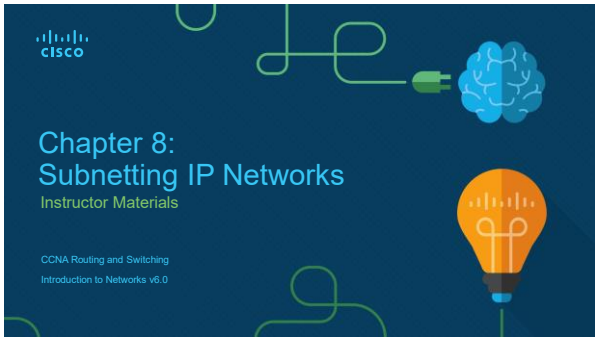
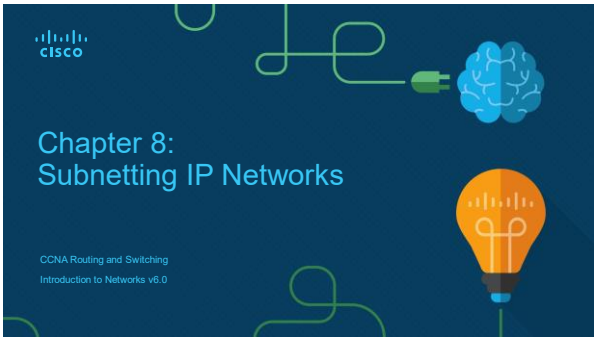
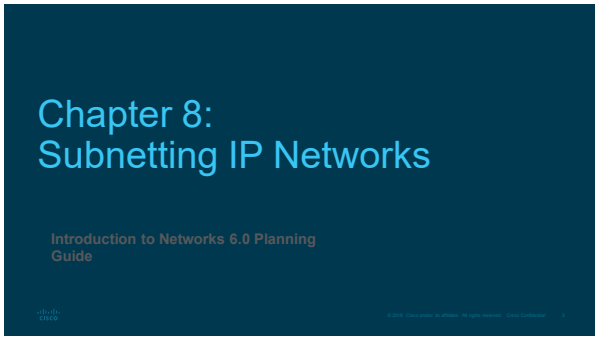






Chapter 8 - Sections & Objectives

- 8.1 Subnetting an IPv4 Network
  - Implement an IPv4 addressing scheme to enable end-to-end connectivity in a small to medium-sized business network.
    - Explain how subnetting segments a network to enable better communication.
    - Explain how to calculate IPv4 subnets for a /24 prefix.
    - Explain how to calculate IPv4 subnets for a /16 and /8 prefix.
    - Given a set of requirements for subnetting, implement an IPv4 addressing scheme.
    - Explain how to create a flexible addressing scheme using variable length subnet masking (VLSM).
- 8.2 Addressing Schemes
  - Given a set of requirements, implement a VLSM addressing scheme to provide connectivity to end users in a small to medium-sized network.
    - Implement a VLSM addressing scheme.

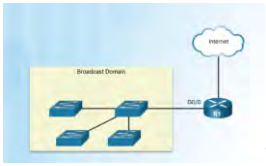
Chapter 8 - Sections & Objectives (Cont.)

- 8.3 Address Schemes
  - Explain design considerations for implementing IPv6 in a business network.
  - Explain how to implement IPv6 address assignments in a business network.

Network Segmentation

Broadcast Domains

- Devices use broadcasts in an Ethernet LAN to locate:
  - **Other devices** - Address Resolution Protocol (ARP) which sends Layer 2 broadcasts to a known IPv4 address on the local network to discover the associated MAC address.
  - **Services –** Dynamic Host Configuration Protocol (DHCP) which sends broadcasts on the local network to locate a DHCP server.
- Switches propagate broadcasts out all interfaces except the interface on which it was received.

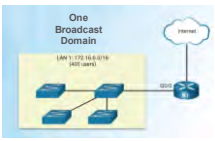


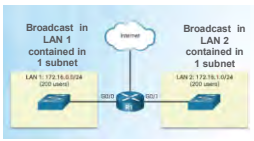
8.1 Subnetting an IPv4 Network

Network Segmentation

Problems with Large Broadcast Domains

- Hosts can generate excessive broadcasts and negatively affect the network.
  - Slow network operations due to the significant amount of traffic it can cause.
  - Slow device operations because a device must accept and process each broadcast packet.
- Solution: Reduce the size of the network to create smaller broadcast domains. These smaller network spaces are called *subnets*.





