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22AIE204
COMPUTER NETWORKS

NETWORK LAYER

- **Subnetting**

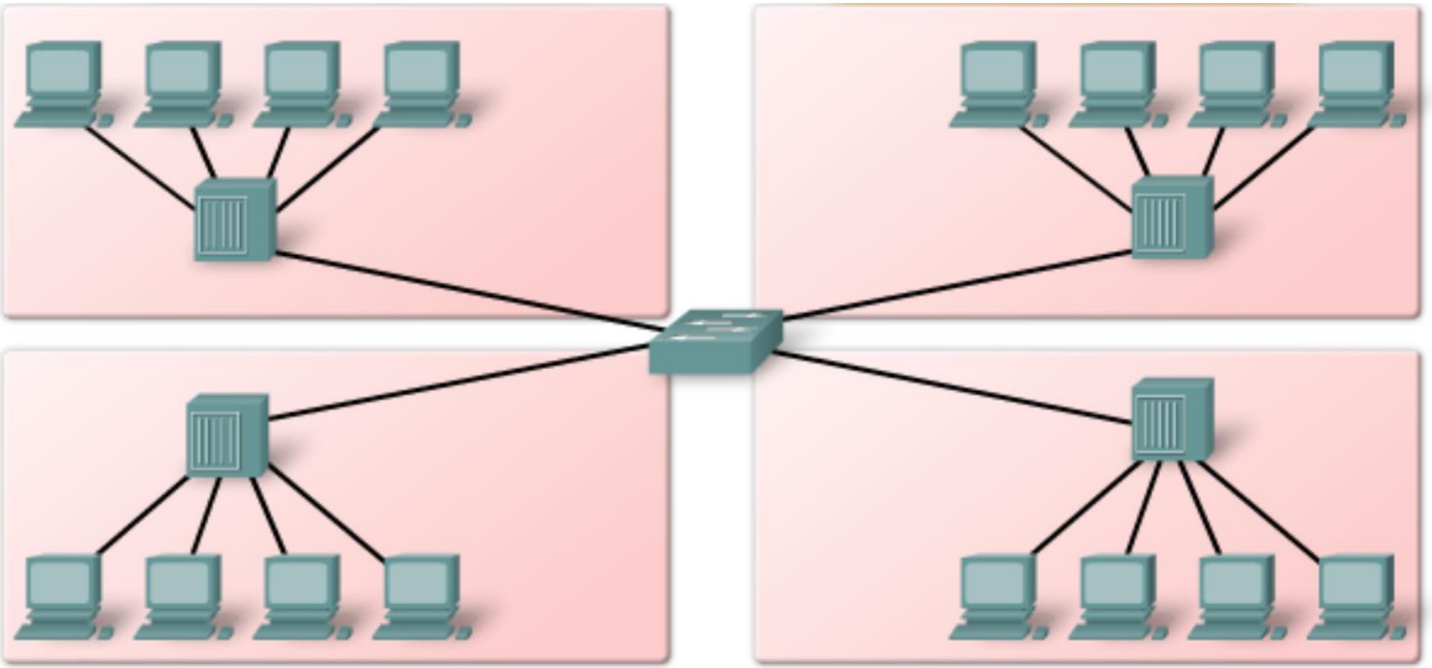
Objectives – Network Segmentation

- Understand and Analyze collision domain and Broadcast domain
- Problems with larger broadcast domain

- Reasons for segmenting networks to subnets
- Subnets classified based on
  - Location
  - Group based on function
  - Device Type

Collision Domain

- Network segment or domain affected by collision.
- Collision occurs during simultaneous transmission in shared medium.
- Switch reduces the size of collision domain.
- It is different from broadcast domain.

