Part B

Name: Alvi Akbar
Std# 11118887

① Assumption:- A single 100 byte is transmitted from one node to another.

Link data rate: 8×10^9 bits/second.

queueing delay = 0

node processing delay = $x + 0.5$ ns/byte

Here $x = 0$ ns for OCN
0.3 Ms for SAN
3 Ms for LAN
30 Ms for WAN

Link distances: 0.5 cm ——— OCN
5m ——— SAN
5000m ——— LAN
5000 km ——— WAN

The speed of signal propagation in each case is 200 000 km/s.

ⓐ $\boxed{\text{ONC}}$ transmission delay $= \dfrac{800 \text{ bits}}{8 \times 10^9 \text{ bits/s}} = 100$ ns.

propagation delay $= \dfrac{5 \times 10^{-3}}{2 \times 10^8} = 0.025$ ns

Processing delay $= x + 0.5$ ns/byte $\times$ 100 byte
$= 0 + 0.5 \times 100$
$= 50$ ns

$\therefore$ Total delay = 100ns + 50ns + 0.025ns = 150.02 ns

% of propagation delay $= \dfrac{0.025}{150.025} = 0.016\%$

(b) SAN

transmission delay $= 100$ ns

Propagation delay $= 0.005/200\,000 = 2.5 \times 10^{-8}$ s $= 25$ ns.

Processing delay $= 0.3\ \mu s + 0.5 \times 100$ ns $= 350$ ns

Total delay $= 100 + 25 + 350 = 475$ ns.

% of Propagation Delay $= \frac{25}{475} \times 100 = 5.26\%$

(c) LAN Transmission delay $= 100$ ns

Processing delay $= 3\ \mu s + 0.5 \times 100$ ns $= 3050$ ns

Propagation delay $= 5/200000 = 25000$ ns

Total delay $= 100 + 25000 + 3050 = 28150$ ns

% propagation delay $= \frac{25000}{28150} = 88.8\%$

(d) WAN

Transmission delay $= 100$ ns.

Processing delay $= 30\ \mu s + 0.5 \times 100$ ns $= 30050.0$ ns

Propagation delay $= \frac{5000}{200\,000} = 25000000$ ns

Total delay $= 25030150$ ns

% of propagation delay $= \frac{25000000}{25030150} = 99.88\%$

(3) Nyquist's Theorem

Number of states = 2^3

3 bits used

Baud Rate = 2 x bandwidth

Link data rate = bits x baud = $3 \times 2 \times 4 \times 10^3$ Hz.

$= 2.4 \times 10^4$ b/s

(a) Shannon's Theorem:

$S/N = 127$

data rate $= B \times \log_2(1 + S/N)$ 127

$= 2.8 \times 10^4$ b/s

Shannon's Theorem

2.8×10^4 b/s

(b) $S/N = 7$

data rate $= 4 \times 10^3 \times \log_2(1+7)$

$= 1.2 \times 10^4$ b/s.

Nyquist Theorem

2.8×10^4 b/s

Q.4.

(a) Achievable data rate = Link data rate / No. of sessions

$$= \frac{10 \times 10^6 \text{ b/s}}{100}$$

$$= 10^5 \text{ b/s}$$

(b) If B = 10 seconds

$$\text{Average data rate} = \frac{10 \times 10^6 \text{ b/s}}{1 + 99\left(\frac{10}{1+10}\right)}$$

$$= 1.1 \times 10^5 \text{ b/s}$$

If B = 1 second,

$$\text{Avg data rate} = \frac{10 \times 10^6 \text{ b/s}}{1 + 99\left(\frac{1}{1+1}\right)} = 198019.8$$

$$\approx 2.0 \times 10^5 \text{ b/s}$$

If B = 0.1 seconds

$$\text{Avg data rate} = \frac{10 \times 10^6 \text{ b/s}}{1 + 99 \times \frac{0.1}{1+0.1}} = 10^6 \text{ b/s}$$

If B = 0.01 s

$$\text{Avg data rate} = \frac{10 \times 10^6}{1 + 99\left(\frac{0.01}{1+0.01}\right)} = 5.05 \times 10^6 \text{ b/s}$$

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Q5 (a) Stop & wait protocol

Achievable throughput = Data size / RTT

$$= \frac{1000 \times 8}{0.05} = 1.6 \text{ k/s}$$

(b) Sliding window Protocol

Achievable data rate = $\left(\text{Max window size} \times \frac{\text{Data size}}{\text{RTT}} \right)$

If $\boxed{\text{sending window size} = 10}$

Achievable data rate = $\frac{10 \times 1000 \times 8}{0.05} = 16 \text{ b/s}$

$\boxed{\text{sending window size} = 50}$

Achievable data rate = $\frac{50 \times 1000 \times 8}{0.05} = 80 \text{ b/s}$

(c)

$$10 = \frac{x \times 1000 \times 8}{0.05}$$

$$\boxed{x = 63}$$

$\therefore$ Max sending window size = 63.

⑥ Communication link using go-back-n

window size = 5 4 bit sequence number.

(0 — 15)

$\underbrace{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,}_{\text{oldest}}$ | 14, 15, 0, 1, 2, 3, ...

packet lost

retransmission

ⓐ Processing delay = 0.

$$\text{Transmission delay} = \frac{4000 \text{ bits}}{100 \times 10^{6} \text{ bits/s}} = 4 \times 10^{-5} \text{ s}$$

$$\text{Propagation delay} = 1 \times 10^{-3} \text{ s.}$$

$$\text{Total delay} = 104 \times 10^{-5} \text{ s}$$

If 2 packets are sent / link

$$\text{transmission delay} = \frac{8000 \text{ bits}}{100 \times 10^{6} \text{ bits/s}} = 8 \times 10^{-5} \text{ s}$$

$$\text{Total delay} = 8 \times 10^{-5} + 100 \times 10^{-5}$$

$$= 108 \times 10^{-5} \text{ s}$$

2 b

With n equal sized packages & H byte header.

total No of bytes = $M + Hn$