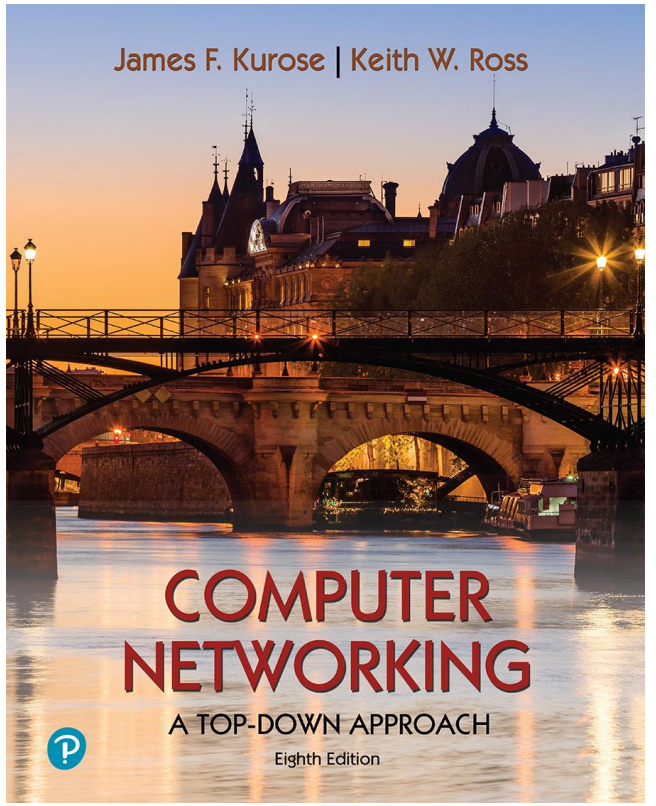
Chapter 1
Introduction



Computer Networking: A Top-Down Approach
8th edition
Jim Kurose, Keith Ross
Pearson, 2020

- What is the Internet?
- What is a protocol?

Question 1

Which of the following descriptions below correspond to a *"nuts-and-bolts"* view of the Internet? Select one or more of the answers below that are correct.

A collection of hardware and software components executing protocols that define the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or other event.

A "network of networks".

A place I go for information, entertainment, and to communicate with people.

A collection of billions of computing devices, and packet switches interconnected by links.

A platform for building network applications.

Question 2

Which of the following descriptions below correspond to a *"services"* view of the Internet? Select one or more of the answers below below that are correct below that are correct.

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A platform for building network applications.

A collection of hardware and software components executing protocols that define the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or other event.

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Question 3

Which of the following human scenarios involve a protocol (recall: "Protocols define the format, order of messages sent and received among network entities, and actions taken on message transmission, receipt")?

One person asking, and getting, the time to/from another person.

A person reading a book.

A person sleeping.

Two people introducing themselves to each other.

A student raising her/his hand to ask a really insightful question, followed by the teaching acknowledging the student, listening carefully to the question, and responding with a clear, insightful answer. And then thanking the student for the question, since teachers *love* to get questions.

- Network edge: hosts, access network, physical media

Access Networks, type and speeds

Access Network	Type	Approximate Speeds experienced by subscribers
Ethernet	Wired	Up to 100's Gbps per link.
802.11 WiFi	Wireless	10’s to 100’s of Mbps per device.
Cable Access Network	Wired	Up to 10’s to 100’s of Mbps downstream per user.
Digital Subscriber Line	Wired	Up to 10’s of Mbps downstream per user.
4 G Cellular LTE	Wireless	Up to 10’s Mbps per device

Question

Which of the following physical layer technologies has the highest transmission rate *and* lowest bit error rate in practice?

Fiber optic cable

Satellite channe

Coaxial cable

4G/5G cellular

802.11 WiFi Channel

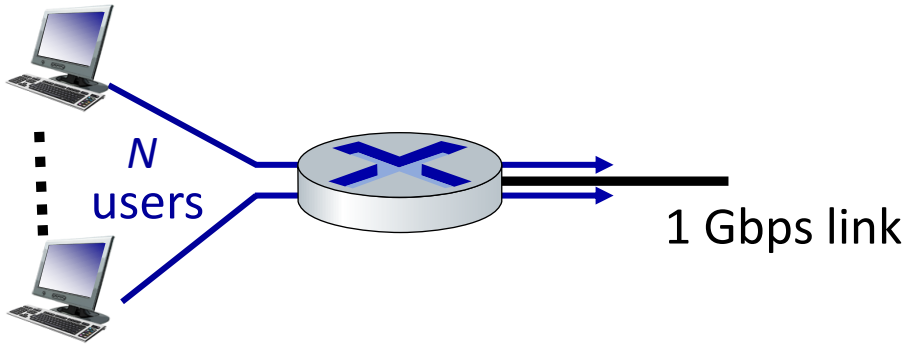
Twisted pair (e.g., CAT5, CAT6)

- Network core: packet/circuit switching, internet structure

Packet switching versus circuit switching

example:

- 1 Gb/s link
- each user:
  - 100 Mb/s when "active"
  - active 10% of time



Q: how many users can use this network under circuit-switching and packet switching?