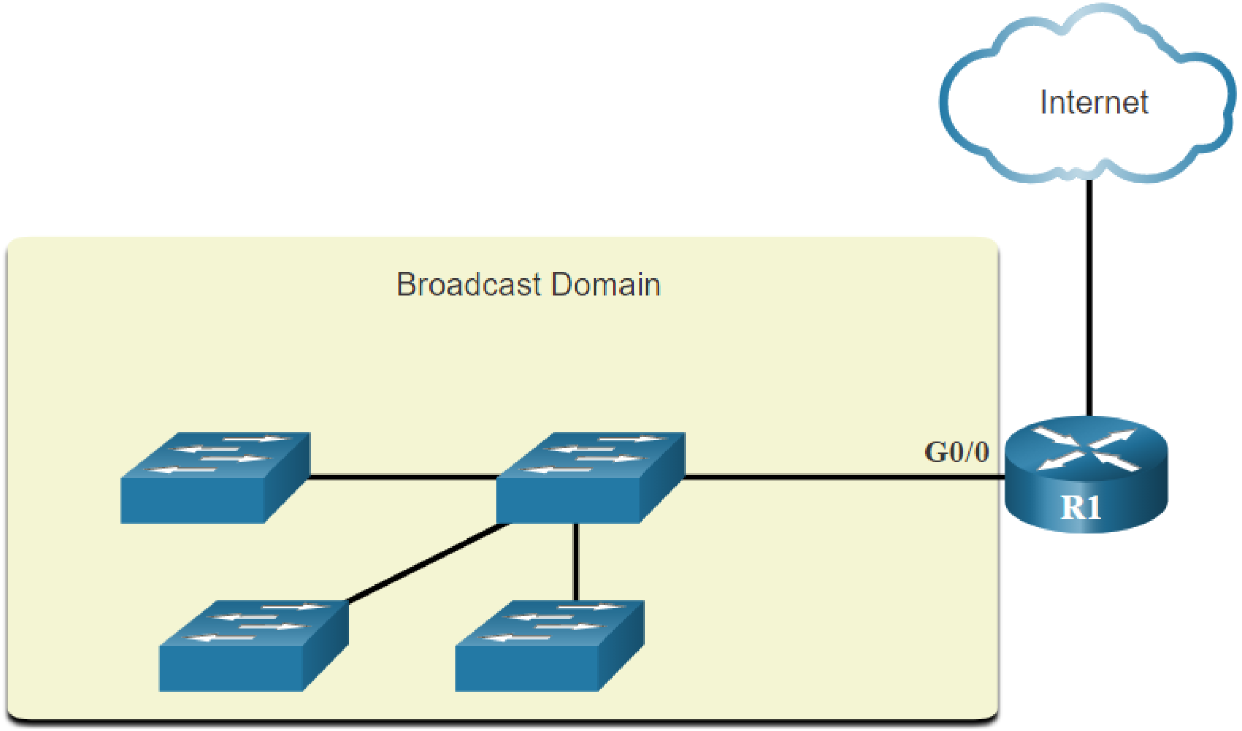


Reference: CCNA Introduction to Networks

Broadcast Domain

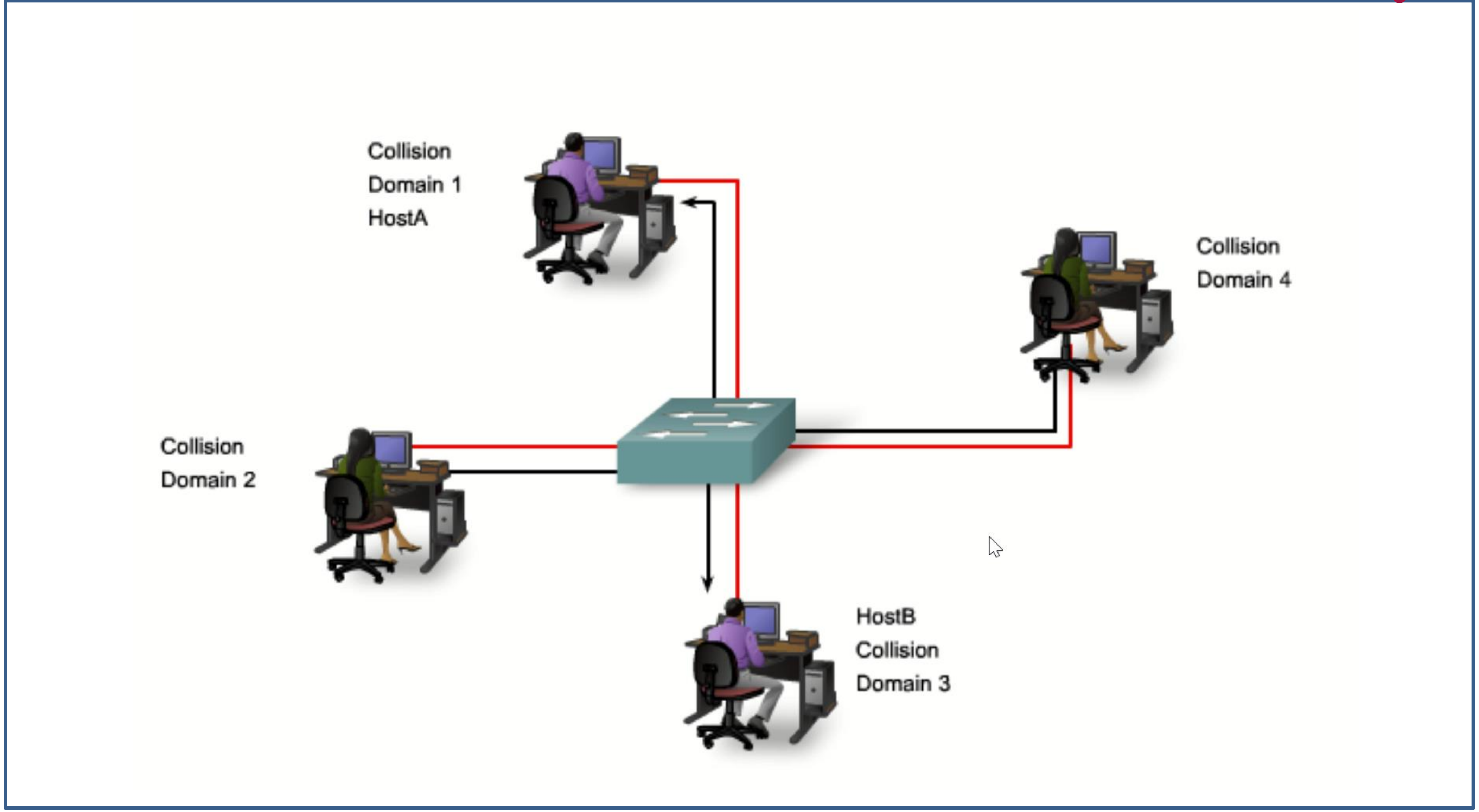
- Broadcasts are only propagated within that specific broadcast domain.
- Switches propagate broadcasts out all interfaces except the interface on which it was received.
- The only device that stops broadcasts is a router.
- Each router interface connects to a broadcast domain.

- Many protocols use broadcasts or multicasts (Ex: ARP, DHCP)



Reference: CCNA ITN Ch11 IPv4 Addressing

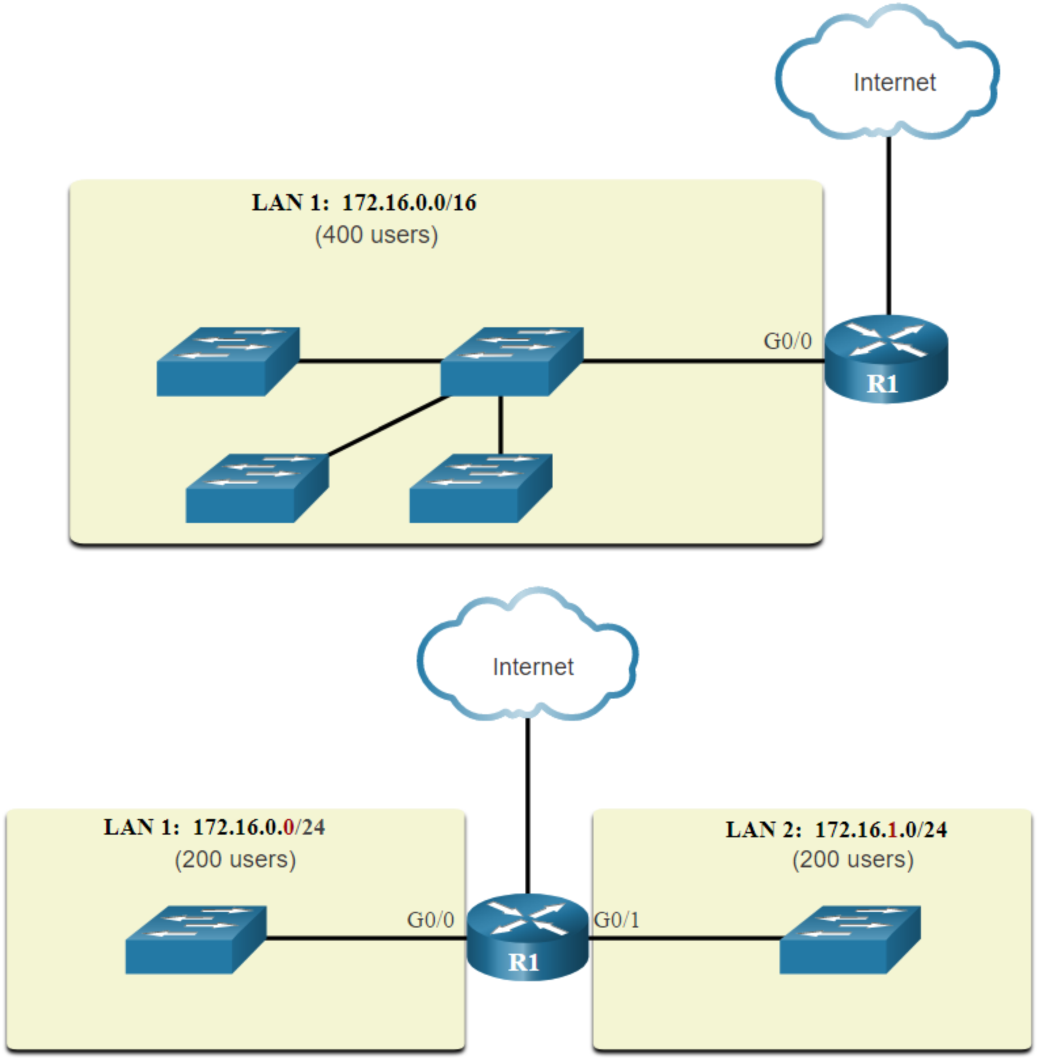
Collision and Broadcast domain Activity



Reference: CCNA ITN Ch11 IPv4 Addressing

Problems with Large Broadcast Domain

- Hosts can generate excessive broadcasts slows the device and network operations
- Solution to reduce the size of the network to create smaller broadcast domains in a process called subnetting.
- Dividing the network address 172.16.0.0 /16 into two subnets of 200 users each.
- Broadcasts are only propagated within the smaller broadcast domains.

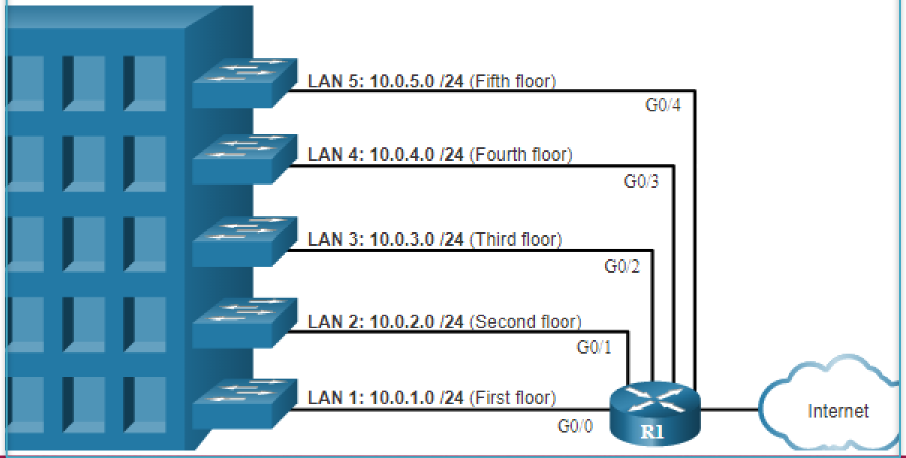


Reference: CCNA ITN Ch11 IPv4 Addressing

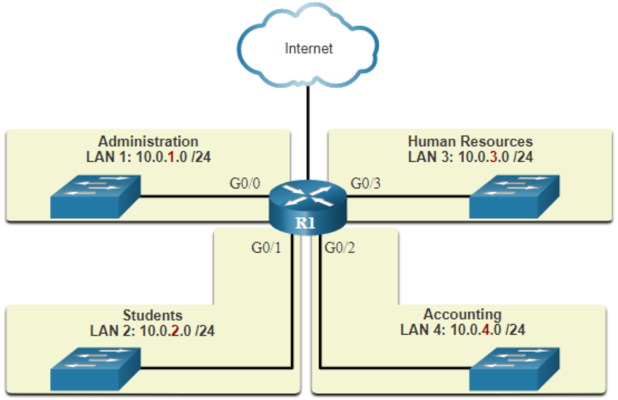
Reasons for Segmenting Networks

- Subnetting reduces overall network traffic and improves network performance.
- It can be used to implement security policies between subnets.
- Subnetting reduces the number of devices affected by abnormal and excessive broadcast traffic.
- Subnets are used for a variety of reasons including:

