Problem 1  Transmission Overhead

19. Suppose an application layer entity wants to send an $L$-byte message to its peer process, using an existing TCP connection. The TCP segment consists of the message plus 20 bytes of header. The segment is encapsulated into an IP packet that has an additional 20 bytes of header. The IP packet in turn goes inside an Ethernet frame that has 18 bytes of header and trailer. What percentage of the transmitted bits in the physical layer correspond to message information, if $L = 100$ bytes, $500$ bytes, $1000$ bytes?

Solution:

TCP/IP over Ethernet allows data frames with a payload size up to 1460 bytes. Therefore, $L = 100$, 500 and 1000 bytes are within this limit.

The message overhead includes:

- TCP: 20 bytes of header
- IP: 20 bytes of header
- Ethernet: total 18 bytes of header and trailer.

Therefore

$L = 100$ bytes, $100/158 = 63\%$ efficiency.

$L = 500$ bytes, $500/558 = 90\%$ efficiency.

$L = 1000$ bytes, $1000/1058 = 95\%$ efficiency.

Problem 2  CD vs. MP3

6. Suppose a storage device has a capacity of 1 gigabyte. How many 1-minute songs can the device hold using conventional CD format? using MP3 coding?

Solution:

A stereo CD signal has a bit rate of 1.4 megabits per second, or 84 megabits per minute, which is approximately 10 megabytes per minute. Therefore a 1 gigabyte storage will hold 1 gigabyte/10 megabyte = 100 songs.

An MP3 signal has a lower bit rate than a CD signal by about a factor of 14, so 1 gigabyte storage will hold about 1400 songs.
Problem 3  Analog Repeater

11. Consider an analog repeater system in which the signal has power $c_s^2$ and each stage adds noise with power $c_n^2$. For simplicity assume that each repeater recovers the original signal without distortion but that the noise accumulates. Find the SNR after $n$ repeater links. Write the expression in decibels: $\text{SNR dB} = 10 \log_{10} \text{SNR}$

**Solution:**

After $n$ stages, the signal power is $c_s^2$ and the noise power is $nc_n^2$, so the SNR is:

$$\text{SNR dB} = 10 \log_{10} \frac{c_s^2}{nc_n^2} = 10 \log_{10} \frac{c_s^2}{c_n^2} + 10 \log_{10} \frac{1}{n} = 10 \log_{10} \frac{c_s^2}{c_n^2} - 10 \log_{10} n$$

Problem 4  The Internet Protocol Stack

**Solution:**

1. There are five layers in the Internet protocol stack: physical layer, data link layer, network layer, transport layer and application layer.

2. **Physical layer:** moves individual bits from one node to the next.

   **Data link layer:** transfers frames (or blocks) across connection between two nodes.

   **Network layer:** transfers data packets across multiple networks using addressing and routing mechanism.

   **Transport layer:** end-to-end transfer of messages between source and destination node across networks.

   **Application layer:** provides network services requested by clients and servers.

3. Application layer messages are the messages exchanged between distributed network entities implementing a protocol. Transport layer segments are data units divided by TCP or UDP protocols. Network layer datagrams are packets of connectionless organization. They are passed with transport layer segments with a destination address in the network layer. Link layer frames are data sent from source to destination by network layer using routes.

4. Router process is done in the network layer.

Problem 5  Rate vs. Bandwidth

**Solution:**

(a) The rate in this case is given by $R_1 = 2W$, which will increase linearly with $W$.

(b) The rate in this case is given by $R_2 = W \log_2(1 + \frac{100}{W})$, this also increases with $W$ but approaches an asymptote as $W$ gets large.

(c) as $W \to \infty$, $R_1 \to \infty$ and $\lim_{W \to \infty} R_2 = \lim_{W \to \infty} \frac{\log_2(1 + \frac{100}{W})}{W} = \frac{100}{\ln 2}$ (this can be found using L'Hopital's rule)
There are some fundamental differences. In part (a), we assume the transmission is noise free, and we don’t put restrictions on the signal power. In addition we try to explore the bandwidth as thoroughly as possible. In fact, with the increment of the bandwidth, we need more and more power. However, in part (b), we use the same signal power for any bandwidth while the noise power increases linearly with the bandwidth. This leads to a vanishing signal-to-noise ratio. In this case, the rate given by Shannon’s capacity formula is the maximum reliable transmission rate under noise and power consumption.

**Problem 6  Network Protocols**

*Solution:* The following figure provides an example.

![Diagram of ATM transaction](image)

**Problem 7  SMTP Protocol**

*Solution:* 25 is the port number for SMTP service. If not using a number, telnet will use the default number 23, which is the port number for telnet connection. 80 is the port number for HTTP service. Using any number other than 25 results in no reply from the SMTP server.