Network Delays

17CS52 - CN: L05/L06

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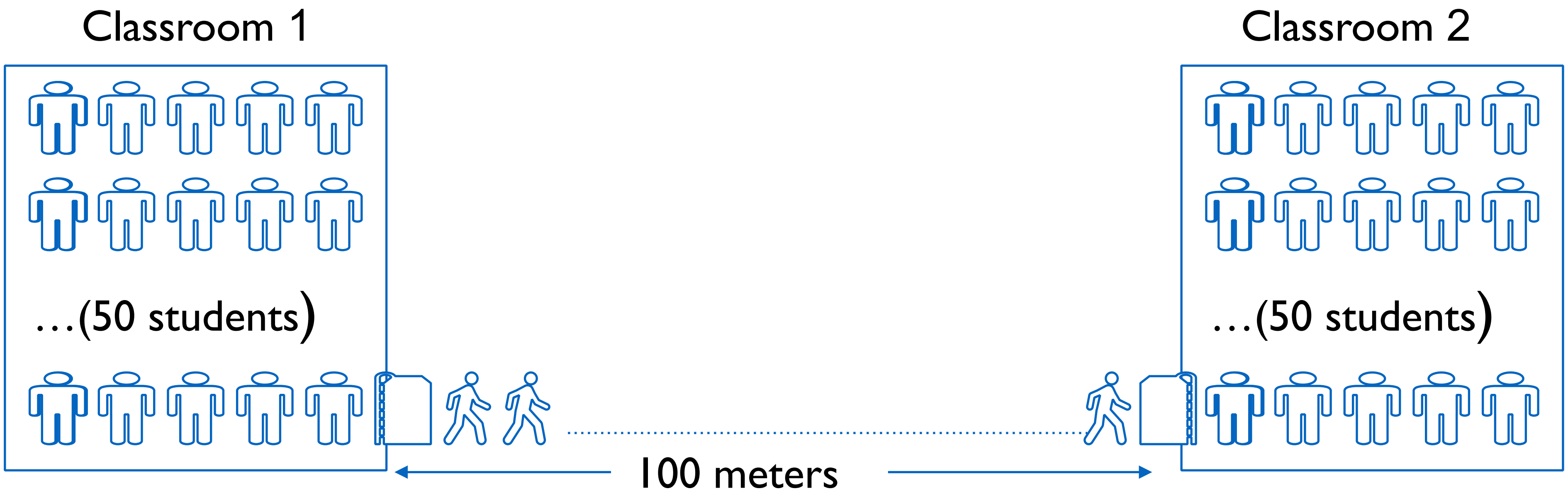
https://www.youtube.com/watch?v=kD90aHoQfFc
https://www.youtube.com/watch?v=_xznsLcMEPw

Resources

- http://wps.pearsoned.com/ecs_kurose_compnetw_6/216/55463/14198700.cw/index.html
- https://acc.digital/experiential-learning-of-networking-technologies-understanding-network-delays/
- https://media.pearsoncmg.com/aw/ecs_kurose_compnetwork_7/cw/content/interactiveanimations/transmission-vs-propogation-delay/transmission-propagation-delay-ch1/index.html
- Computer Networking: A Top Down Approach
  – Kurose, Ross
  – Pearson publications

Transmission vs Propagation Delay



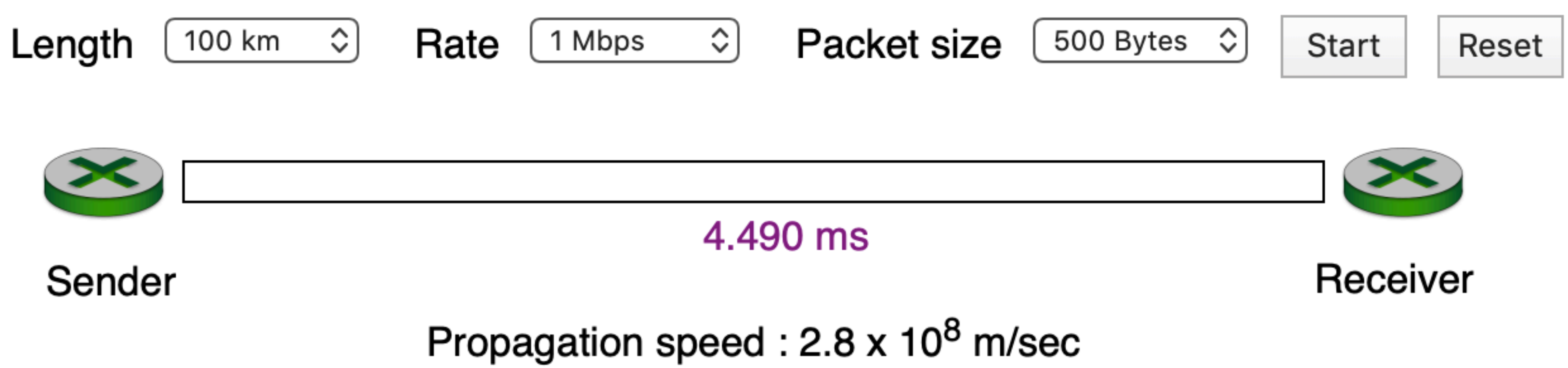
- Consider that a class of 50 students are asked to go (walk) to another classroom which is 100 meters away. The students exit the class room at the rate of 1 student per second and starts walking, at the speed of 3km/hr i.e 50m/minute.
- Q: What is the total time taken by the class to move from class room 1 to class room 2?
- Ans: 2 minutes and 50 seconds.
- Note: When last student exits the class, the first student is still on the way, and have travelled `50*5/6=41.66` meters.

