COMP431 Spring 2012 HW-4

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1 Q1

$$\begin{aligned} \text{Transmission speed: } & T1 = R = 1.5 \text{ Mbps} = 1.5 \times 10^6 \text{ bps} && (1) \\ \text{Propagation speed: } & s = 2.5 \times 10^8 \text{m/s} && (2) \\ \text{Length of physical link: } & d = 5000\text{km} = 5 \times 10^6 \text{m} && (3) \end{aligned}$$

1.1 a

bandwidth-delay product:

$$R \times T_{propagation} = R \times \frac{d}{s} = 1.5 \times 10^6 \text{ bps} \times \frac{5 \times 10^6 \text{ m}}{2.5 \times 10^8 \text{ m/s}} = 3 \times 10^4 \text{ bits} \quad (4)$$

1.2 b

If there is unlimited signal sending from the sender, the maximum bits on the link will be the bits sent by the sender during the propagation delay time, i.e. the bandwidth-delay product. Since 4.5×10^5 bits $> 3 \times 10^4$ bits, the maximum number of bits that will be in the link at any time is the smaller number, i.e. 3×10^4 bits. The link cannot hold all bits of 4.5×10^5 bits, some bits have arrived at the receiver.

1.3 c

The bandwidth-delay product is equal to the maximum amount of data residing on the network link at any given time. That is the data-synchronizing difference between the data has been sent and that has been delivered to the receiver. It shows the amount of data that has been transmitted but not yet received.

1.4 d

end-to-end delay:

$$T_{transmission} + T_{propagation} = \frac{L}{R} + \frac{d}{s} = \frac{4.5 \times 10^5 \text{ bits}}{1.5 \times 10^6 \text{ bps}} + \frac{5 \times 10^6 \text{ m}}{2.5 \times 10^8 \text{ m/s}} = 0.32 \text{ seconds} \quad (5)$$

1.5 e

$$\begin{aligned} T = & 49 \times \left(\frac{L = 9000 \text{ bits}}{R = 1.5 \times 10^6 \text{ bps}} + 2 \times \frac{d = 5 \times 10^6 \text{ m}}{s = 2.5 \times 10^8 \text{ m/s}} \right) && (6) \\ & +1 \times \left(\frac{L = 9000 \text{ bits}}{R = 1.5 \times 10^6 \text{ bps}} + \frac{d = 5 \times 10^6 \text{ m}}{s = 2.5 \times 10^8 \text{ m/s}} \right) && (7) \\ & = 2.28 \text{ seconds} && (8) \end{aligned}$$

1.6 f

1. a single package transmission time:

$$T_{transmission} = \frac{L}{R} = \frac{9000 \text{ bits}}{1.5 \times 10^6 \text{ bps}} = 0.006 \text{ seconds} \tag{9}$$

a single packege propagation time:

$$T_{propagation} = \frac{d}{s} = \frac{5 \times 10^6 \text{ m}}{2.5 \times 10^8 \text{ m/s}} = 0.02 \text{ seconds} \tag{10}$$

The arrival time of the 1st acknowledgement package to Router A:

$$T_{1st\_ackn} = \frac{L}{R} + 2 \times \frac{d}{s} = 0.046 \text{ seconds} \tag{11}$$

Assume packages are sent consecutively, then the number of sent packages is:

$$N_{sending} = \frac{T_{1stAckn}}{T_{transmission}} = 7.66667 \tag{12}$$

That is to say the 8th package are transmitting from Router A. Therefore $m_{max} = 8$.

2. Since $1 \leqslant m \leqslant 8$, When $1 \leqslant m \leqslant 7$, the sender must wait the first acknowledgement frame arrive before start shipping the $(m+1)$ frame. Therefore, the time is equal to the arrival time of 1st acknowledgement frame, i.e.

$$T_{sending\_m+1} = T_{1st\_ackn} = 0.046 \text{ if } 1 \leqslant m \leqslant 7 \tag{13}$$

When $m = 8$, since the mth package has not completed its shippment at the arrival time of the first acknowledgement package, the $(m+1)$th package shipping time is therefore equal to the sending-completion time of the mth package. i.e.

$$T_{sending\_m+1} = T_{sending-complete_m} = 8 \times T_{transmission} = 0.048 \text{ if } m = 8 \tag{14}$$

