Homework 3

1. Traceroute: I ran “traceroute www.columbia.edu” since it is a well-established host far away from my location.
    1.1. The route does not change very much. The only change is that the secondary domain of the destination hop is different every time. In one of my routes, the destination hop is www-ltm.cc.columbia.edu while in another one of my routes the destination hop is ctv.columbia.edu. Since the host “columbia.edu” and IP address are constant, the changes to the secondary domain of the destination hop are likely not noteworthy.
    1.2. Below is a screenshot of one of my traceroute outputs:

```
 1  128.61.112.1 (128.61.112.1)  3.862 ms  3.323 ms  2.420 ms
 2  143.215.253.130 (143.215.253.130)  2.515 ms  2.452 ms  2.191 ms
 3  143.215.254.91 (143.215.254.91)  21.869 ms  4.853 ms  4.380 ms
 4  130.207.254.73 (130.207.254.73)  2.838 ms  2.811 ms  2.875 ms
 5  143.215.194.1 (143.215.194.1)  3.200 ms  3.230 ms  2.901 ms
 6  i2-to-sox-100g.sox.net (143.215.193.2)  2.904 ms  3.461 ms  5.257 ms
 7  ae-4.4079.rtsw.wash.net.internet2.edu (198.71.45.7)  21.058 ms  20.091 ms  19.117
 ms
 8  ae-5.4079.rtsw.newy32aoa.net.internet2.edu (162.252.70.139)  51.358 ms  39.635 ms
  21.293 ms
 9  nyc-9208-i2-newy.nysernet.net (199.109.5.1)  21.716 ms  21.126 ms  20.760 ms
10  columbia.nyc-9208.nysernet.net (199.109.4.14)  170.997 ms  385.625 ms  115.743 ms
11  cc-core-1-x-nyser32-gw-1.net.columbia.edu (128.59.255.5)  21.949 ms  21.807 ms  2
1.885 ms
12  cc-conc-1-x-cc-core-1.net.columbia.edu (128.59.255.210)  22.618 ms  21.826 ms  21
.623 ms
13  tiernobokar.columbia.edu (128.59.105.24)  21.810 ms  21.709 ms  21.561 ms
```

Using maxmind.com, here are the ISPs/ASs of each hop:

1: Georgia Institute of Technology
2: Georgia Institute of Technology
3: Georgia Institute of Technology
4: Georgia Institute of Technology
5: Georgia Institute of Technology
6: Georgia Institute of Technology
7: Internet2
8: Internet2
9: NYSERNet

10: NYSERNet
11: Columbia University
12: Columbia University
13: Columbia University

1.3. Using maxmind.com, here are the geographical locations of each hop:
1: Atlanta, Georgia
2: Atlanta, Georgia
3: Atlanta, Georgia
4: Atlanta, Georgia
5: Atlanta, Georgia
6: Atlanta, Georgia
7: Ann Arbor, Michigan
8: United States (no other information specified)
9: Syracuse, New York
10: Syracuse, New York
11: New York, New York
12: New York, New York
13: New York, New York

2. Included below are my solutions in equation form

2.1. K - number of bit errors to solve for (0 in this problem)
S - total bit length of file
P - probability of error for a single bit

$$P(k) = (1 - p)^{S - k} = e^{-p(S - k)}$$
$$P(0) = e^{-10^{-6}(8*10^6 - 0)} = 0.000335$$

2.2. The probability in part 2 is identical to the probability in part 1 because no matter how many packets we divide our file into, our probability equation is still calculating the probability that our entire file is uncorrupted, not the individual packets.

$$P(k) = (1 - p)^{(N * \frac{S}{N} - k)} = e^{-p(S - k)}$$
$$P(0) = e^{-10^{-6}(8*10^6 - 0)} = 0.000335$$

2.3. Important point to note: Inverse of probability is interpreted as "the expected number of trials before success".

$$Time_{success} = \frac{S}{R} * \frac{1}{P(0)} = \frac{(8 * 10^6)}{(10^6)} * \frac{1}{e^{-10^{-6}(8 * 10^6)}} = 8e8 = 23847.66\ s$$

2.4. General formula is below:

$$Time_{success} = N * (\frac{S}{NR} * \frac{1}{P(0)}) = N * (\frac{S}{NR} * \frac{1}{e^{-p(S/N)}}) = \frac{S}{Re^{-p(S/N)}}$$

Cases for N = 80, 800, and 8000 are below:

$$N = 80 : Time_{success} = \frac{S}{Re^{-p(S/N)}} = \frac{8\ Mb}{1\ Mb\ (e^{-10^{-6}(8\ Mb/80)})} = 8.84\ s$$
$$N = 800 : Time_{success} = \frac{S}{Re^{-p(S/N)}} = \frac{8\ Mb}{1\ Mb\ (e^{-10^{-6}(8\ Mb/800)})} = 8.08\ s$$
$$N = 8000 : Time_{success} = \frac{S}{Re^{-p(S/N)}} = \frac{8\ Mb}{1\ Mb\ (e^{-10^{-6}(8\ Mb/8000)})} = 8.008\ s$$

2.5. From this exercise, I've concluded that the time it takes to transmit a file correctly in a "noisy" network using Stop-and-Wait decreases asymptotically as the number of packets N increases. In perfect conditions with 0 bit error (or infinite value for N), the time it takes to transmit a file is L/R, which matches the formulas that we've learned in class.