Transmission vs Propagation Delay

- Analogy of students moving from one classroom to another.
  - Entire class: one packet
  - Student: 1 bit (of the packet)
  - Rate at which students exit classroom: Link **Bandwidth**
    - 1bit/second
  - Distance between two classrooms: link length (distance)
    - 100 meters
  - Time taken by one student to walk from classroom 1 to classroom 2: **Propagation delay**
    - 2 minutes
  - Time taken by all students to exit the classroom: **Transmission delay**
    - 50 seconds
  - Total delay = propagation delay + transmission delay
    - = 2minutes and 50seconds

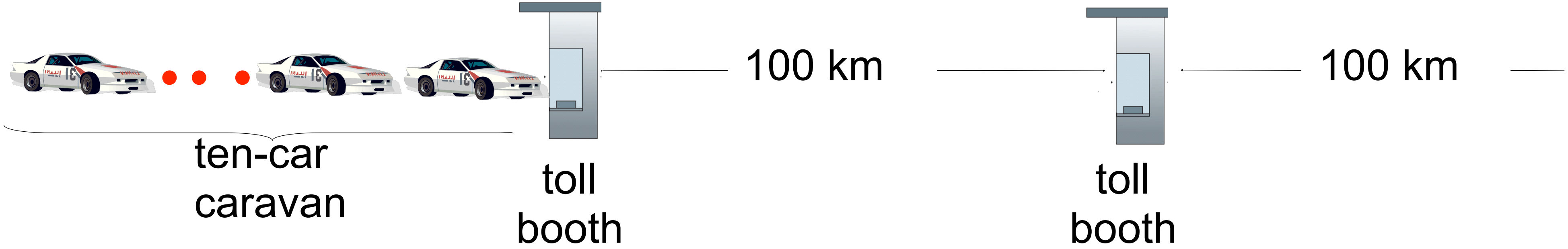
Packet-switching: store-and-forward

- Transmission vs propagation delay
  - https://media.pearsoncmg.com/aw/ecs_kurose_compnetwork_7/cw/content/interactiveanimations/transmission-vs-propogation-delay/transmission-propagation-delay-ch1/index.html



Params	Case 1	Case	Case
Pkt Size (bytes)	100	100	100
Trans rate (Mbps)	1	10	100
Distance (Km)	10	10	100
Trans. Delay (ms)			
Prop. Delay (ms)			
Tot delay (ms)			

Caravan analogy



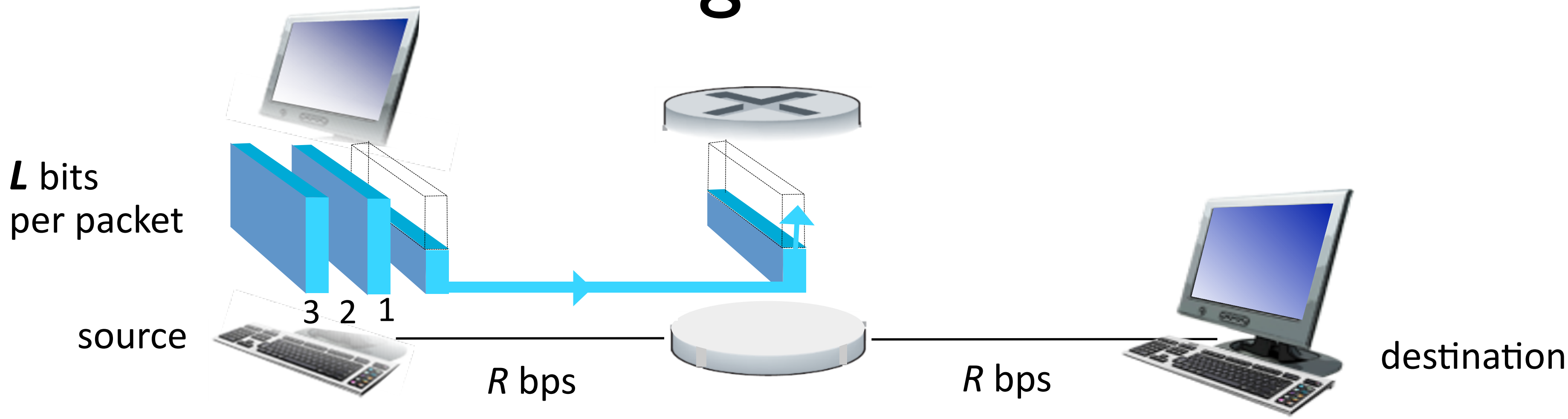
- cars "propagate" at 100 km/hr
- toll booth takes 12 sec to service a car (bit transmission time)
- Analogy:
  - car~bit;
  - caravan ~ packet

- time to "push" entire caravan through toll booth onto highway = 12*10 = 120 sec
- time for last car to propagate from 1st to 2nd toll both: 100km/(100km/hr)
  = 1 hr

- *Q:* How long until caravan is lined up before 2nd toll booth?
- *A:* 62 minutes

src: Computer Network: A top down approach; Kurose, Ross

Packet-switching: store-and-forward



- Takes L/R seconds to transmit (push out) L-bit packet into link at R bps
- *Store and forward:* entire packet must arrive at router before it can be transmitted on next link

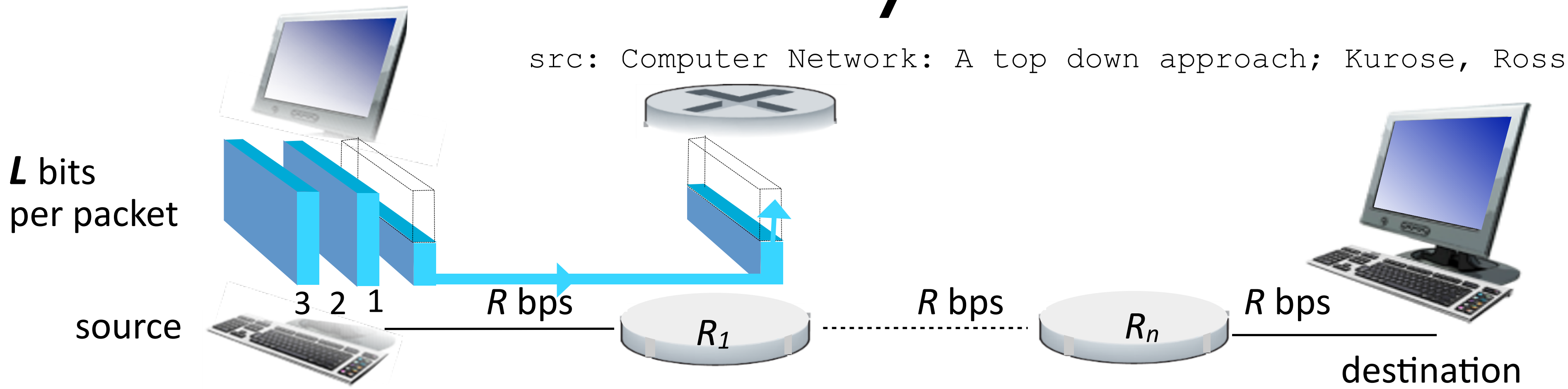
- end-end delay = $2L/R$ (assuming zero propagation delay)

one-hop numerical example:

- L = 7.5 Mbits
- R = 1.5 Mbps
- one-hop transmission delay = 5 sec
- Q: with N routers and P Packets?

