Homework 9 (Part 2) Overview

• P9.8: IP datagram consisting 926 data bytes and a 36 byte header must be transmitted over a link with MTU = 256 bytes
  Find the values for the IHL, Length, More Flag and Offset fields for each of the datagram fragments

IP Subnetting (1/5)

• Recalling the IPv4 datagram header, the Source and Destination fields contain 32-bit addresses as the 4th and 5th words of the header
• The addresses are typically represented as 4 disjoint bytes in decimal shorthand notation, e.g.,
  10000010.00001101.11000010.00100101 = 130.13.194.37
• Every host interface is assigned a 32-bit address

IP Subnetting (2/5)

- Every address consists of a subnet number and host ID
- The purpose of the subnet number is addressing to a specific LAN (i.e., network)
  - Each subnet number is associated with a subnet mask which indicates the number of bits associated with the subnet number
  - Routing between LANs is based on the subnet number of the Destination address
- The host ID specifies the particular host interface on the subnet
Telecommunication Networks (332-423), Fall 2003

IP Subnetting (4/5)

- Subnetting affords scalability
  - Only need to maintain routing information for a range of addresses rather than for each individual address
  - E.g., subnet number / mask (130.13.194.32 / 255.255.255.224) corresponds to all addresses in the range of 130.13.194.32 to 130.13.194.63
  - Subnetting effectively results in a 2-level hierarchical addressing structure
- Address management required to ensure that all host addresses begin with the correct subnet number

Global Addressing (1/7)

- While subnetting is a viable scalability solution for addressing within a single organization (e.g., campus or corporation) it is not sufficient on the global scale
  - Too many subnets to be scalable
  - Scalability advantage achieved by recognizing that packets forwarding between organizations need not be done at the subnet level
  - Assign to each organization a contiguous block of IP addresses

Global Addressing (2/7)

- Address classes: Leading bits (or prefix) of an IP address specify the type (or class) of address
- For class A, B and C addresses, the prefix bits concatenated with the network bits form the network number
- Remaining bits identify specific subnet and host numbers

Global Addressing (3/7)

- Class A: 128 networks, each consisting of $2^{24}$ (> 16 million) addresses
  - Address range: 0.0.0.0 to 127.255.255.255
- Class B: $2^{16}$ (= 65536) networks, each consisting of $2^{16}$ (= 65536) addresses
- Class C: $2^{8}$ (> 2 million) networks, each consisting of 256 addresses
  - Address range: 192.0.0.0 to 223.255.255.255

Global Addressing (4/7)

- 113.68.177.15 = 01110101.10101010.10101010.10010101 (Class A)
  - Network number = 113.0.0.0
- 128.153.12.225 = 10000010.11010011.00001010.01011100 (Class B)
  - Network number = 128.153.0.0
- 207.9.97.140 = 11001110.10011101.01110010.10010100 (Class C)
  - Network number = 207.9.97.0

Global Addressing (5/7)

- Forwarding tables at routers consist of subnet number, subnet mask and next hop fields
- Table look-up based on destination address field of packet header
  - E.g., 130.13.194.37 → Interface 1
- Next Hop Subnet Mask Subnet Number

Internet

- Subnet Mask: 255.255.255.224
  - Subnet Number: 130.13.194.32
- Subnet Mask: 255.255.255.240
  - Subnet Number: 130.13.194.16
- Subnet Mask: 255.255.255.252
  - Subnet Number: 130.13.194.12
Global Addressing (5/7)

- Original rational behind address classes:
  - Address block assignments based on size of network:
    - Assign class A address blocks for organizations with large networks
    - Class B address blocks for organizations with medium-size networks
    - Class C address blocks for organizations with small networks
  - Packet forwarding between organizations based on network number
  - Packet forwarding within organizations based on subnet number
- Unfortunately, Class B address blocks have become scarce

Global Addressing (6/7)

<table>
<thead>
<tr>
<th>Class A</th>
<th>Network</th>
<th>Subnet/Host</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class B</th>
<th>Network</th>
<th>Subnet/Host</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class C</th>
<th>Network</th>
<th>Subnet/Host</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Global Addressing (7/7)

