Module 4

IP Addressing, Subnetting & VLSM

IP Addressing

IP Address

1. IP Address Overview
2. IP Address Classifying
3. Special IP Address
4. Lab IP

IP Addressing

1. IP Address Overview

IP Address Format

Binary : 11000000.10101000.000000001.00001000 and 11000000.10101000.00000001.00001001

Decimal : 192.168.1.8 and 192.168.1.9

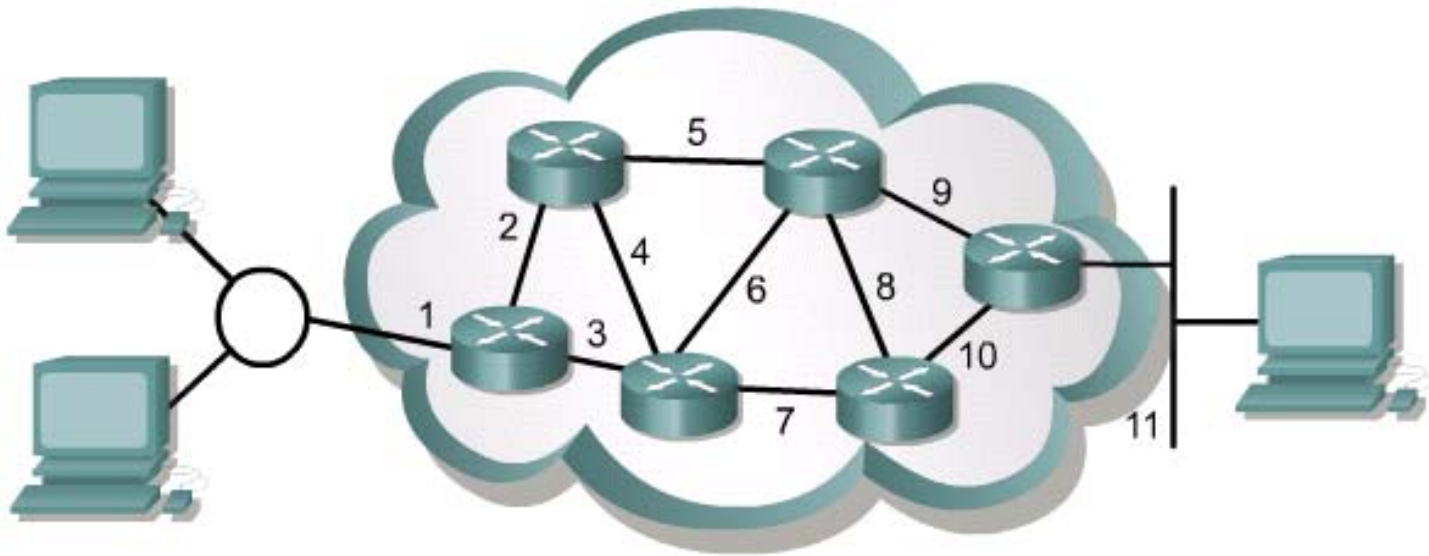
Both the binary and decimal numbers represent the same values, but it is much easier to see with the dotted decimal values. This is one of the common problems found in working directly with binary numbers. The long strings of repeated ones and zeros make transposition and omission errors more likely.

IP address: Logical address

Physical vs. Logical Address

- Physical Address
  - Layer 2
  - MAC address, hardware address, Ethernet address
  - burned in card
  - can’t be changed without changing card
  - flat scheme
  - Analogy: your name
- Logical Address
  - Layer 3
  - Protocol address
  - set by administrator in software
  - can be easily changed
  - hierarchical scheme like Phone Numbers (area code, prefix) or ZIP codes
  - Analogy: your mailing address

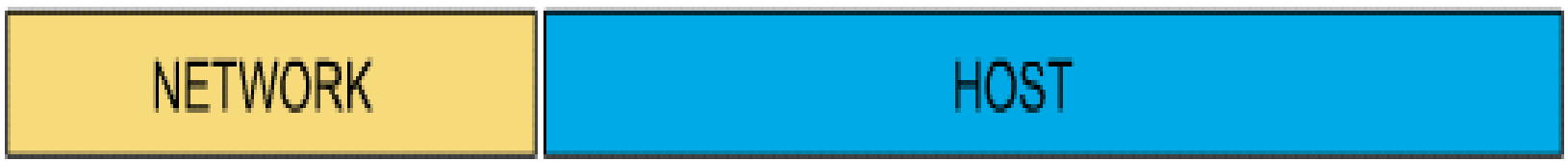
Layer 3 Solves The Routing Problems!



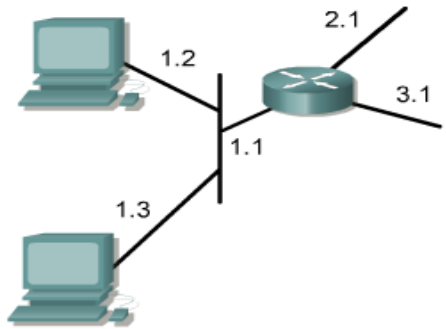
- Allows device moves data through logical addresses.
- Uses routers to control broadcast propagation.
- Provides path determination through routing.
- Uses hierarchical addresses to support world-wide addressing.

Layer 3 Addresses

- Logical or Layer 3 addresses come in different flavors, depending on the layer-3 protocol used:
  - TCP/IP = IP address
  - Novell IPX = IPX address
  - AppleTalk = AT address
- Though the exact length and format of a logical (layer 3) address differs depending on the protocol, all logical addresses share this basic formula:



Network and Host addressing



Network	Host
1	1 2 3
2	1
3	1

AppleTalk address
network 400, host 22

400:22

IPX (Novell)
network 4b39, host 00c0.4f31.03d2

4b39.00c0.4f31.03d2

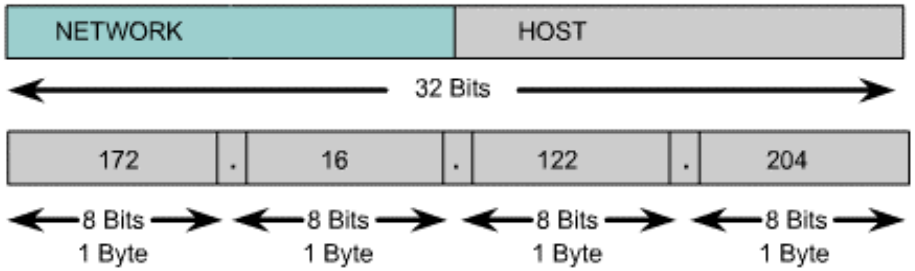
IP (Internet)
network 207.81.104, host 15

207.81.104.15

IP Addressing

2. IP Address Classifying

Address Class Prefixes



An IP address will always be divided into a network and host portion. In a classful addressing scheme, these divisions take place at the octet boundaries.

Class A	Network	Host		
Octet	1	2	3	4

Class B	Network		Host	
Octet	1	2	3	4

Class C	Network			Host
Octet	1	2	3	4

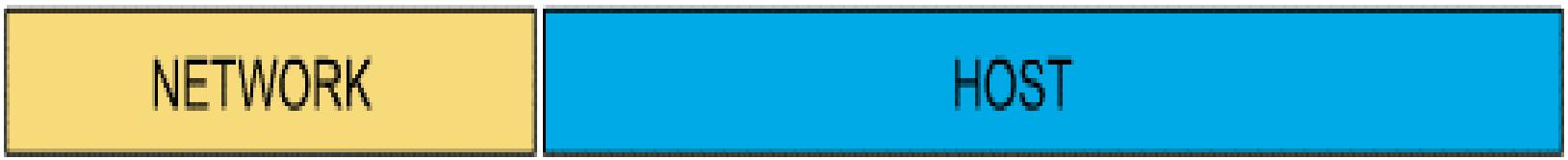
Class D	Host			
Octet	1	2	3	4

Class D addresses are used for multicast groups. There is no need to allocate octets or bits to separate network and host addresses. Class E addresses are reserved for research use only.