Network Segmentation

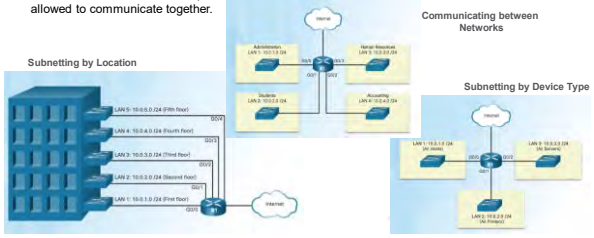
Reasons for Subnetting

- Reduces overall network traffic and improves network performance.
- Enables an administrator to implement security policies such as which subnets are allowed or not allowed to communicate together.

Communicating between Networks

Subnetting by Location

Subnetting by Device Type



Subnetting an IPv4 Network

Subnetting on the Octet Boundary

Subnet Address (256 Possible Subnets)	Host Range (65,534 possible hosts per subnet)	Broadcast
10.0.0.0/16	10.0.0.1 – 10.0.255.254	10.0.255.255
10.1.0.0/16	10.1.0.1 – 10.1.255.254	10.1.255.255
10.2.0.0/16	10.2.0.1 – 10.2.255.254	10.2.255.255
10.3.0.0/16	10.3.0.1 – 10.3.255.254	10.3.255.255
10.4.0.0/16	10.4.0.1 – 10.4.255.254	10.4.255.255
10.5.0.0/16	10.5.0.1 – 10.5.255.254	10.5.255.255
10.6.0.0/16	10.6.0.1 – 10.6.255.254	10.6.255.255
10.7.0.0/16	10.7.0.1 – 10.7.255.254	10.7.255.255
...	...	...
10.255.0.0/16	10.255.0.1 – 10.255.255.254	10.255.255.255

- Subnetting Network 10.x.0.0/16
- Define up to 256 subnets with each subnet capable of connecting 65,534 hosts.
- First two octets identify the network portion while the last two octets are for host IP addresses.

Subnetting an IPv4 Network

Octet Boundaries

Networks are most easily subnetted at the octet boundary of /8, /16, and /24

Prefix Length	Subnet Mask	Subnet Mask in Binary (n = network, h = host)	# of hosts
/8	255.0.0.0	nnnnnnnn.hhhhhhhh.hhhhhhhh.hhhhhhhh 11111111.00000000.00000000.00000000	16,777,214
/16	255.255.0.0	nnnnnnnn.nnnnnnnn.hhhhhhhh.hhhhhhhh 11111111.11111111.00000000.00000000	65,534
/24	255.255.255.0	nnnnnnnn.nnnnnnnn.nnnnnnnn.hhhhhhhh 11111111.11111111.11111111.00000000	254

- Prefix length and the subnet mask are different ways of identifying the network portion of an address.
- Subnets are created by borrowing host bits for network bits.
- More host bits borrowed, the more subnets that can be defined.

Subnetting an IPv4 Network

Subnetting on the Octet Boundary (Cont.)

Subnet Address (65,536 Possible Subnets)	Host Range (254 possible hosts per subnet)	Broadcast
10.0.0.0/24	10.0.0.1 – 10.0.0.254	10.0.0.255
10.0.1.0/24	10.0.1.1 – 10.0.1.254	10.0.1.255
10.0.2.0/24	10.0.2.1 – 10.0.2.254	10.0.1.255
...	...	...
10.0.255.0/24	10.0.255.1 – 10.0.255.254	10.0.255.255
10.1.0.0/24	10.1.0.1 – 10.1.0.254	10.1.0.255
10.1.1.0/24	10.1.1.1 – 10.1.1.254	1.1.1.0.255
10.1.2.0/24	10.1.2.1 – 10.1.2.254	10.1.2.0.255
...	...	...
10.100.0.0/24	10.100.0.1 – 10.100.0.254	10.100.0.255
...	...	...
10.255.255.0/24	10.255.255.1 – 10.255.255.254	10.255.255.255

- Subnetting Network 10.x.x.0/24
- Define 65,536 subnets each capable of connecting 254 hosts.
- /24 boundary is very popular in subnetting because of number of hosts.

