Computer Networks

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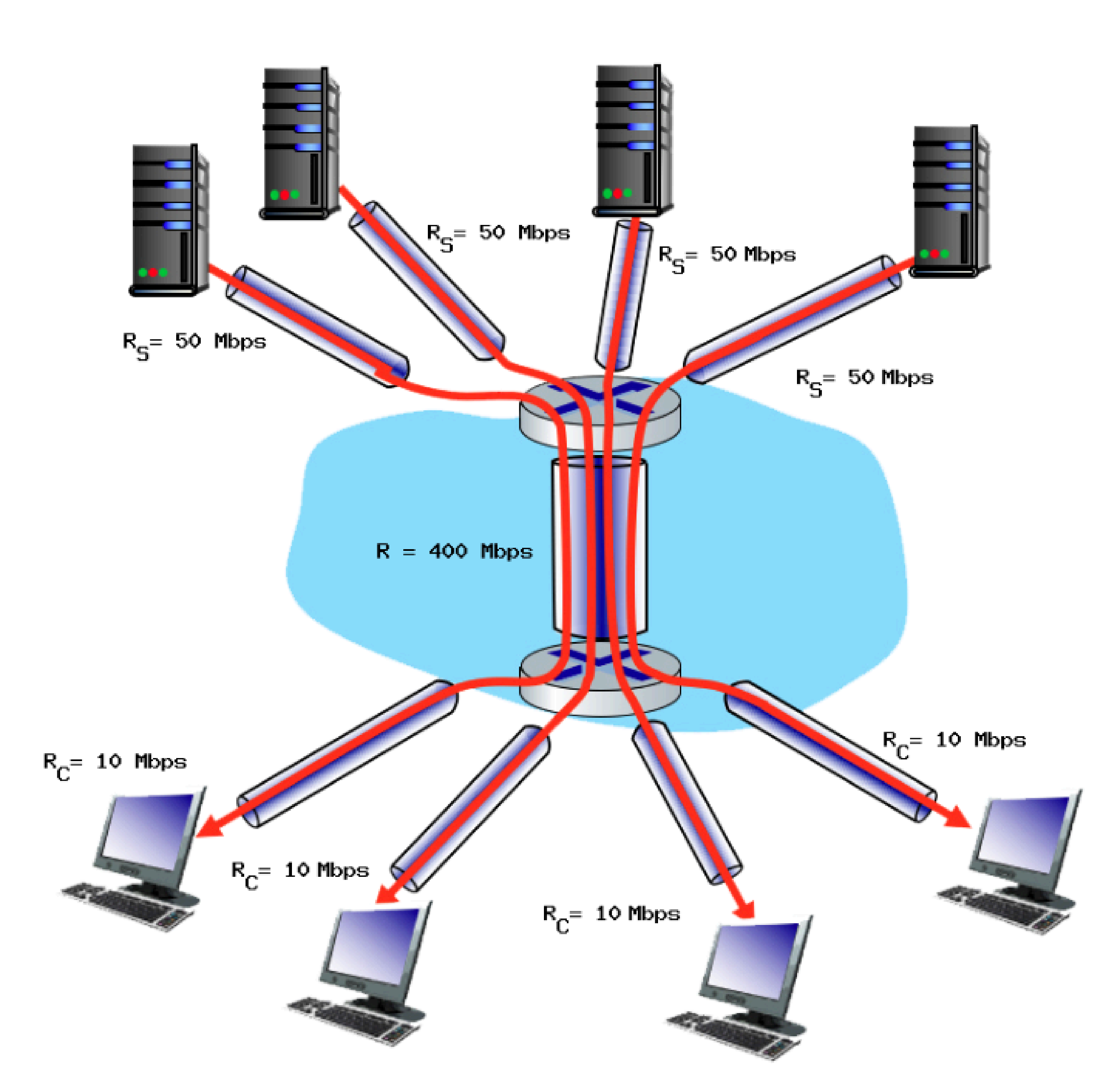
Lab-2

End to End Throughput and Bottleneck Links

Consider the scenario shown below, with four different servers connected to four different clients over four three-hop paths. The four pairs share a common middle hop with a transmission capacity of R = 400 Mbps. The four links from the servers to the shared link have a transmission capacity of R_S = 50 Mbps. Each of the four links from the shared middle link to a client has a transmission capacity of R_C = 10 Mbps.