src: Computer Network: A top down approach; Kurose, Ross

Case Study 01

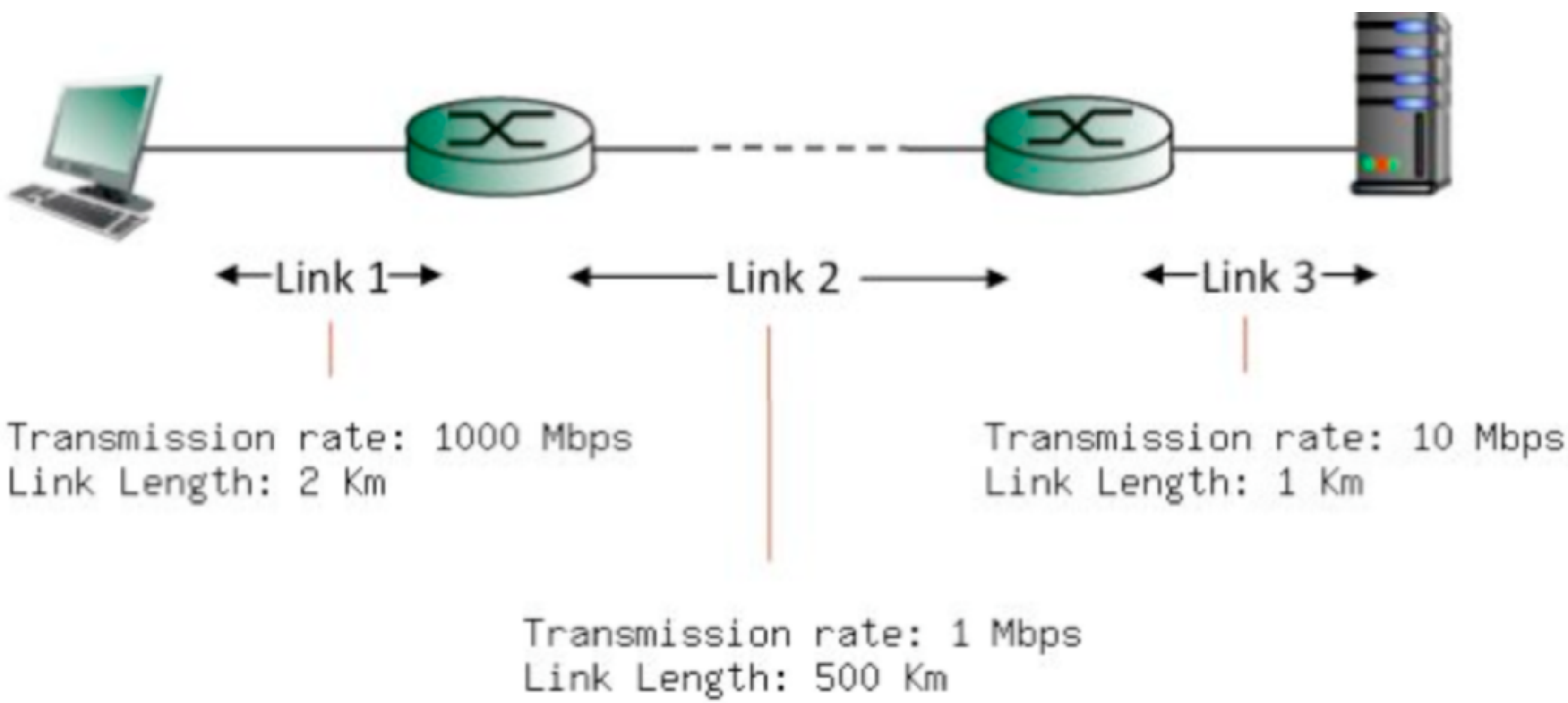


N hops and P Packets example:

- Src sends P packets each of size L bits
- Transmission rate of each link is R bps
- There are N routers between source and destination
- What the total transmission delay i.e. time interval between first bit is transmitted at source and last bit is received at destination (ignore propagation delay).
- Ans:
- **N=1, P=1**, delay = **2L/R**
- **N=n, P=1**, delay = **(n+1)L/R**
- **N=1, P=p**, delay = **(p+1)L/R**, pipelining happens
- **N=n, P=p**, delay = **(P+n)L/R**, pipelining happens for **n** packets

Case Study 02

Consider the following figure. Find the end-to-end delay (including the **transmission** delays, and **propagation** delay, but ignoring the *processing* delays and *queuing* delays) from when the left host begins transmitting the first bit of a packet to the time when the last bit of last packet is received at the server at the right. The host on left sends 1 packet of 1500 Bytes. Take signal traversal speed as $2*10^5$ km/s



Case Study 02 - Answer

- Propagation delay on link 1:
  = 2*1000*1000/(2x10**8)=0.01ms
- Transmission delay for one pkt (1500 bytes=12000 bits) on link 1 :
  = 12000/(1000x10**6) = 12μs = 0.012ms
- Switch 1 will start transmission at = 0.01+0.012 = 0.022ms
- Propagation delay on link 2:
  = 500*1000*1000(2x10**8)=2.5ms
- Transmission delay on one pkt on link 2 :
  = 12000/(1x10**6) = 12000us = 12ms
- Switch 2 will start transmission at = 0.022+2.5+12 = 14.522ms
- Propagation delay on link 3:
  = 1*1000*1000/(2x10**8)=0.005ms
- Transmission delay on one pkt on link 3 :
  = 12000/(10x10**6) = 1200us = 1.2ms.
- Switch 3 will reeceive pkt at = 14.522+0.005+1.2=15.727ms
- Total propagation delay = 15.727ms

Case Study 03

- Use the link below and under the Interactive exercises, use the 3rd option under Chapter 1: Introduction

