University of Southern California
"EE450: Introduction to Computer Networks"
Midterm Exam, 2:10 hour
March 3, 2017

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Undergraduate Graduate

Part 1: True/False	26%	20
Part 2: Quickies	24%	17
Part 3: Error Detection	15%	15
Part 4: Delay/Throughput	15%	13
Part 5: Error & Flow Control	20%	6
Total	100%	

71

Notes:

- All your answers should be on the exam paper.
- You can work the problems in any order you wish (the goal is to try to accumulate as many points as you can). If you get stuck in one problem, go to another. Also don't waste your time giving irrelevant (not requested) details.

Rules:

- This is a closed book, closed notes exam. You are only allowed one post card 5"x7" of formulas ONLY and a Calculator
- Adherence to the University's Code of Ethics will be strictly monitored and enforced. Academic Integrity violations, such as cheating, will result in a series of actions and penalties including the student failing the class.

1. <u>True or False</u>

F a. In stop and wait ARQ, the receiver always send an ACK frame each time it receives a frame with the wrong sequence number

Discard duplicate frame
Send ACK.

F b. The BW x Delay product is the maximum # of bits/sec that can fill the "pipe"

F c. A socket is a protocol that defines the messages exchanged between the application layer and the Network Operating System

T d. Web caching maybe used to reduce the response time as experienced by the user. It may also reduce the load on the link and the load on the web server

T e. Broadcasting the ARP reply (instead of unicasting) may reduce the amount of ARP requests on the network.

F f. In Persistent HTTP, a single TCP connection can transfer multiple images or other embedded objects in on HTML page regardless on whether they all come from the same server or not

T g. Queuing delays may be reduced by increasing the transmission bit rate and reducing the distance between end hosts

T h. In Statistical Multiplexing, the number of time slots in each frame is less than the number of input lines to the Multiplexer

F i. SMTP is a protocol used by an e-mail client to retrieve e-mails from a mail server

T j. HTML protocol transfers files that make up pages on the world wide web

T k. ARP is a protocol used to resolve the "next hop IP address" to its MAC address.

T l. S&W ARQ Works well when propagation time is much less than transmission time

$t_p \ll t_t$

T m. Iterative DNS queries require shorter socket connections with DNS servers than recursive DNS requests

T n. Applications using UNIX Sockets allow users to specify destination hosts by their names or IP addresses.

F o. A DHCP server must be located on every network to assign IP addresses to DHCP clients on that network

T F p. If a computer has multiple Network Interface Cards, The DHCP process must occur separately over each interface to obtain a separate dynamically assigned IP address for each interface.

T q. In the absence of any frame loss or duplication, the S&W ARQ protocol would not need any frame sequencing

F r. Transport Control Protocol is a reliable protocol that can provide guarantees about reliability, bandwidth and latency for each connection

T F s. UDP does not guarantee that you'll only receive the packet once. If you have badly configured networks, you can receive the same packet multiple times

F t. A client computer on a shared network is assigned a MAC address and an IP address by the network administrator

T u. Server name resolution is done by using the address resolution protocol (ARP).

T v. ICANN must authorize the creation of every new domain name

T w. A Process X running in a server machine has a port number of 100. Two hosts A and B each send a UDP datagram to the Server with destination port #100. Both of these datagram will be directed to the same socket.

UDP identified by destination IP & port No.

F x. To be able to recover the analog signal from its sample, the sampling period frequency has to be at least twice the highest frequency component in the signal being sampled

T y. To use a proxy server, the client must be configured to access the proxy instead of the target server.

T z. Two sockets form a bi-directional communications path between two applications.

-6

Part 2: Quickies (every blank is worth 1 point)

1. Consider a transmission link that uses the stop and wait protocol. The ratio of the propagation delay to the transmission time is 5. Frames are transmitted at a rate of 10 Mbps and each frame is 1k bits long. Bits propagate at the speed of light (2×10^8 m/sec)

   a. The length of the link is 100000 meters
   b. The link efficiency (utilization) is 9.09 %

2. Five sources are multiplexed using FDM on a link that has a total bandwidth of 8000 Hz. The maximum bandwidth for each source if there must be a 200 Hz guard band between the channels is 1440 Hz

3. You are designing a Go-Back-N sliding window protocol to be used over a 100 Mbps link from a sender to a receiver at a distance of 10,000 Km. Each frame carry 100 Kbits of data. The speed of light is 2×10^8 m/sec. It is desired to keep the "pipe" full. The maximum sender window size should be 127 100 frames. The minimum number of bits you need for sequencing the frames is 7 bits. If selective reject protocol was used instead, the minimum number of bits you would need to sequence the frames is 7 bits

   RTT = Tt + 2Tp
   Tp = 0.05 s
   Tt = 0.001 s
   |0|-1
   |0|-1
   2^{n-1}
   ? SNS ≤ # of fr

4. Bit stuffing procedure is performed on the following binary sequence: 11011111010111111110110101. The T/x pattern is 110111110010111110110101

5. The bit duration on a T1 line is 0.648×10^{-6} seconds

   $\frac{1}{1.544}$

6. Suppose that Alice wants to send an email message to Bob. This will involve four entities: Alice's mail client (for email composition and sending), Alice's outgoing mail server, Bob's incoming mail server, and Bob's mail client (for email retrieval and viewing). The number of times SMTP Protocol is used is 2.