The rest of my assignment will be my pen and paper work, scanned as a PDF. Unfortunately Google Docs was not cooperating with smaller images of my work that I wanted to embed into this document. Retyping all of my physical work into digital equations would not be feasible right now, so this was my solution.

I apologize in advance if readability is slightly lower in problems 3 - 5.

3. Assumptions:

- There is no network downtime; packets are always being transmitted (or retransmitted in the case of failure)

2. Selective Repeat:

- Fundamental idea: if sender does not receive an ACK, it must only send the packet which corresponds to that ACK
- Step 1: generalized efficiency formula

$$\text{Efficiency} = \begin{pmatrix}\text{amount of} \\ \text{efficient network} \\ \text{usage per packet}\end{pmatrix}\begin{pmatrix}\text{probability of efficient} \\ \text{network usage per packet}\end{pmatrix}$$

- Step 2: establishing probabilities of efficient usage vs total usage of network

$(1-p) \rightarrow$ Probability that packet is delivered correctly

$(1-p)+p \rightarrow$ Probability that packet is delivered at all

$\therefore$

$\frac{(1-p)}{(1-p)+p} = \frac{(1-p)}{1}$, $\rightarrow$ Ratio of probability of efficient use over total use

- Step 3: evaluating data transmission contributing to efficient network usage vs total usage (per packet)

$n-h$ ← data contributing to efficient network usage

n ← data contributing to total network usage

$\therefore$

$\frac{n-h}{n} = \left(1 - \frac{h}{n}\right)$ ← efficient data transmission over total data transmission

- Step 4: identify relationship between efficient data transmission ratio (step 3) and efficient transmission probability (step 2)

$\left(1 - \frac{h}{n}\right)(1-p)$ ← Efficiency of SR

amount of efficient usage during transmission

probability of successful transmission

3. 1. Go-Back-N: only difference with SR is retransmission scheme

- Fundamental idea: if sender does not receive an ACK, it must retransmit all packets in window >= failed PKT seq #
- Step 1: generalized efficiency formula

$$\text{Efficiency} = (\text{Efficiency of SR})\left(\frac{1}{\text{overhead of GBN retransmission scheme during unsuccessful delivery outcomes}}\right)$$

- Step 2: indicate efficiency of SR

$$\left(1-\frac{h}{n}\right)(1-p)$$

- Step 3: derive cost of retransmission for GBN

$1 \leftarrow$ Cost of retransmission of 1 packet (equivalent to cost of retransmission in SR)

$w-1 \leftarrow$ Cost of retransmission of the rest of window

- Step 4: show probality of retransmission when ACK is not received

$1 \leftarrow$ Probability of retransmission of packet that was not ACKed

$p \leftarrow$ Probability of retransmission of other packets in window (idea: probability that failed packet was at any location in window, beginning to end, is p)

- Step 5: calculate efficiency overhead of GBN retransmission scheme by combining steps 3 and 4

$$\begin{pmatrix}\text{cost of retransmission} \\ \text{of the failed delivery packet}\end{pmatrix}\begin{pmatrix}\text{probability of retransmission} \\ \text{of the failed delivery packet}\end{pmatrix} +$$

$$\begin{pmatrix}\text{cost of retransmission} \\ \text{of rest of window}\end{pmatrix}\begin{pmatrix}\text{probability of retransmission} \\ \text{of packets in rest of window}\end{pmatrix} =$$

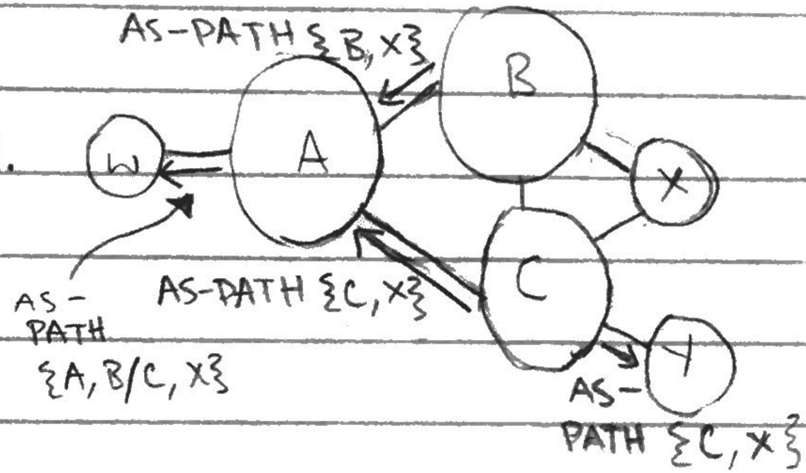
$$(1)(1) + (w-1)(p) = 1 + (w-1)p$$

- Step 6: Consolidate efficiency of SR with added overhead of GBN retransmission scheme to obtain efficiency of GBN

