Simple Network Management Protocol (SNMP)

Port: 161 **Transport Layer Protocol:** TCP

- Protocol used to monitor and manage network devices
- Allows admins to monitor and manage network devices and traffic.
- Allows network devices to communicate information about their state:
  - Memory
  - CPU
  - Bandwidth
- Uses TCP port 161 by default

Lightweight Directory Access Protocol (LDAP)

Port: 389 **Transport Layer Protocol:** TCP

- Protocol that provides a means to access and query directory service systems:
  - Usernames, Passwords, Computer Accounts, etc.
- Typically Unix/Linux-based or Microsoft Active Directory-based
- Uses TCP 389 by default

LDAP Secure (LDAPS)

Port: 636 **Transport Layer Protocol:** TCP

- LDAP over SSL
- A secure version of LDAP that utilizes SSL to encrypt LDAP network traffic
- Uses TCP port 636 by default

Server Message Block (SMB)

Port: 445 **Transport Layer Protocol:** TCP

- Network and file sharing protocol commonly used in Microsoft environments
- Allows systems to share their files and printers with other systems
- Uses TCP port 445 by default

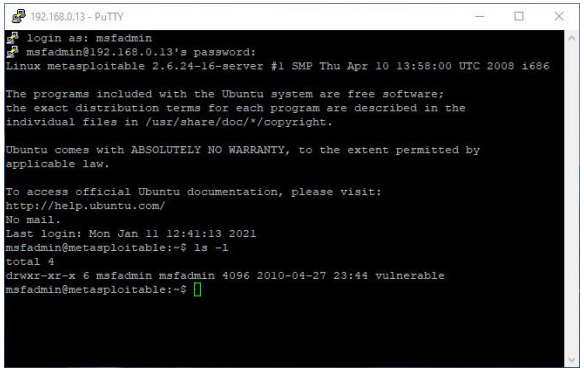
Application Layer Remote Communication Protocols

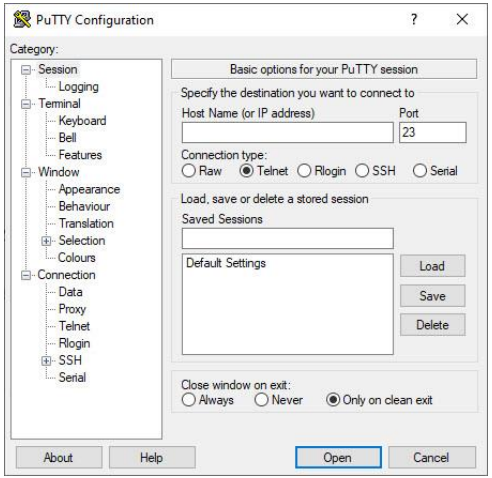
- Telnet
- Secure Shell (SSH)
- Remote Desktop Protocol (RDP)

Telnet

Port: 23 **Transport Layer Protocol:** TCP

- Legacy protocol used to “insecurely” connect to a remote host
  - Data is transferred in clear text, so it’s considered insecure
  - Largely replaced by SSH
- Today it’s primarily used to access managed network devices, such as routers via a serial connection
- Use TCP Port 23 by default

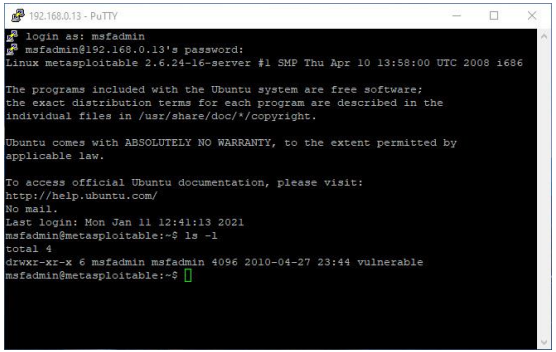


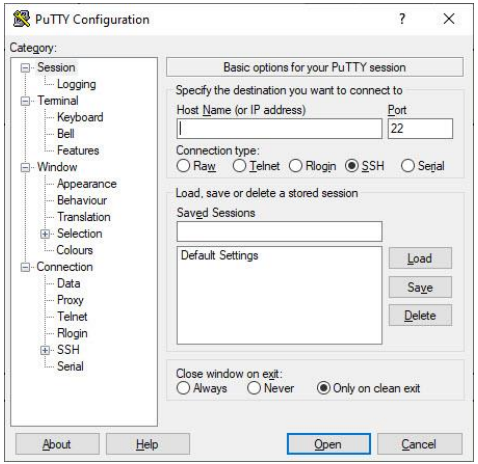


Secure Shell (SSH)

Port: 22 **Transport Layer Protocol:** TCP

- A cryptographic protocol that's used to securely connect to a remote host
  - Utilizes a terminal console
  - Typically Unix and Linux Machines, but also available on Windows and Mac OS
- Encrypts data with public key infrastructure (PKI), making it secure
  - Considered secure replacement for Telnet
- Uses TCP port 22 by default

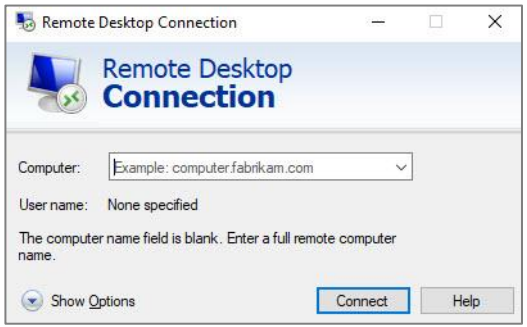


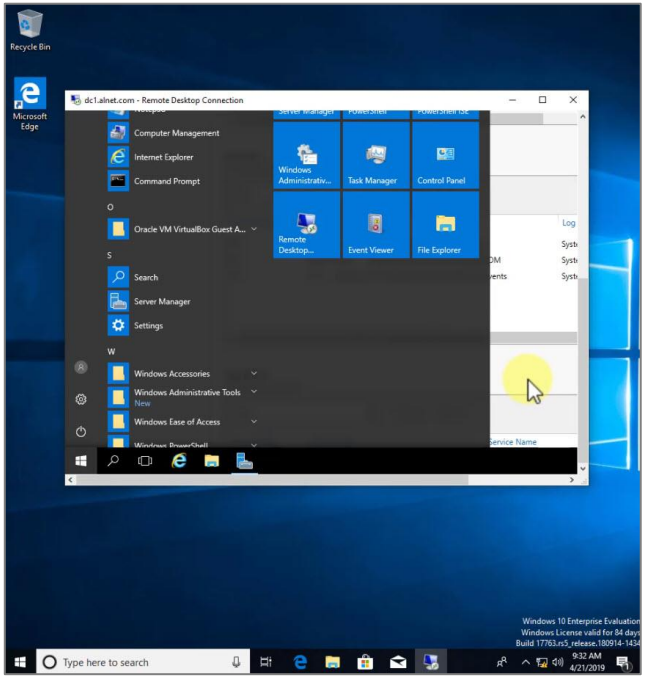


Remote Desktop Protocol (RDP)

Port: 3389 **Transport Layer Protocol:** TCP

- A Microsoft protocol that allows users to remotely connect to, view, and control a remote computer from a Windows desktop.
- Built into the Microsoft operating system.
- Uses TCP port 3389 by default





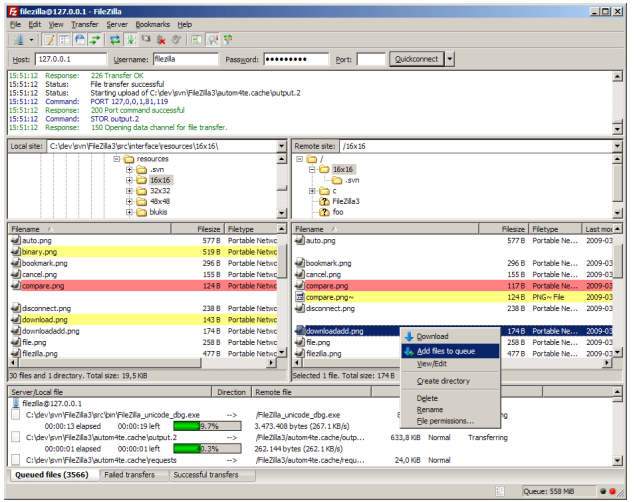
Application Layer File Transfer Protocols

- File Transfer Protocol (FTP)
- Secure File Transfer Protocol (SFTP)
- Trivial File Transfer Protocol (TFTP)

File Transfer Protocol (FTP)

Ports: 20, 21 **Transport Layer Protocol:** TCP

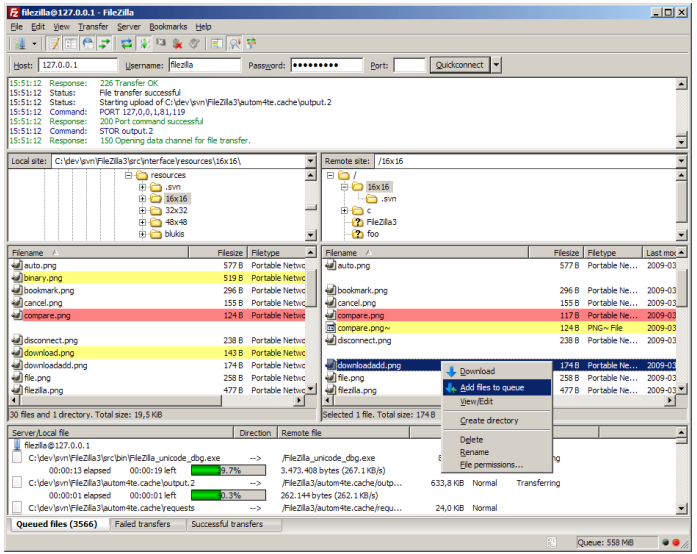
- Legacy protocol used to transfer files between systems
  - Slowly being replaced by Secure FTP (SFTP)
- Can authenticate with a username and password or utilize anonymous logins
- Data is transferred in clear text, so it's considered insecure
- Full-featured functionality:
  - View, list, add, delete, etc. files and folders
- Uses two TCP ports by default:
  - **Port 20 for Data**: Data Transfers
  - **Port 21 for Control**: Commands



