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Chapter 3
IP Addressing

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Objectives

After completing this chapter, you will be able to:

✓Describe the structure of an IPv4 address.

✓Describe the operation of DHCPv4 in a small-to-medium-sized business network.

✓Configure a router as a DHCPv4 server.

✓Describe the purpose of the subnet mask and subnetting.

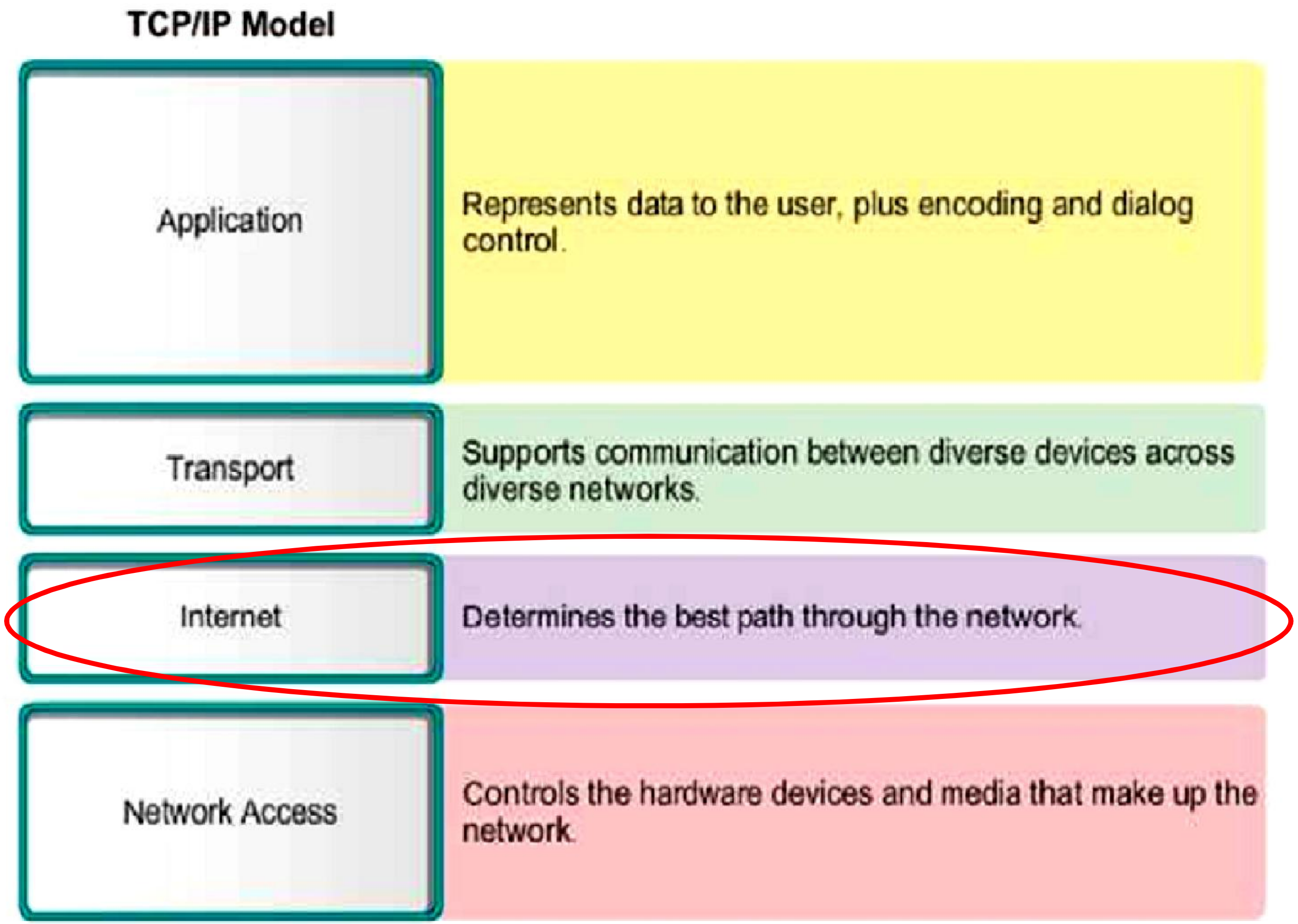
Chap3 Outlines

- Introduction
- IPv4 Network Addresses
- IPv4 Address Formats
- Subnetting

What is Internet Protocol (IP)

Outlines

- Introduction
- IP Network Addresses
- IPv4 Address Formats
- Subnetting



What is Internet Protocol (IP)

Outlines

- Introduction
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❖IP (Internet Protocol) address is

❖protocol used by routers, to select best path from source to destination, across networks and internetworks

❖network layer address, consisting of NETWORK portion, and HOST portion

❖logical address, assigned in software by network administrator

❖part of a hierarchical 'numbering scheme' - unique, for reliable routing

❖may be assigned to a host pc, or router port

Outlines

- IP provides connectionless (datagram) service
- Each packet treated separately
- Network layer protocol common to all routers
  - which is the Internet Protocol (IP)

IPv4/IPv6 (Internet Protocol)

Outlines

- Introduction
- IP Network Addresses
- IPv4 Address Formats
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What is an IP address?

➢ A way to identify machines on a network

➢ A unique identifier

IP usage

➢ Used to connect to another computer

➢ Allows transfers of files and e-mail

➢ This address may change every time a computer restarts. A computer can have one IP at one instance of time and another IP at some different time.

➢ On the other hand, IP address on the public domain is rarely changed.

