Distance Vector: Poison 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)
Still, can have problems when more than 2 routers are involved
Comparison of LS and DV algorithms

Message complexity

- **LS**: with n nodes, E links, $O(nE)$ messages sent
- **DV**: exchange between neighbors only
  - Convergence time varies

Speed of Convergence

- **LS**: $O(n^2)$ algorithm requires $O(nE)$ messages
- **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 propagates)
Address Allocation
Hierarchical Addressing: IP Prefixes

- Divided into network & host portions (left and right)
- 12.34.158.0/24 is a 24-bit prefix with $2^8$ addresses

```
00001100 00100010 10011110 00000101
```

Network (24 bits)  Host (8 bits)
IP Address and 24-bit Subnet Mask

Address

12
34
158
5

00001100 00100010 10011110 00000101

11111111 11111111 11111111 00000000

Mask

255 255 255 0
Classful Addressing

• In the olden days, only fixed allocation sizes
  – Class A: 0*  
    • Very large /8 blocks (e.g., MIT has 18.0.0.0/8)  
  – Class B: 10*  
    • Large /16 blocks (e.g., Princeton has 128.112.0.0/16)  
  – Class C: 110*  
    • Small /24 blocks (e.g., AT&T Labs has 192.20.225.0/24)  
  – Class D: 1110*  
    • Multicast groups  
  – Class E: 11110*  
    • Reserved for future use

• This is why folks use dotted-quad notation!
Classless Inter-Domain Routing (CIDR)

Use two 32-bit numbers to represent a network. Network number = IP address + Mask

IP Address: 12.4.0.0       IP Mask: 255.254.0.0

<table>
<thead>
<tr>
<th>Address</th>
<th>Mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>00001100</td>
<td>00000100</td>
</tr>
<tr>
<td>00000000</td>
<td>00000000</td>
</tr>
<tr>
<td>11111111</td>
<td>11111110</td>
</tr>
<tr>
<td>00000000</td>
<td>00000000</td>
</tr>
</tbody>
</table>

Network Prefix: 12.0.0.0/15

Written as 12.4.0.0/15
CIDR: Hierarchal Address Allocation

Prefixes are key to Internet scalability

- Address allocated in contiguous chunks (prefixes)
- Routing protocols and packet forwarding based on prefixes
- Today, routing tables contain ~250,000-300,00 prefixes
Scalability Through Hierarchy

• Hierarchical addressing
  – Critical for scalable system
  – Don’t require everyone to know everyone else
  – Reduces amount of updating when something changes

• Non-uniform hierarchy
  – Useful for heterogeneous networks of different sizes
  – Initial class-based addressing was far too coarse
  – Classless Inter Domain Routing (CIDR) helps

• Next few slides
  – History of the number of globally-visible prefixes
  – Plots are # of prefixes vs. time

Growth faster than improvements in equipment capability
CIDR Deployed (1994-1996): Much Flatter

Efforts to aggregate (even decreases after IETF meetings!)

Good use of aggregation, and peer pressure in CIDR report

Internet boom and increased multi-homing
Long-Term View (1989-2011)

From: http://bgp.potaroo.net/
Obtaining a Block of Addresses

• Separation of control
  – Prefix: assigned to an institution
  – Addresses: assigned by the institution to their nodes

• Who assigns prefixes?
  – Internet Corporation for Assigned Names and Numbers
    • Allocates large address blocks to Regional Internet Registries
  – Regional Internet Registries (RIRs)
    • E.g., ARIN (American Registry for Internet Numbers)
    • Allocates address blocks within their regions
    • Allocated to Internet Service Providers and large institutions
  – Internet Service Providers (ISPs)
    • Allocate address blocks to their customers
    • Who may, in turn, allocate to their customers…
Figuring Out Who Owns an Address

• Address registries
  – Public record of address allocations
  – Internet Service Providers (ISPs) should update when giving addresses to customers
  – However, records are notoriously out-of-date

• Ways to query
  – UNIX: “whois –h whois.arin.net 128.112.136.35”
  – http://www.arin.net/whois/
  – ...

Example Output for 128.112.136.35

OrgName: Princeton University
OrgID: PRNU
Address: Office of Information Technology
Address: 87 Prospect Avenue
City: Princeton
StateProv: NJ
PostalCode: 08544-2007
Country: US
NetRange: 128.112.0.0 - 128.112.255.255
CIDR: 128.112.0.0/16
NetName: PRINCETON
NetHandle: NET-128-112-0-0-1
Parent: NET-128-0-0-0-0
NetType: Direct Allocation
RegDate: 1986-02-24
Hard Policy Questions

• How much address space per geographic region?
  – Equal amount per country?
  – Proportional to the population?
  – What about addresses already allocated?

• Address space portability?
  – Keep your address block when you change providers?
  – Pro: avoid having to renumber your equipment
  – Con: reduces the effectiveness of address aggregation

• Keeping the address registries up to date?
  – What about mergers and acquisitions?
  – Delegation of address blocks to customers?
  – As a result, the registries are horribly out of date

• Many Of These Questions Still Being Answered
  – Let’s understand how Internet routing works…
Global Internet Routing

- Objective is to provide routes to prefixes
  - Could be an IPv4 prefix
  - Could be an IPv6 prefix

- Route should get you to the right “??”
  - Route to 129.82.0.0/16 should get you to ColoState
  - Once here, packet may follow a RIP or OSPF route to the right subnet
Autonomous Systems

• What is an AS?
  – a set of routers under a single technical administration
  – uses an *interior gateway protocol (IGP)* and common metrics to route packets within the AS
  – uses an *interior gateway protocol (IGP)* to route packets to other AS’s

• AS may use multiple IGPs and metrics, but appears as single AS to other AS’s
BGP Routing Choices

• Link state or distance vector?
  – no universal metric - policy decisions

• Problems with distance-vector:
  – Bellman-Ford algorithm slow to converge
    (counting to infinity problem)

• Problems with link state:
  – metric used by routers not the same - loops
  – LS database too large - entire Internet
  – may expose policies to other AS’s
What’s Next

• Read Chapter 1, 2, 3, and 4.1-4.3
• Next Lecture Topics from Chapter 4.4 - 4.6
  – Multicast, MPLS, and Routing Wrap-up
• Homework
  – Due **Thursday** in lecture
• Project 2
  – Due Friday