The Network Layer: Routing 2: Distance Vector

Smith College, CSC 249
March 6, 2018

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Overview

- Routing Algorithms
  - Link-state – From last week
  - Distance-vector – TODAY

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Overview of Routing so far

- Routing algorithms
  - Find the 'best' path through a network
  - Create forwarding tables
- Routing occurs between routers (not hosts)
- Differences between centralized (global) and decentralized algorithms
  - What are examples of each
  - Amount of information known initially
  - How information is shared/spread
  - Synchronous or asynchronous?

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Algorithm 2: Distance Vector

Rather than using global information, a distance vector algorithm is:

- distributed:
  - each node communicates only with directly-attached neighbors
- iterative:
  - continues until no nodes exchange info.
  - self-terminating: no "signal" to stop
- asynchronous:
  - nodes need *not* exchange information or iterate in lock step!

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Distance Vector Algorithm

Bellman-Ford Equation

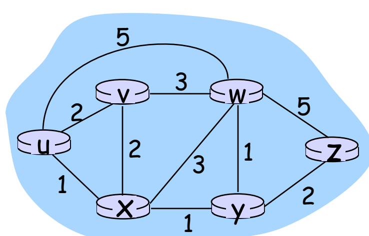
Define
$d_x(y)$:= cost of least-cost path from x to y

Then

$$d_x(y) = \min_v \{c(x,v) + d_v(y)\}$$

where min is taken over all neighbors v of x

Bellman-Ford Equation



Clearly, $d_v(z) =$, $d_x(z) =$, $d_w(z) =$

B-F equation says:

$$\begin{aligned} d_u(z) = \min \{ & c(u,v) + d_v(z), \\ & c(u,x) + d_x(z), \\ & c(u,w) + d_w(z) \} \\ = \min \{ & \\ & \} = \end{aligned}$$

The node that achieves the minimum, is the next hop in the shortest path ➜ forwarding table

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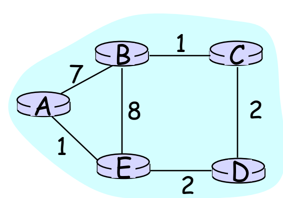
Distance Vector Routing Algorithm

Distance Table data structure

- each node has
  - A row for each possible destination
  - A column for each directly-attached neighbor
- example: in node X, for destination Y via neighbor Z:

$$D^X(Y,Z) = \text{distance } \textit{from } X \textit{ to } Y, \textit{ via } Z \text{ as next hop} = c(X,Z) + \min_w \{D^Z(Y,w)\}$$

Distance Table: example with complete information



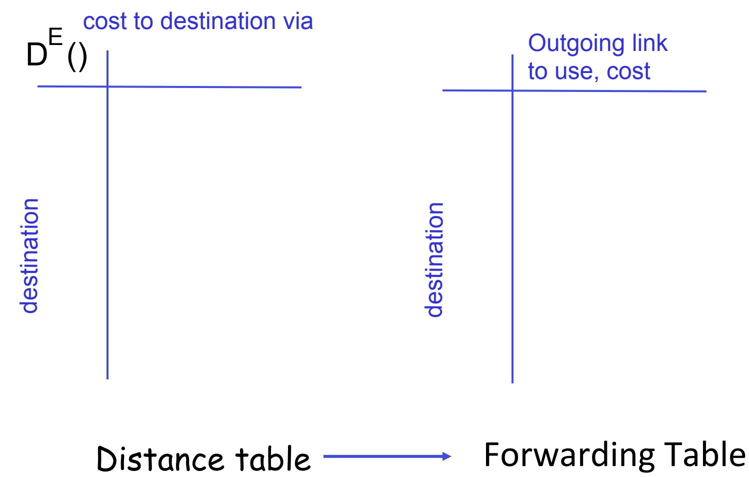
$D^E(C,D) = c(E,D) + \min_w \{D^D(C,w)\}$
$=$

$D^E(A,D) = c(E,D) + \min_w \{D^D(A,w)\}$
$=$

$D^E(A,B) = c(E,B) + \min_w \{D^B(A,w)\}$
$=$

$D^E()$ — cost to destination via (columns); destination (rows)

Distance table to forwarding table



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Distance vector algorithm

Asynchronous Iterations:

- Each node begins with $D_x(y)$
  - An estimate of the cost of the least-cost path from itself to node y, for all nodes in N
- Each node periodically sends its own distance vector estimate to neighbors
  - ➔ A vector of least costs from itself to all routers
- When a node x receives new DV estimate from neighbor, it updates its own DV using B-F equation, and sends any update to its neighbors

$$D_x(y) \leftarrow min_v\{c(x,v) + D_v(y)\} \quad \textit{for each node } y \in N$$