- *circuit-switching:* 10 users
- *packet switching:* with 35 users, probability > 10 active at same time is less than .0004 *

Q: how did we get value 0.0004?

A: HW problem (for those with course in probability only)

Probability Calculation

Number of users (n) = 35

- Probability of a user being active (p) = 0.1 (10%)
- probability of having more than 10 users active at any given time = ?
- P(X > 10) = P(X = 11) + P(X = 12) + ... + P(X = 35)

- P(X = k) = (n choose k) * p^k * (1 - p)^(n - k) ["n choose k" is the binomial coefficient]

-

- P(X > 10) = (35 choose 11) * 0.1^11 * (0.9)^(35- 11) + (35 choose 12) * 0.1^12 * (0.9)^(35- 12) + ... (35 choose 11) * 0.1^35 * (0.9)^(35- 35)

```
from scipy.stats import binom

n = 35
p = 0.1

probability = 1 - binom.cdf(10, n, p)
print(probability)
```

Question: Routing vs Forwarding

Choose one of the following two definitions that makes the correct distinction between routing versus forwarding.

Forwarding is the local action of moving arriving packets from router's input link to appropriate router output link, while **routing** is the global action of determining the source-destination paths taken by packets.

Routing is the local action of moving arriving packets from router's input link to appropriate router output link, while **forwarding** is the global action of determining the source-destination paths taken by packets.

Question: Packet Switching

Which of the characteristics below are associated with the technique of *packet switching*? Select all correct answers.

Reserves resources needed for a call from source to destination.

Data may be queued before being transmitted due to other user's data that's also queueing for transmission.

Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM) are two approaches for implementing this technique.

This technique is used in the Internet.

Resources are used on demand, not reserved in advance.

The technique was the basis for the telephone call switching during the 20th century and into the beginning of this current century.

Congestion loss and variable end-end delays are possible with this technique.

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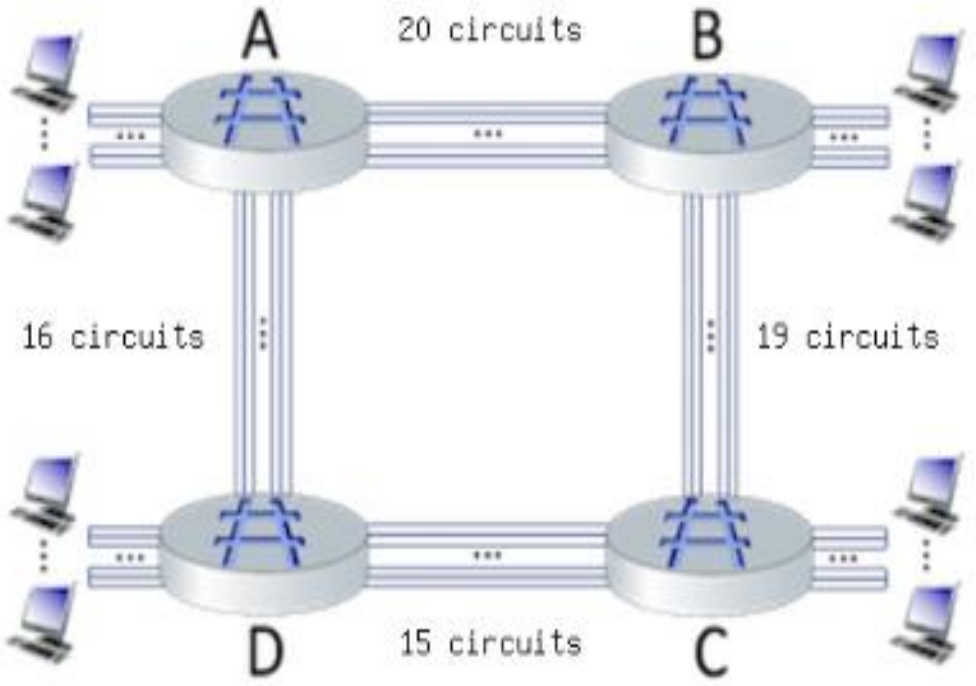
Question: How many calls can be carried?

