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Part B

1) Calculate total delay

OCN

Data rate => 8×10^9 bps ⟶ To send all data: $\frac{800 \text{ bits}}{8\times10^9 \text{ bits/s}} = .1\times10^{-6}$ s

Node proc. delay => 0 + .5 ns/byte
$= (.5 \text{ ns/byte})(100 \text{ bytes})$
$= 50 \text{ ns} = 50\times10^{-9}$ s

link distance => .5 cm = $.5\times10^{-2}$ m

Speed of propagation => $200{,}000\times10^3$ m/s

Time to propagate link distance = $\frac{.5\times10^{-2} \text{ m}}{200{,}000\times10^3 \text{ m}} = 2.5\times10^{-11}$ s

Total delay => sum of 3 above = $.1\times10^{-6}$ s + 50×10^{-9} s + 2.5×10^{-11} s

Total Delay = $.15\times10^{-6}$ s

% of delay that is propagation = $\frac{2.5\times10^{-11} \text{ s}}{.15\times10^{-6} \text{ s}} \times 100\% = .0167\%$

SAN

Data rate remains the same, to send all data => $.1\times10^{-6}$ s

Total node delay => $.3\times10^{-6}$ s + $(.5\times10^{-9}$ s/byte$)(100$ byte)
$= .3\times10^{-6}$ s + 50×10^{-9} s
$= .35\times10^{-6}$ s

Link distance = 5 m

Time to propagate link distance = $\frac{5 \text{ m}}{200{,}000\times10^3 \text{ km/s}} = 25\times10^{-9}$ s

Total delay = sum of 3 = $.1\times10^{-6}$ s + $.35\times10^{-6}$ s + 25×10^{-9} s

Total Delay = $.475\times10^{-6}$ s

% of delay that is propagation = $\frac{25\times10^{-9} \text{ s}}{.475\times10^{-6} \text{ s}} \times 100\% = 5.263\%$

LAN

Data rate remains the same => $.1\times10^{-6}$ s

Total Node Delay => 3×10^{-6} s + $(.5\times10^{-9}$ s/byte$)(100$ bytes$)$
$= 3\times10^{-6}$ s + 50×10^{-9} s
$= 3.05\times10^{-6}$ s

Time to propagate link distance = $\frac{5000 \text{ m}}{200{,}000\times10^3 \text{ m/s}} = 25\times10^{-6}$ s

Total delay = $.1\times10^{-6}$ s + 3.05×10^{-6} s + 25×10^{-6} s
$= 28.15\times10^{-6}$ s

% of propagation delay = $\frac{25\times10^{-6} \text{ s}}{28.15\times10^{-6} \text{ s}} \times 100\% = 88.810\%$

WAN

Data rate remains the same => $.1\times10^{-6}$ s

Total Node Delay => 30×10^{-6} s + $(.5\times10^{-9}$ s/byte$)(100$ bytes$)$
$= 30\times10^{-6}$ s + 50×10^{-9} s
$= 30.05\times10^{-6}$ s

Link distance = $\frac{5000\times10^3 \text{ m}}{200{,}000\times10^3 \text{ m/s}} = .025$ s

Total delay = $.1\times10^{-6}$ s + 30.05×10^{-6} + .025
$= .025030155$ s

% of propa. delay = $\frac{.025 \text{ s}}{.025030155 \text{ s}} \times 100\% = 99.880\%$

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2)

a) $k(1\times10^{-3}\ s) + \frac{n(4000\ bits)}{100\times10^{6}\ bits/s}$, $n=1$ $k=2$

