CS5229 Advanced Computer Networks
Midterm Solution

1. i. (2 points) They realized that they need to support more than one transport services for different application requirements (reliable transport for file transfer and unreliable transport for voice communication). IP is therefore separated from TCP and form the basic building block for transport protocols.

   ii. (3 points) Spam filtering is not 100% accurate. Even if spam is filtered at the mail server, the mail client still needs to perform some form of filtering anyway. Furthermore, the server might blocks some of the non-spam from coming through. From end-to-end argument point of view, the end system here should be the client, since a user should not trust the server with blocking emails. On the other hand, the mail client, under complete control of the user, can be trusted. THerefore option (ii) is better.

2. i. (2 points) PBM should not use TCP as it needs to send a sequence of packets back-to-back. TCP's congestion control and flow control might prevent these from happening.

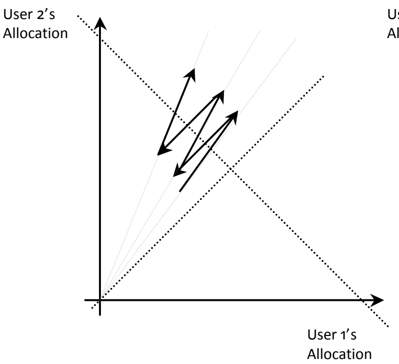
   ii. (1 point) 0.01s

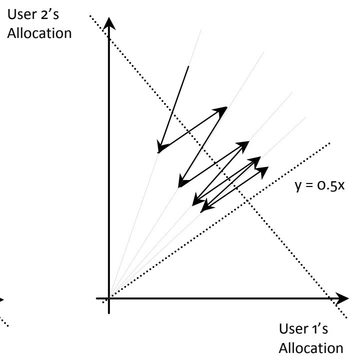
   iii. (2 points) Each measurement causes a maximum error of 10ms. Let m be the measured value and a be the actual value. We want

$$\frac{|m-a|}{a} < 0.1$$

   Since $|m-a|$ is at most 10ms, a should be larger than 100ms. We need to send at least 11 packets to reduce the error to below 10%.

   (Minh correctly pointed out an error in my argument above – to compute an interval, two measurements are needed : the receiving time of the first probe and the receiving time of the last probe. Therefore the maximum error should be 20ms and the number of packets to send should be at least 21.)





3.

   i. (2 points) See figure on the left above.

   ii. (3 points) See figure on the right above. The allocation will converge to the fairness line $y = 0.5x$, i.e., the allocation x_1 will be twice of x_2, or

$$x_1 = 2x_2$$

Therefore,

$$\begin{aligned} F &= \frac{(x_1+x_2)^2}{2(x_1^2+x_2^2)} \\ &= \frac{(3x_2)^2}{2(5x_2^2)} \\ &= \frac{9}{10} \end{aligned}$$

4. i. (2 points) There are 3 partial ACKs. Around 3.1 - 3.2.

   ii. (3 points) Partial ACKs could be lost, or retransmitted packets during fast recovery could be lost.

5. i. (2 points) Let Y_{ss} and Y_{ca} be the number of packets sent during slow start and congestion avoidance respectively. Recall that $X = \frac{W}{2}$

$$Y_{ss} = 1+2+4+8..+\frac{W}{2} \quad (1)$$

$$= W-1 \quad (2)$$

$$Y_{ca} = \sum_{k=1}^{X-1}\left(\frac{W}{2}+k\right)+\frac{W}{2} \quad (3)$$

$$= (X-1)\frac{W}{2}+\frac{W}{2}+\frac{X}{2}(X-1) \quad (4)$$

$$= \left(\frac{3W}{2}-1\right)\frac{W}{4} \quad (5)$$

We know that

$$\begin{aligned} Y_{ss}+Y_{ca} &= W-1+\frac{1}{p} \\ W-1+\left(\frac{3W}{2}-1\right)\frac{W}{4} &= W-1+\frac{1}{p} \\ 3pW^2-2pW-8=0 & \end{aligned}$$

   ii. (3 points) Solving the quadratic equation above gives $W \approx \sqrt{\frac{8}{3p}}$. Let A_{ss} and A_{ca} be the time spent in slow start and congestion avoidance respectively. Then,

$$\begin{aligned} A_{ss} &= RTT\left(\log_2\frac{W}{2}+1\right) \\ &\approx \frac{RTT}{2}\log_2\frac{1}{p} \\ A_{ca} &= RTT(X+1) \\ &\approx RTT\left(\sqrt{\frac{2}{3p}}\right) \end{aligned}$$

The throughput is therefore

$$\begin{aligned} B &\approx \frac{\sqrt{\frac{8}{3p}}-1+\frac{1}{p}}{RTT\left(\frac{1}{2}\log_2\frac{1}{p}+\sqrt{\frac{2}{3p}}\right)} \\ &\approx \frac{1}{RTT\left(\frac{p}{2}\log_2\frac{1}{p}+\sqrt{\frac{2p}{3}}\right)} \end{aligned}$$