Subnetting an IPv4 Network

Classless Subnetting

Subnetting a /24 Network

Prefix Length	Subnet Mask	Subnet Mask in Binary (n = network, h = host)	# of subnets	# of hosts
/25	255.255.255.128	nnnnnnnn.nnnnnnnn.nnnnnnnn.**1**hhhhhhh 11111111.11111111.11111111.**1**0000000	2	126
/26	255.255.255.192	nnnnnnnn.nnnnnnnn.nnnnnnnn.**11**hhhhhh 11111111.11111111.11111111.**11**000000	4	62
/27	255.255.255.224	nnnnnnnn.nnnnnnnn.nnnnnnnn.**111**hhhhh 11111111.11111111.11111111.**111**00000	8	30
/28	255.255.255.240	nnnnnnnn.nnnnnnnn.nnnnnnnn.**1111**hhhh 11111111.11111111.11111111.**1111**0000	16	14
/29	255.255.255.248	nnnnnnnn.nnnnnnnn.nnnnnnnn.**11111**hhh 11111111.11111111.11111111.**11111**000	32	6
/30	255.255.255.252	nnnnnnnn.nnnnnnnn.nnnnnnnn.**111111**hh 11111111.11111111.11111111.**111111**00	64	2

Subnets can borrow bits from *any* host bit position to create other masks.

Subnetting an IPv4 Network

Video Demonstration – The Subnet Mask (Cont.)

Subnetting 192.168.1.0/24

192	168	1	0
255	255	255	128
11000000	10101000	00000001	00000000
11111111	11111111	11111111	10000000
N	N	N	SN H

Subnet bits = $2^1 = 2$
Host bits = $2^7 = 128-2 = 126$
Subnetworks = 2

Subnetting 192.168.1.0/24

192	168	1	68
255	255	255	128
11000000	10101000	00000001	01000100
11111111	11111111	11111111	10000000
11000000	10101000	00000001	00000000
192	168	1	0

192.168.1.0 /25 ------> 192.168.1.127 /25
192.168.1.128 /25 ------> 192.168.1.255 /25

Subnetting an IPv4 Network

Video Demonstration – The Subnet Mask

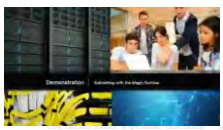
Subnetting in Binary

- ANDING
  - Convert IP address and Subnet Mask to Binary (line up vertically like an addition problem)
  - Logically AND (1 and 1 = 1, all other combinations = 0)
  - Result is network address for original IP address
- Classful Subnetting
  - Class A /8 255.0.0.0
  - Class B /16 255.255.0.0
  - Class C /24 255.255.255.0

Subnetting an IPv4 Network

Video Demonstration – Subnetting with the Magic Number

- Magic number technique used to calculate subnets
- Magic number is simply the place value of the last one in the subnet mask
- /25 11111111.11111111.11111111.**1**0000000 magic number = 128
- /26 11111111.11111111.11111111.**11**000000 magic number = 64
- /27 11111111.11111111.11111111.**111**00000 magic number = 32



Subnetting an IPv4 Network

Video Demonstration – Subnetting with the Magic Number (Cont.)

The Magic Number is the last 1 in Binary

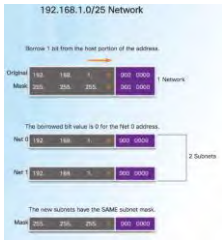
192	168	1	0
255	255	255	224
11000000	10101000	00000001	00000000
11111111	11111111	11111111	11100000
			SN H

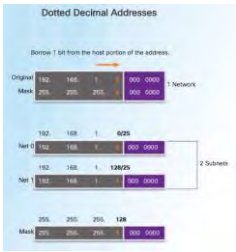
The Magic Number is? 32

192.168.1.0 /27 192.168.1.128 /27
192.168.1.32 /27 192.168.1.160 /27
192.168.1.64 /27 192.168.1.192 /27
192.168.1.96 /27 192.168.1.224 /27

Subnetting an IPv4 Network

Classless Subnetting Example





Subnetting an IPv4 Network

Video Demonstration – Subnetting with the Magic Number (Cont.)