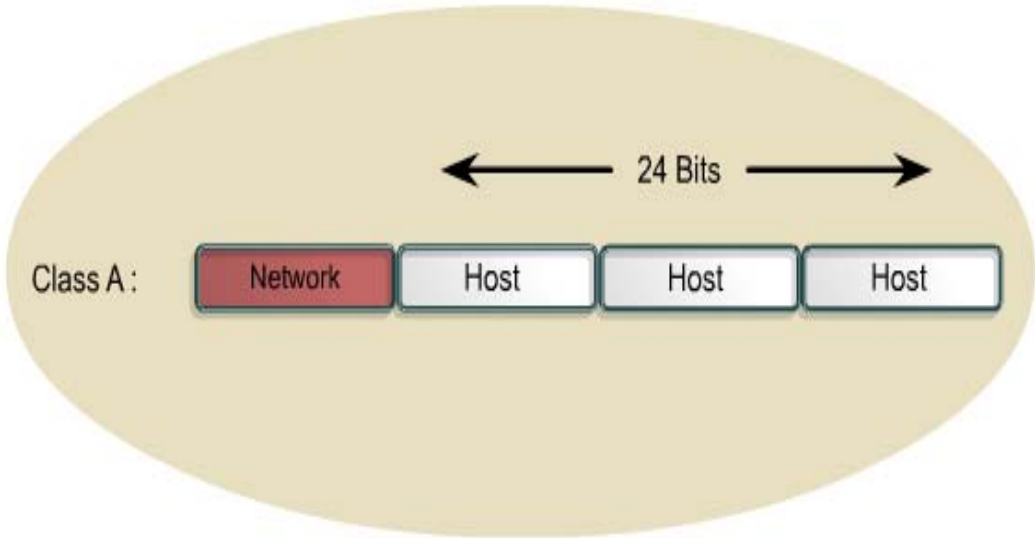
IP Address Classes

Address Class	Number of Networks	Number of Host per Network
A	126 *	16,777,216
B	16, 384	65,535
C	2,097,152	254
D (Multicast)	N/A	N/A

* The 127.x.x.x address range is reserved as a loopback address, used for testing and diagnostic purposes.

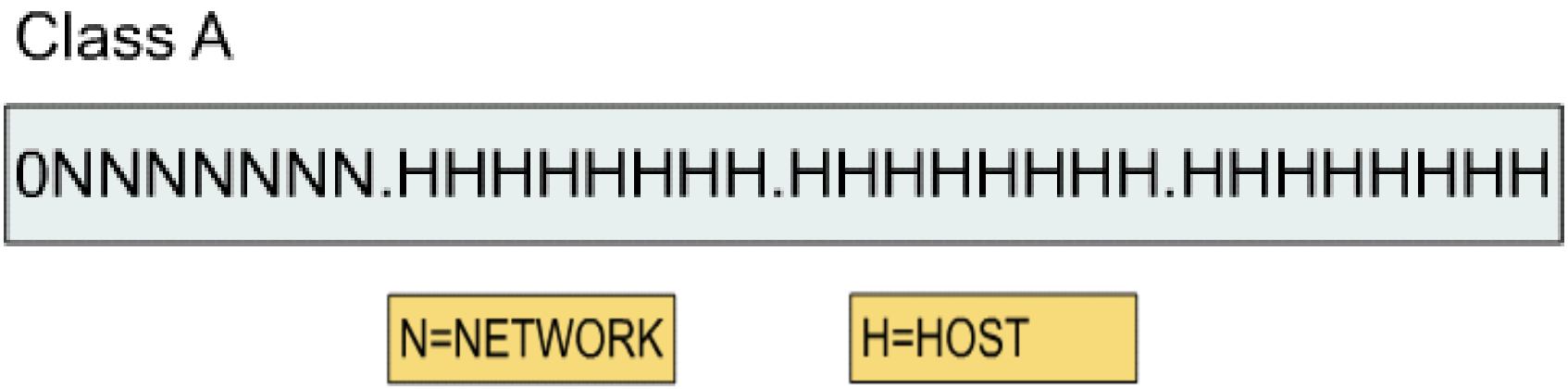


Class A Address



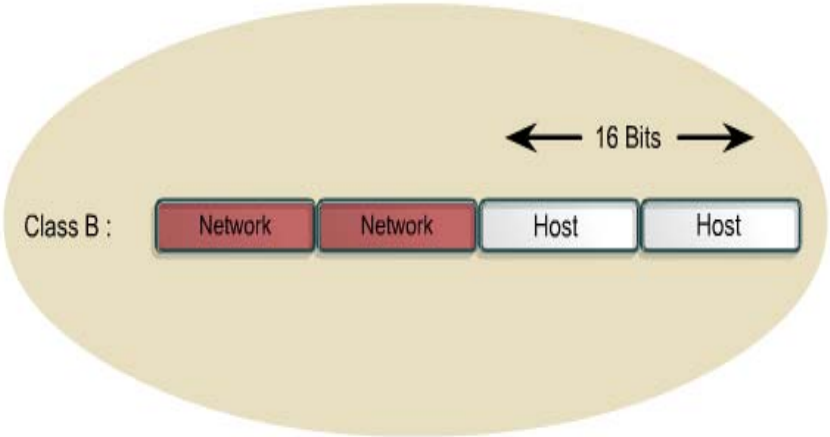
- There are 126 class A addresses.
  - 0 and 127 have special meaning and are not used.
- Only large organizations such as the military, government agencies, universities, and large corporations have class A addresses.

Class A Address



- The first bit of a Class A address is always 0.
- The first 8 bits to identify the network part of the address.
- Possible network address from 1.0.0.0 to 126.0.0.0.
- The remaining three octets can be used for the host portion of the address.
- Each class A network have up to $2^{24} - 2$ or 16,777,214 possible IP addresses.

