COMP90007 Internet Technology

Week3

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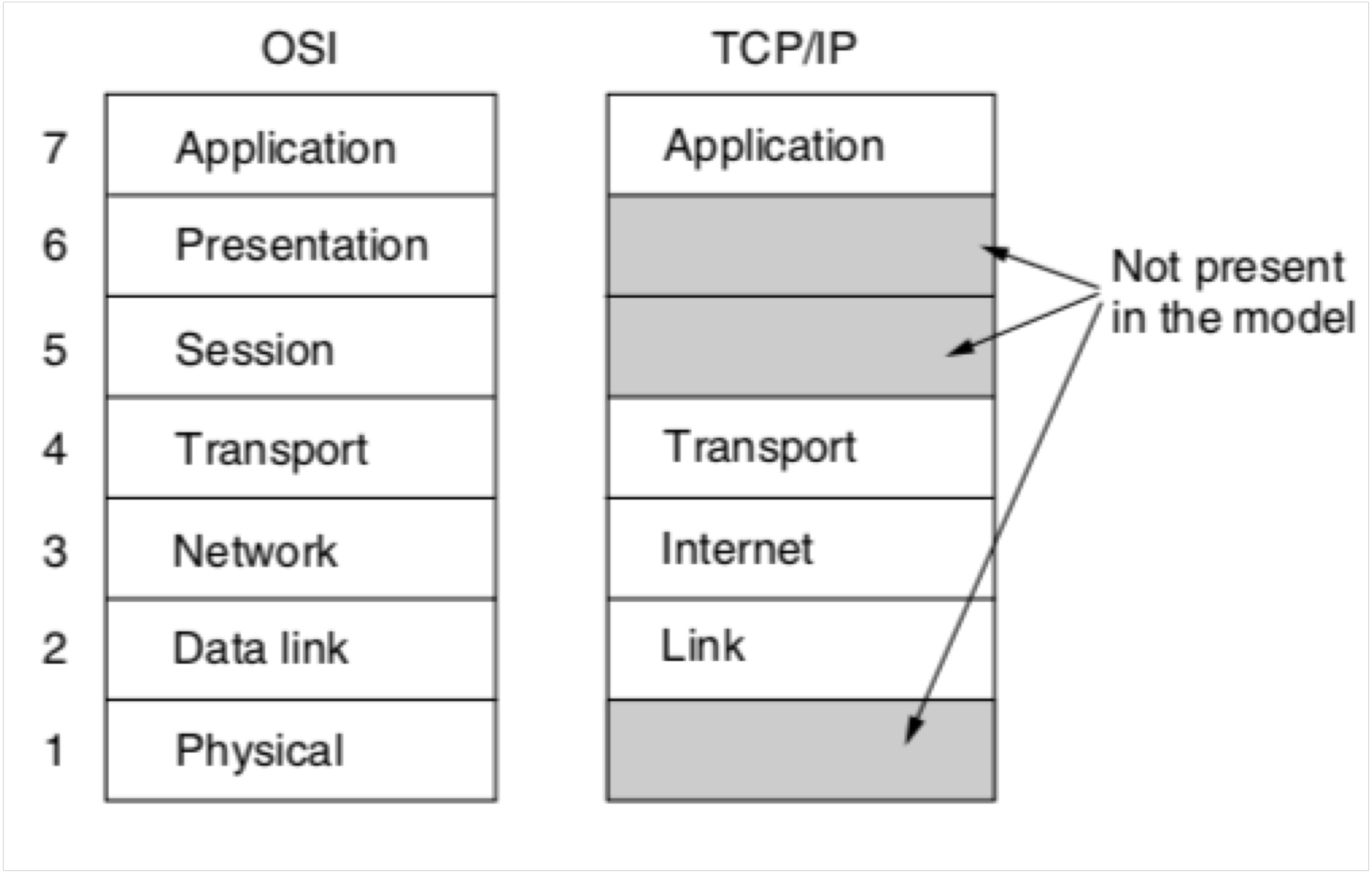
Question 1 (Layers)

- Identify **2 ways** in which the OSI reference model and the TCP/IP reference model are the same.
- Identify **2 ways** in which these models **differ**. (NB: You can use the textbook to solve this question)


OSI
TCP/IP
7
Application
6
Presentation
5
Session
4
Transport
3
Network
2
Data link
1
Physical
Application
Transport
Internet
Link
Not present
in the model

