

More on Network Routing and Internet Protocol

Kai Shen

9/24/2014

CSC 257/457 - Fall 2014

1

Network Routing

"Link state" routing:

- Dijkstra's algorithm – efficient approach to calculate least cost routes
- all routers need complete topology, link cost info
⇒ costly (or impossible) to acquire such information in large networks

Decentralized routing:

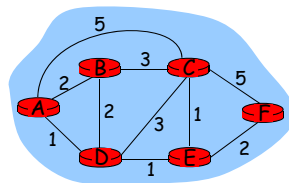
- router only needs to know physically-connected neighbors, link costs to neighbors
⇒ learn more by info exchanges between neighbor routers

9/24/2014

CSC 257/457 - Fall 2014

2

Distance Vector Routing



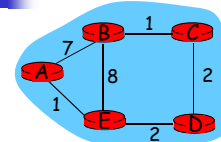
- Routing table (at each host): the next hop for each destination in the network
- Distance vector routing:
 - routing table can be derived from the distance vector at each node
 - distance vectors can be maintained in a decentralized fashion

9/24/2014

CSC 257/457 - Fall 2014

3

Distance Vector: An Example



Distance vector at node E

D (E,x,y)	via first hop x		
	A	B	D
A	1	14	5
B	7	8	5
C	6	9	4
D	4	11	2

$$D(E,D,C) = c(E,D) + \text{shortest}(D,C) = 2+2 = 4$$

$$D(E,D,A) = c(E,D) + \text{shortest}(D,A) = 2+3 = 5 \text{ loop!}$$

$$D(E,B,A) = c(E,B) + \text{shortest}(B,A) = 8+6 = 14 \text{ loop!}$$

9/24/2014

CSC 257/457 - Fall 2014

4

Distance Vector to Routing Table

D ^E ()	cost to destination via			Outgoing link to use, cost
	A	B	D	
A	1	14	5	A, 1
B	7	8	5	D, 5
C	6	9	4	D, 4
D	4	11	2	D, 4

Distance vector → Routing table

9/24/2014

CSC 257/457 - Fall 2014

5

Distance Vector Routing: Constructing Distance Vector

Distance vector can be built on information about local links and neighbors' routing tables!

At node X, each entry D(X,Y,Z) includes:

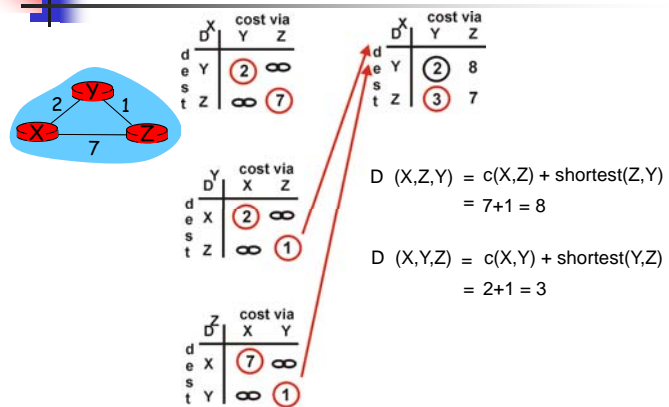
- the distance from X to neighbor Y
- the shortest distance from Y to Z

9/24/2014

CSC 257/457 - Fall 2014

6

Distance Vector Algorithm: An Example

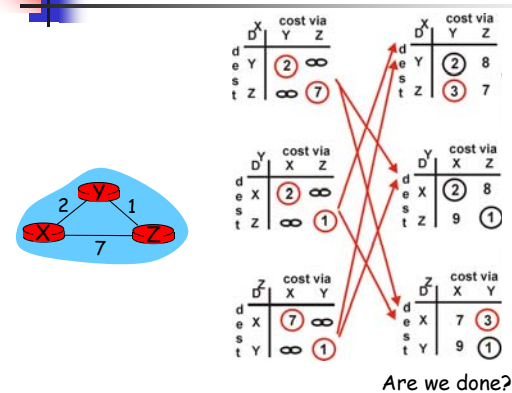


9/24/2014

CSC 257/457 - Fall 2014

7

Distance Vector Algorithm: An Example



9/24/2014

CSC 257/457 - Fall 2014

8

Distance Vector Routing: Maintaining Distance Vector

Information:

- local link cost
- distance vector \rightarrow routing table

Recompute caused by:

- local link cost change
- message from neighbor: its routing table has changed

Notify neighbor:

