IP Addressing

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1 IP Terminology

IP Terminology

- **Octet** - Same as byte, made up of 8 bits
- **Network Address** - This is the designation used in routing to send packets to a remote network—for example, **10**.0.0.0, **172.16**.0.0, and **192.168.10**.0.
- **Host Address** - A logical address used to define a single host
- **Broadcast Address** - Used by applications and hosts to send information to all hosts on a network. For example 255.255.255.255, which designates all networks and all hosts

2 The Hierarchical IP Addressing Scheme

The Hierarchical IP Addressing Scheme

- IP address consists of **32 bits** or **4 bytes** or **4 octets**
- Represented as:
  - 54.164.151.235 or
  - 00110110.10100100.10010111.11101011 or
  - 66.A4.97.EB
- 32-bit IP address is *structured* (or *hierarchical*) address to make routing possible
- If IP address was *flat* (or *non hierarchical*) routing would be impossible

The Hierarchical IP Addressing Scheme

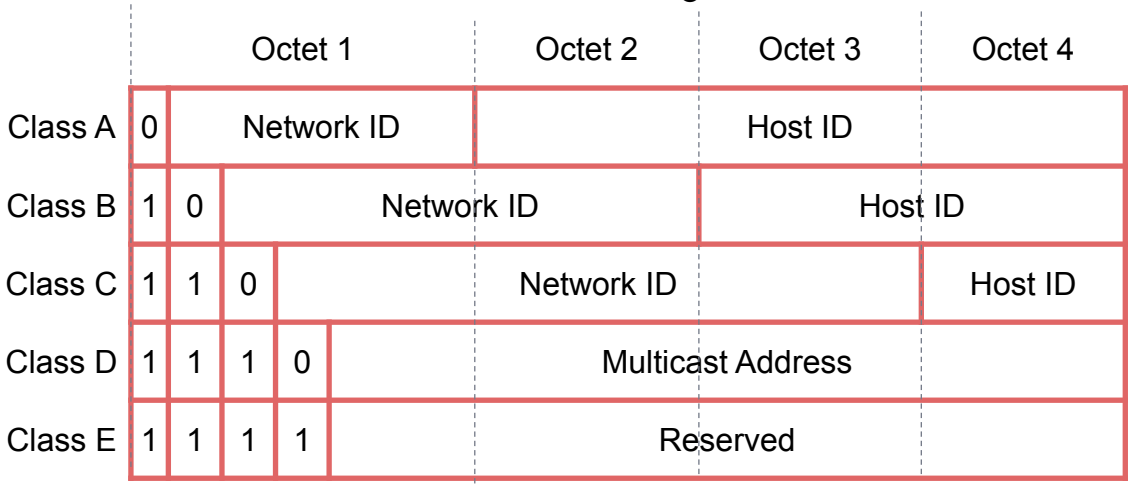
- The **network address** (or **network number**) uniquely identifies each network
- Every machine on the same network shares that network address as part of its IP address
- For example:

IP Address: **154.101.** **51.235** → **Host address**

Network address: Every device in this network starts with these numbers

The Hierarchical IP Addressing Scheme

Network addresses are divided into 5 classes:



The Hierarchical IP Addressing Scheme

Class A Addresses

network	host	host	host

- Class A Network address is 1-byte long, first bit is always **0**
- Maximum 2^7 = 128 Class A networks can be created
- Maximum 2^{24} = 16,777,214 hosts (excluding 2 reserved addresses)
- First bit is always **0** then
  00000000 = 0
  01111111 = 127
- The addresses **00000000** and **01111111** are reserved for default route and troubleshooting respectively
- So Class A network addresses start with 1-126

The Hierarchical IP Addressing Scheme

Class A Addresses

Address	Function
Network address of all 0s (0.X.X.X)	Means "this network or segment."
Network address of all 1s (127.X.X.X)	Means "all networks."
127.0.0.1	Reserved for loopback tests. Designates the local host and allows that host to send a test packet to itself without generating network traffic.
Host address of all 0s (X.0.0.0)	Means "network address" or any host on the specified network.
Host address of all 1s (X.255.255.255)	Means "all hosts" on the specified network
Entire IP address set to all 0s (0.0.0.0)	Any host on any network
Entire IP address set to all 1s (255.255.255.255)	Broadcast to all hosts on the current network

