COMPUTER COMMUNICATION NETWORKS

Department of Electronics and Communication Engineering

COMPUTER COMMUNICATION NETWORKS (UE22EC351A)

UNIT 1: INTERNET ARCHITECTURE AND APPLICATIONS – Classes 4 & 5 – Delay, Loss & Throughput in Packet-Switched Networks

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UNIT 1 – Classes 4 & 5 – Delay, Loss & Throughput in Packet-Switched Networks – Text book reference – Section 1.4 – pages 65 to 76

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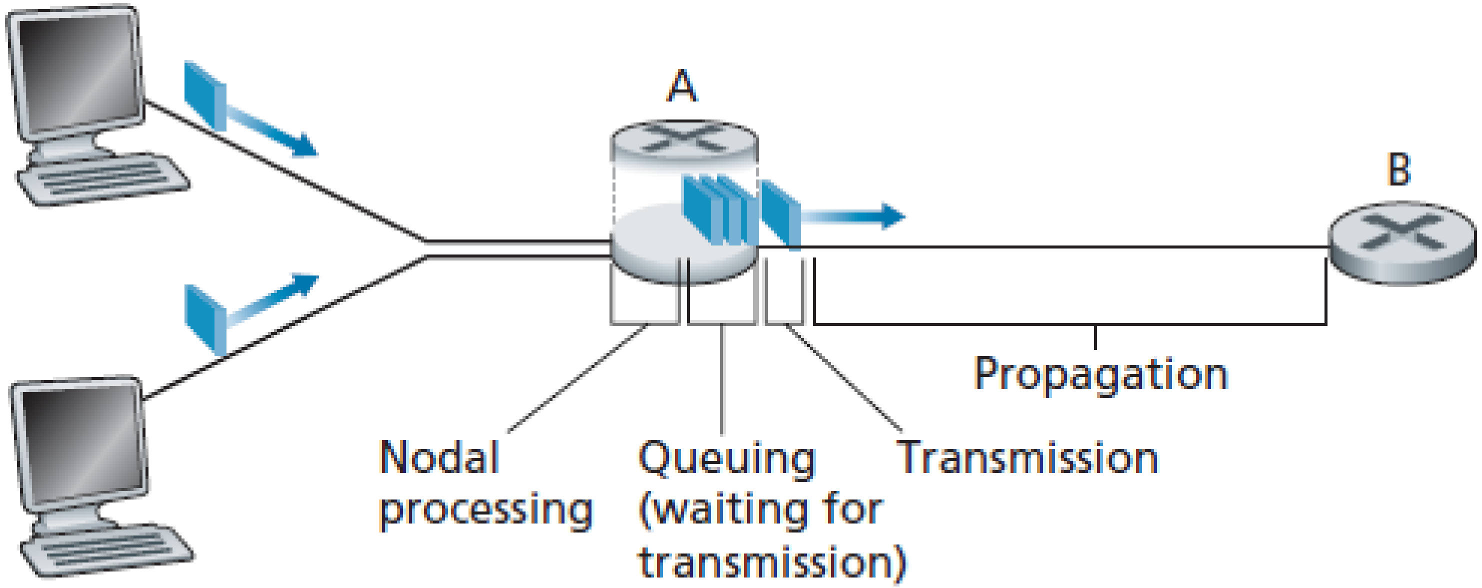
Classes 4 & 5 - Delay, loss and throughput