Solution 1 (Layers)

- Similarities:
  - stacking of layered protocols
  - similar functionality in each of the layers
  - layers above transport layer relate to applications

Solution 1 (Layers)

- Differences:
  - TCP/IP does not distinguish between **services**, **interfaces** and **protocols**
  - TCP/IP does not clearly separate physical and data link functions
  - OSI supports connectionless and connection-oriented communication at the network layer, while TCP/IP supports only connectionless communication at the IP layer *
  - OSI supports only connection-oriented communication at the transport layer, while TCP/IP supports both connection-oriented and connectionless communication at the transport layer *

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Solution 1 (Layers)

Services: Each layer performs some services for the layer above it. The service definition tells what the layer does, not how entities above it access it or how the layer works. It defines the layer's semantics.

Interfaces: A layer's interface tells the processes above it how to access it. It specifies what the parameters are and what results to expect.

Protocols: the peer protocols used in a layer are the layer's own business. It can use any protocols it wants to, as long as it gets the job done (i.e., provides the offered services). It can also change them at will without affecting software in higher layers. About how the layer works inside.

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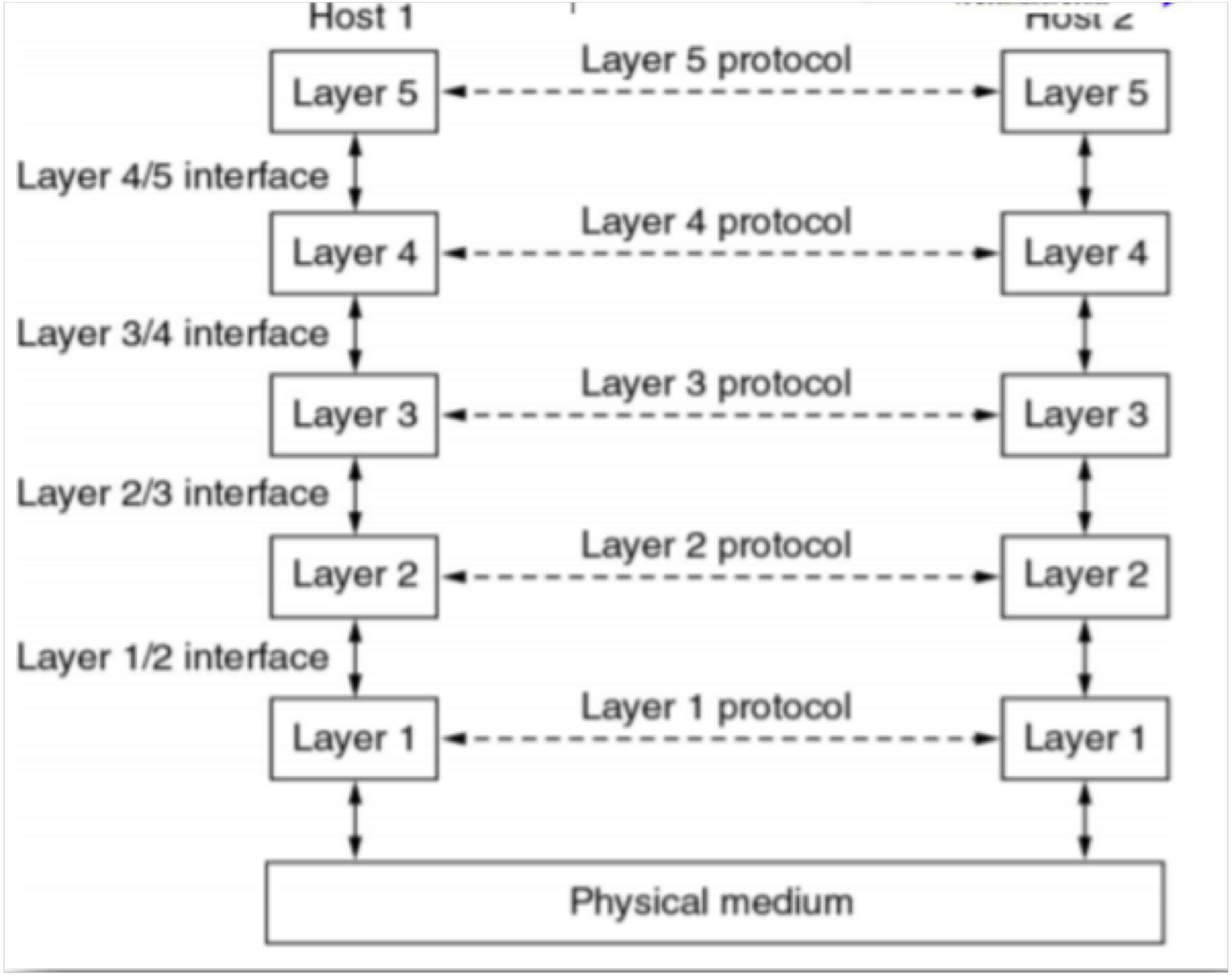