Consider the circuit-switched network shown in the figure below, with four circuit switches A, B, C, and D. Suppose there are 20 circuits between A and B, 19 circuits between B and C, 15 circuits between C and D, and 16 circuits between D and A. What is the maximum number of connections that can be ongoing in the network at any one time?

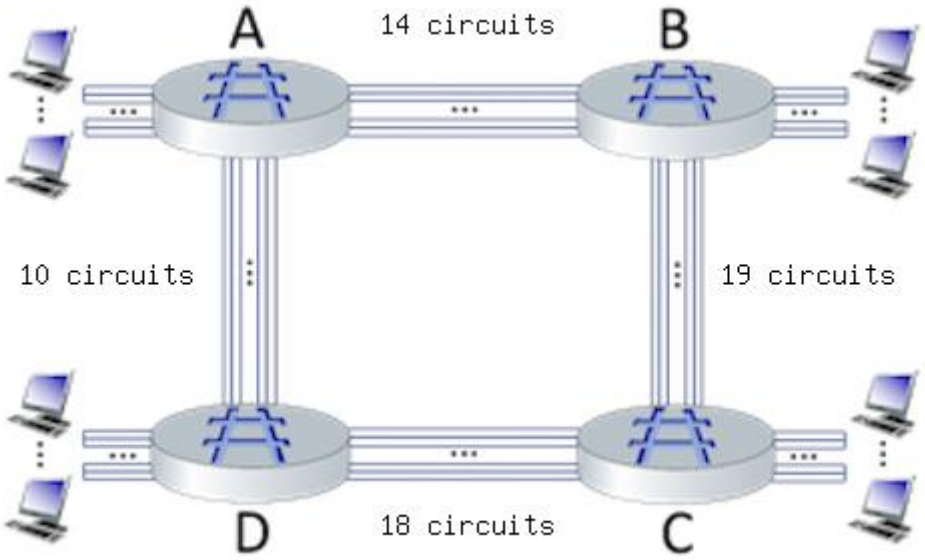
70 39 16 31 20



Question: How many calls can be carried?

Consider the circuit-switched network shown in the figure below, with four circuit switches A, B, C, and D. Suppose there are 14 circuits between A and B, 19 circuits between B and C, 18 circuits between C and D, and 10 circuits between D and A. What is the maximum number of connections that can be ongoing in the network at any one time?

Total: 61 connections



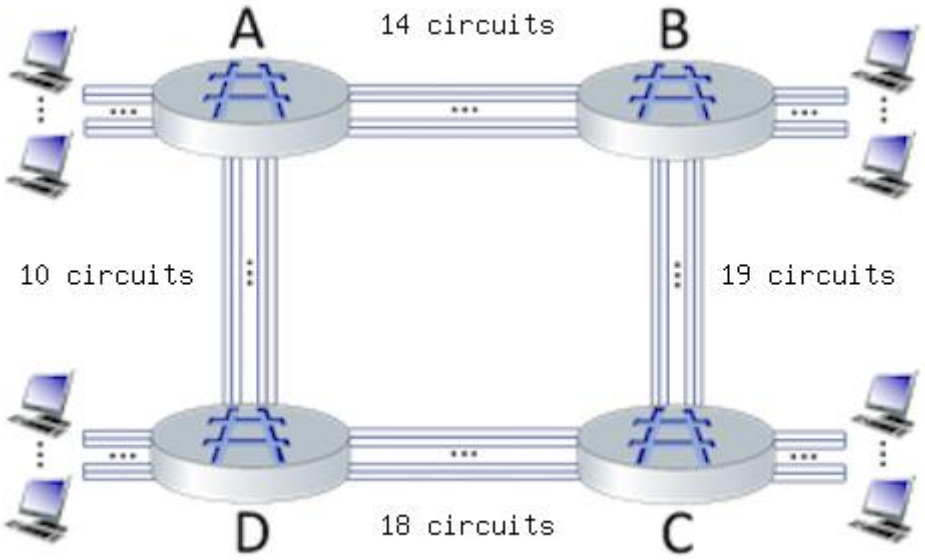
Question: How many calls can be carried?