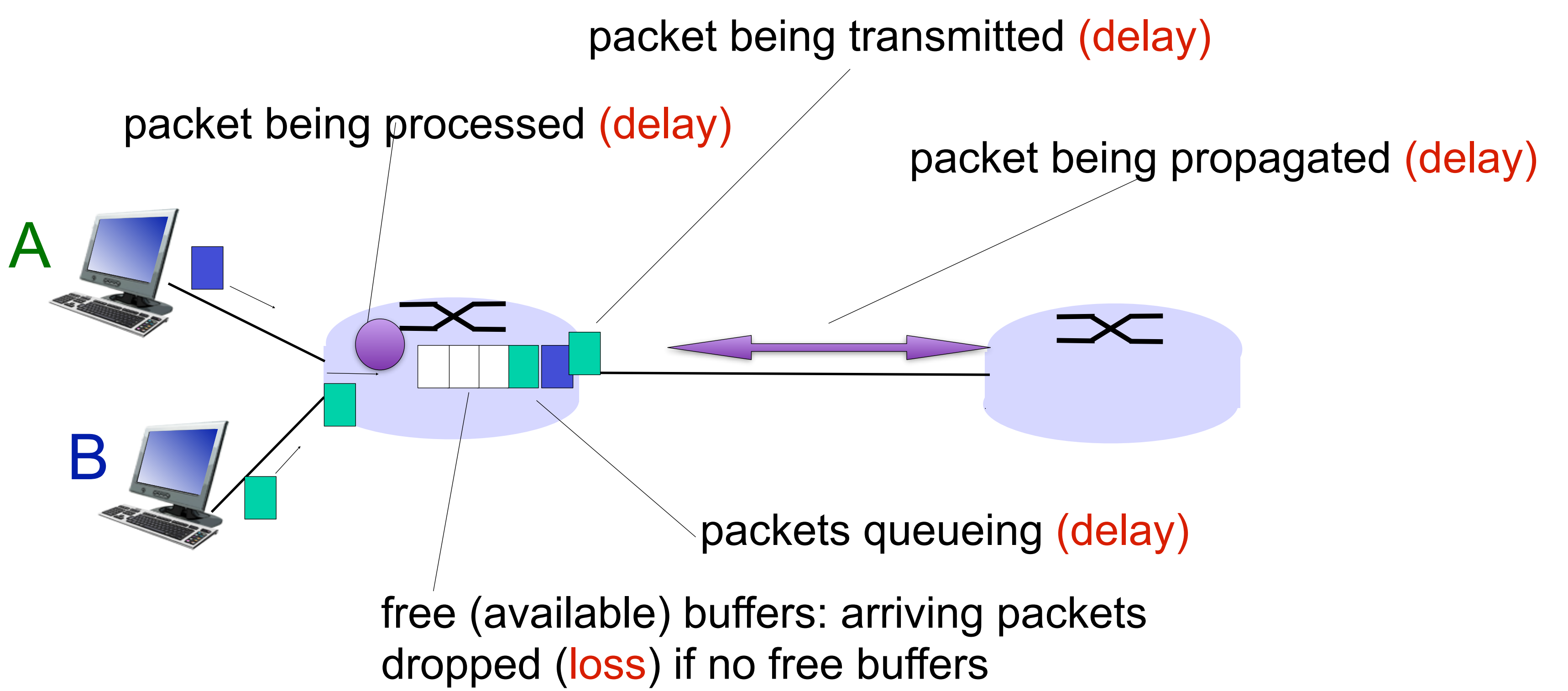
  http://wps.pearsoned.com/ecs_kurose_compnetw_6/216/55463/14198700.cw/index.html

- Carry out at least 3 exercises and verify your answers as given on the website and help consoliate your understanding.

How do loss and delay occur?

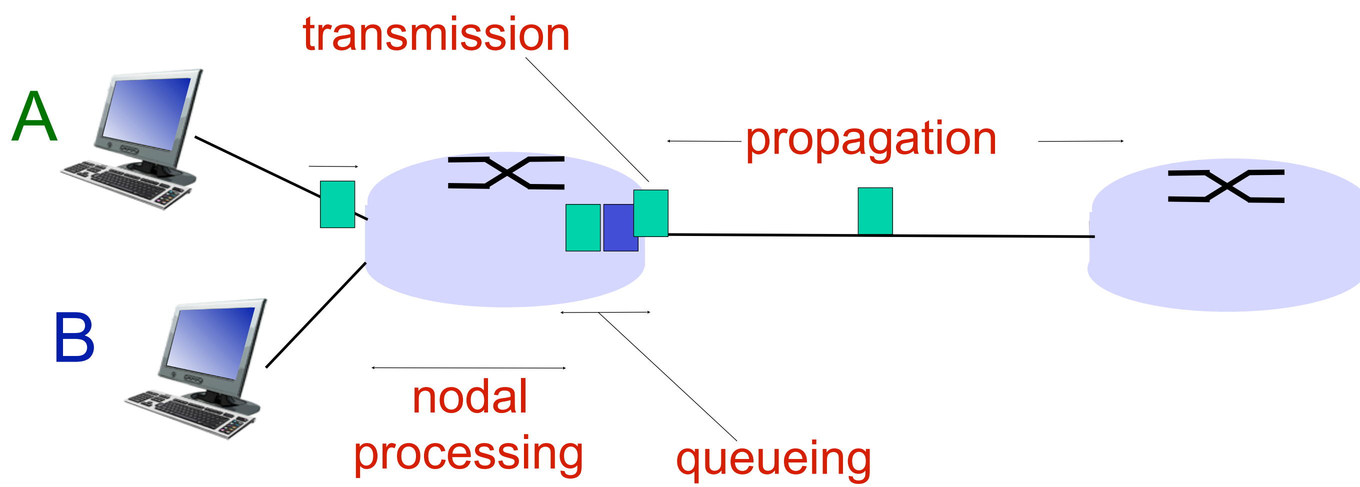
Packets *queue* in router buffers

- Packet arrival rate (temporarily) exceeds output link capacity
- Packets queue, wait for turn