3. Simliar to the argument above,
when $1 \leqslant m \leqslant 7$,

$$T_{sending\_2m} = T_{1st\_ackn} + (m-1) \times T_{transmission} = 0.046 + 0.006(m-1) = 0.04 + 0.006m \tag{15}$$

when $m = 8$

$$T_{sending\_2m} = T_{transmission}(2m-1) = 0.006 \times 15 = 0.09 \tag{16}$$

4. when $1 \leqslant m \leqslant 7$, and $\left\lfloor \frac{50}{m} \right\rfloor$ is not an integer

$$T_{total} = T_{1st\_ackn} \times \left\lfloor \frac{50}{m} \right\rfloor + T_{transmission} \times \left(50 - m \left\lfloor \frac{50}{m} \right\rfloor\right) + T_{propagation} \tag{17}$$

$$= 0.046 \times \left\lfloor \frac{50}{m} \right\rfloor + 0.006 \times \left(50 - m \left\lfloor \frac{50}{m} \right\rfloor\right) + 0.02 \tag{18}$$

when $1 \leqslant m \leqslant 7$, and $\left\lfloor \frac{50}{m} \right\rfloor$ is an integer

$$T_{total} = T_{1st\_ackn} \times \left(\left\lfloor \frac{50}{m} \right\rfloor - 1\right) + T_{transmission} \times m + T_{propagation} \tag{19}$$

$$= 0.046 \times \left(\left\lfloor \frac{50}{m} \right\rfloor - 1\right) + 0.006 \times m + 0.02 \tag{20}$$

when $m = 8$,

$$T_{total} = T_{sending\_m+1} \times \left\lfloor \frac{50}{8} \right\rfloor + T_{transmission} \times \left(50 - 8 \left\lfloor \frac{50}{8} \right\rfloor\right) + T_{propagation} \tag{21}$$
$$= 0.048 \times \left\lfloor \frac{50}{8} \right\rfloor + 0.006 \times \left(50 - 8 \times \left\lfloor \frac{50}{8} \right\rfloor\right) + 0.02 = 0.32 \tag{22}$$

Which computed table is

m	1	2	3	4	5	6	7	8
T	2.28	1.136	0.768	0.584	0.464	0.4	0.348	0.32

2 Q2

$$\text{Transmission speed: } T1 = R = 600 \text{ Mbps} = 6 \times 10^8 \text{ bps} \tag{23}$$
$$\text{Propagation speed: } s = 2.5 \times 10^8 \text{m/s} \tag{24}$$
$$\text{Length of physical link: } d = 5000\text{km} = 5 \times 10^6 \text{m} \tag{25}$$

2.1 a

bandwidth-delay product:

$$R \times T_{propagation} = R \times \frac{d}{s} = 6 \times 10^8 \text{ bps} \times \frac{5 \times 10^6 \text{ m}}{2.5 \times 10^8 \text{ m/s}} = 1.2 \times 10^7 \text{ bits} \tag{26}$$

2.2 b

Since 4.5×10^5 bits $< 1.2 \times 10^7$ bits, the maximum number of bits that will be the total bits that Router A will send in total i.e. 4.5×10^5 bits

2.3 d

end-to-end delay:

$$T_{transmission} + T_{propagation} = \frac{L}{R} + \frac{d}{s} = \frac{4.5 \times 10^5 \text{ bits}}{6 \times 10^8 \text{ bps}} + \frac{5 \times 10^6 \text{ m}}{2.5 \times 10^8 \text{ m/s}} = 0.02075 \text{ seconds} \tag{27}$$

2.4 e

$$T = 49 \times \left(\frac{L = 9000 \text{ bits}}{R = 6 \times 10^8 \text{ bps}} + 2 \times \frac{d = 5 \times 10^6 \text{ m}}{s = 2.5 \times 10^8 \text{ m/s}}\right) \tag{28}$$
$$+1 \times \left(\frac{L = 9000 \text{ bits}}{R = 6 \times 10^8 \text{ bps}} + \frac{d = 5 \times 10^6 \text{ m}}{s = 2.5 \times 10^8 \text{ m/s}}\right) \tag{29}$$
$$= 1.98075 \text{ seconds} \tag{30}$$

2.5 f

1. a single package transmission time:

$$T_{transmission} = \frac{L}{R} = \frac{9000 \text{ bits}}{6 \times 10^8 \text{ bps}} = 1.5 \times 10^{-5} \text{ seconds} \tag{31}$$

   a single packege propagation time:

$$T_{propagation} = \frac{d}{s} = \frac{5 \times 10^6 \text{ m}}{2.5 \times 10^8 \text{ m/s}} = 0.02 \text{ seconds} \tag{32}$$

   The arrival time of the 1st acknowledgement package to Router A:

$$T_{1st\_ackn} = \frac{L}{R} + 2 \times \frac{d}{s} = 0.040015 \text{ seconds} \tag{33}$$

   Assume packages are sent consecutively, then the number of sending package is:

$$N_{sending} = \frac{T_{1stAckn}}{T_{transmission}} = 2667.67 \tag{34}$$

   That is to say the 2668th package are transmitting from Router A. Therefore $m_{max} = 2668$.