IPv4

Outlines

- Introduction
- IP Network Addresses
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IPv4 Structure

➢IP addresses consist of four sections

➢Each section is 8 bits long (32-bit)

➢Each section can range from 0 to 255

➢Written, for example, 128.35.0.72

IPv4 Structure

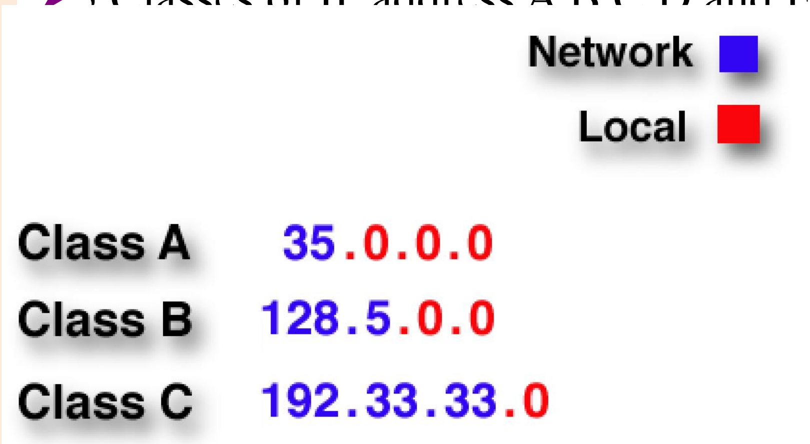
➢These four sections represent the machine itself and the network it is on.

➢The network portion is assigned.

➢The host section is determined by the network administrator.

IPv4 Structure

➢5 Classes of IP address A B C D and E



IPv4 Structure

➢Class D are reserved for multicasting

➢Class E are reserved for future use

➢**Class A** begins **1 to 126**

➢**Class B** begins **128 to 191**

➢**Class C** begins **192 to 223**

IP

Outlines

- Introduction
- IP Network Addresses
- IPv4 Address Formats
- Subnetting

- Bits borrowed from host field

Network	Network	Host	Host

Network	Network	Subnet	Host

Network	Network	Subnet	Subnet/Host

e.g.

- 130.5.0.0 - Network address
- 130.5.2.144 - Host address
- 255.255.255.0 - Subnet Mask
- 130.5.2.0 - Subnet

Outlines

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IPv6

IPv6 Structure

- Exhaustion of IPv4 addresses gave birth to a next generation IPv6.
- 128-bit
- The 128 bits of the address are divided into 8 groups of 16 bits represented by 4 hexadecimal digits and separated by ":"

e.g.

5800:10C3:E3C3:F1AA:48E3:D923:D494:AAFF

- provides plenty of address space for future to be used on entire planet or beyond.
- IPv6 has introduced Anycast addressing but has removed the concept of broadcasting.
- IPv6 enables devices to self-acquire an IPv6 address and communicate within that subnet.
- This auto-configuration removes the dependability of Dynamic Host Configuration Protocol (DHCP) servers.

IPv6 Structure

- IPv6 provides new feature of IPv6 mobility. Mobile IPv6 equipped machines can roam around without the need of changing their IP addresses.
- IPv6 is still in transition phase and is expected to replace IPv4 completely in coming years.
- At present, there are few networks which are running on IPv6.
- There are some transition mechanisms available for IPv6 enabled networks to speak and roam around different networks easily on IPv4. These are:
    - Dual stack implementation
    - Tunneling
    - NAT-PT

1. Internet Protocol v4 (IPv4)

1.1. Types of IP Address

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- Introduction
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- IPv4 Address Formats
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✓Static address

✓Dynamic address

Outlines

- Introduction
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✓Static address

✓Dynamic address

- manually input by network administrator
- manageable for small networks
- requires careful checks to avoid duplication

Outlines

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✓Static address

✓Dynamic address

examples - BOOTP, DHCP

- assigned by server when host boots
- derived automatically from a range of addresses
- duration of 'lease' negotiated, then address released back to server

Outlines

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DHCPv4 uses three different address allocation methods:

- **Manual Allocation** – The administrator assigns a pre-allocated IPv4 address to the client, and DHCPv4 communicates only the IPv4 address to the device.
- **Automatic Allocation** – DHCPv4 automatically assigns a static IPv4 address permanently to a device, selecting it from a pool of available addresses.
- **Dynamic Allocation** – DHCPv4 dynamically assigns, or leases, an IPv4 address from a pool of addresses for a limited period of time chosen by the server, or until the client no longer needs the address. This method is the most commonly used.

