Section B

IP Addressing/Address Resolution

Addressing at Network Layer: IP Addressing

- Internet a combination of different physical networks.
- Packets travel different physical networks to destination.
- A global identification system necessary for hosts (and routers).
- Solution: Unique identifier is IP address in Internet.
- IP address:
  - Unique
  - Universal.
- **Location not names.**

Address Format

- Address 32 bit long, composed of four 8 bit fields called octets.
- Octets separated by periods.
- Each octet represents a decimal number in the range 0-255.
  - Dotted decimal notation.
- Address divided into two parts:
  - Netid: identifies systems located on same physical segment.
  - Hostid: Identifies individual entity (host, server, router) within the segment.

IP Address Format

Network ID	Host ID

Address Classes

- Five address classes defined.
- Class: Defines
  - bits for netid and hostid.
  - number of networks/number of hosts per network.
- Five classes defined
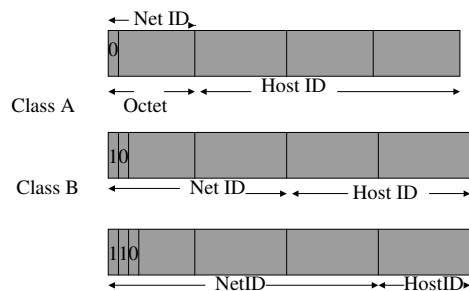 - A, B, C, D, and E.

Address Classes

Class A — Net ID / Octet / Host ID

Class B — Net ID / Host ID

NetID / HostID

Table 1: Address Class Summary

	Number of networks	Number of Hosts per Network	Range of Network Ids (First Octet
Class A	126	16, 777, 214	1 n 126
Class B	16, 384	65, 534	128 n 191
Class C	2, 097, 152	254	192 n 223

Multihomed Devices

- Internet address defines node's connection to its network.
- Multihomed: A device connected to more than one network.
  - Different address for each network.
  - Address can be of different classes.

- Can you think of such a multihomed device??

Special Addresses

- Some parts of address space (A,B,C) are used for special addresses.
- Network address: A,B,C, address with hostid set to zero.
  - Defines the network itself.
- Direct Broadcast Address
  - True for A, B, C.
  - All hostid's are set to 1.
  - Packets sent to all hosts in a specific network.

Special Addresses

- Limited Broadcast Address
  - True for A, B, C.
  - All 1s in the netid and host id.
  - Broadcast within the current network.
- This host on this network
  - True for A only.
  - All zeroes address.
- Specific host on this network
  - True for A only.
  - Netid of all zeroes.

Special Addresses

- Loopback Address.
  - True for A only.
  - First byte set to 127.
  - To test IP software in a machine.
  - Packet returns to protocol software: Does not leave machine.

Unicast, Multicast and Broadcast Addresses

- **Unicast: One to one communication.**
  - Addresses belong to class A, B, or C.
- **Multicast: One to many communication.**
- **Broadcast: One to all communication.**
  - Internet limits broadcast to local level.
  - No global level broadcast. Why??
  - Example: Limited broadcast, direct broadcast.

Private Networks

- For orgs.not requiring internet access.
- Org. uses TCP/IP.
- Addressing scheme options:
  - Apply for unique address and NOT connect to Internet.
  - Use any class A, B, C without registering with authority.
  - Use reserved block of private addresses.
- Reserved block.

Applying for IP addresses

- Organization applies for netid. (A, B, C)
- Problem: Class A addresses depleted, very few B addresses left.
- Proof for procuring A.
- Organization assigns hostids from the given netid.
- Application for netid: Network Information Centers.

Assigning Netids and Hostids

- Netid: identifies host located on same physical segment.
- Unique id for each router interface.
- Figure:
- Networks 1 and 3 represent two routed networks.
- Network 2: Wide area connection between two routers.
- Network 2 requires network id so that interfaces between two routres can be assigned unique host ids.

