Module 12

IPv4 Addressing and Subnetting

Objectives

1. 2.3 Explain the properties and characteristics of TCP/IP and IPv4 subnetting

NETWORKING
AND IP ADDRESSING

Addressing Schemes

Flat

1. Used by Intranetworks
2. Used by Layer 2
3. Used in MAC address
4. Is assigned statically based on next available number or random
   A. Social Security Number
   B. Your Name
   C. MAC- C0:AD:00:23:4F:89

Hierarchical

1. Used by Internetworks
2. Used by Layer 3
3. Used by IP address
4. Is assigned dynamically based on you location
   A. Phone System
   B. ZIP Code
   C. IP- 182.157.63.219

Internet Protocol address (IP address)

1. A numerical label assigned to each device participating in a network
2. Every device on the Internet must have a unique IP address to identify itself
3. **Internet Assigned Numbers Authority** (IANA)
4. Manages the IP address space allocations globally
5. Delegates five **regional Internet registries** (RIRs) to allocate IP address blocks to local Internet registries (Internet service providers)
6. For an IP to be routable over the Internet, it must have:
   A. IP address
   B. Subnet Mask
   C. Default Gateway
   D. DNS address (only for address lookup, i.e. web sites)

Types of Addressing

1. **Static IP address**
   A. Manually assigned to a device by an administrator
   B. Constant and does not change.
2. **Dynamic IP address**
   A. Assigned to device each time it starts
   B. Requires less human intervention
   C. Less administration
   D. Uses Dynamic Host Configuration Protocol (DHCP)
   E. Enabled by default
   F. No user intervention

Classful vs Classless

Classful

1. Divided into 5 classes A, B, C, D (multicast) and E (reserved)
2. Does not send subnet information
3. All networks are the same size
4. Have the same subnet mask
5. Can NOT use first or last subnets

Classless

1. Also known as CIDR (Classless Inter-Domain Routing)
2. Sends subnet information
3. Network can be different sizes
4. Networks can have different subnet masks using VLSM (Variable Length Subnet Mask)
5. Can use first and last subnets

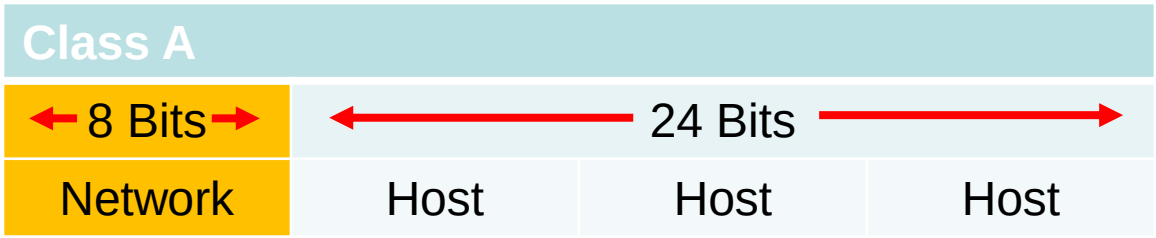
Network & Host Numbers

	1 Byte ←8 Bits→	1 Byte ←8 Bits→	1 Byte ←8 Bits→	1 Byte ←8 Bits→
Class A	**N**	**H**	**H**	**H**
Class B	**N**	**N**	**H**	**H**
Class C	**N**	**N**	**N**	**H**

The formulas are the default configuration for each class:

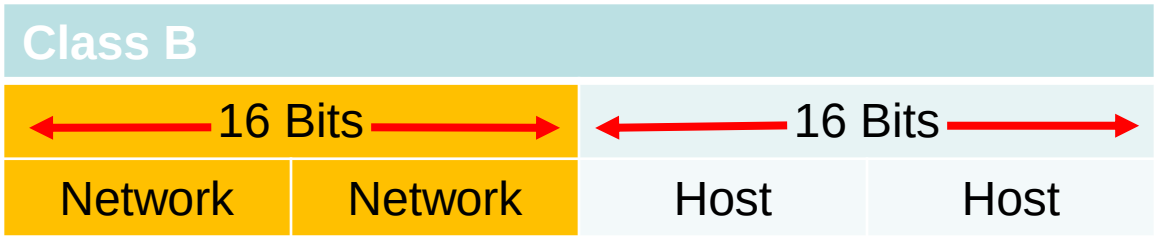
1. **N = Network Number**
   - A. Assigned by the American Registry for Internet Numbers (ARIN)
   - B. Administrator has no control over this part of the address
2. **H = Host Number**
   - A. Assigned and controlled by the network administrator