Secure File Transfer Protocol (SFTP)

Port: 22 **Transport Layer Protocol:** TCP

- A secure cryptographic version of FTP that uses SSH to provide encryption services.
  - Provides file transfer over SSH
- Uses TCP port 22 by default (same port as SSH)



Trivial File Transfer Protocol (TFTP)

Port: 69 **Transport Layer Protocol:** UDP

- A bare-bones version of FTP used for simple downloads
  - Doesn't support authentication
  - Doesn't support directory navigation
- Requires that you request the exact file (and location)
- Often used to transfer software images for routers and switches during upgrades
- Utilizes UDP port 69 by default

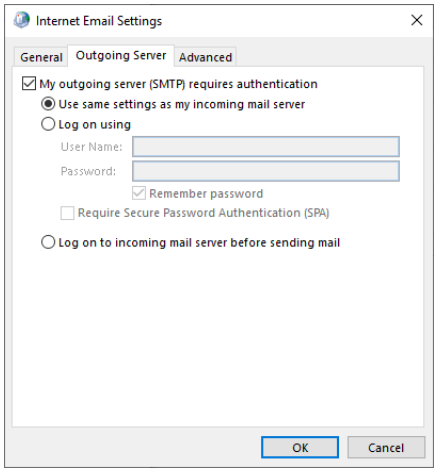
Application Layer Email Protocols

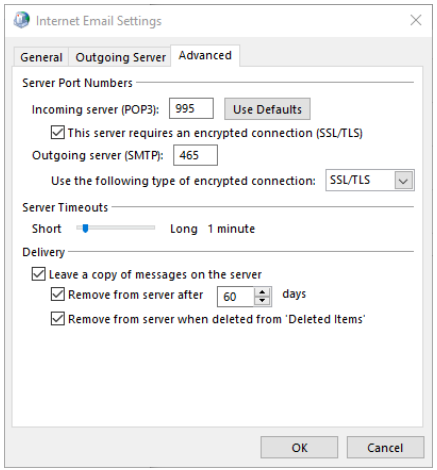
- Simple Mail Transfer Protocol (SMTP)
- Post Office Protocol Version 3 (POP3)
- Internet Message Access Protocol (IMAP)

Simple Mail Transfer Protocol (SMTP)

Port: 25 **Transport Layer Protocol:** TCP

- Email protocol that is used to deliver emails from an email client (Outlook) to a destination email server
- Can be configured to use encryption (recommended) or plain text
- Uses TCP Port 25 by default

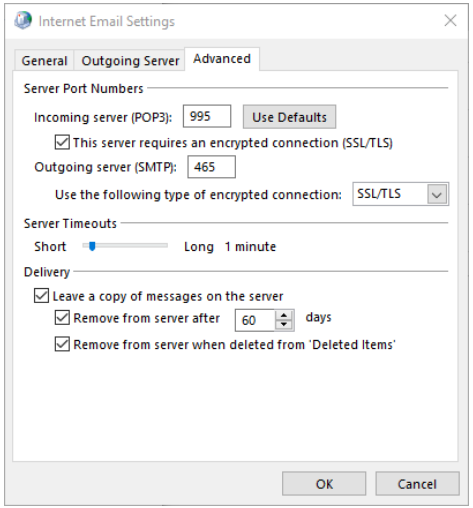




Post Office Protocol Version 3 (POP3)

Port: 110 **Transport Layer Protocol:** TCP

- Email protocol that is used to retrieve emails from an email server
- Can be configured to use encryption (recommended) or plain text
- Uses TCP Port 110 by default



Internet Message Access Protocol (IMAP)

Port: 143 **Transport Layer Protocol:** TCP

- Another email protocol that is quickly replacing POP3
- Allows users to access email on servers and either read the email on the server or download the email to the client machine
- Popular when a user accesses email from multiple different devices
- Web-based email clients, such as Gmail, use IMAP
- Uses TCP port 143 by default

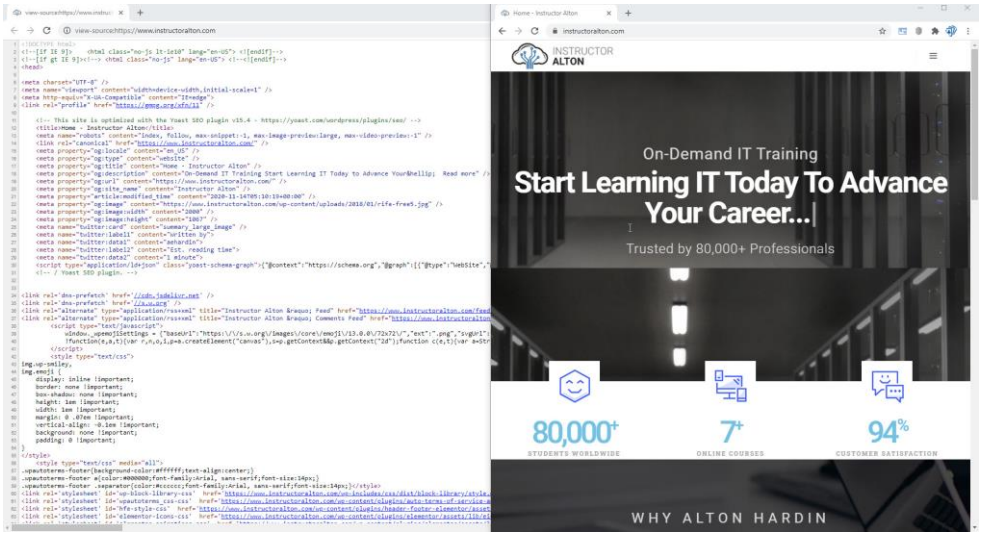
Application Layer Web Browser Protocols

- Hypertext Transfer Protocol (HTTP)
- HTTP Secure (HTTPS)

Hypertext Transfer Protocol (HTTP)

Port: 80 **Transport Layer Protocol:** TCP

- Protocol that provides browsing services for the World Wide Web (WWW)
  - Retrieves the content of a web page from a web server
  - Requests are made in hypertext markup language (HTML) and returned to your browser in that format
- Data is sent in plain text
- Uses TCP Port 80 by default



HTTP Secure (HTTPS)

Port: 443 **Transport Layer Protocol:** TCP

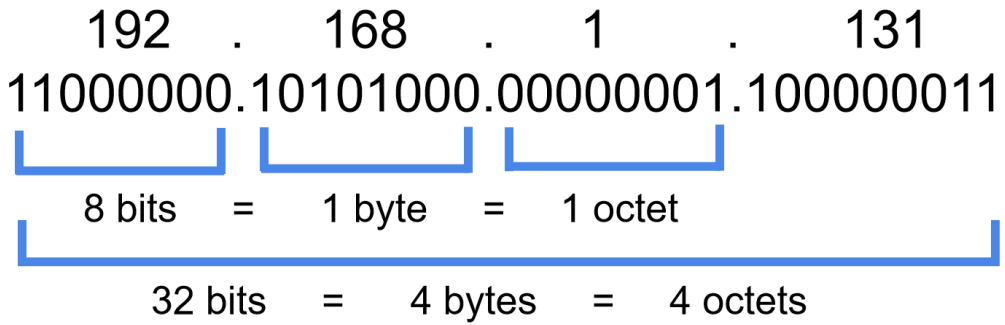
- HTTP over Secure Socket Layer (SSL) or Transport Layer Security (TLS)
- A secure version of HTTP that utilizes SSL/TLS to encrypts HTTP content
- Utilizes Public Key Infrastructure (PKI)
- Uses TCP Port 443 by default

Understanding IPv4 Addresses

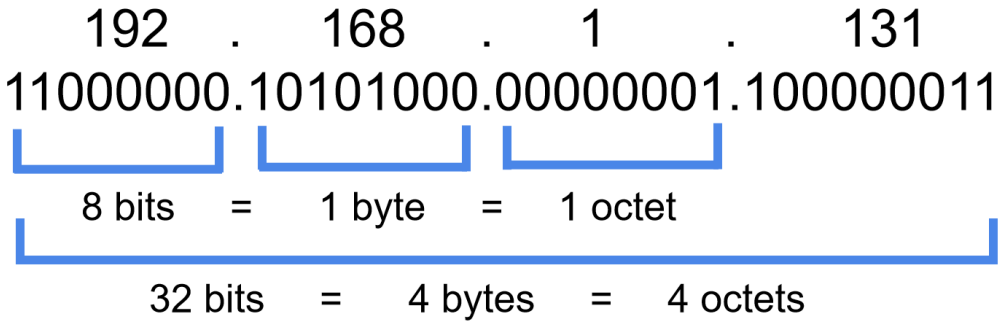
- An IP Address is a **logical address** used in order to **uniquely identify** a device on an IP network.
- It's a **Network Layer** Address
- There are Two Versions:
  - IP version 4 (IPv4)
  - IP version 6 (IPv6)
- This lesson focuses on IPv4, and we'll discuss IPv6 later in the course.