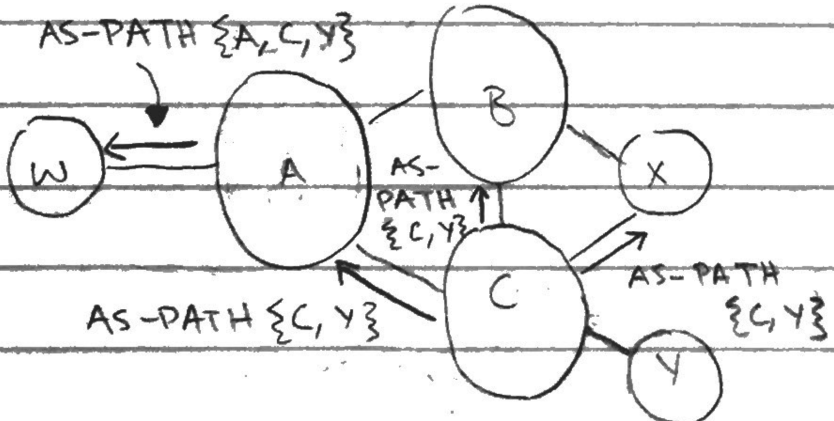
$$\left(1-\frac{h}{n}\right)(1-p)\left(\frac{1}{1+(w-1)p}\right) =$$

$$\frac{\left(1-\frac{h}{n}\right)(1-p)}{1+(w-1)p} \longleftarrow \text{Efficiency of GBN}$$

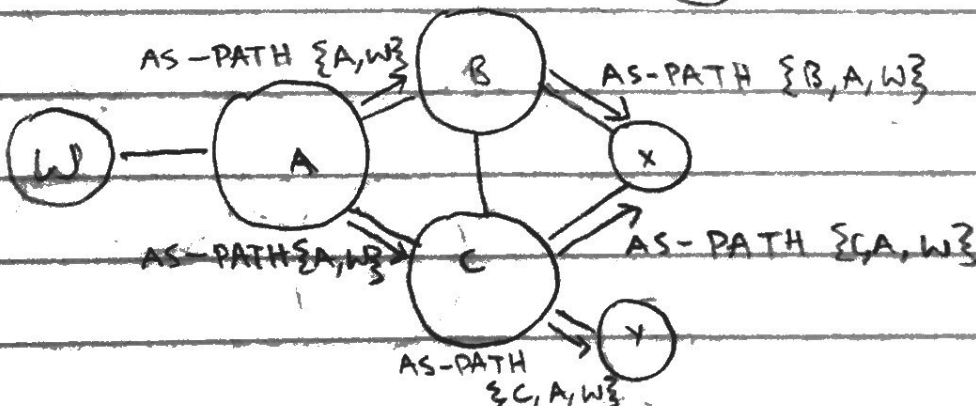
4. 1.



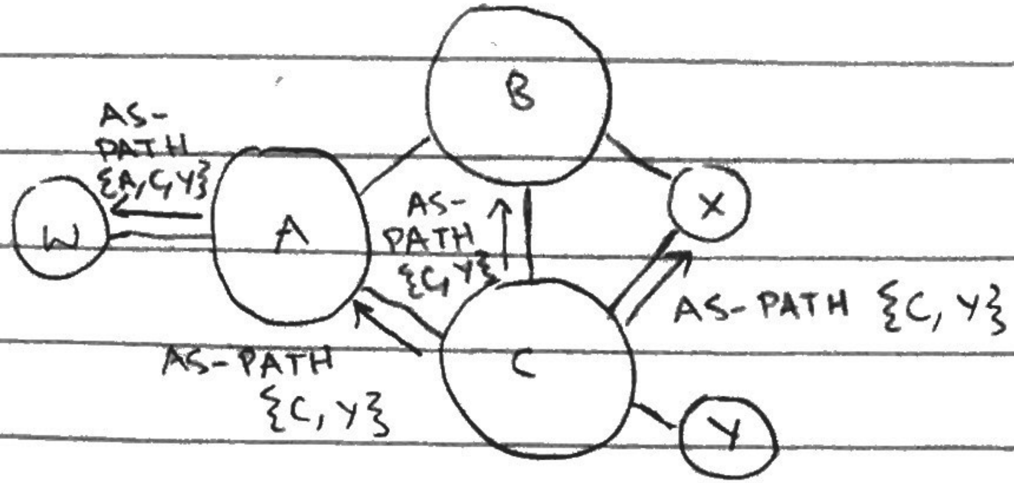
W → X: W would use either route {A, B, X} or {A, C, X}. No tiebreaking scheme specified.