- Forwarding decisions based on addressing with classes:
  - Router maintains separate forwarding table for each of the 3 classes (A, B and C)
  - Upon receipt of packet, router looks at first 4 bits of Destination and decides to which class the packet belongs
  - Router then looks for a network number match in the appropriate forwarding table
  - Forward to next hop associated with the network number or, if no match, forward to the next hop associated with the default entry

CIDR: Classless Inter-Domain Routing (1/5)

- Relative scarcity of Class B address block poses a scalability problem:
  - Suppose an organization has 300 hosts
    - Single Class C address block not sufficient
  - 2 Class C blocks are assigned, say, 192.40.8.0 and 199.55.189.0
  - However, multiple Class C block assignments may span multiple disjoint address ranges
    - Multiple routing entries needed in Internet routing tables to reach a single organization

CIDR (2/5)

- Class Inter-Domain Routing (CIDR)
  - Removes restriction placed on the network number due to addressing with classes
  - Network number need not be exactly 8, 16 or 24 bits
  - Instead, addresses are assigned in blocks of $2^n$ addresses ($n \geq 8$) such that the block starts and stops on a $2^n$ address block boundary
  - Routers apply a 32-bit mask to obtain network number
    - E.g., a company has 700 hosts
      - Assign block of $2^{10}$ addresses, i.e., 4 Class C blocks (Why not 3?)
      - Start block at X.Y.Z.0000.00000000
      - End block at X.Y.Z.1111.11111111
      - Mask = 11111111.11111111.11111111.11111111.00000000 (denoted as "/22")

CIDR (3/5)

- CIDR address allocation example:
  - Assume Class C address range of 192.50.128.0 through 192.50.255.255 is available for assignment
  - Assume address blocks requested in the following order:
    - Company 1 requests 1 Class C block
    - Company 2 requests 4 Class C blocks
    - Company 3 requests 2 Class C blocks
    - Company 4 requests 2 Class C blocks
    - Company 5 requests 6 Class C blocks
  - Assume requests are processed immediately, in the order in which they were received
  - Assume addresses are allocated from start of range in such a way so as to maximize contiguous address space utilization
CIDR (4/5)

- CIDR address allocation example (cont.):
  - Company 1 requests 1 Class C block
    - Assign 192.50.128.0 through 192.50.128.255
    - Network number/mask: 192.50.128.0/24
  - Company 2 requests 4 Class C blocks
    - Assign 192.50.132.0 through 192.50.135.255
    - Network number/mask: 192.50.132.0/22
  - Company 3 requests 2 Class C blocks
    - Assign 192.50.130.0 through 192.50.131.255
    - Network number/mask: 192.50.130.0/23
  - Company 4 requests 2 Class C blocks
    - Assign 192.50.136.0 through 192.50.137.255
    - Network number/mask: 192.50.136.0/23
  - Company 5 requests 6 Class C block
    - Assign 192.50.144.0 through 192.50.151.0
    - Network number/mask: 192.50.144.0/21

CIDR (5/5)

- Routing with CIDR
  - Router ANDs subnet mask with Destination field of packet header and compares result with the network number in table
  - If there is a match with more than one table entry, pick match with longest mask
  - If no matches with network number entries, pick match with longest mask
  - If no matches with network number entries, forward packet to Next Hop associated with the Default entry

Example CIDR forwarding table:

<table>
<thead>
<tr>
<th>Network / Mask Length</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.50.128/24</td>
<td>R4</td>
</tr>
<tr>
<td>192.50.132/22</td>
<td>R4</td>
</tr>
<tr>
<td>192.50.136/23</td>
<td>R4</td>
</tr>
<tr>
<td>192.50.130/23</td>
<td>R3</td>
</tr>
<tr>
<td>192.50.144/21</td>
<td>R5</td>
</tr>
</tbody>
</table>

Telecommunication Networks
(332-423), Fall 2003

Auxiliary Protocols

- Some important auxiliary protocols to support IP-based networking include:
  - Address Resolution Protocol (ARP)
  - Domain Name Service (DNS)
  - Dynamic Host Configuration Protocol (DHCP)
  - Internet Control Message Protocol (ICMP)
  - Network Address Translation (NAT)

References