Assignment 5: Switched Networks

Due the week of October 10/11, 2012

This week, we will consider another approach to constructing a data network: switching. This will mark the beginning of our consideration of wide area networks. While most of the techniques we have considered for the last two weeks are primarily used in local area networks, switching is more common in networks that span much larger distances. Our introduction to switching, however, will start with its application in local area networks in the form of transparent bridges/switches.

A significant issue addressed in switched networks is the problem of finding routes to use when delivering data. We will discuss several algorithms for choosing routes this week.

Please read Chapter 3 from Peterson and Davie. While reading Chapter 3, you may just skip §3.2 (we will get to this material next week).

In addition, I would like you to read a paper that discusses the details of some of the improvements made to the routing algorithms used in the ARPANET discussed in the text. (the ARPANET eventually morphed into the Internet).

- Khanna, Atul and John Zinky, "The Revised ARPANET Routing Metric," *Proceedings of the ACM SIGCOMM '89 Symposium on Communication Architectures and Protocols*, pp. 45-56.

The last two questions refer to this paper. You should read the questions before reading the paper! They are this week's somewhat open-ended questions.

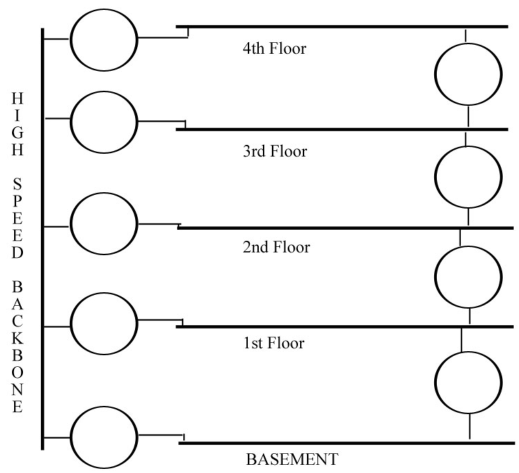
Luckily, unlike previous weeks, most of this week's questions are short questions from the text. Yes, this is a good sign! In our meetings, we will use some of these questions to explore the basic operations of the protocols/algorithms described in the text.

Exercises

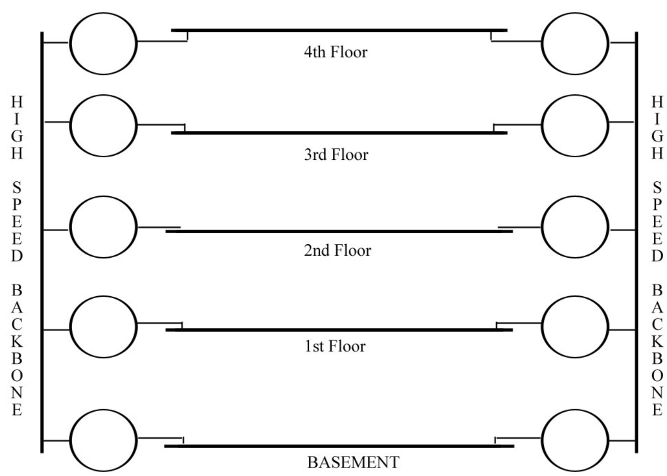
1. Complete parts a, b, and c of 3.1.
2. Complete problem 3.3.
3. Complete problem 3.13. Explain the process used, not just the final results.
4. Complete problem 3.17.
5. Consider the problem of designing the network infrastructure for an office building. The building has four floors and a basement. There are computers located on all five levels. The organization using the building has assigned offices in such a way that members of the same department/group tend to have offices on the same level. So, they hope to maximize network performance by installing a separate LAN on each floor and interconnecting the LANs with bridges and a backbone network. The backbone network will support a higher data rate than the networks on individual floors. Therefore, if possible, all traffic between stations on distinct floors should be routed through the backbone.

   They want to build redundancy into the design. At the least, if any single bridge fails, they want all the LANs to remain interconnected.

(a) A possible design for this network is shown below. As in the diagrams in the text, the little circles represent bridges and the straight lines are Ethernet segments. The goal is to use the bridges that connect networks on adjacent floors (i.e. the bridges on the right side of the diagram) only as backups in case one of the connections to the backbone fails. What id numbers should be assigned to the bridges in the network to provide the desired behavior?