1. What is the maximum achievable end-end throughput (in Mbps) for each of four client-to-server pairs, assuming that the middle link is fairly shared (divides its transmission rate equally)?
2. Which link is the bottleneck link? Format as Rc, Rs, or R.
3. Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the server links (R_S)? Answer as a decimal.
4. Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the client links (R_C)? Answer as a decimal.
5. Assuming that the servers are sending at the maximum rate possible, what is the link utilizations for the shared link (R)? Answer as a decimal.



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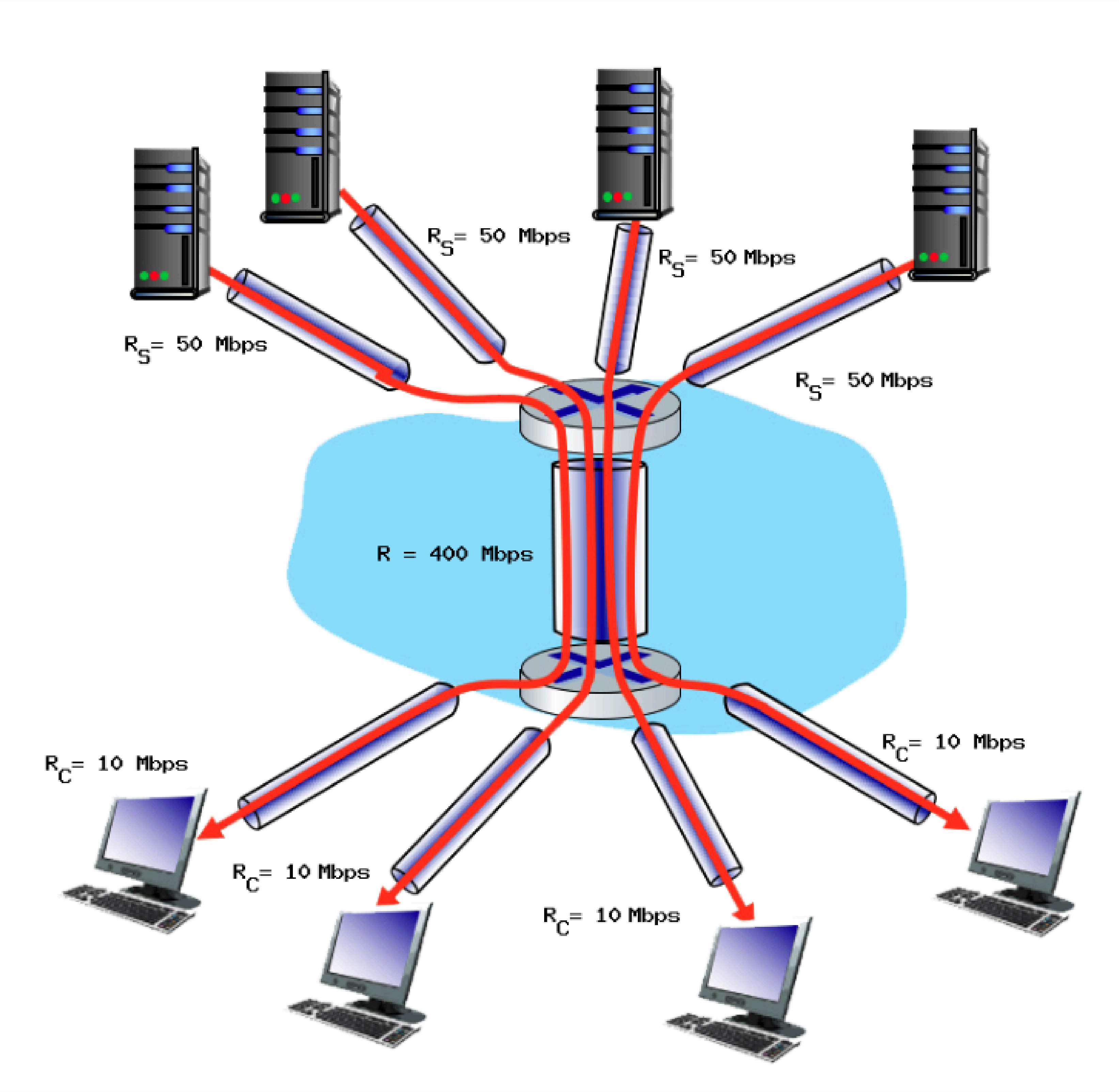
1. What is the maximum achievable end-end throughput (in Mbps) for each of four client-to-server pairs, assuming that the middle link is fairly shared (divides its transmission rate equally)?
    - The maximum achievable end-end throughput is the capacity of the link with the minimum capacity, which is 10 Mbps
2. Which link is the bottleneck link? Format as Rc, Rs, or R.
    - The bottleneck link is the link with the smallest capacity between R_S, R_C, and R/4. The bottleneck link is R_C.
3. Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the server links (R_S)? Answer as a decimal.
    - The server's utilization = $R_{bottleneck}$ / R_S = 10 / 50 = 0.2
4. Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the client links (R_C)? Answer as a decimal.
    - The client's utilization = $R_{bottleneck}$ / R_C = 10 / 10 = 1
5. Assuming that the servers are sending at the maximum rate possible, what is the link utilizations for the shared link (R)? Answer as a decimal.
    - The shared link's utilization = $R_{bottleneck}$ / (R / 4) = 10 / (400 / 4) = 0.1



