Lecture 4: Routing

CSE 222A: Computer Communication Networks

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Lecture 4 Overview

- Pop quiz
- Paxon ‘95 discussion
- *Brief* intro to overlay and active networking

End-to-End Routing Behavior

- Importance of paper
  - Revitalized field of network measurement
  - Use of statistical techniques to capture new types of measurements
  - Empirical findings of routing behavior (motivation for future work)
- Various routing pathologies
  - Routing loops
  - Erroneous
  - Connectivity altered mid-stream
  - Fluttering…

Paxson Study: Forwarding Loops

- Forwarding loop
  - Packet returns to same router multiple times
- May cause traceroute to show a loop
  - If loop lasted long enough
  - So many packets traverse the loopy path
- Traceroute may reveal false loops
  - Path change that leads to a longer path
  - Causing later probe packets to hit same nodes
- Heuristic solution
  - Require traceroute to return same path 3 times

Routing Loops

- Persistent Routing Loops
  - 10 persistent routing loops in D1
  - 50 persistent routing loops in D2
- Temporary Routing Loops
  - 2 loops in D1
  - 21 in D2
- Location of Routing Loops: All in one AS

Paxson Study: Causes of Loops

- Transient vs. persistent
  - Transient: routing-protocol convergence
  - Persistent: likely configuration problem
- Challenges
  - Appropriate time boundary between the two?
  - What about flaky equipment going up and down?
  - Determining the cause of persistent loops?
- Anecdote on recent study of persistent loops
  - Provider has static route for customer prefix
  - Customer has default route to the provider

End-to-End Routing Behavior

Pathology type	Prevalence in 1995	Prevalence in 1996
Long-lived Routing loops	~ 0.14%	same
Short-lived Routing loops	~ 0.065%	same
Outage>30s	0.96%	2.2%
Total	1.5%	3.4%

Paxson Study: Path Fluttering

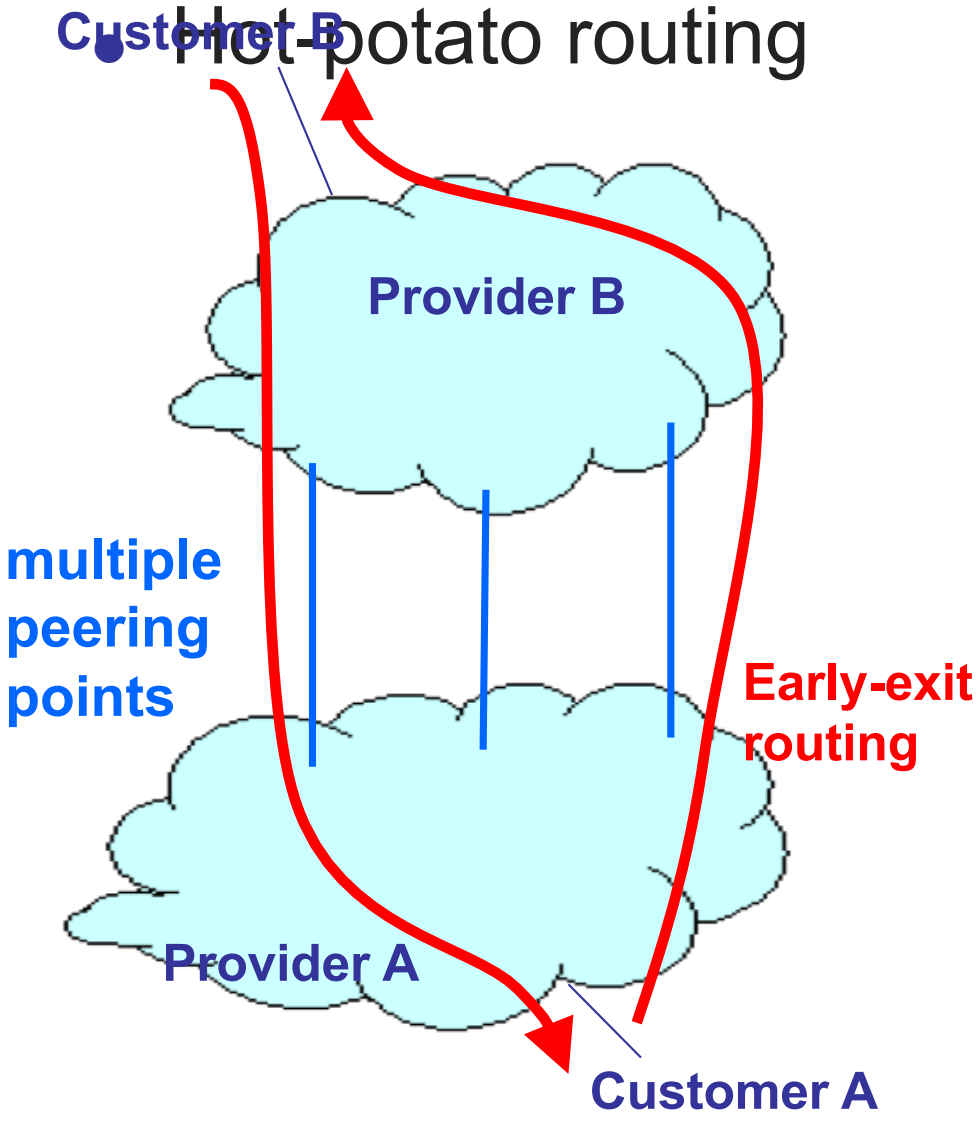
- Rapid changes between paths
  - Multiple paths between a pair of hosts
  - Load balancing policies inside the network
- Packet-based load balancing
  - Round-robin or random
  - Multiple paths for packets in a single flow
- Flow-based load balancing
  - Hash of some fields in the packet header
  - E.g., IP addresses, port numbers, etc.
  - To keep packets in a flow on one path

