Problem 1] Computing end-to-end delays

a) Both routers are store & forward routers

(L) Total delay = $d_{nodal} = (d_{processing} + d_{queue} + d_{transmission} + d_{propagation}) \times 3$

$= (5\mu sec + 0sec + \frac{L}{R} + \frac{d}{s}) \times 3$ links

$= (5\mu sec + 0sec + \frac{1KB \times 8bits}{10^6 bytes} + \frac{100KM}{20,000 KM/s}) \times 3$ links

$= (5 \times 10^{-6} sec + 0.00819 2 sec + \frac{1}{200} secs) \times 3$ links

$L = (0.013197 secs) \times 3 = 0.039591$ seconds

b) Cut-through routers ⇒ 1 transmission delay through both routers

(L) Total delay = $d_{nodal} = (d_{processing} + d_{queue} + d_{propagation}) \times 3$ links $+ d_{transm}$

$= 3(5\mu sec + 0sec + \frac{100KM}{20,000 KM/s}) + \frac{1KB \times 8bits}{10^6 bytes}$

$= 3(0.005005 sec) + 0.008192 sec$

$L = 0.23207$ sec

c) Supposing R1 = R2 = R3 = 1 Gbps for (a) & (b)

(a) Total delay = $d_{nodal} = (d_{proc} + d_{queue} + d_{trans} + d_{prop}) \times 3$ links

$= (5\mu sec + 0sec + \frac{1KB \times 8bits}{10^9 bytes} + \frac{100KM}{20,000 KM/sec}) \times 3$ links

$L = (0.005006 sec) \times 3$

$L = 0.015018$ sec

(b) Total delay = $d_{nodal} = (d_{proc} + d_{queue} + d_{prop}) \times 3$ links $+ d_{transm}$

$= 3(5\mu sec + 0sec + \frac{100KM}{20000 KM/sec}) + \frac{1KB \times 8bits}{10^9 bytes}$

$= 3(0.005005) + \frac{2^{13}}{10^9}$

$L = 0.01523$ sec

d) $R1 = R2 = 2\,Mbps$ & $R3 = 1\,Mbps$

(a) $L = d_{nodal} = d_{transm\,R1,R2} + d_{transm\,R3} + 3(d_{proce} + d_{prop}) + d_{queue}$

$L = 2\left(\frac{1KB \times 8bytes}{2\times10^{9}}\right) + \frac{1KB \times 8bytes}{10^{6}} + 3\left(\frac{100\,km}{20{,}000\,km/s}\right) + \frac{2^{13}\,bits}{10^{6}}$

$L = 8.192\times10^{-6} + 8.192\times10^{-3} + 0.015 + 8.192\times10^{-3}$

$L = 0.03139\,sec$

(b) $L = d_{nodal} = d_{transm\,R1,R2} + d_{transm\,R3} + 3(d_{prop})$

$= 2\left(\frac{1KB \times 8bytes}{2\times10^{9}}\right) + \frac{1KB \times 8bytes}{10^{6}} + 3\left(\frac{100\,km}{20{,}000\,km}\right)$

$L = 0.0232\,sec$

e)

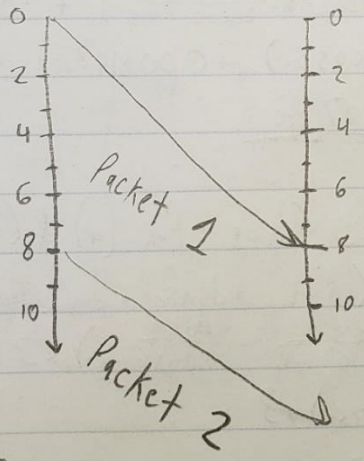
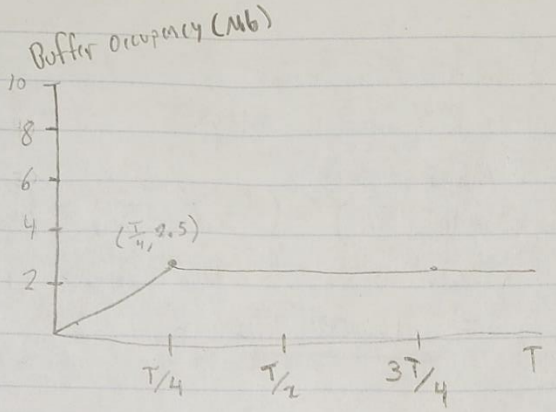


Figure 2

Problem 2]

(a)



b) The minimum value of R_0 must be 2.5 Mbps, since the throughput is 10 Mbps and there are 2 arriving traffic links

c) $D(R) \rightarrow T = \frac{L}{R} \rightarrow R = \frac{L}{T}$

d) $L(R) = \left(10\left(\frac{T}{4}\right) + 0\left(\frac{3T}{4}\right)\right) L$

$= 2.5\ L$

e) $L(R) = \lambda D(R)$

$2.5\ LT = 2.5\left(\frac{L}{T}\right)$

P3] a) In this case, circuit-switched network. The data flow is steady and predictable. It will be able to handle the set data flow to a complete bandwidth. It is because the data is so laid out for us, it is better to use circuit-switched network

b) If packet-switched network is used, the data sent by the application is less than the capabilities, therefore there will be no congestion. There will be enough bandwidth to not need a congestion device

