Lecture 18: Router Design

Homework 3 due FRIDAY
Lecture 18 Overview

- BGP examples
- AS relationships
- Router internals
Example: Local Pref

Higher Local preference values are more preferred

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How does traffic flow from AS1239 to AS9?

A. 1239 7018 9
B. 1239 73 701 9
C. 1239 9
D. You can’t tell
Assuming identical local pref, how does traffic flow from AS5 to AS1?

A. 5 3 2 1
B. 5 4 1
C. 3 2 1
D. You can’t tell
Business Relationships

- Neighboring ASes have business contracts
  - How much traffic to carry
  - Which destinations to reach
  - How much money to pay

- Common business relationships
  - Customer-provider
    » E.g., UCSD is a customer of Sprint
    » E.g., MIT is a customer of Level3
  - Peer-peer
    » E.g., UUNET is a peer of Sprint
    » E.g., Harvard is a peer of Harvard Business School
A History of Settlement

- The telephone world
  - LECs (local exchange carriers) (e.g., PacBell, NYNEx)
  - IXCs (inter-exchange carriers) (e.g., Sprint, AT&T)

- LECs MUST provide IXCs access to customers
  - This is enforced by laws and regulation

- When a call goes from one phone company to another:
  - Call billed to the caller
  - The money is split up among the phone systems – this is called “settlement”
Customer/Provider

- Customer needs to be reachable from everyone
  - Provider tells all neighbors how to reach the customer
- Customer does not want to provide transit service
  - Customer does not let its providers route through it

Traffic to the customer

Traffic from the customer

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Multi-Homing

- Customers may have more than one provider
  - Extra reliability, survive single ISP failure
  - Financial leverage through competition
  - Better performance by selecting better path
  - Gaming the 95th-percentile billing model

Does the customer forward route announcements from Provider 1 to Provider 2?

A. Yes
B. No
C. It depends on the customer’s policy
Peer-to-Peer Relationship

- Peers exchange traffic between customers
  - AS exports *only* customer routes to a peer
  - AS exports peer’s routes *only* to its customers
  - Often the relationship is settlement-free (i.e., no $$)

Traffic to/from the peer and its customers

Can a peer’s providers send traffic to it over the peering link?

A. Yes  
B. No  
C. It depends on the peer’s policy
**Tier-1 Providers**

- Make up the “core” of the Internet
  - Has no upstream provider of its own
  - Typically has a national or international backbone
- Top of the Internet hierarchy of ~10-20 ASes
  - E.g., AT&T, Level 3 (Global Crossing), NTT/Verio, Century Link (formerly Qwest), Sprint, Verizon
  - Full peer-peer connections between tier-1 providers
A New Internet Model

- Flatter and much more densely interconnected Internet
- Disintermediation between content and "eyeball" networks
- New commercial models between content, consumer and transit

The Internet Hierarchy

Global Internet Core

Regional / Tier2 Providers

Customer IP Networks

Global Transit / National Backbones

"Hyper Giants"
Large Content, Consumer, Hosting CDN

IXP

ISP1

ISP2

Settlement free
Pay for BW
Pay for access BW
BGP Has Lots of Problems

- Instability
  - Route flapping (network x.y/z goes down… tell everyone)
  - Long AS-path decision criteria defaults to DV-like behavior (bouncing)
  - Not guaranteed to converge, NP-hard to tell if it does

- Scalability still a problem
  - >500,000 network prefixes in default-free table today
  - Tension: Want to manage traffic to very specific networks (eg. multihomed content providers) but also want to aggregate information.

- Performance
  - Non-optimal, doesn’t balance load across paths
BGP Summary

- Interdomain-routing
  - Exchange reachability information (plus hints)
  - BGP is based on path vector routing
  - Local policy to decide which path to follow

- Traffic exchange policies are a big issue $$$
  - Complicated by lack of compelling economic model (who creates value?)
  - Can have significant impact on performance
What’s in a Router?

- Physical components
  - One or more input interfaces that receive packets
  - One or more output interfaces that transmit packets
  - A chassis (box + power) to hold it all

- Functions
  - **Forward** packets
  - **Drop** packets (congestion, security, QoS)
  - **Delay** packets (QoS)
  - **Transform** packets? (Encapsulation, Tunneling)
Router Functions

1. Receive incoming packet from link input interface
2. Lookup packet destination in forwarding table (destination, output port(s))
3. Validate checksum, decrement ttl, update checksum
4. Buffer packet in input queue
5. Send packet to output interface (interfaces?)
6. Buffer packet in output queue
7. Send packet to output interface link
Functional architecture

Control Plane
- Complex
- Per-control action
- May be slow

Data plane
- Simple
- Per-packet
- Must be fast

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Interconnect architecture

- Input & output connected via switch fabric

- Kinds of switch fabric
  - Shared Memory
  - Bus
  - Crossbar

- How to deal with transient contention?
  - Buffering
First Generation Routers

Single CPU and shared memory;
All classification by main CPU

Which resource most limits router capacity in first-generation routers?

A. Line cards
B. Main memory
C. CPU
D. Shared bus
Which resource most limits router capacity in second-generation routers?

A. Line cards
B. Main memory
C. CPU
D. Shared bus
Third Generation Routers

- Shared interconnect (frequently crossbar)
- Centralized scheduler
- Full forwarding table in line card
- Fixed cells
For Next Time

- Read P&D 6.1
- Homework 3 due Friday
- Keep chugging on P2a