7. You desire to download a certain html web page. The web page contains 2 images, 1 applet, and 3 images embedded within the applet (i.e. you need to open the applet first before you can see the images). How many RTTs does it take to download all of the above (including the html file) if

a. Non-Persistent HTTP is used? 14 RTTs

b. Persistent HTTP without Pipelining? 8 RTTs

c. Persistent HTTP with Pipelining? 5 RTTs

8. We have 3 information sources, two of which generate traffic at a rate of 200 bps each. The third one generates traffic at a rate of 250 bps. They are to be multiplexed using multiple-slot (each slot supporting 1 bit), synchronous TDM. Each source is active 50% of the time. Ignore any synchronization bits.

a. The length of the TDM frame is = 3 bits

b. The duration of the TDM frame is 4.6×10^{-3} sec

c. The TDM frame rate is 216.7 frames/sec

d. The multiplexed rate is 650 bps

e. The output of the multiplexor is applied to a 8-QAM modem. The signaling rate at the output of the modem is 216.7 Baud

9. A video signal is 6 MHz wide. It is sampled at the Nyquist sampling rate and then quantized using 64-levels and then encoded. The bit rate of the digital stream is 72M bps

10. Assume that you have 8 input sources as follows: Three sources generates 1 Kbps (each), 75% of the time, Three sources generates 2 Kbps (each), 50% of the time and two sources generates 6 Kbps, 25% of the time. A Statistical TDM with a link utilization of 80% is used. The required data rate at the output of the MUX is 10312.5 bps.

11. A channel with bandwidth of 4 KHz. It is desired to transmit data reliably at a rate of 50 Kbps over this channel. The minimum signal to noise ratio required is 37.6 dB

50k = 4 log₂(1+SNR)
SNR = 2^12.5 − 1
10 log₁₀(2^12.5 − 1)

12. A 64 Kbyte message is to be transmitted over a 2-hop packet network. The network limits the size of the packet to 1 Kbytes. The links are error free and each has speed of 50 Mbps. Each hop is 100 Km long and the bits are transmitted at the speed of light of 2×10^8 m/sec. It will take 11.24×10⁻³ seconds for the message to get from the source to the destination. Ignore processing and queuing delays.

