Lecture 17: Interdomain Routing

CSE 123: Computer Networks
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Overview

• Mitigating loops in DV
  ◆ Split horizon and poison reverse

• Autonomous Systems
  ◆ Each network on the Internet has its own goals

• Path-vector Routing
  ◆ Allows scalable, informed route selection
Handling Link Failure

![Graph showing network nodes A, B, C, D, E with distances]

<table>
<thead>
<tr>
<th>Info at node</th>
<th>Distance to Node</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
</tr>
</tbody>
</table>
Handling Link Failure

- A marks distance to E as $\infty$, and tells B
- E marks distance to A as $\infty$, and tells B and D
- B and D recompute routes and tell C, E and E
- etc… until converge

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<tr>
<th>Info at node</th>
<th>Distance to Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 7 8 10 12</td>
</tr>
<tr>
<td>B</td>
<td>7 0 1 3 5</td>
</tr>
<tr>
<td>C</td>
<td>8 1 0 2 4</td>
</tr>
<tr>
<td>D</td>
<td>10 3 2 0 2</td>
</tr>
<tr>
<td>E</td>
<td>12 5 4 2 0</td>
</tr>
</tbody>
</table>
Problem: Counting to Infinity

Distance to C

A 3 1 B 2 2 C

A 1 B 4 C

A 1 B 4 C

Update 3

Update 4

Etc…
Why so High?

Updates don’t contain enough information

Can’t totally order “bad news” (a link has gone down) above “good news” (a link is available)

\[ B \text{ accepts } A’s \text{ path to } C \text{ that is } implicitly \text{ through } B! \]

Aside: this also causes delays in convergence even when it doesn’t count to infinity
Mitigation Strategies

Hold downs
- As metric increases, delay propagating information
- Limitation: Delays convergence

Loop avoidance
- Full path information in route advertisement
- Explicit queries for loops

Split horizon
- Never advertise a destination through its next hop
  » A doesn’t advertise C to B
- Poison reverse: Send negative information when advertising a destination through its next hop
  » A advertises C to B with a metric of ∞
  » Limitation: Only works for “loop”s of size 2
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)

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Split Horizon Limitations

A tells B & C that D is unreachable

B computes new route through C
- Tells C that D is unreachable (poison reverse)
- Tells A it has path of cost 3 (split horizon doesn’t apply)

A computes new route through B
- A tells C that D is now reachable

Etc…
RIP: Routing Information Protocol

- DV protocol with hop count as metric
  - Infinity value is 16 hops; limits network size
  - Includes split horizon with poison reverse
- Routers send vectors every 30 seconds
  - With triggered updates for link failures
  - Time-out in 180 seconds to detect failures
- Rarely used today

EIGRP: proprietary Cisco protocol

- Ensures loop-freedom (DUAL algorithm)
- Only communicates changes (no regular broadcast)
- Combine multiple metrics into a single metric (BW, delay, reliability, load)
Distance Vector shortest-path routing

- Each node sends list of its shortest distance to each destination to its neighbors
- Neighbors update their lists; iterate

Weak at adapting to changes out of the box

- Problems include loops and count to infinity
Link-state vs. Distance-vector

Message complexity

**LS:** with \( n \) nodes, \( E \) links, \( O(nE) \) messages sent

**DV:** exchange between neighbors only

Speed of Convergence

**LS:** relatively fast

**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:**
Node can advertise incorrect *path* cost
Each node’s table used by others (error propagates)
Routing so far…

Shortest-path routing

- Metric-based, using link weights
- Routers share a common view of path “goodness”

As such, commonly used *inside* an organization

- EIGRP and OSPF are mostly used as *intradomain* protocols

But the Internet is a “network of networks”

- How to stitch the many networks together?
- When networks may not have common goals
- … and may not want to share information
Inter-domain versus intra-domain routing

The Internet is Complicated

You at work —

You at home

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A Brief History

Original ARPAnet had single routing protocol
- Dynamic DV scheme, replaced with static metric LS algorithm

New networks came on the scene
- NSFnet, CSnet, DDN, etc…
- The total number of nodes was growing exponentially
- With their own routing protocols (RIP, Hello, ISIS)
- And their own rules (e.g. NSF AUP)

New requirements
- Huge scale: millions of routers
- Varying routing metrics
- Need to express business realities (policies)
Shortest Path Doesn’t Work

All nodes need common notion of link costs
Incompatible with commercial relationships

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Separate routing inside a domain from routing between domains

- Inside a domain use traditional interior gateway protocols (RIP, OSPF, etc)
  » You've seen these already

- Between domains use **Exterior Gateway Protocols** (EGPs)
  » Only exchange reachability information (not specific metrics)
  » Decide what to do based on local policy

What is a domain?
Internet is divided into **Autonomous Systems**

- Distinct regions of administrative control
- Routers/links managed by a single “institution”
- Service provider, company, university, …

**Hierarchy of Autonomous Systems**

- Large, “tier-1” provider with a nationwide backbone
- Medium-sized regional provider with smaller backbone
- Small network run by a single company or university

**Interaction between Autonomous Systems**

- Internal topology is not shared between ASes
- … but, neighboring ASes interact to coordinate routing
Border routers summarize and advertise their routes to external neighbors and vice-versa

- Border routers apply policy

Internal routers can use notion of default routes

Core is default-free; routers must have a route to all networks in the world

But what routing protocol?
Issues with Link-state

Topology information is flooded
- High bandwidth and storage overhead
- Forces nodes to divulge sensitive information

Entire path computed locally per node
- High processing overhead in a large network

Minimizes some notion of total distance
- Works only if policy is shared and uniform

Typically used only inside an AS
- E.g., OSPF and IS-IS
Distance Vector *almost there*

**Advantages**
- Hides details of the network topology
- Nodes determine only “next hop” toward the destination

**Disadvantages**
- Minimizes some notion of total distance, which is difficult in an interdomain setting
- Slow convergence due to the counting-to-infinity problem (“bad news travels slowly”)

**Idea:** extend the notion of a distance vector
- To make it easier to detect loops
Path-vector Routing

Extension of distance-vector routing
- Support flexible routing policies
- Avoid count-to-infinity problem

Key idea: advertise the entire path
- Distance vector: send *distance metric* per destination
- Path vector: send the *entire path* for each destination
Node can easily detect a loop
- Look for its own node identifier in the path
- E.g., node 1 sees itself in the path “3, 2, 1”

Node can simply discard paths with loops
- E.g., node 1 simply discards the advertisement
Each node can apply local policies

- Path selection: Which path to use?
- Path export: Which paths to advertise?

Examples

- Node 2 may prefer the path “2, 3, 1” over “2, 1”
- Node 1 may not let node 3 hear the path “1, 2”
For next time…

- NO CLASS WEDNESDAY – Veterans Day
- Read Ch 4.1.2 in P&D
- HW 3 due in one week