Host 1
Host 2
Layer 5 protocol
Layer 5
Layer 5
Layer 4/5 interface
Layer 4 protocol
Layer 4
Layer 4
Layer 3/4 interface
Layer 3 protocol
Layer 3
Layer 3
Layer 2/3 interface
Layer 2 protocol
Layer 2
Layer 2
Layer 1/2 interface
Layer 1 protocol
Layer 1
Layer 1
Physical medium

Question 2 (Delay and bandwidth)

- Calculate the end-to-end transit time for a packet for
  - GEO (*Geostationary orbit*) (altitude: 35,800 km),
  - MEO (*Medium Earth orbit*) (altitude: 18,000 km) and
  - LEO (*Low Earth orbit*) (altitude: 750 km) satellites.

Delay

- Delay = transmission delay + propagation delay
  - Time required for the first bit to travel from computer A to computer B.
  - **Transmission delay**: the amount of time required to **transmit** all of the packet's bits into the link.
  - **Propagation delay**: the time taken for a packet to reach from sender(A) to receiver(B).
  - ***Round-Trip Delay**:
    - Satellite
    - Altitude above the earth, round-trip delay
    - Round-trip distance, light speed

Solution 2 (Delay and bandwidth)

- *Transit time* = 2 × *distance* / *speed of light*, where *c* = 3.0×10^8 m/s
- GEO: $\frac{35800\times10^3\times2}{3.0\times10^8} = 0.239s$
  - 239 ms
- MEO: $\frac{18000\times10^3\times2}{3.0\times10^8} = 0.120s$
  - 120 ms
- LEO: $\frac{750\times10^3\times2}{3.0\times10^8} = 0.005s$
  - 5 ms

Question 3 (Delay and bandwidth)

- An image is **1600 × 1200 pixels with 3 bytes/pixel.** Assume the image is uncompressed.
  - How long does it take to transmit it over a 56-kbps modem channel, assuming zero propagation delay over the channel?
  - Over a 1-Mbps cable modem? Over a 10-Mbps Ethernet?
  - Over 100-Mbps Ethernet? Over gigabit Ethernet?

Bandwidth

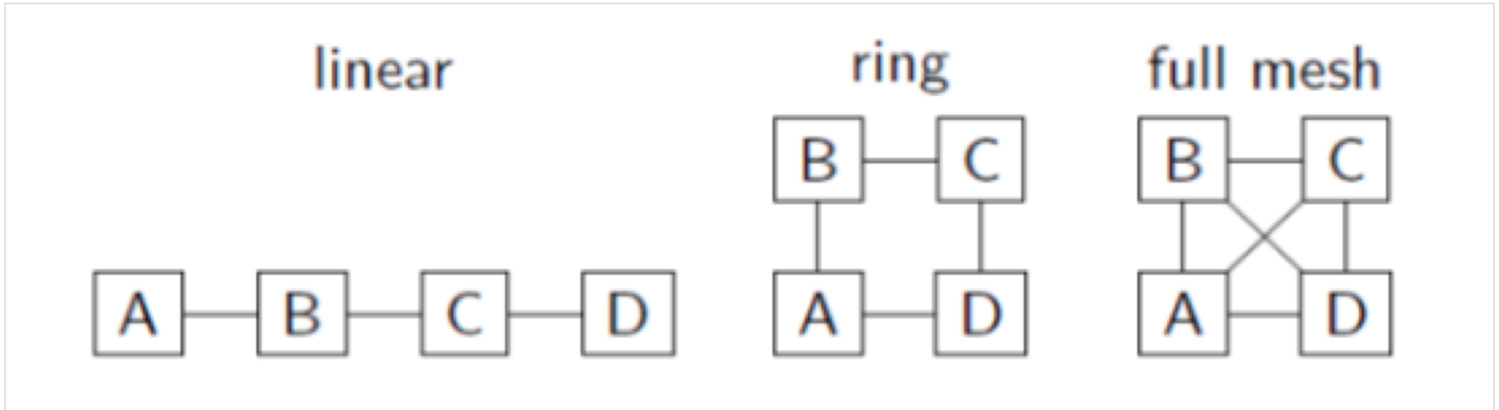
- 1. Bandwidth is treated as rate of transmission with the unit **bits/second.**
- 2. The second definition, commonly used in signal processing, is the range of frequencies an electronic signal uses on a given transmission medium (Hz)