The Hierarchical IP Addressing Scheme

Class B Addresses

network	network	host	host

- Class B Network Address is 2-byte long, first 2 bits are always **10**
- Maximum 2^{14} = 16,384 Class B networks can be created
- Maximum 2^{16} = 65,534 hosts (excluding 2 reserved addresses)
- First 2 bits are always **10** then
  10000000 = 128
  10111111 = 191
- Class B Network Addresses start with 128-191

The Hierarchical IP Addressing Scheme

Class C Addresses

network	network	network	host

- Class C Network Address is 3-byte long, first 3 bits are always **110**
- Maximum 2^{21} = 2,097,152 Class C networks can be created
- Maximum 2^{8} = 254 hosts (excluding 2 reserved addresses)
- First 3 bits are always **110** then
  11000000 = 192
  11011111 = 223
- Class C Network Addresses start with 192-223

The Hierarchical IP Addressing Scheme

Class D Addresses

- Not assigned to devices on a network
- Used for special-purpose, multicast applications (such as video- and audio-streaming applications)
- Need to be registered with IANA to be used globally
- First 4 bits are always **1110** then
  11100000 = 224
  11101111 = 239
- Class D Network Addresses start with 224-239

The Hierarchical IP Addressing Scheme

Class E Addresses

- No defined use
- Reserved for usage and testing by IANA and the Internet Research Task Force (IRTF)
- Need to be registered with IANA to be used globally
- First 4 bits are always **1111** then
  11110000 = 240
  11111111 = 255
- Class E Network Addresses start with 240-255

The Hierarchical IP Addressing Scheme

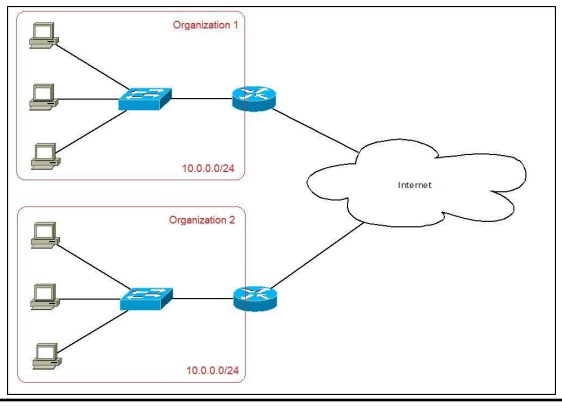
IP Address Classes:

Address Class	1st Octet Range	1st Octet Bits	Network & Host Parts	# of Possible Networks # of Hosts per Network
A	1-126	00000000 - 01111111	N.H.H.H	128 nets (2^7) 16,777,214 hosts per net (2^{24})-2
B	128-191	10000000 - 10111111	N.N.H.H	16,384 nets (2^{14}) 65,534 hosts per net (2^{16})-2
C	192-223	11000000 - 11011111	N.N.N.H	2,097,150 nets (2^{21}) 254 hosts per net (2^8)-2

The Hierarchical IP Addressing Scheme

Private IP Addresses (RFC 1918)

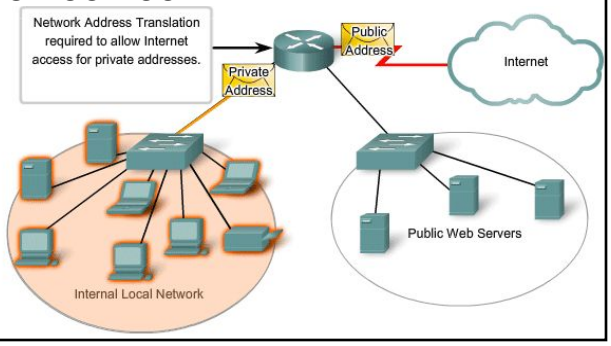
Every host on every network should have a routable IP address. But if every host on every network in the world was required to have an unique IP address, we would have run out of IP addresses!