IPv4 Address Anatomy

- Made up of 32 binary bits, which can be divided into a **network portion** and a **host portion** with the help of a subnet mask.
  - The 32 binary bits are broken into four octets (1 octet = 8 bits).
  - Each octet is converted to decimal and separated by a period (dot).
  - For this reason, an IP address is said to be expressed in dotted decimal format.



IPv4 Address Anatomy



First Octet		Second Octet		Third Octet		Fourth Octet
192	.	168	.	1	.	131
11000000	.	10101000	.	00000001	.	10000011
8 bits		8 bits		8 bits		8 bits

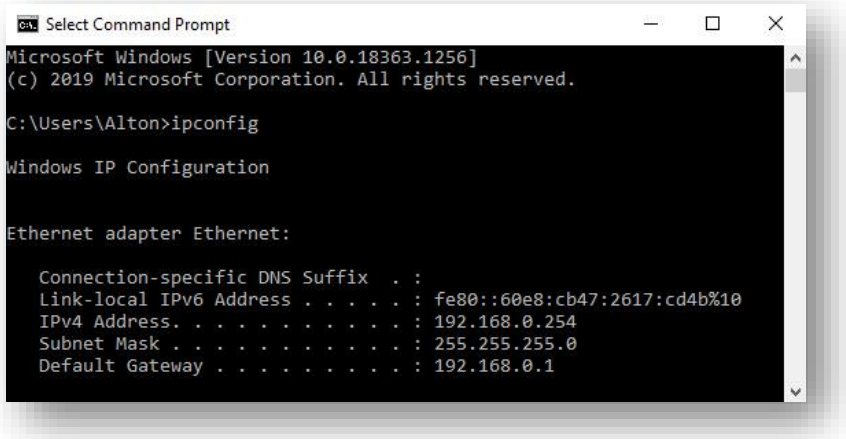
Network and Host Portion

- An IP address is broken down into two parts:
  - **Network Address**
    - Uniquely identifies each network
    - Your Street Name: 7682 **Wilshire Drive**
  - **Host Address**
    - Uniquely identifies each machine on a network
    - Your House Address: **7682** Wilshire Drive

- Network Address + Host Address = IP Address
  - **Wilshire Drive 7682**

IPv4 Address Components

- Each device on a network is assigned an IP address, subnet mask and default gateway:
  - **IP Address**: Unique logical address assigned to each device on a network.
  - **Subnet Mask**: Used by the device to determine what subnet it's on, specifically the network and host portions of the IP address.
  - **Default Gateway**: The IP address of a network's router that allows devices on the local network to communicate with other networks.



Basics of Binary Math

Lecture Goals

- Convert Binary to Decimal
- Convert Decimal to Binary

Basics of Binary Math

Why is it important?

We need to know basic binary math to perform subnetting, as well as to understand how IPv4 addresses work.

Remember This

128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255

What is the binary 11111111 in decimal?

	128		64		32		16		8		4		2		1		
Binary	1		1		1		1		1		1		1		1		
Decimal	128	+	64	+	32	+	16	+	8	+	4	+	2	+	1	=	**255 Decimal**

Add the number where there is a “1”.
Add zero, when there is a “0”.

What is the binary 10101010 in decimal?

	128		64		32		16		8		4		2		1		
Binary	1		0		1		0		1		0		1		0		
Decimal	128	+	0	+	32	+	0	+	8	+	0	+	2	+	0	=	**170 Decimal**

Add the number where there is a “1”.
Add zero, when there is a “0”.

What is the binary 10000011 in decimal?

	128		64		32		16		8		4		2		1		
Binary	1		0		0		0		0		0		1		1		
Decimal	128	+	0	+	0	+	0	+	0	+	0	+	2	+	1	=	**131 Decimal**

Add the number where there is a “1”.
Add zero, when there is a “0”.

What's 192 in binary?

	128		64		32		16		8		4		2		1		
Binary	1		1		0		0		0		0		0		0	=	**11000000**
Decimal	128	+	64	+	0	+	0	+	0	+	0	+	0	+	0	=	**192 Decimal**

Start adding the numbers from left to right until you achieve the decimal amount you are looking for!

What's 202 in binary?

	128		64		32		16		8		4		2		1		
Binary	1		1		0		0		1		0		1		0	=	**11001010**
Decimal	128	+	64	+	0	+	0	+	8	+	0	+	2	+	0	=	**202 Decimal**

Start adding the numbers from left to right until you achieve the decimal amount you are looking for!

What's 54 in binary?

	128		64		32		16		8		4		2		1		
Binary	0		0		1		1		0		1		1		0	=	**00110110**
Decimal	0	+	0	+	32	+	16	+	0	+	4	+	2	+	0	=	**54 Decimal**

Start adding the numbers from left to right until you achieve the decimal amount you are looking for!

IP Address Conversion Process

192.	168.	32.	4	Dotted Decimal
11000000.	10101000.	00100000.	00000100	Binary
1st Octet	2nd Octet	3rd Octet	4th Octet	

Whether you are given an IP address in dotted-decimal or binary format, follow the respective process above for each octet one by one until you have completed the process.

BINARY MATH WORKSHEET ANSWER KEY

CONVERSION CHART

128 + 64 + 32 + 16 + 8 + 4 + 2 + 1

1. CONVERT 11110000 TO DECIMAL

	128		64		32		16		8		4		2		1		
Binary	1		1		1		1		0		0		0		0	=	
Decimal	128	+	64	+	32	+	16	+	0	+	0	+	0	+	0	=	**240 Decimal**

2. CONVERT 10011001 TO DECIMAL

	128		64		32		16		8		4		2		1		
Binary	1		0		0		1		1		0		0		1	=	
Decimal	128	+	0	+	0	+	16	+	8	+	0	+	0	+	1	=	**153 Decimal**

3. CONVERT 01101011 TO DECIMAL

	128		64		32		16		8		4		2		1		
Binary	0		1		1		0		1		0		1		1	=	
Decimal	0	+	64	+	32	+	0	+	8	+	0	+	2	+	1	=	**107 Decimal**

4. CONVERT 10110011 TO DECIMAL

	128		64		32		16		8		4		2		1		
Binary	1		0		1		1		0		0		1		1	=	
Decimal	128	+	0	+	32	+	16	+	0	+	0	+	2	+	1	=	**179 Decimal**

5. CONVERT 240 TO BINARY

	128		64		32		16		8		4		2		1		
Binary	1		1		1		1		0		0		0		0	=	**11110000 Binary**
Decimal	128	+	64	+	32	+	16	+	0	+	0	+	0	+	0	=	

6. CONVERT 163 TO BINARY

	128		64		32		16		8		4		2		1		
Binary	1		0		1		0		0		0		1		1	=	**10100011 Binary**
Decimal	128	+	0	+	32	+	0	+	0	+	0	+	2	+	1	=	

7. CONVERT 94 TO BINARY

	128		64		32		16		8		4		2		1		
Binary	0		1		0		1		1		1		1		0	=	**01011110 Binary**
Decimal	0	+	64	+	0	+	16	+	8	+	4	+	2	+	0	=	

8. CONVERT 225 TO BINARY

	128		64		32		16		8		4		2		1		
Binary	1		1		1		0		0		0		0		1	=	**11100001 Binary**
Decimal	128	+	64	+	32	+	0	+	0	+	0	+	0	+	1	=	

9. CONVERT THE FOLLOWING IP ADDRESS FROM DECIMAL TO BINARY

192.168.98.18

- 192 = 11000000
- 168 = 10101000
- 98 = 01100010
- 18 = 00010010

Binary Format: 11000000. 10101000. 01100010. 00010010

10. CONVERT THE FOLLOWING IP ADDRESS FROM BINARY TO DECIMAL

01000010.11010010.11000110.11000101

- 01000010 = 66
- 11010010 = 210
- 11000110 = 198
- 11000101 = 197

Dotted Decimal Format: 66.210.198.197

BINARY MATH WORKSHEET

CONVERSION CHART

128 + 64 + 32 + 16 + 8 + 4 + 2 + 1

1. CONVERT 11110000 TO DECIMAL

	128		64		32		16		8		4		2		1	
Binary																=
Decimal		+		+		+		+		+		+		+		=

2. CONVERT 10011001 TO DECIMAL

	128		64		32		16		8		4		2		1	
Binary																=
Decimal		+		+		+		+		+		+		+		=

3. CONVERT 01101011 TO DECIMAL

	128		64		32		16		8		4		2		1	
Binary																=
Decimal		+		+		+		+		+		+		+		=

4. CONVERT 10110011 TO DECIMAL

	128		64		32		16		8		4		2		1	
Binary																=
Decimal		+		+		+		+		+		+		+		=

5. CONVERT 240 TO BINARY

	128		64		32		16		8		4		2		1	
Binary																=
Decimal		+		+		+		+		+		+		+		=

6. CONVERT 163 TO BINARY

	128		64		32		16		8		4		2		1	
Binary																=
Decimal		+		+		+		+		+		+		+		=