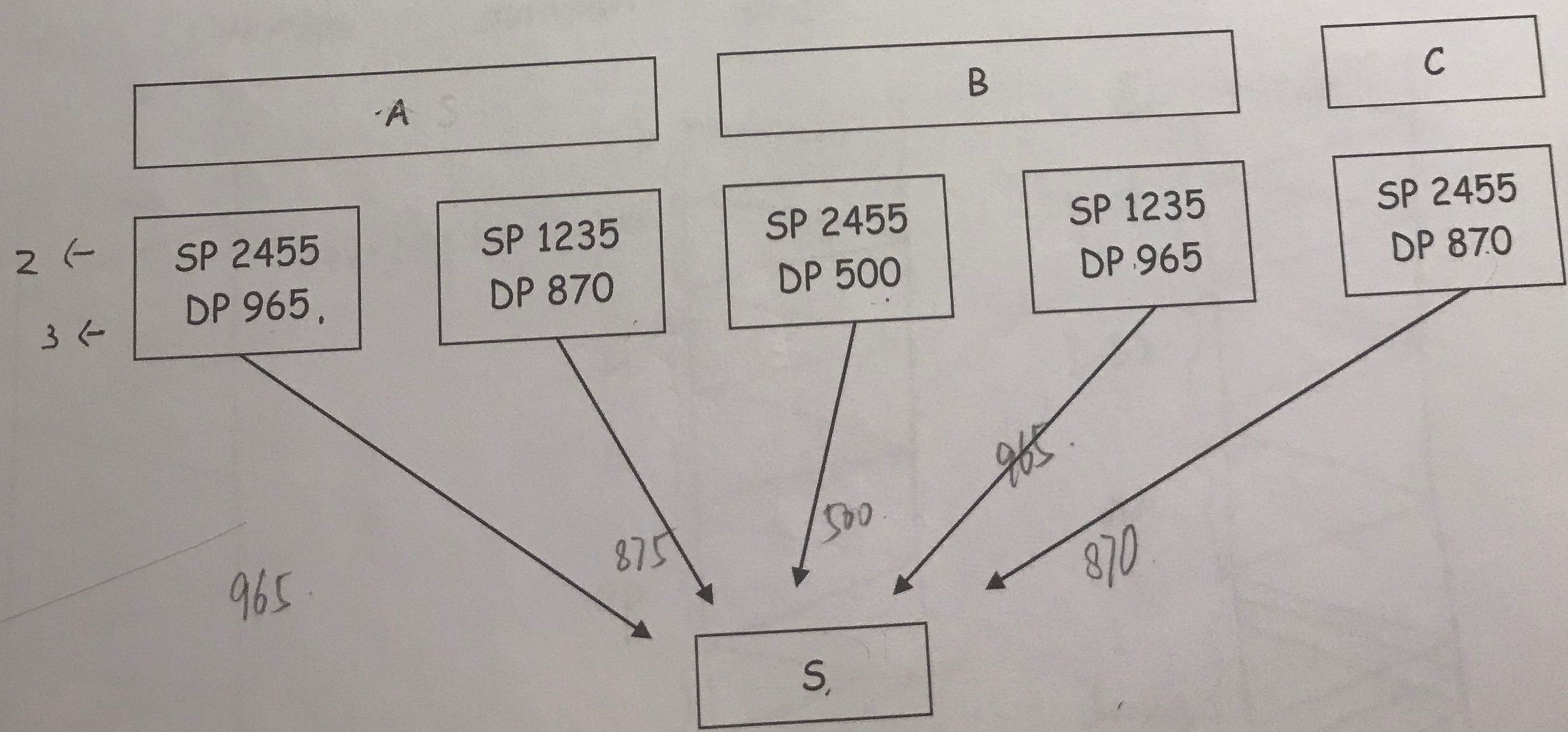
11.4×10⁻³

13. Three nodes A, B, C are communicating with a server node S. with the indicated Source and Destination Port numbers. From this diagram determine, what is the "total" number of sockets does S have to open assuming

a. UDP Sockets: 4 3

b. TCP Sockets: 9 8

−7



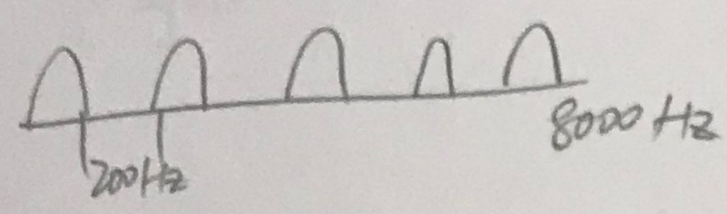
Work Sheet#1

Part 2: 1. S&W $\frac{d_p}{d_t} = 5$ 10Mbps. 1000 bits/frame 2×10^8 m/sec.

$d_t = \frac{1000}{10M} = \frac{1000}{10^7} = 10^{-4}$ sec. $\therefore d_p = 5\times10^{-4}$ sec. Link length $= d_p \times 2\times10^8 = 5\times2\times10^{-4}\times10^8 = 10\times10^4$ m.

$Eff = \frac{1000}{10\times10^6\times RTT} = \frac{1000}{10^7\times(10\times10^{-4}+10^{-4})} = \frac{1000}{10^7\times11\times10^{-4}} = \frac{1000}{11\times10^3} = \frac{1}{11}$

2. 5 sources



$5B + 4\times200 = 8000$.
$5B = 7200$
$B =$

3. G-B-N. $2^m - 1$

100Mbps 10000 km 100k bits/frame 2×10^8 m/sec

$\# frame = \frac{100M\times RTT}{100k \text{ bits}} = \frac{100M\times\left(\frac{100k}{100M} + 2\times\frac{10000k}{2\times10^8}\right)}{100k} = \frac{10^8\times(10^{-3}+2\times0.5\times0.1)}{100k\cdot10^5}$

$= 1000\times10^{-3} + 1000\times0.1$
$= 101$.

$SWS \le 2^m - 1$
$2^7 - 1$

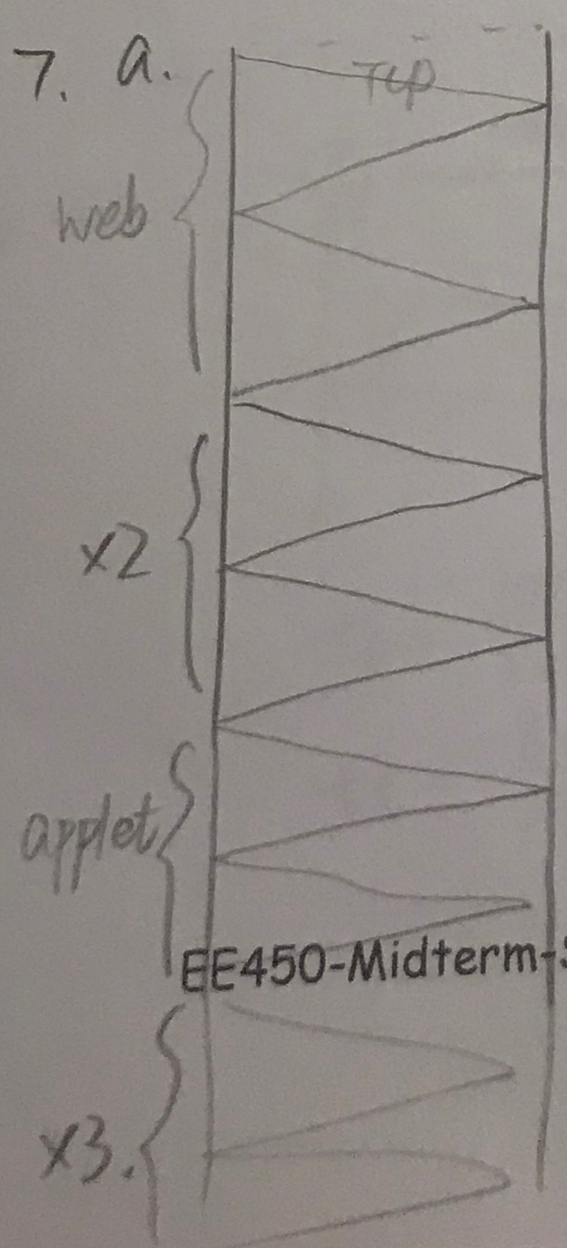
$2^m - 1 \ge 100$.
$2^m \ge 101$. $m \ge 7$.
$(2^7 = 128)$

$SWS \le 2^{m-1}$. $2^m \ge 101$.