src: Computer Network: A top down approach; Kurose, Ross

Four sources of packet delay



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

d_{proc}: nodal processing

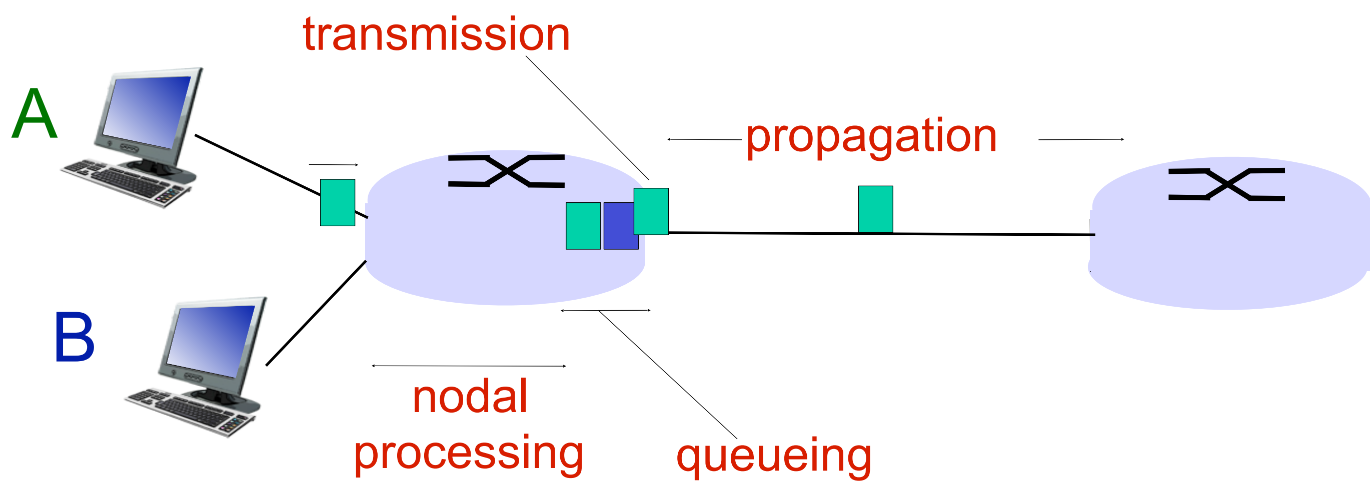
- check bit errors
- determine output link
- typically < microsec

d_{queue}: queueing delay

- time waiting at output link for transmission
- depends on congestion level of router
  - Determined by packets coming on other links.

src: Computer Network: A top down approach; Kurose, Ross

Four sources of packet delay



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

d_{trans}: transmission delay:

- L: packet length (bits)
- R: link *bandwidth (bps)*
- $d_{trans} = L/R$

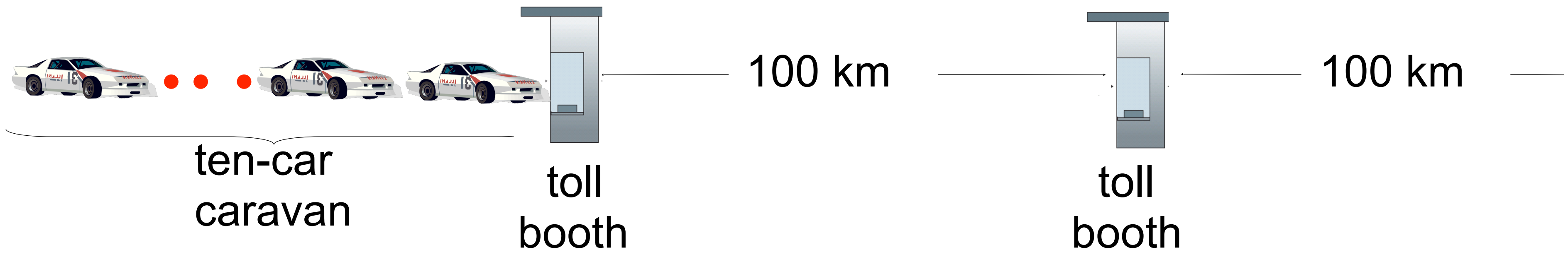
d_{prop}: propagation delay:

- d: length of physical link
- s: propagation speed in medium (~2×10^8 m/sec)
- $d_{prop} = d/s$

d_{trans} and d_{prop} *very* different

src: Computer Network: A top down approach; Kurose, Ross

Caravan analogy (more)



- suppose cars now "propagate" at 1000 km/hr
- and suppose toll booth now takes one min to service a car
- *Q:* Will cars arrive to 2nd booth before all cars serviced at first booth?
- Yes/No ?
- *A: Yes!* after 7 min, 1st car arrives at second booth; three cars still at 1st booth

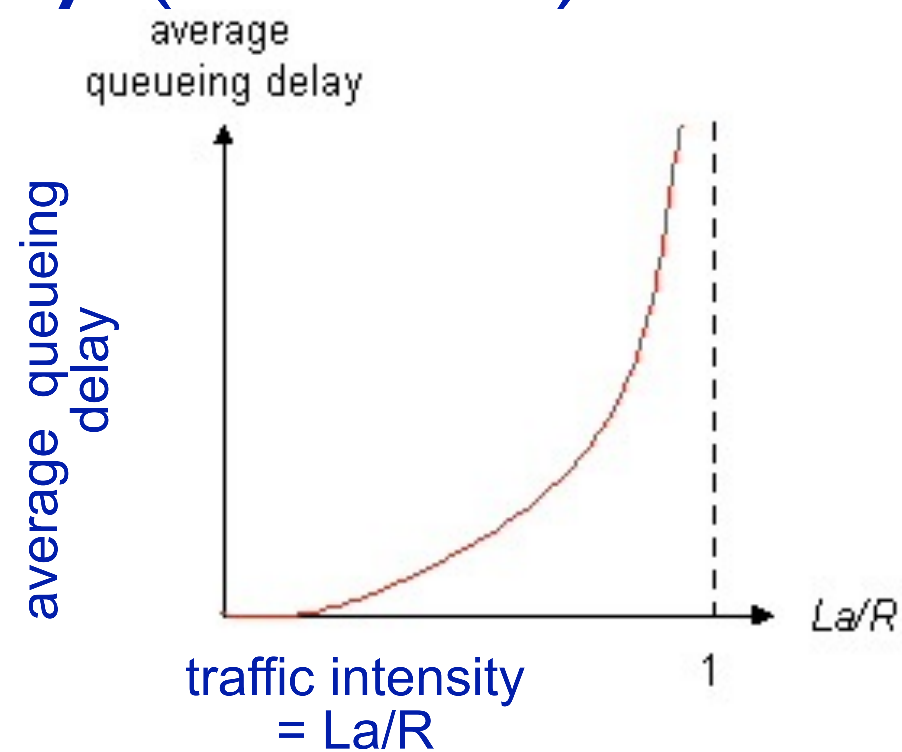
src: Computer Network: A top down approach; Kurose, Ross

Queueing delay (revisited)

- 4 components of delay
  - Processing delay
  - Queuing delay
  - Transmission delay
  - Propagation delay
- Which of these delays is unpredictable and depends on traffic pattern
  - Periodically: one packet per L/R seconds
  - In bursts but periodically
    - N packets arrive in burst in N(L/R) seconds
  - In general, packets arrival is random
    - Packets are spaced random amount of time

Queueing delay (revisited)

- R: link bandwidth (bps)
- L: packet length (bits)
- a: average packet arrival rate



- *La/R* ~ 0: avg. queueing delay small
- *La/R* -> 1: avg. queueing delay large
- *La/R* > 1: more "work" arriving
- than can be serviced, average delay infinite!

