Lecture 13: Naming

CSE 123: Computer Networks
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Project 1 due Friday

Some material courtesy Mike Freedman
Lecture 13 Overview

- Packet forwarding example
- User-friendly names (DNS)
- Discovering addresses (DHCP/ARP)
- End-to-end lookup and forwarding example
Forwarding example

- Packet to 10.1.1.6 arrives
- Path is R2 – R1 – H1 – H2
Forwarding example (2)

- Packet to 10.1.1.6
- Matches 10.1.0.0/23

Forwarding table at R2

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>127.0.0.1</td>
<td>loopback</td>
</tr>
<tr>
<td>Default or 0/0</td>
<td>10.1.16.1</td>
</tr>
<tr>
<td>10.1.8.0/24</td>
<td>interface1</td>
</tr>
<tr>
<td>10.1.2.0/23</td>
<td>interface2</td>
</tr>
<tr>
<td><strong>10.1.0.0/23</strong></td>
<td><strong>10.1.2.2</strong></td>
</tr>
<tr>
<td>10.1.16.0/24</td>
<td>interface3</td>
</tr>
</tbody>
</table>
Forwarding example (3)

- Packet to 10.1.1.6
- Matches 10.1.1.4/30
  - Longest prefix match

Routing table at R1

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>127.0.0.1</td>
<td>loopback</td>
</tr>
<tr>
<td>Default or 0/0</td>
<td>10.1.2.1</td>
</tr>
<tr>
<td>10.1.0.0/24</td>
<td>interface1</td>
</tr>
<tr>
<td><strong>10.1.1.0/24</strong></td>
<td>interface2</td>
</tr>
<tr>
<td>10.1.2.0/23</td>
<td>interface3</td>
</tr>
<tr>
<td><strong>10.1.1.4/30</strong></td>
<td>10.1.1.7</td>
</tr>
</tbody>
</table>

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Forwarding example (4)

- Packet to 10.1.1.6
- Direct route
  - Longest prefix match

Routing table at H1

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>127.0.0.1</td>
<td>loopback</td>
</tr>
<tr>
<td>Default or 0/0</td>
<td>10.1.1.1</td>
</tr>
<tr>
<td>10.1.1.0/24</td>
<td>interface1</td>
</tr>
<tr>
<td>10.1.1.4/30</td>
<td>interface2</td>
</tr>
</tbody>
</table>

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Layers of Identifiers

- **Host name** (e.g., www.ucsd.edu)
  - Used by *humans* to specify host of interest
  - Unique, selected by host administrator
  - Hierarchical, variable-length string of alphanumeric characters

- **IP address** (e.g., 128.54.70.238)
  - Used by *routers* to forward packets
  - Unique, topologically meaningful locator
  - Hierarchical namespace of 32 bits

- **MAC address** (e.g., 58:B0:35:F2:3C:D9)
  - Used by *network adaptors* to identify interesting frames
  - Unique, hard-coded identifier burned into network adaptor
  - Flat name space (of 48 bits in Ethernet)
Host name: www.ucsd.edu
- **Domain**: registrar for each top-level domain (e.g., .edu)
- **Host name**: local administrator assigns to each host

IP addresses: 128.54.70.238
- **Prefixes**: ICANN, regional Internet registries, and ISPs
- **Hosts**: static configuration, or dynamic using DHCP

MAC addresses: 58:B0:35:F2:3C:D9
- **OIDs**: assigned to vendors by the IEEE
- **Adapters**: assigned by the vendor from its block
Mapping Between Identifiers

- Domain Name System (DNS)
  - Given a host name, provide the IP address
  - Given an IP address, provide the host name

- Address Resolution Protocol (ARP)
  - Given an IP address, provide the MAC address
  - To enable communication within the Local Area Network

- Dynamic Host Configuration Protocol (DHCP)
  - Automates host boot-up process
  - Given a MAC address, assign a unique IP address
  - … and tell host other stuff about the Local Area Network
Domain Name System (DNS)

- Distributed administrative control
  - Hierarchical name space divided into zones
  - Distributed over a collection of DNS servers

- Hierarchy of DNS servers
  - Root servers
  - Top-level domain (TLD) servers
  - Authoritative DNS servers

- Performing the translations
  - Local DNS servers
  - Resolver software
DNS: Distributed Database