Solution 3 (Delay and bandwidth)

- Image size = 1600 × 1200 × 3 × 8 = 46.08 ×10^6 bits
- 56 kbps modem: $\frac{46.08\times10^6}{56\times10^3} = 823s$
- 1 Mbps modem: $\frac{46.08\times10^6}{1\times10^6} = 46.1s$
- 10 Mbps Ethernet: $\frac{46.08\times10^6}{10\times10^6} = 4.61s$
- 100 Mbps Ethernet: $\frac{46.08\times10^6}{100\times10^6} = 0.46s$
- 1 Gbps Ethernet: $\frac{46.08\times10^6}{1\times10^9} = 0.046s$

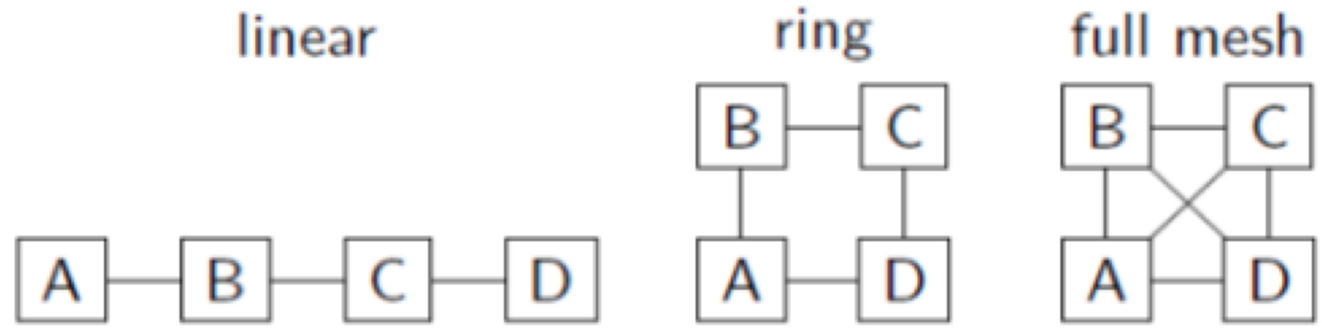
Question 4 (Topology)

- Consider the following 3 network topologies for connecting N nodes. In the general case of an **N** node network:



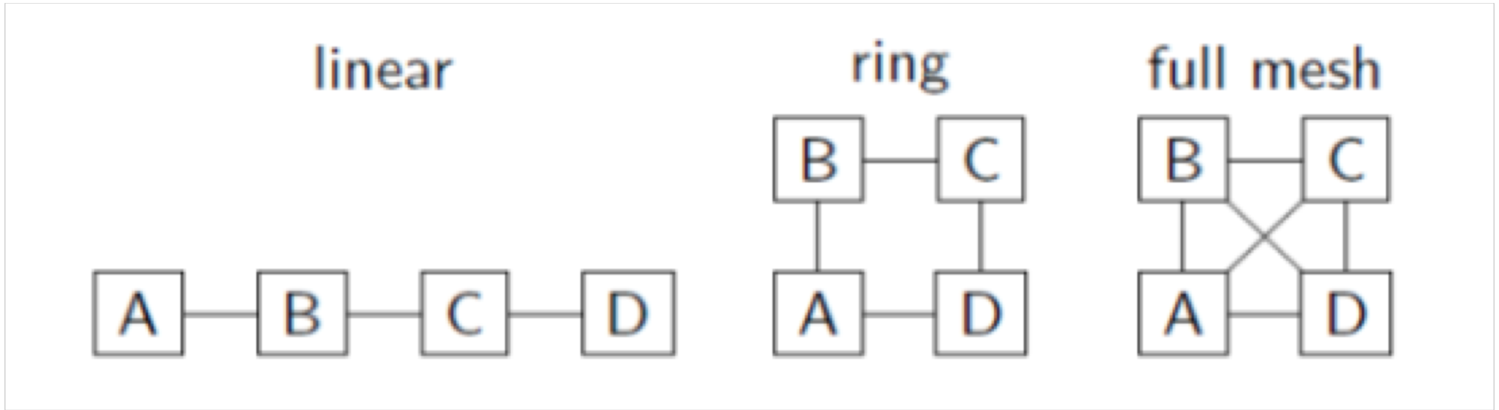
Question 4 (Topology)