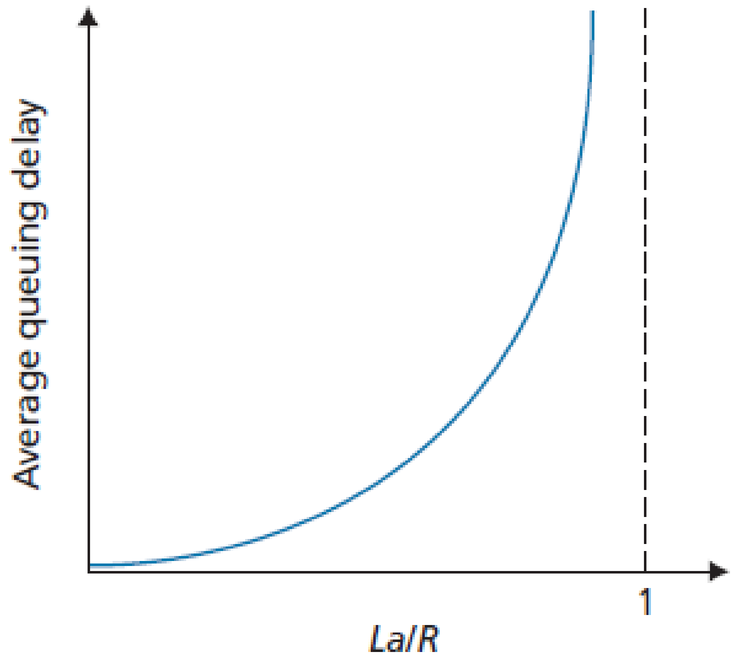
- The different delays that occur in packet switched transmission are depicted below



Classes 4 & 5 - Delay, loss and throughput

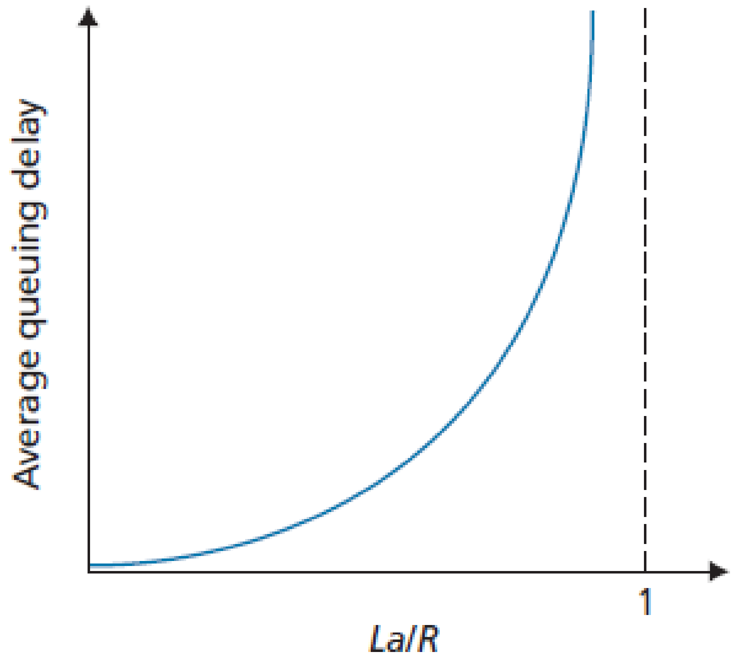
- **Processing delay:** Time taken to inspect (or make) a packet at a packet switch (or source host). Range: Microseconds
- **Queuing delay:** Time spent by a packet in the queue before processing. Depends on the number of packets waiting ahead, traffic intensity and distribution of the arrival process. Range: Microseconds to milliseconds
- **Transmission delay:** Time taken to push a packet on to the link. Depends on length of the packet (L bits) and link rate (R bits/sec). Expressed as L/R
- **Propagation delay:** Time taken by a bit to travel over a link. Depends on the length of the link and the physical medium's propagation speed (e.g., 2×10^8 to 3×10^8 m/s).