Subnetting 172.16.0.0/16 -->/23

172	16	0	0
255	255	254	0
10101010	00010000	00000000	00000000
11111111	11111111	11111110	00000000
		SN H	H

What is the magic number? 2
172.16.0.0 ---- 172.16.1.255 /23
172.16.2.0 /23
172.16.4.0 /23

Subnetting an IPv4 Network

Creating 2 Subnets

- /25 Subnetting Topology

Subnetting an IPv4 Network

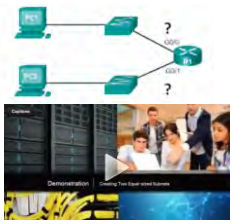
Video Demonstration – Creating Two Equal-sized Subnets (/25)

Create 2 Equal-sized Subnets from 192.168.1.0 /24

- **Subnet Mask** - 11111111.11111111.11111111.10000000

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

- Magic Number = 128
- 192.168.1.0 /25 (start at 0)
- 192.168.1.128 /25 (Add 128)



Subnetting an IPv4 Network

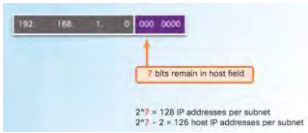
Subnetting Formulas (Cont.)

Calculate Number of Hosts Formula

2^n-2

n = the number of bits remaining in the host field

Calculating the Number of Hosts



Subnetting an IPv4 Network

Subnetting Formulas

Calculate Number of Subnets Formula

2^n

n = bits borrowed

Subnetting a /24 Network

192 . 168 . 1 . 0

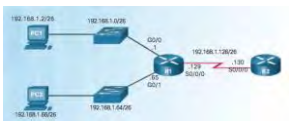
nnnnnnnn.nnnnnnnn.nnnnnnnn.hhhhhhhh

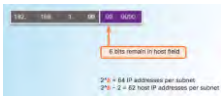
Borrowing 1 bit:	$2^1 = 2$
Borrowing 2 bits:	$2^2 = 4$
Borrowing 3 bits:	$2^3 = 8$
Borrowing 4 bits:	$2^4 = 16$
Borrowing 5 bits:	$2^5 = 32$
Borrowing 6 bits:	$2^6 = 64$

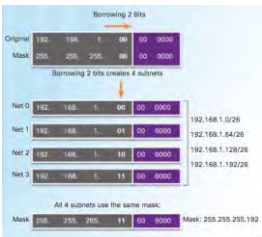
Subnetting an IPv4 Network

Creating 4 Subnets

- /26 Subnetting Topology







Subnetting an IPv4 Network

Creating 4 Subnets (Cont.)

- /26 Subnetting Topology

Net 0	Network	192.	168.	1.	00	00 0000	192.168.1.0
	First	192.	168.	1.	00	00 0001	192.168.1.1
	Last	192.	168.	1.	00	11 1110	192.168.1.62
	Broadcast	192.	168.	1.	00	11 1111	192.168.1.63
Net 1	Network	192.	168.	1.	01	00 0000	192.168.1.64
	First	192.	168.	1.	01	00 0001	192.168.1.65
	Last	192.	168.	1.	01	11 1110	192.168.1.126
	Broadcast	192.	168.	1.	01	11 1111	192.168.1.127
Net 2	Network	192.	168.	1.	10	00 0000	192.168.1.128
	First	192.	168.	1.	10	00 0001	192.168.1.129
	Last	192.	168.	1.	10	11 1110	192.168.1.190
	Broadcast	192.	168.	1.	10	11 1111	192.168.1.191

Subnetting an IPv4 Network

Video Demonstration – Creating Four Equal-sized Subnets (/26)

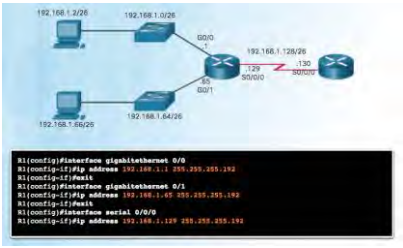
Create 4 Equal-sized Subnets from 192.168.1.0 /24

- Subnet Mask in Binary – 11111111.11111111.11111111.11000000
- 2^2 = 4 Subnets
- Magic Number = 64
- 192.168.1.0 /26
- 192.168.1.64 /26
- 192.168.1.128 /26
- 192.168.1.192 /26

Subnetting an IPv4 Network

Creating 4 Subnets (Cont.)