- Under normal conditions, the estimate $D_x(y)$ converges to the actual least cost $d_x(y)$

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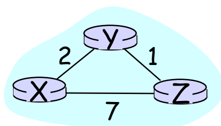
Distance Vector Algorithm: example for ***obtaining*** complete information



D^X	cost via Y	Z
dest Y		
Z		

D^X	cost via Y	Z
dest Y		
Z		

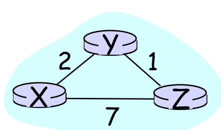
D^Y	cost via X	Z
dest X		
Z		

D^Z	cost via X	Y
dest X		
Y		

$$D^X(Y,Z) = c(X,Z) + \min_w\{D^Z(Y,w)\}$$
$$=$$

$$D^X(Z,Y) = c(X,Y) + \min_w\{D^Y(Z,w)\}$$
$$=$$

Distance Vector Algorithm: obtaining info



D^X	cost via Y	Z
dest Y		
Z		

D^X	cost via Y	Z
Y		
Z		

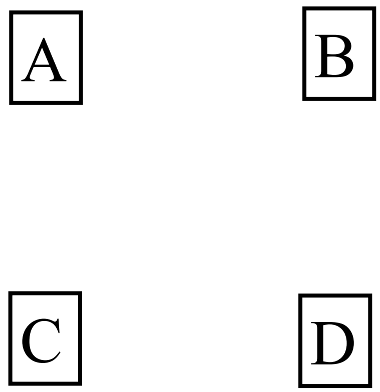
D^Y	cost via X	Z
dest X		
Z		

D^Y	cost via X	Z
X		
Z		

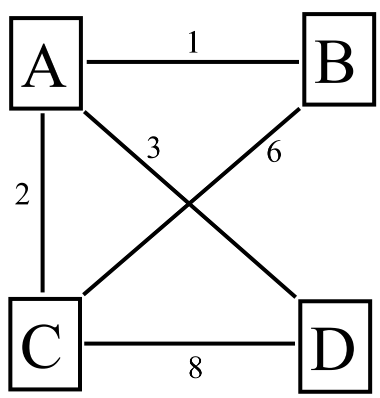
D^Z	cost via X	Y
dest X		
Y		

D^Z	cost via X	Y
X		
Y		

Distance Vector Routing Activity

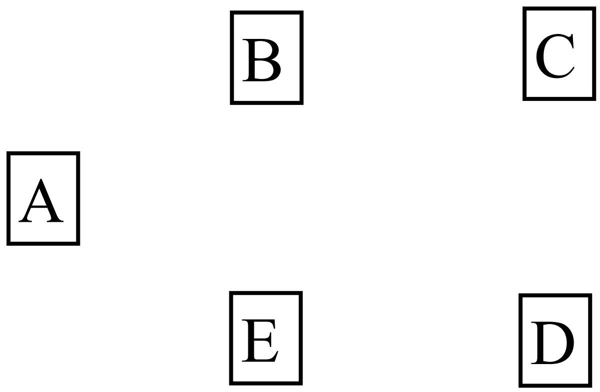


Distance Vector Routing Activity



- Review actual graph – does it match activity results?
- What happens if/when c(A,D) = 4 & c(C,D) = 1?

Distance Vector Routing Activity



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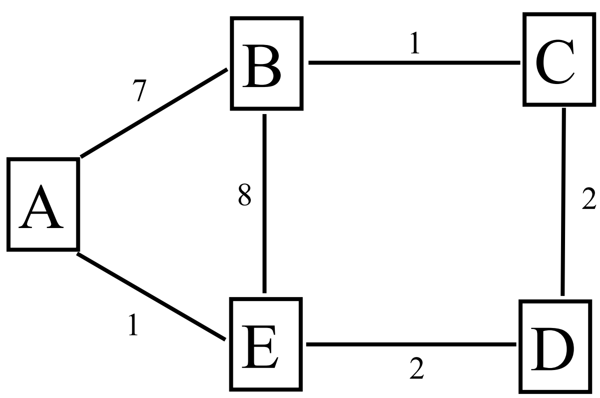
Distance Vector Routing Activity



- Review actual graph – does it match your results?
- What happens if/when c(A,B) = 2 and/or if c(C,D) = 5?

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Comparison of LS and DV algorithms

- Information requirements
- Message complexity
- Convergence time varies
- Robustness: what happens if router malfunctions?
- Oscillations possible?
- Loops possible?

Summary

Forwarding:

- Leads to questions of addressing
  - Assignment of IP addresses
  - NAT, IPv6 …

Routing:

- Routing objectives
- Routing notation
- Routing classification
- Link state v. Distance Vector
- Hierarchical structure