2. Since $1 \leqslant m \leqslant 2668$, When $1 \leqslant m \leqslant 2667$, the sender must wait the first acknowledgement frame arrive before start shipping the $(m+1)$ frame. Therefore, the time is equal to the arrival time of 1st acknowledgement frame, i.e.

$$T_{sending\_m+1} = T_{1st\_ackn} = 0.040015 \text{ if } 1 \leqslant m \leqslant 2667 \tag{35}$$

   When $m = 2668$, since the mth package has not completed its shippment at the time of the first acknowledgement package arrives, the $(m+1)$th package shipping time should be equal to the sending-completion time of the mth package. i.e.

$$T_{sending\_m+1} = T_{sending-complete_m} = 2668 \times T_{transmission} = 0.04002 \text{ if } m = 2668 \tag{36}$$

3. Simliar to the argument above,
   when $1 \leqslant m \leqslant 2667$,

$$\begin{aligned} T_{sending\_2m} &= T_{1st\_ackn} + (m-1) \times T_{transmission} && (37) \\ &= 0.040015 + 0.000015(m-1) = 0.04 + 0.000015m && (38) \end{aligned}$$

   when $m = 2668$

$$\begin{aligned} T_{sending\_2m} &= T_{transmission}(2m-1) && (39) \\ &= 0.000015 \times 5335 = 0.080025 && (40) \end{aligned}$$

4. when $1 \leqslant m \leqslant 49$, and $\lfloor \frac{50}{m} \rfloor$ is not an integer

$$\begin{aligned} T_{total} &= T_{1st\_ackn} \times \left\lfloor \frac{50}{m} \right\rfloor + T_{transmission} \times \left(50 - m \left\lfloor \frac{50}{m} \right\rfloor\right) + T_{propagation} && (41) \\ &= 0.040015 \times \left\lfloor \frac{50}{m} \right\rfloor + 0.000015 \times \left(50 - m \left\lfloor \frac{50}{m} \right\rfloor\right) + 0.02 && (42) \end{aligned}$$

when $1 \leqslant m \leqslant 49$, and $\lfloor \frac{50}{m} \rfloor$ is an integer

$$T_{total} = T_{1st\_ackn} \times \left(\left\lfloor \frac{50}{m} \right\rfloor - 1 \right) + T_{transmission} \times m + T_{propagation} \tag{43}$$
$$= 0.040015 \times \left(\left\lfloor \frac{50}{m} \right\rfloor - 1 \right) + 0.000015 \times m + 0.02 \tag{44}$$

when $50 \leqslant m \leqslant 2668$,

$$T_{total} = 50 \times T_{transmission} + T_{propagation} \tag{45}$$
$$= 50 \times 0.000015 + 0.02 = 0.02075 \tag{46}$$

Which computed table is

frames	m	Cycles	left	T
50	1	49	1	1.98075
50	2	24	2	0.98039
50	3	16	2	0.66027
50	4	12	2	0.50021
50	5	9	5	0.38021
50	6	8	2	0.34015
50	7	7	1	0.30012
50	8	6	2	0.26012
50	9	5	5	0.22015
50	10	4	10	0.18021
50	11	4	6	0.18015
50	12	4	2	0.18009
50	13	3	11	0.14021
50	14	3	8	0.140165
50	15	3	5	0.14012
50	16	3	2	0.140075
50	17	2	16	0.10027
50	18	2	14	0.10024
50	19	2	12	0.10021
50	20	2	10	0.10018
50	21	2	8	0.10015
50	22	2	6	0.10012
50	23	2	4	0.10009
50	24	2	2	0.10006
50	25	1	25	0.06039

frames	m	Cycles	left	T
50	26	1	24	0.060375
50	27	1	23	0.06036
50	28	1	22	0.060345
50	29	1	21	0.06033
50	30	1	20	0.060315
50	31	1	19	0.0603
50	32	1	18	0.060285
50	33	1	17	0.06027
50	34	1	16	0.060255
50	35	1	15	0.06024
50	36	1	14	0.060225
50	37	1	13	0.06021
50	38	1	12	0.060195
50	39	1	11	0.06018
50	40	1	10	0.060165
50	41	1	9	0.06015
50	42	1	8	0.060135
50	43	1	7	0.06012
50	44	1	6	0.060105
50	45	1	5	0.06009
50	46	1	4	0.060075
50	47	1	3	0.06006
50	48	1	2	0.060045
50	49	1	1	0.06003
50	⩾50	0	50	0.02075