- (a) How many links are there in each network?
- (b) What is the maximum delay between any pair of nodes, assuming each link has a delay of 10ms, and the shortest path is used between nodes?
- (c) What is the minimum number of links that need to be cut in order to isolate one or more nodes?
- (d) Which topology would you use to connect <u>military command centres</u>?



Solution 4 (Topology)

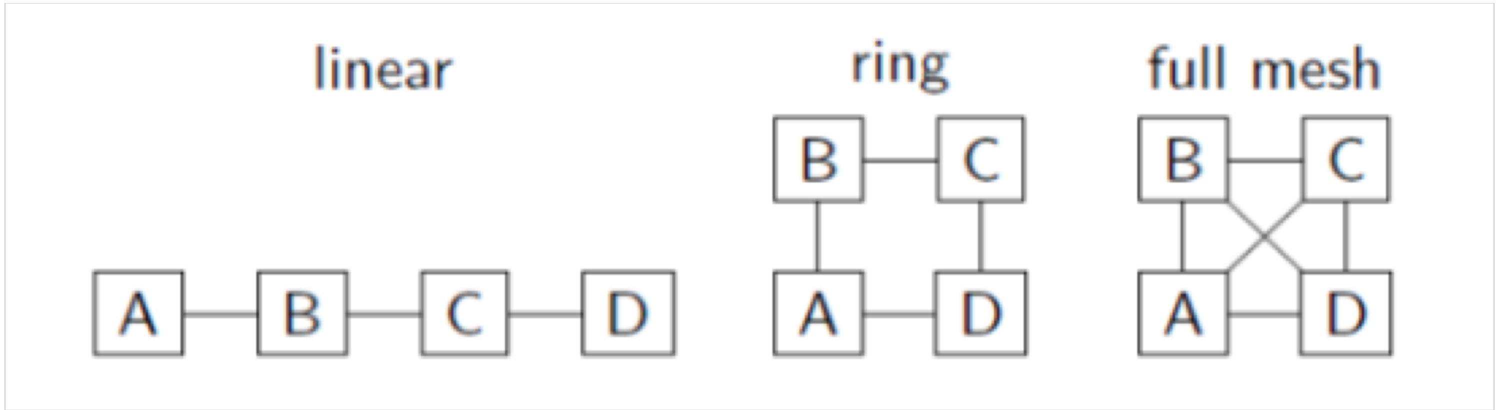
- (a)



  - Linear: *N – 1* links
  - Ring: *N* links
  - Full mesh: *N(N – 1)/2* links

Solution 4 (Topology)

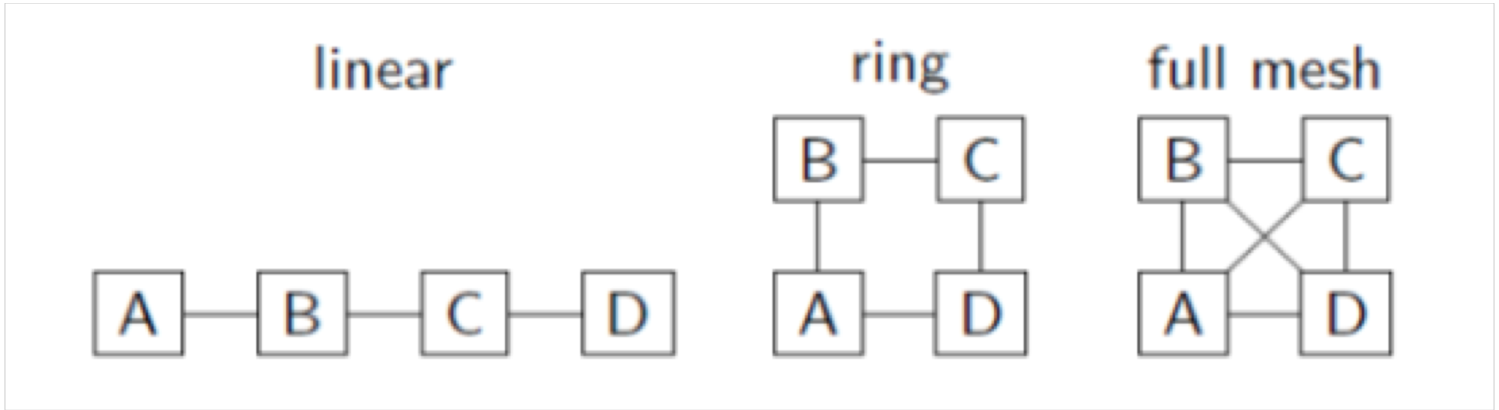
- (b)