- /26 Subnetting Topology



Subnetting an IPv4 Network

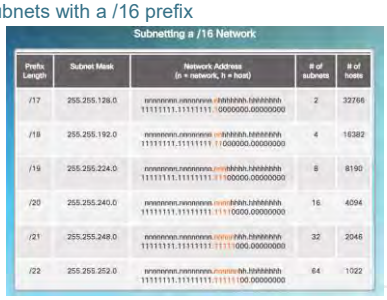
Video Demonstration – Creating Eight Equal-sized Subnets (/27)

Create 8 Equal-sized Subnets from 192.168.1.0 /24

- Borrow 3 bits – 11111111.11111111.11111111.11100000
- Magic Number = 32
- 192.168.1.0 /27 (Start at 0)
- 192.168.1.32 /27 (Add 32 to previous network)
- 192.168.1.64 /27 (Add 32)
- 192.168.1.96 /27 (Add 32)
- 192.168.1.128 /27 (Add 32)
- 192.168.1.160 /27 (Add 32)
- 192.168.1.192 /27 (Add 32)
- 192.168.1.224 /27 (Add 32)

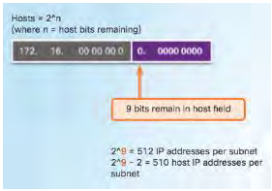
Subnetting a /16 and /8 Prefix

Creating Subnets with a /16 prefix



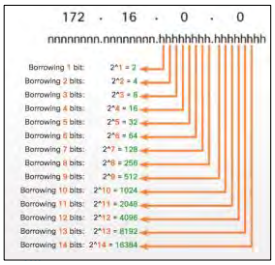
Subnetting a /16 and /8 Prefix

Calculating the Hosts



Subnetting a /16 and /8 Prefix

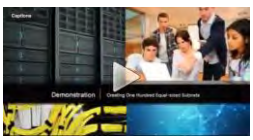
Creating 100 Subnets with a /16 prefix



Subnetting a /16 and /8 Prefix

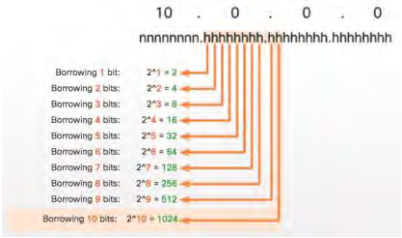
Video Demonstration – Creating One Hundred Equal-sized Subnets

- An enterprise network requires 100 equal-sized subnets starting from 172.16.0.0/16
  - New Subnet Mask
    - 11111111.11111111.1111111**0**.00000000
  - 2^7 = 128 Subnets
  - 2^9 = 512 hosts per subnet
  - Magic Number = **2**
  - 172.16.**0**.0 /23
  - 172.16.**2**.0 /23
  - 172.16.**4**.0 /23
  - 172.16.**6**.0 /23
  - …
  - 172.16.**254**.0 /23



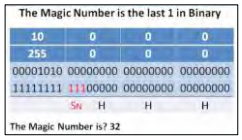
Subnetting a /16 and /8 Prefix

Creating 1000 Subnets with a /8 Network



Subnetting a /16 and /8 Prefix

Video Demonstration – Subnetting Across Multiple Octets



10.0.0.0/11 10.128.0.0/11
10.32.0.0/11 10.160.0.0/11
10.64.0.0/11 10.192.0.0 – 10.223.255.255/11
10.96.0.0/11 10.224.0.0/11

New Challenge Problem: Create over 300 Equal-sized Subnets of 20,000 Hosts each starting from 10.0.0.0/8

Subnetting a /16 and /8 Prefix

Creating 1000 Subnets with a /8 Network (Cont.)

Subnetting to Meet Requirements

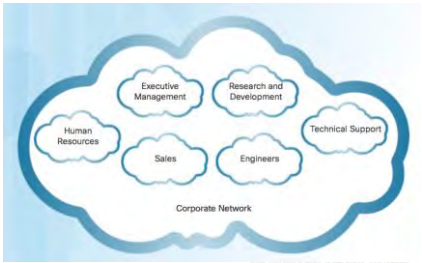
Subnetting Based on Host Requirements

Prefix Length	Subnet Mask	Subnet Mask in Binary (n = network, h = host)	# of subnets	# of hosts
/25	255.255.255.128	nnnnnnnn.nnnnnnnn.nnnnnnnn.**n**hhhhhhh 11111111.11111111.11111111.**1**0000000	2	126
/26	255.255.255.192	nnnnnnnn.nnnnnnnn.nnnnnnnn.**nn**hhhhhh 11111111.11111111.11111111.**11**000000	4	62
/27	255.255.255.224	nnnnnnnn.nnnnnnnn.nnnnnnnn.**nnn**hhhhh 11111111.11111111.11111111.**111**00000	8	30
/28	255.255.255.240	nnnnnnnn.nnnnnnnn.nnnnnnnn.**nnnn**hhhh 11111111.11111111.11111111.**1111**0000	16	14