- **Traffic intensity versus queuing delay**
  - Suppose arrival rate is *a* packets per sec and departure rate is L/R seconds per packet, then traffic intensity is given by La/R
  - Let buffer size be infinite
  - When La/R < 1, every new packet sees an empty queue
  - When La/R ≥ 1, queue starts to build up and mean queuing delay could approach infinity



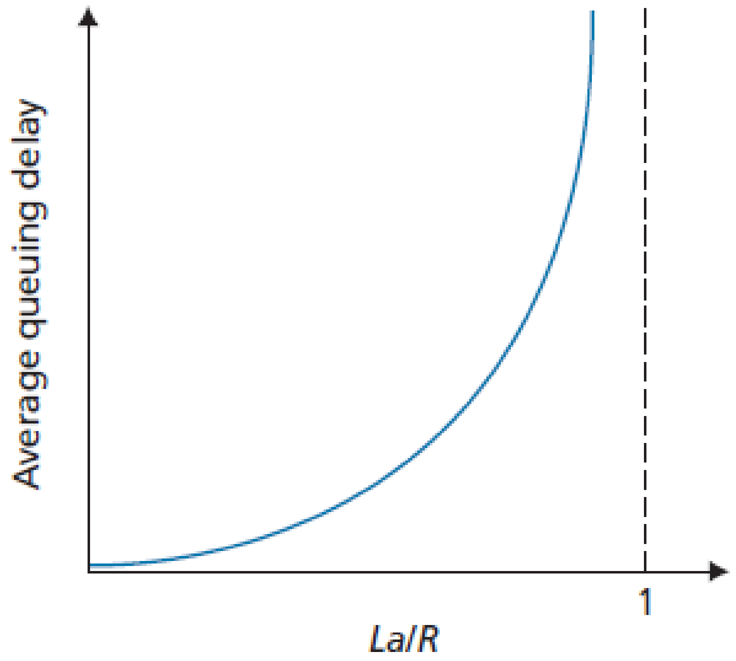
When buffer is finite and La/R ≥ 1, then packet losses occur

- **Traffic intensity versus queuing delay**
  - a = average rate at which packets arrive at the queue
  - R = transmission rate
  - L = no of bits/packet
  - Average rate at which bits arrive at the queue = La bits/sec
  - Traffic intensity = La/R plays an important role in estimating the extent of queuing delay



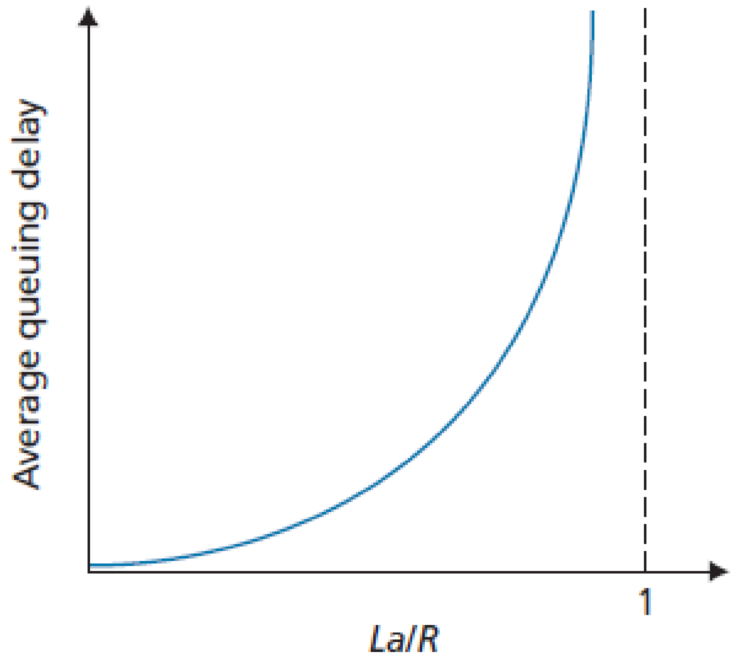
Classes 4 & 5 - Delay, loss and throughput

- **Traffic intensity versus queuing delay**
  - La/R > 1 – average rate at which bits arrive at the queue exceed the rate at which the bits can be transmitted from the queue.
  - Queuing delay approaches infinity
  - Case 1 - If traffic intensity is close to 0 – Packets arrival are few & far between.



