Distance Vector Routing Algorithm

iterative:
- continues until no nodes exchange info.
- *self-terminating*: no "signal" to stop

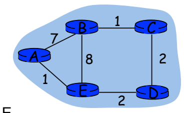
asynchronous:
- nodes need *not* exchange info/iterate in lock step!

distributed:
- each node communicates *only* with directly-attached neighbors

Distance Table data structure
- each node has its own
  - row for each possible destination
  - column for each directly-attached neighbor to node
- example: in node X, for dest. 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



$D^E(C,D) = c(E,D) + \min_W\{D^D(C,w)\}$
$= 2+2 = 4$

$D^E(A,D) = c(E,D) + \min_W\{D^D(A,w)\}$
$= 2+3 = 5$ loop!

$D^E(A,B) = c(E,B) + \min_W\{D^B(A,w)\}$
$= 8+6 = 14$ loop!

cost to destination via

$D^E()$	A	B	D
A	1	14	5
B	7	8	5
C	6	9	4
D	4	11	2

destination

Distance table gives routing table

cost to destination via

$D^E()$	A	B	D
A	1	14	5
B	7	8	5
C	6	9	4
D	4	11	2

destination

	Outgoing link to use, cost
A	A,1
B	D,5
C	D,4
D	D,2

destination

Distance table → Routing table

Distance Vector Routing: overview

Iterative, asynchronous: each local iteration caused by:
- local link cost change
- message from neighbor: its least cost path change from neighbor

Distributed:
- each node notifies neighbors *only* when its least cost path to any destination changes
  - neighbors then notify their neighbors if necessary

Each node:

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

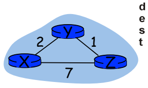
↓

recompute distance table

↓

if least cost path to any dest has changed, *notify* neighbors

Distance Vector Algorithm: example



D^X (dest \ cost via)	Y	Z
Y	2	∞
Z	∞	7

D^Y (dest \ cost via)	X	Z
X	2	∞
Z	∞	1

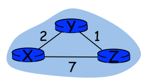
D^Z (dest \ cost via)	X	Y
X	7	∞
Y	∞	1

D^X (dest \ cost via)	Y	Z
Y	2	8
Z	3	7

$D^X(Y,Z) = c(X,Z) + \min_w \{D^Z(Y,w)\}$
$= 7+1 = 8$

$D^X(Z,Y) = c(X,Y) + \min_w \{D^Y(Z,w)\}$
$= 2+1 = 3$

Distance Vector Algorithm: example



D^X (dest \ cost via)	Y	Z
Y	2	∞
Z	∞	7

D^Y (dest \ cost via)	X	Z
X	2	∞
Z	∞	1

D^Z (dest \ cost via)	X	Y
X	7	∞
Y	∞	1

D^X (dest \ cost via)	Y	Z
Y	2	8
Z	3	7

D^Y (dest \ cost via)	X	Z
X	2	8
Z	9	1

D^Z (dest \ cost via)	X	Y
X	7	3
Y	9	1

D^X (dest \ cost via)	Y	Z
Y		
Z		

D^Y (dest \ cost via)	X	Z
X		
Z		

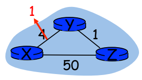
D^Z (dest \ cost via)	X	Y
X		
Y		

Computer Networking and Applications

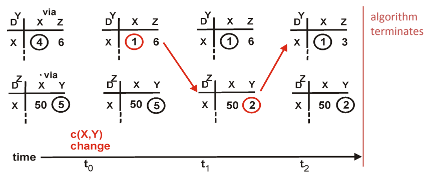
Link cost changes

Link cost changes:

- node detects local link cost change
- updates distance table
- if cost change in least cost path, notify neighbors



"good news travels fast"

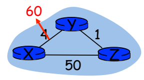


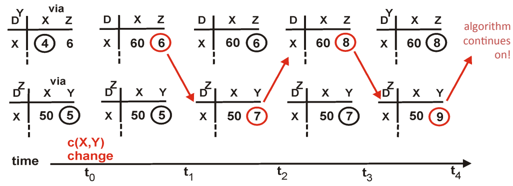
Computer Networking and Applications

Link cost changes

Link cost changes:

- good news travels fast
- bad news travels slow - "count to infinity" problem!



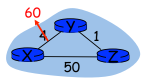


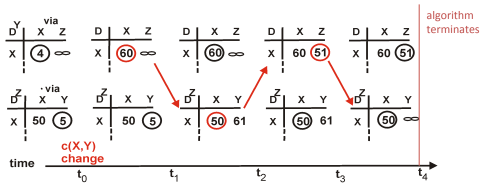
Computer Networking and Applications

DV: 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?





Computer Networking and Applications

Comparison of LS and DV algorithms

Message complexity

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

Speed of Convergence

- LS: O(n**2) algorithm requires O(nE) msgs
  - may have oscillations
- DV: convergence time varies
  - may be routing loops
  - count-to-infinity problem

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 incorrect *path* cost
- each node's table used by others
  - error propagate thru network

Computer Networking and Applications

Hierarchical Routing

Our routing study thus far - idealization

- all routers identical
- network "flat"

... *not* true in practice

> ~~100~~
~~67~~

scale: with 50 million destinations:

- can't store all dest's in routing tables!
- routing table exchange would swamp links!

administrative autonomy

- internet = network of networks
- each network admin may want to control routing in its own network

Computer Networking and Applications

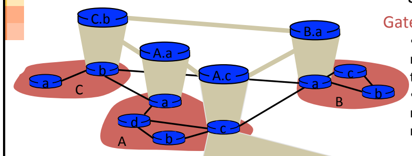
Hierarchical Routing

- aggregate routers into regions, "autonomous systems" (AS)
- routers in same AS run same routing protocol
  - "intra-AS" routing protocol
  - routers in different AS can run different intra-AS routing protocol

gateway routers

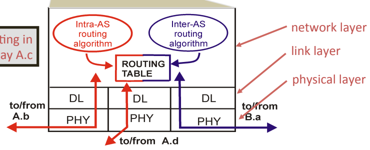
- special routers in AS
- run intra-AS routing protocol with all other routers in AS
- *also* responsible for routing to destinations outside AS
  - run *inter-AS routing* protocol with other gateway routers

Intra-AS and Inter-AS routing

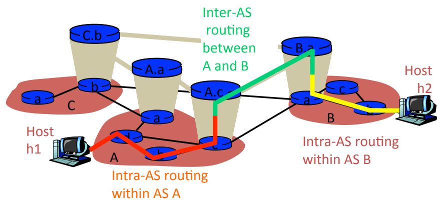


Gateways:
- perform inter-AS routing amongst themselves
- perform intra-AS routers with other routers in their AS

inter-AS, intra-AS routing in gateway A.c



Intra-AS and Inter-AS routing



- Intra-AS protocols include RIP (DV), EIGRP (Hybrid) and OSPF (LSA).
- Inter-AS protocols include BGP (Path Vector Protocol). BGP lets every AS in the Internet know about the subnets in YOUR AS.