Subnetting to Meet Requirements

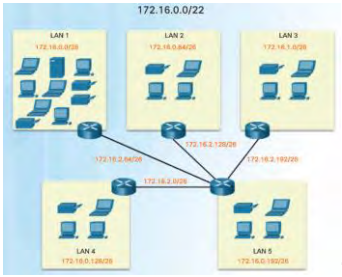
Subnetting Based On Network Requirements

Host devices used by employees in the Engineering department in one network and Management in a separate network.



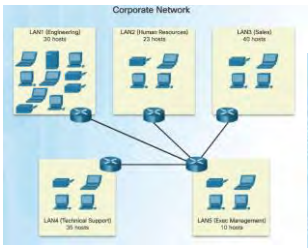
Subnetting to Meet Requirements

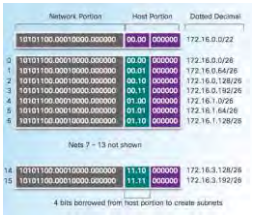
Network Requirement Example (Cont.)



Subnetting to Meet Requirements

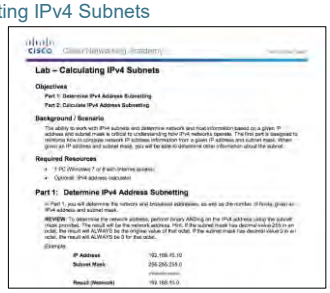
Network Requirement Example





Subnetting to Meet Requirements

Lab – Calculating IPv4 Subnets



Lab – Calculating IPv4 Subnets

Objectives

Part 1: Determine IPv4 Address Subnetting

Part 2: Calculate IPv4 Address Subnetting

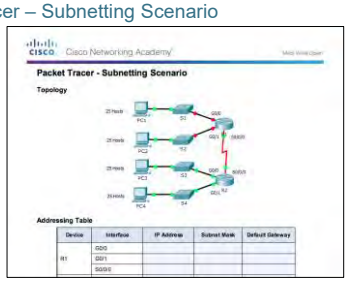
Background / Scenario

Required Resources

Part 1: Determine IPv4 Address Subnetting

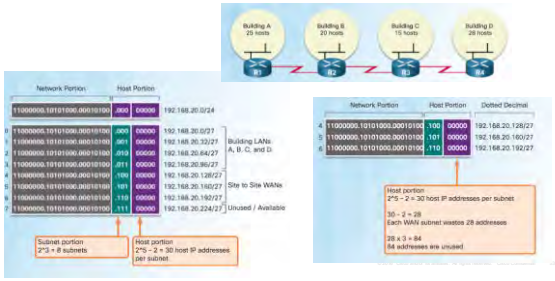
Subnetting to Meet Requirements

Packet Tracer – Subnetting Scenario



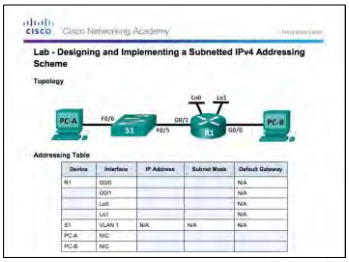
Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses



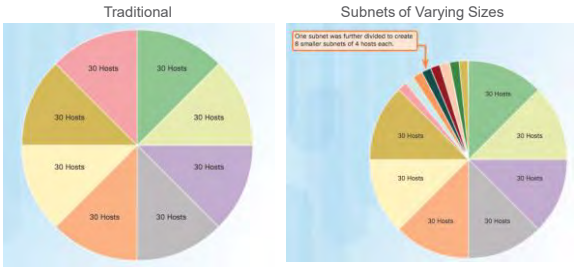
Subnetting to Meet Requirements

Lab – Designing and Implementing a Subnetted IPv4 Addressing Scheme



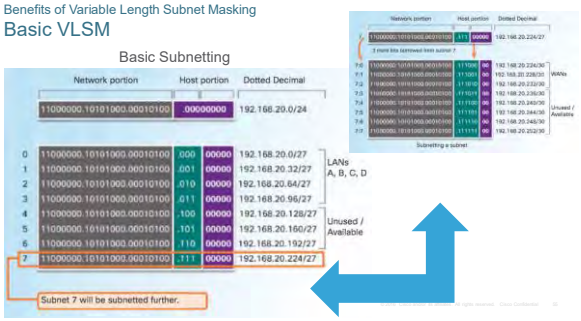
Benefits of Variable Length Subnet Masking