(b) The preceding design only has one backbone. So, if one of the routers connecting a floor to the backbone were to fail, the network would have to route traffic from that floor to other floors through either the floor above or below where the failure occurred. To make the network even more tolerant of failure, we might consider adding a backup backbone. That is, we will add a second backbone network and connect it to the floor networks with bridges as shown below.



The hope would be that if one of the bridges connected to the primary backbone failed, the traffic would be shifted to the added backbone. It would also be nice, of course, if during normal operation the two backbones could share the load. Explain why neither of these goals is attainable using the transparent bridge spanning tree algorithm.

(c) Suggest a way to use one or more backbone networks together with bridges to interconnect the floor networks so that all inter-floor traffic will use a backbone network even in the event that a single bridge fails. That is, all the packets seen on the network serving a given floor should either come from or be destined to one of the computers on that floor.

Show both the topology and the bridge id number assignments.

6. Complete problem 3.46. Show the intermediate stages of the computation.
7. Complete problem 3.48.
8. For this question, I would like you to compare the routes used by a local network built using transparent bridges to a switched network with the same topology in which shortest path routing is used. To do this, consider the network used as an example in problem 3.13 from the text.
   (a) First, redraw the network as a graph in which:
      - each of the network segments shown in Figure 3.48 (i.e. A, B, C...) is a node, and
      - there is an edge between two nodes exactly when the corresponding network segments are attached to a common bridge.

   (b) Simulate Dijkstra's algorithm on the resulting graph to find the best routes from B to all other network segments. Assume all edge weights are 1.
   (c) Compare the route that would be used in this scenario to transmit packets from B to A and B to D to the routes determined by the spanning tree algorithm used by transparent bridges (i.e. the answer to the original question from the book). Which appears to be more efficient?
   (d) When the transparent bridge spanning tree approach is used, bridges that are not forwarding do not forward any packets. Their potential bandwidth is completely unused. The spanning tree you computed using Dijkstra's algorithm for part (b) does not use every bridge. However, this tree is only used when sending from B. Other nodes compute their own spanning trees and use those trees to determine their routes. When all the spanning trees used by all the nodes are considered, will any bridges go completely unused? Would this change if the weights on the edges were not all 1s?
9. One nice consequence of the fact that the "Revised ARPANET Routing Metric" paper describes routing in a network that has vanished into the mists of history, is that it makes it clear that the fact that time marches on should be an inherent part of the design process of any network algorithm/protocol. What was good enough when the network was small (100s of computers) and slow (56Kbps lines), worked less well as the network grew larger (1000s of computer) and faster (1Mbps lines) and might be unworkable in today's network. Basically, good protocols must scale.

   One concrete place to look for scaling issues is in the magic numeric constants that appear here and there in the description of a network protocol. For example, in paper, they state that the reported cost for a 56 kb/s link ranges from 30 units to 90 units. Why 30 to 90? Why not 0 to 100? Are 30 and 90 universal constants of the network universe, or are they likely to require adjustment as the network grows larger or faster?

   What I would like you to do for this problem is make an annotated list of examples of such constants that appear in this paper. For each example, I would ask you to identify the section of the paper in which the parameter is discussed, specify the value being used and "briefly" explain the role it plays in the protocol/algorithm. For most of the examples you can find, that is all I ask. For two of the examples (any two you like), however, I would like you to explore the "is it likely to require adjustment as the network grows" question. In particular, I would like you to discuss what changes you would expect to be necessary in the values used as the network grows larger and faster. A possible answer would be that you do not believe any change would be required. In all cases, you should justify your prediction. It would be particularly nice if you could suggest a procedure for identifying good values to use either analytically or experimentally.

10. In one way, it is possible to criticize the Khanna and Zinky paper as an example of a bad scientific experiment. In a well designed experiment, one carefully varies one variable while keeping other variables fixed and measures the results of the changes. In their work, however, Khanna and Zinky modified many aspects of the existing routing mechanisms and evaluated the net effect of all the changes. Briefly list the major changes they made. Which (if any) of these changes could have been made independently of the others?