7. CONVERT 94 TO BINARY

	128		64		32		16		8		4		2		1	
Binary																=
Decimal		+		+		+		+		+		+		+		=

8. CONVERT 225 TO BINARY

	128		64		32		16		8		4		2		1	
Binary																=
Decimal		+		+		+		+		+		+		+		=

9. CONVERT THE FOLLOWING IP ADDRESS FROM DECIMAL TO BINARY

192.168.98.18

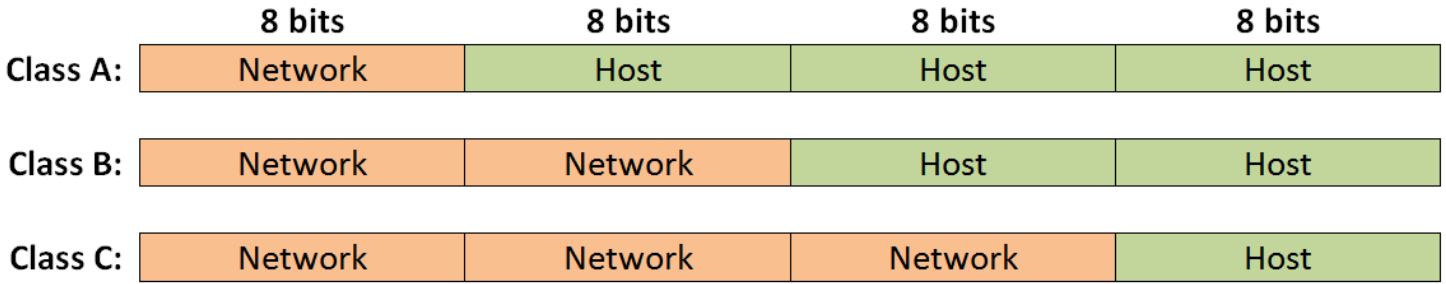
10. CONVERT THE FOLLOWING IP ADDRESS FROM BINARY TO DECIMAL

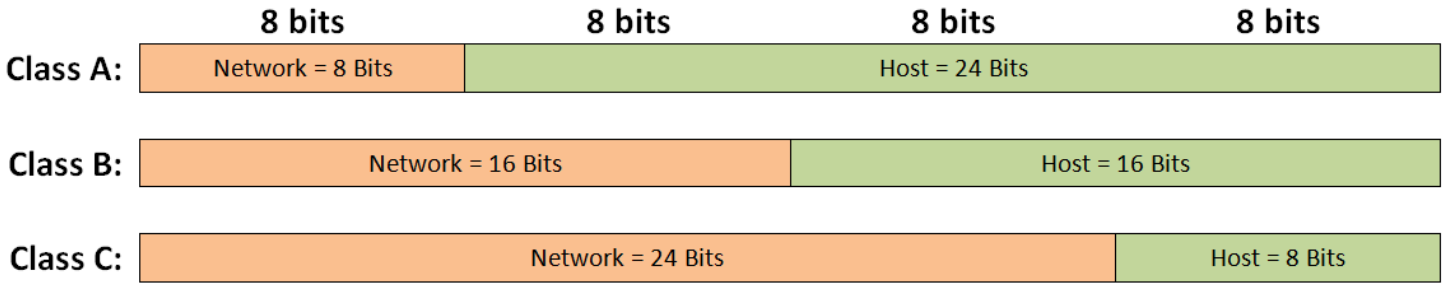
01000010.11010010.11000110.11000101

IPv4 Address Classes (Simplified)

Class	Network Bits	Host Bits	Address Range
A	8	24	1.0.0.0 – 126.255.255.255
B	16	16	128.0.0.0 – 191.255.255.255
C	24	8	192.0.0.0 – 223.255.255.255

Network and Host Bits





IPv4 Address Classes (Detailed)

Class	Leading Bits	Network Bits	Remaining Bits	Number of Networks	Hosts Per Network	Default Subnet Mask
Class A	0 (1-126)	8	24	128 (2^7)	16,777,216 (2^{24})	255.0.0.0
Class B	10 (128-191)	16	16	16,384 (2^{14})	65,536(2^{16})	255.255.0.0
Class C	110 (192-223)	24	8	2,097,152 (2^{21})	256(2^8)	255.255.255.0
Class D (multicast)	1110 (224-239)	Not Defined	Not Defined	Not Defined	Not Defined	Not Defined
Class E (reserved)	1111 (240-255)	Not Defined	Not Defined	Not Defined	Not Defined	Not Defined

Default Subnet Masks

- The Subnet Mask tells you which portion of the IP address identifies the network and which portion identifies the host.
- Below are default Class A, B, and C Subnet Masks.

	8 bits	8 bits	8 bits	8 bits
Class A:	Network	Host	Host	Host
IP Address	10.	0.	0.	15
Subnet Mask	11111111.	00000000.	00000000.	00000000
	255.	0.	0.	0
Class B:	Network	Network	Host	Host
IP Address	172.	16.	0	.110
Subnet Mask	11111111.	11111111.	00000000.	00000000
	255.	255.	0.	0
Class C:	Network	Network	Network	Host
IP Address	192.	168.	1.	50
Subnet Mask	11111111.	11111111.	11111111.	00000000
	255.	255.	255.	0

Let's Practice

What class are the following IP Addresses?

- **IP Address**: 9.10.40.15
- **Subnet Mask**: 255.0.0.0

- **IP Address**: 135.240.110.100
- **Subnet Mask**: 255.255.0.0

- **IP Address**: 196.200.10.5
- **Subnet Mask**: 255.255.255.0

CIDR Notation

- **CIDR**: Classless Inter-Domain Routing
  - A methodology for subnetting
  - “Slash” Notation tells you how many bits are associated with the Subnet Mask

- A shortcut way of telling us what the Subnet Mask is:
  - /8 = 11111111.00000000.00000000.00000000
  - /8 = 255.0.0.0

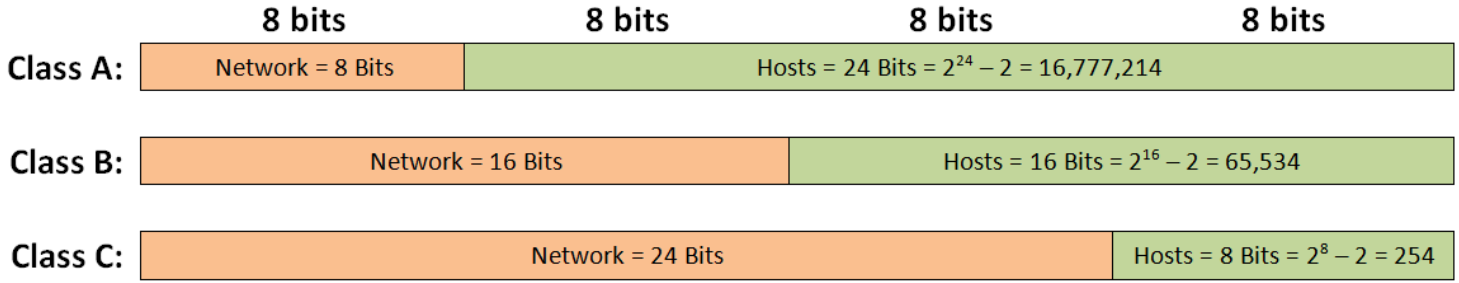
- 192.168.1.0 /24 = 255.255.255.0
- 10.1.0.0 /16 = 255.255.0.0
- 196.10.10.0/25 = 255.255.255.128

Understanding the Power of 2

- We use the power of 2 in IP addressing and subnetting.
- It's important to memorize the power of 2.

$2^1 = 2$	$2^2 = 4$	$2^3 = 8$	$2^4 = 16$
$2^5 = 32$	$2^6 = 64$	$2^7 = 128$	$2^8 = 256$
$2^9 = 512$	$2^{10} = 1{,}024$	$2^{11} = 2{,}048$	$2^{12} = 4{,}096$

Using Power of 2 to Determine Network Hosts



- **Hosts Per Network** = $2^h - 2$, where *h* is the number of host bits available.
- We subtract two because each network includes a **network address** and **broadcast address** that are not available for use by network end devices.

Public versus Private IP Addresses

Public IP Addresses

- Original Design of Internet
- “Registered” Public IP Addresses
- Assigned by an ISP to a Business or Home
- Must be Globally Unique
  - Web Servers
  - DNS Servers
  - Routers
- By the Early 1990s, the World was Running out of Public IP Addresses
- Private IP Addresses & Network Address Translation (NAT) were Born!

Private IP Addresses

- “Unregistered” – Free for Use by Anybody!
- Designed for Use within Private Internal Networks
- Can Be Used Over and Over Again
- Cannot be Used or Routed on a Public Network
- Utilizes NAT to “Speak” to Public Networks, i.e., the Internet!