Variable Length Subnet Masks (VLSM)



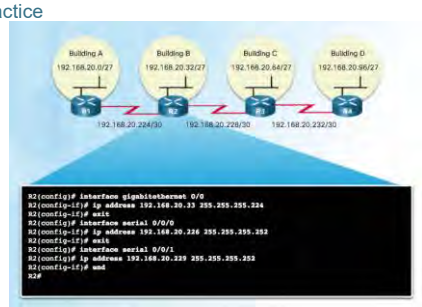
Benefits of Variable Length Subnet Masking

Basic VLSM



Benefits of Variable Length Subnet Masking

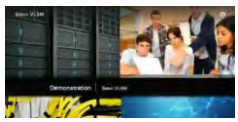
VLSM in Practice

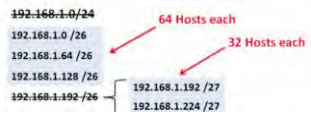


Benefits of Variable Length Subnet Masking

Video Demonstration – VLSM Basics

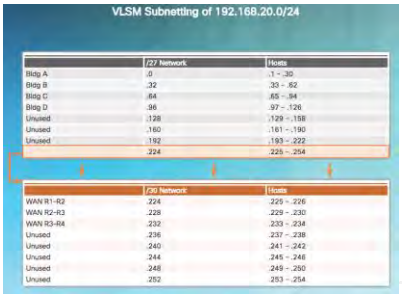
- Basic VLSM
  - Subnets do not have to be equal sizes, as long as their address ranges do not overlap.
  - When creating subnets it is easier to work from larger to smaller.





Benefits of Variable Length Subnet Masking

VLSM Chart

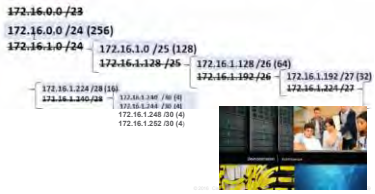


Benefits of Variable Length Subnet Masking

Video Demonstration – VLSM Example

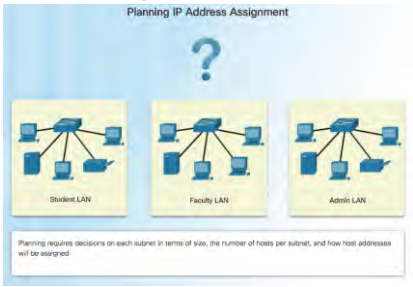
- Given the network 172.16.0.0 /23 creates subnets:
  - 1 network for 200 hosts - 256
  - 1 network for 100 hosts - 128
  - 1 network for 50 hosts - 64
  - 1 network for 25 hosts - 32
  - 1 network for 10 hosts - 16
  - 4 point-to-point networks for 2 hosts each – 4x4 = 16

/23 = 2^9 hosts = 512
256+128+64+32+16+16 = 512 hosts needed
Address range 172.16.0.0 – 172.16.1.255



Structured Design

Network Address Planning



8.2 Addressing Schemes

Structured Design

Planning to Address the Network

- Each host in an internetwork must have a unique address.
- Need proper planning & documentation.
- Must provide & control access to servers from internal hosts and external hosts.
- Layer 3 STATIC address assigned to a server can be used to control access to that server.
- Monitoring security and performance of hosts means network traffic is examined for source IP addresses that are generating or receiving excessive packets.

Structured Design

Assigning Addresses to Devices

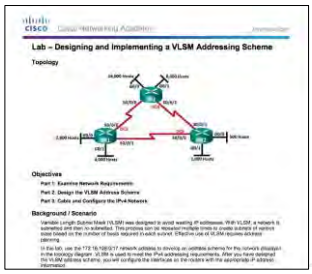
- Devices that require addresses:
  - **End user clients**
  - Can be set for DHCP to save time and manual errors.
  - A change in the subnetting scheme requires reconfiguration of DHCP server. IPv6 clients use DHCPv6/SLAAC.
  - **Servers**
  - Configured with static addresses.
  - Private addresses translated to public addresses if accessible from the Internet.
  - **Intermediary devices**
  - Set with static addresses for remote management.
  - **Gateway**
  - Router interface used to exit the network.

