Exercise 1 (***Network & Internet***)

Suppose two hosts, A and B, are separated by 20,000 kilometers and are connected by a direct link of $R = 2$ Mbps. Suppose the propagation speed over the link is 2.5×10^8 meters/sec.

a. Calculate the bandwidth-delay product.

b. Consider sending a file of 800,000 bits from Host A to Host B. Suppose the file is sent continuously as one large message. What is the maximum number of bits that will be in the link at any given time?

c. Provide an interpretation of the bandwidth-delay product.

d. What is the width (in meters) of a bit in the link? Is it longer than a football field?

e. Derive a general expression for the width of a bit in terms of the propagation speed *s,* the transmission rate *R,* and the length of the link *m*.

Exercise 2 (***Network & Internet***)

Consider host A and B connected by a single link of rate R bps. Suppose that the two hosts are separated by M meters, and suppose the propagation speed along the link is S meters/sec. Host A is to send a packet of size L bits to Host B.

a. What is the propagation delay, d_{prop} and determine the transmission time of a packet, $d_{trans.}$

b. Suppose Host A begins to transmit the packet at time t=0. At time t= d_{trans}, where is the last bit of the packet?

c. Suppose d_{prop} is greater than d_{trans}. At time t= d_{trans}, where is the first bit of the packet?

d. Suppose d_{prop} is less than d_{trans}. At time t= d_{trans}, where is the first bit of the packet?

Exercise 3 (***Transport Layer***)

In TCP,

a. Consider transferring a file of L bytes. Assume the MSS is 1460 bytes, the RTT is 0.1 second, and a total of 66 bytes of transport, network and data-link headers are added to each segment before the packet is sent out over a 10 Mbps link. How large the TCP congestion window?

b. Explicit loss/congestion notification is proposed to solve false-congestion detection at TCP, mention one problem of such scheme.

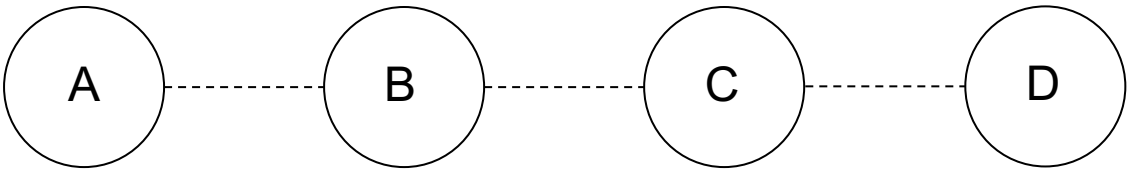
c. TCP is clocked based on RTT. Mention one proposed TCP-layer solution to overcome the problem of RTT fairness at the bottleneck.

d. Bandwidth Asymmetry damages TCP clocking mechanism. Mention one receiver-side solution.

e. Name a single problem that faces dropping-based TCP over wireless links and name one TCP implementation that is used to overcome this problem.

Exercise 4 (TCP over *Wireless Network*)

Consider a three-hop wireless network as shown below. Nodes A, B, C, and D have a single radio each configured to a common channel. Node C acts as a relay node when node B wishes to transmit to node D. Similarly, nodes B and C act as relay nodes when node A transmits to node D. Each wireless link capacity is W b/s.



f. Consider a single flow from node A to node D. What is the optimal end-to-end capacity (rate) for this flow, assuming no link capacity is wasted.

g. Consider a single TCP flow transferring a file from A to D. Assume the MSS is 1460 bytes, the RTT is 0.1 second, and a total of 66 bytes of transport. Each wireless link capacity is 11 Mbps. How large the TCP congestion window?

h. Consider the same network, but with the three flows: one flow from node A to node B, one from node A to node C using node B as relay, and one from node A to node D using nodes B and C as relays. What is the optimal end-to-end capacity (rate) for each flow, if our objective is to:

   i) Fairly share the network capacity between the three flows

   ii) Maximize the aggregate network capacity (defined as the sum of the three end-to-end flow rates)

i. 802.11 MAC uses link layer retransmissions to counter wireless losses. TCP also provides retransmissions for reliable delivery of data. Are TCP retransmissions redundant/unnecessary in 802.11 wireless networks? Briefly state why or why not.

Exercise 5 (*Optical Network*)

In optical networks,

a. Resource reservation in optical burst switched (OBS) networks is considered critical to the success of its functionality. Name two resource-reservation protocols for OBS networks. Do not explain.

b. Mention the two most important performance measurements of OBS networks. Do not explain.

c. Explain the concept of delayed reservation in OBS networks

d. Optical packet switched networks is a promising switching technology. Name one problem that faces this technology from being deployed. Do not explain.

e. Mention one problem induced when delay-based TCPs run over optical burst switched networks with deflection routing

Exercise 6 (TCP over *Heterogeneous/Optical Network*)

In TCP over heterogeneous networks

a) Consider applications that transmit data at a constant rate. Suppose that a packet-switched network is used and the only traffic in this network comes from such applications. The sum of the application data rates is less that the capacities of each and every link. Is some form of congestion control needed? Justify your answer.

b) List the TCP congestion control phases and explain the purpose of each phase.

c) List one problem induced when delay-based TCPs run over Optical Burst Switched Networks

d) Name one approach that assists the problem of running dropping-based TCP over Optical Burst Switched networks

e) Repeat (c) by replacing optical burst switched links with wireless links