ECE 363 Spring 2026 Assignment 1 Solutions

Q. 1

a) $t_{prop} = d/v$

b) $t_{trans} = L/R$

c) end-to-end delay

$$t_{prop} + t_{trans} = d/v + L/R$$

d) the last bit will be on the link (just being transmitted)

e) the first bit will be on the link (not reached B yet)

f) the first bit will be at B

g) $v = 2 \times 10^8$ m/s $L = 1$ Mbit $R = 100$ Mbps

$$d = \frac{vL}{R} = \frac{2 \times 10^8 \times 10^6}{100 \times 10^6} = 2 \times 10^6 \text{ m}$$

$$= 2000 \text{ kms}$$

Q. 2

a) the total queueing delay is

$$L/R\,(0+1+\cdots+N-1)$$

$$= L/R\,\frac{(N(N-1))}{2}\,s$$

the average delay is $\frac{\text{total delay}}{N}$

$$= \frac{L(N-1)}{2R}\,.s$$

b) the total queueing delay is

$$\frac{L}{2R}(0+1+\cdots+N-1) = \frac{L}{2R}\left(\frac{N(N-1)}{2}\right)s$$

the average delay is

$$\frac{L}{4R}(N-1)\cdot s$$

Q.3 $R = 10$ Mbps

a) $d = 36 \times 10^6$ m $\quad V = C = 3 \times 10^8$ m/s

$$t_{prop} = d/V = \frac{36 \times 10^6}{3 \times 10^8} = 120 \text{ msec}$$

b) $BD = R \times t_{prop} = 10 \times 10^6 \times 120 \times 10^{-3}$

$= 1.2$ Mbits

c) $L_{min} = 60 \times 10$ Mbps

$= 600$ Mbits

Q 4 1 Gbps link N users 200 Mbps users access the link 5% of the time

circuit switching can accomodate

$$\frac{1000}{200} = 5 \text{ users}$$

with packet switching the probability that more than 5 users will access the link simultaneously is

$$p = \sum_{i=6}^{N} \binom{N}{i} (.05)^i (.95)^{N-i}$$

for $N = 24$ $p = .000962$

for $N = 25$ $p = .00123 > .1\%$

so the maximum number of users is

$N = 24$ for $p < .1\%$

b) the statistical multiplexing gain is

$$\frac{24}{5} = 4.8 \times$$

c) the average rate with $N=10$ users is

$10 \times 200 \times .05 = 100$ Mbps

this is below the link capacity of 1Gbps

the probability of exceeding the link capacity is

$$p = \sum_{i=6}^{10} \binom{10}{i} (.05)^i (.95)^{9-i}$$

$$= 2.76 \times 10^{-6}$$

negligible but nonzero so congestion can still occur

Q.5 Bandwidth 3.1 kHz

a) Nyquist rate is $2B\log_2 V$

16-QAM $V = 16$

$R = 2(3100)\log_2 16 = 6200 \times 4$

$= 24.8$ kbps

b) SNR = 30 dB $S/N = 10^3 = 1000$

$C = B\log_2(1+1000)$

$= 3100 \times 9.967 = 30.91$ kbps

Q6 $t_{proc} = .020$ msec

assume the distance between Vancouver and Toronto is 4500 kms

considering the location of fiber optic cables

$V = 2 \times 10^8$ m/s $t_{prop} = d/V = 22.5$ msec

thus $\frac{t_{proc}}{t_{prop}} = .889 \times 10^{-3}$

which is negligible

even with 10 switches

t_{proc} is .20 msec which is less than 1% of the total delay

Q.7 10 4000 Hz signals

require 10% guard bands

$4000 \times .1 = 400$ Hz

11 guard bands are required

$11 \times 400 = 4400$ Hz

the minimum required bandwidth is

$4000 \times 10 + 4400 = 44.4$ kHz