Network: 192.168.1.0/24

Use	First	Last
Host Devices	.1	.229
Servers	.230	.239
Printers	.240	.249
Intermediary Devices	.250	.253
Gateway (router LAN interface)	.254	

Structured Design

Lab – Designing and Implementing a VLSM Addressing Scheme


Lab – Designing and Implementing a VLSM Addressing Scheme

Topology

Objectives

Part 1: Examine Network Requirements

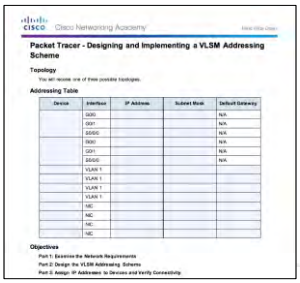
Part 2: Design the VLSM Address Scheme

Part 3: Cable and Configure the IPv4 Network

Background / Scenario

Structured Design

Packet Tracer – Designing and Implementing a VLSM Addressing Scheme


Packet Tracer - Designing and Implementing a VLSM Addressing Scheme

Topology

Addressing Table

Device	Interface	IP Address	Subnet Mask	Default Gateway
	G0/0			N/A
	G0/1			N/A
	S0/0/0			N/A
	S0/0/1			N/A
	G0/1			N/A
	S0/0/0			N/A
	VLAN 1			
	VLAN 1			
	VLAN 1			
	VLAN 1			
	NIC			
	NIC			
	NIC			
	NIC			

Objectives

Part 1: Examine the Network Requirements

Part 2: Design the VLSM Addressing Scheme

Part 3: Assign IP Addresses to Devices and Verify Connectivity

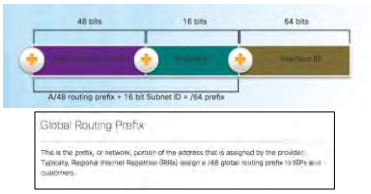
8.3 Design Considerations for IPv6

Subnetting an IPv6 Network

The IPv6 Global Unicast Address

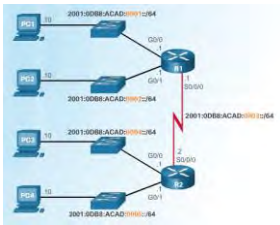
- IPv6 subnetting is not concerned with conserving address space.
- IPv6 subnetting is about building an addressing hierarchy based on the number of subnetworks needed.
- IPv6 link-local address is never subnetted.
- IPv6 global unicast address can be subnetted.
- IPv6 global unicast address normally consists of a /48 global routing prefix, a 16 bit subnet ID, and a 64 bit interface ID.

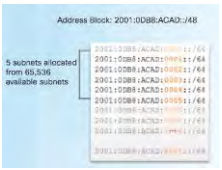
Structure



Subnetting an IPv6 Network

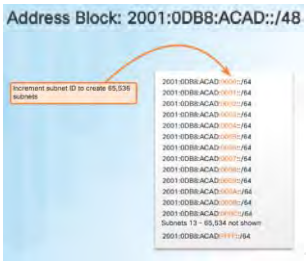
IPv6 Subnet Allocation





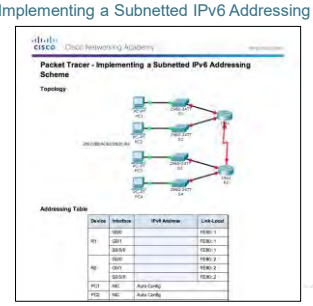
Subnetting an IPv6 Network

Subnetting Using the Subnet ID



Subnetting an IPv6 Network

Packet Tracer – Implementing a Subnetted IPv6 Addressing Scheme



8.4 Chapter Summary

Conclusion

Chapter 8: Subnetting IP Networks

- Implement an IPv4 addressing scheme to enable end-to-end connectivity in a small to medium-sized business network.
- Given a set of requirements, implement a VLSM addressing scheme to provide connectivity to end users in a small to medium-sized network.
- Explain design considerations for implementing IPv6 in a business network.

Conclusion

Packet Tracer - Skills Integration Challenge