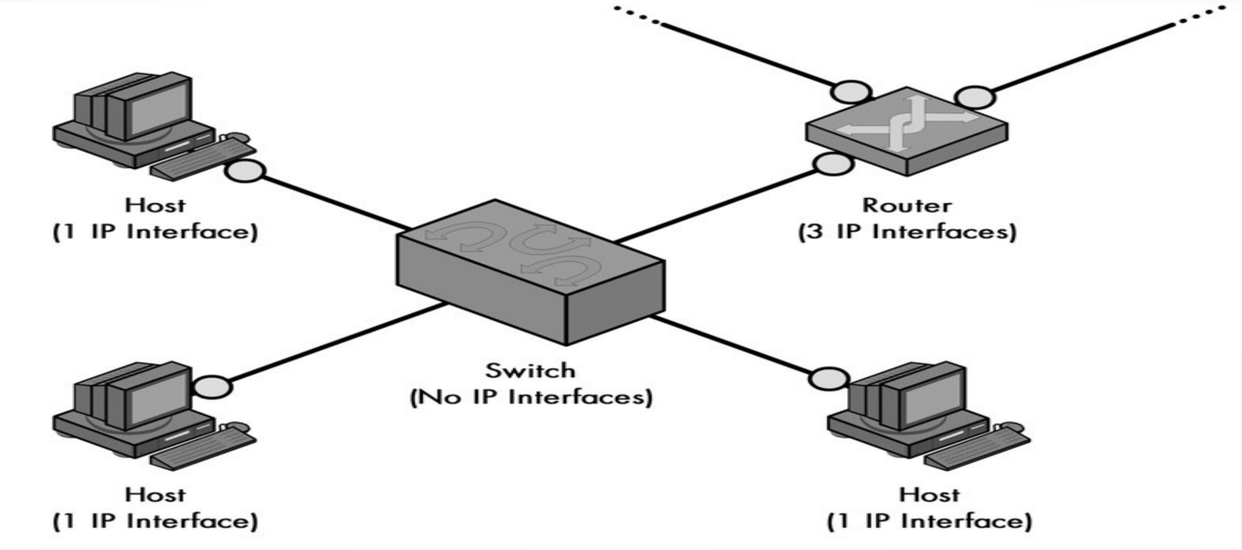
IP Addressing and Forwarding

Manas Ranjan Lenka
School of Computer Engineering,
KIIT University

IP Addressing

- IP address identifies the network interface, not that it identifies the device itself.

- Hence, one device may be associated with more than one IP Address. E.g. Router



IP Address space & its problem

- IP address is 32 bits wide, this provides a theoretical address space of 2^{32} , or 4,294,967,296 i.e. around 4 billion addresses.

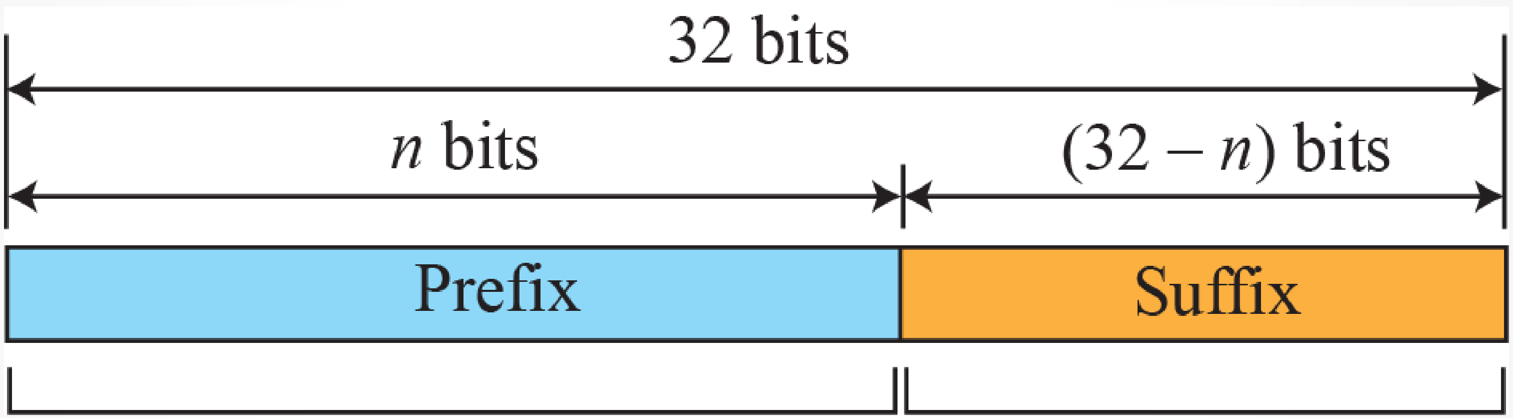
- In reality, every one of those available addresses can not actually be used.