Class B Address



Class B

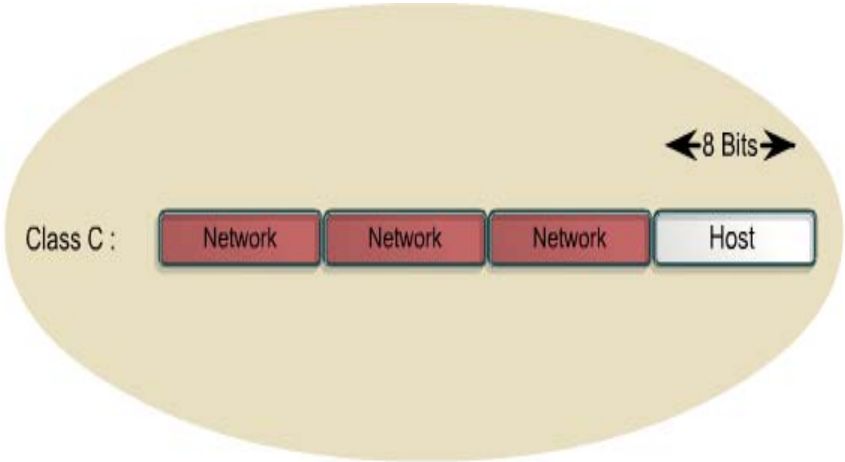
10NNNNNN.NNNNNNNN.HHHHHHHH.HHHHHHHH

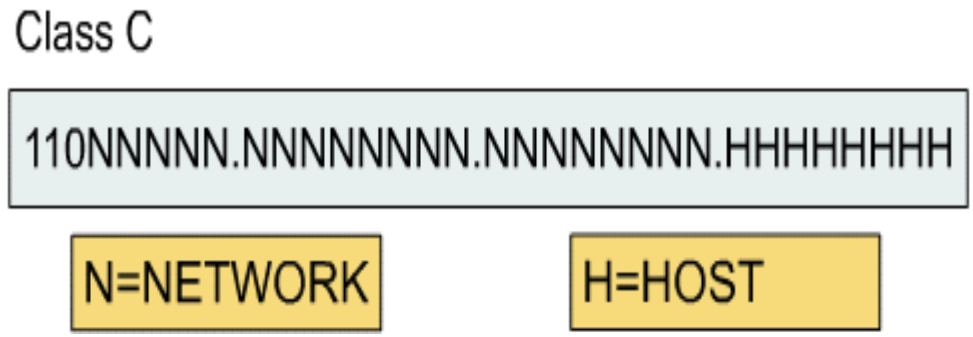
N=NETWORK

H=HOST

- The first 2 bits of a Class B address is always 10.
- The first two octets to identify the network part of the address.
- Possible network address from 128.0.0.0 to 191.255.0.0.
- The remaining two octets can be used for the host portion of the address.
- Class B network have up to 2^{16} – 2 or 65.534 possible IP addresses.

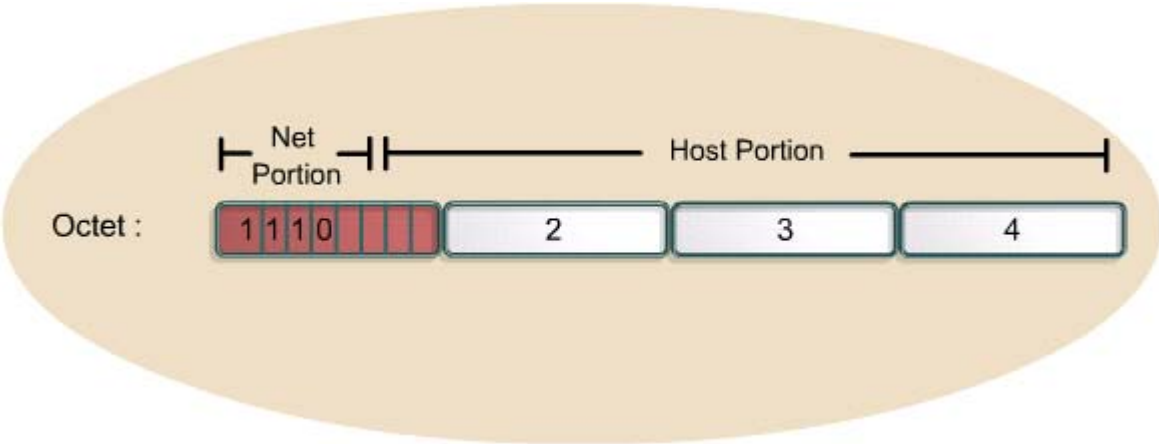
Class C Addresses





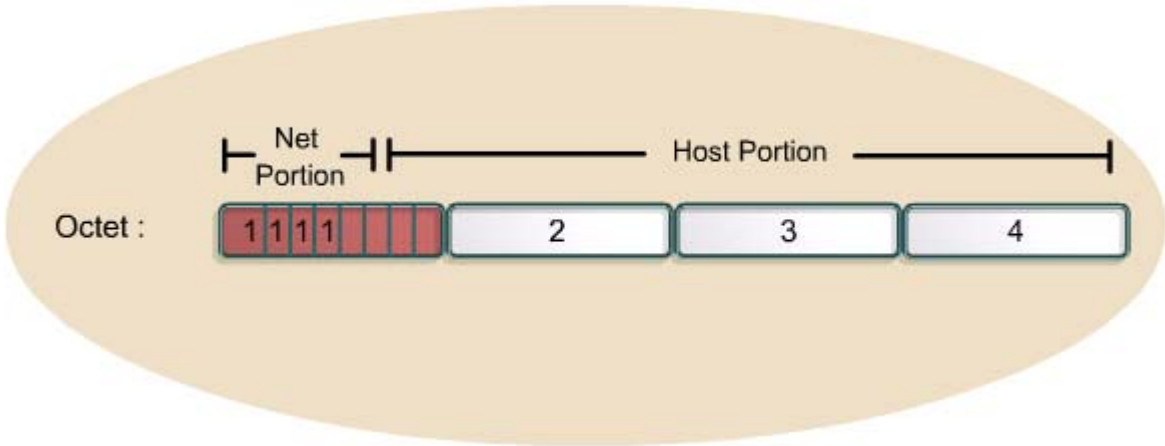
- The first 3 bits of a Class C address is always 110.
- The first three octets to identify the network part of the address.
- Possible network address from 192.0.0.0 to 223.255.255.0.
- The remaining last octet can be used for the host portion of the address.
- Class C network have up to 2^8 – 2 or 254 possible IP addresses.

Class D Address



- The Class D address class was created to enable multicasting in an IP address.
- A multicast address is a unique network address that directs packets with that destination address to predefined groups of IP addresses.
- Therefore, a single station can simultaneously transmit a single stream of data to multiple recipients

Class E Address



- A Class E address has been defined. However, the Internet Engineering Task Force (IETF) reserves these addresses for its own research.
- Therefore, no Class E addresses have been released for use in the Internet.
- The first four bits of a Class E address are always set to 1s. Therefore, the first octet range for Class E addresses is 11110000 to 11111111, or 240 to 255.

IP address range

IP address class	IP address range (First Octet Decimal Value)
Class A	1-126 (00000001-01111110) *
Class B	128-191 (10000000-10111111)
Class C	192-223 (11000000-11011111)
Class D	224-239 (11100000-11101111)
Class E	240-255 (11110000-11111111)

Determine the class based on the decimal value of the first octet

* 127 (011111111) is a Class A address reserved for loopback testing and cannot be assigned to a network.

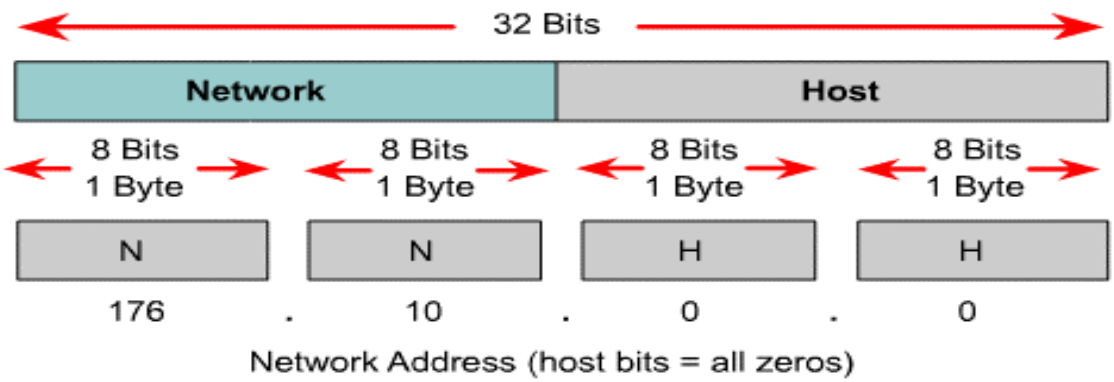
IP Addressing

3. Special IP Address

Reserved IP addresses

- Network address
- Broadcast address

Network Address



This class B address has all of its host bits set to zero. That is why it is identified as the network address.