The Hierarchical IP Addressing Scheme

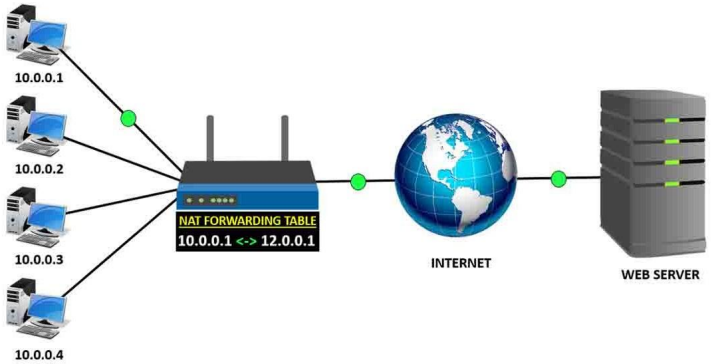
Private IP Addresses (RFC 1918)

- The IANA reserved the following IP address blocks for use as private IP addresses:
  - Class A: 10.0.0.0 to 10.255.255.255
  - Class B: 172.16.0.0 to 172.31.255.255
  - Class C: 192.168.0.0 to 192.168.255.255



Introduction to NAT

- NAT is a process in which one or more local IP addresses are translated into one or more global IP address and vice versa to provide Internet access to the local hosts
- NAT allows multiple devices to access the Internet through a single public address



Introduction to NAT

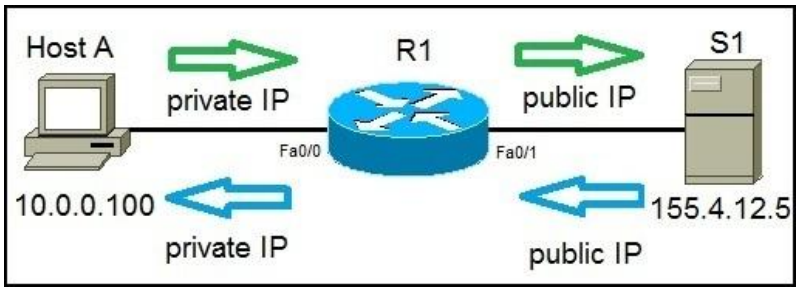
- Advantages:
  - Hides internal structure of the network from the outsider and thus increases network security
  - Eliminates address renumbering when a network evolves
  - Allows unlimited private IP address range

- Disadvantages:
  - Changes the IP addresses, thus troubleshooting becomes more complex
  - Translation results in switching path delays
  - Certain applications will not function while NAT is enabled
  - Complicates tunneling protocols such as IPsec

Introduction to NAT

Types of NAT:

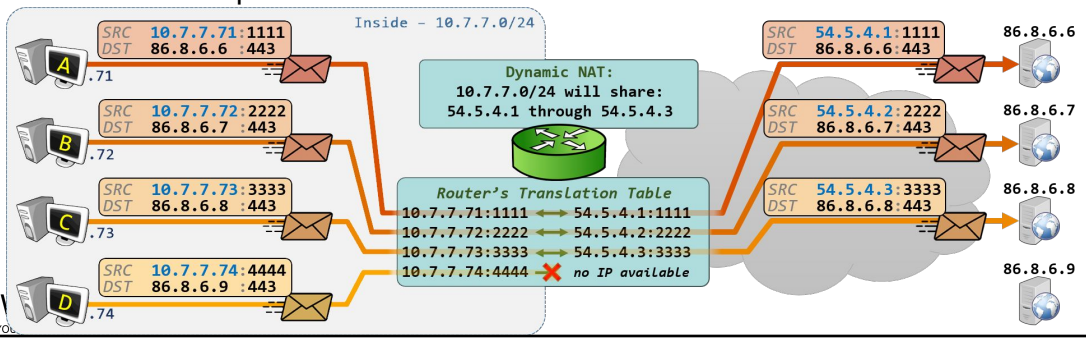
- **Static NAT (SNAT):**
  - One-to-one mapping (A single private IP with a single global IP)
  - Each device needs a public IP address
  - Generally used for web hosting



Introduction to NAT

Types of NAT:

