Notes: There are five questions in this assignment. Each question has 10 points.

1. (10 pt.) Describe the special properties of the following transmission media: optical, wireless, satellite, and electronic.

   **Answer: Book 1.2.2**
   - Optical: high capacity, immune to electromagnetic interference, low signal attenuation, very hard to tap, preferred for long-haul guided transmission.
   - Wireless: require no physical wire, can penetrate walls, provide connectivity to a mobile user, potentially carry a signal for long distances, subject to interference, performance decrease as distance increases.
   - Satellite: cover wide area, significant latency, high cost, low bit rate.
   - Electronic: various bit rate, off-the-shelf, low cost.

   **Grading:**
   No points will be deducted unless most information is missing in your answer.

2. (10 pt.) There are 80 computers to be connected to each other. How many connections required if they are connected to each other with a direct link? Given a set of 6X6 switches (6 inputs and 6 outputs), what is the minimum number of switches needed to provide connectivity between any two computers? Please show how these switches are connected.

   **Answer:**
   1) \( \binom{80}{2} = \frac{80 \times 79}{2 \times 1} = 3160 \)
   2) For a 6x6 switch, we mean that the switch has 6 ports that can both be inputs and outputs. Thus we can connect them in series.

   ![Diagram](image)
   Assume there are \( x \) intermediate switches, thus we have
   \[ 5 \times 2 + 4x \geq 80 \]
   Then we have \( x \geq 17.5 \).
   Hence we need at least \( 2 + 18 = 20 \) switches
   (This is not the only structure; some other structure can also be build but the least switches needed is still 20)

   **Grading:**
3. (10 pt.) Compute the time required for circuit switching and packet switching with the following conditions:

- The destination is 3 hops away from the source: Two intermediate switches between the source and the destination, with 3 links.
- The distance between source (or end) computer and the connected switches nodes is 1 Km. The distance between two adjacent switches is 100 Km.
- The signal propagation speed is $5 \times 10^5$ m per second.
- The message size is 10 Mega bits (1 Mega = $10^6$).
- The maximum packet size is 100k bits (1k = $10^3$). You can ignore the size of the header.
- The transmission speed of source (or end) computer to its connected switch is 10 Mbps (Megabits per second). The link speed between adjacent switches is 1 Giga bits per second.
- The circuit setup time is $2 \times 10^{-1}$ second for the case of circuit switching.
- The processing time for routing decision at each switch is negligible.

In this case, which switching method has a shorter completion time? If the message size can be enlarged, is there a chance the other switching method can be better?

**Note:** Please show your computation steps.

**Answer: Book 1.4.1, 1.4.3**

**Circuit switching:**

\[ d_{\text{setup}} = 0.2 \text{ s} \]

\[ d_{\text{trans}} = \frac{L}{R} = \frac{10 \text{ Mb}}{10 \text{ Mbps}} = 1.0 \text{ s} \quad \text{(Consider lowest rate.)} \]

\[ d_{\text{prop}} = \frac{10^3 \text{m} + 100 \times 10^3 \text{m} + 10^3 \text{m}}{5 \times 10^5 \text{ m/s}} = 0.204 \text{ s} \]

\[ d_{\text{end-\text{end}}} = 1.404 \text{ s} \]

**Packet switching:**
We consider the time duration from the first packet start transmission until last packet reach destination.

\[ N_{\text{Packet}} = \frac{10 \times 10^6}{100 \times 10^3} = 100 \]

\[ d_{\text{source}} = \frac{L}{R_1} = \frac{100k}{10 \text{ Mbps}} = 0.01 \text{ s} \]

\[ d_{\text{switch1}} = \frac{L}{R_2} = \frac{100k}{1 \text{ Gbps}} = 0.0001 \text{ s} \]

\[ d_{\text{switch2}} = \frac{L}{R_3} = \frac{100k}{10 \text{ Mbps}} = 0.01 \text{ s} \]

\[ d_{\text{wait}} = (N_{\text{Packet}} - 1) \times d_{\text{source}} = 0.99 \text{ s} \]

\[ d_{\text{trans}} = d_{\text{source}} + d_{\text{switch1}} + d_{\text{switch2}} = 0.0201 \]

\[ d_{\text{prop}} = \frac{10^3 m + 100 \times 10^3 m + 10^3 m}{5 \times 10^5 \text{ m/s}} = 0.204 \text{ s} \]

\[ d_{\text{end-end}} = d_{\text{wait}} + d_{\text{trans}} + d_{\text{prop}} = 1.2141 \]