- A network number is the address of the network itself.
- It is not the address of any host on the network.
- Network numbers are reserved and cannot be assigned to any host.
- An IP address that ends with binary 0s in all host bits is reserved for the network address.

Network Numbers by Class

- Following are examples of network numbers.
- Notice that the entire host portion is 0.

	1st octet	2nd octet	3rd octet	4th octet
Class A	63	0	0	0
Class B	142	56	0	0
Class C	209	126	155	0

- Network numbers are reserved, and cannot be assigned to any workstation.

Network Address Numbers

How do you write a network number?

Set the entire host portion to all zeros.

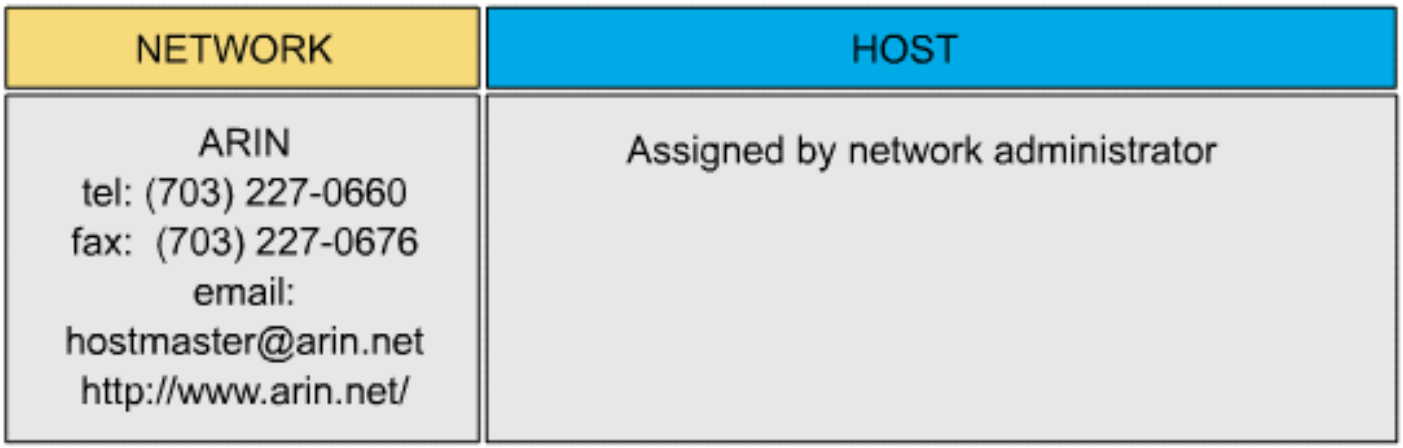
84.124.51.1 (host address)

84.0.0.0 (network number)

170.98.34.2 (host address)

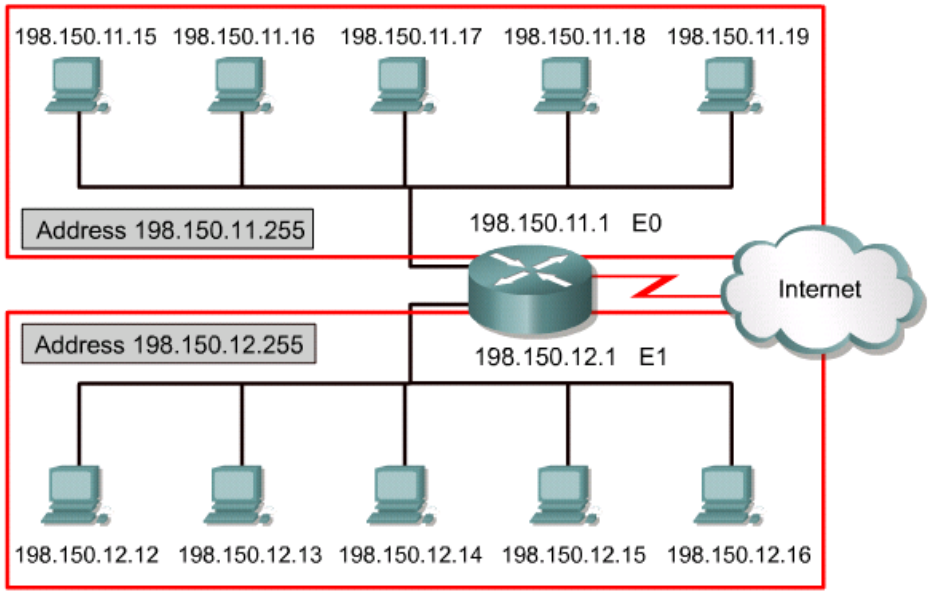
170.98.0.0 (network number)

The Network Number



- Because the network number provides logical order, it can *not* be randomly assigned.
- One organization administrates IP addressing.
- Originally, an organization known as the Internet Network Information Center (InterNIC) handled this procedure.
- InterNIC no longer exists and has been succeeded by the Internet Assigned Numbers Authority (IANA). IANA carefully manages the remaining supply of IP addresses to ensure that duplication of publicly used addresses does not occur.

Broadcast Address



- Packets sent to a broadcast address will be sent to all hosts on the network.
- A broadcast address is not the address of any host on the network.
- Broadcast addresses are reserved and cannot be assigned to any host.
- An IP address that ends with binary 1s in all host bits is reserved for the broadcast address.

Broadcast Addresses by Class

- Following are examples of broadcast addresses.
- Notice that the entire host portion is 255.

	1st octet	2nd octet	3rd octet	4th octet
Class A	**63**	**255**	**255**	**255**
Class B	**142**	**56**	**255**	**255**
Class C	**209**	**126**	**155**	**255**