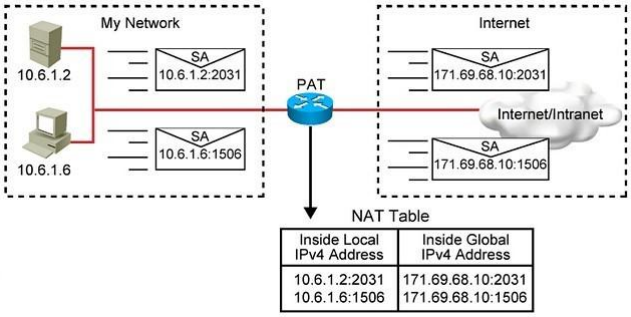
- **Dynamic NAT (DNAT):**
  - Public IP is picked from a pool of IP addresses
  - If no IP is left, data packet is dropped by the NAT
  - Very costly as many global IP addresses have to be bought to make a pool



Introduction to NAT

Types of NAT:

- **Overloading or Port Address Translation (PAT)**:
  - Most popular type of NAT
  - Port numbers are used to distinguish the traffic
  - Cost-effective as lots of users can be connected by using only one public IP address



The Hierarchical IP Addressing Scheme

APIPA

- In a network, Dynamic Host Configuration Protocol (DHCP) server assigns IP addresses to all the hosts connected to the network
- If DHCP server isn't available, Windows provides **Automatic Private IP Addressing (APIPA)** service to configure the IP addresses for the hosts
- 169.254.0.1 - 169.254.255.254 reserved for **APIPA**

3

IPv4 Address Types

IPv4 Address Types

Layer 2 Broadcasts

- Layer 2 broadcast traffic stays within a local area network (LAN) boundary; known as the **broadcast domain**
- A MAC address of FF:FF:FF:FF:FF:FF is used for broadcast

IPv4 Address Types

Layer 3 Broadcasts

- Layer 3 broadcast traffic is sent to all devices in a network
- A network address of **X.255.255.255** is used for broadcast
- **Address Resolution Protocol (ARP)** uses broadcasting to map MAC addresses to IP addresses
- **Dynamic Host Configuration Protocol (DHCP)** uses broadcasting to dynamically assign IP addresses to hosts

IPv4 Address Types

Unicast Address

- Identifies a unique node on a network
- Packets addressed to a unicast address are delivered to the node identified by the address
- Unicast address has the MAC address of the destination device

IPv4 Address Types

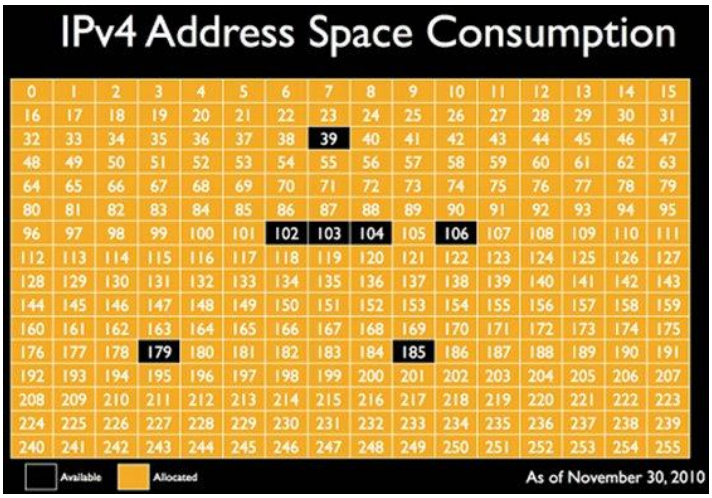
Multicast Address

- Represent a group of devices in a LAN
- Multicast frames have a value of 1 in the least-significant bit of the first octet of the destination address
- Multicast addresses range from 224.0.0.0 to 239.255.255.255 (Class D)

4 Internet Protocol Version 6 (IPv6)

Internet Protocol Version 6 (IPv6)

Why do we need IPv6?