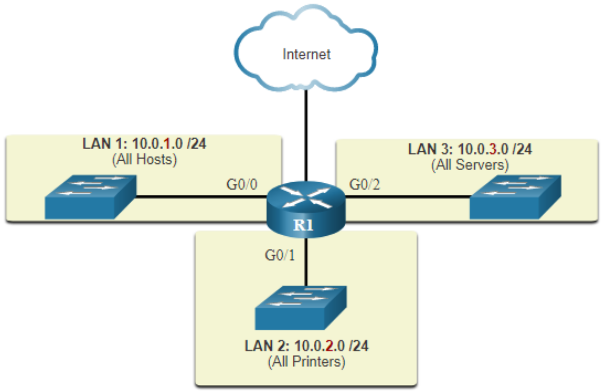
Location



Group or Function



Device Type



Reference: CCNA ITN Ch11 IPv4 Addressing

Re-cap – Network Segmentation

- Collision domain separated by Switch
- Broadcast domain separated by Router
- Segmenting networks to subnets to avoid larger broadcast domain
- Subnets classified based on
  - Location
  - Group based on function
  - Device Type
- Next, discuss on Subnetting in IPv4 addresses

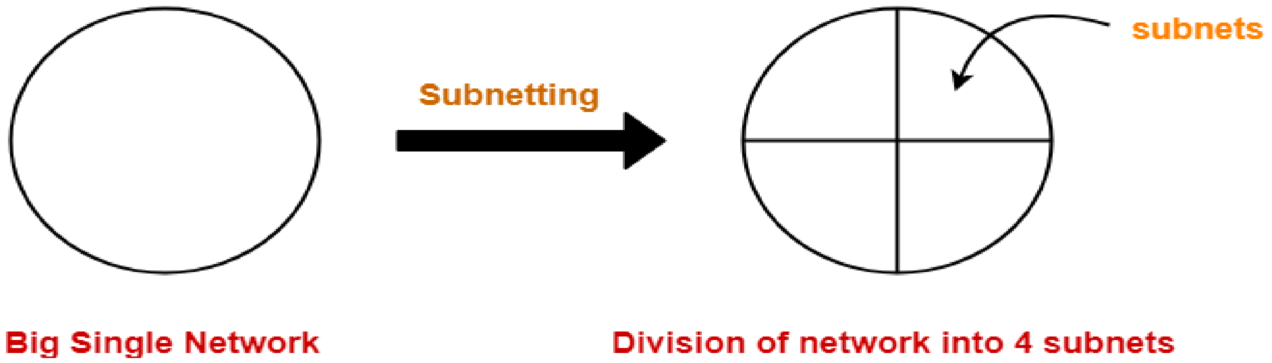
Subnet an IPv4 Network

Reference: CCNA ITN Chapter 11.5 Subnet an IPv4 network

Subnetting in Networking-

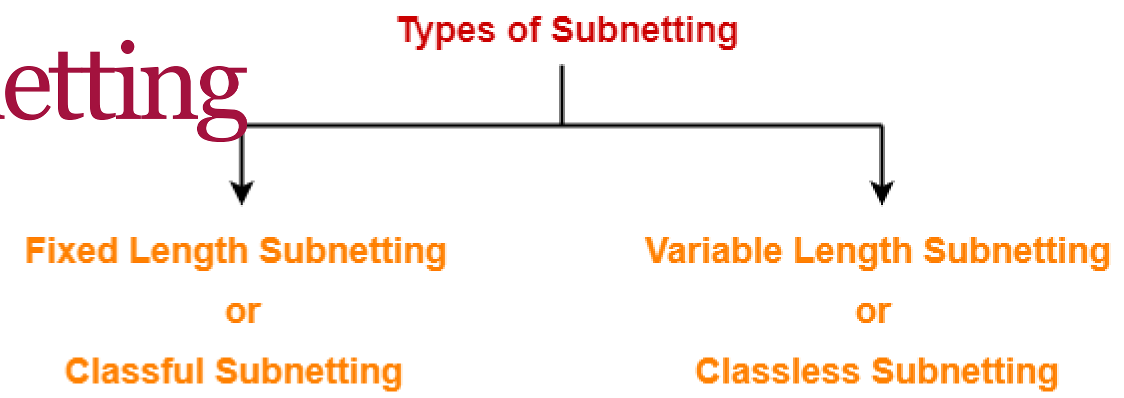
- Process of dividing a single network into multiple sub networks is called subnetting. Sub networks so created are called subnets

Subnet ID-



- Each subnet has its unique network address known as its Subnet ID.
- The subnet ID is created by borrowing some bits from the Host ID part of the IP Address.
- The number of bits borrowed depends on the number of subnets created.

Types of subnetting



1. Fixed Length Subnetting-

Fixed length subnetting also called as **classful subnetting** divides the network into subnets where-

- All the subnets are of same size.
- All the subnets have equal number of hosts.
- All the subnets have same subnet mask.

2. Variable Length Subnetting-

Variable length subnetting also called as **classless subnetting** divides the network into subnets where-

- All the subnets are not of same size.
- All the subnets do not have equal number of hosts.
- All the subnets do not have same subnet mask.

Fixed length Subnetting: Subnet on an Octet Boundary

- Networks are most easily subnetted at the octet boundary of /8, /16, and /24.
- Notice that using longer prefix lengths decreases the number of hosts per subnet.

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
/n			$\mathbf{2^{\#h} - 2}$

Reference: CCNA ITN Ch11 IPv4 Addressing

Subnetting on 10.x.0.0/16

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

Reference: CCNA ITN Ch11 IPv4 Addressing

Classless subnetting

- /25 – Borrowing 1 bit from the fourth octet creates 2 subnets supporting 126 hosts each.

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
/29	255.255.255.248	nnnnnnnn.nnnnnnnn.nnnnnnnn.**nnnnn**hhh 11111111.11111111.11111111.**11111**000	**32**	6
/30	255.255.255.252	nnnnnnnn.nnnnnnnn.nnnnnnnn.**nnnnnn**hh 11111111.11111111.11111111.**111111**00	**64**	2

Reference: CCNA ITN Ch11 IPv4 Addressing

Classless Subnetting Example

192.168.1.0/25 Network

Borrow 1 bit from the host portion of the address.

Original	192.	168.	1.	0	000	0000
Mask	255.	255.	255.	0	000	0000

1 Network

The borrowed bit value is **0** for the Net 0 address.

Net 0	192.	168.	1.	0	000	0000

The borrowed bit value is **1** for the Net 1 address.

Net 1	192.	168.	1.	1	000	0000

2 Subnets

The new subnets have the **SAME** subnet mask.

Mask	255.	255.	255.	1	000	0000

Dotted Decimal Addresses

Borrow 1 bit from the host portion of the address.

Original	192.	168.	1.	0	000	0000
Mask	255.	255.	255.	0	000	0000

1 Network

192. 168. 1. **0/25**

Net 0	192.	168.	1.	0	000	0000

192. 168. 1. **128/25**

Net 1	192.	168.	1.	1	000	0000

2 Subnets

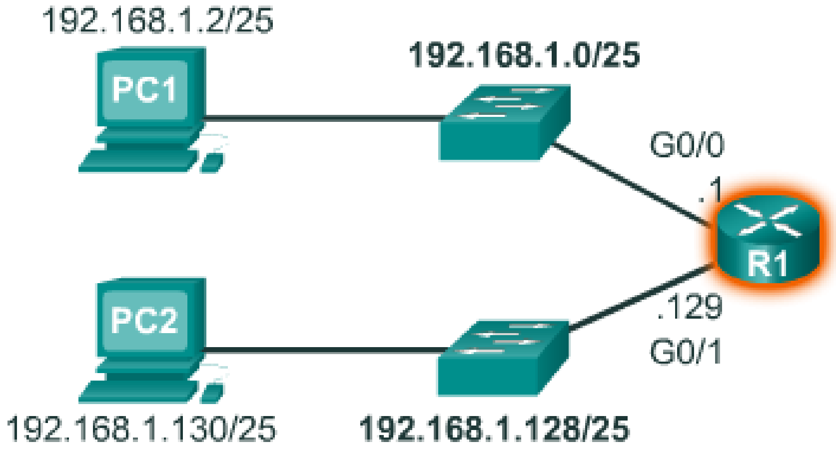
255. 255. 255. **128**

Mask	255.	255.	255.	1	000	0000

Reference: CCNA ITN Ch11 IPv4 Addressing

Creating 2 Subnets

/25 Subnetting Topology



Address Range for 192.168.1.0/25 Subnet

Address	Network portion	Host portion	Result
Network Address	192. 168. 1. 0	000 0000	= 192.168.1.0
First Host Address	192. 168. 1. 0	000 0001	= 192.168.1.1
Last Host Address	192. 168. 1. 0	111 1110	= 192.168.1.126
Broadcast Address	192. 168. 1. 0	111 1111	= 192.168.1.127

