Network Layer Addressing

CS640, 2015-02-17

Announcements
● Quiz 2 is Thursday
● Project 2 has been released

Overview
● Motivation for Network Layer
● Network Layer Addressing

Motivation for Network Layer
● **What are some scalability problems with using link layer forwarding?**
  ○ Switches broadcast packets when the path to the destination is not known
    => volume of traffic increases as number of hosts and size of network increases
  ○ Link layer addresses have no hierarchy
    => size of forwarding tables grows linearly as number of hosts increases
  ○ Can address some scalability issues using virtual local area networks (VLANs)
● Want to create a network-of-networks (i.e., an “internetwork”) to address these issues
● Two main concerns for network layer
  ○ Addressing -- want something hierarchical
  ○ Routing -- want better control over forwarding

Addressing
● Requirements
  ○ Global uniqueness -- every interface (on host or router) must have an IP address that’s not used by any other node on the Internet
  ○ Hierarchical -- provide a way to organize networks and reduce forwarding table size
● Representation
  ○ 32-bit integer
  ○ Typically written in dotted-decimal form -- each byte is written as a decimal number and the decimals are separated by dots; e.g., 128.105.14.122
● **How do we provide hierarchy?**
  ○ Class-based addressing; subnets

Class-Based Addressing
● Divide 32-bits into two parts
  ○ Network: same for all hosts in a switched network
  ○ Host: unique to each host
Three classes: A, B, & C

- First few bits determine class
- Number of host bits determines the maximum number of hosts within a network
  - A: \(2^{24} - 2\) = about 16.7 million
  - B: \(2^{16} - 2\) = 65,534
  - C: \(2^8 - 2\) = 254
- All-zeros host value reserved for network address
- All-ones host address reserved for broadcast address

Limitation: allocation is too coarse grained
- Only allows for extremely large, moderate, and extremely small networks
  - If number of hosts is in-between, then addresses are wasted -- e.g., network with 255 hosts requires class B, which wastes >65K addresses
  - Could assign multiple class C’s to avoid wasting part of a class B, but now you need multiple entries in forwarding tables in routers
- Only allows for 127 networks with more than 65,534 hosts

**How do we address these issues?**

Classless Interdomain Routing (CIDR)
- Do not limit network sizes to three classes
- Assign network numbers in powers of 2
- Use a mask to identify number of bits used for network number

<table>
<thead>
<tr>
<th>Mask</th>
<th>Network (8)</th>
<th>Host (24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11111111</td>
<td>00000000 00000000 00000000</td>
<td></td>
</tr>
</tbody>
</table>

Two ways to specify netmask
- In dotted-decimal form -- e.g., 255.0.0.0 is 8-bit netmask
- In slash notation -- e.g., /8 is 8-bit netmask
- Conversion: dotted-decimal to slash
  - For each octet of 255: add 8
  - For each octet between 0 and 255: add \(8 - \log_2(256\text{-octet})\)
- Conversion: slash to dotted-decimal
  - While \(\geq 8\): add 255 octet, subtract 8
  - Add octet 256 - \(2^{(8-\text{remain})}\)
  - Add 0 octets until there are four octets

**What is the slash notation for the netmask 255.255.0.0?** -- /8

**What is the netmask for the slash notation /20?** -- 255.255.240.0

Backwards compatible with class-based addressing
- Class A -- 255.0.0.0 or /8
- Class B -- 255.255.0.0 or /16
- Class C -- 255.255.255.0 or /24
- Number of hosts = \(2^{(32-\text{slash})} - 2\)
  - **What netmask should be used if a network should accommodate up to 62 hosts?** -- 255.255.255.192
  - **What slash notation should be used if a network should accommodate up to 510 hosts?** -- /23
- Network address = bitwise AND of IP address and mask
  - Also referred to as “network prefix”
  - **What is the network address if a host’s IP is 172.0.10.10 and netmask is 255.255.255.0?** -- 172.0.10.0
  - **What is the network address if a host’s IP is 172.0.35.128/20?** -- 172.0.32.0

**Subnetting**
- May want to divide a network into multiple subnetworks
  - E.g., UW-Madison network is divided into subnets by department
    - Link layer switching used within department
    - Network layer routing used within core (i.e., between departments)

![Subnetwork diagram]

- Network = single administrative domain
- Define subnets by using a longer mask

<table>
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<tr>
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<th>11111111 11111111</th>
<th>00000000 00000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network (8)</td>
<td>Subnet (8)</td>
<td>Host (24)</td>
</tr>
</tbody>
</table>

- Given a subnet mask, we don’t know how many bits are for network and how many are for subnet, but this division doesn’t matter
- We’ll use the terms “netmask” and “subnet mask” interchangeably
- We'll also use the terms “network address”, “network prefix”, “subnet address”, and “subnet prefix” interchangeably.