Classes 4 & 5 - Delay, loss and throughput

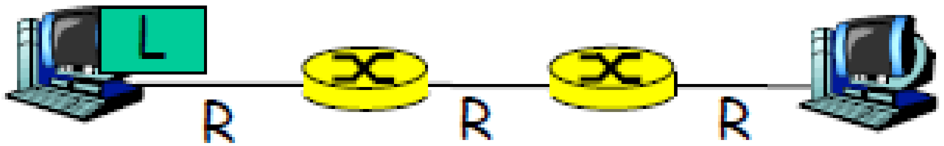
- **Traffic intensity versus queuing delay**
  - It is unlikely that an arriving packet will find another packet in the queue.
  - In this case, Average queuing delay will be zero.
  - Case 2 – Traffic Intensity is close to 1 – There will be intervals of time when the arrival rate exceeds the transmission capacity & a queue will form during these periods of time



Classes 4 & 5 - Delay, loss and throughput

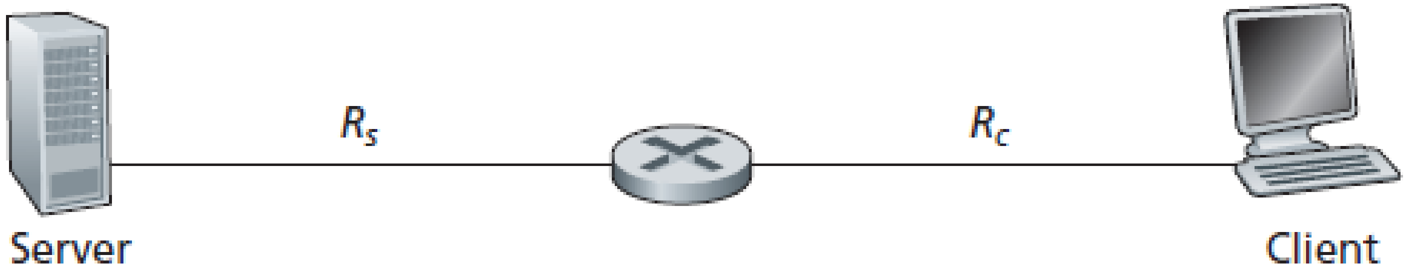
- **End-to-end delay** ($d_{end\text{-}end}$)**:** The total time spent by a packet to travel from the source to the destination.
  - End-to-end delay is the sum of the delays at the source, delays at each packet switch and the propagation delays on each communication link along the path.
  - Delay at a packet switch equals the sum of queuing delay, processing delay and transmission delay
- Consider N–1 identical and uncongested routers between the source and destination. Let all N–1 links be identical. Let propagation delay on any link, transmission delay and processing delay at any router and source be denoted by d_{prop}, d_{trans} and d_{proc} respectively. What is the end-to-end delay?

- Numerical #3:
  - For the scenario given below, assume the queuing delay, propagation delay and processing delay to be negligible. Suppose packet length L = 7.5 Mb and link rate R = 1.5 Mbps. Calculate the end-to-end delay.



  - Solution – 3L/R
  - Packet Loss – A packet can arrive to find a full queue
  - With no place to store such a packet, a router will drop that packet; the packet will be lost.

- **Throughput** is the rate (bits/sec) at which the destination host receives the packets.
- **Instantaneous throughput** is the throughput at a given time instant whereas **average throughput** is throughput over the entire file transfer time (e.g., F/T where F is file size and T is file transfer time).
- Example: What is the maximum achievable throughput?