Class A Addresses



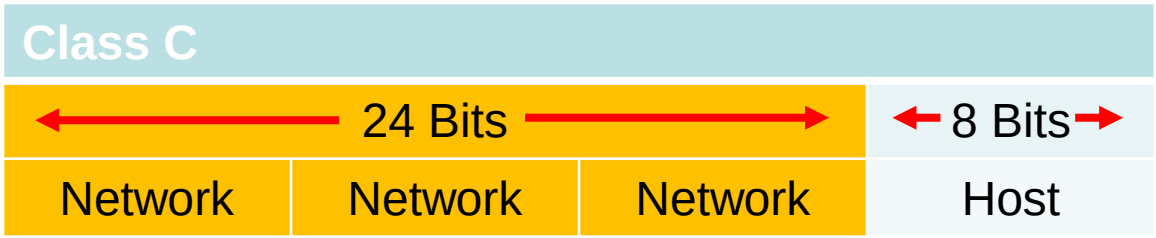
1. First octet only identifies the network
2. When written in a binary format, the first (leftmost) bit of a Class A address is always **0 (zero)**
3. Class A IP address example: 124.95.44.15
4. Range from **1-126** in their first octet
5. 127 is part of a class A range but has been reserved for loopback testing
6. Zero (0) can't be used
7. Remaining three octets can be used for the host portion of the address
8. 2^{24} or 16,777,216, possible IP addresses per class A network

Class B Addresses



1. When written in a binary format, the first (leftmost) bit of a Class B address is always **10 (one and zero)**
2. Class B IP address example: 151.10.13.28
3. The first two octets identify the network number assigned by ARIN
4. Range from **128 to 191** in their first octet
5. Remaining two octets can be used for the host portion of the address
6. 2^{16} or 65,536, possible IP addresses per class B network

Class C Addresses



1. When written in a binary format, the first (leftmost) bit of a Class C address is always **110 (one, one and zero)**
2. Class C IP address example: 201.110.213.28
3. The first three octets identify the network number assigned by ARIN
4. Range from **192 to 223** in their first octet
5. Last octet can be used for the host portion of the address
6. 2^8 or 256, possible IP addresses per class C network

