CS3200: Computer Networks

Lecture 19

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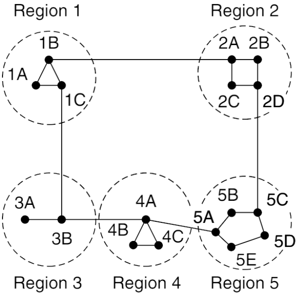
Hierarchical Routing

- As networks grow in size, the router routing tables grow proportionally. At a certain point, the network may grow to the point where it is no longer feasible for every router to have an entry for every other router.
- When hierarchical routing is used, the routers are divided into **regions**. Each router knows all the details about how to route packets to destinations within its own region but knows nothing about the internal structure of other regions.
- For huge networks, a two-level hierarchy may be insufficient; it may be necessary to group the regions into clusters, the clusters into zones, the zones into groups, and so on.

Hierarchical Routing



disadv is that opitmality is lost for some routers but it is usually ac

Full table for 1A

Dest.	Line	Hops
1A	–	–
1B	1B	1
1C	1C	1
2A	1B	2
2B	1B	3
2C	1B	3
2D	1B	4
3A	1C	3
3B	1C	2
4A	1C	3
4B	1C	4
4C	1C	4
5A	1C	4
5B	1C	5
5C	1B	5
5D	1C	6
5E	1C	5

Hierarchical table for 1A

Dest.	Line	Hops
1A	–	–
1B	1B	1
1C	1C	1
2	1B	2
3	1C	2
4	1C	3
5	1C	4

Hierarchical Routing

- For 720 routers, without hierarchy, each router has 720 entries.
- If the network is partitioned into 24 regions of 30 routers each, each router needs 30 local entries plus 23 remote entries.
- For a three-level hierarchy, with 8 clusters each containing 9 regions of 10 routers, each router needs 10 entries for local routers, 8 entries for routing to other regions within its own cluster, and 7 entries for distant clusters.
- How many levels should the hierarchy have?
- Kamoun and Kleinrock (1979) discovered that the optimal number of levels for an N router network is $\log N$, requiring a total of $e \log N$ entries per router.
- Also, increase in effective mean path length is usually acceptable.

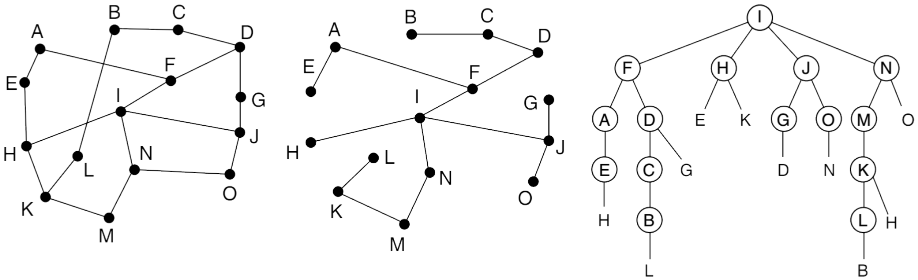
Broadcast Routing

- In some applications, hosts need to send messages to many or all other hosts. Sending a packet to all destinations simultaneously is called **broadcasting**.
- A naive approach is to use **flooding**.
- One broadcasting method that requires no special features from the network is for the source to simply send a distinct packet to each destination.
- An improvement is **multidestination** routing, in which each packet contains either a list of destinations or a bit map indicating the desired destinations. When a packet arrives at a router, the router checks all the destinations to determine the set of output lines that will be needed.

Broadcast Routing

- However, it turns out that we can do better still once the shortest path routes for regular packets have been computed.
- **Reverse path forwarding** is elegant and remarkably simple once it has been pointed out (Dalal and Metcalfe, 1978).
- When a broadcast packet arrives at a router, the router checks to see if the packet arrived on the link that is normally used for sending packets toward the source of the broadcast.
- If so, there is an excellent chance that the broadcast packet itself followed the best route from the router and is therefore the first copy to arrive at the router. This being the case, the router forwards copies of it onto all links except the one it arrived on.
- If, however, the broadcast packet arrived on a link other than the preferred one for reaching the source, the packet is discarded as a likely duplicate.