Q: Suppose that these maximum number of connections are all ongoing. What happens when another call Connection request arrives to the network, will it be accepted? Answer Yes or No

A: Suppose that every connection requires 2 consecutive hops, and calls are connected clockwise. For example, a connection can go from A to C, from B to D, from C to A, and from D to B. With these constraints, what is the maximum number of connections that can be ongoing in the

network at any one time?

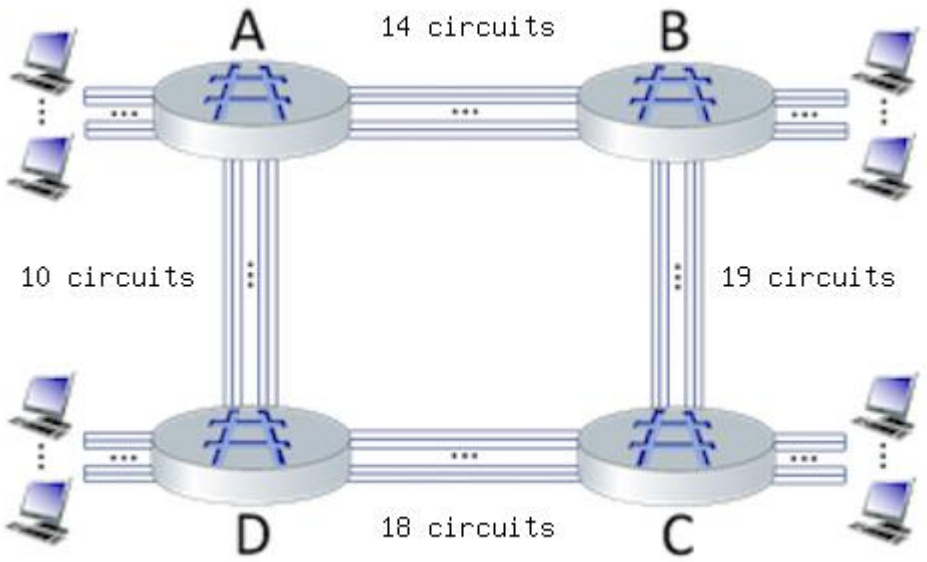
Answer: **29 connections**



Question: How many calls can be carried?

Q: Suppose that 19 connections are needed from A to C, and 13 connections are needed from B to D. Can we route these calls through the four links to accommodate all 32 connections? Answer Yes or No.

No



Question: Circuit Switching

- Perform a traceroute from your computer (on whatever network you happen to be on) to gaia.cs.umass.edu. Use traceroute (on Mac terminal) or `tracert` (on Windows command line) or `tracepath` (on a Linux command line). Enter the missing part of the name of the router just before the host gaia.cs.umass.edu is reached:

- ??.cs.umass.edu

Question: Network of Networks

- When we say that the Internet is a “network of networks,” we mean? Multiple options may be correct.

- The Internet is the *largest* network ever built.
- **The Internet is made up of a lot of different networks that are interconnected to each other.**
- The Internet is the *fastest* network ever built.
- **The Internet is made up of access networks at the edge, tier-1 networks at the core, and interconnected regional and content provider networks as well.**

- **Performance: loss, delay, throughput**

Question: Packet or Circuit Switching?

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Question: Packet delay components

The description below belongs to which component of packet delay?

- Time needed to perform an integrity check, lookup packet information in a local table and move the packet from an input link to an output link in a router.

Processing delay

- Time spent waiting in packet buffers for link transmission.

Queueing delay

- Time spent transmitting packets bits into the link

Transmission delay

- Time need for bits to physically propagate through the transmission medium from end one of a link to the other.