- if my own routing table has changed, notify my neighbors

Each node:

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

recompute distance vector

if the local routing table has changed, notify neighbors

9/24/2014

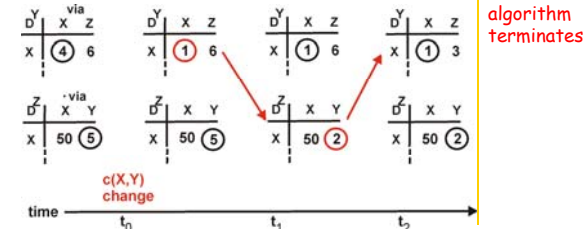
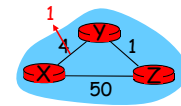
CSC 257/457 - Fall 2014

9

Distance Vector: Link Cost Changes

Link cost changes:

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



9/24/2014

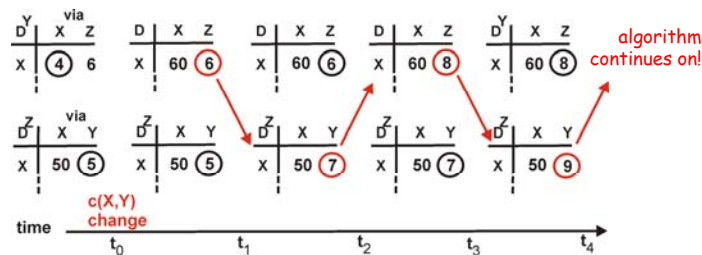
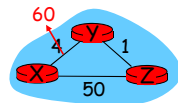
CSC 257/457 - Fall 2014

10

Distance Vector: Link Cost Changes

A pathological case:

- recursive distance vector updates
- applies only to link cost increase
- \Rightarrow bad news settles slowly



9/24/2014

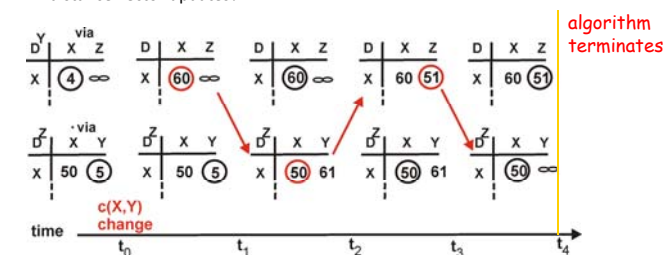
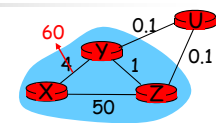
CSC 257/457 - Fall 2014

11

Distance Vector: Link Cost Changes

If Z routes through Y to get to X :

- Z tells Y its (Z's) distance to X is infinity (so Y won't route to X via Z)
- Will this completely solve the problem of recursive distance vector updates?



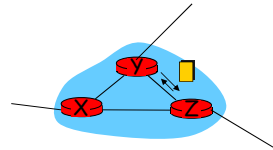
9/24/2014

CSC 257/457 - Fall 2014

12

Routing Loops

- In packet switching networks, each node computes its own routing table independently
- What if?
 - Y's next hop to X is Z;
 - and Z's next hop to X is Y.
- Routing loops
 - during recursive distance vector updates
 - routing mis-behaviors



9/24/2014

CSC 257/457 - Fall 2014

13

Comparison of LS and DV Algorithms

Speed of convergence

- Link state routing: $O(n \log n)$ algorithm in local computation
- Distance vector routing:
 - convergence time?
 - recursive distance vector updates in a pathological case

Robustness: what happens if router malfunctions?

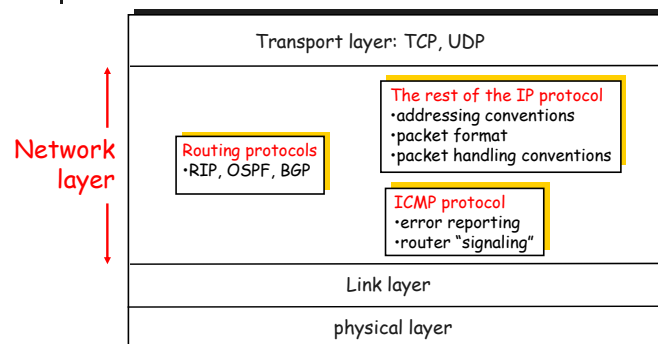
- Link state routing: node can advertise incorrect link cost
- Distance vector routing: node can advertise incorrect routing table

