

CENG460 Assignment 1

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1. Consider two hosts, A and B, connected by a single link of rate R bps. Suppose that the two hosts are separated by m meters, and suppose the propagation speed along the link is s meters/sec. Host A is to send a packet of size L bits to Host B.

- (a) Express the propagation delay, d_{prop} , in terms of m and s .

Ans : $d_{prop} = m/s$

- (b) Determine the transmission time of the packet, d_{trans} , in terms of L and R .

Ans : $d_{trans} = L/R$

- (c) Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.

Ans : end-to-end delay = $d_{prop} + d_{trans} = m/s + L/R$

- (d) Suppose Host A begins to transmit the packet at time $t = 0$. At time $t = d_{trans}$, where is the last bit of the packet?

Ans : The last bit will be on the link (just being transmitted from the transmitter and put to the wire).

- (e) Suppose d_{prop} is greater than d_{trans} . At time $t = d_{trans}$, where is the first bit of the packet?

Ans : The first bit will be in the link (have not reached the receiver yet).

- (f) Suppose d_{prop} is less than d_{trans} . At time $t = d_{trans}$, where is the first bit of the packet?

Ans : The first bit will be at the receiver.

- (g) Suppose $s = 2.5 \times 10^8$ meters/sec, $L = 100$ bits, and $R = 28$ kbps. Find the distance m so that $d_{prop} = d_{trans}$.
Ans : $m = sL/R = 0.89 \times 10^6 \text{ meter}$

2. Consider the queueing delay in a router buffer. Suppose all packets are L bits, and the transmission rate is R bps.

- (a) Suppose that N packets simultaneously arrive at the buffer every LN/R seconds. Find the average queueing delay of a packet. (*Hint*: The queueing 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.)
Ans : Total queueing delay $= L/R \times [0 + 1 + 2 + \dots + (N - 1)] = (L/R) \times [N(N - 1)/2]$ second
 Average queueing delay $= \text{total queueing delay}/N = (L/(2R)) \times (N - 1)$ second

- (b) Suppose that N packets arrive at the buffer every LN/R seconds, and the inter-arrival time of two adjacent packets is $L/(2R)$ (that is, if the first packet arrives at t_0 , the 2nd packet arrives at $t_0 + L/(2R)$, the 3rd packet arrives at $t_0 + 2L/(2R)$, ..., and the N th packet arrives at $t_0 + NL/(2R)$). Find the average queueing delay of a packet.
Ans : Total queueing delay $= (L/(2R)) \times [0 + 1 + 2 + \dots + (N - 1)] = (L/(2R)) \times [N(N - 1)/2]$ second
 Average queueing delay $= \text{total queueing delay}/N = (L/(4R)) \times (N - 1)$ second

3. Suppose there is a $R = 10$ Mbps microwave link between a geostationary satellite and its base station on Earth. Every minute the satellite takes a digital photo and sends it to the base station. Assume a propagation speed of 2.4×10^8 meters/sec.

- (a) What is the propagation delay of the link?
Ans : The geostationary satellites are 36,000 km above earth.
 $t_{prop} = 36 \times 10^6 / 2.4 \times 10^8 = 150 \text{ ms}$

(b) What is the bandwidth-delay product, $R \times t_{prop}$?

$$Ans : R \times t_{prop} = 10 \times 10^6 \times 150 \times 10^{-3} = 1.5 \times 10^6 bits$$

(c) Let x denote the size of the photo. What is the minimum value of x for the microwave link to be continuously transmitting?

$$Ans : x_{min} = 1(minute) \times 10 \times 10^6(bps) = 60(sec) \times 10 \times 10^6(bps) = 600 \times 10^6 bits$$

4. In a few sentences, please compare the following terms and explain the relationship between them: link bandwidth (in Hertz), baud rate (in sample-per-second), symbol rate (in symbol-per-second), and data rate (in bit-per-second).

Link bandwidth: the range of frequencies that the channel can reliably transfer (without strong attenuation).

Baud rate: number of samples per second

Symbol rate: number of symbols per second, one sample is considered to represent one symbol.

Data rate: number of bits per second, one symbol can represent $\log_2 V$ bits of information, where V is the number of discrete levels of signal)

5. In traditional telephone systems, local loop (i.e., between a telephone set and its nearest telephone switch) link bandwidth is about 3KHz.

a) If using 16-QAM, what is the maximum achievable baud rate and data rate (assume noiseless channel)? [Hint: Nyquist limit]

According to Nyquist limit, $2H \log_2 V = 6000 \log_2 16 = 24$ Kbps.

b) If the signal-to-noise ratio imposed by the system between two remote telephone sets is about 30dB, what is the maximum achievable data rate? [Hint: Shannon's Limit]

$$30dB = 10^{30/10} = 1000.$$

According to Shannon's limit, $H \log_2(1 + S/N) = 3000 \log_2 1000 \approx 30$ Kbps.

c) In a few sentences, please explain how telecommunication companys can achieve a data rate higher than the one calculated above.

Increase H or increase S .