$2^6 = 2^3\times2^3 = 64\times2 = 128$

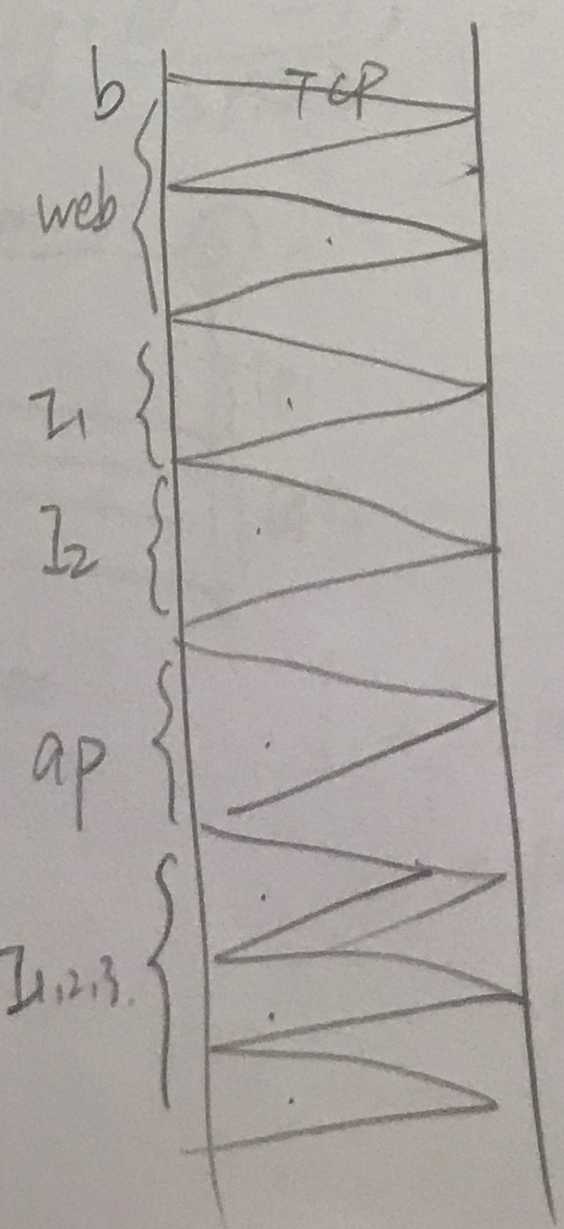
5. T_1: 1.544 Mbps. duration $= \frac{1}{1.544\times10^6} = 0.648\times10^{-6}$.

7. a.

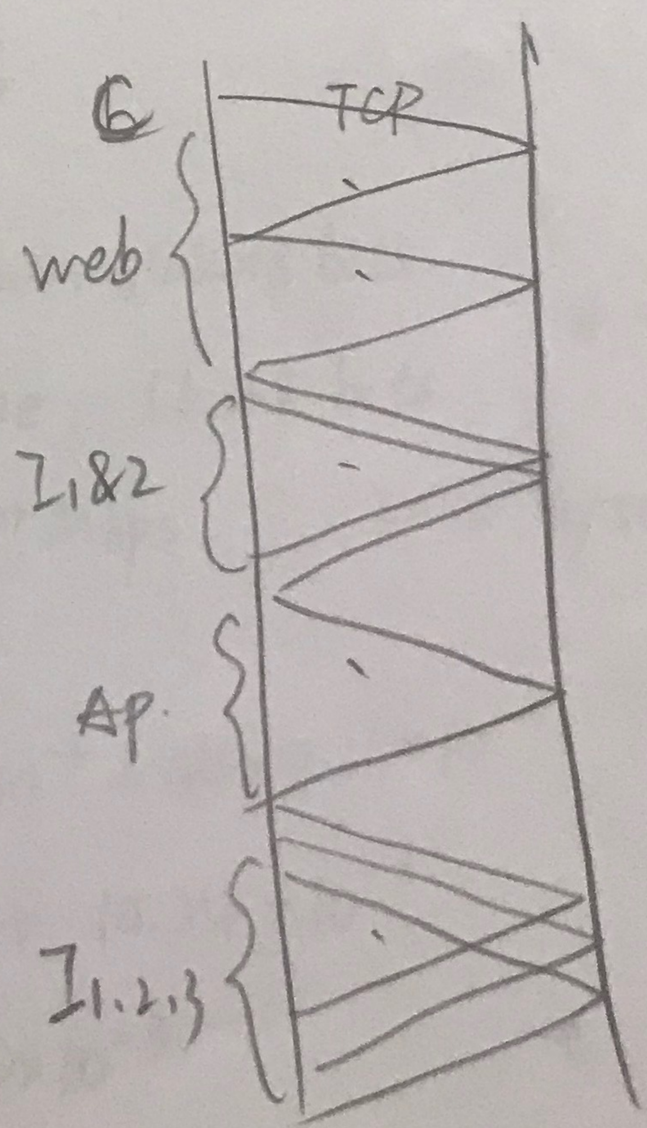


$2+2\times2+2+2\times3$

b

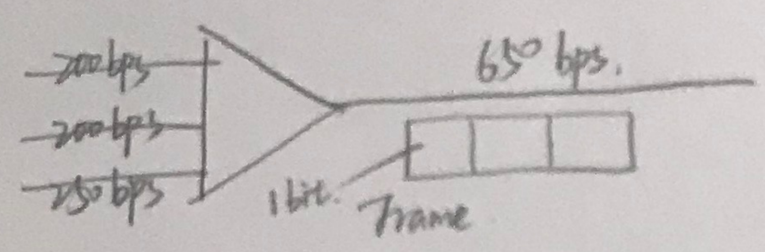


c



Work Sheet#2

8.