Propagation delay

Question: Packet Transmission delay

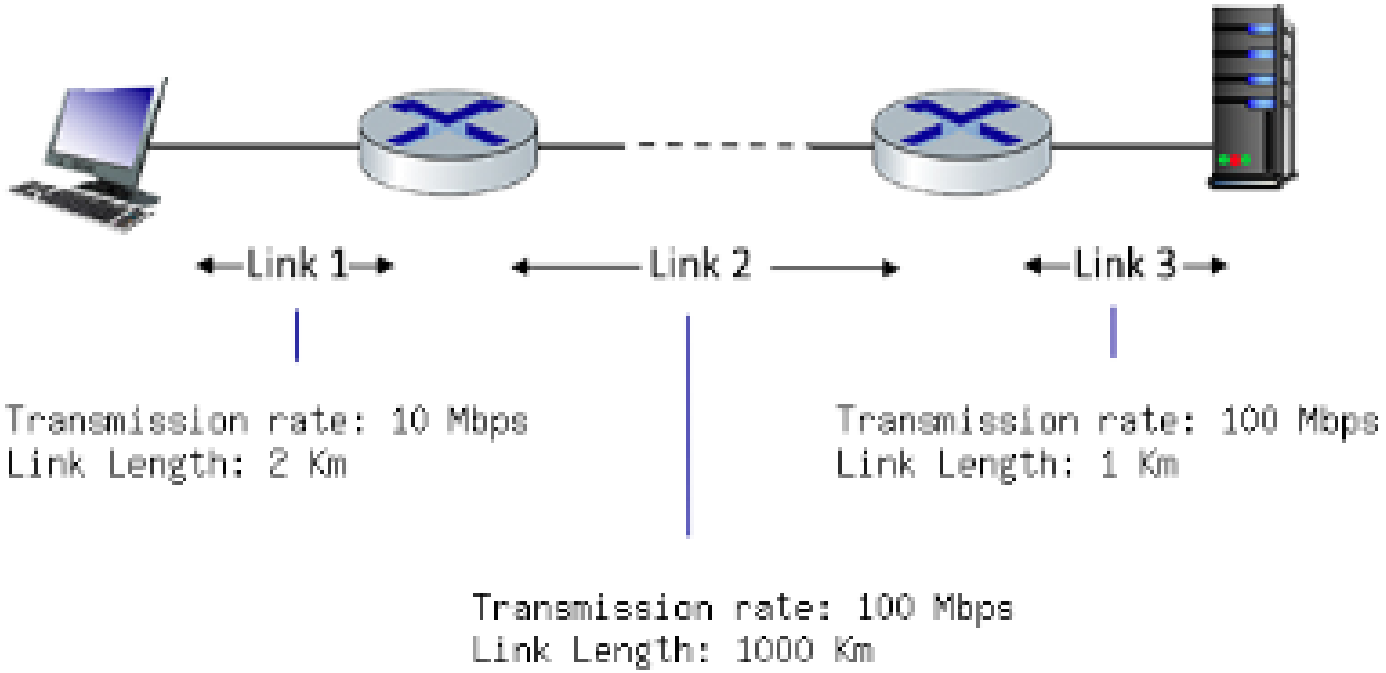
- Suppose a packet is L = 1500 bytes long (one byte = 8 bits), and link transmits at R = 1 Gbps (i.e., a link can transmit 1,000,000,000 bits per second). What is the transmission delay for this packet?

- Suppose that the packet length is L= 8000 bits, and that the link transmission rate along the link to router on the right is R = 100 Mbps.
  - What is the transmission delay? (Round your answer to two decimals after leading zeros)
  - What is the maximum number of packets per second that can be transmitted by this link?

- Suppose that the packet length is L= 16000 bits, and that the link transmission rate along the link to router on the right is R = 100 Mbps.
  - What is the transmission delay? (Round your answer to two decimals after leading zeros)
  - What is the maximum number of packets per second that can be transmitted by this link?