* Check out the Java applet for an interactive animation on queuing and loss

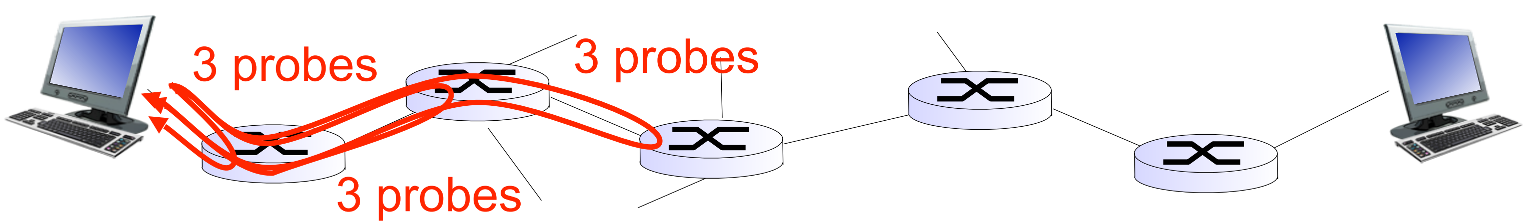
End to End Delay

- Total delay at all routers from src to dstn
  - Assume `N-1` routers (`N` links)
  - Assume queuing delay to be zero
    - In real life it may not be zero
  - The end to end delay is given by

$$\boxed{d_{\text{end-end}} = N * (d_{\text{proc}} + d_{\text{trans}} + d_{\text{prop}})}$$

“Real” Internet delays and routes

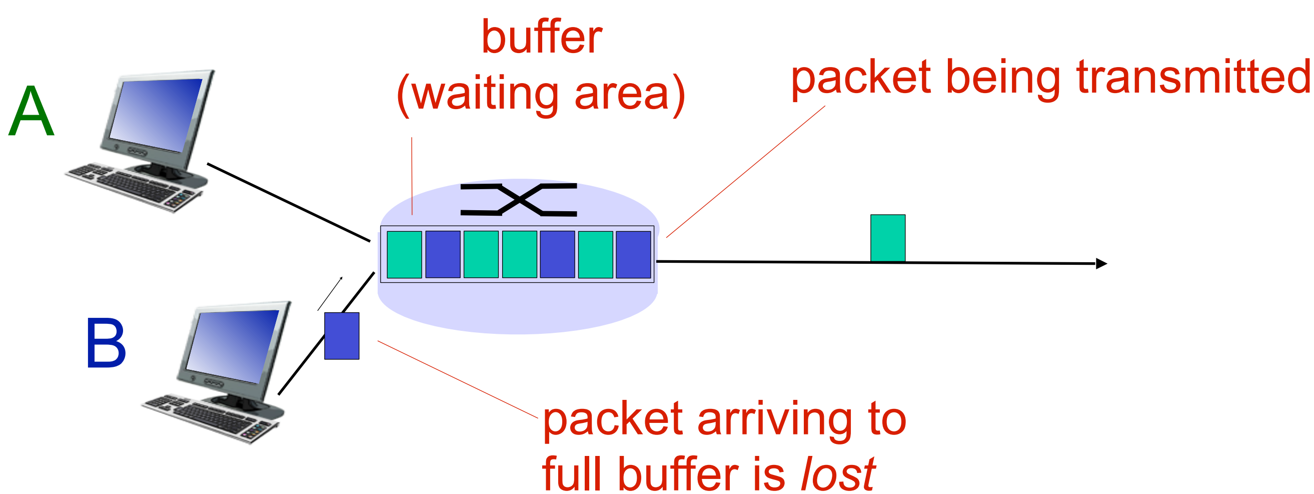
- what do “real” Internet delay & loss look like?
- `traceroute` program: provides delay measurement from source to router along end-end Internet path towards destination. For all *i:*
  - sends three packets that will reach router *i* on path towards destination
  - router *i* will return packets to sender
  - sender times interval between transmission and reply.



src: Computer Network: A top down approach; Kurose, Ross

Packet loss

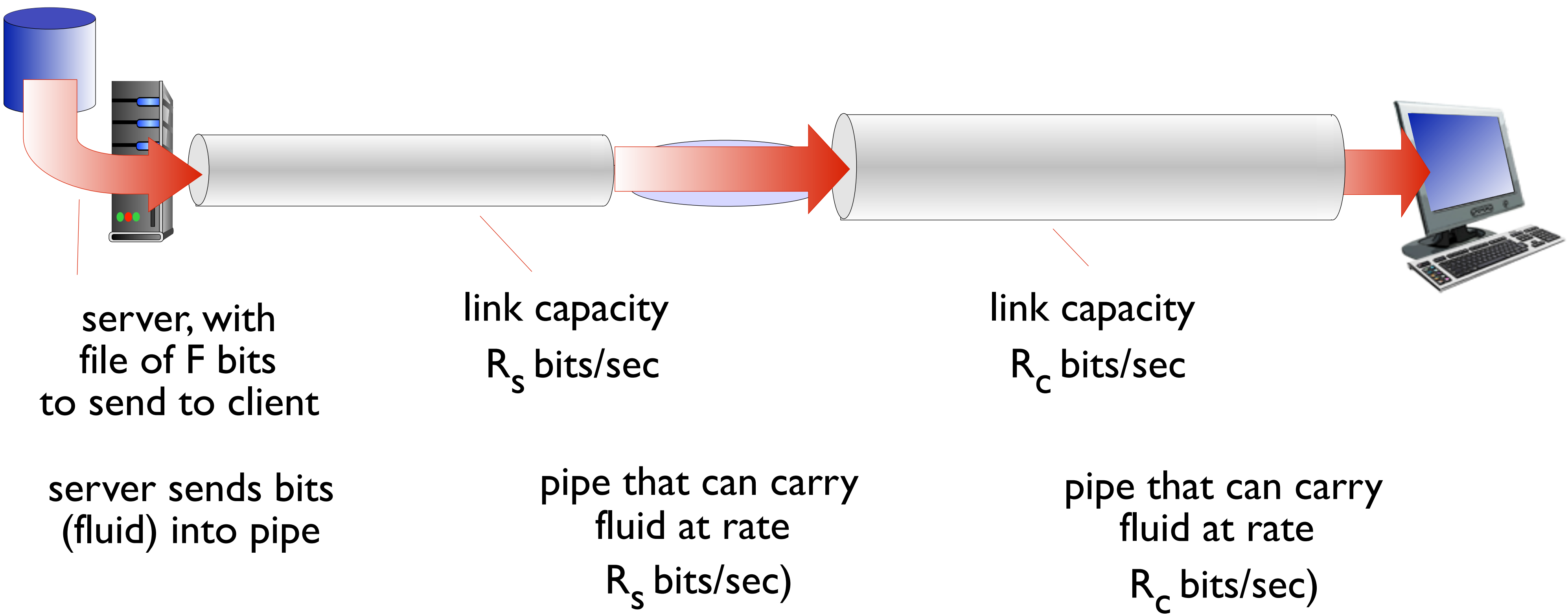
- queue (aka buffer) preceding link in buffer has finite capacity
- packet arriving to full queue dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not at all