Assigning Network IDs

Router   Router

192.121.73.z

Net id: 124.x.y.z
Network 1

Net id: 131.107.y.z
Network 2
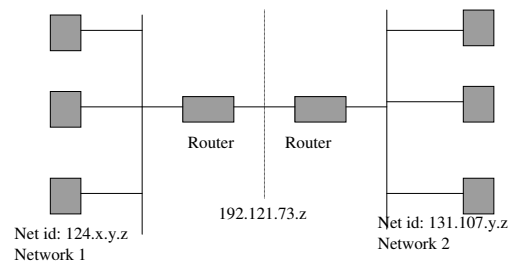
Assigning Host IDs

- Host id: identifies a host in network.
  - Unique to network id.
  - Assigned to: hosts, interfaces to routers.
- Hostid of router interface: Default gateway for other hosts.
- Suggestions
  - No rules for assigning valid host ids.
  - **Guidelines**:
  - Assign host ids in groups based on host or server type.
  - Designate routers by their IP address.
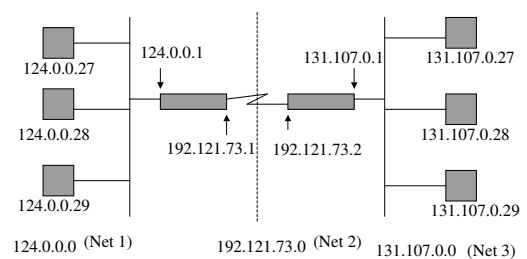
Assigning Host Ids

124.0.0.27

124.0.0.1   131.107.0.1   131.107.0.27

124.0.0.28

192.121.73.1   192.121.73.2   131.107.0.28

124.0.0.29

131.107.0.29

124.0.0.0 (Net 1)   192.121.73.0 (Net 2)   131.107.0.0 (Net 3)

Table 2: Valid Host IDs

Address Class	Beginning Range	Ending range
Class A	w.0.0.1	w.255.255.254
Class B	w.x.0.1	w.x.255.254
Class C	w.x.y.1	w.x.y.254

Subnet Mask

What is a subnet mask?
- Distinguishes network id from host id.
- Specifies if destination host is local or remote.

Default subnet mask
- Used on networks not divided into subnets.
- What is a subnet??
- All hosts on TCP/IP network need a subnet mask.
- Its use depends on address class.
- All bits corresponding to network id are set to 1.
- All bits corresponding to host id are set to 0.

Subnet Mask

Default subnet mask
- Class A: 255.0.0.0
- Class B: 255.255.0.0
- Class C: 255.255.255.0

Determining local \remote hosts
- ANDing: Internal process to determine whether a packet is local or remote.
- Host's IP address and remote address ANDed with default subnet mask.
- If both match, they belong to same network.

Subnetting

Subnet
- Division of a single class A, B, or C network into smaller pieces.
- Each piece: A physical network in TCP/IP environment.
- Uses IP address derived from single network ID.
- Result: Single network (Single Netid) divided into smaller subnets.
  - Each subnet has different network ID.

Need for Subnetting

- IP addresses rapidly getting saturated.
- Internet Routing tables beginning to grow.
- Local administrators request another network number from Internet before new network could be installed.

Subnetting:
- Organization gets one Net ID from InterNIC.
- One Net id divided into Multiple subnetworks.
- Each sub ID can represent a single physical network.
- Implemented by borrowing bits from host id section of address.

Subnetting

Benefits
- Mix different technologies.
- Overcome limitations of current technologies.
- Reduce network congestion.
- Subnetworks appear as single network to the rest of Internet.

- Note: Subnetting defined in RFC 950.

Extended Network Prefix

Network-Prefix	Subnet Number	Host-Number

Subnet Design Considerations

Key Questions
- How many total subnets does organization need today?
- How many total subnets will organization need in future?
- How many hosts are there on Organization's largest subnet today?
- How many hosts will there be in organization's largest subnet in future?

Special Subnet Addresses

- Initially, it was prohibited to use all-0s and all-1s subnet.
- Reason: To eliminate situations that could potentially confuse a router.
- Today a router has functionality to support this feature.
- Our examples: We will label these as special addresses.