Private IP Address Ranges

Class	IP Address Range	Network ID(s) (CIDR Notation)	Number of Addresses
A	10.0.0.0 – 10.255.255.255	10.0.0.0 /8 • 1 Private Class A Network	16,777,216 IP Addresses Per Network ID
B	172.16.0.0 – 172.31.255.255	172.16.0.0 – 172.31.0.0 /16 • 16 Private Class B Networks	65,534 IP Addresses Per Network ID
C	192.168.0.0 – 192.168.255.255	192.168.0.0 – 192.168.255.0 /24 • 256 Private Class C Networks	254 IP Addresses Per Network ID

The Loopback Address

- **127.0.0.0 to 127.255.255.255** is reserved for loopback, i.e., a host's own address, also known as the localhost address.
  - **127.0.0.1** is typically configured as the default loopback address on operating systems.
- Used for diagnostics purposes to check that TCP/IP is correctly installed on a host's operating system.
  - When a process creates a packet destined to the loopback address, the operating system loops it back to itself without it ever interfacing with the NIC.
  - Data sent on the loopback is forwarded by the operating system to a virtual network interface within the operating system.
- If you can successfully ping 127.0.0.1 or any IP within the loopback range, then TCP/IP on your computer is properly working.
  - Ping 127.0.0.1
  - Ping localhost
  - Ping loopback

Why Subnet?

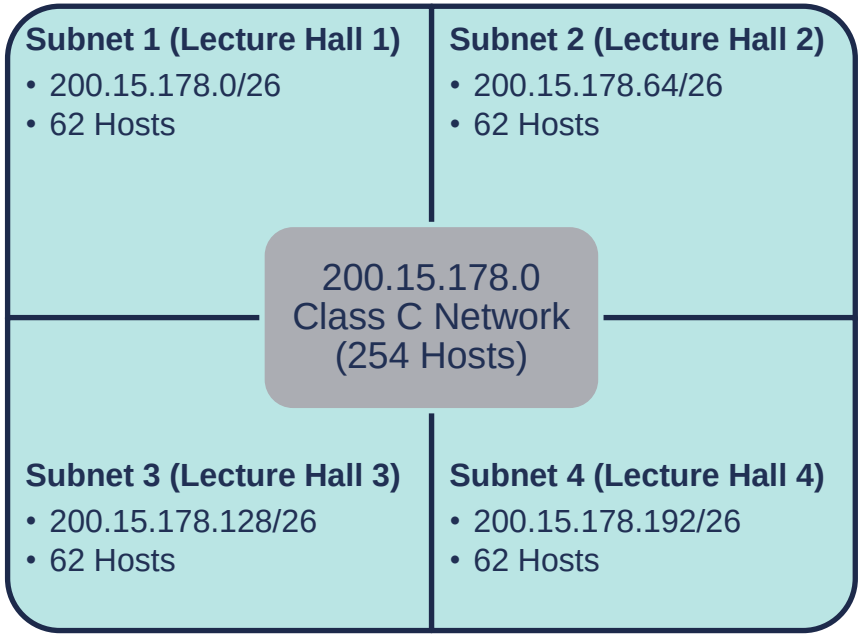
- Using default Class A, B and C subnets (called Classful IP Addressing) is inefficient:
  - Wastes unused IP Addresses (Public IP Addresses)
- Allows you to create multiple logical networks that exist within a single Class A, B, or C network.
  - Breaks up larger networks into multiple smaller sub-networks, which are called subnets
- Allows for more efficient routing via router summarization.
- Increased network security!

Fixed Length Subnetting

- We will be learning about fixed-length subnetting, known as a fixed-length subnet mask (FLSM).
- There is also variable-length subnetting (VLSM), which is beyond the scope of this beginner's course.

Class C Subnetting Example

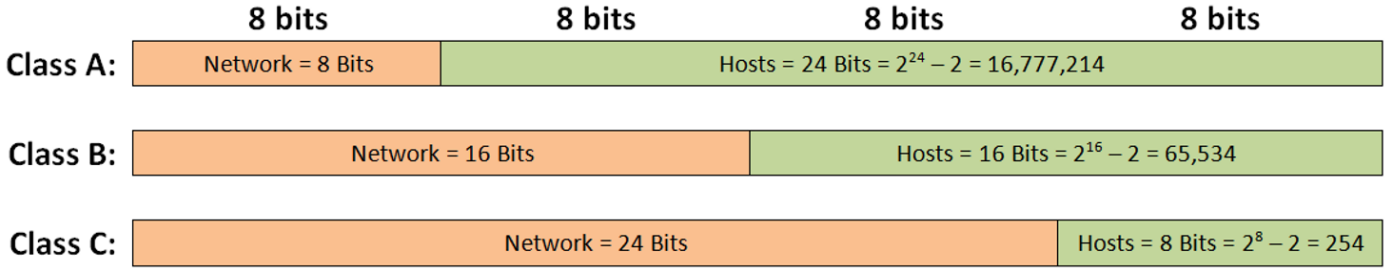
- You're the network administrator for the Computer Science department at a university.
- You're setting up four new lecture halls that must have their own 60-person wireless network.
- You've been assigned the 200.15.178.0 Class C Network by the university, that supports 254 hosts per network by default.
- How do you break up this one Class C network into 4 smaller networks that support 60 host IP addresses per network?
- You subnet it.
- Subnetting allows your to breakup a larger network into smaller networks (subnets).



Process of Subnetting

- We borrow host bits to create more sub-networks (subnets) from a Class A, B, or C network.

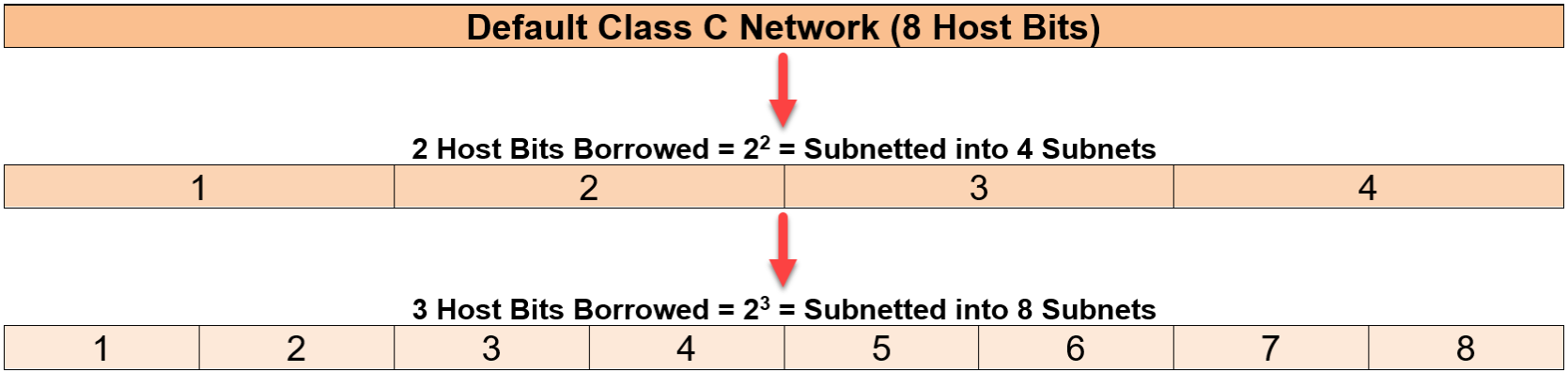
- When you borrow hosts bits:
  - You create additional sub-networks, i.e., subnets
  - You also decrease the amount of host IP addresses available to use



How to Create Subnets

- Borrow bits from the host portion of an IP address
  - Each bit we borrow is equal to 2^1 Subnets
    - Borrow 1 Host Bit = $2^1 = 2$
    - Borrow 2 Host Bits = $2^2 = 4$
    - Borrow 3 Host Bits = $2^3 = 8$
    - Borrow 4 Host Bits = $2^4 = 16$
    - Etc.

Creating Subnets Visualized



Subnetting Questions

- To Create a Subnet, Answer the Following Questions:
  - How many subnets are needed?
  - How many hosts do you need per subnet?

Class C Possible Subnets

Binary (N.N.N.H)	Decimal	CIDR	# Subnets (2^x)	Block Size (2^y)	# Hosts (2^y - 2)
N.N.N.00000000	255.255.255.0	/24	$2^0 = 1$	$2^8 = 256$	$2^8 – 2 = 254$
N.N.N.10000000	255.255.255.128	/25	$2^1 = 2$	$2^7 = 128$	$2^7 – 2 = 126$
N.N.N.11000000	255.255.255.192	/26	$2^2 = 4$	$2^6 = 64$	$2^6 – 2 = 62$
N.N.N.11100000	255.255.255.224	/27	$2^3 = 8$	$2^5 = 32$	$2^5 – 2 = 30$
N.N.N.11110000	255.255.255.240	/28	$2^4 = 16$	$2^4 = 16$	$2^4 – 2 = 14$
N.N.N.11111000	255.255.255.248	/29	$2^5 = 32$	$2^3 = 8$	$2^3 – 2 = 6$
N.N.N.11111100	255.255.255.252	/30	$2^6 = 64$	$2^2 = 4$	$2^2 – 2 = 2$

Number of Subnets (2^x)

- X = number of host bits we borrow to create subnets

Block Size (2^y)

- Y = number of remaining host bits left that are used for the subnet IP addresses

Hosts per Subnet ($2^y – 2$)

- There are two addresses per network (or subnet) that we cannot use to assign to hosts on that network:
    - **Network Address**: This is the address used to uniquely identify the network (or subnet).
    - **Broadcast Address**: Address reserved for broadcast communication on the network.