Reverse Path Forwarding: An Example



After five hops and 24 packets, the broadcasting terminates, compared with four hops and 14 packets had the sink tree been followed exactly.

A possible improvement

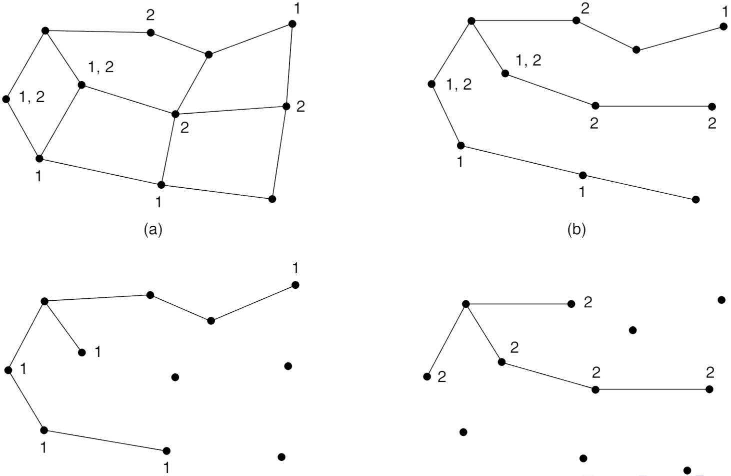
- Let us consider any **spanning tree**. Sink tree is a spanning tree.
- If each router knows which of its lines belong to the spanning tree, it can copy an incoming broadcast packet onto all the spanning tree lines except the one it arrived on.
- Generates the absolute minimum number of packets necessary to do the job.
- Does it have any drawbacks?

Multicast Routing

- Some applications, such as a multiplayer game or live video of a sports event streamed to many viewing locations, send packets to multiple receivers.
- Unless the group is very small, sending a distinct packet to each receiver is expensive.
- On the other hand, broadcasting a packet is wasteful if the group consists of, say, 1000 machines on a million-node network.
- Sending a message to well-defined groups that are numerically large in size but small compared to the network is called **multicasting**, and the routing algorithm used is called **multicast routing**.

Multicast Routing

The solution explored by Deering and Cheriton (1990) is to prune the broadcast spanning tree by removing links that do not lead to members. The result is an efficient multicast spanning tree.

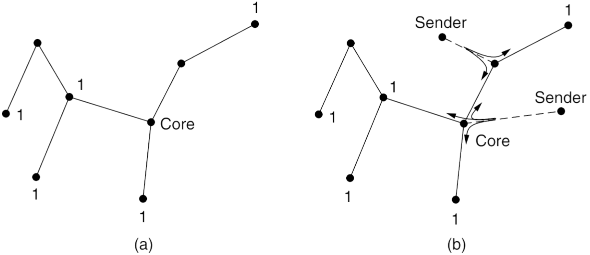


Multicast Routing

- Pruning results in efficient spanning trees that use only the links that are actually needed to reach members of the group. However, it is lots of work for routers, especially for large networks.
- Suppose a network has n groups, each with an average of m nodes. At each router and for each group, m pruned spanning trees must be stored, for a total of mn trees.
- When many large groups with many senders exist, considerable storage is needed to store all the trees.
- An alternative design uses **core-based trees** to compute a single spanning tree for the group (Ballardie et al., 1993).

Multicast Routing

All of the routers agree on a root (called the **core** or **rendezvous point**) and build the tree by sending a packet from each member to the root. The tree is the union of the paths traced by these packets.



Each router has to keep only one tree per group, instead of m trees. Further, routers that are not part of the tree do no work at all to support the group.