Network Delays and Pipelining

Suppose that we are sending a 50 Mbit file from a source host to a destination host. All links in the path between source and destination have a transmission rate of 10 Gbps. Assume that the propagation speed is 2 * 10^8 meters/sec, there are two links between source and destination, with one router connecting the two links. Each link is 2,000 km long.

1. Suppose first that the file is sent as one packet. Suppose there is no congestion, so that the packet is transmitted onto the second link as soon as the router receives the entire packet. What is The end-to-end delay?
2. Now suppose that the MP3 file is broken into 5 packets, each of 10 Mbits. Ignore headers that may be added to these packets. Also ignore router processing delays. Assuming store and forward packet switching at the router, What is the total delay?

Diagram?

Network Delays and Pipelining

Suppose that we are sending a 50 Mbit file from a source host to a destination host. All links in the path between source and destination have a transmission rate of 10 Gbps. Assume that the propagation speed is $2 * 10^8$ meters/sec, there are two links between source and destination, with one router connecting the two links. Each link is 2,000 km long.

1. suppose first that the file is sent as one packet. Suppose there is no congestion, so that the packet is transmitted onto the second link as soon as the router receives the entire packet. What is The end-to-end delay?
   - D(trans1) = D(trans2) = 50/10000 = 0.005 sec = 5 msec.
   - D(prop1) = D(prop2) = 2000000/(2*10^8) = 0,01 sec = 10 msec.
   - D(total) = D(trans1)+D(trans2)+D(prop1)+D(prop2) = 5+5+10+10= 30 msec.
2. Now suppose that the MP3 file is broken into 5 packets, each of 10 Mbits. Ignore headers that may be added to these packets. Also ignore router processing delays. Assuming store and forward packet switching at the router, What is the total delay?
   - D(trans1For1packet) = 10/10000 = 0.001 sec = 1 msec.
   - D(trans1) = 5*1= 5 msec.
   - D(total) = D(prop1)+D(prop2)+ D(transFor5+1 packets) = 10+10+(5+1) = 26 msec.