Class B Possible Subnets

Binary (N.N.H.H)	Decimal	CIDR	# Subnets (2^x)	Block Size (2^y)	# Hosts (2^y - 2)
N.N.00000000.00000000	255.255.0.0	/16	$2^0 = 1$	$2^{16} = 65{,}536$	$2^{16} – 2 = 65{,}534$
N.N.10000000.00000000	255.255.128.0	/17	$2^1 = 2$	$2^{15} = 32{,}768$	$2^{15} – 2 = 32{,}766$
N.N.11000000.00000000	255.255.192.0	/18	$2^2 = 4$	$2^{14} = 16{,}384$	$2^{14} – 2 = 16{,}382$
N.N.11100000.00000000	255.255.224.0	/19	$2^3 = 8$	$2^{13} = 8{,}192$	$2^{13} – 2 = 8{,}190$
N.N.11110000.00000000	255.255.240.0	/20	$2^4 = 16$	$2^{12} = 4{,}096$	$2^{12} – 2 = 4{,}094$
N.N.11111000.00000000	255.255.248.0	/21	$2^5 = 32$	$2^{11} = 2{,}048$	$2^{11} – 2 = 2{,}046$
N.N.11111100.00000000	255.255.252.0	/22	$2^6 = 64$	$2^{10} = 1{,}024$	$2^{10} – 2 = 1{,}022$
N.N.11111110.00000000	255.255.254.0	/23	$2^7 = 128$	$2^9 = 512$	$2^9 – 2 = 510$
N.N.11111111.00000000	255.255.255.0	/24	$2^8 = 256$	$2^8 = 256$	$2^8 – 2 = 254$
N.N.11111111.10000000	255.255.255.128	/25	$2^9 = 512$	$2^7 = 128$	$2^7 – 2 = 126$
N.N.11111111.11000000	255.255.255.192	/26	$2^{10} = 1{,}024$	$2^6 = 64$	$2^6 – 2 = 62$
N.N.11111111.11100000	255.255.255.224	/27	$2^{11} = 2{,}048$	$2^5 = 32$	$2^5 – 2 = 30$
N.N.11111111.11110000	255.255.255.240	/28	$2^{12} = 4{,}096$	$2^4 = 16$	$2^4 – 2 = 14$
N.N.11111111.11111000	255.255.255.248	/29	$2^{13} = 8{,}192$	$2^3 = 8$	$2^3 – 2 = 6$
N.N.11111111.11111100	255.255.255.252	/30	$2^{14} = 16{,}384$	$2^2 = 4$	$2^2 – 2 = 2$

Class A Possible Subnets

Binary (N.H.H.H)	Decimal	CIDR	# Subnets (2^x)	Block Size (2^y)	# Hosts (2^y - 2)
N.00000000.00000000.00000000	255.0.0.0	/8	$2^0 = 1$	$2^{22} = 16{,}777{,}216$	$2^{22} - 2 = 16{,}777{,}214$
N.10000000.00000000.00000000	255.128.0.0	/9	$2^1 = 2$	$2^{23} = 8{,}388{,}608$	$2^{23} - 2 = 8{,}388{,}606$
N.11000000.00000000.00000000	255.192.0.0	/10	$2^2 = 4$	$2^{22} = 4{,}194{,}304$	$2^{22} - 2 = 4{,}194{,}302$
N.11100000.00000000.00000000	255.224.0.0	/11	$2^3 = 8$	$2^{21} = 2{,}097{,}152$	$2^{21} - 2 = 2{,}097{,}150$
N.11110000.00000000.00000000	255.240.0.0	/12	$2^4 = 16$	$2^{20} = 1{,}048{,}576$	$2^{20} - 2 = 1{,}048{,}574$
N.11111000.00000000.00000000	255.248.0.0	/13	$2^5 = 32$	$2^{19} = 524{,}288$	$2^{19} - 2 = 524{,}286$
N.11111100.00000000.00000000	255.252.0.0	/14	$2^6 = 64$	$2^{18} = 262{,}144$	$2^{18} - 2 = 262{,}142$
N.11111110.00000000.00000000	255.254.0.0	/15	$2^7 = 128$	$2^{17} = 131{,}072$	$2^{17} - 2 = 131{,}070$
N.11111111.00000000.00000000	255.255.0.0	/16	$2^8 = 256$	$2^{16} = 65{,}536$	$2^{16} - 2 = 65{,}534$
N.11111111.10000000.00000000	255.255.128.0	/17	$2^9 = 512$	$2^{15} = 32{,}768$	$2^{15} - 2 = 32{,}766$
N.11111111.11000000.00000000	255.255.192.0	/18	$2^{10} = 1{,}024$	$2^{14} = 16{,}384$	$2^{14} - 2 = 16{,}382$
N.11111111.11100000.00000000	255.255.224.0	/19	$2^{11} = 2{,}048$	$2^{13} = 8{,}192$	$2^{13} - 2 = 8{,}190$
N.11111111.11110000.00000000	255.255.240.0	/20	$2^{12} = 4{,}096$	$2^{12} = 4{,}096$	$2^{12} - 2 = 4{,}094$
N.11111111.11111000.00000000	255.255.248.0	/21	$2^{13} = 8{,}192$	$2^{11} = 2{,}048$	$2^{11} - 2 = 2{,}046$
N.11111111.11111100.00000000	255.255.252.0	/22	$2^{14} = 16{,}384$	$2^{10} = 1{,}024$	$2^{10} - 2 = 1{,}022$
N.11111111.11111110.00000000	255.255.254.0	/23	$2^{15} = 32{,}768$	$2^9 = 512$	$2^9 - 2 = 510$
N.11111111.11111111.00000000	255.255.255.0	/24	$2^{16} = 65{,}536$	$2^8 = 256$	$2^8 - 2 = 254$
N.11111111.11111111.10000000	255.255.255.128	/25	$2^{17} = 131{,}072$	$2^7 = 128$	$2^7 - 2 = 126$
N.11111111.11111111.11000000	255.255.255.192	/26	$2^{18} = 262{,}144$	$2^6 = 64$	$2^6 - 2 = 62$
N.11111111.11111111.11100000	255.255.255.224	/27	$2^{19} = 524{,}288$	$2^5 = 32$	$2^5 - 2 = 30$
N.11111111.11111111.11110000	255.255.255.240	/28	$2^{20} = 1{,}048{,}576$	$2^4 = 16$	$2^4 - 2 = 14$
N.11111111.11111111.11111000	255.255.255.248	/29	$2^{21} = 2{,}097{,}152$	$2^3 = 8$	$2^3 - 2 = 6$
N.11111111.11111111.11111100	255.255.255.252	/30	$2^{22} = 4{,}194{,}304$	$2^2 = 4$	$2^2 - 2 = 2$

Subnet Calculation Table (2^x)

Host Bits Borrowed	2^x	Number of Subnets Created
1	2^1	2
2	2^2	4
3	2^3	8
4	2^4	16
5	2^5	32
6	2^6	64
7	2^7	128
8	2^8	256
9	2^9	512
10	2^{10}	1,024
11	2^{11}	2,048
12	2^{12}	4,096
Etc.…		

Subnet Hosts & Addresses Calculation Table (2^y)

Host Bits Left	2^y	Addresses per Subnet (2^y)	Hosts per Subnet ($2^y - 2$)
~~1~~	~~2^1~~	~~2~~	~~0~~
2	2^2	4	2
3	2^3	8	6
4	2^4	16	14
5	2^5	32	30
6	2^6	64	62
7	2^7	128	126
8	2^8	256	254
9	2^9	512	510
10	2^{10}	1,024	1,022
11	2^{11}	2,048	2,046
12	2^{12}	4,096	4,094

Subnetting Reference Tables

POWER OF 2'S TABLE

$2^1 = 2$
$2^2 = 4$
$2^3 = 8$
$2^4 = 16$
$2^5 = 32$
$2^6 = 64$
$2^7 = 128$
$2^8 = 256$
$2^9 = 512$
$2^{10} = 1{,}024$
$2^{11} = 2{,}048$
$2^{12} = 4{,}096$
$2^{13} = 8{,}192$
$2^{14} = 16{,}384$
$2^{15} = 32{,}768$
$2^{16} = 65{,}536$

DEFAULT SUBNET MASK

Class	Format	Default Subnet Mask
A	network.host.host.host	255.0.0.0
B	network.network.host.host	255.255.0.0
C	network.network.network.host	255.255.255.0

BINARY MATH TABLE

128	64	32	16	8	4	2	1
1	1	1	1	1	1	1	1

SUBNET MASK TABLE

Binary	Decimal
00000000	0
10000000	128
11000000	192
11100000	224
11110000	240
11111000	248
11111100	252

SUBNET CALCULATION TABLE (2^x)

Host Bits Borrowed	2^x	Number of Subnets Created
1	2^1	2
2	2^2	4
3	2^3	8
4	2^4	16
5	2^5	32
6	2^6	64
7	2^7	128
8	2^8	256
9	2^9	512
10	2^{10}	1,024
11	2^{11}	2,048
12	2^{12}	4,096

SUBNET HOSTS & ADDRESSES CALCULATION TABLE (2^y)

Host Bits Left	2^y	Hosts per Subnet ($2^y - 2$)	Addresses per Subnet (2^y)
~~**1**~~	~~2^1~~	~~0~~	~~2~~
2	2^2	2	4
3	2^3	6	8
4	2^4	14	16
5	2^5	30	32
6	2^6	62	64
7	2^7	126	128
8	2^8	254	256
9	2^9	510	512
10	2^{10}	1,022	1,024
11	2^{11}	2,046	2,048
12	2^{12}	4,094	4,096