3 Q3

3.1 a

$$T_a = N \times \frac{(F+h) \text{ Bytes}}{R \text{ bits/s}} = \frac{8N(F+h)}{R} \text{ seconds} \tag{47}$$

3.2 b

$$T_b = (M-1)\frac{8(P+h)}{R} + N\frac{8(P+h)}{R} = \frac{8(M+N-1)(P+h)}{R} \text{ seconds} \tag{48}$$

3.3 c

$$T_c = T_s + \frac{8(M+N-1)(P+h/2)}{R} \text{ seconds} \tag{49}$$

3.4 d

$$T_d = T_s + \frac{8(F+h/2)}{R} \text{ seconds} \tag{50}$$

3.5 e

$$T_b - T_d < 0 \tag{51}$$

$$\Longrightarrow 8 \times \frac{(N-1)P + (M+N-3/2)h}{R} < T_s \tag{52}$$

$$\Longrightarrow T(P,h,N) = \frac{8}{R}\left((N-1)P + \frac{Fh}{P} + (N-3/2)h\right) < T_s \tag{53}$$

From the above formula, T(P, h, N) is increasing with respect to h and N. Therefore to minimize $T(P,h,N)$, the header size and the number of links between A and B should be sufficiently small. For fixed h and N, according to the mathmatical formula:

$$a + b \geqslant \sqrt{ab} \text{ '=' holds if and only if } a = b \tag{54}$$

we have,

$$T(P,h,N) \geqslant \frac{8}{R}\left(2\sqrt{(N-1)P \times \frac{Fh}{P}} + (N-3/2)h\right) \tag{55}$$

$$= \frac{8}{R}\left(2\sqrt{(N-1)Fh} + (N-3/2)h\right) \tag{56}$$

where the minimum is achieved when

$$P = \sqrt{\frac{Fh}{N-1}} \tag{57}$$

Therefore, in order to make the packet-switched network provide a faster transfer speed. We should make the added file header size(h) small and decrease the number of hops(N), and chose the package size according to the above formula.

4 Q4

The sender generates one byte immediately after one sampling. however, the receiver must wait for the arrival of an entire package before the first byte can be converted.

$$T_{oneSample} = \frac{48 \times 8 \text{ bits}}{8000/s \times 8 \text{ bits}} = \frac{48}{6000} = 0.006 \text{ seconds} \tag{58}$$

4.1 a

$$T = T_{oneSample} + T_{transmission} + T_{propagation} \tag{59}$$
$$= 0.006 + \frac{60 \times 8 \text{ bits}}{1.5 \times 10^6 \text{ bps}} + 10 \times 10^{-3} \text{ seconds} = 0.01632 \text{ seconds} \tag{60}$$

4.2 b

$$T = T_{oneSample} + T_{transmission} + T_{propagation} \tag{61}$$
$$= 0.006 + \frac{60 \times 8 \text{ bits}}{30 \times 1.5 \times 10^6 \text{ bps}} + 10 \times 10^{-3} \text{ seconds} = 0.0160107 \text{ seconds} \tag{62}$$

The improved elasped time delay was due to the decreased transmission delay, but since the propagation delay takes the major role in this link. The improvement is limited.

5 Q5

$$L = 1.0 \times 10^4 \text{ bits} \tag{63}$$
$$a = 9.0 \times 10^4 \text{ frames/s} \tag{64}$$
$$R = 1.0 \times 10^9 \text{ bps} \tag{65}$$

5.1 a

$$I = \frac{La}{R} = \frac{1.0 \times 10^4 \times 9.0 \times 10^4}{1.0 \times 10^9} = 0.9 \tag{66}$$
$$q = \frac{I}{1 - I} = 9 \tag{67}$$
$$T_{transmission} = \frac{L}{R} = \frac{1.0 \times 10^4}{1.0 \times 10^9} = 0.00001 \tag{68}$$
$$T_{queuing} = q \times T_{transmission} = 0.00009 \text{ seconds} \tag{69}$$

5.2 b

$$T_{delay} = T_{queuing} + T_{transmission} \tag{70}$$
$$= 0.00009 + 0.00001 = 0.0001 \text{ seconds} \tag{71}$$

5.3 c

$$
\begin{aligned}
T_{delay} &= T_{queuing} + T_{transmission} && (72)\\
&= q \times T_{transmission} + T_{transmission} && (73)\\
&= (q+1)T_{transmission} && (74)\\
&= \left(\frac{I}{1-I} + 1\right) T_{transmission} && (75)\\
&= \left(\frac{1}{1-La/R}\right)\frac{L}{R} && (76)\\
&= \frac{L}{R-La} && (77)\\
&= 1.0989 \times 10^{-6} \text{ seconds} && (78)
\end{aligned}
$$