Outlines

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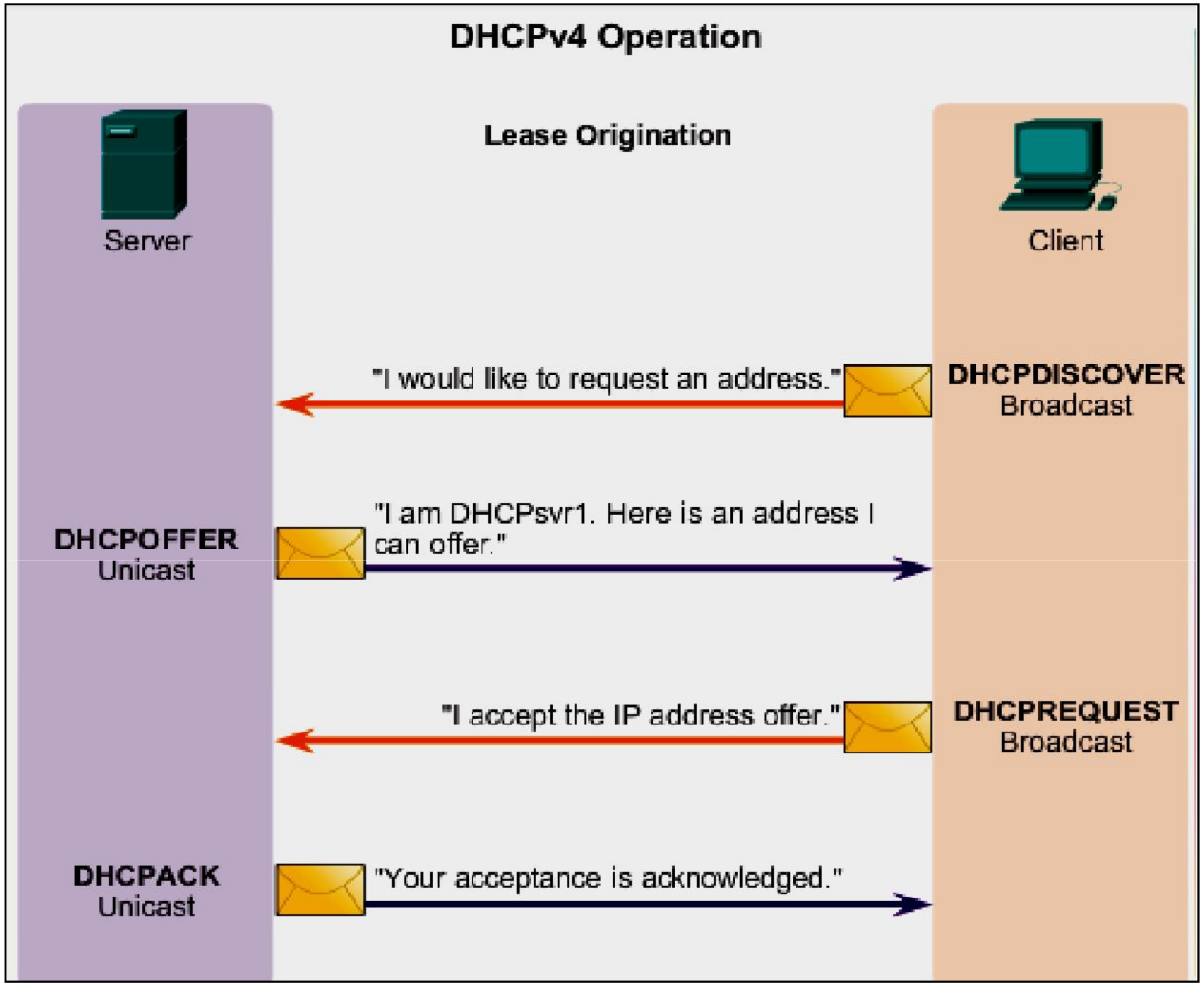

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Configuring a DHCPv4 Server

A Cisco router running the Cisco IOS software can be configured to act as a DHCPv4 server. To set up DHCP:

1. Exclude addresses from the pool.
2. Set up the DHCP pool name.
3. Define the range of addresses and subnet mask. Use the **default-router** command for the default gateway. Optional parameters that can be included in the *pool – dns server*, *domain-name*.

```
R1(config)# ip dhcp excluded-address 192.168.10.1 192.168.10.9
R1(config)# ip dhcp excluded-address 192.168.10.254
R1(config)# ip dhcp pool LAN-POOL-1
R1(dhcp-config)# network 192.168.10.0 255.255.255.0
R1(dhcp-config)# default-router 192.168.10.1
R1(dhcp-config)# dns-server 192.168.11.5
R1(dhcp-config)# domain-name example.com
R1(dhcp-config)# end
R1#
```

To disable DHCP, use the **no service dhcp** command.