- For example, all IP addresses starting with 127 in the first octet are reserved for the loopback function. This one decision makes 1/256th of the total number, or 16,277,216 addresses, no longer available.

- Hence, to utilize the existing Internet IP address space more efficiently various techniques are used as follows.
  - Subnetting / Supernetting
  - Classless Inter-Domain Routing (CIDR)
  - NAT

Hierarchical Addressing

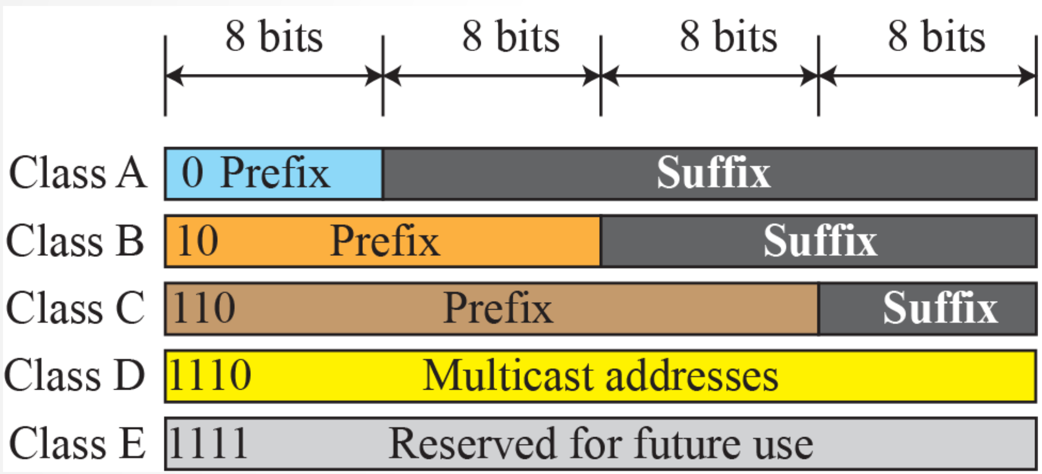
- Structure to addresses: Address captures location in the network topology
- IP address (32 bits) consists of two parts: network and host



  - Network part identifies the network to which host is connected
  - Host part uniquely identifies each host in the network
- How does this help?
  - An entire network (in some specific direction) could be represented by a single entry at a router

Classful IP Address

- Size of network and host part are not the same
- Organizations obtain set of addresses of a given class



Class	Prefixes	First byte
A	$n = 8$ bits	0 to 127
B	$n = 16$ bits	128 to 191
C	$n = 24$ bits	192 to 223
D	Not applicable	224 to 239
E	Not applicable	240 to 255

- Private IP addresses:
  - A: (10.0.0.0/8) 10.0.0.0 through 10.255.255.255
  - B: (172.16.0.0/12) 172.16.0.0 through 172.31.255.255
  - C: (192.168.0.0/16) 192.168.0.0 through 192.168.255.255
  - 127.0.0.1 is loopback address. The range (127.0.0.0/8) of loopback addresses are 127.0.0.0 through 127.255.255.255

Classful IP Address inefficiency

- Network part uniquely identifies a physical network
- Network with just 2 hosts needs Class C address
  - Efficiency: 2/2^8 = 0.7%
- Network with 256 hosts needs a Class B address
  - Efficiency: 256/2^16 = 0.4 %
- Need to solve "Address assignment inefficiency"
  - Challenge: Within IP framework (using 32-bits)

Scenario –1

- An organization has 30 different physical networks, each network has about 2000 hosts

- Current Allocation: Allocate 30 class B addresses
  - Efficiency = 2000/2^16 = 3%

- Will one class B address suffice?
  - Can support 2^{16} = 65536 hosts > 30*2000

Solution: Subnetting

- Subnetting : One class address shared among many physical networks
  - Divide host part into subnet id and host id

Network Number	Host Number	
Network Number	Subnet ID	Host ID

Rule 1 :

- If the host bits in a given IP address are all set to 0, this is the network or subnet address.
- If the host bits in a given IP address are all set to '1', this is the broadcast address (all hosts in the subnet/network are destination).