  - Linear: *10(N – 1)* ms
  - Ring: *10*N/2* ms
  - Full mesh: *10* ms

Solution 4 (Topology)

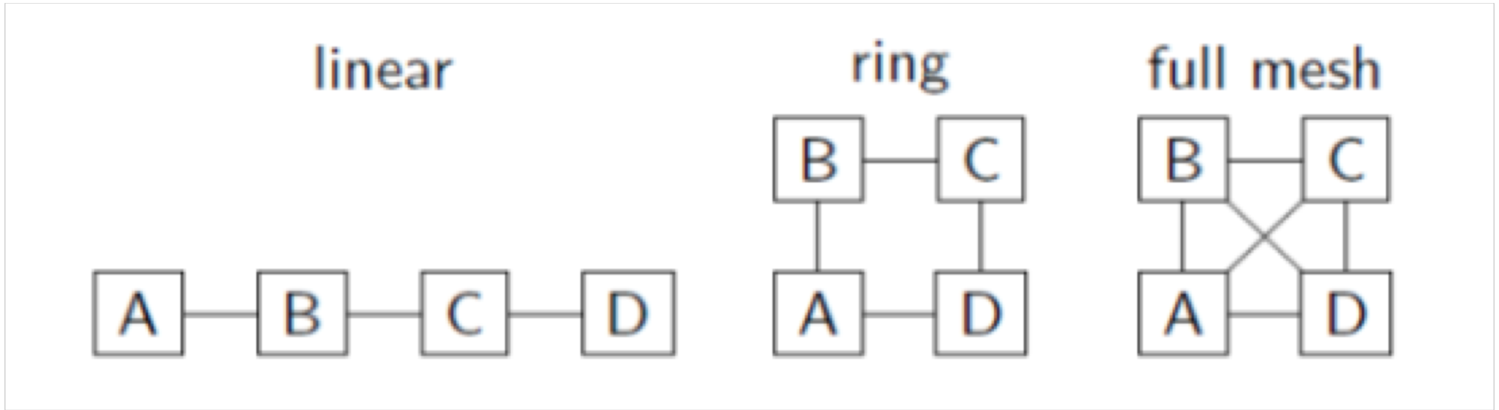
- (c)



  - Linear: *1* link
  - Ring: *2* link
  - Full mesh: *N – 1* links

Solution 4 (Topology)

- (d)