Address Range for 192.168.1.128/25 Subnet

Address	Network portion	Host portion	Result
Network Address	192. 168. 1. 1	000 0000	= 192.168.1.128
First Host Address	192. 168. 1. 1	000 0001	= 192.168.1.129
Last Host Address	192. 168. 1. 1	111 1110	= 192.168.1.254
Broadcast Address	192. 168. 1. 1	111 1111	= 192.168.1.255

Reference: CCNA ITN Ch11 IPv4 Addressing

Subnetting Formulas

- To calculate the number of subnets. 2^n

$n=$ bits borrowed

- To calculate the number of hosts 2^n-2

$n=$ the number of bits remaining in the host field

```
 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

```
192.   168.   1.   0   000 0000
```

7 bits remain in host field

2^7 = 128 hosts per subnet
2^7 - 2 = 126 valid hosts per subnet

Reference: CCNA ITN Ch11 IPv4 Addressing

Activity – Subnet Mask and prefix

11.6.5

Activity - Calculate the Subnet Mask

Instructions:

In this activity, you are given a subnet mask in decimal format. Enter the binary representation of the subnet mask in the octet fields provided. Additionally, convert the mask to prefix notation format in the Prefix Notation field.

Subnet Mask	255	255	128	0
Subnet Mask in binary	11111111	11111111	10000000	0
Prefix notation	/	17		

Check | New Problem | Show Me | Reset

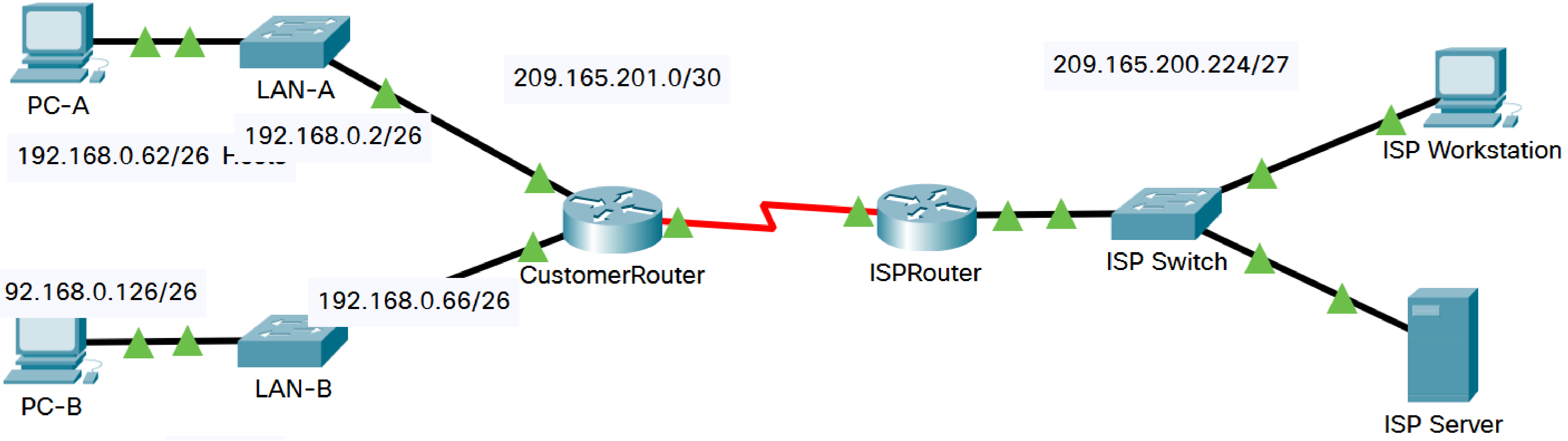
Summary – Subnet an IPv4 Network

- Subnet on Octet Boundary
- Subnetting on 10.x.0.0/16
  - 256 subnets possible
  - 2^16 – 2 hosts/subnet
- Classless subnetting
  - 192.168.1.0/24 address space
- Creating 2 subnets
  - 192.168.1.0/25, 192.168.1.128/25
- Subnetting formulas

Objectives – Subnet an IPv4 Network

- To work out a subnetting problem for a scenario
- Identify the subnets needed based on the requirement of hosts
- Identify the IP addresses for the devices in each subnet
- Configure the Router interfaces and Switch
- Test the connectivity

Classless subnetting Example Problem



- Given IPv4 address space for subnetting - 192.168.0.0/24
- 50 hosts are required in LAN-A network and 40 hosts are required in LAN-B network and 2 more subnets needs to be reserved
- 50 and 40 hosts can be accommodated by 6 bits for 64 hosts
- 2 bits can be borrowed for having 4 subnets. Magic number = 64

Reference: CCNA ITN Ch11 IPv4 Addressing

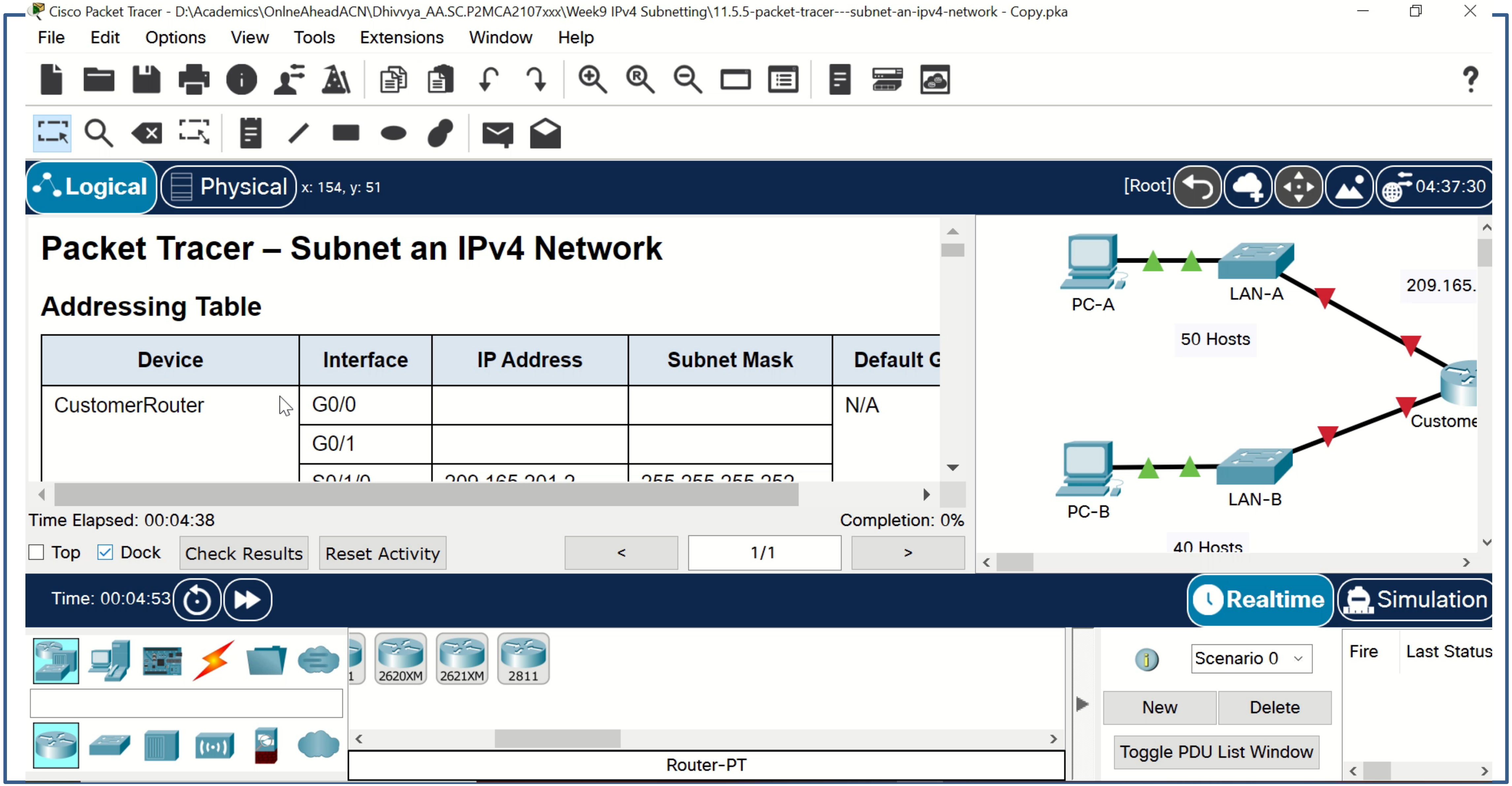
Classless subnetting Example Problem

- Given IPv4 address space for subnetting - 192.168.0.0/24
- 2 subnet bits needed for accommodating 4 subnets and each subnet with 64-2=62 hosts
- Magic number = 64. LAN-A starts with 0, S2 starts with 64*1, S3 starts with 64*2 = 128, S4 starts with 64*3=192