Rule 2 :

$$\text{Number of Subnets} = 2^{s}$$

where 's' = number of subnet bits

Rule 3 :

$$\text{Number of Hosts} = 2^{h} - 2$$

where 'h' = number of host bits (unmasked)

subnet mask

- **non-subnetted classful environment :** first octet of the IP address determines the network ID and host ID.

- **subnetted classful environment :** additional information required to determines the subnet ID and host ID

- This information is given in the form of a 32-bit binary number called a **subnet mask**.

- **subnet mask :** bits used for either the network ID or subnet ID are ones, while the bits used for the host ID are zeros.

- Thus, when subnet mask is used on an IP address, the bits in the network ID and subnet ID are left intact, while the host ID bits are removed.

Finding the Subnet Address

Suppose you have a host on this network with an IP of 154.71.150.42 and the subnet mask is 255.255.248.0. Then find out the subnet address.

Solution:
we use binary notation for both the address and the mask and then apply the AND operation to find the subnet address.

```
10011010 01000111 10010110 00101010
11111111 11111111 11111000 00000000
----------------------------------------------------------
10011010 01000111 10010000 00000000
```

The subnet address is 154.71.144.0.

Problem solving : subnetting

- Given the prefix 192.168.1.0/24. Find the netmask, network ID, what should be the length of subnet mask allowing up to 9 subnets, sub-net mask, sub-net ID?

- Given the host address 192.168.1.177/29, what are the subnet and broadcast addresses?

- Given the prefix 172.16.0.0/17, how many subnets can you create?

Problem with regular subnetting

- In regular subnetting, You can’t have subnets of different sizes —they must all be the same.

- Suppose in a class C network you want to have a configuration where 3 subnets had only 50 hosts each but the 4th had 100 hosts.

- Now regular subnetting will not work rather an enhancement to subnetting called Variable Length Subnet Masking (VLSM) will be used to solve this problem

VLSM Example

An organization is granted a block of addresses with a Class C network, 201.45.222.0/24. The organization needs to have 4 subnets in their networks with 1st two subnets containing 16 hosts each, the 3rd one having 50, and the 4th one having 100 hosts. Design the subnet. Find the subnet id, subnet mask and broadcast id of each subnet.

Solution

To satisfy the above requirement, we assign addresses to subnets, starting with the largest and ending with the smallest one.

VLSM Example

subnet with 100 hosts:

Subnet id – 201.45.222.0
Broadcast id – 201.45.222.127
Subnet mask – 255.255.255.128
Range of IP Address – 201.45.222.1 - 201.45.222.126

subnet with 50 hosts:

Subnet id – 201.45.222.128
Broadcast id – 201.45.222.191
Subnet mask – 255.255.255.192
Range of IP Address – 201.45.222.129 - 201.45.222.190

subnet with 16 hosts:

Subnet id – 201.45.222.192
Broadcast id – 201.45.222.223
Subnet mask – 255.255.255.224
Range of IP Address – 201.45.222.192 - 201.45.222.222

subnet with 16 hosts:

Subnet id – 201.45.222.192
Broadcast id – 201.45.222.223
Subnet mask – 255.255.255.224
Range of IP Address – 201.45.222.192 - 201.45.222.222

Problem with Subnetting

- Subnetting works within the classful address blocks

- If an organization needing 2,000 IP addresses requested a Class B block, they could use subnetting to more efficiently manage their block.

- However, subnetting could do nothing about the fact that this organization would never use over 62,000 of the addresses in its block—about 97 percent of their allocated address space.

- solution to the above problem is Eliminate Address classes.

Problem with Subnetting

- An organization has a physical network with 4000 hosts
- Current Solution: Give a class B address
  - Efficiency: $4000/2^{16} = 6\%$
- How about assigning multiple class C addresses?
- Problem: 16 entries for same organization in the routing table

Solution : super-netting

- Assign multiple contiguous class C addresses & aggregate
- 222.7.16.* through 222.7.31.*, top 20 bits in this range are the same (0001 bits, 20-bit network number)
- Advertise 222.7.16/20 as the organization's network address
- Supernetting: Subnetting the Internet

Classless Interdomain Routing (CIDR)

- solve both of the main problems with classful addressing
  - inefficient address space use
  - exponential growth of routing tables.

- The idea behind CIDR is to adapt the concept of subnetting a single network to the entire Internet.

- CIDR is an Internet-wide application of not just regular one-level subnetting, but of Variable Length Subnet Masking (VLSM)

- Address block represented as A/X, where A is the address prefix and X is the prefix length
  - X is represented as a network mask as well
  - E.g. 222.7.16.0/20 (Mask 255.255.240.0)