src: Computer Network: A top down approach; Kurose, Ross

Throughput

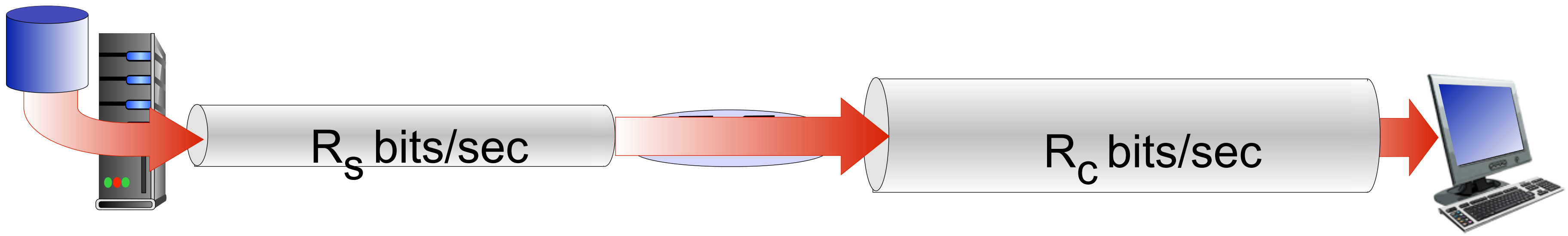
- *throughput:* rate (bits/time unit) at which bits transferred between sender/receiver
  - *instantaneous:* rate at given point in time
  - *average:* rate over longer period of time



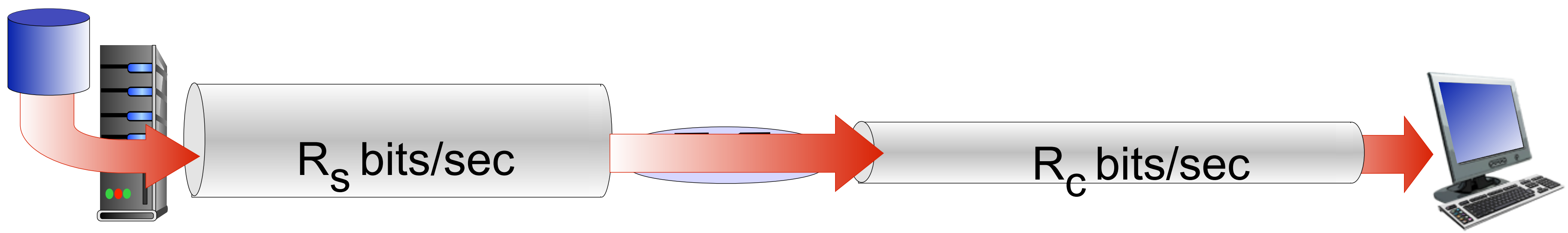
src: Computer Network: A top down approach; Kurose, Ross

Throughput (more)

- $R_s < R_c$ What is average end-end throughput?



- $R_s > R_c$ What is average end-end throughput?



bottleneck link

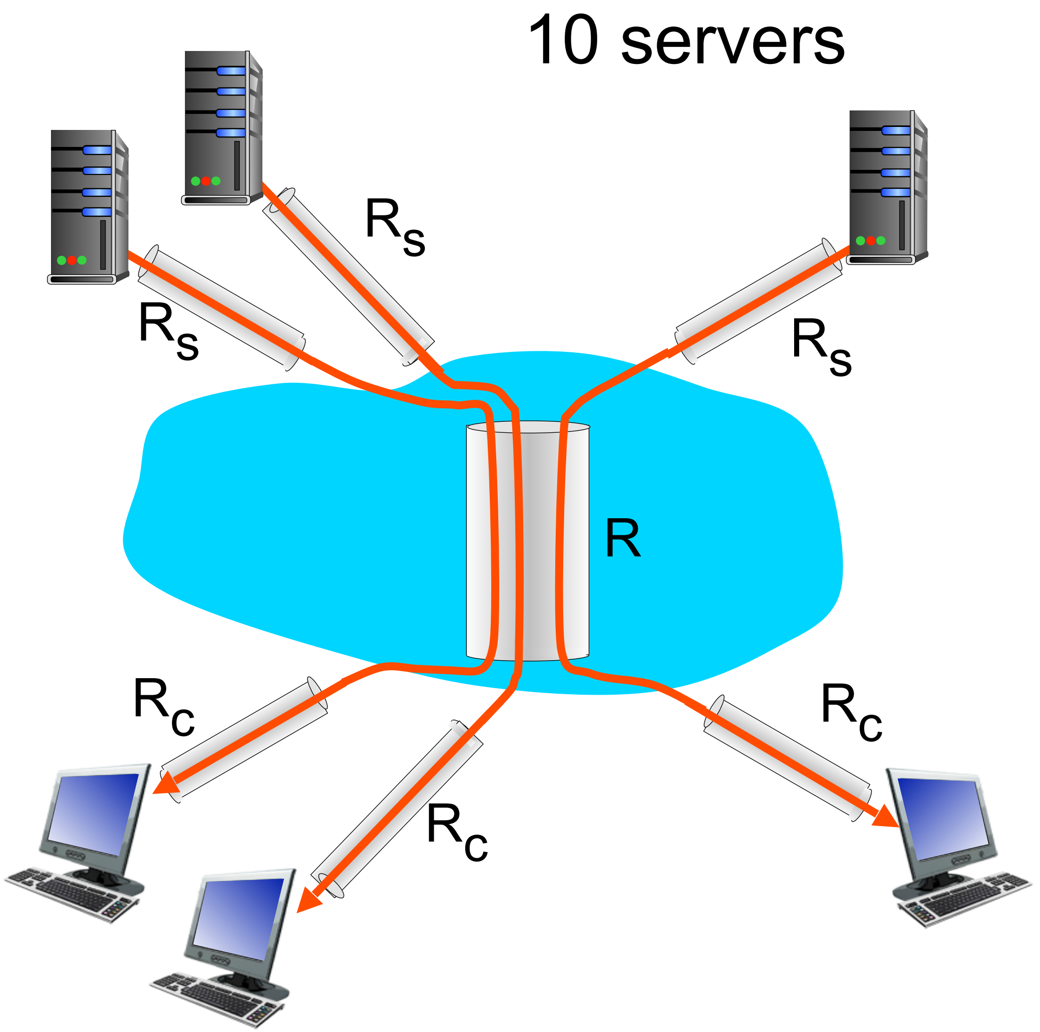
link on end-end path that constrains end-end throughput