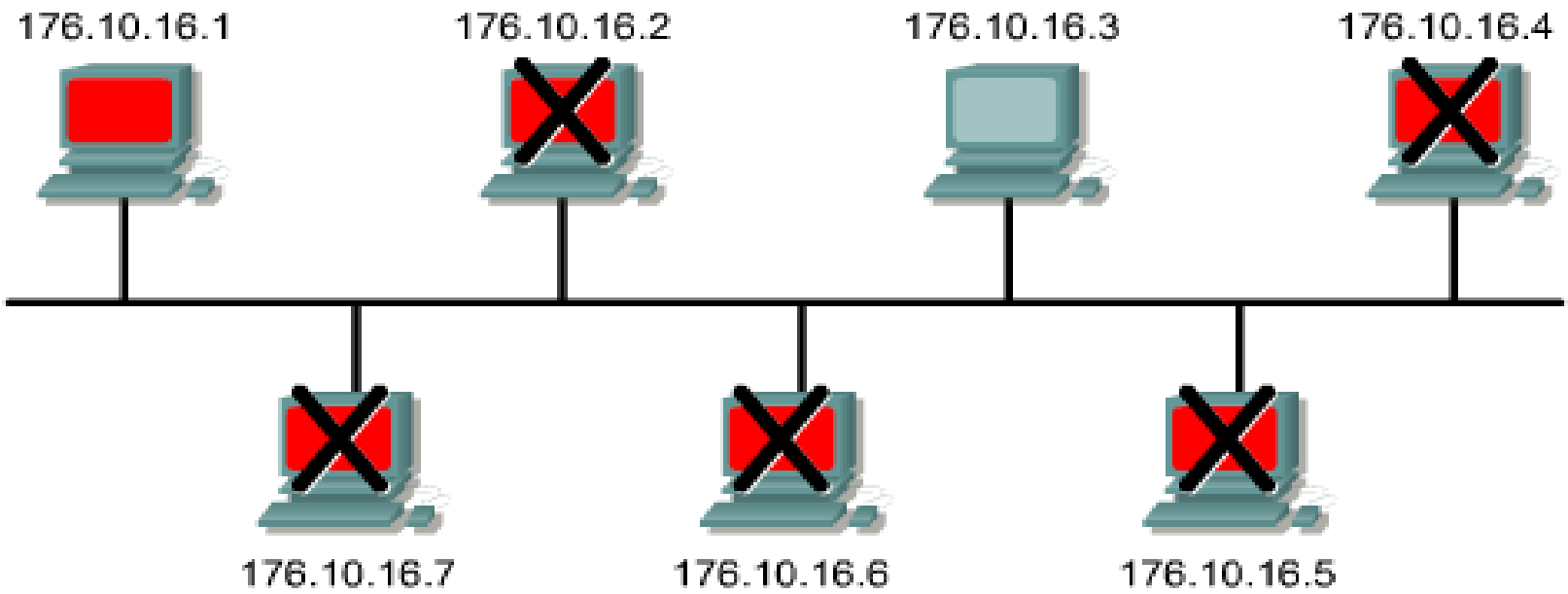
- Broadcast addresses are reserved, and cannot be assigned to any workstation.

Broadcast Addresses

- How do you write a broadcast address?
  - Set the entire host portion to all ones.
    - 84.124.51.1 (host address)
    - 84.255.255.255 (broadcast address)

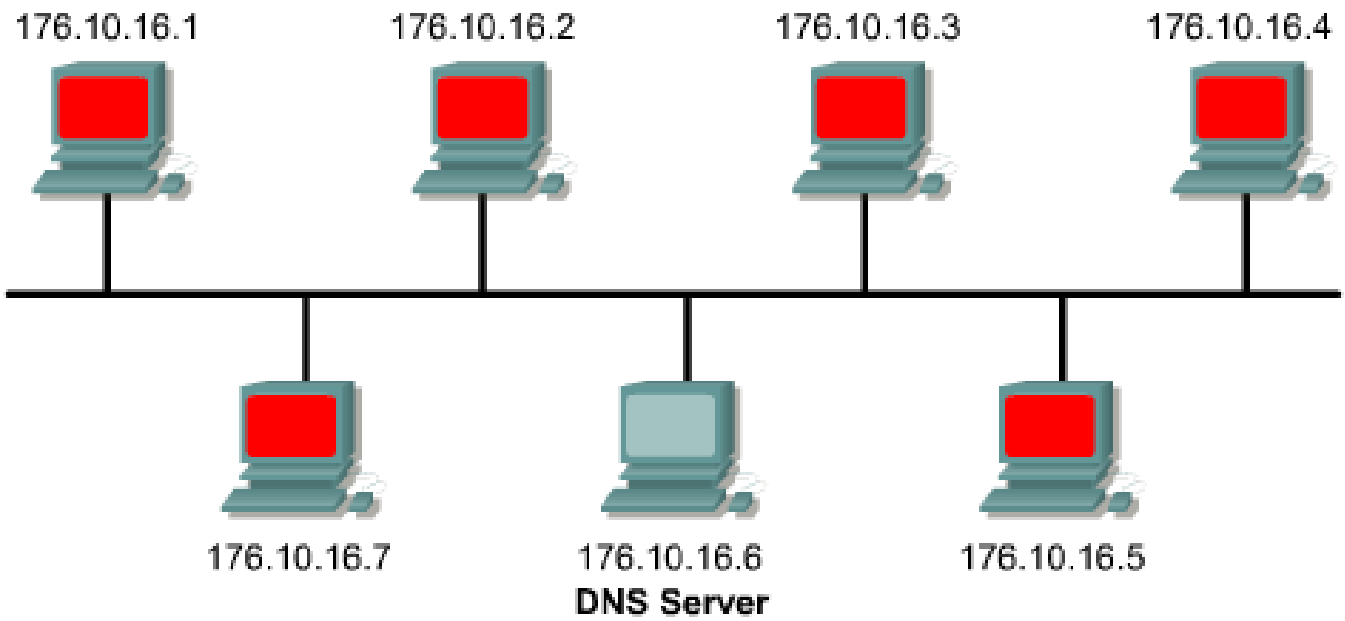
    - 170.98.34.2 (host address)
    - 170.98.255.255 (broadcast address)