Packet switching has shorter completion time.
Let message be \( X \) mb, here we compare the time of circuit switching and packet switching as follows:

\[ d_{\text{CircuitSwitching}} = 0.2 + \frac{X}{10 \text{ Mbps}} + 0.204 = 0.404 + 0.1X \]

\[ d_{\text{PacketSwitching}} = \left(\frac{X}{0.1} - 1\right) \times 0.01 + 0.0201 + 0.204 = 0.2141 + 0.1X \]

Hence we can learn that packet switching is always faster regardless of message length.

Grading: 4 points for each time result, 2 points for final conclusion.
At least 1 points will be given for each if you realize there are several types of delay;
4. (10 pt.) Consider the queuing delay in a router buffer (preceding an outbound link). Suppose all packets are \( L \) bits, the transmission rate is \( R \) bps, and the \( N \) packets simultaneously arrive at the buffer every \( LN/R \) seconds. Find the average queuing delay of a packet. (Hint: The queuing delay for the first packet is zero; for the second packet \( L/R \); for the third packet \( 2L/R \). The \( N \)th packet has already been transmitted when the second batch of packets arrives.)

Answer:

\[
\bar{d}_{\text{queue}} = \frac{1}{N} \left[ 0 + \frac{L}{R} + \frac{2L}{R} + \cdots + \frac{(N-1)L}{R} \right] = \frac{(N-1)L}{2R}
\]

Grading:

A large portion of points will be deducted if you answer is wrong and there is no derivation

-2 if you count from 1 to \( N \) instead of from 0 to \( N-1 \)
-1 or -2 if a final formula is not given

5. What is today’s Internet? Describe the essential components as well as the design principles in details. However, your answer should be no more than two pages

Answer:

Basically, the Internet can be divided into two main components: the Internet core and the end system. The services provided by these two parts are different. The end system can have a variety of applications to server for different purposes, like web browsing, video streaming, file sharing. Thus there are a lot of protocols for people to choose, like HTTP, FTP, and SMTP. It’s more flexible and can be update quickly and easily. While the core part of the Internet focuses exclusively on the routing and switching of the packet. This makes the core part more efficient in doing their own job. Thus there are only a few protocols in the Network layer. IP plays like a narrow waist in the protocol stack of the Internet.
The division of the functions of core part and end system also reflects the most important design principles of the Internet: push the complexity of Internet to the end system and keep the core part simple and efficient. The two famous features of TCP protocol, flow control and congestion control, both try to recognize and fix the problem at the end instead of adding extra functions to the routers. This design principle can also be observed in the evolution from IPv4 to IPv6. Some functions originally performed in the router at Network layer, like checksum, are moved to the end system to improve the efficiency of the routers.

Layering is another important design principle in the Internet. This brings benefits as well as drawbacks. By dividing the design into different layers, the complexity of the lower layer would be transparent to the upper layer. Moreover, no matter what implementation is used in the lower layer, the upper layer can treat them as the same as long as they provide uniformed interfaces to the upper layer. This makes the mobile network possible in some ways. The APPs on our phone can perform perfectly regardless of connecting LTE of Wi-Fi. Although some disadvantages emerge, such as function duplication in different layers (integrity checking is performed both in the transport layer and network layer) and difficulties in upgrading the key layer: Network layer, the strength of layer brings the prosperity of current Internet.

The Internet is said to be the network of network. This can be interpreted in many ways. First, Internet is becoming increasingly complex since the initial ARPANET. We have LAN, WLAN, Ethernet and mobile network. Each itself is a network and can be a part of the whole Internet. Second, the Internet is also a commercial place. BGP4 acts as a backbone of the whole Internet and different level of AS all have their own profit and customers in the market of the Internet.

At the end of this semester, hopefully we will have a better understanding of the Internet.

Grading:
No points will be deducted unless your answer is too short to convey the basic ideas.