends on the physical link between the routers.
- In range of 2×10^8 m/s $- 3 \times 10^8$ m/s
- Propagation delay depends on the distance between the routers.

Propagation delay $= \frac{d}{s}$, d: distance, s: Propagation speed

Nodal delay

$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

Traffic intensity

- Queuing delays are random in nature
- Arrivals to a queue are also random in nature
- Let a denote the average number of packets arriving at a queue
- Assume each packet is of length L bits

Traffic intensity $= \frac{La}{R}$,

R is the transmission rate

If $\frac{La}{R} > 1$, queue length increases to ∞.

It is desirable to have $0 < \frac{La}{R} < 1$

If $\frac{La}{R} \approx 1$, typically every arriving packet will experience queuing delay

If $\frac{La}{R} \approx 0$, then may have '0' queuing delay or negligible delay

End-to-End delay

Let there are N-1 routers between Source and destination. Assume that network is not congested ($d_{queue} \approx 0$)

$$d_{end-end} = N\left(d_{proc} + d_{trans} + d_{prop}\right)$$

Throughput

Suppose Host A is sending data to Host B across a Computer network.

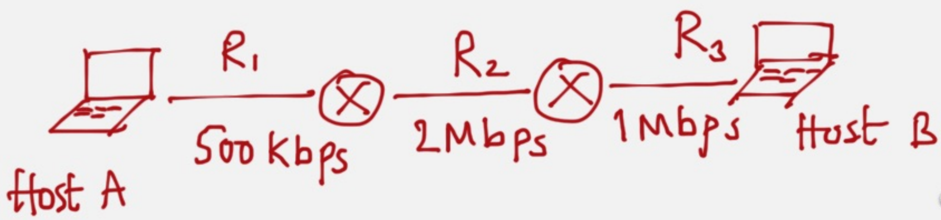
Instantaneous throughput is the rate at which Host B is receiving data.

Suppose Host A is sending a file of F bits and it took T secs to transfer the file.

$$\text{Average throughput} = \frac{F}{T} \text{ bits/sec}$$

Problems

① Suppose Host A wants to send a large file to Host B



ⓐ Assuming no other traffic in the network, what is the throughput for the file transfer?

(b) Suppose file size is 4 million bytes. How long will it take to transfer the file to Host B?

(c) Repeat (a) and (b) with $R_2 = 100$ kbps

(2) How long does it take packet of length 1000 bytes to propagate over a link of distance 2,500 km, with propagation speed 2.5×10^8 m/s and transmission rate 2Mbps.

(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 queuing delay for the N packets.