Subnet #	#hosts	Network Address	Broadcast Address	First Usable host address	Last Usable host address
LAN-A	50	192.168.0.0/26	192.168.0.63/26	192.168.0.1/26	192.168.0.62/26
LAN-B	40	192.168.0.64/26	192.168.0.127/26	192.168.0.65/26	192.168.0.126/26
S3-Unused	-	192.168.0.128/26	192.168.0.191/26	192.168.0.129/26	192.168.0.190/26
S4-Unused	-	192.168.0.192/26	192.168.0.255/26	192.168.0.193/26	192.168.0.254/26

Reference: CCNA ITN Ch11 IPv4 Addressing

Activity – Packet Tracer



Summary – Subnet an IPv4 Network

- Subnet example of borrowing 2 bits from 192.168.0.0/24
- 4 subnets of having 6 bits in the host can meet 50 or 40 host requirement
- Followed Equal division Equal Length subnetting to 4 subnets having 64-2=62 hosts/network
- Configured in the Packet Tracer with suitable IP addresses in this example

Subnet to meet Requirements

Reference: CCNA ITN 11.7 Subnet to meet requirements

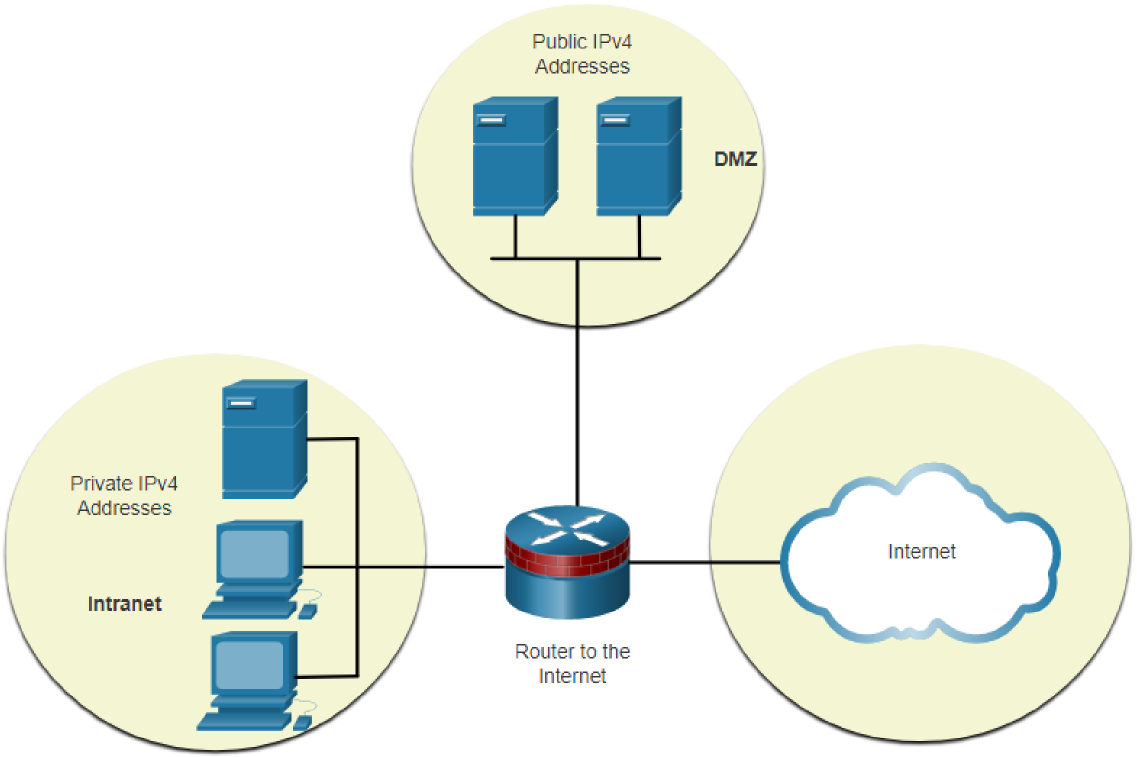
Objectives – Subnet to Meet Requirements

- Subnet Private Vs Public IPv4 Address space
- Minimize Unused Host Address & Maximize subnets
- Example: Efficient IPv4 Subnetting
- Activity to determine the number of bits to borrow

Subnet Private Vs Public IPv4 Address space

Enterprise networks will have an:

- Intranet - A company's internal network typically using private IPv4 addresses.
  - A company could use the 10.0.0.0/8 and subnet on the /16 or /24 network boundary.
- DMZ – A companies internet facing servers. Devices in the DMZ use public IPv4 addresses
  - The DMZ devices would have to be configured with public IP addresses.
  - DMZ stands for demilitarized zone



Reference: CCNA ITN Ch11 IPv4 Addressing

Minimize Unused Host address & Maximize subnets

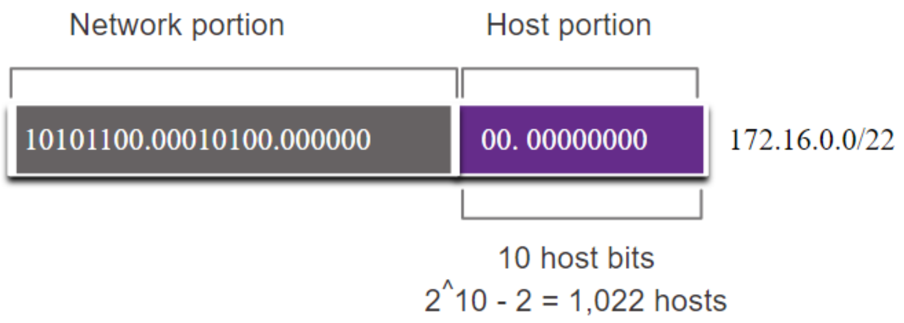
There are two considerations when planning subnets:

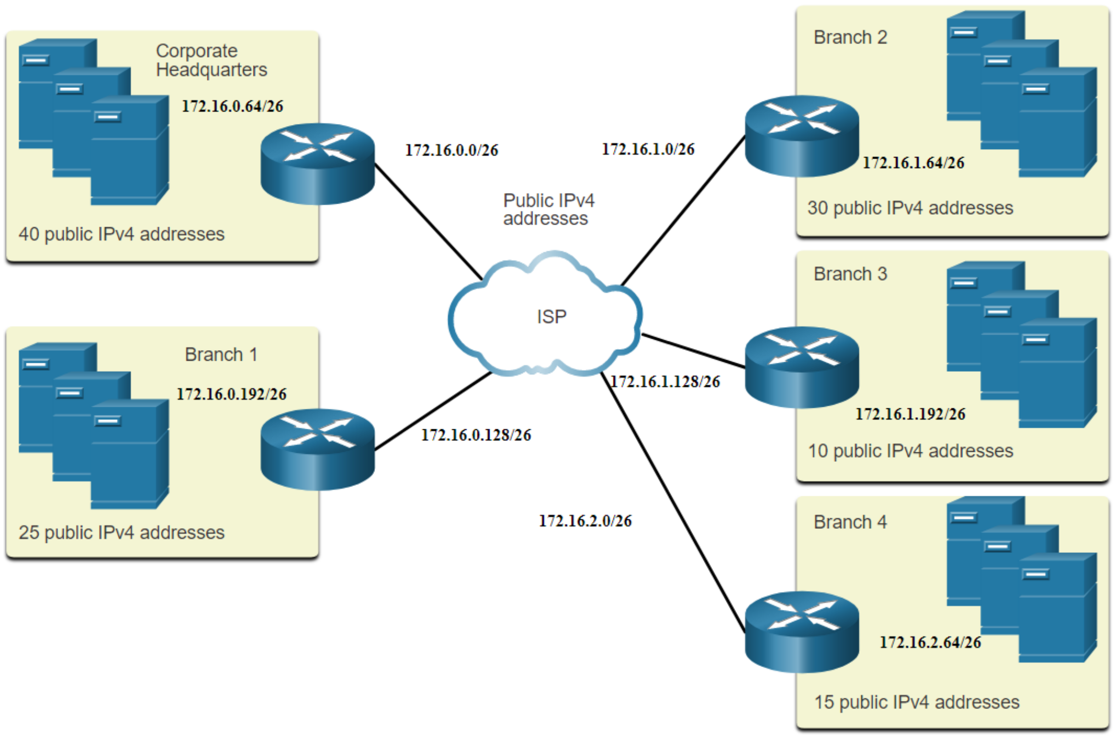
- The number of host addresses required for each network
- The number of individual subnets needed

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
/29	255.255.255.248	nnnnnnnn.nnnnnnnn.nnnnnnnn.**nnnnn**hhh 11111111.11111111.11111111.**11111**000	**32**	6
/30	255.255.255.252	nnnnnnnn.nnnnnnnn.nnnnnnnn.**nnnnnn**hh 11111111.11111111.11111111.**111111**00	**64**	2

Example: Efficient IPv4 Subnetting

- In this example, corporate headquarters has been allocated a network address of 172.16.0.0/22 (10 host bits) by its ISP providing 1,022 host addresses.
- There are five sites and therefore five internet connections which means the organization requires 10 subnets with the largest subnet requires 40 addresses.