Configuring a Router as a DHCPv4 Client

Outlines

- Introduction
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```
SOHO(config)# interface g0/1
SOHO(config-if)# ip address dhcp
SOHO(config-if)# no shutdown
SOHO(config-if)#
*Jan 31 17:31:11.507: %DHCP-6-ADDRESS_ASSIGN: Interface
GigabitEthernet0/1 assigned DHCP address 209.165.201.12, mask
255.255.255.224, hostname SOHO
SOHO(config-if)# end
SOHO# show ip interface g0/1
GigabitEthernet0/1 is up, line protocol is up
  Internet address is 209.165.201.12/27
  Broadcast address is 255.255.255.255
  Address determined by DHCP
  <Output omitted>
```

Outlines

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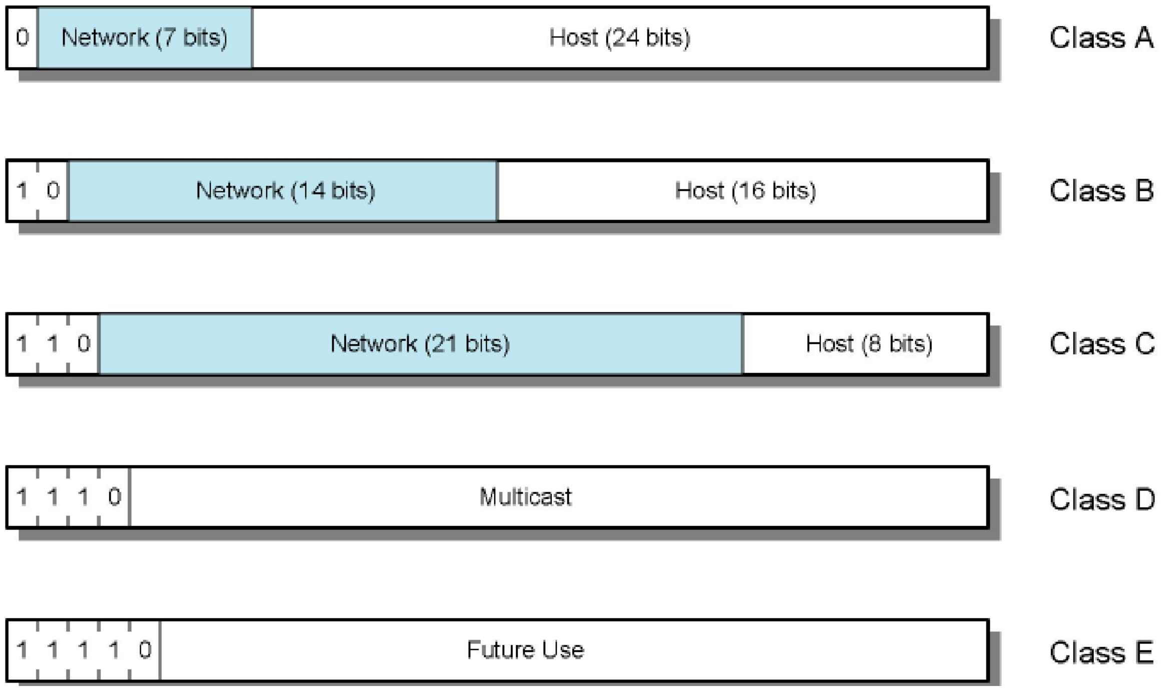
2. IPv4 Address Formats

- 32 bit global Internet address
- Network part and host part
- **All-zero host part identifies the network**
- **All-one host part means broadcast (limited to current network)**



2.1. IP Addresses - Class A

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- Introduction
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- IPv4 Address Formats
- Subnetting

- Start with binary 0
- 7-bit network - 24-bit host
- All zero
  - Special meaning (means "this computer")
- 01111111 (127) (network part) reserved for loopback
  - Generally 127.0.0.1 is used
- Range 1.x.x.x to 126.x.x.x
  - 10.x.x.x is for private networks
- Few networks - many hosts
- All networks have been allocated

Outlines

- Introduction
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- IPv4 Address Formats
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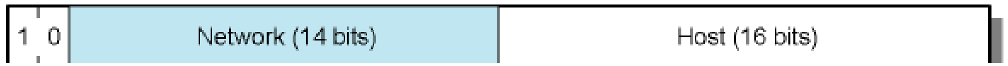
2.2. IP Addresses - Class B



- Starts with binary 10
- Range 128.x.x.x to 191.x.x.x
  - Second octet is also part of the network id.
- 14-bit network, 16-bit host number
  - 2^{14} = 16,384 class B addresses
  - 2^{16} = 65,536 hosts per network
    - Actually minus 2 due to network and broadcast addresses
- All networks have been allocated

Outlines