Internet Protocol Version 6 (IPv6)

- IPv4 → 4,294,467,295 IP addresses

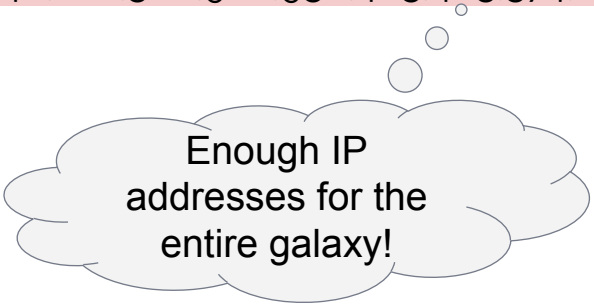
  Class A → 16,777,216
  Class B → 65,535
  Class C → 256

Large companies (Apple, IBM, Microsoft, etc.) allocated one or more Class A addresses

Internet Protocol Version 6 (IPv6)

- IPv6 is 128-bit long:

340,282,366,920,938,463,463,374,607,431,768,211,456



Internet Protocol Version 6 (IPv6)

- IPv6 is 128-bit long:
    - 340 - undecillion
    - 282 - decillion
    - 366 - nonillion
    - 920 - octillion
    - 938 - septillion
    - 463 - sextillion
    - 463 - quintillion
    - 374 - quadrillion
    - 607 - trillion
    - 431 - billion
    - 768 - million
    - 211 - thousand
    - 456

Internet Protocol Version 6 (IPv6)

- More Efficient Routing
- More Efficient Packet Processing
- Directed Data Flows - No broadcasts!
- Simplified Network Configuration
- Support For New Services - No need for NAT!
- Security

Internet Protocol Version 6 (IPv6)

- IP Address representation:

  IPv4 → 51.151.64.242
  IPv6 → 2041:1234:140F:1122:AB91:564F:875B:131B

  Octet

  Hexadectet or **hextet**

- On browsers:

  IPv4: http://51.151.64.242/index.html

  IPv6: http://[2041:1234:140F:1122:AB91:564F:875B:131B]/index.html

Internet Protocol Version 6 (IPv6)

- Shortening IPv6 Addresses:

  Original : 2041:0000:140F:0000:0000:0000:875B:131B
  Short : 2041:0000:140F::875B:131B

  Original : 2001:0000:0000:0012:0000:0000:1234:56ab
  Wrong! : 2001::0012::1234:56AB

  You can remove zeros only once!

Internet Protocol Version 6 (IPv6)

- Shortening IPv6 Addresses:

  Original : 2041:0000:140F:0000:0000:0000:875B:131B
  Short : 2041:0:140F::875B:131B

  Original : 2001:0001:0002:0003:0004:0005:0006:0007
  Short : 2001:1:2:3:4:5:6:7

- Rules:
  - An entire string of zeros can be removed, you can only do this once
  - 4 zeros can be removed, leaving only a single zero
  - Leading zeros can be removed

Internet Protocol Version 6 (IPv6)

IPv6 Address Types:

- **Unicast Address**
  - **Link Local Address:** Only valid in local networks. Starts with *FE80::/10*
  - **Global Unicast Address:** Worldwide unique address. Starts with *2000* to *3FFF*
- **Multicast address -** Same as IPv4. Starts with *FF00::/8*
- **Anycast Address -** Similar to broadcast but instead of sending to all nodes, sends to the closest nodes to sender.

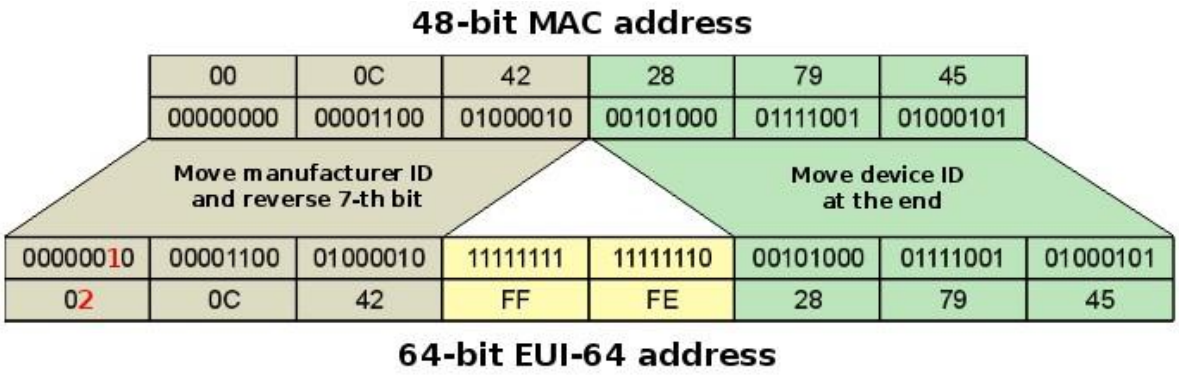
Internet Protocol Version 6 (IPv6)