src: Computer Network: A top down approach; Kurose, Ross

Throughput: Internet scenario

- per-connection end-end throughput: $\min(R_c, R_s, R/10)$
- in practice:
  - R_c or R_s is often bottleneck
- Example:
  - R_s=2Mbps
  - R_c=1Mbps
  - R = 5Mbps
  - Thruput for each server= ?

500Kbps



10 connections (fairly) share backbone bottleneck link R bits/sec

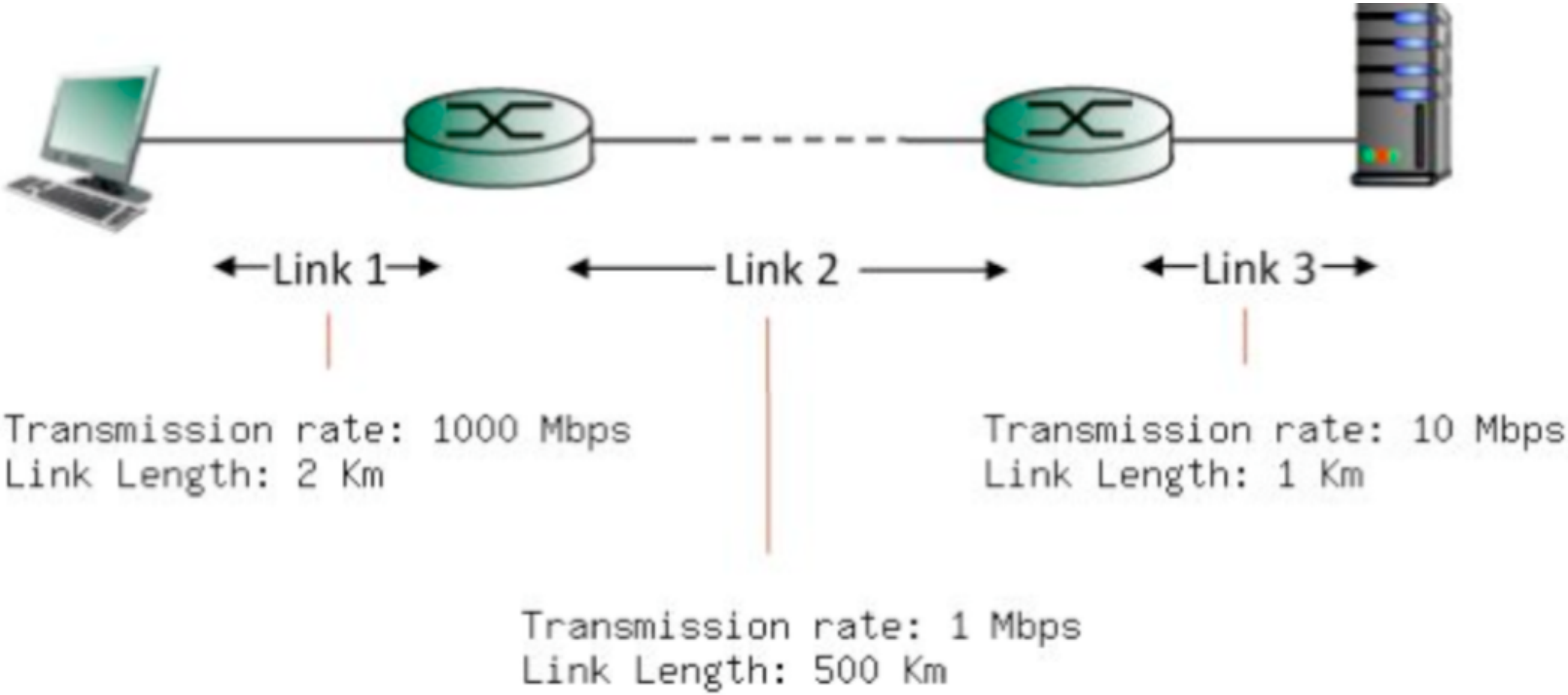
Bandwidth Delay product

- Transmission Rate: R
- Propagation delay: d_{prop}

- Bandwidth-delay product = $R*d_{prop}$
- Implies number of bits on the link
  - When transmission is not complete

Case Study 01

Consider the following figure. Find the end-to-end delay (including the **transmission** delays, **propagation** and **queuing** delays, but ignoring the processing delays) from when the left host begins transmitting the first bit of a packet to the time when the last bit of last packet is received at the server at the right. The host on left sends 3 packets each of 1500 Bytes.



Cast Study - Answer

Propagation delay on link 1: 2*1000*1000/(2x10**8)=0.01ms
Propagation delay on link 2: 500*1000*1000(2x10**8)=2.5ms
Propagation delay on link 3: 1*1000*1000/(2x10**8)=0.005ms

Total propagation delay = 0.01 + 2.5 + 0.005 = 2.515ms
Trans. delay for 1 pkt on link 1: 12000/(1000x10**6) = 0.012ms
Trans. delay for 1 pkt on link 2: 12000/(1x10**6) = 12ms
Trans. delay for 1 pkt on link 3: 12000/(10x10**6) = 1.2ms.
Switch 1 will start transmission of first packet after 0.022ms,

- 2^{nd} packet after 12.022ms, and
- 3^{rd} packet after 24.022ms

Similarly, compute trans. start time on 2^{nd} and 3^{rd} switch for each packet.

Adding the transmission delay to last packet on 3rd switch will provide end to end delay

Summary

- End to end delay
  - Propgation delay
  - Transmission delay
  - Queueing delay
  - Processing delay
- Queueing delay is unpredictable
  - Depending on traffic from other sources