### TOC – Interdomain Routing

- Review
- Why Hierarchical Routing?
- Interconnections
- Big Picture
- Peering and Transit
- Reachability
- BGP

### Review

- BGP

### Why Hierarchical Routing?

- Is a natural way for routing to scale
  - Size
  - Network Administration
  - Governance
- Allows multiple metrics at different levels of the hierarchy
- Exploits address aggregation and allocation

### Interconnections

- The internet is an interconnection of unequal networks
- Interconnection arrangements drive
  - the competitive landscape
  - the robustness of the network
  - End-to-end performance
- Interconnection is central to all large networks
  - Voice
  - Data
  - Wireless
  - Cable

### Interconnections

- [www.thelist.com](http://www.thelist.com)
  - How many ISP’s in the 415 area code?
    - That start with A-C: about 200…
    - Just DSL that start with A-C: about 80
  - In the telephone network
    - How many independent telephone companies in 1894-1902 in the US?
      - 3039 commercial companies, 979 co-operatives
    - By controlling interconnection Bell got rid of them
    - Interconnection is now regulated (CLECs)

### Big Picture

The Internet contains a large number of diverse networks
Peering & Transit

- Peering
  - The business relationship whereby ISPs reciprocally provide to each other connectivity to each others' transit customers

- Transit
  - The business relationship whereby one ISP provides (usually sells) access to all destinations in it's routing table

William B. Norton, "Internet Service Providers and Peering"

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Peering & Transit

Peering

West and East Peer with USNet but they can't reach each other

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Peering & Transit

Transit

Benefits of Transit v/s Peering

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Peering & Transit

Moving from Transit to Peering

Reachability

- Interdomain routing is about implementing policies of reachability
  - Routing efficiency and performance is important, but not essential
- ISPs could be competitors and do not want to share internal network statistics such as load and topology
- Use Border Gateway Protocol (BGP)
  - Border routers communicate over TCP port 179
  - A Path Vector Protocol
    - Communicate entire paths: Route Advertisements
    - A Router Can be involved multiple BGP sessions

William B. Norton, "Internet Service Providers and Peering"
BGP – Border Gateway Protocol

- Concept
- I-BGP & E-BGP
- Border Routers
- Sharing Routes
- Message Types
- Issues
- BGP - Protocol

I-BGP and E-BGP

- Border Routers
  - from the same AS speak IBGP
  - from different AS’s speak EBGP
  - EBGP and IBGP are essentially the same protocol
    - IBGP can only propagate routes it has learned directly from its EBGP neighbors
    - All routers in the same AS form an IBGP mesh
    - Important to keep IBGP and EBGP in sync

Sharing routes

- One router can participate in many BGP sessions.
  - Initially … node advertises ALL routes it wants neighbor to know (could be > 50K routes)
  - Ongoing … only inform neighbor of changes

Message types: 4

- Open: Session establishment id exchange
- Notification: exception driven information
- Keep Alive: soft state
- Update: path vector information
Issues

- Advertising a Route
- Routing Table Scaling
- Update Message

Advertising a Route

- One router telling another one
  - The prefix
  - IP address of the next hop
  - Path list of AS's that the announcement has passed through
    - Since announcement propagates from destination, this yields the path
- No refresh messages required
- The announcing router will follow the path itself

BGP Routing Table Scaling

- Many small networks
- Aggregation hides a lot...