Paxson Study: Routing Stability

- Route prevalence
  - Likelihood of observing a particular route
  - Relatively easy to measure with sound sampling
  - Poisson arrivals see time averages (PASTA)
  - Most host pairs have a dominant route
- Route persistence
  - How long a route endures before a change
  - Much harder to measure through active probes
  - Look for cases of multiple observations
  - Typical host pair has path persistence of a week

Paxson Study: Route Asymmetry

- Hot-potato routing



- Other causes
  - Asymmetric link weights in intradomain routing
  - Cold-potato routing, where AS requests traffic enter at particular place
- Consequences
  - Lots of asymmetry
  - One-way delay is not necessarily half of the round-trip time

Questions

- Why can't we measure the Internet more directly?
  - What can we do about it?
- Right division of labor between host and network?
  - For path selection
  - For network monitoring
- How do we fix these routing problems?
  - In a decentralized, federated network
  - How to incentivize better network management

Internet "Ossification"

- Internet protocols evolve over long timescales
  - Witness the paper we just read from 1974
  - IPv6 was proposed almost 15 years ago now! (RFC2460)
- Yet new ideas appear all the time
  - RFCs are now at 7400+
  - SIGCOMM/NSDI/etc. are full of new protocols/architectures
- Key challenge: how to deploy new things STAT?
  - In particular changes to the networking layer
  - Would naively require changing every router on the Internet!

Obvious solution: Overlays

- Build the service at a layer above IP
  - Create an “overlay” of nodes connected by IP
  - Functionality implemented at IP “end hosts” and forwarded on
  - IP provides “tunnels” between nodes of overlay
- Exactly the same approach originally used by IP
  - IP treated the phone network as a series of tunnels
- Used to introduce a variety of services in the ‘90s
  - M-Bone, X-Bone, A-Bone, etc., etc.
- Major downside is performance
  - Each packet needs to be handled by an end host
  - Likely traverses an inefficient route

An Alternative Approach

- Make the routers extensible: Active Networking
  - Provide a mechanism to implement services at an Internet router
  - Removes the need to route indirectly
  - But still requires additional end-host-like processing
- Same idea, two different layers
  - Active nodes are implemented at the (extended) network layer
  - Overlay nodes operate at the application layer
- Performance/deployment tradeoffs
  - Anybody can deploy an overlay network
  - But Active networks could be much more efficient

Active Nodes

- Execute protocols in restricted environment
  - Limits access to sensitive/shared resources
- Primitives for application-defined protocol processing
- Enforce limits on resource consumption
  - Active Nodes responsible for network integrity and errors
  - TTL fields decreased as resources are consumed
  - Capsules with 0 TTL's discarded
- Code propagation
  - Capsules identify protocol
  - Protocol uniquely define code path, Active Node retrieves it
  - MD-5 signature for safety

ANTS

- Java toolkit for writing and executing active protocol code
- Goals
  - Simultaneous use of multiple network protocols
  - Deploy multiple protocols with no central control (orig)
  - Dynamic deployment of new protocols (orig)
- Migration path from non-active to active world
  - Benefits from a small number of active nodes
  - Rather than make hop by hop routing decisions, make active node to active node routing decisions
  - Minimum number of nodes necessary for success?
  - Small number of nodes successful/meltdown under scale?

For Next Class…

- Read and review Wetherall ‘98
- Submit project ideas by Wednesday
  - We’ll post ideas/names to help you find groups afterwards
  - Email to me