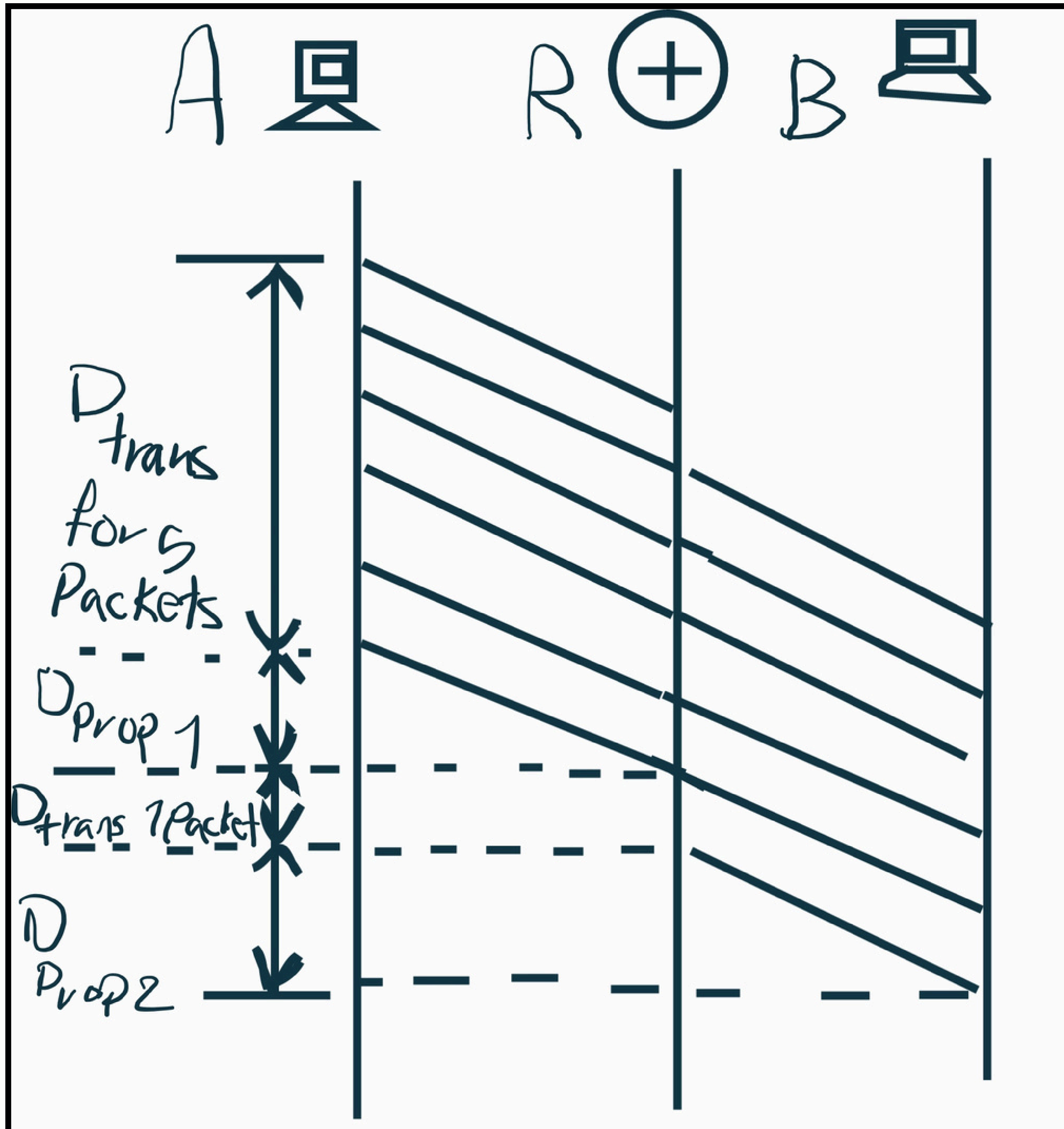


Diagram for 2nd part of the problem.

Data in Flight

A data communication link connects two computers using a fiber optic cable of length 1,200 km. The propagation speed of signals in the fiber is approximately 2×10^8 meters per second. The throughput of the link is 10 Gbps (gigabits per second).

Question:
How many bits of data are "in flight" (i.e., on the wire) at any given time?

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Given:

- Cable length = 1,200 km = 1,200,000 m.
- Propagation speed = 2 * 10^8 m/sec.
- Throughput = 10 Gbps = 10*10^9 bps.