50% time active.

Frame rate $= \frac{650 \text{ bps}}{3 \text{ bps}} = 216$ frame/s

$\frac{650 \text{ bits}}{\text{sec}} = \frac{3 \text{ bits}}{\text{frame}}$ duration

Baud rate $= \frac{650}{\log_2 8} = \frac{650}{3}$.

9. 12Msample/s. $\times$ $\log_2 64 = 12 \times 6$

10. 3 — 1kbps. 75%
3 — 2kbps. 50%
2 — 6kbps. 25%.

$\rho = \frac{0.75 \times 3 \times 1k + 0.5 \times 3 \times 2k + 0.25 \times 2 \times 6k}{R}$.

$\rho \downarrow 0.8$

$\therefore R = \frac{2.25k + 3k + 3k}{0.8} = \frac{8.25k}{0.8} = 1$

11. $B = 4kHz$. $R = 50kbps$. S/N

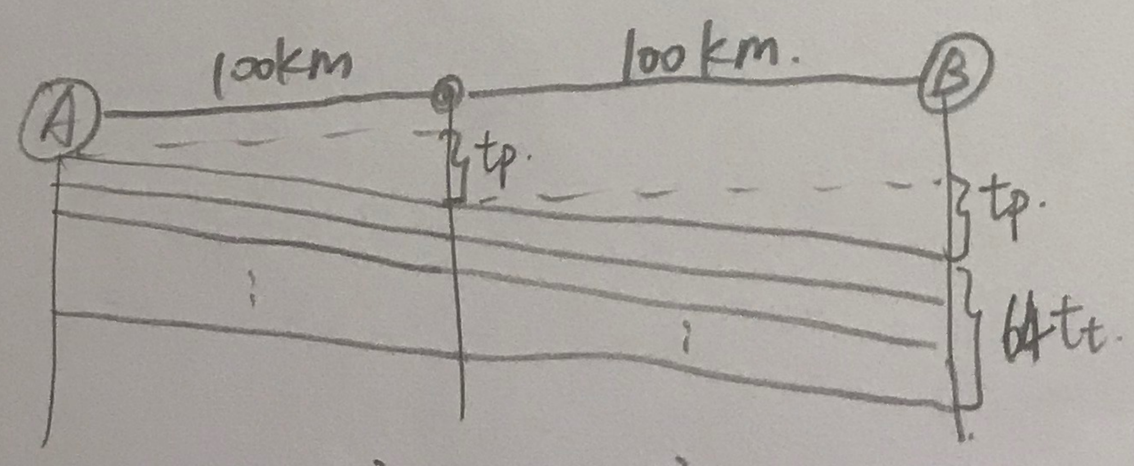
$50k = 4k \cdot \log_2(1 + S/N)$

$12.5 = \log_2(1+S/N) = \frac{\lg(1+S/N)}{\lg 2}$

$\lg(1+S/N) = 3.763$. $S/N = 10^{3.763} - 1$

$S/N\ dB = 10\log_{10}(S/N) = 10\lg\left(\frac{10^{3.763} - 1}{5793.3}\right) = 37.6$

12.



packet: 64k×8 bits. # = 64.

size: 1k×8 bits.

50 Mbps. 2×10^8 m/sec

$t_p = \frac{100 \times 10^3}{2 \times 10^8} = 0.5 \times 10^{-3}$ sec

$t_t = \frac{8 \times 10^3}{50 \times 10^6} = 0.16 \times 10^{-3}$

$\therefore t = 2 \times 0.5 \times 10^{-3} + 64 \times 0.16 \times 10^{-3}$

$= 10^{-3} + 10.24 \times 10^{-3}$.

$= 11.24 \times 10^{-3}$.

Work Sheet#3

13.

3. An FCS error detection mechanism is used over a communications link. The message bit sequence is ~~11100011~~ 11101. An FCS generator pattern of 1001 is used to generate the FCS sequence.

a) How many FCS bits are generated? What are they? What is the transmitted bit sequence? Identify the FCS bits in that sequence. Show details of your work.

b) Now suppose the received sequence is 11001010. Did errors occur? Will the receiver detect the errors? Prove your answer

c) Now suppose the channel introduces the following error sequence 10010111. Will the receiver be able to detect the error? Prove your answer analytically.

a) 3 FCS bits are generated.

```
        1111
1001 ) 11101000
       1001
        1111
        1001
         1100
         1001
          1010
          1001
           110
```

∴ the FCS bits is 110

the transmitted bits sequence is

11101110.
FCS bits

(b) The errors occur because the received sequence is different with transmitted sequence.

```
        1101
1001 ) 11001010
       1001
        1011
        1001
         1001
         1001
          000
```

because the remain is "000", the receiver does not detect the errors.