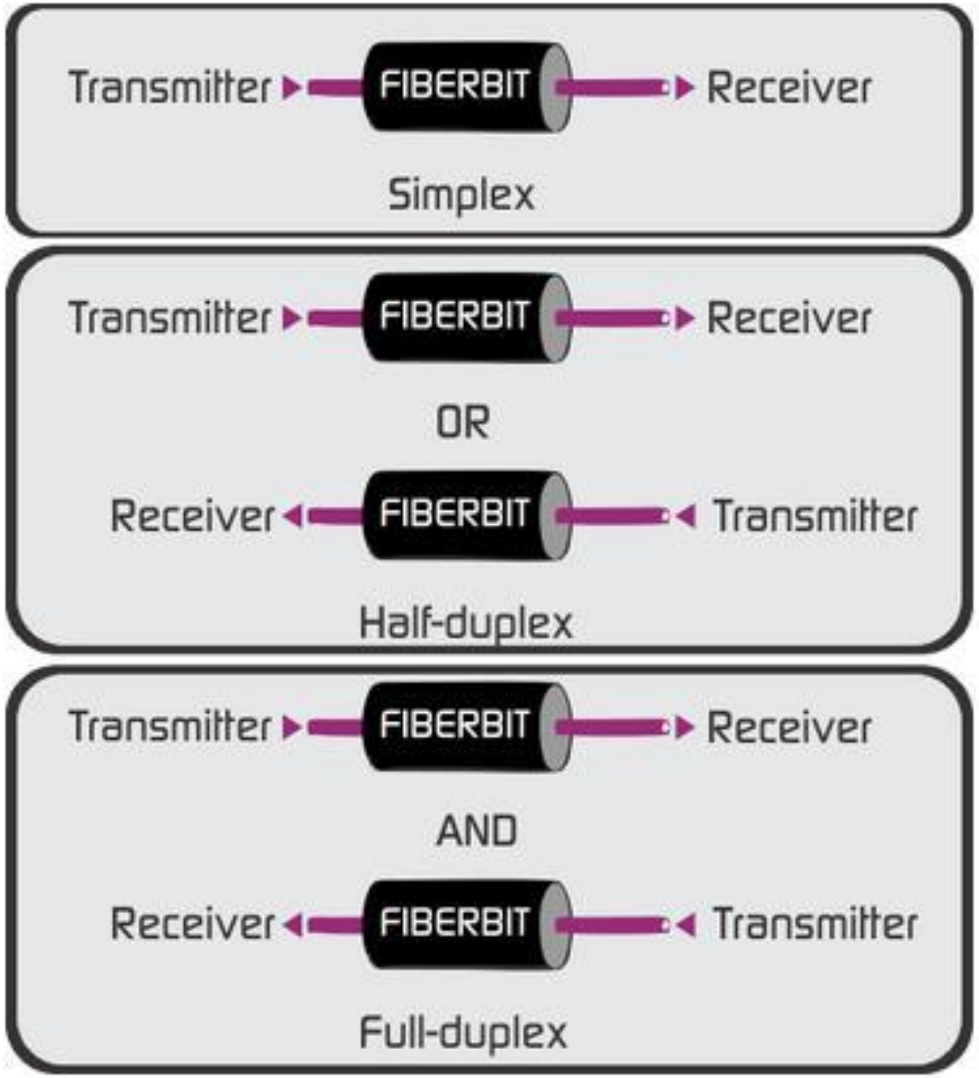


  - Full mesh – cost not important, but reliability is essential

Question 5 (Topology)

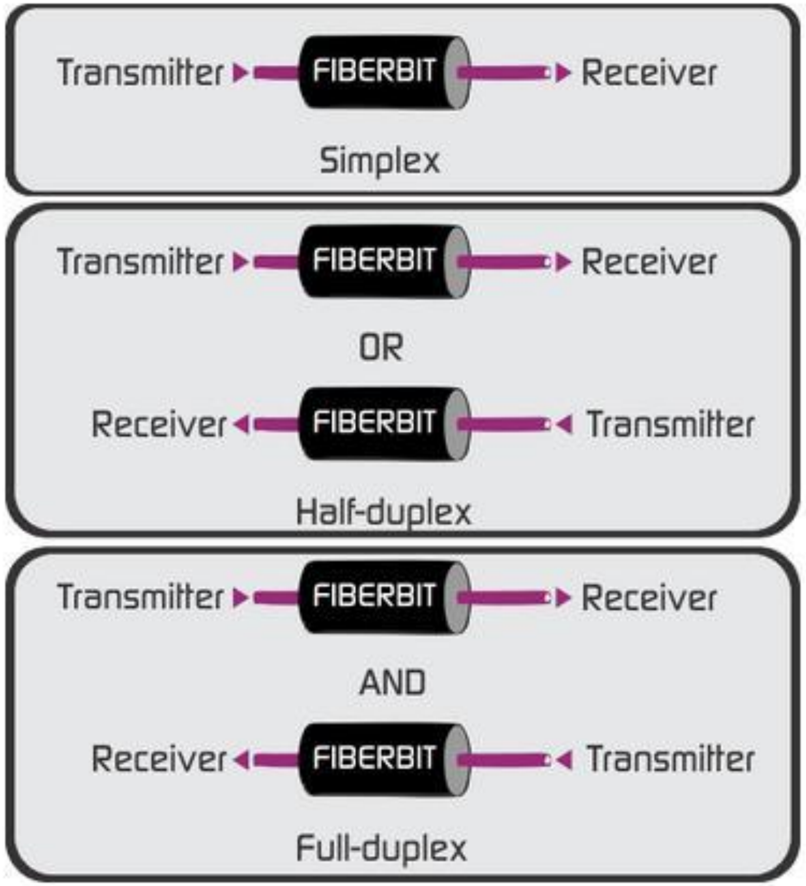
- Is an oil pipe a simplex system, a half-duplex system, a full duplex system or none of the above? Under which conditions?