W → Y: W would use route {A, C, Y}

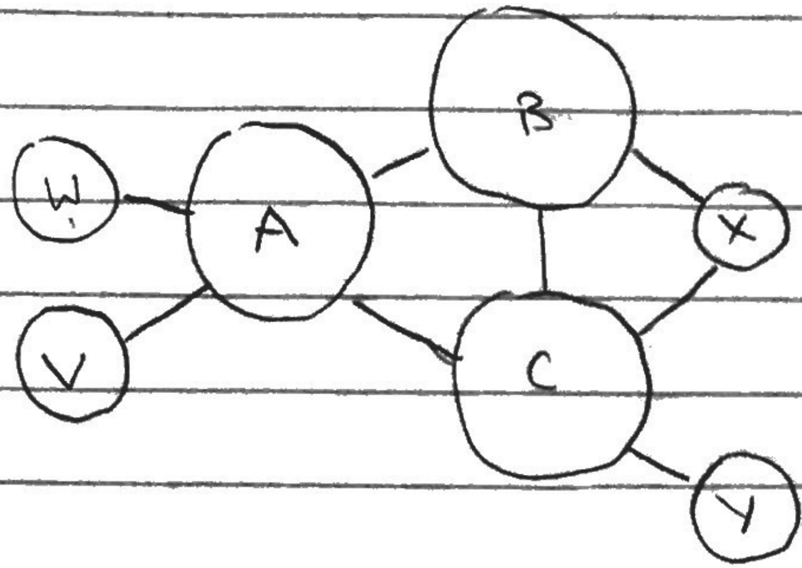


X → W: X would use either route {B, A, W} or {C, A, W}



X → Y: X would use route {C, Y}

4.2.



B receives from A:

AS-PATH {A, W}

AS-PATH {A, V}

C receives from A:

AS-PATH {A, V}

AS routes C receives:

AS-PATH {A, V}

AS-PATH {B, A, W}

Counters

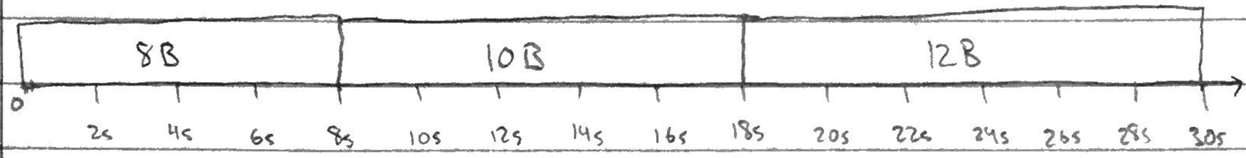
5\. 1. Buf 1: $\boxed{16B}$ 0 8 12 16 20

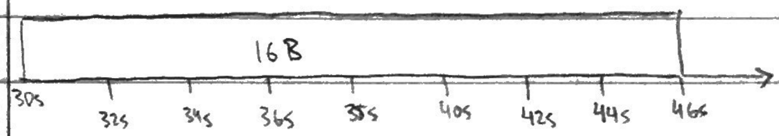
Buf 2: $\boxed{10B}$ 0 8 ~~12~~ 6 10   ← Initial state

Buf 3: $\boxed{12B}$ 0 8 12 ~~16~~ 8

Buf 4: $\boxed{8B}$ 0 ~~8~~ 4 8 12

$\delta = \boxed{4B}$





2\. The data transmission capacity will be evenly distributed across the two buffers. 1 packet will be taken from the 1st buffer for every 4 packets taken from the 2nd buffer.

3\. N = 4   I would change the quantum for each buffer
R = 10Mbps   to a value based on the bitrate we would like to assign to that buffer

Buf-1: $\delta_1 = \frac{4Mbps}{(4+2+1+1)Mbps} * 10Mbps = 5\ Mb$

Buf-2: $\delta_2 = \frac{2Mbps}{(4+2+1+1)Mbps} * 10Mbps = 2.5\ Mb$

Buf-3: $\delta_3 = \frac{1Mbps}{(4+2+1+1)Mbps} * 10Mbps = 1.25\ Mb$

Buf-4: $\delta_4 = \frac{1Mbps}{(4+2+1+1)Mbps} * 10Mbps = 1.25\ Mb$