BGP Update Message

- Contains information about
  - New Routes
  - Withdrawn Routes: No longer valid
  - Path Attributes:
    - Path Weights
    - Multiple Exit Discriminators
    - Local Preferences
    - Etc.
- Attribute information allows policies to be implemented

BGP –Protocol

- Path Vector
- Multi-Homing
- Multi-Exit Discriminators
- Routing Process Overview
- Attribute
- Choosing Best Route
- BGP Policies
- Transit vs. Non-Transit AS
- Customer Transit Problem
- BGP and Performance
- Skitter
- Summary

Path Vector

```plaintext
user@router# show ip bgp
BGP table version is 6128791, local router ID is 4.2.34.165
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete
Network     Next Hop         Metric LocPrf Weight Path
* 12.3.2.0/24  192.205.32.153  0     50      0 70184266 4448 25 i
* e128.32.0.0/16 192.205.32.153  0     50      0 70184266 4448 25 e

* Every route advertisement contains the entire AS path
* Generalization of distance vector
* Can implement policies for choosing best route
* Can detect loops at an AS level
```
Multihoming

- Two or more interdomain connections between the same AS's
- Two or more interdomain connections between a customer and different ISPs

Multiexit Discriminators (MEDs)

One AS influences the decisions of a neighboring AS

- AS_A wants to tell AS_B that network x is closer to router 2 than to router 3
- Router 2 advertises a smaller MED value for x than Router 3
- AS_B prefers the path to x that does not go through 6 and 3
- AS_B does not propagate MEDs from AS_A any further

Routing Process Overview

Import Policy Engine
- Decision process
- Routes used by router
- Routes received from neighbors

Export Policy Engine
- Routes sent to neighbors
- Routes in IP routing table
- Routes in BGP table

Attribute: Local Preference

- Used to indicate preference among multiple paths for the same prefix anywhere in the Internet.
- The higher the value the more preferred
- Exchanged between IBGP peers only. Local to the AS.
- Often used to select a specific exit point for a particular destination

Choosing best route

- Choose route with highest LOCAL_PREF
  - Preference-based routing
  - If multiple choices, select route with shortest hop-count
  - If multiple choices for same neighboring AS, choose path with max MED value
  - Choose route based on lowest origin type
    - IGP < EGP < INCOMPLETE
    - Among IGP paths, choose one with lowest cost
    - Finally use router ID to break the tie.

BGP Policies

- Multiple ways to implement a "policy"
  - Decide not propagate advertisements
    - I'm not carrying your traffic
  - Decide not to consider MEDs but use shortest hop
    - Hot potato routing
  - Prepend own AS# multiple times to fool BGP into not thinking AS further away
  - Many others...
Transit vs. Nontransit AS

Transit traffic = traffic whose source and destination are outside the AS

Nontransit AS does not carry transit traffic:
• Advertise own routes only
• Do not propagate routes learned from other AS's

Transit AS does carry transit traffic:
• Advertise its own routes PLUS routes learned from other AS's

Customer-Transit Problem

• Assume that the small ISP is a customer of two large ISPs
• If customer ISP does not obey export rules
  • forwards advertisements from one large ISP to another
  • carries huge volume of transit traffic between two large ISPs

BGP and Performance

• BGP isn’t designed for policy routing not performance
  • Hot Potato routing is most common but suboptimal
  • Performance isn’t the greatest
  • 20% of internet paths inflated by at least 5 router hops

• Very susceptible to router misconfiguration
  • Blackholes: announce a route you cannot reach
  • October 1997: one router brought down the internet for 2 hours
  • Flood update messages (don’t store routes, but keep asking your neighbors to clue you in), 3-5 million useless withdrawals!

• In principle, BGP could diverge

  • Various solutions proposed to limit the set of allowable policies
  • Focuses on avoiding “policy cycles”

Skitter Legend

• Plot the AS based on polar co-ordinates (r,θ):
  • r = 1 – log (As degree +1 / Max Degree+1)
  • Higher the degree lower the radius
  • θ = longitude of AS headquarters

Summary

• The Internet is composed of various ASes which use BGP to inter-network themselves
• The Internet uses classless addressing
• BGP as a routing protocol
  • Path-vector based
  • Supports route-aggregation
  • Supports preferential routing
  • Uses Import and Export policies
• BGP is the protocol that “holds” the Internet together
Summary (cont.)

BGP

Transit Peering Agreements, Customer-Provider

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