COMP90007 Internet Technologies
Week 3 Workshop

Semester 2, 2018

Suggested solutions

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*)

Similarities:

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

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

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.

- *Transit time* = 2 × *distance* / *speed of light*, where $c = 3.0 \times 10^8$ m/s

- GEO: 239 ms
- MEO: 120 ms
- LEO: 5 ms

Question 3 (Delay and bandwidth)

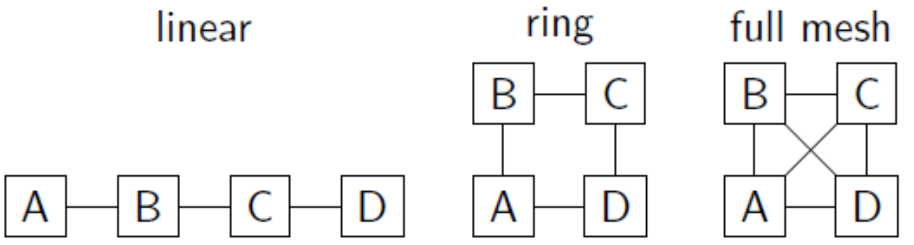
- An image is 1600 × 1200 pixels with 3 bytes/pixel. Assume the image is uncompressed.
  - How long does it take to transmit it over a 56-kbps modem channel, assuming zero propagation delay over the channel?
  - Over a 1-Mbps cable modem? Over a 10-Mbps Ethernet?
  - Over 100-Mbps Ethernet? Over gigabit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

- Image size = 1600 × 1200 × 3 × 8 = 46.08×10^6 bits

• 56 kbps modem:	823 s
• 1 Mbps modem:	46.1 s
• 10 Mbps Ethernet:	4.61 s
• 100 Mbps Ethernet:	0.46 s
• 1 Gbps Ethernet:	0.046 s

Question 4 (Topology)

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



  - (a) How many links are there in each network?

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

  - (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?

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

  - (c) What is the minimum number of links that need to be cut in order to isolate one or more nodes?

    Linear: 1 link Ring: 2 links Full mesh: $N - 1$ links

  - (d) Which topology would you use to connect military command centres?

    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?

  - 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?

    By Nyquist's Theorem: min. sampling rate = 2×4000 = 8 kHz = 8000 samples/s
  - (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
  - (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?

- The Nyquist theorem is a property of mathematics and has nothing to do with technology.
- The Nyquist theorem states that if you have a function whose Fourier spectrum (frequency domain representation) does not contain any frequency components (sines or cosines) 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?

• A noiseless channel can carry an arbitrarily large amount of information, no matter how often it is sampled. (i.e. there can be an infinite number of signalling levels because there is no noise)

• 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.

• The key word here is “noiseless.” With a normal noisy 4 kHz channel, Shannon specifies a limit on the information rate on the channel known as its *capacity*.

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.

  - Using the Nyquist theorem, we should sample at 12 MHz or 12 million times/s.
  - Four levels of signalling provide:

    $\log_2 4 = 2$ bits/sample
  - Hence, the total data rate is:

    12 million samples/s × 2 bits/sample = 24 Mbps.

Question 10 (Sampling)

- Radio antennas often work best when the diameter of the antenna is equal to the wavelength of the radio wave. Reasonable antennas range from 1 cm to 5 meters in diameter. What frequency range does this cover?

  - $\lambda f = c$, where $c = 3.0\times10^8$ m/s
  - For $\lambda = 0.01$ m, $f = 30\times10^9$ Hz
  - For $\lambda = 5$ m, $f = 60\times10^6$ Hz

  - Thus, the band covered is 60 MHz to 30 GHz.

Question 11 (Modulation)

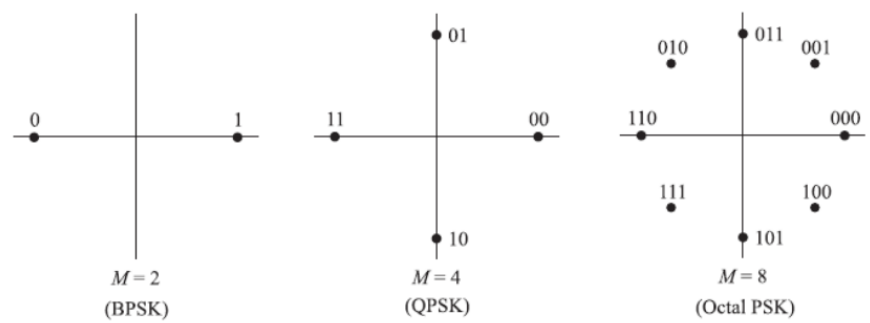
- Ten signals of bandwidth 4 kHz, are multiplexed onto a single channel using FDM (*frequency division multiplexing*). What is the minimum bandwidth required for the multiplexed channel? Assume that guard bands of 400 Hz are used.

- There are ten signals of 4 kHz. Nine guard bands are required in between the modulated bandpass signals to avoid interference when demultiplexing.

- Therefore the minimum bandwidth required of the channel is: $(4000 \times 10) + (400 \times 9) = 43.6$ kHz.

Question 12 (Modulation)

- In a constellation diagram, all points lie on a circle centred on the origin. What kind of modulation is being used?
  - If all points are equidistant from the origin, they all have the same amplitude, so amplitude modulation is not being used. Frequency modulation is never used in constellation diagrams, so the encoding is pure phase-shift keying (PSK).



Binary phase-shift keying *Quadrature phase-shift keying*