Spring term 2008
TELCOM 2321 - CS 2520
Wide Area Networks

Homework 2

Due date: Tuesday Jan 22, 2008

One-day late submissions will be accepted without penalties.

Problem 1

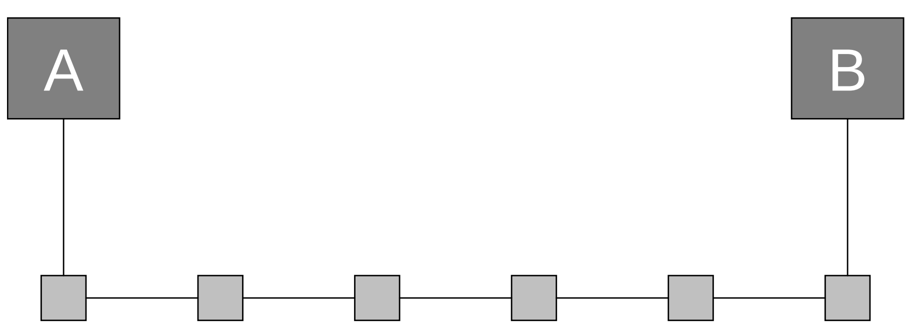
With reference to the communication channel depicted in the figure below where A sends both a file and several voice packets to B, define the following parameters:

- $N = 5$, the number of hops from A to B
- $L = 15000$ bytes, the file size
- $V = 40$ bytes, the voice packet size
- $C = 64$ Kbps, the data rate (same value for all links)
- $t_d = 5$ ms, the propagation delay per link (same value for all links)
- $P_e = 10^{-5}$, the bit error rate on each link (same value for all links).

Assume that the whole file is sent as a single message, that the intermediate devices (the small boxes in the figure) do not provide any error control service at the data link layer and that they do not store any message or packet. Also ignore the processing delay. Find

1. the probability P_M that the file is correctly received by B with a single transmission
2. the probability P_V that a voice packet is correctly received by B with a single transmission
3. the end-to-end delay for a voice packet

Assume now that, in order to improve the file transfer performance, the message is split into frames of size $F = 1500$ bytes and some limited form of error control is implemented at the intermediate devices so that the probability P_F that a frame is transmitted successfully over a single link improves. However, in order to increase the success rate, each intermediate device located at the end of a link requires an



average number of frame retransmissions r (not including the first transmission) which is linked to P_F by the following expression:

$$P_F(r) = 1 - (1 - P_{F0})e^{-r}$$

where P_{F0} is the probability that a frame is correctly transmitted over a single link without retransmissions, given the link bit error rate P_e. Each retransmission on a given link takes place immediately after the sending device is notified by the receiving device about the damaged frame. Considering r as a design parameter for the data link layer devices:

4. find the minimum value of r such that the probability that a frame is transmitted successfully from A to B is above 95%

5. find the corresponding average end-to-end delay for a voice packet that is now subject to the same error control scheme, keeping in mind that intermediate devices now store frames and packets before forwarding them

6. find the maximum value of r such that the end-to-end delay for a voice packet does not exceed 150 ms and find the corresponding probability that a frame is transmitted successfully from A to B.

Problem 2

With reference to the small network depicted in the figure below, let C_{ij} be the bandwidth in Mbps and d_{ij} the physical distance in miles between nodes i and j. Assume the following values

link A–B: $C_{AB} = 10$, $d_{AB} = 250$

link B–C: $C_{BC} = 20$, $d_{BC} = 180$

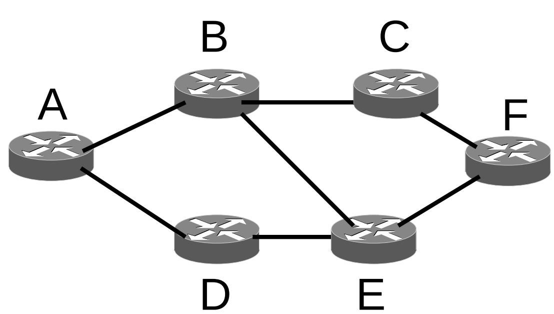
link A–D: $C_{AD} = 40$, $d_{AD} = 300$

link B–E: $C_{BE} = 0.1$, $d_{BE} = 100$

link D–E: $C_{DE} = 1$, $d_{DE} = 200$

link C–F: $C_{CF} = 10$, $d_{CF} = 130$

link E–F: $C_{EF} = 10$, $d_{EF} = 100$



Assume also that a traffic source on node A generates packets with size $P = 1500$ bytes directed to a destination on node F and that the source adapts its transmission rate to the bandwidth available end-to-end. Each node (including the source node) introduces a delay due to packet queuing and transmission.

On a given link (i, j) this delay can be approximated as

$$T_{ij} = \frac{10}{C_{ij}}$$

where T_{ij} is measured in milliseconds and C_{ij} in Mbps.

1. Compute the shortest path between A and F in terms of hop count
2. Compute the shortest path between A and F in terms of physical distance
3. Compute the best path between A and F in terms of bandwidth
4. Find which paths are latency limited and which are bandwidth limited

Assignment 3

www.speedtest.net provides a nice data rate and delay testing tool toward several web servers spread all over the globe. From your school or home Internet connection use this tool (or choose another one providing the same global connectivity if you prefer) and pick up a server on the west coast, one in Central/South America and one for each of the other four continents. Measure the average download rate and round trip (ping) delay for each server by testing it 10 times and then

1. plot a chart that shows the relation between the measured average one-way delay and the approximate distance for each server selected
2. find the packet size in bytes that should be used in theory by each server so that the critical bandwidth would be equal to the measured average download rate.