

Network Layer

1 Routing Algorithms

Routing is the process of discovering network paths

- Decide what to optimize (e.g., fairness vs efficiency)
- Model the network as a graph of nodes and links
- Update routes for changes in topology (e.g. failures)

2 Optimality Principle

Identify the optimal path from source to destination

Definition: Sink tree

Optimal routes from all sources to a given destination

Distance metric: the number of hops, or time delay

3 Shortest Path Algorithm

Dijkstra's algorithm computes a sink tree on the graph

- Each node is labelled with its distance from the source node to the best known path
- Initially no paths are known
- Each link is assigned a non-negative weight/distance
- Shortest path is the one with the lowest total weight

Algorithm

- Start with sink, set distance at other nodes to infinity
- Labels tentative (◦) or permanent (●), initially all tentative
- Pick the lowest distance non-permanent node, make it permanent
- Repeat from this node, until all nodes are permanent

4 Distance vector routing

There are two dynamic routing algorithms

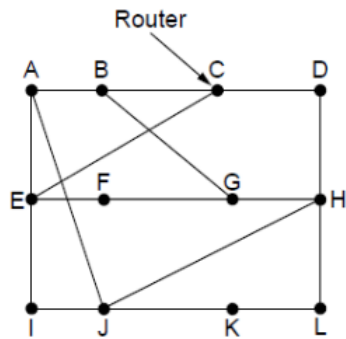
4.1 Distance vector

- Each node maintains a table (vector of best known destination)
- Tables are updated by exchanging information between nodes
- Tables have 2 entries: **outgoing line** and **estimated distance** (# hops or propagation delay)

Algorithm:

- Each node knows distance of links to its neighbours
- Each node advertises a vector of the lowest known distances to all neighbours
- Each node uses received vectors to update its own

- Repeat periodically



Network

Compute the route from J to G.

J → A in 8 msec

A → G 18 msec

J → 8 + 18 = 26 msec.

					New estimated delay from J	
To	A	I	H	K	Line	
A	0	24	20	21	8	A
B	12	36	31	28	20	A
C	25	18	19	36	28	I
D	40	27	8	24	20	H
E	14	7	30	22	17	I
F	23	20	19	40	30	I
G	18	31	6	31	18	H
H	17	20	0	19	12	H
I	21	0	14	22	10	I
J	9	11	7	10	0	—
K	24	22	22	0	6	K
L	29	33	9	9	15	K
					New vector for J	
					JA delay is 8	
					JI delay is 10	
					JH delay is 12	
					JK delay is 6	

Vectors received at J from Neighbours A, I, H and K

4.1.1 The Count-to-Infinity Problem

Failures can cause DV to "count to infinity" while seeking a path to an unreachable node

A	B	C	D	E	
•	•	•	•	•	Initially
	•	•	•	•	After 1 exchange
	1	•	•	•	After 2 exchanges
	1	2	•	•	After 3 exchanges
	1	2	3	•	After 4 exchanges

Good news of a path to A spreads quickly

A	B	C	D	E	
•	•	•	•	•	Initially
•	1	2	3	4	After 1 exchange
•	3	2	3	4	After 2 exchanges
•	3	4	3	4	After 3 exchanges
•	5	4	5	4	After 4 exchanges
•	5	6	5	6	After 5 exchanges
•	7	6	7	6	After 6 exchanges
•	7	8	7	8	After 6 exchanges
•	•	•	•	•	

Bad news of no path to A is learned slowly

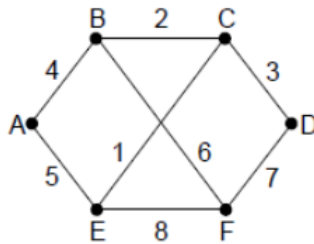
4.2 Link State Routing

Link state is an alternative to distance vector algorithm. There are 5 steps:

1. Learn the network address of the neighbouring routers by sending HELLO packet, record name
2. Set the distance to each neighbour
3. Construct a packet telling all other routers what it has just learned
4. Send the packet to neighbours and receive packet from all other routers
5. Compute the shortest path by using Dijkstra's algorithm

Definition: LSP (Link State Packet)

A list of the node's neighbours and weights of links to reach them



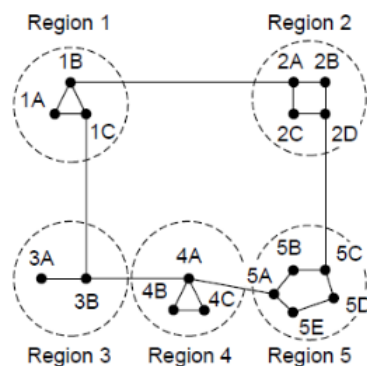
Network

A	B	C	D	E	F
Seq.	Seq.	Seq.	Seq.	Seq.	Seq.
Age	Age	Age	Age	Age	Age
B 4	A 4	B 2	C 3	A 5	B 6
E 5	C 2	D 3	F 7	C 1	D 7
	F 6	E 1		F 8	E 8

LSP for each node

5 Hierarchical Routing

Hierarchical routing reduces the work of route computation but may result in slightly longer paths than flat routing



a

What router should we use from 2A to 4B?

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

b

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

Best choice to reach nodes in 5 except for 5C

c

Useful in the internet, each region would be geographical, makes routing much faster to compute.

6 Flooding

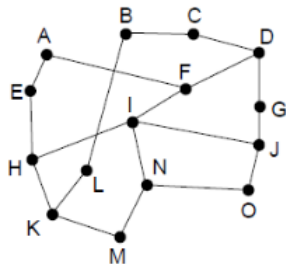
- A simple method to send a packet to all network nodes
- Each node floods a new packet received on an incoming link by sending it out of the other links
- Nodes need to keep track of flooded packets to stop the flood

7 Broadcasting

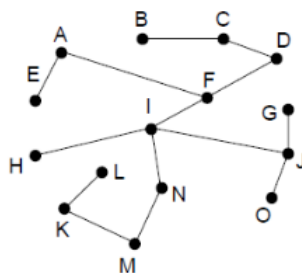
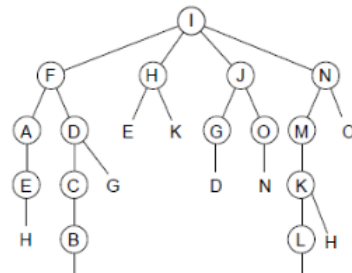
Broadcast sends a packet to all nodes:

- RPF (Reverse Path Forwarding): Arrived packets are checked to see if they arrived from a preferred link, which is the link that is normally used for sending packets towards the source of the broadcast
- 1st hop: I sends packets to F, H J and N. Packets arrive on the same link that is used to send to I

- 2nd hop: 8 packets are generated, two by each router. 5 of them arrive on the preferred link



Network

Sink tree for I is efficient
broadcastRPF from I is larger than
sink tree