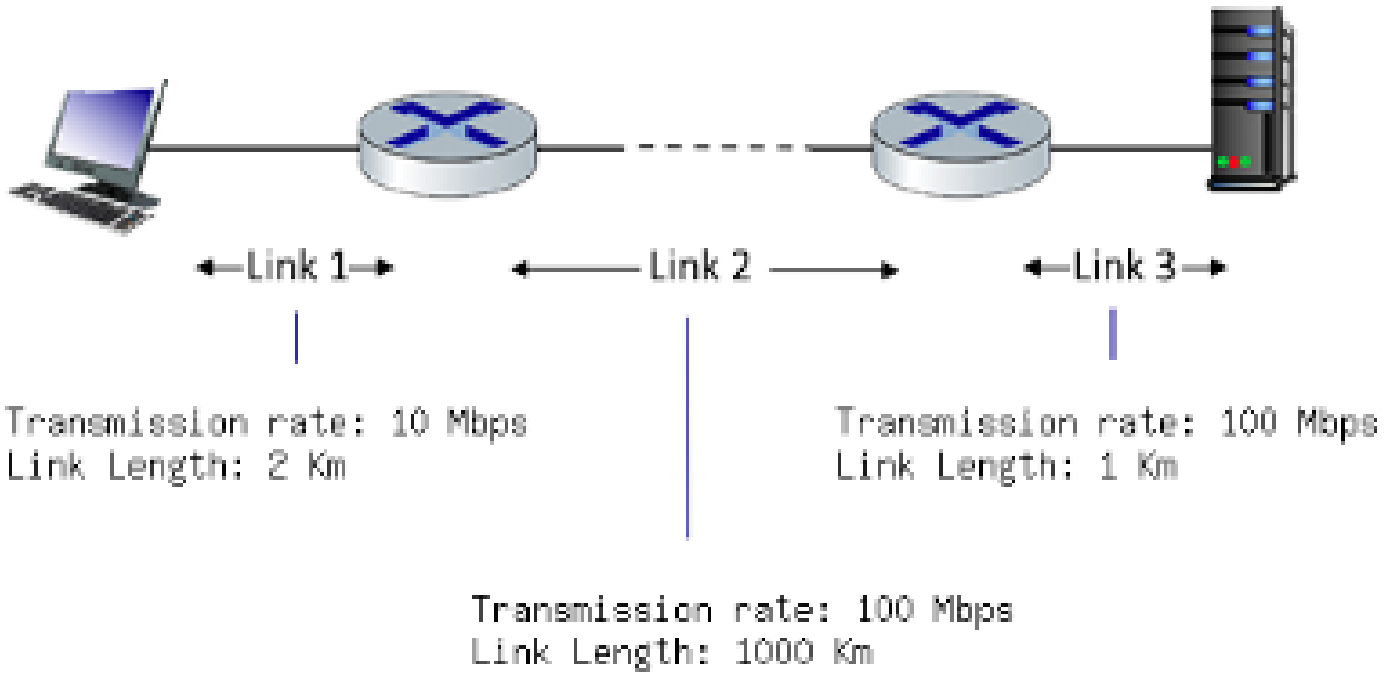
Question: Packet Transmission delay

- Consider the network shown in the figure, with three links, each with the specified transmission rate and link length. Assume the length of a packet is 8000 bits. What is the transmission delay at link 2?



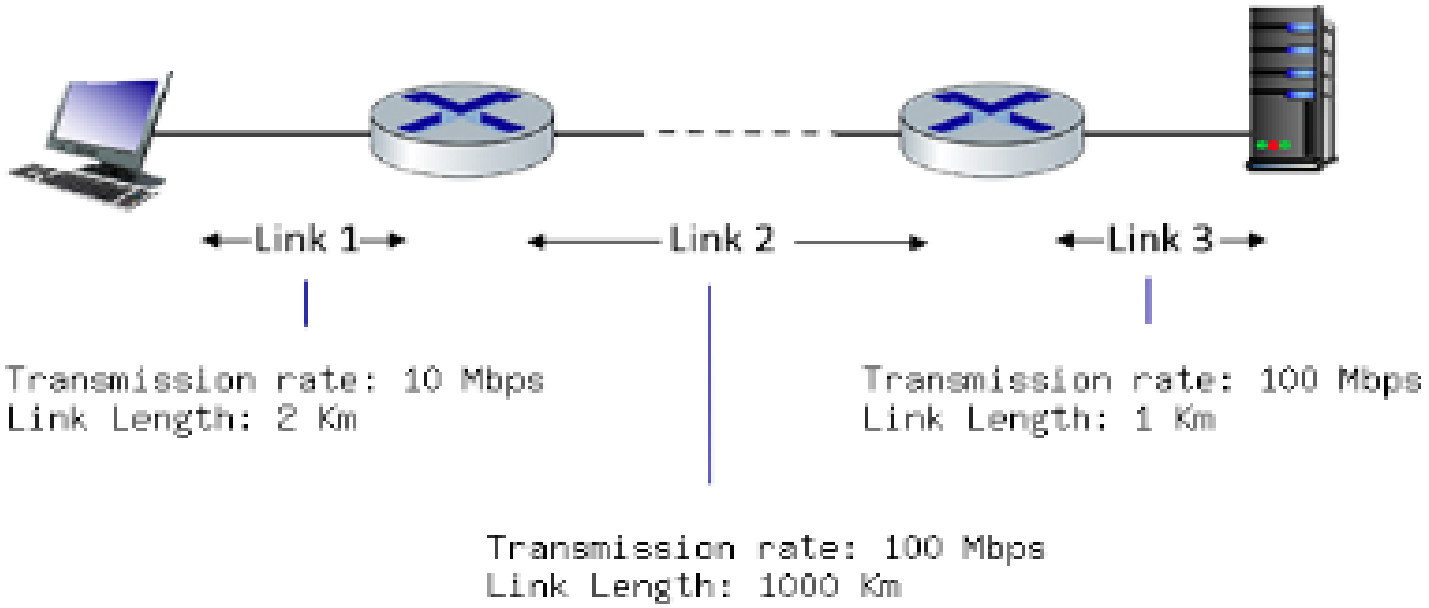
Question: Propagation delay

- Consider the network shown in the figure below, with three links, each with the specified transmission rate and link length. Assume the length of a packet is 8000 bits. The speed of light propagation delay on each link is 3x10^8 m/sec. What is the propagation delay at (along) link 2?