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- IP Network Addresses
- IPv4 Address Formats
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2.3. IP Addresses - Class C

- Start binary 110
- Range 192.x.x.x to 223.x.x.x
- Second and third octets are also part of network address
- 2^{21} = 2,097,152 addresses (networks)
- 256 – 2 = 254 hosts per network
- Nearly all allocated

2.4. Some Special IP address forms

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- Introduction
- IP Network Addresses
- IPv4 Address Formats
- Subnetting

Prefix (network)	**Suffix (host)**	**Type & Meaning**
all zeros	all zeros	this computer (used during bootstrap)
network address	all zeros	identifies network
network address	all ones	broadcast on the specified network
all ones	all ones	broadcast on local network
127	any	loopback (for testing purposes)

2.5. Network Masks

Outlines

- Introduction
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- IPv4 Address Formats
- Subnetting

- Distinguishes which portion of the address identifies the network and which portion of the address identifies the node.
- Default masks:
  - Class A: 255.0.0.0
  - Class B: 255.255.0.0
  - Class C: 255.255.255.0

2.5.1. Calculating the Netmask Length (also called a prefix)

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1. Convert the dotted-decimal representation of the netmask to binary.
2. Then, count the number of contiguous 1 bits, starting at the most significant bit in the first octet (i.e. the left-hand-side of the binary number).

Example:
255.255.248.0 in binary:
11111111 11111111 11111000 00000000
--- I counted twenty-one 1s -------> /21
The prefix of 128.42.5.4 with a 255.255.248.0 netmask is /21
Thus: 182.42.5.4/21

2.5.2. Calculating the Network Address

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The network address is the logical AND of the respective bits in the binary representation of the IP address and network mask.

1. Align the bits in both addresses, and perform a logical AND on each pair of the respective bits.