IPv6 Special Addresses:

Address	Meaning
0:0:0:0:0:0:0:0	Equals ::. The equivalent of IPv4's 0.0.0.0 and is typically the source address of a host before the host receives an IP address when you're using DHCP-driven stateful configuration
0:0:0:0:0:0:0:1	Equals ::1. The equivalent of 127.0.0.1 in IPv4.
2000::/3	The global unicast address range allocated for Internet access.
FC00::/7	The unique local unicast range.
FE80::/10	The link-local unicast range.
FF00::/8	The multicast range.
3FFF:FFFF::/32	Reserved for examples and documentation.
2001:0DB8::/32	Also reserved for examples and documentation.
2002::/16	Used with 6to4 tunneling, which is an IPv4-to-IPv6 transition system.

Internet Protocol Version 6 (IPv6)

Stateless Autoconfiguration (EUI-64):



Internet Protocol Version 6 (IPv6)

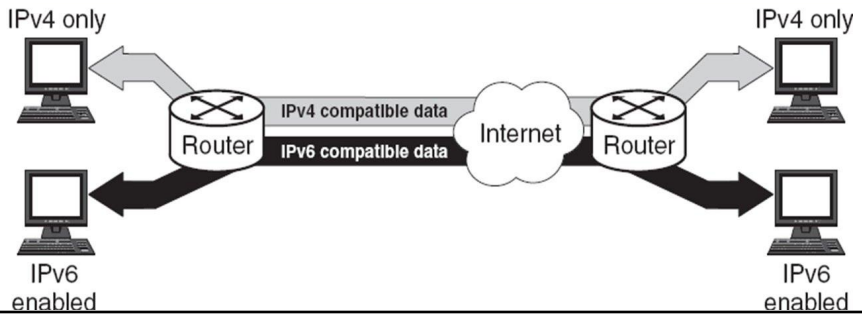
Advantages of EUI-64:

- Doesn't require support of a DHCP server
- Allows hot plugging of network devices
- Suitable for applications requiring secure connection without additional intermediaries in the form of a proxy or a DHCP server
- Cost effective
- Suitable for wireless networks

Internet Protocol Version 6 (IPv6)

Migrating to IPv6:

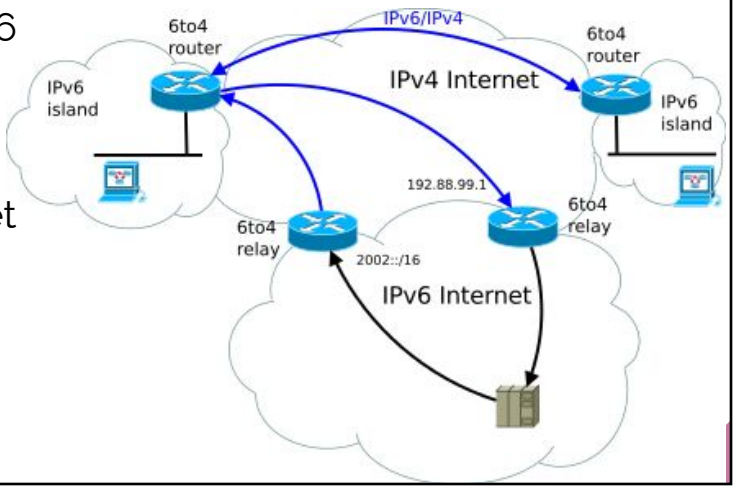
- Dual Stacking
  - Most common and easiest migration
  - Allows devices to communicate either IPv4 or IPv6
  - Lets you upgrade your devices to IPv6 one at a time



Internet Protocol Version 6 (IPv6)

Migrating to IPv6:

- 6to4 Tunneling
  - Useful for carrying IPv6 packets over IPv4 network
  - Puts IPv4 header onto the front of IPv6 packet



THANKS!

Any questions?

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