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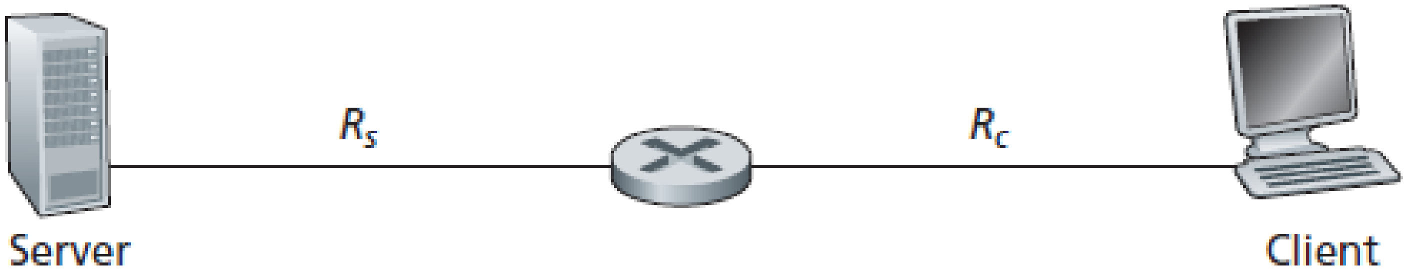
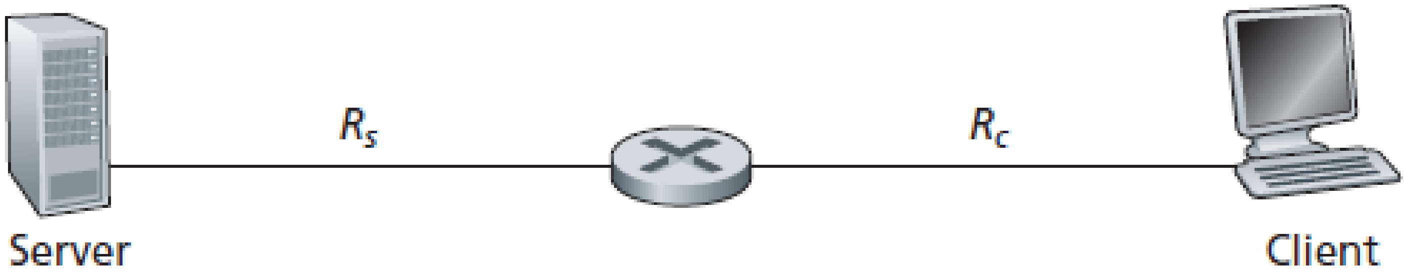
- Example: What is the maximum achievable throughput?

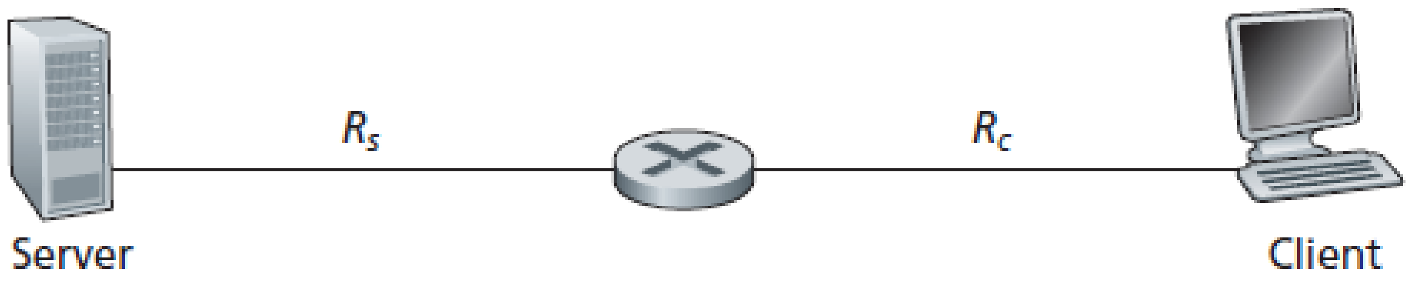


- Case 1 – Rs < Rc – The bits pumped by the server will flow right through the router & arrive at the client at a rate of Rs bits/sec giving a throughput of Rs bits/sec

- Example: What is the maximum achievable throughput?



