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

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 nose 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
- Relax distance to other nodes
- Pick the lowest distance node, add it to sink tree
- Repeat until all nodes are in the sink tree

4 Distance vector routing

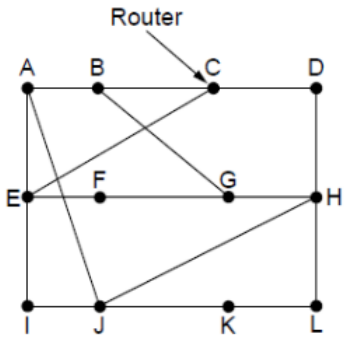
There are two dynamic routing algorithms

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: outline line and estimate 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



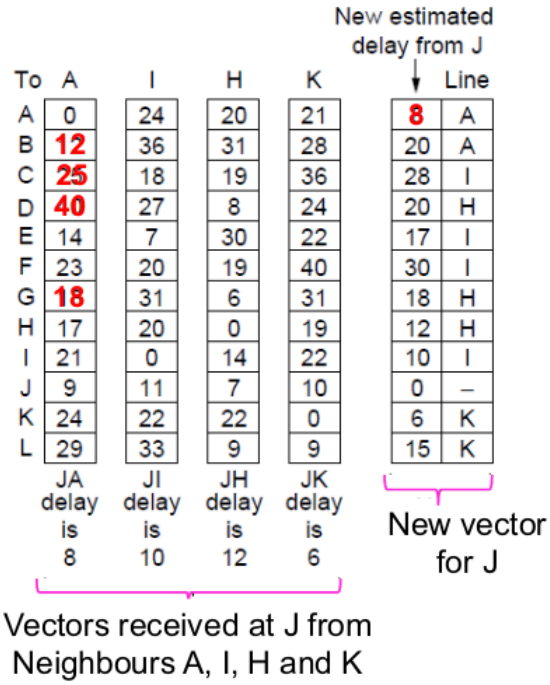
Network

Compute the route from J to G.

J → A in 8 msec

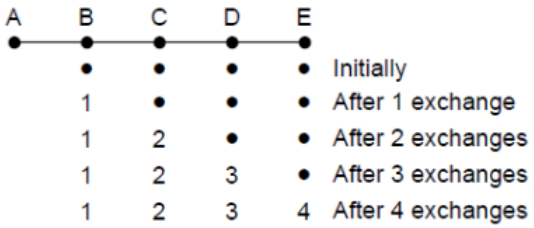
A → G 18 msec

J → 8 + 18 = 26 msec.

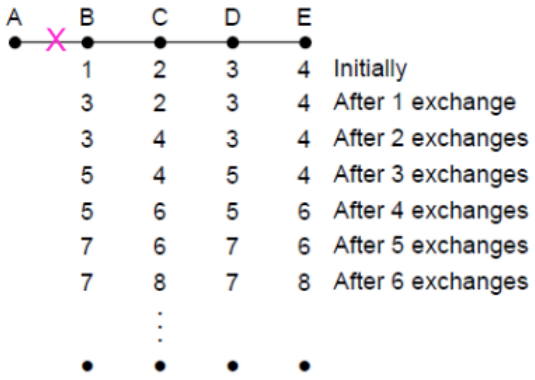


4.1.1 The Count-to-Infinity Problem

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



Good news of a path to *A* spreads quickly



Bad news of no path to *A* is learned slowly

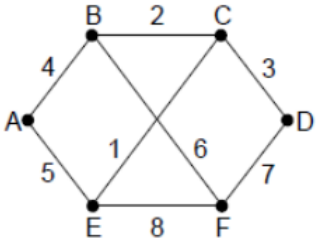
4.2 Link State Routing

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

1. Learn the network address of the neighb ouring routers
2. Set the distance to each neighbour
3. Construct a (HELLO) packet telling all neighbours what it has just learned
4. Send the packet to neighbours and receive packet from neighbours
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	
Seq.	
Age	
B	4
E	5

B	
Seq.	
Age	
A	4
C	2
F	6

C	
Seq.	
Age	
B	2
D	3
E	1

D	
Seq.	
Age	
C	3
F	7

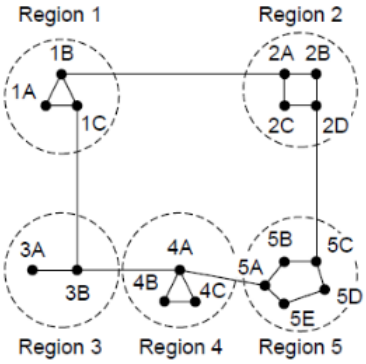
E	
Seq.	
Age	
A	5
C	1
F	8

F	
Seq.	
Age	
B	6
D	7
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

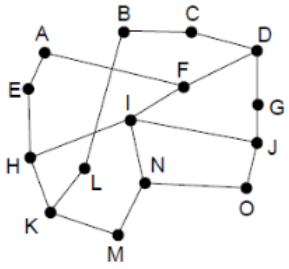
6 Flooding (i.e. broadcasting)

- 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

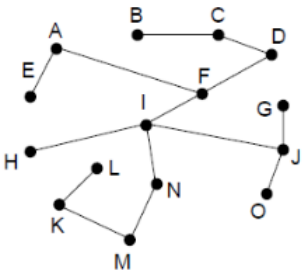
6.1 Broadcast sends a packet to all nodes

Broadcast sends a packet to all nodes:

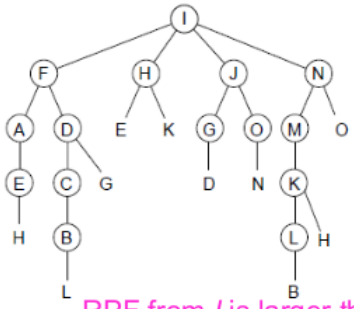
- RPF (Reverse Path Forwarding): Arrived packets are checked to see if they arrived from a preferred link, which is the link that is normally used for sending packets towards the source of the broadcast
- 1st hop: I sends packets to F, H J and N. Packets arrive on the same link that is used to send to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



RPF from *I* is larger than sink tree