CS 528: Second Midterm (Fall’01)

Answer all problems. This is a take-home exam. The papers are due December 4. Please try to be concise.

Consulting papers and external literature is not cheating. Discussing the problems (not the solutions) is not cheating. Discussing answers or key ideas is. If you are in doubt, talk to me.

Honor code: Please copy the following statement to your answer sheet and sign it. “I pledge that I did not receive or provide help in answering the problems on this midterm. Signed: _________”.

(Easy/Medium) Problem 1:
(a) (4 points) What are 3 factors helping Internet scalability? Explain how they do so.
(b) (8 points) Problem 4.33 Peterson and Davie
(c) (8 points) Problem 4.47 Peterson and Davie
(d) (5 points) Problem 6.2 Peterson and Davie

(Medium) Problem 2: In RIP, the cost metric for each link are all of equal cost and the cost of a path is simply the number of hops.
(a) (3 points) Explain the advantages/disadvantages of using such a cost metric
(b) (7 points) Assume that you want to use a more sophisticated way for modeling the cost of links that takes into account the current load on a link as well as the link properties. Show with an example or otherwise how such a metric can cause destructive behavior for a network using distance vector routing such as RIP. (Hint: This is due to the same general reasons that cause the count to infinity problem)
(c) (5 points) Is this an inherent problem for distance vector routing? If not suggest a modification to it that will allow dynamic link costs.

(Medium) Problem 3: Consider a TCP connection between two nodes A and B going through a router R. The connection between A and R is very high bandwidth (assume infinite), but the connection between R and B has a 10Kbps bandwidth. Ignore propagation delays. Assume that R has a buffer space of 4 Kbits for this connection and that packet sizes are 1 Kbits. Assume that every segment is ACK’d immediately and that ACK’s are of negligible size. Assume that the advertised window size is infinite. There is no fast retransmit or fast recovery.
(a) (7 points) Ignoring propagation delays, show a timeline of the packets sent until operation stabilizes (until we reach the additive stage of the congestion window increase). Track the size of the window.
(b) (5 points) Track the value of the Retransmission timer using the Jacobson/Karel’s algorithm with the parameters $\alpha = 0.125$, $\beta = 0.25$ and $\phi = 4$.
(c) (3 points) Would things change if there is fast retransmit/recovery? If yes, show the updated timeline.

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- A ----------- B ----------- C -
--- wired     --- wireless    ---

(Medium/Difficult) Problem 4: (20 points) Consider a TCP connection established between hosts A and C as shown in the diagram above. The connection between A and B is wired, while the connection between B and C is wireless.
(a) (5 points) Explain any performance problems with TCP’s congestion control scheme that may arise due to such a connection. (Recall, that wireless connections can drop packets frequently and in bursts due to mobility and transient errors.)
(b) (9 points) Compare and contrast the following three general approaches to solving this problem. Use examples to illustrate your point.
(1) Make the link layer reliable (ARQ or FEC...);
(2) When a receiver gets a corrupted packet, it explicitly informs the source that it was lost due to errors (Explicit Loss Notification/ELN) using ICMP or a similar mechanism.
(3) Split the TCP connection into two parts: A to B and B to C. The connection from B to C runs a “special” wireless TCP (optimized to wireless operation; for example, by using ELNs, SACKs or NAKs).

Note: This is a difficult problem. It may help you to work through a few scenarios and see how the different approaches would work. Think about the purpose of TCP’s congestion avoidance mechanism and under what situations each of the approaches manages to achieve this purpose. Also, where applicable, consider the interaction of the retransmit timers at the link layer and TCP.

(c) (6 points) With mobility, the wireless portion of the connection may get disconnected (potentially for an extended period of time). Assume that that the connection remains alive through Mobile IP or a similar mechanism but packets in transit are dropped until the connection is reestablished. Describe the effect of this disconnection on the performance of TCP and suggest an optimization to reduce its effect.

(Difficult) Problem 5: (25 points) A limit on the delay in a connection where the intermediate routers are all implementing WFQ and the traffic follows the leaky bucket model states:

\[
D \leq (\frac{\sigma}{r}) + \sum_{i=1}^{H} \frac{P_{\text{max}}}{r_i} + \sum_{i=1}^{H} \frac{P_{\text{max}}}{C_i}
\]  

(1)

where \((\sigma, \rho)\) are the leaky bucket parameters (\(\sigma\) is the size of the bucket, \(\rho\) is the rate of bucket emptying), \(r\) is the minimum amount of bandwidth reserved for the connection over all links of the path \((r \geq \rho)\), \(H\) is the number of links on the path, \(r_i\) is the amount of bandwidth reserved for the connection on link \(i\), \(C_i\) is the total bandwidth of link \(i\), and \(P_{\text{max}}\) is the maximum packet size. Note that this result ignores propagation delay.

(a) (10 points) A network implementing per-flow WFQ at each link with equal weights on all connections. Each link has a rate of 1.5 Mbps. Each connection is leaky-bucket with parameters (8Kbytes,10Kbps). The maximum packet size is 1 Kbyte. What is the admission control rule on a path of 3 hops if we want end to end delay to be at most 80 msec?

(b) (10 points) If the source had perfect knowledge about the state of the network, it may be able to find a path through the network that will satisfy its quality of service requirements. Explain how you would extend link-state routing to support this functionality. How would your answer be different for distance vector?

(c) (5 + 5 bonus) Prove that the bound on the delay in the equation above is true. (Hint: Do not panic; work from the basic equation for the end to end delay as propagation delay — ignored—, transmission delay and queueing delay. Even if you don’t get the full proof, partial credit will apply).