Subnetting Procedure

- Defining subnet mask:
  - Determine number of physical segments required.
  - Convert this number to binary.
  - Count number of bits required to represent number of physical segments in binary.
  - Convert required number of bits to decimal format in high order.

Subnetting Procedure

Defining subnet Ids.
- List number of bits in high order used for subnet id.
- Convert the bit with lowest value to decimal format.
  - Increment value.
  - Starting with zero increment value for each bit combination until next increment is 256.
- Tip: If you know number of bits you need, you can raise 2 to the power of bit, then subtract 2 to determine possible bit combinations.

Subnetting Procedure

To determine number of hosts per subnet.
- Calculate bits available for hostid.
- Convert binary hostid bits to decimal.
- Subtract 1.
- Tip: If you know2 number of host id bits you need, raise 2 to the power of host id bits, then subtract 2.

Variable Length Subnetting

- Scheme to divide a subnet further into smaller subnets.
- Subnetted network uses more than one subnet mask.
- Mask can be of variable length: Variable length Subnet mask (VLSM)

VLSM Benefits:
- Efficient use of Organization's assigned IP address space.
- Route aggregation.

Figure 8: Address Strategy for VLSM

140.25.0.0/16

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

| 0 | 1 | 2 | 3 | (level 1) | 0 | 1 | 2 | 3 |

(Level 2)   0   1   2   3
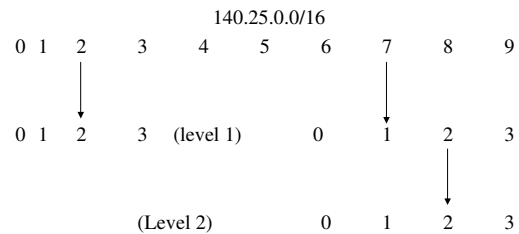
VLSM Design Considerations

- How many total subnets does this level need today?
- How many total subnets will this level need in the future?
- How many hosts are there on this level's largest subnet today?
- How many6 hosts will there be on thi9s level's largest subnet in the future?

Address Resolution

- At network level: Host id are logical addresses: IP
  - Jurisdiction is universal.
- At physical level, hosts, routers recognized by physical address.
  - Jurisdiction is local.
  - MAC addresses.
- Two unique identifiers (logical and physical) essential. Why??
- Delivery of packet needs two levels of addressing.
- Mapping essential.

Address Resolution

- Mapping: To map logical address to physical address and vice versa.
- Mapping:
  - Static versus Dynamic

Address Resolution Protocol (ARP)

- Successful mapping of IP (Logical) address to a hardware (Physical) address.
- Address resolution is function of ARP.
- ARP uses local broadcast to obtain a hardware address.
- Address mappings are stored in cache for future reference.
- Two cases of resolution:
  - Local
  - Remote

ARP: Resolving local IP address

- ARP request initiated
- Determine IP address. Is local/remote.
- If local, check ARP cache.
- If no mapping found
  - Generate ARP request
  - Broadcast request to all hosts.
- Concerned target host
  - Validates IP address in request.
  - Generates ARP reply
- Sender updates its cache.

ARP: Resolving Remote Addresses

- ARP request initiated
  - IP address identified as remote.
- Determine IP address Of default gateway.
- Check cache for hardware address Of gateway
- If not found, generate ARP request for gateway's hardware address
- Get gateway response.
- Send data packet to gateway.
- At gateway, determine address local or remote.
- If local, broadcast ARP request, obtain hardware address
- Else, determine default gateway and repeat the process.

ARP Cache

- Maintains static/dynamic entries.
- Dynamic entries added/deleted automatically.
- Hardware broadcast address maintained as static entry.
- Each entry has potential lifetime: 10 minutes.
- Each entry when added is timestamped.
- Default timeout: 2 minutes for unused entries, 10 minutes for used entries.

ARP Command

- Cache examined using arp command.
  - -a: displays all entries in ARP cache.
  - -d: deletes entry from arp cache.
  - -s: adds entry into arp cache
- What does Reverse ARP do?
- **Gratuitous ARP**:An ARP message broadcasting your IP address and your corresponding physical address.
  - Why is this used?
- What is **Proxy ARP**?