- Case 2 – Rc < Rs – The router will not be able to forward bits as quickly as it receives them. Bits will only leave the router at rate Rc, giving a throughput of Rc bits/sec
- For a simple two-link network, throughput = min{Rc,Rs}



- Example: Suppose you are downloading a MP3 file of F = 32 million bits, the server has a transmission rate of Rs = 2 Mbps & Rc = 1 Mbps
- What is the time needed to transfer the file ?
- Solution – T = F/ min {Rc,Rs} = 32 *10^6 / 1*10^6 = 32 seconds

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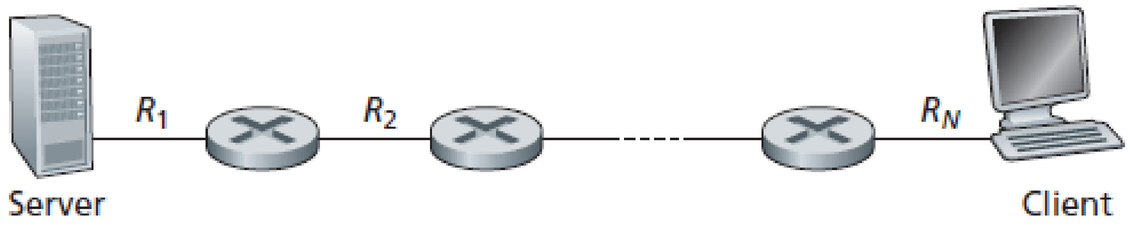
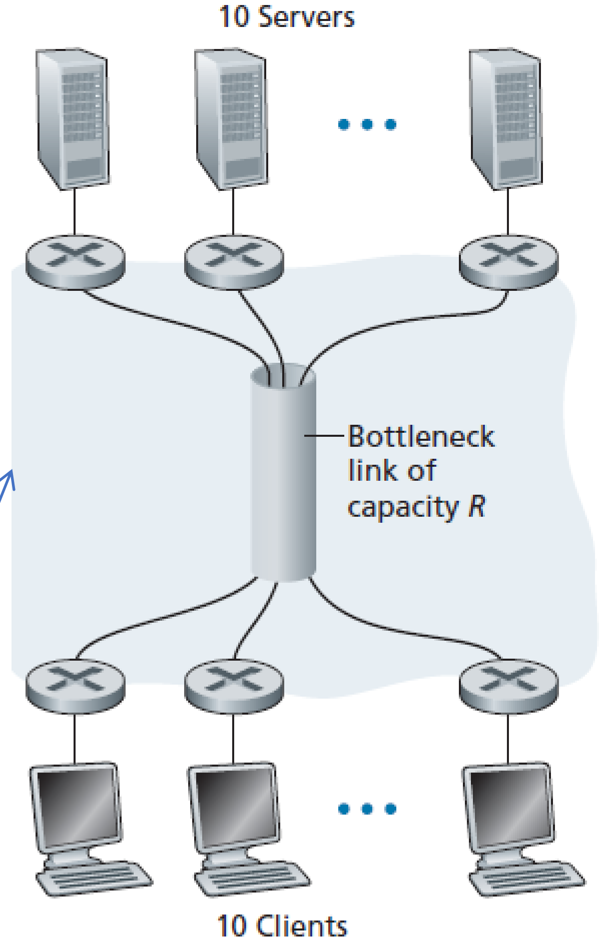
- Example: What is the maximum achievable throughput in the following cases?





Let the link rate in the access networks and the bottleneck link in the network core be R=10 Mbps

- Example: What is the maximum achievable throughput in the following cases?

- Consider 10 servers & 10 clients connected to the core of computer network.
- There are 10 simultaneous downloads taking place involving client-server pairs
- There is a link in the core that is traversed by all 10 downloads
- Let R be the transmission rate of this link
- Server access links have the rate Rs
- Client access links have the rate Rc

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- Suppose Rs = 2 Mbps, Rc = 1 Mbps, R = 5 Mbps, and the common link divides its transmission rate equally among the 10 downloads.
- The bottleneck for each download is no longer in the access network, but is now instead the shared link in the core, which only provides each download with 500 kbps of throughput.
- Thus, the end-to-end throughput for each download is now reduced to 500 kbps

THANK YOU

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