CLASS C POSSIBLE SUBNET MASKS

Binary (N.N.N.H)	Decimal	CIDR	# Subnets (2^x)	Block Size (2^y)	# Hosts (2^y - 2)
N.N.N.00000000	255.255.255.0	/24	$2^0 = 1$	$2^8 = 256$	$2^8 - 2 = 254$
N.N.N.10000000	255.255.255.128	/25	$2^1 = 2$	$2^7 = 128$	$2^7 - 2 = 126$
N.N.N.11000000	255.255.255.192	/26	$2^2 = 4$	$2^6 = 64$	$2^6 - 2 = 62$
N.N.N.11100000	255.255.255.224	/27	$2^3 = 8$	$2^5 = 32$	$2^5 - 2 = 30$
N.N.N.11110000	255.255.255.240	/28	$2^4 = 16$	$2^4 = 16$	$2^4 - 2 = 14$
N.N.N.11111000	255.255.255.248	/29	$2^5 = 32$	$2^3 = 8$	$2^3 - 2 = 6$
N.N.N.11111100	255.255.255.252	/30	$2^6 = 64$	$2^2 = 4$	$2^2 - 2 = 2$

CLASS B POSSIBLE SUBNET MASKS

Binary (N.N.H.H)	Decimal	CIDR	# Subnets (2^x)	Block Size (2^y)	# Hosts (2^y - 2)
N.N.00000000.00000000	255.255.0.0	/16	$2^0 = 1$	$2^{16} = 65,536$	$2^{16} - 2 = 65,534$
N.N.10000000.00000000	255.255.128.0	/17	$2^1 = 2$	$2^{15} = 32,768$	$2^{15} - 2 = 32,766$
N.N.11000000.00000000	255.255.192.0	/18	$2^2 = 4$	$2^{14} = 16,384$	$2^{14} - 2 = 16,382$
N.N.11100000.00000000	255.255.224.0	/19	$2^3 = 8$	$2^{13} = 8,192$	$2^{13} - 2 = 8,190$
N.N.11110000.00000000	255.255.240.0	/20	$2^4 = 16$	$2^{12} = 4,096$	$2^{12} - 2 = 4,094$
N.N.11111000.00000000	255.255.248.0	/21	$2^5 = 32$	$2^{11} = 2,048$	$2^{11} - 2 = 2,046$
N.N.11111100.00000000	255.255.252.0	/22	$2^6 = 64$	$2^{10} = 1,024$	$2^{10} - 2 = 1,022$
N.N.11111110.00000000	255.255.254.0	/23	$2^7 = 128$	$2^9 = 512$	$2^9 - 2 = 510$
N.N.11111111.00000000	255.255.255.0	/24	$2^8 = 256$	$2^8 = 256$	$2^8 - 2 = 254$
N.N.11111111.10000000	255.255.255.128	/25	$2^9 = 512$	$2^7 = 128$	$2^7 - 2 = 126$
N.N.11111111.11000000	255.255.255.192	/26	$2^{10} = 1,024$	$2^6 = 64$	$2^6 - 2 = 62$
N.N.11111111.11100000	255.255.255.224	/27	$2^{11} = 2,048$	$2^5 = 32$	$2^5 - 2 = 30$
N.N.11111111.11110000	255.255.255.240	/28	$2^{12} = 4,096$	$2^4 = 16$	$2^4 - 2 = 14$
N.N.11111111.11111000	255.255.255.248	/29	$2^{13} = 8,192$	$2^3 = 8$	$2^3 - 2 = 6$
N.N.11111111.11111100	255.255.255.252	/30	$2^{14} = 16,384$	$2^2 = 4$	$2^2 - 2 = 2$

CLASS A POSSIBLE SUBNET MASKS

Binary (N.H.H.H)	Decimal	CIDR	# Subnets (2^x)	Block Size (2^y)	# Hosts (2^y - 2)
N.00000000.00000000.00000000	255.0.0.0	/8	$2^0 = 1$	$2^{22} = 16{,}777{,}216$	$2^{22} - 2 = 16{,}777{,}214$
N.10000000.00000000.00000000	255.128.0.0	/9	$2^1 = 2$	$2^{23} = 8{,}388{,}608$	$2^{23} - 2 = 8{,}388{,}606$
N.11000000.00000000.00000000	255.192.0.0	/10	$2^2 = 4$	$2^{22} = 4{,}194{,}304$	$2^{22} - 2 = 4{,}194{,}302$
N.11100000.00000000.00000000	255.224.0.0	/11	$2^3 = 8$	$2^{21} = 2{,}097{,}152$	$2^{21} - 2 = 2{,}097{,}150$
N.11110000.00000000.00000000	255.240.0.0	/12	$2^4 = 16$	$2^{20} = 1{,}048{,}576$	$2^{20} - 2 = 1{,}048{,}574$
N.11111000.00000000.00000000	255.248.0.0	/13	$2^5 = 32$	$2^{19} = 524{,}288$	$2^{19} - 2 = 524{,}286$
N.11111100.00000000.00000000	255.252.0.0	/14	$2^6 = 64$	$2^{18} = 262{,}144$	$2^{18} - 2 = 262{,}142$
N.11111110.00000000.00000000	255.254.0.0	/15	$2^7 = 128$	$2^{17} = 131{,}072$	$2^{17} - 2 = 131{,}070$
N.11111111.00000000.00000000	255.255.0.0	/16	$2^8 = 256$	$2^{16} = 65{,}536$	$2^{16} - 2 = 65{,}534$
N.11111111.10000000.00000000	255.255.128.0	/17	$2^9 = 512$	$2^{15} = 32{,}768$	$2^{15} - 2 = 32{,}766$
N.11111111.11000000.00000000	255.255.192.0	/18	$2^{10} = 1{,}024$	$2^{14} = 16{,}384$	$2^{14} - 2 = 16{,}382$
N.11111111.11100000.00000000	255.255.224.0	/19	$2^{11} = 2{,}048$	$2^{13} = 8{,}192$	$2^{13} - 2 = 8{,}190$
N.11111111.11110000.00000000	255.255.240.0	/20	$2^{12} = 4{,}096$	$2^{12} = 4{,}096$	$2^{12} - 2 = 4{,}094$
N.11111111.11111000.00000000	255.255.248.0	/21	$2^{13} = 8{,}192$	$2^{11} = 2{,}048$	$2^{11} - 2 = 2{,}046$
N.11111111.11111100.00000000	255.255.252.0	/22	$2^{14} = 16{,}384$	$2^{10} = 1{,}024$	$2^{10} - 2 = 1{,}022$
N.11111111.11111110.00000000	255.255.254.0	/23	$2^{15} = 32{,}768$	$2^9 = 512$	$2^9 - 2 = 510$
N.11111111.11111111.00000000	255.255.255.0	/24	$2^{16} = 65{,}536$	$2^8 = 256$	$2^8 - 2 = 254$
N.11111111.11111111.10000000	255.255.255.128	/25	$2^{17} = 131{,}072$	$2^7 = 128$	$2^7 - 2 = 126$
N.11111111.11111111.11000000	255.255.255.192	/26	$2^{18} = 262{,}144$	$2^6 = 64$	$2^6 - 2 = 62$
N.11111111.11111111.11100000	255.255.255.224	/27	$2^{19} = 524{,}288$	$2^5 = 32$	$2^5 - 2 = 30$
N.11111111.11111111.11110000	255.255.255.240	/28	$2^{20} = 1{,}048{,}576$	$2^4 = 16$	$2^4 - 2 = 14$
N.11111111.11111111.11111000	255.255.255.248	/29	$2^{21} = 2{,}097{,}152$	$2^3 = 8$	$2^3 - 2 = 6$
N.11111111.11111111.11111100	255.255.255.252	/30	$2^{22} = 4{,}194{,}304$	$2^2 = 4$	$2^2 - 2 = 2$

Subnetting a Class C Network #1

Details & Requirements

You've been assigned a 192.168.1.0/24 Class C network, and you need to create two subnets from it.

How many host bit do we need to borrow?

1 host bit, 2^1 = 2 Subnets

How many host addresses per subnet?

7 host bits left, 2^7 = 128 Addresses / Subnet

2^7 - 2= 126 Addresses / Subnet

What are the valid subnets?

192.168.1.0 and 192.168.1.128

New Subnet Mask?