Work Sheet#4

(c) the received sequence is:

$$
\begin{array}{r}
11101110 \\
\oplus\ 10010111 \\
\hline
01111001
\end{array}
$$

$$
\begin{array}{r|l}
 & 1110 \\
\hline
1001 & 01111001 \\
 & 1001 \\
\hline
 & 1100 \\
 & 1001 \\
\hline
 & 1010 \\
 & 1001 \\
\hline
 & 111
\end{array}
$$

∵ the remain is not '000', the receiver is able to detect the error.

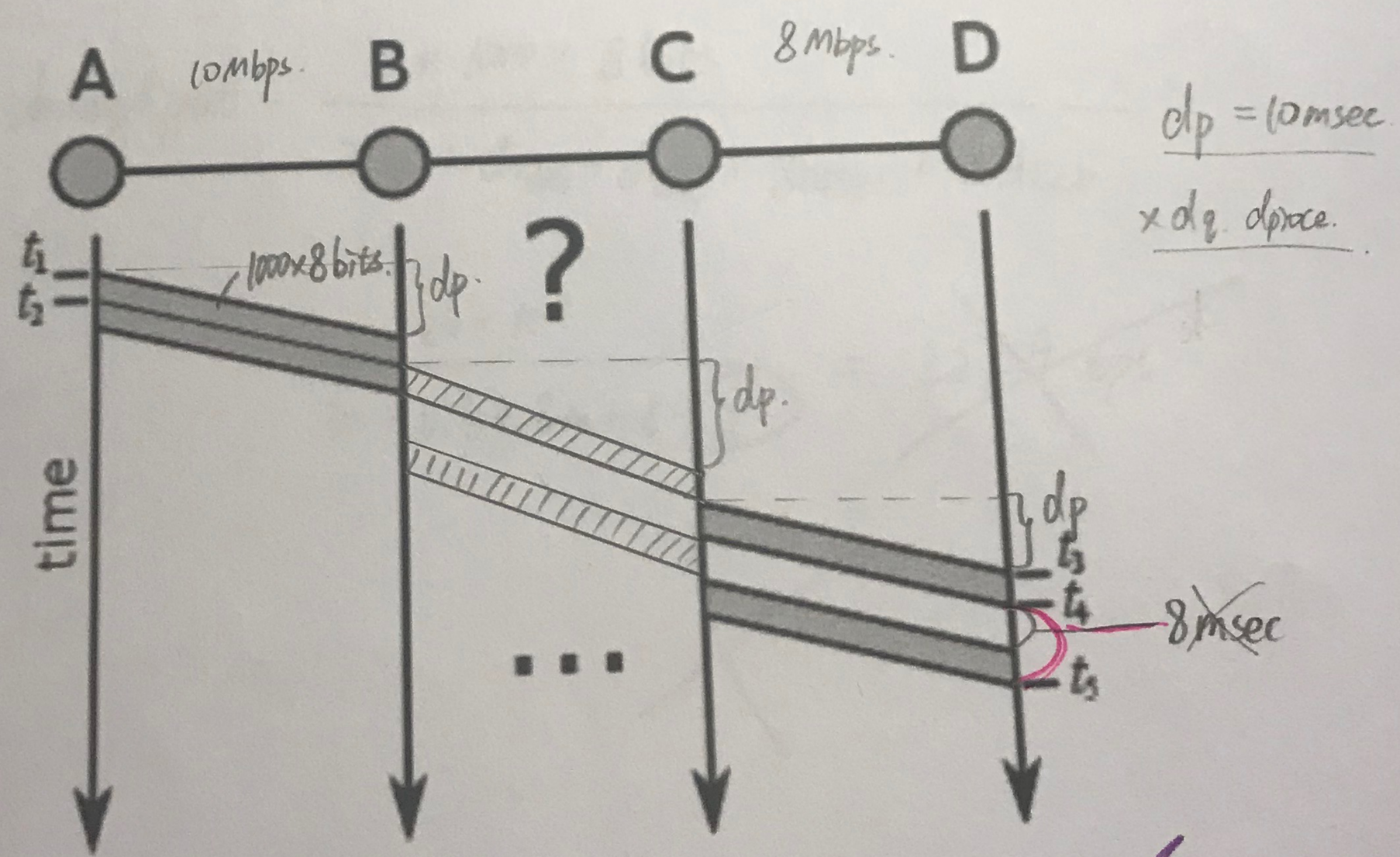
Part 4:

Consider the following technique used to estimate the bottleneck bandwidth in a network. Consider the following setup. Link AB has a bandwidth of 10 Mbps. Link CD has bandwidth of 8 Mbps. All three links have propagation delay of 10 msec. Assume that there is no Queuing or processing delay. Nodes (B and C) can forward a packet as soon as

a. The entire Packet has been received **AND**

b. The outgoing link is free.

Two packets, each 1000 Bytes long, were transmitted consecutively as shown below. The delay between the end of receptions of the two packets was measured to be 8 msec. Draw the transmissions of the packets over link BC and estimate its bandwidth and explain your reasoning. Calculate the end-to-end throughput.



$$d_{t_{AB}} = \frac{1000 \times 8 \text{ bits}}{10 \text{ Mbps}} = 8 \times 10^{-4} \text{ sec} = 0.8 \text{ msec}$$

$$d_{t_{CD}} = \frac{1000 \times 8 \text{ bits}}{8 \text{ Mbps}} = 1 \times 10^{-3} \text{ sec} = 1 \text{ msec}$$

Work Sheet#5

because both node B and C has to forward the first packet after receive the whole packet. then for the second packet from B to C. the transmission time is equal to the delay of the receptions of 1 and 2.