Unicast Transsmision

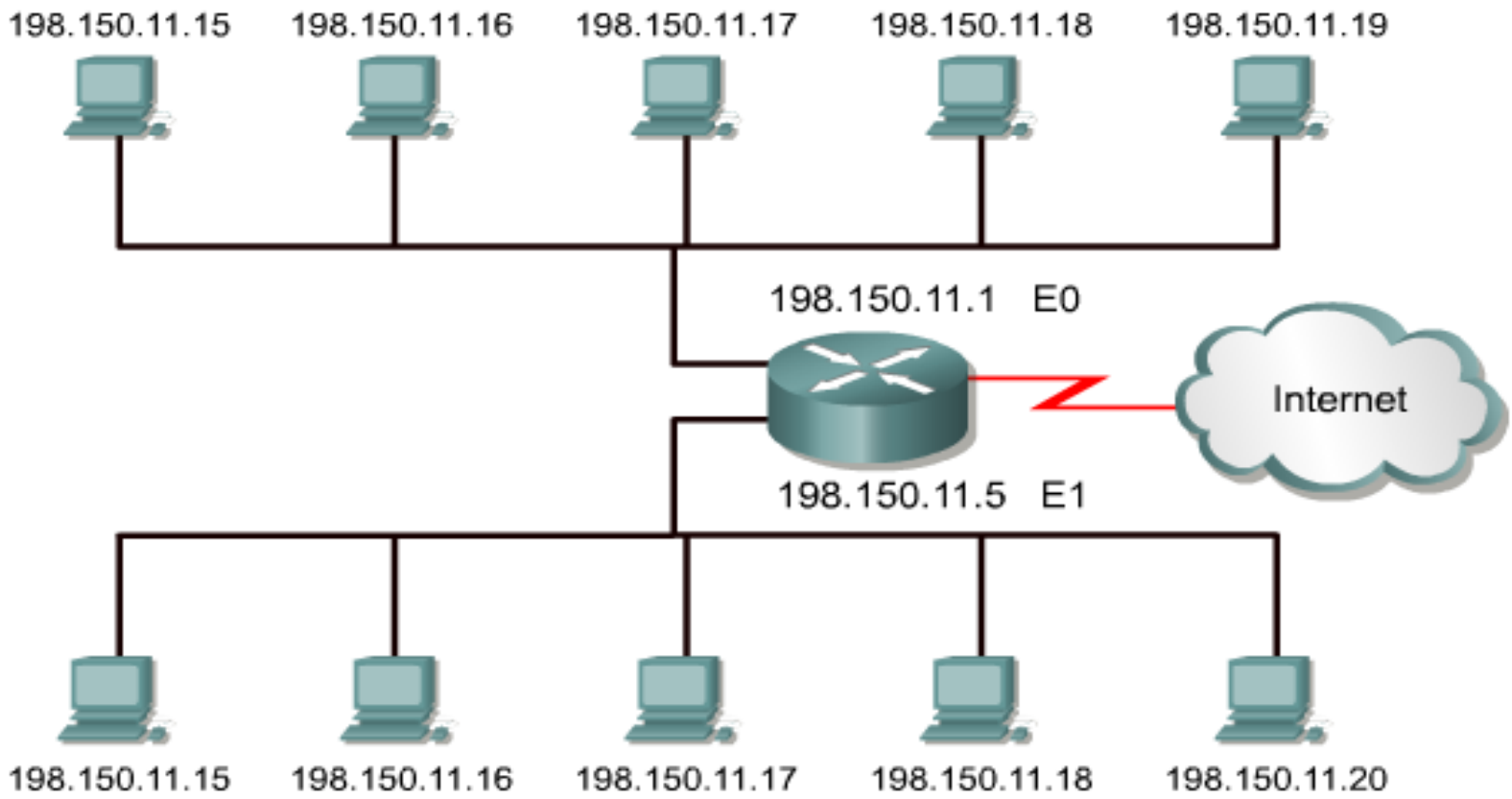


Broadcast Transmission

- The broadcast that would be sent out to all devices on that network would include a destination address of 176.10.255.255.



Public IP addresses



Required Unique Address

Private IP Addresses

Class	RFC 1918 internal address range
A	10.0.0.0 to 10.255.255.255
B	172.16.0.0 to 172.31.255.255
C	192.168.0.0 to 192.168.255.255

IP Addressing

4. Lab IP Address

Lab 1

1. What is the decimal and binary range of the first octet of class B IP addresses?
   - Decimal: 128 – 191
   - Binary: 10000000 – 10111111
2. Which octet(s) represent the network portion of a class C IP address?
   - The first three octets
3. Which octet(s) represent the host portion of a class A IP address?
   - The last three octets

Lab 2

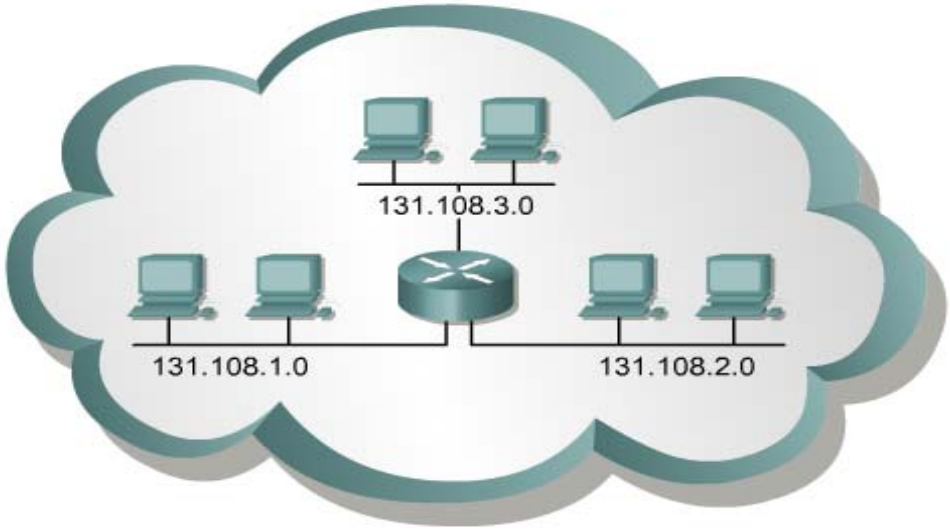
Host IP Address	Address Class	Network Address	Host Address	Broadcast Address
218.14.55.137				
123.1.1.15				
150.127.221.244				
194.125.235.199				
175.12.239.244				

Lab 3 – Valid IP Address

1. 150.100.255.255
2. 175.100.255.18
3. 1.25.26.27
4. 188.258.221.176
5. 195.234.253.0
6. 0.123.214.5
7. 100.0.0.23
8. 127.34.25.189
9. 224.156.217.73

Subnetting

Introduction to Subnetting

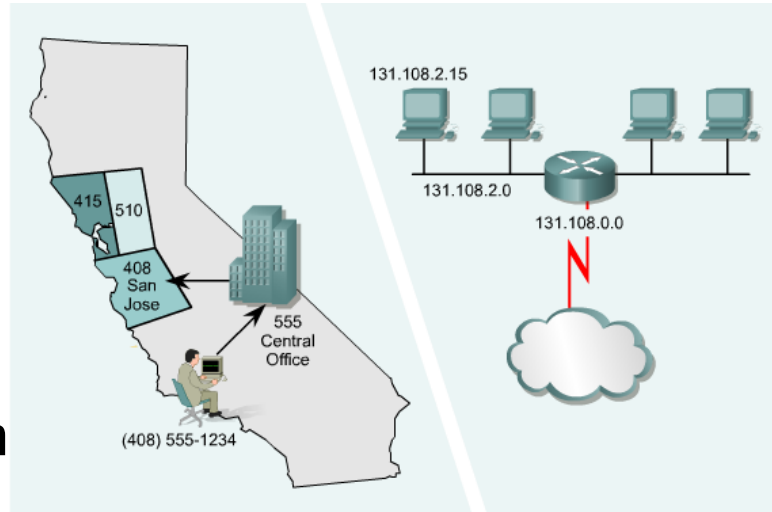


- Subnetting is another method of managing IP addresses.
- This method of dividing full network address classes into smaller pieces has prevented complete IP address exhaustion
- As a system administrator it is important to understand subnetting as a means of dividing and identifying separate networks throughout the LAN.
- It is not always necessary to subnet a small network.
- However, for large or extremely large networks, subnetting is required

Reasons for Subnetting

- Reduce the size of a broadcast domain.
- Improve network security.
- Implement the hierarchical managements.

Introduction to Subnetting



- Subnetting a network means to use the subnet mask to divide the network and break a large network up into smaller, more efficient and manageable segmen or subnets.
- Subnet addresses include the network portion, plus a subnet field and a host field.
- To create a subnet address, a network administrator borrows bits from the host field and designates them as the subnet field

Classes of Network IP addresses

Class A	Network	Host		
Octet	1	2	3	4

Class B	Network		Host	
Octet	1	2	3	4

Class C	Network			Host
Octet	1	2	3	4

Class D	Host			
Octet	1	2	3	4

Class D addresses are used for multicast groups. There is no need to allocate octets or bits to separate network and host addresses. Class E addresses are reserved for research use only.

Subdividing Class C address

Class C network address 192.168.10.0

11000000.10101000.00001010.00000000
N . N . N . H

11000000.10101000.00001010.00000000
N . N . N . sN H

In this example three bits have been assigned to designate the subnet.

Subnetting

- Subnetworks are smaller divisions of network.
- Subnet addresses include the Class A, Class B, or Class C network portion, plus a subnet field and a host field.
- To create a subnet address, a network administrator borrows bits from the original host portion and designates them as the subnet field.
- Subnet addresses are assigned locally, usually by a network administrator.