- Step 1: Find the Propagation Delay Propagation delay is the time it takes for a signal to travel from one end of the cable to the other.
  - Propagation delay = Distance/ Propagation speed = 1,200,000/2*10^8 =0.006 sec= 6 msec.
- Step 2: Find the Data in Flight
  - Data in flight = Throughput × Propagation delay = 10*10^9*0.006 = 60 Mb = 60 000 000 bits.

Time Division Multiplexing (TDM)

Scenario: Consider a circuit-switched network that uses TDM to allocate bandwidth to users. In this setup:

- Each TDM frame is divided into 5 slots.
- Each slot allows transmission of 1 MB of data.
- The network operates at 10 frames per second.

Three users, A, B, and C, are connected to this network and each has been assigned 1 slots per frame.

Questions:

1. Calculate the data rate (in MBps) for each user, given their assigned slots and the frame rate of the network. Show all steps.
2. Calculate the total data rate of the network. Show your calculations.
3. If user A needs to send a 20 MB file, calculate how long it will take to send the entire file using their assigned slots. Show all steps.

Solution:

Given:

- 5 slots per frame
- Each slot = 1 MB
- Frame rate = 10 frames/sec
- Users A, B, C each have 1 slots per frame

Step 1: Data rate per user = $1 \times 2 \times 1 = 2$ MBps

Step 2: Total network rate = $5 \times 1 \times 2 = 10$ MBps

Step 3: Time for A to send 20 MB = $20 / 2 = 10$ second

Time Division Multiplexing (optional extra question)

A telephone exchange uses TDM-based circuit switching on a 2.0 Mbps physical link. Each voice circuit requires a constant 64 kbps channel. The system uses fixed frames: each frame lasts 10 ms. One slot is assigned per user per frame (i.e., a user sends once each frame in its assigned slot).

Answer the questions below and show your calculations.

1. How many bits does one user send per frame? (i.e., bits per slot)
2. What is the duration of one slot (in milliseconds)?
3. What is the maximum number of users that can be supported simultaneously on this link?
4. What total raw bandwidth (in bps) is left unused because of slot/granularity rounding? (i.e., wasted capacity)
5. If only 5 users are actually active but their slots remain reserved, what is the link utilization (as a percentage) and how many bps are wasted?
6. How many bytes fit in one slot?
7. What is the worst-case and the average waiting time (latency) a user experiences before its next slot begins?

- Given:
  - C = 2,000,000 bps
  - R = 64,000 bps
  - T_frame = 10 ms = 0.01 s

1. Bits per slot: R × T_frame = 64,000 × 0.01 = 640 bits
2. Slot duration: T_slot = 640 / 2,000,000 = 0.00032 s = 0.32 ms
3. Maximum users: N_max = floor(C / R) = floor(2,000,000 / 64,000) = 31 users
4. Wasted capacity due to granularity:
   - Used = 31 × 64,000 = 1,984,000 bps
   - Wasted = 2,000,000 - 1,984,000 = 16,000 bps (≈ 0.8%)
5. If only 5 users active:
   - Used = 5 × 64,000 = 320,000 bps
   - Utilization = 320,000 / 2,000,000 = 16%
   - Wasted = 2,000,000 - 320,000 = 1,680,000 bps
6. Bytes per slot: 640 bits = 80 bytes
7. Waiting times:
   - Frame interval = 10 ms
   - Worst-case waiting = 10 ms
   - Average waiting = 5 ms

Time Division Multiplexing (TDM) Summary

- TDM circuit switching guarantees constant bandwidth per user but can waste capacity when users are inactive.

- Key points:
    - Predictable latency and reserved slots are ideal for voice.
    - Bandwidth efficiency limited by number of slots.
    - Compare with packet switching for better utilization but variable delay.

Wireshark

- Install wireshark on your computer.
- on the companion website of the teaching book you will find many wireshark labs. Read the first one (Getting Started) in the remaining time and ask questions if you have any: https://gaia.cs.umass.edu/kurose_ross/wireshark.php