Address Ranges

IMPORTANT!!!
MEMORIZE

Class A	1 – 126	N.H.H.H
Class B	128 – 191	N.N.H.H
Class C	192 – 223	N.N.N.H

Converting to Binary

1. An IP Address is made up of 32 bits broken down into 4 Octets (8 bits each)

2. 11000000.00001100.00000101.10101010
   or
   192.12.5.170

3. Known as the Dotted Decimal

Converting to Binary

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

Decimal to Binary

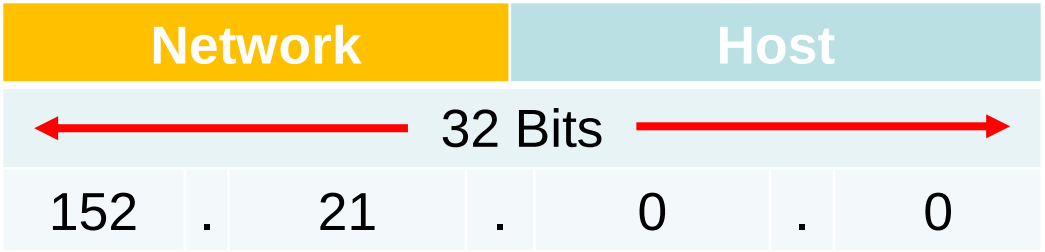
Binary to Decimal

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

Binary

Network Address



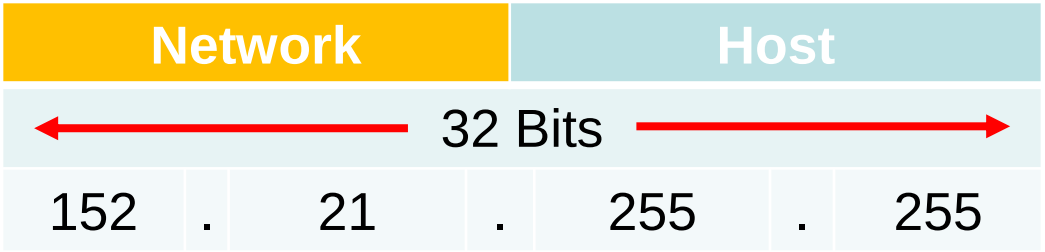
1. **Ends with binary 0s in all host bits**
2. Also know as the **wire address**
3. Never used as a device IP address
4. Used by routers to forward data
5. Example IP address: 152.21.2.3
   A. Class B
   B. First two octets are assigned
   C. Last two octets are host numbers used for devices in the network
   D. Network address: 152.21.0.0

Examples of Network Numbers

What is the network number for this IP address?

1. 194.78.112.6 → **194.78.112.0**
2. 117.23.8.3 → **117.0.0.0**
3. 156.132.64.12 → **156.132.0.0**
4. 208.150.112.16 → **208.150.112.0**
5. 91.118.125.2 → **91.0.0.0**

Broadcast Address



1. **End with binary 1s in host bits**
2. Used to send data to all devices on a network
3. Never used as a device IP address
4. Example IP address: 152.21.2.3
   A. Class B address
   B. First two octets are assigned
   C. Last two octets are host numbers used for devices in the network
   D. Broadcast address: 152.21.255.255

Examples of Broadcast Address

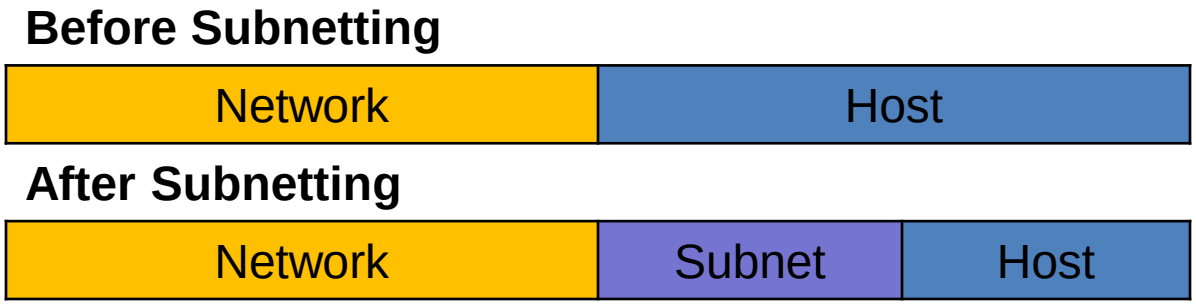
What is the Broadcast address for this IP address?

1. 194.78.112.6 → **194.78.112.255**
2. 117.23.8.3 → **117.255.255.255**
3. 156.132.64.12 → **156.132.255.255**
4. 208.150.112.16 → **208.150.112.255**
5. 91.118.125.2 → **91.255.255.255**

Network Number and Broadcast Address

1. All 0's in the host address is the Network Number
2. All 1's in the host address in the Broadcast Address
3. These two addresses can never be used when assigning IP's
4. When finding the number of useable host addresses, you will always subtract 2 (network & Broadcast)

Why Subnet?



1. A way of breaking networks into smaller more manageable pieces
2. More efficiently use IP addresses
3. Reduces the amount of wasted space
4. Reduce the size of a broadcast domains
5. Better bandwidth utilization

Subneting

Network	Network	Network	Host	
8 Bits	8 Bits	8 Bits	8 Bits	
2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0	2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0	2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0	2^7 2^6 2^5	2^4 2^3 2^2 2^1 2^0
11000000 .	00000101 .	00100010 .	000	01011
			Subnet	Host

1. Subnet addresses include:
   A. The Class A, Class B, or Class C network portion
   B. A subnet field
   C. A host field
2. Subnet field and the host field are created from the original host portion
3. Provides addressing flexibility
4. To create a subnet address:
   A. Network administrator borrows bits from the original host portion
   B. Designates them as the subnet field (gives up control)

IMPORTANT!!!

1. You must always borrow at least 2 bits and you must always leave at least 2 bits

2. One for the network number and one for the broadcast

What is a Subnet Mask?