$$\therefore \quad \frac{1000 \times 8 \text{ bits}}{R_{BC}} = 8 \text{ msec} \Rightarrow R_{BC} = 1 \text{ Mbps}$$

$\therefore$ the bandwidth of link BC is 1MHz.

then

$$\text{throughput} = \frac{2 \times 1000 \times 8 \text{ bits}}{3d_p + d_{t_{AB}} + d_{t_{BC}} + 8\text{msec} + 2d_{t_{CD}}}$$

$$= \frac{16 \times 10^3}{30 + 0.8 + 8 + 8 + 2} = \cancel{327.9 \text{ bps}}$$

-2

5. Consider a Data link that uses Continuous ARQ to transmit frames each 1 kbits long over a 1 Mbps link with one-way propagation delay of 2 msec. The receiver will acknowledge every correctly-received in-order frame. Ignore the transmission time of the ACK (but do NOT ignore its propagation delay). For every frame, the sender sets a timer equal to 1.5 RTT (assume the RTT = $2T_p$) measured from the start of the transmission of a frame. For each of the following ARQ protocols, calculate the SWS that will ensure relatively high link utilization. Calculate m = # of bits used for sequencing frames (start at F_0). Finally calculate the throughput and the link utilization for each case. Assume the sender has 5 frames to send (numbered F_0 through F_4)

-14

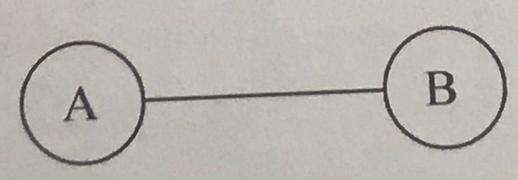
a. Selective Repeat with SWS = RWS = ? In this case, out-of-order frames are buffered but NOT acknowledged. When the lost frame is received, the receiver will use accumulative acknowledgements
b. Go-back N with SWS = ? and RWS = 1. In this case, the receiver will not accept any out-of order frames.

Draw the frame-exchange-timing diagram for the following sequence of events:
F_1 and F_3 are lost during the first time they were sent.