- It allocated 10 subnets with a /26 (i.e., 255.255.255.192) subnet mask.





Reference: CCNA ITN Ch11 IPv4 Addressing

Activity – Determine the number of bits to borrow

11.7.4

Activity - Determine the Number of Bits to Borrow

Instructions:

In this activity, you are given the number of hosts that are needed. Determine the subnet mask that would support the number of hosts as specified. Enter your answers in binary, decimal, and prefix notation format in the fields provided.

Hosts Needed	Subnet Mask (binary)	Subnet Mask (decimal)	Prefix Notation(/x)
250	**11111111.11111111.11111111.00000000**	**255.255.255.0**	**/24**
25	. . .		/
1000	. . .		/
75	. . .		/
10	. . .		/
500	. . .		/

Check Show Me Reset

Summary – Subnet to Meet Requirements

- Private addresses for Intranet & Public addresses for servers in DMZ demands subnets

- Minimize Wastage of IPv4 addresses

- Example for Equal Length Subnet Mask for 10 subnets all having 62 hosts/subnet

- Activity to determine the number of bits to borrow

- Next, we will explore Variable Length Subnet Mask(VLSM)

Variable Length subnet Mask (VLSM)

Reference: 11.8.1 Video - VLSM basics, 11.8.2 Video - VLSM example

Variable Length Subnet Mask (VLSM)

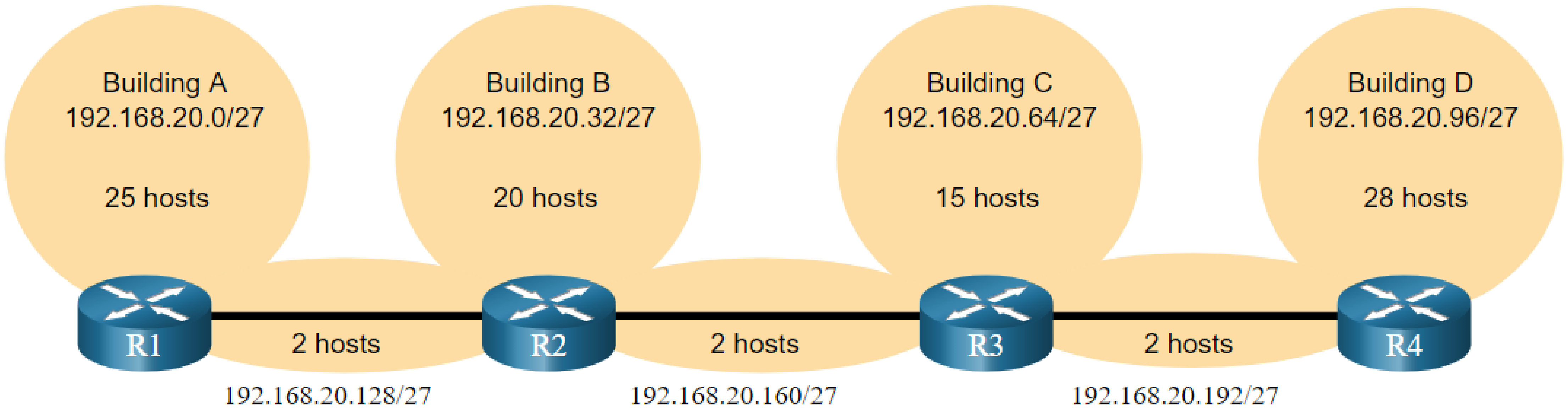
Reference: CCNA Chapter 11.6 Subnetting to meet requirements, 11.7 VLSM

Objectives – Variable Length Subnet Mask

- IPv4 Address Conservation
  - Problems with traditional subnetting causing wastage of IPv4 addresses
- Variable Length Subnet Mask (VLSM) Vs Traditional subnetting
- Activity – Variable Length Subnet Mask

IPv4 Address Conservation

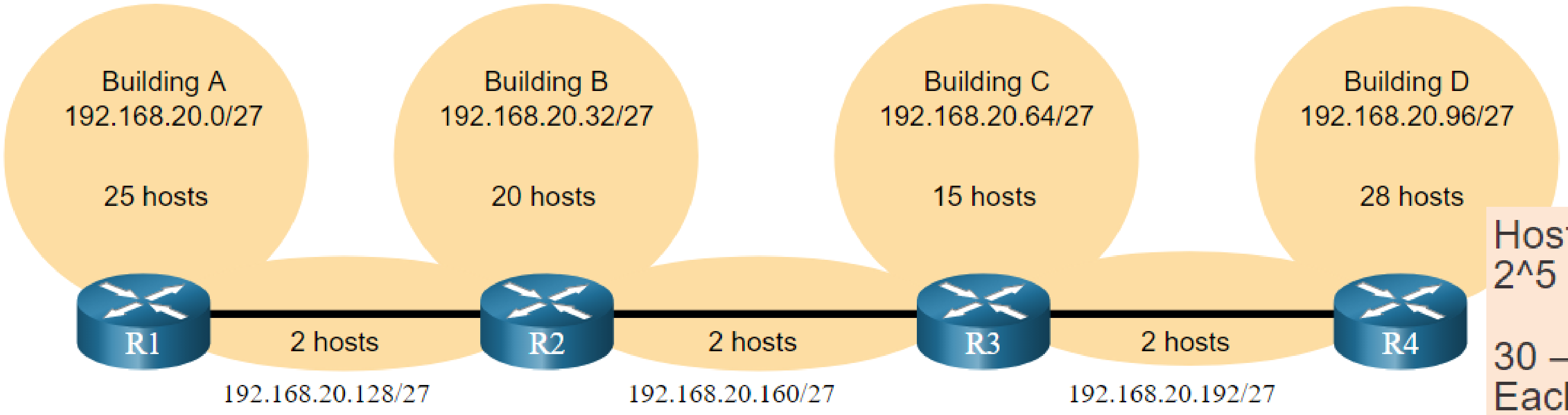
- Given the topology, 7 subnets are required (i.e, four LANs and three WAN links) and the largest number of host is in Building D with 28 hosts.
- A /27 mask would provide 8 subnets of 30 host IP addresses and therefore support this topology.



Reference: CCNA ITN Ch11 IPv4 Addressing

IPv4 Address Conservation

- Point-to-point WAN links only require two addresses and therefore waste 28 addresses each for a total of 84 unused addresses.
- Applying a traditional subnetting scheme here is not very efficient.
- VLSM was developed to avoid wasting addresses by enabling us to subnet a subnet.



Host portion
2^5 – 2 = 30 host IP addresses per subnet

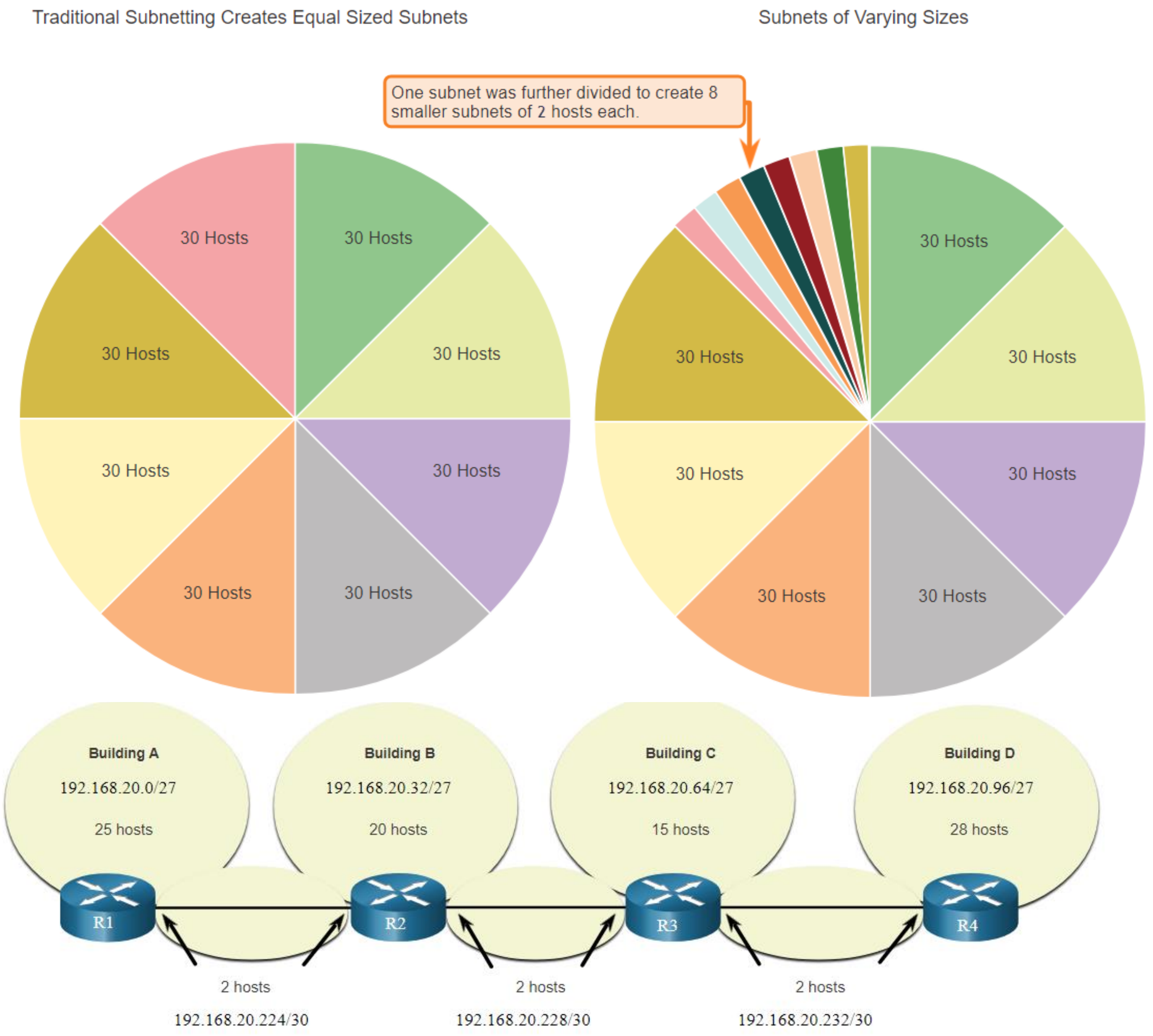
30 – 2 = 28
Each WAN subnet wastes 28 addresses

28 x 3 = 84
84 addresses are unused

Reference: CCNA ITN Ch11 IPv4 Addressing

VLSM