Class B Default Subnet Mask	Class B Subnet Mask with 4 bits borrowed
255.255.0.0	**255.255.240.0**

1. Formal name: **extended network prefix**
2. Tells the network devices which part of an address is the network field and which part is the host field
3. 32 bits long and 4 octets, just like an IP address
4. Bits are always borrowed from the left most available bit
5. Allow numbers: 255, 254, 248, 240, 224, 192, 128, 0
6. Step to determine the subnet mask:
   A. Express the subnetwork IP address in binary form
   B. Replace the network and subnet portion of the address with all 1s
   C. Replace the host portion of the address with all 0s
   D. Convert the binary expression back to dotted-decimal notation

Subnet Mask

If you have a class C address:

1. How many bits are used without subneting?

24

2. What is the subnet mask?

11111111.11111111.11111111.00000000 or 255.255.255.0

3. If you borrowed 4 bits, how many are used?

28

4. What is the subnet mask?

11111111.11111111.11111111.11110000 or 255.255.255.240

Examples of Subnet Mask

What is the Subnet Mask for this IP address?

1. 194.78.112.6/28 → **255.255.255.240**
2. 117.23.8.3/10 → **255.192.0.0**
3. 156.132.64.12/19 → **255.255.224.0**
4. 208.150.112.16/30 → **255.255.255.252**
5. 91.118.125.2/16 → **255.255.0.0**

Subneting

1. Always remember that there are two reserved/unusable subnets
2. Each time you borrow another bit from the host field, the number of subnets created increases by a power of 2 (doubles)
3. Examples:
   A. Borrowing 2 bits creates four possible subnets 2^2 (2x2)
   B. Eight possible subnets are created by borrowing 3 bits: 2^3 (2 x 2 x 2)
   C. Sixteen possible subnets are created by borrowing 4 bits: 2^4 (2 x 2 x 2 x 2)
   D. What if you borrow one bit?

Useable Subnets and Host

MEMORIZE

1. Formula for calculating **USEABLE Subnets** (borrowed bits):

$$2^{b} - 2 = \text{useable subnets}$$

2. Formula for calculation **USEABLE Hosts** (unused bits):

$$2^{u} - 2 = \text{useable hosts}$$

Calculating Subnets and Hosts

Example: Class C network, borrowing 3 bits:

1. What is the subnet mask?

255.255.255.224

2. How many usable subnets?

2^b-2= ? **2^3 (8) - 2 = 6 usable subnets**

3. How many useable hosts per subnet?

2^u-2= ? **2^5 (32) - 2 = 30 usable hosts**

Calculating Subnets and Hosts

The more subnets you create, the less hosts each subnet will have

Class "C" Subnetting

Number of Bits Borrowed	Number of Subnets Created $2^{(B=Bits\ Borrowed)}$	Number of Hosts Per Subnet $2^{(U=Unused\ Bits)}$
2 6 left for Host	2^2 (4) - 2 = 2 4 Possible and 2 Usable	2^6 (64) - 2 = 62 64 Possible and 62 Usable
3 5 left for Host	2^3 (8) - 2 = 6 8 Possible and 6 Usable	2^5 (32) - 2 = 30 32 Possible and 30 Usable
4 4 left for Host	2^4 (16) - 2 = 14 16 Possible and 14 Usable	2^4 (16) - 2 = 14 16 Possible and 14 Usable
5 3 left for Host	2^5 (32) - 2 = 30 32 Possible and 30 Usable	2^3 (8) - 2 = 6 8 Possible and 6 Usable
6 2 left for Host	2^6 (64) - 2 = 62 64 Possible and 62 Usable	2^2 (4) - 2 = 2 4 Possible and 2 Usable

Boolean Operations

1. The term "operations" in mathematics refers to rules that define how one number combines with other numbers
2. Boolean operators binary numbers:
   A. **AND** is like multiplication
   B. **OR** is like addition
   C. **NOT** changes 1 to 0, and 0 to 1
3. In order to route a data packet, the router must first determine the destination network/subnet address by performing a logical AND using the destination host's IP address and the subnet mask
4. Result will be the network/subnet address

ANDing

Find the network address for this class B IP:

1. 180.160.120.8/18

2. What the subnet mask? **255.255.192.0**
3. Change IP to binary `10110100.10100000.01111000.00001000`
4. Change SM to binary `11111111.11111111.11000000.00000000`
5. AND function

   `10110100.10100000.01000000.00000000`
6. Convert back to decimal
7. Network address **180.160.64.0**

