Electrical, Computer, and Systems Engineering
ECSE-6600: Internet Protocols
Spring 2002

Problem Set 1- Due Wednesday, February 21st, 2002
[Tape-delayed students ONLY: Due February 27th 2001]

I. Reading assignments:

- **Reading:** Notes for Protocol Design, E2e Principle, IP and Routing: (esp Routing section 3.3)
- Chapters 4,5,8,10, 14, 16 in Comer's book
- **Reading:** Routing 101: Notes on Routing: (upto CIDR, qn 7)
- **Reading:** Khanna and Zinky, The revised ARPANET routing metric
- **Reading:** Alaettinoglu, Jacobson, Yu: "Towards Milli-Second IGP Convergence"

Questions based upon reading assignments:

a) ***(10 pts) Why is routing different from bridging? Why is routing more scalable than bridging?***

Routing is a network layer function that finds a path between a source and a destination. The network layer utilizes the hierarchal structure of the IP address to forward packets between networks. Bridging is a data link layer function that forwards a packet within a network. MAC addresses used by the data link layer have no hierarchal structure to be utilized. When the forwarding entry for the destination address is not found, routers forward packets to a default router while bridges flood.

Filtering is the key to scale and routers are better than bridges in doing so. Because of the lack of structure in the MAC addresses, bridges filtering capability is limited and is based on setting up a spanning tree that grows with the number of nodes attached to the bridge. Until the spanning tree is built, the bridge floods the network with the incoming packets. Routers, on the other hand, utilize the hierarchal structure of IP addresses and use more complex control plane functions to create complete and consistent routing tables that are used for filtering and forwarding. Routers utilize more information, such as TTL and sequence numbers, to avoid looping.

b) ***(10 pts) Discuss the distinction between the notions of "completeness" and "consistency" in routing. Why do both of them lead to scalability limitations on routing protocols?***

Completeness requires each node to know about every node in the network. This implies a large amount of information will be passed between the nodes in the network. As the network grows, the amount of information exchanged will grow too large and will prohibit scaling.

Consistency implies that concatenation of several local forwarding decisions results in a path between a source and a destination. If there is no consistency, scalability will be limited since the network's ability to filter and forward is affected.

Routing algorithms are required to be consistent even if they are not complete. Default paths are used to resolve the problem of completeness.

c) ***(15 pts) What were the problems with the delay metric used in the original ARPANET routing? How do Khanna and Zinky propose to solve that problem? Why do you think the OSPF routing opts for relatively static values of metrics compared to the adaptive dynamic ARPANET metrics?***

The delay metric for a link was solely based on its queuing delay. When the network is lightly loaded, delay does not vary very much and it is a good metric. However, under high load, there is no limit to the variation of delay between successive updates. Such variations in delay can cause frequent changes in routes and route oscillations.

Hence delay as a metric can cause problems due to its dynamic nature. A metric that is more static will not cause frequent route changes.

d) ***(15 pts) What are the ways in which OSPF could be improved to achieve millisecond convergence (Alaettinoglu et al's paper)? What are the risks in such methods ? What would be the advantages of milli-second convergence?***

OSPF could be improved to achieve millisecond convergence by:

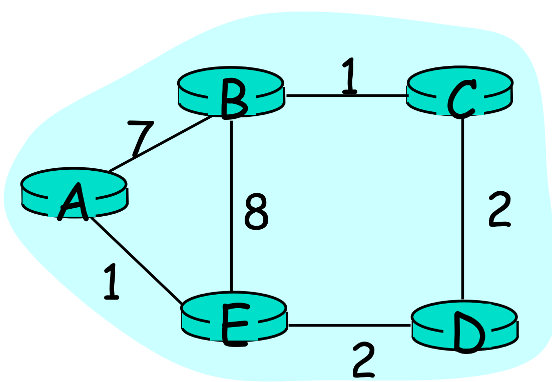
- Using improved SPF algorithms.
- Using Shorter Hello intervals (milliseconds instead of seconds).
- Differentiating between good and bad news.
- Giving higher priority to LSP propagation than SPF computation.
- Ensuring that control packets have higher priority than data packets.

Risks:

- Network-wide stability issues caused by the router trying to follow rapid link transients (route-flapping).
- Too many Hello packets may consume valuable network bandwidth resources.

Advantages:

- Greater network reliability.
- Lower packet loss due to packet delays.
- Elimination of expensive and complex layer 2 protection schemes.



<u>II. Routing computation:</u> For the network shown above,

a) ***[15 pts] Use the DV approach (Bellman Ford algorithm) to show the DVs at nodes A and B, after each iteration till they terminate. What would be the final set of next-hops to every distance at A and B respectively?***

Node A:

	B	C	D	E
0	7,B	∞	∞	1,E
1	7,B	8,B	3,E	1,E
2	7,B	5,E	3,E	1,E
3	6,E	5,E	3,E	1,E

Node B:

	A	C	D	E
0	7,A	1,C	∞	8,E
1	7,A	1,C	3,C	8,E
2	7,A	1,C	3,C	5,C
3	6,C	1,C	3,C	5,C

b) [10 pts] Use the LS approach (Dijkstra's algorithm) to compute the progression of steps to compute the shortest paths from node B to all other nodes.

Step	Set N	D(A),p(A)	D(C),p(C)	D(D),p(D)	D(E),p(E)
0	B	7,B	1,B	∞	8,B
1	BC	7,B		3,C	8,B
2	BCD	7,B			5,D
3	BCDE	6,E			
4	BCDEA				

III. Mapping OSPF to Broadcast LANs.

[15pts] Briefly explain the four central problems encountered when mapping OSPF to broadcast LANs (Dijkstra view of the LAN, LSA encoding, database synchronization, LSA and Hello transmission efficiency) and the solutions chosen by OSPFv2.

- With broadcast LANs, Dijkstra's algorithm has to deal with $O(N^2)$ adjacencies. Hence there can be a lot of unnecessary traffic.
- LSA acks can cause equal amount wasteful traffic since each ack reaches all the nodes.
- Similarly every Hello packet reaches all the nodes on the network.

- An option could be to use multicast where each node sends information about a selected set of LSA nodes. But all nodes need to synchronize their databases, so although this makes the adjacency O(N), the DB synch info is still O(N^2).

OSPFv2 does the following to get around this problem:

- A new Network-LSA is introduced. A node is elected as a "Designated Router" (DR) which creates this network-LSA.
- New LSAs and Hellos are sent to the multicast address "AllSPFRouters", whereas acks are sent only to "AllDRRouters" thus avoiding separate acks to DR and backup DR routers.

IV. Hierarchical OSPF:

[10 pts] Explain the differences between normal areas, stub areas and not-so-stubby areas in OSPFv2?

- AS-External-LSAs are NOT flooded into stub areas.
- A subset of external-LSAs may be flooded into Not-So-Stubby-Areas
- AS-External-LSAs are flooded into Normal Areas.