Question: Throughput

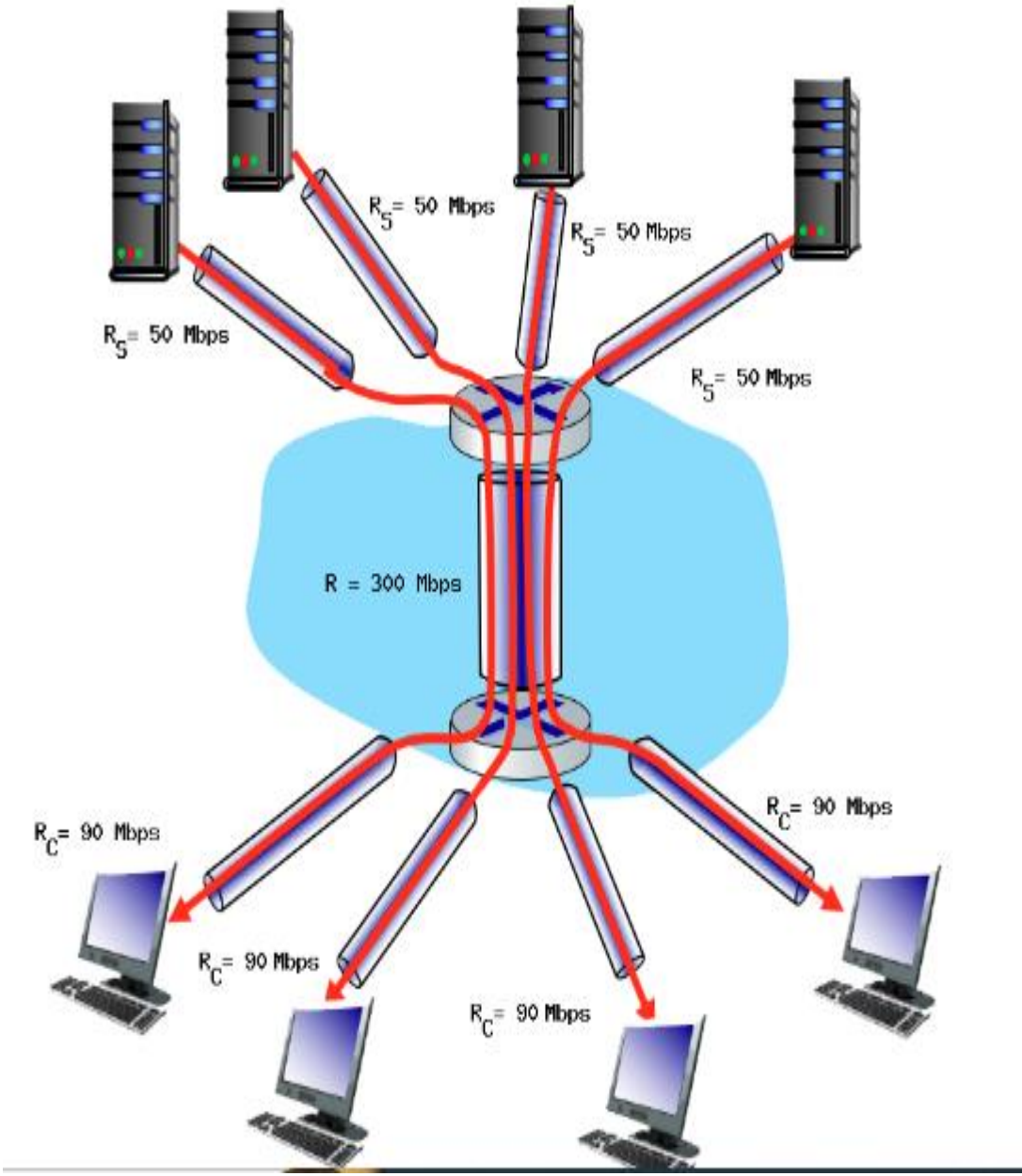
- What is the maximum throughput achievable between sender and receiver in the scenario shown below?