9/24/2014

CSC 257/457 - Fall 2014

14

The Internet Network Layer



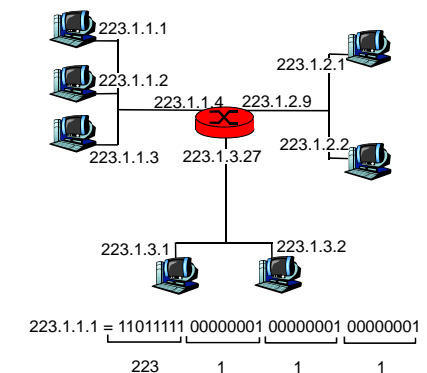
9/24/2014

CSC 257/457 - Fall 2014

15

IP Addressing: Introduction

- IP address:**
 - 32-bit identifier for each host, router interface
- Interface:** connecting point into each data link
 - A router typically has multiple interfaces
 - A host often has single interface



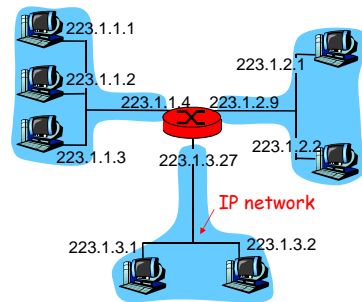
9/24/2014

CSC 257/457 - Fall 2014

16

IP Network and Hierarchical Addressing

- What's an IP network?
 - can physically reach each other without intervening router (*intervening switches?*)
- IP address:
 - network part (high order bits); host part (low order bits)
 - devices with same network part of IP address are in the same IP network



network consisting of 3 IP networks

9/24/2014

CSC 257/457 - Fall 2014

17

IP Addresses: Original Standard

Given notion of "network", let's re-examine IP addresses:

"class"-based addressing:

class

A	0	network	host	1.0.0.0 to 127.255.255.255
B	10	network	host	128.0.0.0 to 191.255.255.255
C	110	network	host	192.0.0.0 to 223.255.255.255
D	1110	multicast address		224.0.0.0 to 239.255.255.255

← 32 bits →

9/24/2014

CSC 257/457 - Fall 2014

18

IP Addressing: CIDR

- "Class"-based addressing:
 - inefficient use of address space, address space exhaustion
 - e.g., class B network allocated enough addresses for 65K hosts, even if only 2K hosts in that network
- CIDR: classless addressing
 - network portion of address of arbitrary length
 - address format: *a.b.c.d/x*, where *x* is # bits in network portion

network part host part
 11001000 00010111 00010000 00000000
 200.23.16.0/23

9/24/2014

CSC 257/457 - Fall 2014

19

IP Address Depletion (DHCP)

Address depletion \Rightarrow 32-bit address space soon to be used up.

Observation: not every host is online at a given time.

DHCP: allow host to *dynamically* obtain its IP address from network server when it joins network

- can renew its lease on address in use
- allows reuse of addresses (only hold address while connected)

9/24/2014

CSC 257/457 - Fall 2014

20

IP Address Depletion (NAT)

Observations:

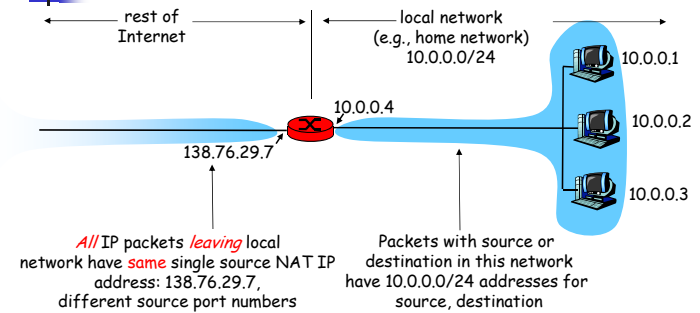
- A lot of traffic is local
- Although IP addresses are few, possible (IPaddr, port) tuples are more abundant and they can identify communication end point

9/24/2014

CSC 257/457 - Fall 2014

21

IP Address Depletion (NAT)



Problem: inbound connection not allowed!

9/24/2014

CSC 257/457 - Fall 2014

22

Disclaimer

- Parts of the lecture slides contain original work of James Kurose, Larry Peterson, and Keith Ross. The slides are intended for the sole purpose of instruction of computer networks at the University of Rochester. All copyrighted materials belong to their original owner(s).

9/24/2014

CSC 257/457 - Fall 2014

23