11111111.11111111.11111111.10000000

255.255.255.128 or /25

Subnet	#1	#2
Network Address	192.168.1.0	192.168.1.128
First Host IP	192.168.1.1	192.168.1.129
Last Host IP	192.168.1.126	192.168.1.254
Broadcast Address	192.168.1.127	192.168.1.255

Binary (N.N.N.H)	Decimal	CIDR	# Subnets (2^x)	Block Size (2^y)	# Hosts (2^y - 2)
N.N.N.00000000	255.255.255.0	/24	$2^0 = 1$	$2^8 = 256$	$2^8 - 2 = 254$
N.N.N.10000000	255.255.255.128	/25	$2^1 = 2$	$2^7 = 128$	$2^7 - 2 = 126$
N.N.N.11000000	255.255.255.192	/26	$2^2 = 4$	$2^6 = 64$	$2^6 - 2 = 62$
N.N.N.11100000	255.255.255.224	/27	$2^3 = 8$	$2^5 = 32$	$2^5 - 2 = 30$
N.N.N.11110000	255.255.255.240	/28	$2^4 = 16$	$2^4 = 16$	$2^4 - 2 = 14$
N.N.N.11111000	255.255.255.248	/29	$2^5 = 32$	$2^3 = 8$	$2^3 - 2 = 6$
N.N.N.11111100	255.255.255.252	/30	$2^6 = 64$	$2^2 = 4$	$2^2 - 2 = 2$

Visualizing Subnetting a Class C Network #1

Details & Requirements
- Network Address: 192.168.1.0
- Default Subnet Mask: 255.255.255.0
- Requires 2 Subnets

How many host bit do we need to borrow?
- 1 host bit, $2^1 = 2$ Subnets

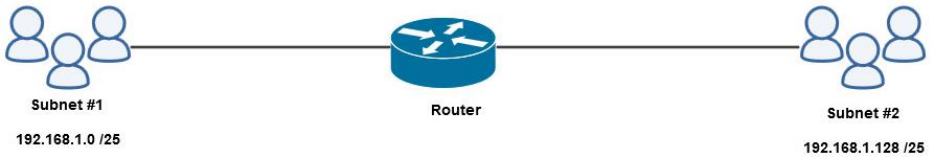
How many addresses hosts per subnet?
- 7 host bits left, $2^7 = 128$ Addresses / Subnet
- $2^7 - 1 = 126$ Addresses / Subnet

What are the valid subnets?
- 192.168.1.0 and 192.168.1.128

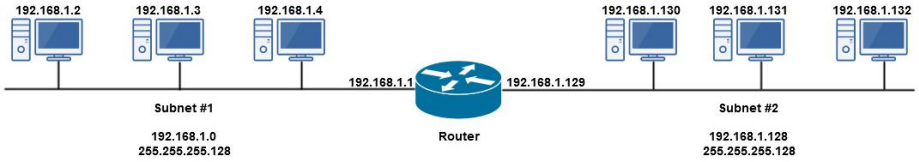
New Subnet Mask?
- 11111111.11111111.11111111.10000000
- 255.255.255.128 or /25

Subnet	#1	#2
Network Address	192.168.1.0	192.168.1.128
First Host IP	192.168.1.1	192.168.1.129
Last Host IP	192.168.1.126	192.168.1.254
Broadcast Address	192.168.1.127	192.168.1.255

Network Simplified View



Network Detailed View



Default Class C Network (8 Host Bits): 192.168.1.0 /24 Network

1 Host Bits Borrowed = 2^1 = Subnetted into 2 Subnets

Subnet #1: 192.168.1.0 /25	Subnet #2: 192.168.1.128 /25

CLASS C POSSIBLE SUBNET MASKS

Binary (N.N.N.H)	Decimal	CIDR	# Subnets (2^x)	Block Size (2^y)	# Hosts (2^y - 2)
N.N.N.00000000	255.255.255.0	/24	$2^0 = 1$	$2^8 = 256$	$2^8 - 2 = 254$
N.N.N.10000000	255.255.255.128	/25	$2^1 = 2$	$2^7 = 128$	$2^7 - 2 = 126$
N.N.N.11000000	255.255.255.192	/26	$2^2 = 4$	$2^6 = 64$	$2^6 - 2 = 62$
N.N.N.11100000	255.255.255.224	/27	$2^3 = 8$	$2^5 = 32$	$2^5 - 2 = 30$
N.N.N.11110000	255.255.255.240	/28	$2^4 = 16$	$2^4 = 16$	$2^4 - 2 = 14$
N.N.N.11111000	255.255.255.248	/29	$2^5 = 32$	$2^3 = 8$	$2^3 - 2 = 6$
N.N.N.11111100	255.255.255.252	/30	$2^6 = 64$	$2^2 = 4$	$2^2 - 2 = 2$

Subnetting a Class C Network #2

Details & Requirements

You've been assigned a 192.168.1.0/24 Class C network, and you need to create four subnets from it.

How many host bit do we need to borrow?

2 host bits, $2^2 = 4$ Subnets

How many host addresses per subnet?

6 host bits left, $2^6 = 64$ Addresses / Subnet

$2^6 - 2 = 62$ Addresses / Subnet

What are the valid subnets?

192.168.1.**0**, 192.168.1.**64**,
192.168.1.**128**, 192.168.1.**192**

New Subnet Mask?

11111111.11111111.11111111.**11**000000
255.255.255.192 or /26

Subnet	Network /Subnet Address	Host IP Addresses	Broadcast Address
1	192.168.1.**0**	1 thru 62	192.168.1.**63**
2	192.168.1.**64**	65 thru 126	192.168.1.**127**
3	192.168.1.**128**	129 thru 190	192.168.1.**191**
4	192.168.1.**192**	193 thru 254	192.168.1.**255**

Binary (N.N.N.H)	Decimal	CIDR	# Subnets (2^x)	Block Size (2^y)	# Hosts ($2^y - 2$)
N.N.N.**00000000**	255.255.255.0	/24	$2^0 = 1$	$2^8 = 256$	$2^8 - 2 = 254$
N.N.N.**10000000**	255.255.255.128	/25	$2^1 = 2$	$2^7 = 128$	$2^7 - 2 = 126$
N.N.N.**11000000**	255.255.255.192	/26	$2^2 = 4$	$2^6 = 64$	$2^6 - 2 = 62$
N.N.N.**11100000**	255.255.255.224	/27	$2^3 = 8$	$2^5 = 32$	$2^5 - 2 = 30$
N.N.N.**11110000**	255.255.255.240	/28	$2^4 = 16$	$2^4 = 16$	$2^4 - 2 = 14$
N.N.N.**11111000**	255.255.255.248	/29	$2^5 = 32$	$2^3 = 8$	$2^3 - 2 = 6$
N.N.N.**11111100**	255.255.255.252	/30	$2^6 = 64$	$2^2 = 4$	$2^2 - 2 = 2$

Visualizing Subnetting a Class C Network #2

Details & Requirements
- Network Address: 192.168.1.0
- Default Subnet Mask: 255.255.255.0
- Requires 4 Subnets

How many host bit do we need to borrow?
- 2 host bit, $2^2 = 4$ Subnets

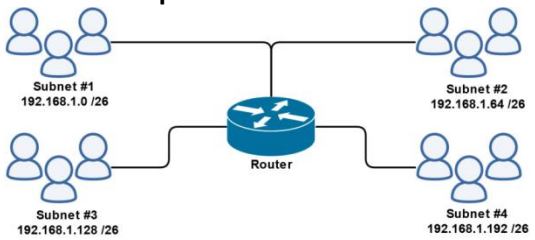
How many addresses hosts per subnet?
- 6 host bits left, $2^6 = 64$ Addresses / Subnet
- $2^6 - 1 = 62$ Addresses / Subnet

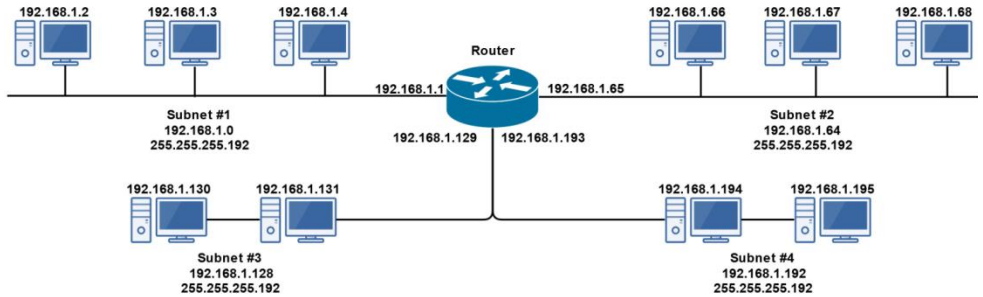
What are the valid subnets?
- 192.168.1.**0**, 192.168.1.**64**, 192.168.1.**128**, 192.168.1.**192**

New Subnet Mask?
- 11111111.11111111.11111111.**11**000000
- 255.255.255.192 or /26

Subnet	Network Address	Host IP Addresses	Broadcast Address
1	.0	.1 to .62	.63
2	.64	.65 to .126	.127
3	.128	.129 to .190	.191
4	.192	.193 to .254	.255

Network Simplified & Detail Views





Default Class C Network (8 Host Bits)

2 Host Bits Borrowed = 2^2 = Subnetted into 4 Subnets

1	2	3	4

CLASS C POSSIBLE SUBNET MASKS

Binary (N.N.N.H)	Decimal	CIDR	# Subnets (2^x)	Block Size (2^y)	# Hosts (2^y - 2)
N.N.N.00000000	255.255.255.0	/24	$2^0 = 1$	$2^8 = 256$	$2^8 - 2 = 254$
N.N.N.10000000	255.255.255.128	/25	$2^1 = 2$	$2^7 = 128$	$2^7 - 2 = 126$
N.N.N.11000000	255.255.255.192	/26	$2^2 = 4$	$2^6 = 64$	$2^6 - 2 = 62$
N.N.N.11100000	255.255.255.224	/27	$2^3 = 8$	$2^5 = 32$	$2^5 - 2 = 30$
N.N.N.11110000	255.255.255.240	/28	$2^4 = 16$	$2^4 = 16$	$2^4 - 2 = 14$
N.N.N.11111000	255.255.255.248	/29	$2^5 = 32$	$2^3 = 8$	$2^3 - 2 = 6$
N.N.N.11111100	255.255.255.252	/30	$2^6 = 64$	$2^2 = 4$	$2^2 - 2 = 2$