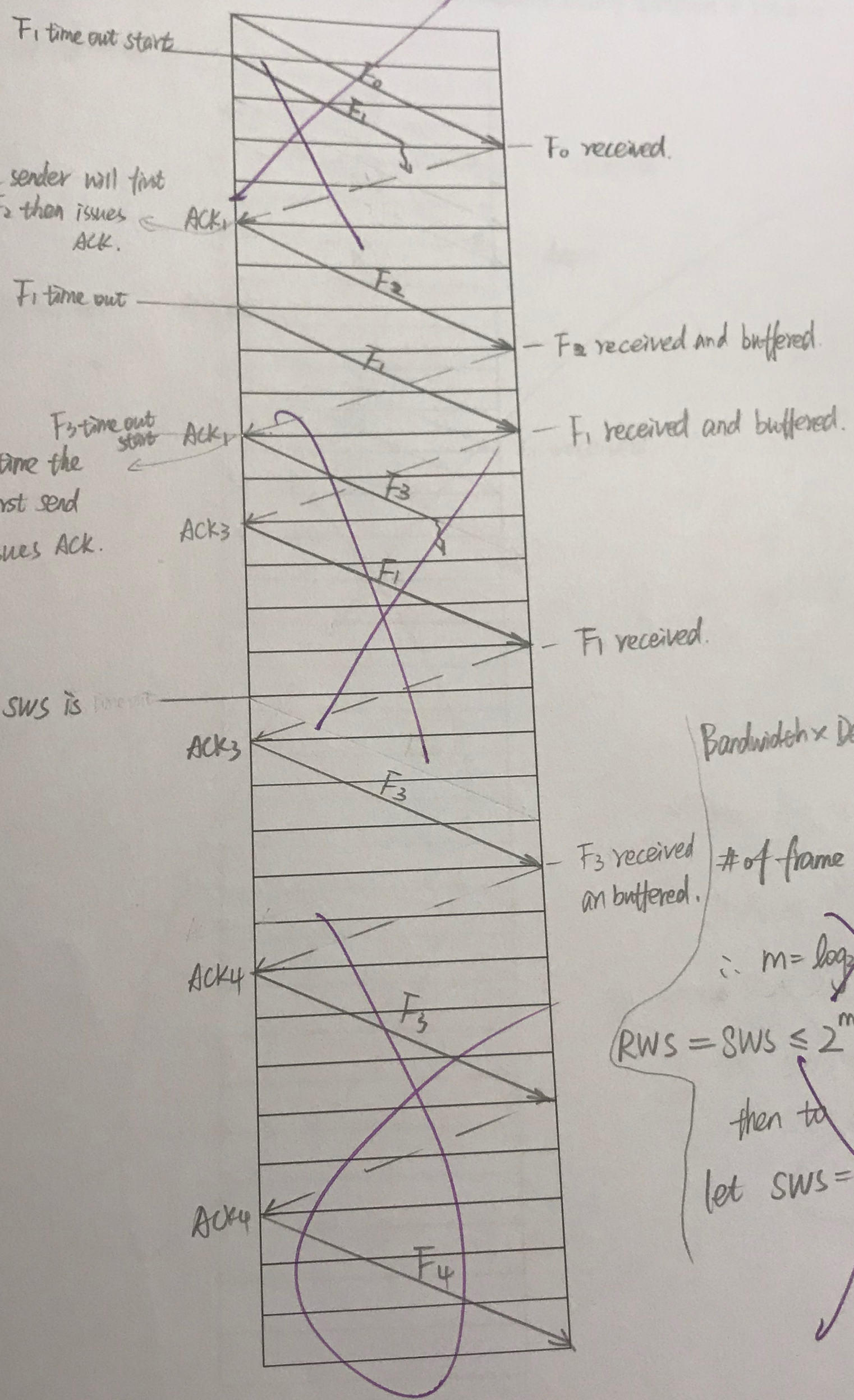
$t_p = 2msec$

$t_t = \frac{1k}{1M} = 10^{-3} sec = 1 msec.$

time out = 1.5RTT = 1.5×2×2m
= 6msec.



Graph paper is provided. Start from t = 0 and assume every division is 1 msec SR.



Bandwidth × Delay = 1Mbps × 2 × 2msec.

= 4000 bits

# of frame = $\frac{4000 \text{ bits}}{1000 \text{ bits/frame}} = 4$.

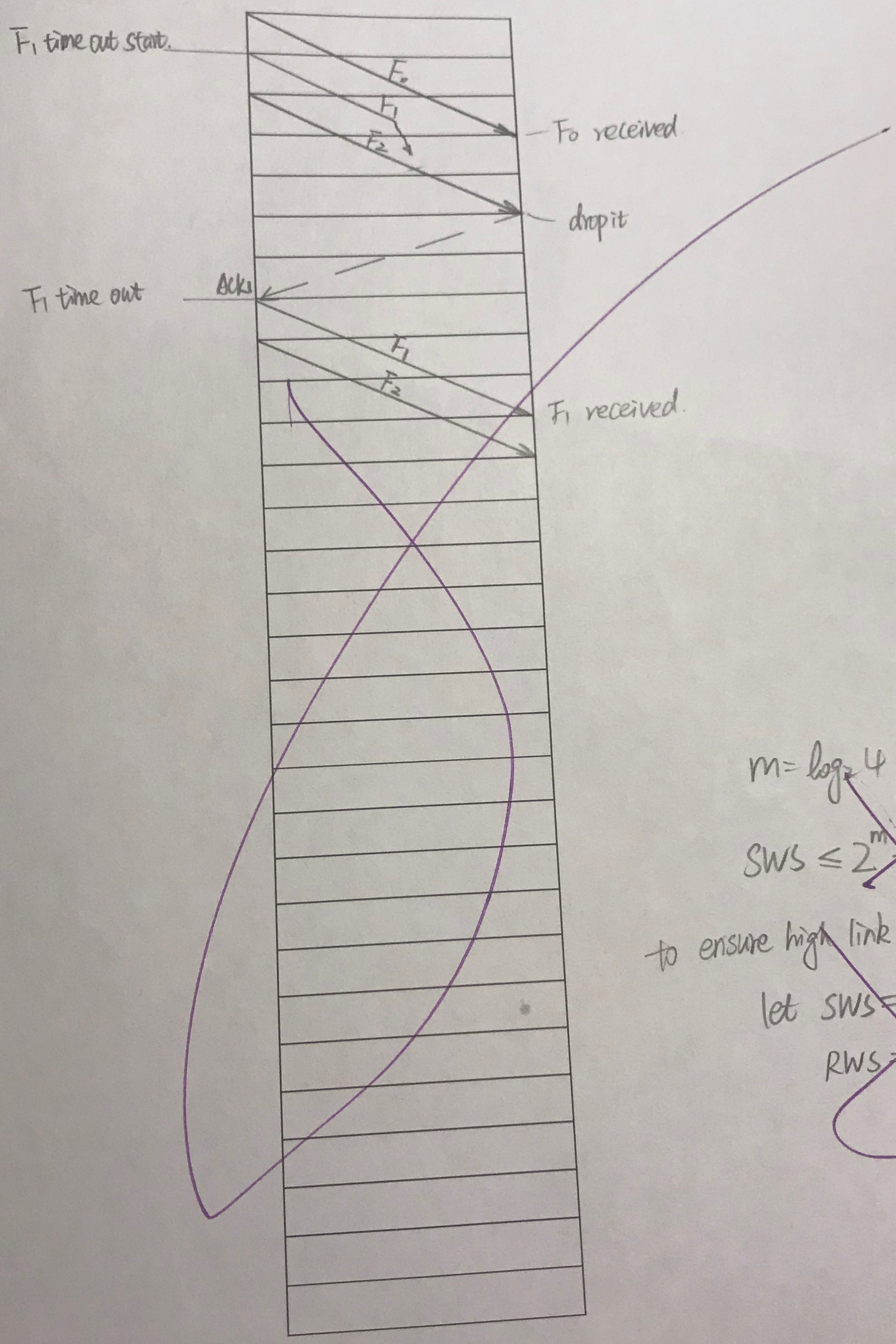
$\therefore m = \log_2 4 = 2$.

$RWS = SWS \leq 2^{m-1} = 2$

then to ensure high utilization.

let SWS = RWS = 2

Graph paper is provided. Start from 0 and assume every division is 1 msec G-B-N



$m = \log_2 4 = 2$.

$SWS \leq 2^m - 1 = 3$.

to ensure high link utilization,

let SWS = 3

RWS = 1