2. Then convert the individual octets of the result back to decimal.

Example:

128.42.5.4 in binary: 10000000 00101010 00000101 00000100

255.255.248.0 in binary: 11111111 11111111 11111000 00000000

[Logical AND] 10000000 00101010 00000000 00000000

------> 128.42.0.0

2.6. Loopback Address

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- IP defines a loopback address used to test network applications.
- Programmers often use loopback testing for preliminary debugging after a network application has been created.
- To perform a loopback test, a programmer must have two application programs that are intended to communicate across a network.
- Each application includes the code needed to interact with TCP/IP protocol software.
- Instead of executing each program on a separate computer, the programmer runs both programs on a single computer and instructs them to use a loopback IP address when communicating.

3. Subnetting

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- Introduction
- IP Network Addresses
- IPv4 Address Formats
- Subnetting

- Subnetting is a method for getting the most out of the limited 32-bit IP addressing space.
- With any address class, subnetting provides a mean of allocating a part of the host address space to network addresses, which will let you have more networks.
- The part of the host address space allocated to new network addresses is known as the subnet number.
- Creates multiple logical networks that exist within a single Class A, B, or C network.

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- If you do not subnet, you will only be able to use one network from your Class A, B, or C network, which is unrealistic
- Each data link on a network must have a unique network ID, with every node on that link being a member of the same network.

3.1. Why subnetting?

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- Introduction
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- Subnetting

- Preservation of address space