- Traditional subnetting scheme do not cater to reduce the unused addresses
- When using VLSM, always begin by satisfying the host requirements of the largest subnet and continue subnetting until the host requirements of the smallest subnet are satisfied.
- The resulting topology with VLSM applied



Reference: CCNA ITN Ch11 IPv4 Addressing

Activity – VLSM

Correct

You have correctly calculated the subnet.

Click the second **full** subnet range (/26) from Table 1

192.168.5.96-192.168.5.127	/27	192.168.5.64-192.168.5.127	255.255.255.224	192.168.5.64-192.168.5.95

Click the new VLSM Subnet Mask (decimal)

192.168.5.96-192.168.5.127	/27	192.168.5.64-192.168.5.127	255.255.255.224	192.168.5.64-192.168.5.95

Click the **VLSM** Prefix notation

192.168.5.96-192.168.5.127	/27	192.168.5.64-192.168.5.127	255.255.255.224	192.168.5.64-192.168.5.95

Click the first **full VLSM** subnet range

192.168.5.96-192.168.5.127	/27	192.168.5.64-192.168.5.127	255.255.255.224	192.168.5.64-192.168.5.95

Click the last **full VLSM** subnet range

192.168.5.96-	/27	192.168.5.64-	255.255.255.224	192.168.5.64-

Summary – VLSM

- IPv4 Address Conservation
  - Example problem where 84 unused addresses due to inefficient subnetting
- Variable Length Subnet Mask (VLSM) Vs Traditional Equal Length subnet Mask
- Activity – Variable Length Subnet Mask
- Next, we shall explore Structured Design

Structured Design

Reference: CCNA ITN Chapter 11.8 Structured design

Objectives – Structured Design

- IPv4 Network Address Planning
- Device Address Assignment

- Packet Tracer Activity
  - VLSM design based on requirement
  - Implementation by assigning IP address to the devices in the subnets

IPv4 Network Address Planning

- IP network address planning is crucial to develop a scalable solution to an enterprise network.
- What we should know to develop an IPv4 network wide addressing scheme?
  - how many subnets are needed,
  - how many hosts a particular subnet requires,
  - what devices are part of the subnet,
  - which parts of your network use private addresses and
  - which use public and
  - many other determining factors.

Reference: CCNA ITN Ch11 IPv4 Addressing

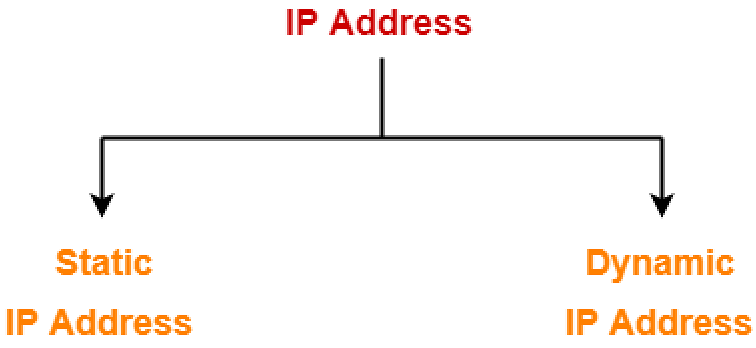
IPv4 Network Address Planning

Examine the needs of an organization’s network usage and how the subnets will be structured.

- Perform a network requirement study by looking at the entire network to determining how each area will be segmented.
- Determine how many subnets are needed and how many hosts per subnet.