$= 2(1\times10^{-3}\ s) + \frac{2(4000\ b)}{100\times10^{6}\ b/s}$

$= 2\times10^{-3}\ s + .08\times10^{-3}\ s$

$= 2.08\times10^{-3}\ s$

b) $k(1\times10^{-3}\ s) + n(.04\times10^{-3}\ s)$

3) max. bps , Shannon's Theorem

a) max bps $= H\log_2(1+S/N)$

$H = 4\times10^{3}\ Hz$

$S/N = 127$

max bps $= (4\times10^{3}\ Hz)(\log_2(1+127))$

max bps $= 28{,}000$ bps

max framerate $= \frac{28{,}000\ bps}{3\ bit/frame} = 9{,}333\ fps$

b)

max bps $= H\log_2(1+S/N)$

$H = 4\times10^{3}\ Hz$

$S/N = 7$

max bps $= 4\times10^{3}\ Hz\left[\log_2(1+7)\right]$

max bps $= 12{,}000$ bps

max framerate $= \frac{12{,}000\ bps}{3\ bits/frame} = 4000\ frames/s$

4)

a) Each session receives $\frac{10\times10^{6}\ bps}{100\ sessions} = 100\times10^{3}$ bps

b) For $B = 10s$

number of other busy sessions $\sim (99)\left(\frac{10}{11}\right) = 90$

Total busy sessions $= 91$

Total data rate $= \frac{10\times10^{6}\ bps}{91\ sessions} = 109.89\times10^{3}$ bps

$B = 1s$, # busy sessions $\sim (99)\left(\frac{1}{2}\right) = 49.5$

Data rate $= \frac{10\times10^{6}\ bps}{50.5\ sec.} = 198.01\times10^{3}$ bps

For $B = 100\times10^{-3}\ s$

busy sessions $\sim (99)\left(\frac{.1s}{1.1s}\right) = 9$

Total data rate $= \frac{10\times10^{6}\ bps}{10\ sec.} = 1\times10^{6}$ bps

$B = 10\times10^{-3}\ s$

busy sessions $\sim (99)\left(\frac{.01s}{1.01s}\right) = .980$

Total data rate $= \frac{10\times10^{6}\ bps}{1.98\ sec.} = 5.05\times10^{6}$ bps

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5)

a) $RTT = 2d + (m/b)$, b = max bit rate
m = # of bits = 1000 bytes $\Rightarrow$ 8000 bits
RTT = Round Trip Time $\Rightarrow 50 \times 10^{-3}$ s / 2 only want 1 way $= 25 \times 10^{-3}$ s
d = node proc. delay $\Rightarrow$ negligible?

solve for b

$RTT = m/b$

$b = \frac{m}{RTT} = \frac{8000 \text{ bits}}{25 \times 10^{-3} \text{ s}} = 320 \times 10^3$ bps

b) max window size = 1

$\frac{(\text{data rate})(RTT)}{\text{packet size}} = \text{max window size}$

$\text{data rate} = \frac{(\text{m.win.size})(\text{p.size})}{RTT/2} = \frac{(1)(8000 \text{ bits})}{25 \times 10^{-3} \text{ s}} = 320 \times 10^3$ bps

max window size = 10

$\text{d.r.} = \frac{(10)(8000 \text{ bits})}{25 \times 10^{-3} \text{ s}} = 3.2 \times 10^6$ bps

max window size = 50

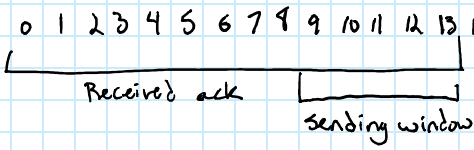
$\text{d.r.} = \frac{(50)(8000 \text{ bits})}{25 \times 10^{-3} \text{ s}} = 16 \times 10^6$ bps, over capacity, so 10×10^6 bps is maximum

c)

$\text{window size} = \frac{\text{d.r.}(RTT)}{\text{packet size}} = \frac{(10 \times 10^6 \text{ bps})(50 \times 10^{-3} \text{ s})}{8000 \text{ bits}}$

window size = 62.5, round up to 63

6)



Anything in the range: $[i - w + 1 \% 16, i + w \% 16]$

$: [13 - 5 + 1 \% 16, 13 + 5 \% 16]$

$: [9 \% 16, 18 \% 16]$

$: [9, 2]$