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03 Internet Addressing

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IP Addresses

- There are two Internet naming systems:
  1. The primary system is the internet address system which uses binary IP addresses.
  2. The secondary system is the domain name system (DNS) which uses natural language DNS names.
- IP addresses are 32-bit integers.
  - Composed of four 8-bit octets.
  - Represented as four integers, usually in base 2 or base 10, separated by dots.

    base 2: 11000111.00010001.00101000.11010010.
    base 10: 199.17.40.210.
    base 16. C7.11.28.D2.

IP Address Assignment

- IP addresses are assigned to network interfaces, not hosts.
  - A host with one network interface is assigned an IP address by default.
- A network interface is normally assigned a unique IP address.
  - In practice, an interface may be assigned more than one address.
  - In some rare cases, an interface may be assigned no address at all.
  - In certain cases, different interfaces may have the same IP address.

Class Networks (1)

- IP addresses are organized into class networks to facilitate address assignment and packet routing.
  - Class A: 0nnnnnnn.iiiiiiii.iiiiiiii.iiiiiiii.
  - Class B: 10nnnnnn.nnnnnnnn.iiiiiiii.iiiiiiii.
  - Class C: 110nnnnn.nnnnnnnn.nnnnnnnn.iiiiiiii.
  - Class D: 1110bbbb.bbbbbbbb.bbbbbbbb.bbbbbbbb.
  - Class E: 1111bbbb.bbbbbbbb.bbbbbbbb.bbbbbbbb.
- A class network is really a set of IP addresses and not a network.
- The Internet Corporation for Assigned Names and Numbers (ICANN) is responsible for assigning class A, B, and C networks to organizations.
- Each address in a class A, B, or C network is a pair (N, I) where N is its network identification and I is its a interface (or host) identification. n and i denote bits in the network and interface identifications, respectively.

Class Networks (2)

- By convention, the address in a class A, B, or C network whose interface bits are all 0 (e.g., 199.17.40.0) is the network address for the class.
- By convention, the address in a class A, B, or C network whose interface bits are all 1 (e.g. 199.17.40.255) is the (direct) broadcast address for the class.
- The limited broadcast address is 255.255.255.255.
- The addresses in a class D network are for multicasting.
- The addresses in a class E network are reserved for unspecified purposes.

Reserved IP Addresses

- 10.0.0.0 to 10.255.255.255 (1 class A network) for private IP addresses.
- 169.254.0.0 to 169.254.255.255 (1 class B network) for zero configuration networking.
- 172.16.0.0 to 172.31.255.255 (16 class B networks) for private IP addresses.
- 192.168.0.0 to 192.168.255.255 (256 class C networks) for private IP addresses.
- 240.0.0.0 to 240.255.255.255 (all class E network addresses).

The Loopback

- Each host running TCP/IP has a virtual interface called the loopback interface which is the only interface on a virtual network called the loopback network.
- The network and interface addresses of the loopback are 127.0.0.0 and 127.0.0.1, respectively.

Weaknesses of IP Address System

- Some hosts (e.g., a multi-homed host) have more than one IP address.
- The class networks are too rigid.
- There are not enough IP addresses for future expansion.
    - IPv6 solves this problem.

Subnets

- IP addresses are also organized into subnets to facilitate address assignment, network organization, and routing.
- Each subnet is a set of addresses determined by:
  1. A subnet address (e.g., 199.17.35.96).
  2. A subnet mask (e.g., 255.255.255.240).
- Each address in a subnet is pair (S, I) where S is its subnet identification and I is its interface (or host) identification.
- Special cases:
  - Set of all IP addresses.
  - Class A, B, and C networks.
  - Individual interface (or host) IP address.

Subnet Conventions

- Usually, but not necessarily, the subnet identification of a class A, B, or C address is an extension of the network identification of the address.
- Usually, but not necessarily, the subnet mask consists of a block of 1s followed by a block of 0s.
- By convention, there is one subnet corresponding to each SPN.
  - Each interface on the SPN is assigned the same subnet address and subnet mask.

Address Resolution Problem

- High-level IP addresses are used for communication across an internet and are assigned independently of physical hardware addresses.
- Low-level physical addresses are needed for physically delivering a packet to an interface on a network.
- How are IP addresses mapped to physical addresses?
  - A solution is an address resolution function f that maps each IP address i to a physical address $f(i)$.
  - The function must be changed as the internet changes.
  - The function must be represented efficiently.

Address Resolution Solutions

1. Physical addresses are encoded in IP addresses.
   - Possible for proNET networks.
   - Not viable for Ethernet.
2. Each machine contains a table that represents the local part of an address resolution function.
   - Awkward for Ethernet because physical addresses change when a host or interface is replaced.
3. IP addresses are bound to physical addresses dynamically.

Address Resolution Protocol (ARP)

- Used for dynamically binding an IP address to a physical address (especially on Ethernet networks).
- ARP process:
  1. A host h_A broadcasts a request for the physical address which resolves an IP address i.
  2. The host h_B with the network interface having the address i sends a reply to h_A containing the physical address of the interface.
- The results of ARP queries are kept in a cache on each host.
- When a sender requests a physical address, it can include its physical address in the message.

Complications

- Several packets may simultaneously need to know the same physical address.
- The host of the requested physical address may be down.
- The cache may contain out-of-date bindings.
  - When a host boots it can send a broadcast message informing the other computers on the network of its physical address.
- Hosts may provide bogus address bindings.
- At boot-time a diskless host knows its physical address but not its IP address.
  - The host must get its IP address from a server on another computer.

Reverse Address Resolution Protocol (RARP)

- Used for obtaining the IP address that is bound to a physical address.
- RARP process:
  1. A host h_A broadcasts a request for the IP address which reversely resolves a physical address p.
  2. The RARP servers which receive the request send replies back to the h_A containing the requested IP address.
- Some scheme is needed to keep all the RARP servers from sending replies at the same time (and causing collisions on an Ethernet network).

ARP and RARP Messages

- ARP and RARP messages are encapsulated in a physical frame.
  - ARP and RARP share the same message format.
  - Type field says the data is an ARP or RARP message.
  - The message itself is held in the data portion of the frame.
- Each message has the following address fields:
  - Sender IP address.
  - Sender physical address.
  - Target IP address.
  - Target physical address.