- Control network traffic, avoid collisions
- Reduce the routing complexity
- Improve network performance
- Security

3.2. Basic Subnetting

- Borrowing Bits to Create Subnets
- Borrowing 1 bit $2^1 = 2$ subnets

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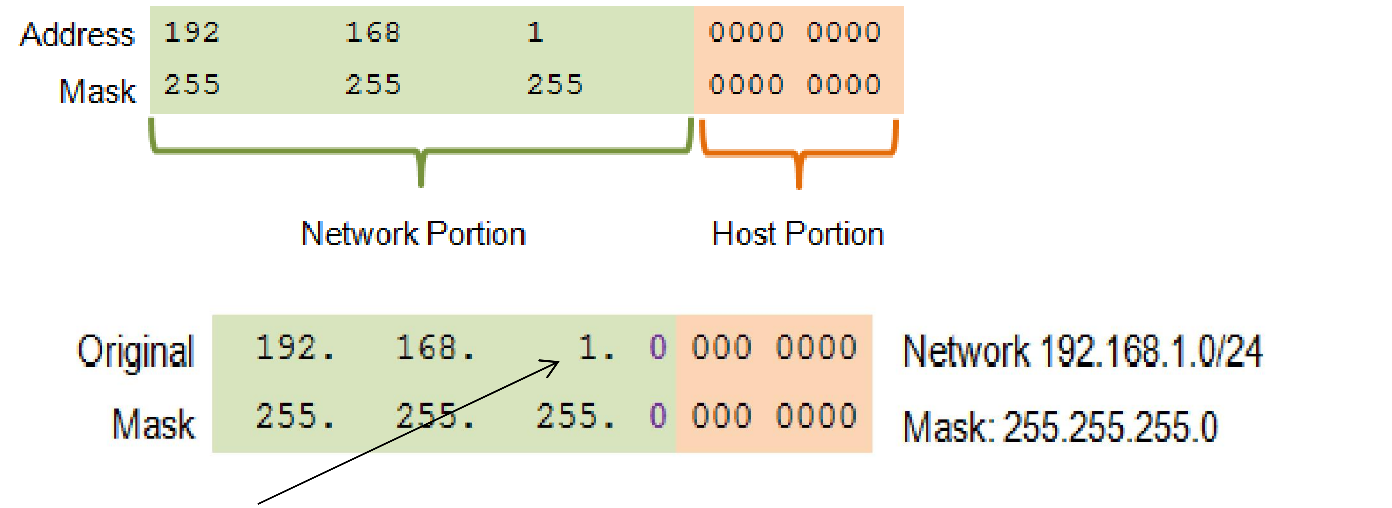

Borrowing 1 Bit from the host portion creates 2 subnets with the same subnet mask

Subnet 0

Network 192.168.1.**0-127**/**25**

Mask: 255.255.255.**128**

Subnet 1

Network 192.168.1.**128-255**/**25**

Mask: 255.255.255.**128**

Outlines

- Introduction
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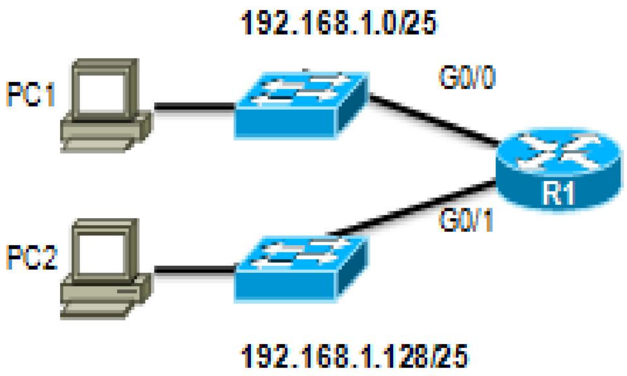
Subnets in Use

Subnet 0

Network 192.168.1.**0-127**/**25**



Subnet 1

Network 192.168.1.**128-255**/**25**

Address Range for 192.168.1.0/25 Subnet

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

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

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Calculate number subnets

Subnets = 2^n
(where n = bits borrowed)

`192. 168. 1. 0 000 0000`

1 bit was borrowed

2^1 = 2 subnets

Calculate number of hosts

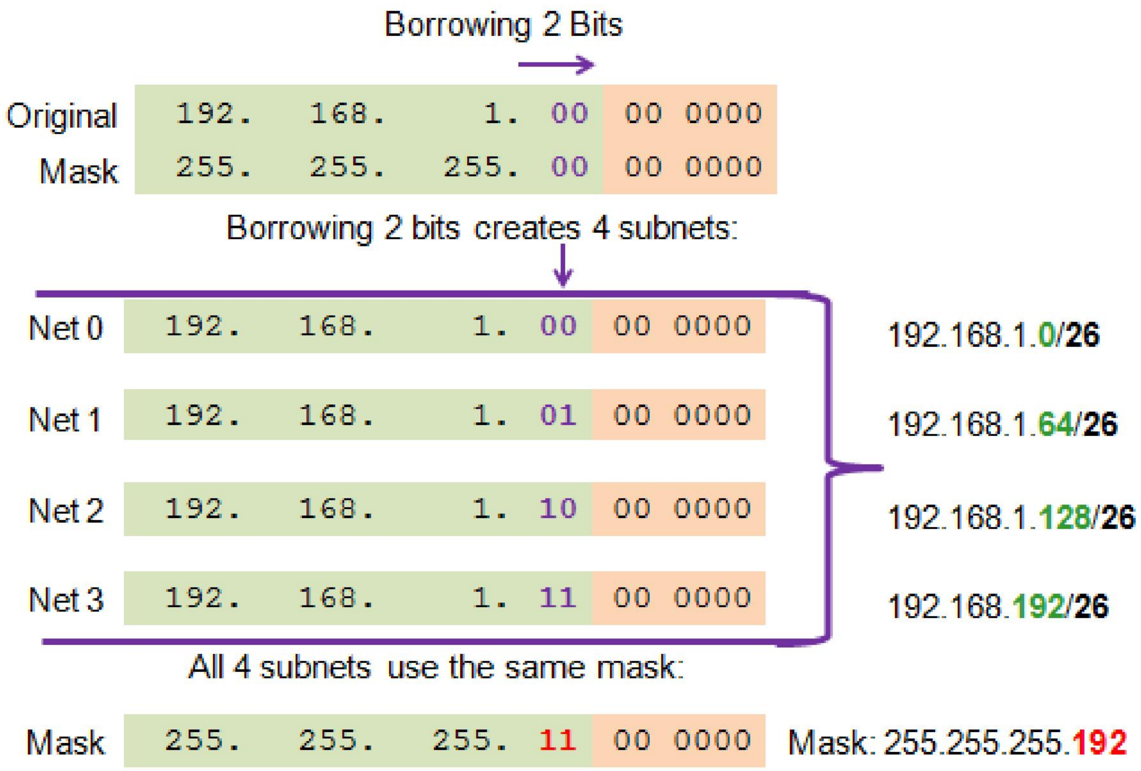
Hosts = 2^n
(where n = host bits remaining)

`192. 168. 1. 0 000 0000`

7 bits remain in host field

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

Borrowing 2 bits to create 4 subnets. 2^2 = 4 subnets



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Subnetting Based on Host Requirements

Two considerations when planning subnets:

- Number of subnets required
- Number of host addresses required

Formula to determine number of usable hosts: 2^n-2

- 2^*n* (where *n* is the number of remaining host bits) is used to calculate the number of hosts.
- -2 (The subnetwork ID and broadcast address cannot be used on each subnet.)

- Introduction
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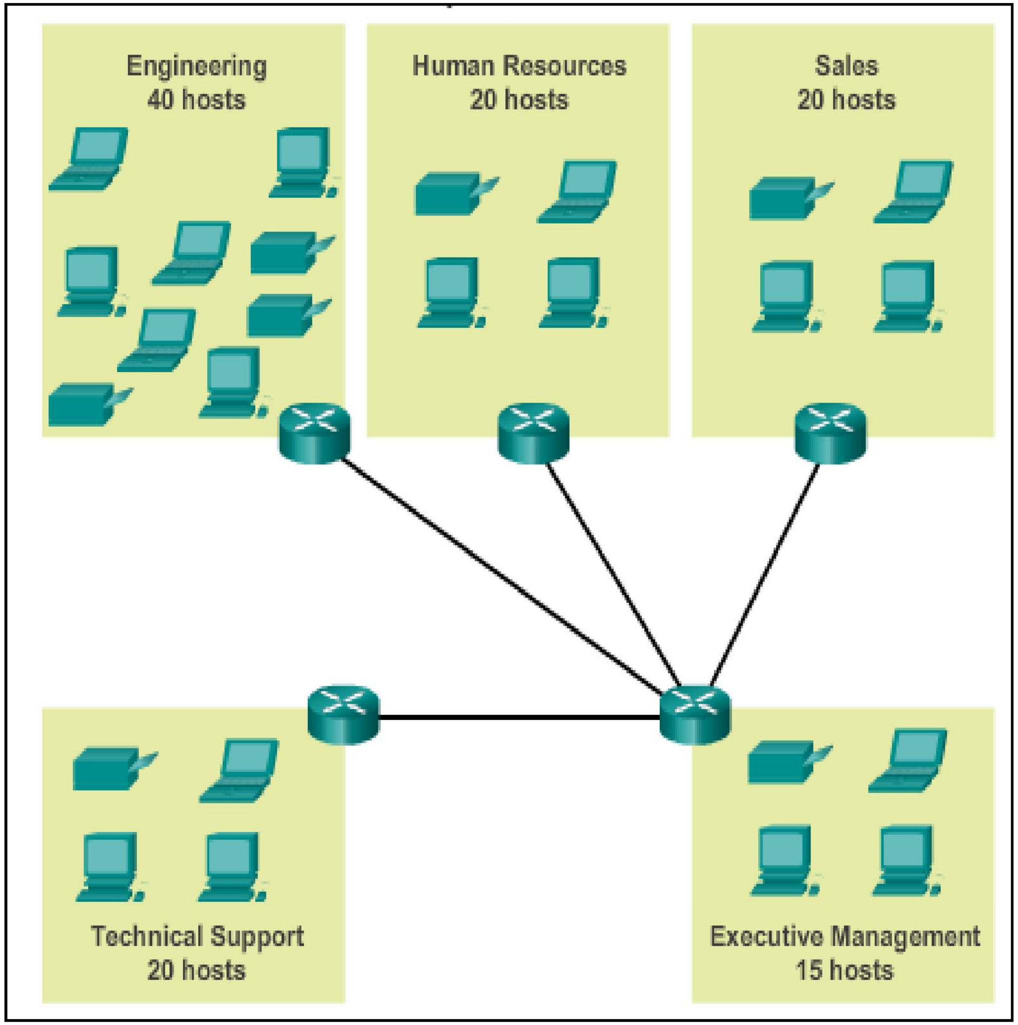
Subnetting To Meet Network Requirements