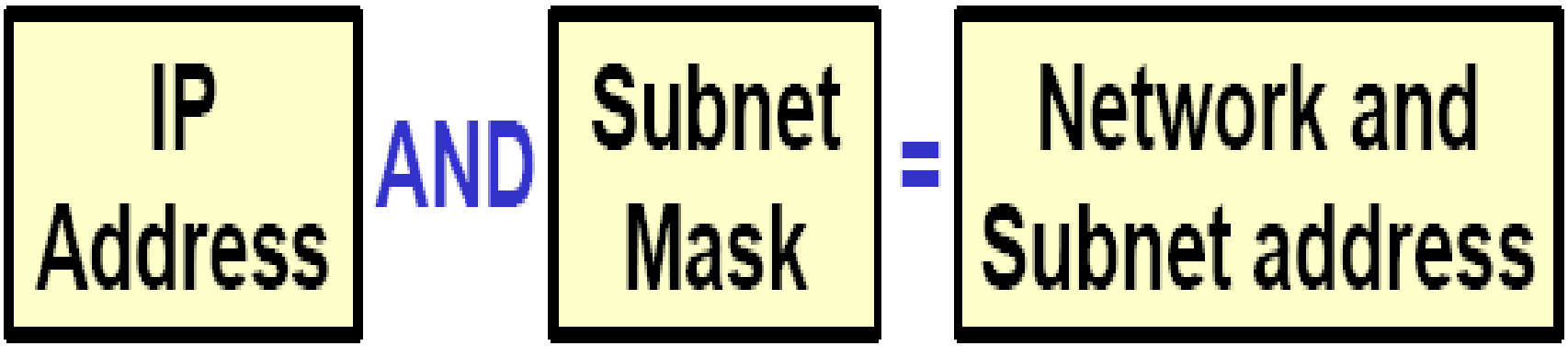
Establishing the Subnet Mask Address

Slash format	/25	/26	/27	/28	/29	/30	N/A	N/A
Mask	128	192	224	240	248	252	254	255
Bits borrowed	1	2	3	4	5	6	7	8
Value	128	64	32	16	8	4	2	1
Total Subnets		4	8	16	32	64		
Usable Subnets		2	6	14	30	62		
Total Hosts		64	32	16	8	4		
Usable Hosts		62	30	14	6	2		

Applying The Subnet Mask

Subnetwork #	Subnetwork ID	Host Range	Broadcast ID
0	192.168.10.0	.1--.30	192.168.10.31
1	192.168.10.32	.33--.62	192.168.10.63
2	192.168.10.64	.65--.94	192.168.10.95
3	192.168.10.96	.97--.126	192.168.10.127
4	192.168.10.128	.129--.158	192.168.10.159
5	192.168.10.160	.161--.190	192.168.10.191
6	192.168.10.192	.193--.222	192.168.10.223
7	192.168.10.224	.225--.254	192.168.10.255

Why we need to know Boolean ops?



Network layer performs the Boolean operations in order to find the network ID of a subnet.

Default subnet mask: Example

- 192.168.2.100 / 255.255.255.0.
  - 11000000.10101000.00000010.01100100
  - 11111111.11111111.11111111.00000000
  - 11000000.10101000.00000010.00000000
- Class C network:
  - 24 bits for network portion.
  - 0 bits for subnet portion.
  - 8 bits for host portion.
- Subnet address: 192.168.2.0.

Subnet mask: Example

- 172.16.65.100 / 255.255.240.0.
  - 10101100.00010000.01000001.01100100
  - 11111111.11111111.11110000.00000000
  - 10101100.00010000.01000000.00000000
- Class B network:
  - 16 bits for network portion.
  - 4 bits for subnet portion.
  - 12 bits for host portion.
- Subnet address: 172.16.64.0.

How many bits can I borrow?

- All of subnet bits are:
  - 0 : reserved for network address.
  - 1 : reserved for broadcast address.
- The minimum bits you can borrow is: 2 bits.
- The maximum bits you can borrow is:
  - A: 22 bits ~ 2^{22} - 2 = 4.194.302 subnets.
  - B: 14 bits ~ 2^{14} - 2 = 16.382 subnets.
  - C: 06 bits ~ 2^{6} - 2 = 62 subnets.

Subnetting

Examples

Subnetting Example

- Given network 172.16.0.0.
- We need 8 usable subnets and up to 1000 hosts on each subnet.

Method calculating a subnet

1. Determine the class of network and default subnet mask.
2. Determine how many bits to borrow.

   Determine the subnet mask and the actual number of subnets and hosts.
3. Determine the ranges of host address for each subnet. Choose the subnets that you want to use.

Calculating a subnet: STEP 1

- Given network 172.16.0.0.
- We need 8 usable subnets and up to 1000 hosts on each subnet
- Determine the Class of network
  - Class B
- Determine the default subnet mask
  - 255.255.0.0

Calculating a subnet: STEP 2

- Given network 172.16.0.0.
- We need 8 usable subnets and up to 1000 hosts on each subnet
- Number of subnets <= $2^n - 2$,

  with n is number of bits that are borrowed.
- Number of hosts <= $2^m - 2$,

  with m is number of remaining bits.
- Determine how many bits to borrow from the host portion from requirement:
  - 8 subnets.
  - 1000 hosts on each subnet.

Calculating a subnet: STEP 2 (Cont.)

- Given network 172.16.0.0.
- We need 8 usable subnets and up to 1000 hosts on each subnet
- Choose n = 4:

  Number of possible subnets is:

  $2^4 - 2 = 14$
- Number of possible hosts on each subnet is:

  $2^{(16-4)} - 2 = 4094$
- *Other choice n = 5 , n = 6 ?*

Calculating a subnet: STEP 2 (Con't.)

128	64	32	16	8	4	2	1	
1	0	0	0	0	0	0	0	= 128
1	1	0	0	0	0	0	0	= 192
1	1	1	0	0	0	0	0	= 224
1	1	1	1	0	0	0	0	= 240
1	1	1	1	1	0	0	0	= 248
1	1	1	1	1	1	0	0	= 252
1	1	1	1	1	1	1	0	= 254
1	1	1	1	1	1	1	1	= 255

➔ **The subnet mask: 255.255.240.0.**

Calculating a subnet: STEP 3

- Given network 172.16.0.0.
- We need 8 usable subnets and up to 1000 hosts on each subnet
- Determine the subnets and the ranges of host address for each subnet. Including:
  - Sub-network addresses
  - Range of usable IP addresses
  - Sub-network broadcast addresses

Calculating a subnet: STEP 3 (Cont.)

- Determine the subnets from 4 borrowed bits from the host portion (last 2 bytes):
  - 1st subnet: .00000000.00000000
  - 2nd subnet: .00010000.00000000
  - 3rd subnet: .00100000.00000000
  - ...
  - 15th subnet: .11110000.00000000

Calculating a subnet: STEP 3 (Cont.)

No	Sub-network address	Possible host address	Broadcast address	Use ?
0	172.16.0.0	172.16.0.1 – 172.16.15.254	172.16.15.255	N
1	172.16.16.0	172.16.16.1 – 172.16.31.254	172.16.31.255	Y
2	172.16.32.0	172.16.32.1 – 172.16.47.254	172.16.47.255	Y
..	..	..	..	..
..	..	..	..	..
13	172.16.208.0	172.16.208.1 – 172.16.223.254	172.16.223.255	Y
14	172.16.224.0	172.16.224.1 – 172.16.239.254	172.16.239.255	Y
15	172.16.240.0	172.16.240.1 – 172.16.255.254	172.16.255.255	N

Addresses are loose by subnetting.