Question: Throughput

- Consider the scenario shown, 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 = 300 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 = 90 Mbps.

- What is the maximum achievable end-end throughput (an integer value, in Mbps) for each of four client-to-server pairs, assuming that the middle link is fairly shared (divides its transmission rate equally) and all servers are trying to send at their maximum rate?



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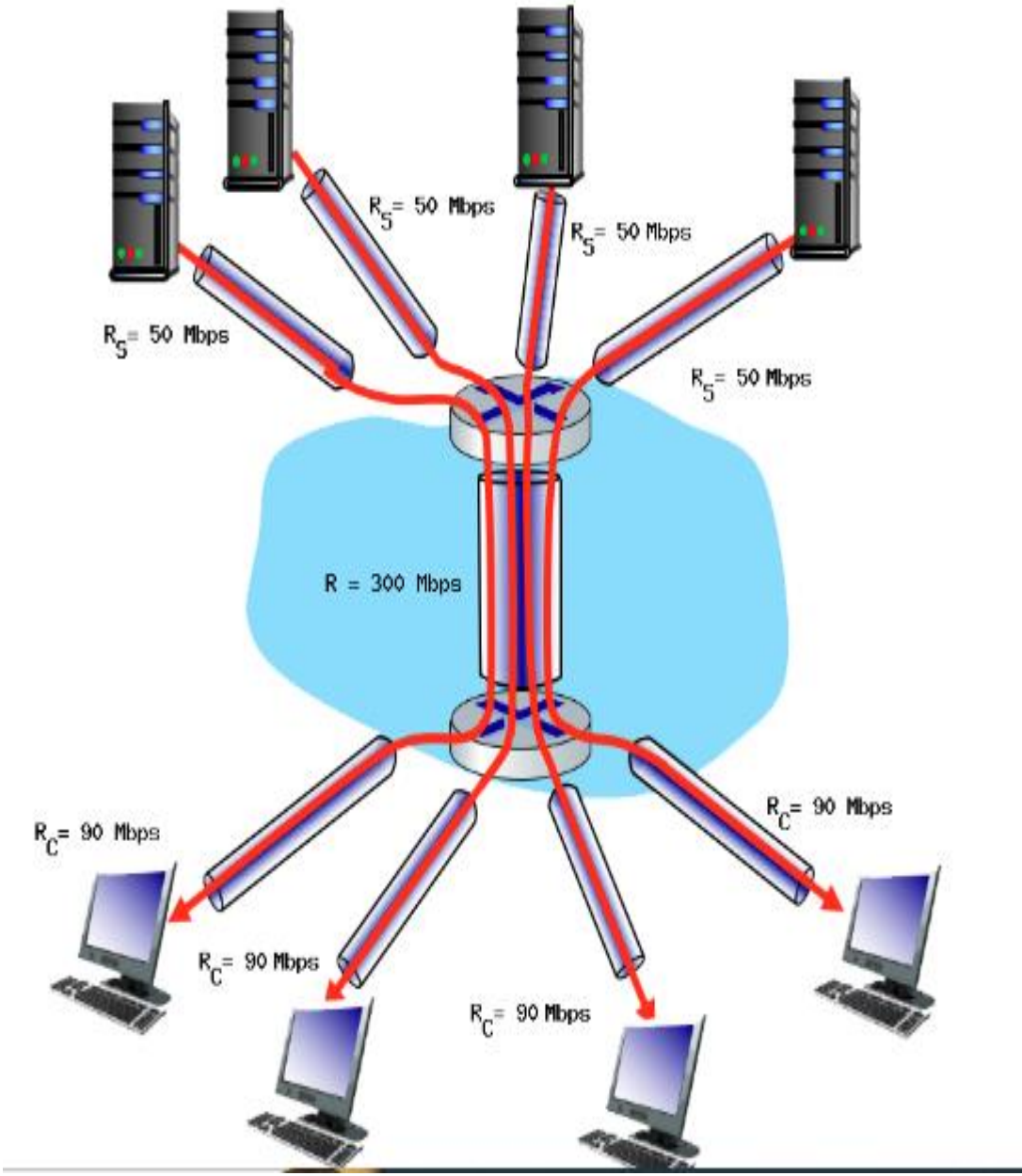
- Assuming that the servers are all sending at their maximum rate possible, what are the link utilizations for the server links (with transmission capacity R_S)? Enter your answer in a decimal form of 1.00 (if the utilization is 1) or 0.xx (if the utilization is less than 1)



- Protocol layers, service models