Solution 5 (Topology)



Solution 5 (Topology)

- Oil can flow in either direction, but not both ways at once, therefore it **cannot** be *full duplex*.
- Depending on the situation, at an oil refinery, for example, an oil pipe is *simplex*, as the oil only flows in one direction.
- Theoretically oil can flow both ways, therefore it can be consider *half duplex*, similar to a single railroad track.



Question 6 (Sampling)

- Consider a **telephone signal** that is bandwidth limited to 4 kHz.
  - (a) At what rate should you sample the signal so that you can completely reconstruct the signal?
  - (b) If each sample of the signal is to be encoded at 256 levels, how many **bits/symbol** are required for each sample?
  - (c) What is the **minimum** bit rate required to transmit this signal?

Sampling

- **Sampling** is a fundamental bridge between continuous signals and discrete (digital) signals.
- Nyquist theorem (noiseless channel)
    - Maximum data rate = $2B \times \log_2 V \ \ bits/sec$
    - **If a signal has bandwidth B, then the signal can be fully reconstructed by sampling with at least 2B rate.**
- Shannon theorem ("noise-related")

Nyquist's theorem

- Nyquist proved that if an arbitrary signal has been run through a low-pass filter of bandwidth *B*, the filtered signal can be completely reconstructed by making only 2*B* (exact) samples per second.
- Sampling the line faster than 2*B* times per second is pointless because the higher-frequency components that such sampling could recover have already been filtered out.
- If the signal consists of *V* discrete levels, Nyquist's theorem states:

Maximum data rate = $2B \times \log_2 V \ \ bits/sec$

Sampling

- **Frequency**: the number of oscillations per second of a wave is called frequency, measured in Hertz
- The **second concept about bandwidth**: the frequency range in the given medium – continuous signal

Solution 6 (Sampling)

- (a) At what rate should you sample the signal so that you can completely reconstruct the signal?
- By Nyquist's Theorem:

  min. sampling rate = 2×4000 = 8 kHz = 8000 samples/s

Solution 6 (Sampling)

- (b) If each sample of the signal is to be encoded at 256 levels, how many **bits/symbol** are required for each sample?

- 256 possible values per sample requires $\log_2 256 = 8\ bits/sample$

Solution 6 (Sampling)

- (c) What is the **minimum** bit rate required to transmit this signal?

- 8 bits/sample × 8000 samples/s = 64 kbps

Question 7 (Sampling)

- Is the Nyquist theorem true for optical fibre or only for copper wire?

Solution 7 (Sampling)

- The Nyquist theorem is a property of mathematics and has nothing to do with technology.
- It states that if you have a function whose Fourier spectrum (frequency domain representation) **does not contain** any frequency components (sines or) **above *f*, then by sampling at a frequency of *2f*,** you capture all the information there is. The Nyquist theorem is **independent of the transmission medium.**

Question 8 (Sampling)

- A **noiseless 4 kHz channel** is sampled every 1 ms. What is the maximum data rate of the communications channel?

Solution 8 (Sampling)

- Just send a lot of data per sample. Assume a **4 kHz channel, sampled at 8 kHz.** If each sample is **16 bits**, the channel can send **128 kbps**. If each sample is 1024 bits, the channel can send 8.2 Mbps.
- *(16/T -> 16*f -> 16bits * 8kHz -> 128kbps)*

Question 9 (Sampling)

- The **bandwidth** of a television video stream is 6 MHz. How many bits/sec are sent if **four-level digital signals are used**? Assume a noiseless channel.

Solution 9 (Sampling)

- Using the Nyquist theorem, we should sample at 12 MHz or 12 million samples/s.
- Four levels of signalling provide:
  - $\log_2 4 = 2\ bits/sample\ (V = 4)$
- Hence, the total data rate is:
  - $12\ million\ samples/s \times 2\ bits/sample = 24\ Mbps$