Classful Subnetting

Things you know by default:

1. Class
2. Formulas
3. Default Mask

Things you must always find out first before finding your IP's:

1. Bits Borrowed
2. Subnet Mask
3. Number of subnets
4. Numbers of hosts
5. Increment

An IP address of 196.112.48.12 with the most hosts:

1. Bits Borrowed **2**
2. Subnet Mask **255.255.255.192**
3. Number of subnets **2^2 (4) - 2 = 2 usable**
4. Numbers of hosts **2^6 (64) - 2 = 62 usable**
5. Increment **64**

An IP address of 196.112.48.12/27:

1. Bits Borrowed **3**
2. Subnet Mask **255.255.255.224**
3. Number of subnets **2^3 (8) - 2 = 6 usable**
4. Numbers of hosts **2^5 (32) - 2 = 30 usable**
5. Increment **32**

A class C address with 4 bits borrowed would have:

1. Bits Borrowed **4**
2. Subnet Mask **255.255.255.240**
3. Number of subnets **2^4 (16) - 2 = 14 usable**
4. Numbers of hosts **2^4 (16) - 2 = 14 usable**
5. Increment **16**

An IP address of 196.112.48.12/29:

1. Bits Borrowed **5**
2. Subnet Mask **255.255.255.248**
3. Number of subnets **2^5 (32) - 2 = 30 usable**
4. Numbers of hosts **2^3 (8) - 2 = 6 usable**
5. Increment **8**

An IP address of 196.112.48.12 with the most subnets:

1. Bits Borrowed **6**
2. Subnet Mask **255.255.255.252**
3. Number of subnets **2^6 (64) - 2 = 62 usable**
4. Numbers of hosts **2^2 (4) - 2 = 2 usable**
5. Increment **4**

Class C Subnetting Chart

Subnet Number	Network Address	Usable Range	Broadcast Address
SN0	196.112.48.**0**	196.112.48.**1** – 196.112.48.**62**	196.112.48.**63**
SN1	196.123.48.**64**	196.112.48.**65** – 196.112.48.**126**	196.112.48.**127**
SN2	196.112.48.**128**	196.112.48.**129** – 196.112.48.**190**	196.112.48.**191**
SN3	196.112.48.**192**	196.112.48.**193** – 196.112.48.**254**	196.112.48.**255**

Subnetting Fundamentals

Class	Range	Formula	Default Mask
A	0-126	N.H.H.H	255.0.0.0
B	128-191	N.N.H.H	255.255.0.0
C	192-223	N.N.N.H	255.255.255.0

1. Determine the Class of each given
2. Determine how many bits you must borrow (if applicable).
3. Determine the possible number and usable number of subnets.
   $2^{(B)} - 2$ = Usable Subnets
4. Determine how many possible number and usable number of hosts.
   $2^{(U)} - 2$ = Usable Hosts
5. Determine the Default Mask.
6. Determine the Subnet Mask.
7. Determine the increment. (Increment = Possible Number of Hosts)
8. Determine the network and broadcast address for each subnetwork.
9. Determine the usable range for each subnetwork.

Private Addresses

The following rages are available for private addressing:	
Class A	10.0.0.0 – 10.255.255.255
Class B	172.16.0.0 – 172.31.255.255
Class C	192.168.0.0 – 192.168.255.255

1. Found in each class
2. Preserve IP addresses used on the Internet
3. Not routable or usable on the Internet
4. Added security
5. Used by:
   A. Hosts that use **Network Address Translation** (NAT)
   B. Proxy server to connect to a public network
   C. Hosts that do not connect to the Internet at all

Automatic Private IP Addressing (APIPA)

1. Feature of modern operating systems
2. Automatically self-configures an IP address and subnet mask when a DHCP server isn't available
3. IP address range: 169.254.0.1 through 169.254.255.254
4. Configures a default class B subnet mask of 255.255.0.0
5. Used until a DHCP becomes available
6. APIPA cannot be routed over the Internet

Summary

In this module we discussed:

1. Flat and Hierarchical address schemes
2. What is Internet Protocol (IP)
3. Types of addressing
4. Classful and Classless addressing
5. Network/Host formulas
6. The different classes and how they are used
7. Ranges for each class
8. Network and Broadcast addresses
9. Subnetting and the Subnet Mask
10. Calculating subnets and hosts
11. Private IP addressing