Lecture 4: Routing

CSE 222A: Computer Communication Networks
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Thanks: Amin Vahdat
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

<table>
<thead>
<tr>
<th>Pathology type</th>
<th>Prevalence in 1995</th>
<th>Prevalence in 1996</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-lived Routing loops</td>
<td>~ 0.14%</td>
<td>same</td>
</tr>
<tr>
<td>Short-lived Routing loops</td>
<td>~ 0.065%</td>
<td>same</td>
</tr>
<tr>
<td>Outage&gt;30s</td>
<td>0.96%</td>
<td>2.2%</td>
</tr>
<tr>
<td>Total</td>
<td>1.5%</td>
<td>3.4%</td>
</tr>
</tbody>
</table>
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