Unnamed root

- com
- edu
- ... (generic domains)
- org
- ac
- ... (country domains)
- uk
- zw

- bar
  - west
  - east
  - foo
  - my
  - my.east.bar.edu

- ac
  - cam
  - usr
  - usr.cam.ac.uk

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DNS Root Servers

- 13 root servers (see http://www.root-servers.org/)
  - Labeled A through M

  A Verisign, Dulles, VA
  C Cogent, Herndon, VA (also Los Angeles)
  D U Maryland College Park, MD
  G US DoD Vienna, VA
  H ARL Aberdeen, MD
  J Verisign, (11 locations)
  K RIPE London (+ Amsterdam, Frankfurt)
  I Autonomica, Stockholm
    (plus 3 other locations)
  E NASA Mt View, CA
  F Internet Software C. Palo Alto, CA (and 17 other locations)
  B USC-ISI Marina del Rey, CA
  L ICANN Los Angeles, CA
  m WIDE Tokyo

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Using DNS

- Local DNS server ("default name server")
  - Usually near the end hosts who use it
  - Local hosts configured with local server (e.g., /etc/resolv.conf) or learn the server via DHCP

- Client application
  - Extract server name (e.g., from the URL)
  - Do `gethostbyname()` to trigger resolver code

- Server application
  - Extract client IP address from socket
  - Optional `gethostbyaddr()` to translate into name
Host at cis.poly.edu wants IP address for gaia.cs.umass.edu!

cis.poly.edu

requesting host
dns.poly.edu

local DNS server

root DNS server

tld.cs.umass.edu

TLD DNS server

authoritative DNS server

dns.cs.umass.edu

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Reliability

- DNS servers are replicated
  - Name service available if at least one replica is up
  - Queries can be load balanced between replicas

- UDP used for queries
  - Need reliability: must implement this on top of UDP
  - Try alternate servers on timeout
  - Exponential backoff when retrying same server

- Cache responses to decrease load
  - Both at end hosts and local servers
Whence come IP Addresses?

- You already have a bunch from the days when you called Jon Postel and asked for them (e.g. BBN)

- You get them from another provider
  - E.g. buy service from Sprint and get a /24 from one of their address blocks

- You get one directly from a routing registry
  - ARIN: North America, APNIC (Asia Pacific), RIPE (Europe), LACNIC (Latin America), etc.
  - Registries get address from IANA (Internet Assigned Numbers Authority)
How Do You And I Get One?

- Well from your provider!

- But how do you know what it is?

- Manual configuration
  - They tell you and you type that number into your computer (along with the default gateway, DNS server, etc.)

- Automated configuration
  - Dynamic Host Resolution Protocol (DHCP)
Bootstrapping Problem

- Host doesn’t have an IP address yet
  - So, host doesn’t know what source address to use

- Host doesn’t know who to ask for an IP address
  - So, host doesn’t know what destination address to use

- Solution: shout to discover a server who can help
  - Install a special server on the LAN to answer distress calls

DHCP server

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DHCP

- Broadcast-based LAN protocol algorithm
  - Host broadcasts “DHCP discover” on LAN (e.g. Ethernet broadcast)
  - DHCP server responds with “DHCP offer” message
  - Host requests IP address: “DHCP request” message
  - DHCP server sends address: “DHCP ack” message w/IP address

- Easy to have fewer addresses than hosts (e.g. UCSD wireless) and to renumber network (use new addresses)

- What if host goes away (how to get address back?)
  - Address is a “lease” not a “grant”, has a timeout
  - Host may have different IP addresses at different times?
Address Resolution Protocol

- Every node maintains an ARP table
  - (IP address, MAC address) pair
- Consult the table when sending a packet
  - Map destination IP address to MAC address
  - Encapsulate and transmit the data packet
- What if the IP address is not in the table?
  - Broadcast: “Who has IP address x.x.x.x?”
  - Sender caches the result in its ARP table
Summary

- Domain Name System
  - Distributed, hierarchical database
  - Distributed collection of servers
  - Caching to improve performance

- IP to MAC Address mapping
  - Dynamic Host Configuration Protocol (DHCP)
  - Address Resolution Protocol (ARP)
For Next Time

- Read 3.4 in P&D
- Finish up Project 1!
  - Lose a letter grade for each day late.