P8] 3 Mbps link. 150 kbps transmission, but each user transmits only 10%

a) # users = $\frac{\text{transmission rate of user}}{\text{transmission required}} = \frac{3 \text{ Mbps}}{150 \text{ kbps}} = \frac{3 \times 10^6}{150 \times 10^3} = \frac{3000}{150}$

= 20 users

b) Probability is 10%

c) 120 users, n users transmitting, $p = .10$

Binomial cdf ($N = 120$, $p = 0.10$) $\rightarrow {}^{n}C_{n}(p)^{n}(1-p)^{N-n}$

$= {}^{120}C_{n}(0.1)^{n}(.9)^{120-n}$

← remove all less than 21 #

d) $P(X \geq 21) \rightarrow 1 - P(X \leq 20)$

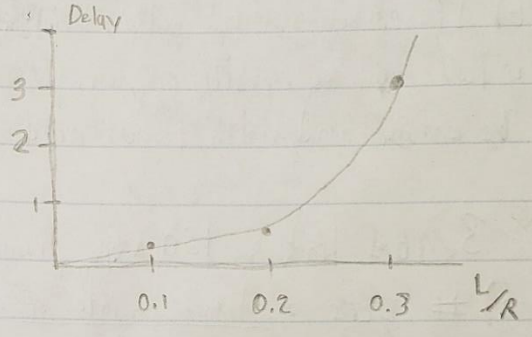
at least 21 $1 - \sum_{n=0}^{20} {}^{120}C_{n}(0.1)^{n}(0.9)^{120-n}$

P14] $I = La/R$, queueing delay: $IL/R(1-I)$ for $I<1$

a) Total Delay = $d_{transmission} + d_{queue}$

$$\frac{L}{R} + \frac{IR}{R(1-I)} \rightarrow \frac{L}{R}\left[1 + \frac{I}{1-I}\right] \text{ sec}$$

L/R	Delay
0	0
0.1	0.14
0.2	0.50
0.3	3



P16] N = average packets in buffer, a = rate of packets arriving

d = average total delay $N = a \cdot d$, 10 packets, 10 msec delay

a) $A = \frac{N}{d} \rightarrow \frac{10 \text{ packets}}{10 \text{ msec}} = \underline{0.01 \text{ packet per second}}$

b) Avg queueing delay at each node, so d = transm + queue

$= \frac{10}{.01}\text{ sec} + 10 \text{ msec} = 0.01 + 0.01$

$= 0.02$

$A = \frac{10 \text{ packets}}{0.02 \text{ sec}} = \underline{500 \text{ packets/sec}}$

Student Right-to-Know and Campus Security Act

Under the Student Right-to-Know and Campus Security Act, Florida International University will, upon request, make

(4)

P 18] Trace route

a) I chose Steadfast Networks (AS32748) in the US

Tracing route to lookingglass.cdi.steadfast.net via IPv4 from Chicago

Trace 1 @ 6PM 0.523 ms, 0.521 ms, 0.514 $\mu = 0.528$ ms $\sigma = 0.011$ ms

Trace 2 @ 11PM 0.499 ms, 0.495 ms, 0.426 ms $\mu = 0.473$ ms $\sigma = 0.041$

Trace 3 @ 12 AM 0.556 ms, 0.598 ms, 0.544 ms $\mu = 0.563$ ms $\sigma = .0321$

b) All trace routes showed 4 routers & the paths never changed

c) The traceroute passed through 3 ISP networks. In my experiment, the largest delay occured in peering interface between adjacent ISPs.

d) I tried to do a traceroute from New Jersey to UK, but the site never finished completing. I would assume that means that intercontinental trace route takes a longer time

Problem 25] 20,000 kilometers, direct link $R = 2$ Mbps, prop $= 2.5 \times 10^8$ m/s

a) Bandwidth = R × propagation delay

$= 2 \text{ Mbps} \times \left(\frac{d}{s}\right)$

$= (2 \times 10^6 \text{ bits/s}) \times \left(\frac{20{,}000 \times 1000 \text{ m}}{2.5 \times 10^8 \text{ m/s}}\right)$

$= (2 \times 10^6 \text{ bits/s}) \times (0.08 \text{ sec})$

$= 160{,}000$ bits

b) 800,000 bits, max bits?

File size does not matter as it does not effect the max bits able to be sent. It is the bandwidth that controls max bits, so it is 160,000 bits

c) Bandwidth-delay product is the maximum bits able to be on a transmission link

d) width (L) $\rightarrow \frac{\text{prop rate}}{\text{transmission rate}} = \frac{2.5 \times 10^8}{2 \text{ Mbps}} = \frac{2.5 \times 10^8}{2 \times 10^6} =$ 125 meters

A football field is 120 meters, so yes it is longer.

e) The equation for width of a bit is $\boxed{\frac{s}{d}}$, as used in the previous answer

Traceroute used for P18