- Determine DHCP address pools and Layer 2 VLAN pools.

Reference: CCNA ITN Ch11 IPv4 Addressing

IP Addresses two types-Static and Dynamic



When a device is assigned a **static IP address**, the **address** does not change. Most devices use **dynamic IP addresses**, which are assigned by the network when they connect and change over time.

Static IP Address-

•Static IP Address is an IP Address that once assigned to a network element always remains the same.
•They are configured manually.
•Static IP Addresses are more costly than dynamic IP Addresses.

Dynamic IP Address-

•Dynamic IP Address is a temporarily assigned IP Address to a network element.
•It can be assigned to a different device if it is not in use.
•Dynamic Host Configuration Protocol(DHCP) assigns dynamic IP addresses.

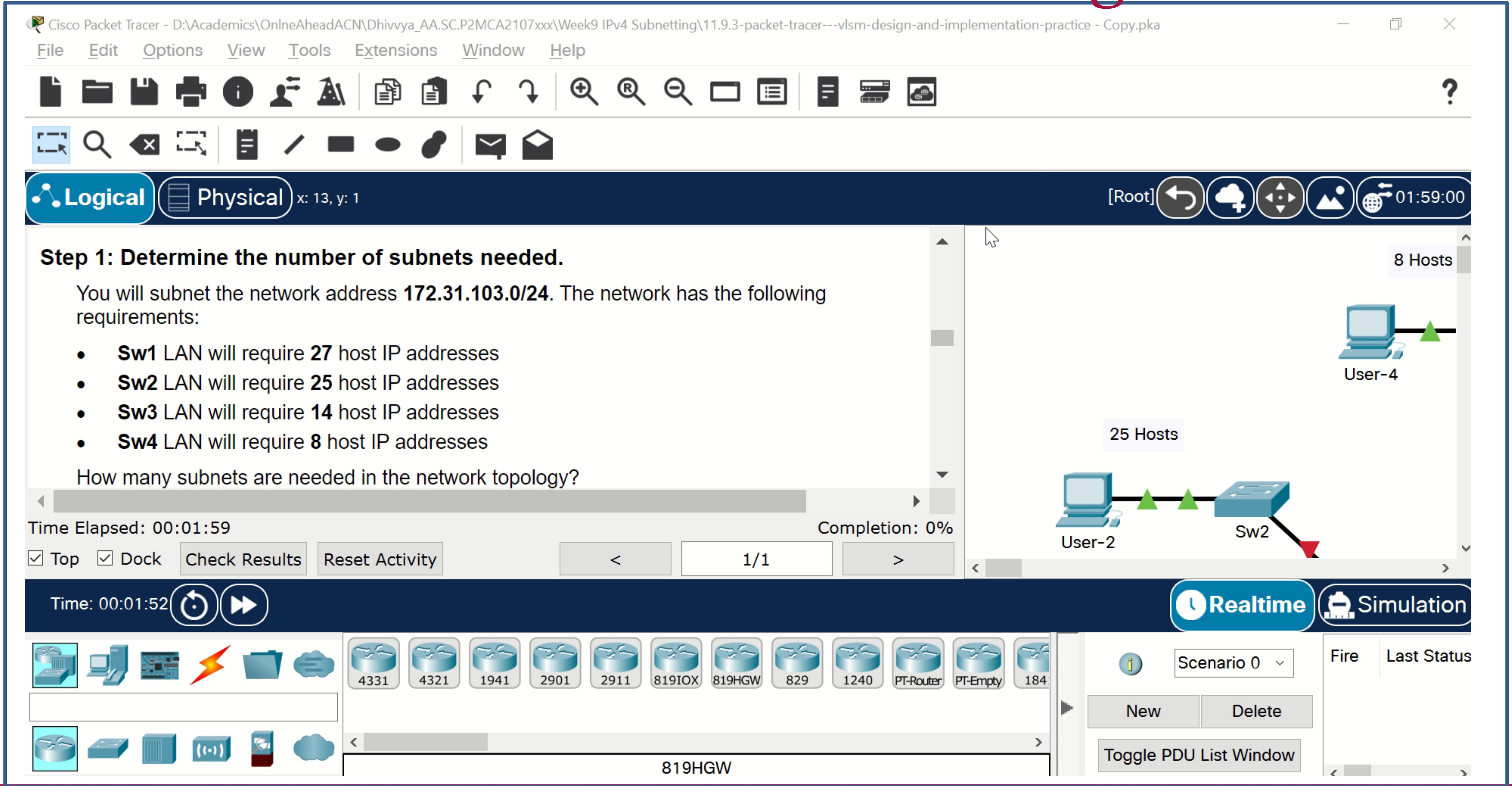
Device Address Assignment

Different types of devices within a network that require addresses:

- End user clients – Most use DHCP to reduce errors and burden on network support staff.
- Servers and peripherals – These should have a predictable static IP address.
- Servers that are accessible from the internet – Servers must have a public IPv4 address, most often accessed using NAT.
- Intermediary devices – Devices are assigned addresses for network management, monitoring, and security.
- Gateway – Routers and firewall devices are gateway for the hosts in that network.

Reference: CCNA ITN Ch11 IPv4 Addressing

VLSM Network Address Design PT



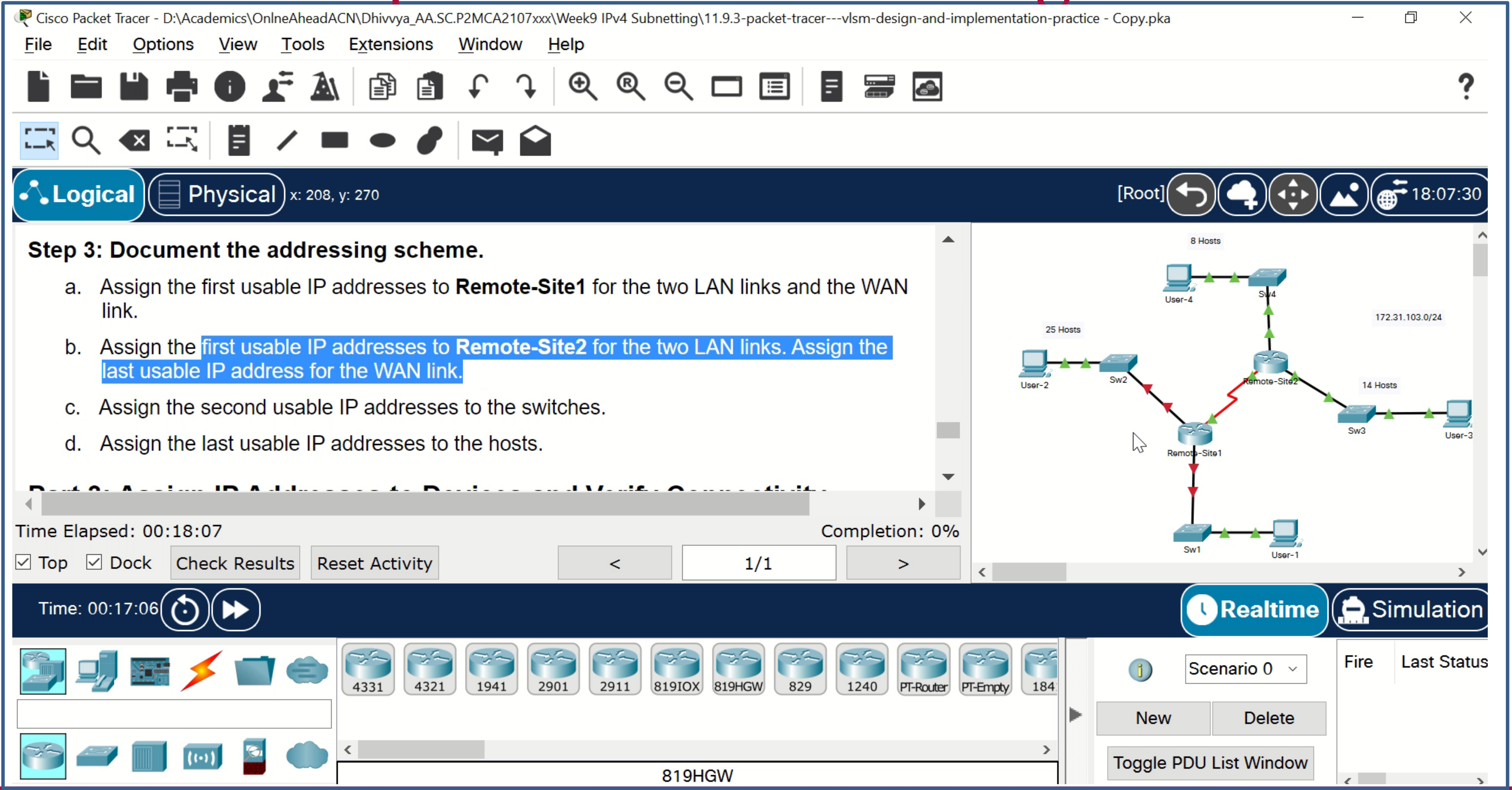
VLSM Implementation – Device Assignment PT

172.31.103.0/24

Subnet Description	Number of hosts needed	Network Address/CIDR	Network Address @last octet	Broadcast Address @last octet
Sw1	27	/27	0	31
Sw2	25	/27	32	63
Sw3	14	/28	64	79
Sw4	8	/28	80	95
WAN	2	/30	96	99

Device	Interface	IP Address	Subnet Mask	Default Gateway
Remote-Site1	Gi0/0(Sw1)			N/A
Remote-Site1	Gi0/1(Sw2)			N/A
Remote-Site1	S0/0/0(WAN)			N/A
Remote-Site2	Gi0/0(Sw3)			N/A
Remote-Site2	Gi0/1(Sw4)			N/A
Remote-Site2	S0/0/0(WAN)			N/A
Sw1	VLAN 1			
Sw2	VLAN 1			
Sw3	VLAN 1			
Sw4	VLAN 1			
User-1 @ Sw1	NIC			
User-2 @ Sw2	NIC			
User-3 @ Sw3	NIC			
User-4 @ Sw4	NIC			

VLSM Implementation – Configuration PT



Summary – Structured Design

- Packet Tracer Activity
  - VLSM design based on Network Address Planning considering #subnets, #hosts
  - VLSM Implementation by assigning IP address to the devices in the subnets
  - Configuring the Assigned IP address and testing the connectivity

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