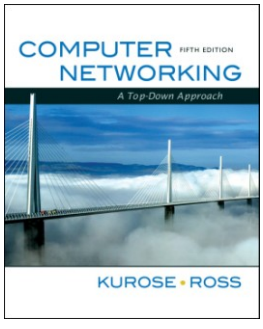
RSC
Part II: Network Layer
5. Network routing (2nd Part)



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These slides are, mainly, part of the companion slides to the book "Computer Networking: A Top Down Approach" generously made available by their authors (see copyright below). The slides have been adapted, where required, to the teaching needs of the subject above.

Computer Networking: A Top Down Approach 5th edition.
Jim Kurose, Keith Ross
Addison-Wesley, April 2009.

RSC Part II: Network Layer

- II. 1 Basic Network layer concepts
- II.2 Introduction to IP
  - Datagram format
  - ICMP
- II.3 IP addressing
  - Obtaining addresses
- II.5 Network routing
  - Link state
  - Distance Vector
- II.6 Routing in the Internet
  - Hierarchical routing
  - RIP

Distance Vector Algorithm

Bellman-Ford Equation (dynamic programming)

Define

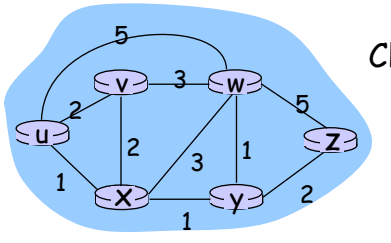
$d_x(y)$:= cost of least-cost path from x to y

Then

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

where min is taken over all neighbors v of x

Bellman-Ford example



Clearly, $d_v(z) = 5$, $d_x(z) = 3$, $d_w(z) = 3$

B-F equation says:

$$d_u(z) = \min \{ c(u,v) + d_v(z), \; c(u,x) + d_x(z), \; c(u,w) + d_w(z) \}$$
$$= \min \{2 + 5,$$

Distance Vector Algorithm

- $D_x(y)$ = estimate of least cost from x to y
- Node x knows cost to each neighbor v: $c(x,v)$
- Node x maintains distance vector $\mathbf{D_x} = [D_x(y): y \in N]$
- Node x also maintains its neighbors' distance vectors
  - For each neighbor v, x maintains $\mathbf{D_v} = [D_v(y): y \in N]$

Distance vector algorithm (4)

Basic idea:

- From time-to-time, each node sends its own distance vector estimate to neighbors
- Asynchronous
- When a node x receives new DV estimate from neighbor, it updates its own DV using B-F equation:

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

Distance Vector Algorithm (5)

Iterative, asynchronous:
each local iteration caused by:

- local link cost change
- DV update message from neighbor

Distributed:

- each node notifies neighbors *only* when its DV changes
  - neighbors then notify their neighbors if necessary

Each node:

wait for (change in local link cost or msg from neighbor)

↓

recompute estimates

↓

if DV to any dest has changed, *notify* neighbors

$D_x(y) = \min\{c(x,y) + D_y(y), c(x,z) + D_z(y)\}$
$= \min\{2+0 , 7+1\} = 2$

$D_x(z) = \min\{c(x,y) + D_y(z), c(x,z) + D_z(z)\}$
$= \min\{2+1 , 7+0\} = 3$

node x table

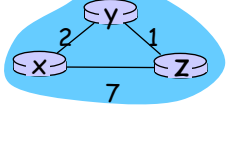
from	cost to x	cost to y	cost to z
x	0	2	7
y	∞	∞	∞
z	∞	∞	∞

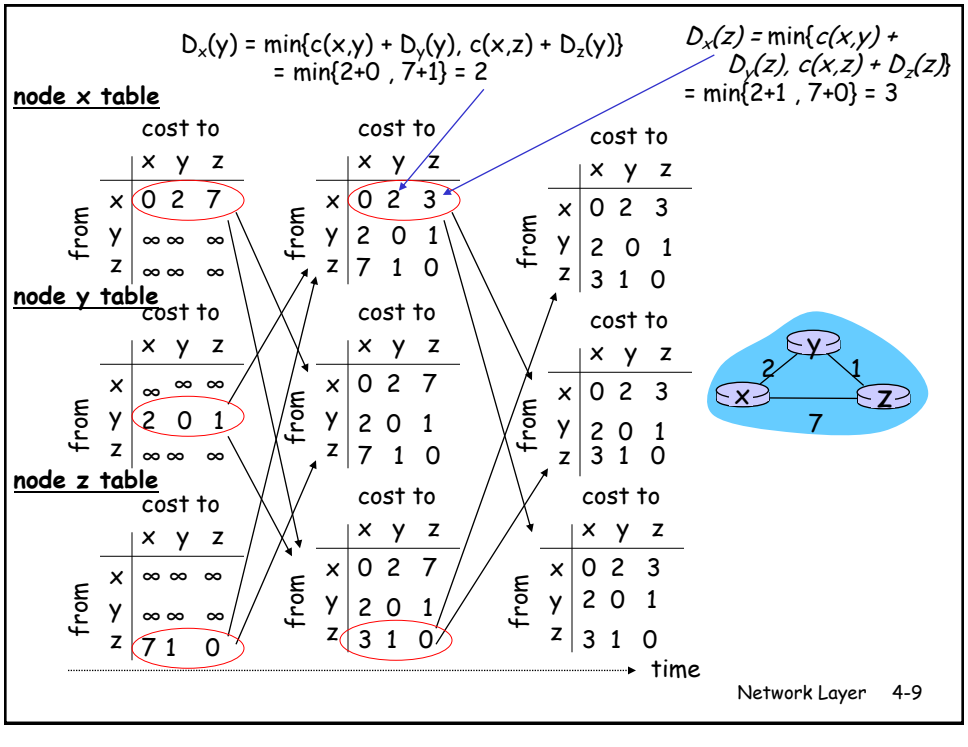
from	cost to x	cost to y	cost to z
x	0	2	3
y	2	0	1
z	7	1	0

node y table

from	cost to x	cost to y	cost to z
x	∞	∞	∞
y	2	0	1
z	∞	∞	∞

node z table

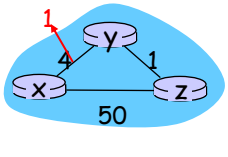




Distance Vector: link cost changes

Link cost changes:

- node detects local link cost change
- updates routing info, recalculates distance vector
- if DV changes, notify neighbors



"good news

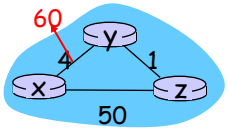
At time t_0, y detects the link-cost change, updates its DV, and informs its neighbors.

At time t_1, z receives the update from y and updates its table.

Distance Vector: link cost changes

Link cost changes:

- good news travels fast
- bad news travels slow - "count to infinity" problem!
- 44 iterations before algorithm stabilizes: see text



Poisoned reverse:

- If Z routes through Y to get to X :
  - Z tells Y its (Z's) distance to X is infinite (so Y won't route to X via Z)
- will this completely solve count to infinity problem?

Comparison of LS and DV algorithms

Message complexity

- LS: with n nodes, E links, O(nE) msgs sent
- DV: exchange between neighbors only
  - convergence time varies

Speed of Convergence

- LS: $O(n^2)$ algorithm requires O(nE) msgs

Robustness: what happens if router malfunctions?

LS:

- node can advertise incorrect *link* cost
- each node computes only its *own* table

DV:

- DV node can advertise