- Balance the required number of subnets and hosts for the largest subnet.
- Design the addressing scheme to accommodate the maximum number of hosts for each subnet.
- Allow for growth in each subnet.



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Subnets and Addresses

	10101100.00010000.00000000.00000000	172.16.0.0/22
0	10101100.00010000.00000000.00000000	172.16.0.0/26
1	10101100.00010000.00000000.01000000	172.16.0.64/26
2	10101100.00010000.00000000.10000000	172.16.0.128/26
3	10101100.00010000.00000000.11000000	172.16.0.192/26
4	10101100.00010000.00000001.00000000	172.16.1.0/26
5	10101100.00010000.00000001.01000000	172.16.1.64/26
6	10101100.00010000.00000001.10000000	172.16.1.128/26
	Nets 7 – 14 not shown	
15	10101100.00010000.00000011.10000000	172.16.3.128/26
16	10101100.00010000.00000011.11000000	172.16.3.192/26

2^4 = 16 subnets

2^6 – 2 = 62 Hosts per subnet

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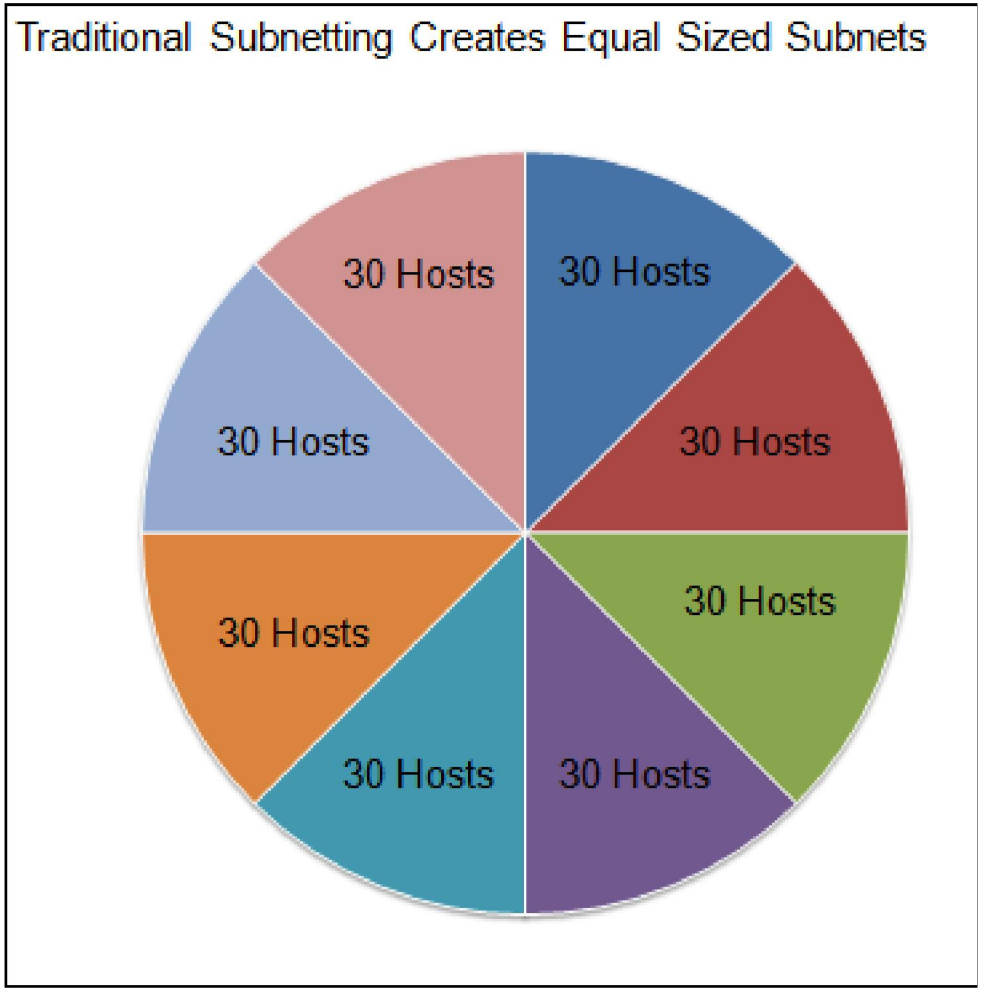
- Traditional subnetting – Uses the same number of addresses is allocated for each subnet.
- Subnets that require fewer addresses have unused (wasted) addresses; for example, WAN links only need two addresses.



3.3. Variable Length Subnet Masks (VLSM)

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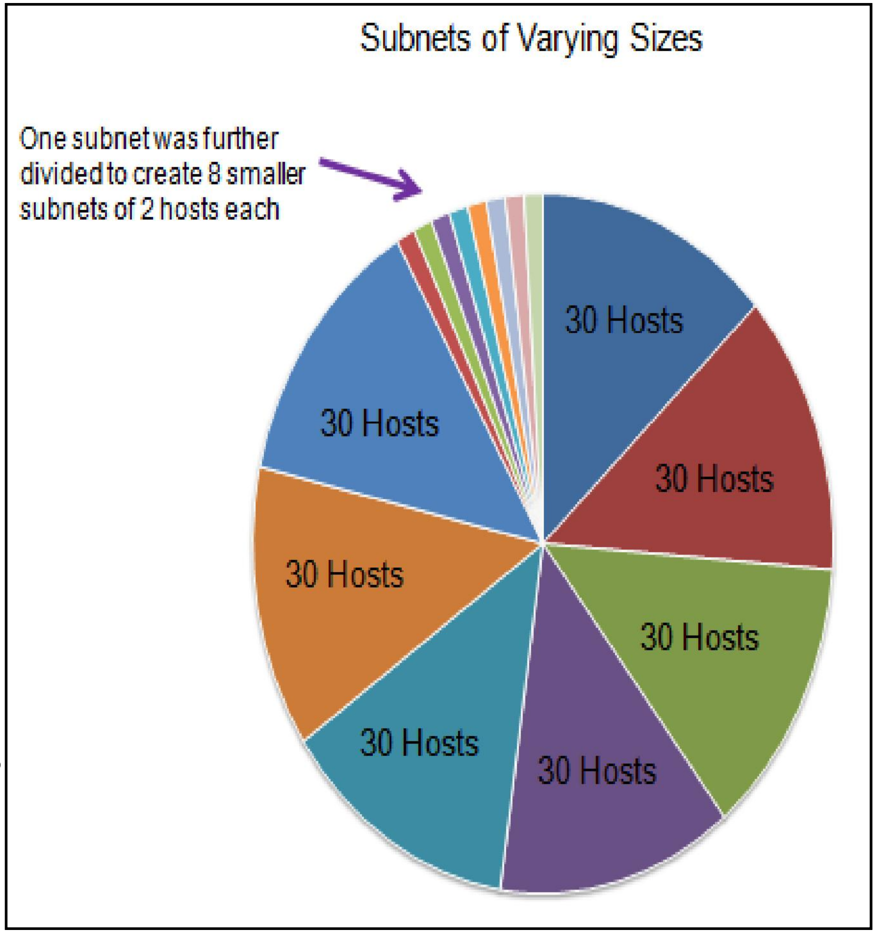
- The variable-length subnet mask (VLSM) or subnetting a subnet provides more efficient use of addresses.
- VLSM allows a network space to be divided in unequal parts.
- Subnet mask varies, depending on how many bits have been borrowed for a particular subnet.
- Network is first subnetted, and then the subnets are resubnetted.



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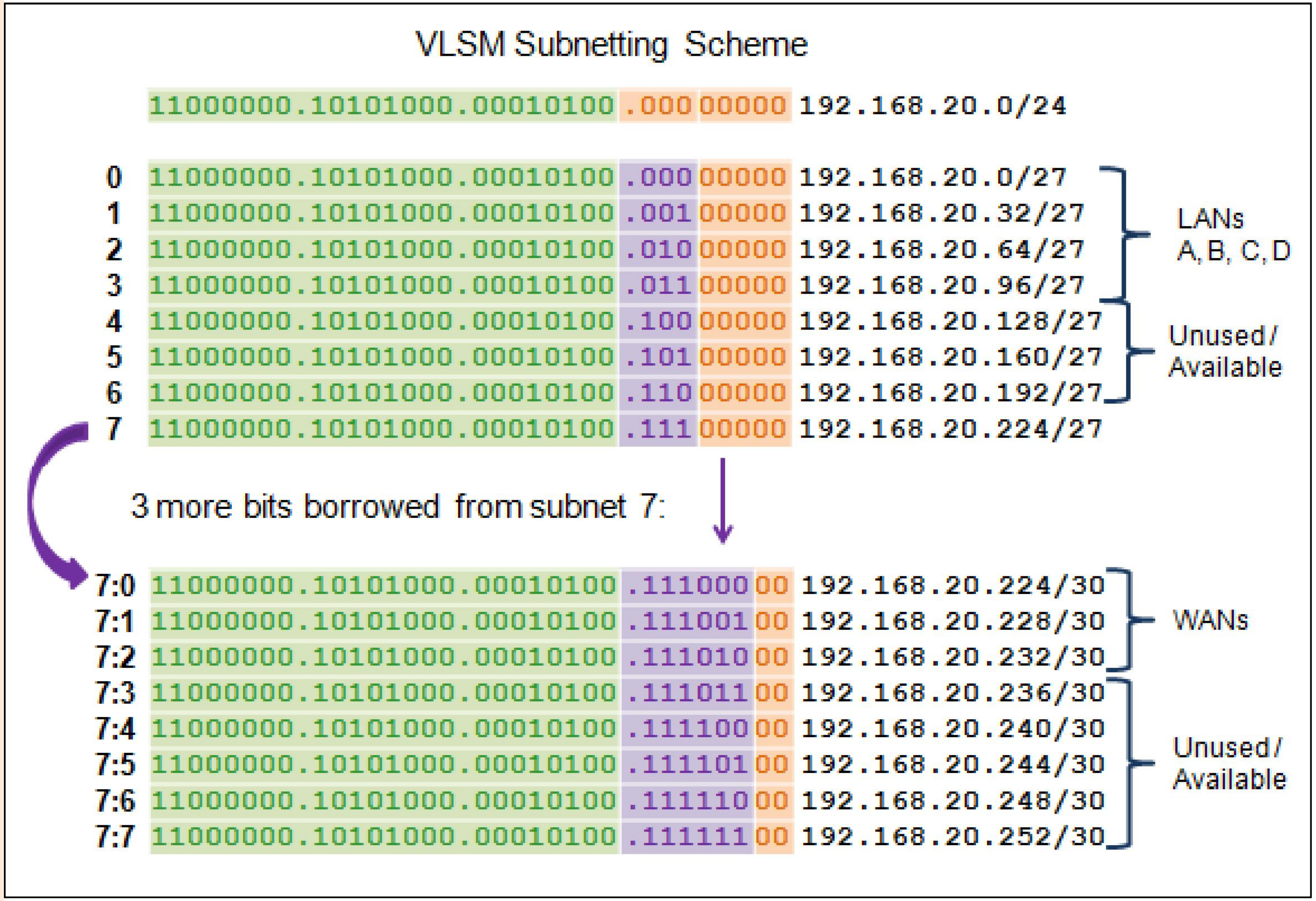

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VLSM in Practice (Example)

- Using VLSM subnets, the LAN and WAN segments in example below can be addressed with minimum waste.
- Each LANs will be assigned a subnet with /27 mask.
- Each WAN link will be assigned a subnet with /30 mask.