Lecture 17:
Border Gateway Protocol

CSE 123: Computer Networks
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Some figures courtesy Mike Freedman
Lecture 17 Overview

- Border Gateway Protocol (BGP)
  - The canonical path vector protocol
  - How routing gets done on the Internet today
Autonomous Systems

- 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

How does traffic flow from d to s?
A. 3, 2, 1
B. 1, 2, 3
C. 3, 1
D. You can’t tell
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
Loop Detection

- Routers can easily detect a loop
  - Look for its own node identifier in the path
  - E.g., AS 2 sees itself in the path “3, 2, 1”
- Routers discard paths with loops
  - E.g., AS 2 simply discards the advertisement
Policy Support

- Each AS can apply local policies
  - Path selection: Which path to use?
  - Path export: Which paths to advertise?
- Examples
  - AS 2 may prefer the path “2, 3, 1” over “2, 1”
  - AS 1 may not let node 3 hear the path “1, 2”
Border Gateway Protocol

- Interdomain routing protocol for the Internet
  - Prefix-based path-vector protocol
  - Policy-based routing based on AS Paths
  - Evolved during the past 30 years

- 1989 : BGP-1 [RFC 1105], replacement for EGP
- 1990 : BGP-2 [RFC 1163]
- 1991 : BGP-3 [RFC 1267]
- 1995 : BGP-4 [RFC 1771], support for CIDR
- 2006 : BGP-4 [RFC 4271], update
Basic BGP Operation

- Establish session
- Exchange route advertisements
- Exchange incremental updates

While connection is ALIVE exchange route UPDATE messages

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Step-by-Step

- A node learns multiple paths to destination
  - At most one from each neighbor
  - Stores all of the learned routes in a routing table
  - Applies policy to select a single active route
  - ... and may advertise the route to its neighbors

- Two types of incremental updates
  - Announcement
    » Upon selecting a new active route, add own node id to path
    » ... and (optionally) advertise to each neighbor
  - Withdrawal
    » If the active route is no longer available
    » ... send a withdrawal message to the neighbors
A Simple BGP Route

- Destination prefix (e.g., 128.112.0.0/16)
- Route attributes, including
  - AS path (e.g., “7018 88”)
  - Next-hop IP address (e.g., 12.127.0.121)

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(some) BGP Attributes

- **AS path**: ASs the announcement traversed
- **Next-hop**: where the route was heard from
- **Origin**: Route came from IGP or EGP
- **Local pref**: Statically configured ranking of routes within AS
- **Multi Exit Discriminator (MED)**: preference for where to *exit* network
- **Community**: opaque data used for inter-ISP policy
In conventional path vector routing, a router has one \textit{ranking function}, which reflects its routing policy.
BGP Decision Process

- Default decision for route selection
  - Highest local pref, shortest AS path, lowest MED, prefer eBGP over iBGP, lowest IGP cost, router id

- Many policies built on default decision process, but...
  - Possible to create arbitrary policies in principle
    - Any criteria: BGP attributes, source address, prime number of bytes in message, …
    - Can have separate policy for inbound routes, installed routes and outbound routes
  - Limited only by power of vendor-specific routing language
For Next Time

- Read P&D 3.5
- Homework 3 due Friday