Number of Bits Borrowed	Number of Subnets Created	Number of Hosts Per Subnet	Total Number of Hosts	Percent Used
2	2	62	124	49%
3	6	30	180	71%
4	14	14	196	77%
5	30	6	180	71%
6	62	2	124	49%

- Network administrator must strike a balance between the number of subnets required, the hosts per subnet that is acceptable, and the resulting waste of addresses.

Quick Refference Subnetting Chart

Decimal notation for first Host octet	Number of Subnets	Number of Class A Hosts per Subnet	Number of Class B Hosts per Subnet	Number of Class C Hosts per Subnet
.192	2	4,194,302	16,382	62
.224	6	2,097,150	8,190	30
.240	14	1,048,574	4,094	14
.248	30	524,286	2,046	6
.252	62	262,142	1,022	2
.254	126	131,070	510	-
.255	254	65,534	254	-

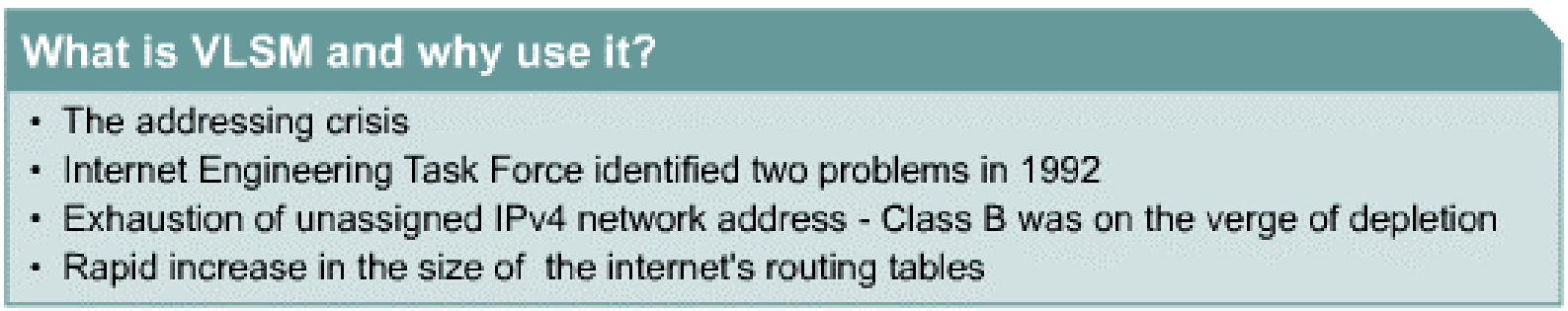
VLSM

VLSM

- What is VLSM and why is it used?
- A waste of space
- When to use VLSM?
- Calculating subnets with VLSM
- Configuring VLSM

What is VLSM and why is it used?

- With the growth of the Internet and TCP/IP, virtually every enterprise must now implement an IP addressing scheme.
- But:
  - The original architects of TCP/IP offered a limited capacity for growth..
  - IP version 4 (IPv4) offered an inefficient allocation of addresses.



- Solution???

What Is VLSM and Why Is It Used?

- **These are:**

What is VLSM and why use it?

- Short term extensions to IPv4
- Subnetting 1985
- Variable length subnetting 1987
- Classless Interdomain Routing 1993
- Private IP addresses
- Network Address Translation (NAT)

What is VLSM and why use it?

- Ultimate solution: IPv6 128 bit address space
- Allows for: 340,283, 366, 920, 938, 463, 374, 607, 431, 768, 211, 456 possibilities

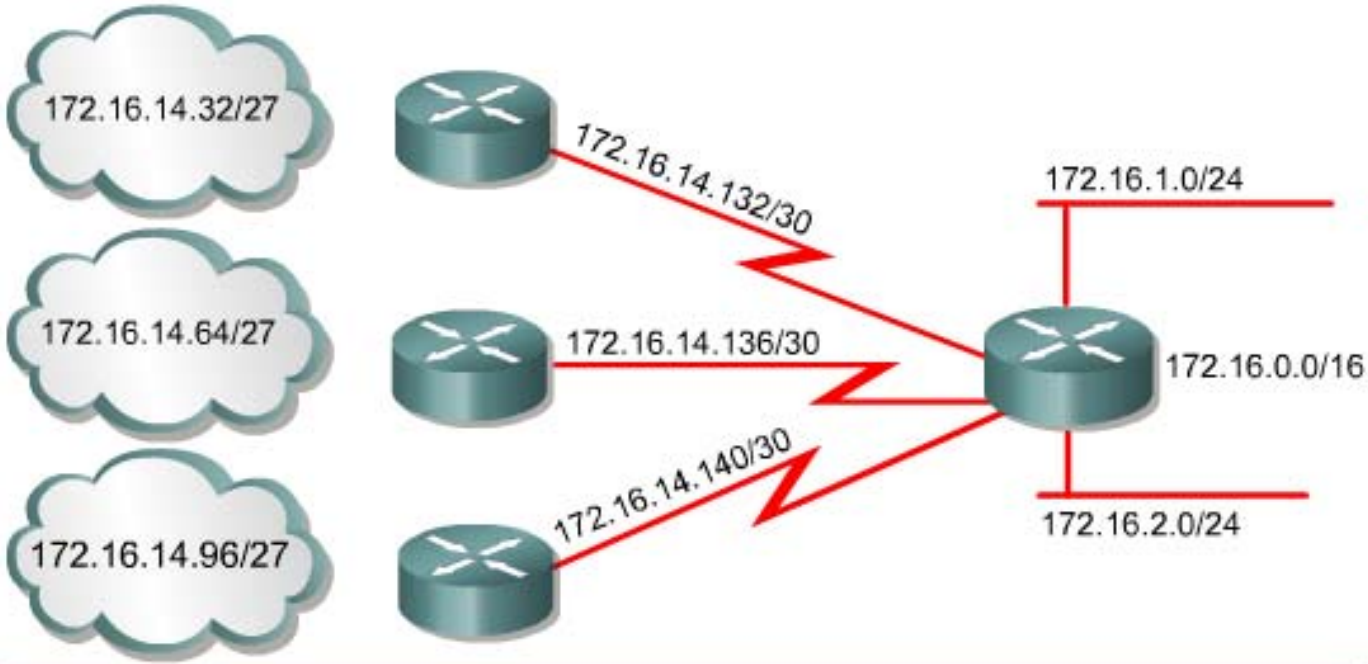
What Is VLSM and Why Is It Used?

- One technique is called Variable-Length Subnet Masks (VLSM).
- VLSM is a feature that allows a single autonomous system to have networks with different subnet masks >>> VLSM allows an organization to use more than one subnet mask within the same network address space.
- In order to use VLSM, a network administrator must use a routing protocol that supports it.

VLSM is supported by:

- OSPF
- Integrated IS-IS
- EIGRP
- RIP v2
- Static routing

What Is VLSM and Why Is It Used?



- Subnet 172.16.14.0/24 is divided into smaller subnets
- Subnet with one mask (/27)
- Then further subnet one of the unused /27 subnets into mutiple /30 subnets

A Waste of Space

- In the past, it has been recommended that the first and last subnet not be used.
- But IP address depletion has become of real concern, it has become acceptable practice to use the first and last subnets in a subnetted network in conjunction with VLSM.
- Note: *ip subnet-zero*: can be used subnet zero, *no ip subnet-zero*: cannot be used subnet zero. From IOS v 12.0, Cisco routers use subnet zero by default.
- A Waste of Space also because of simple address for point-to-point links.

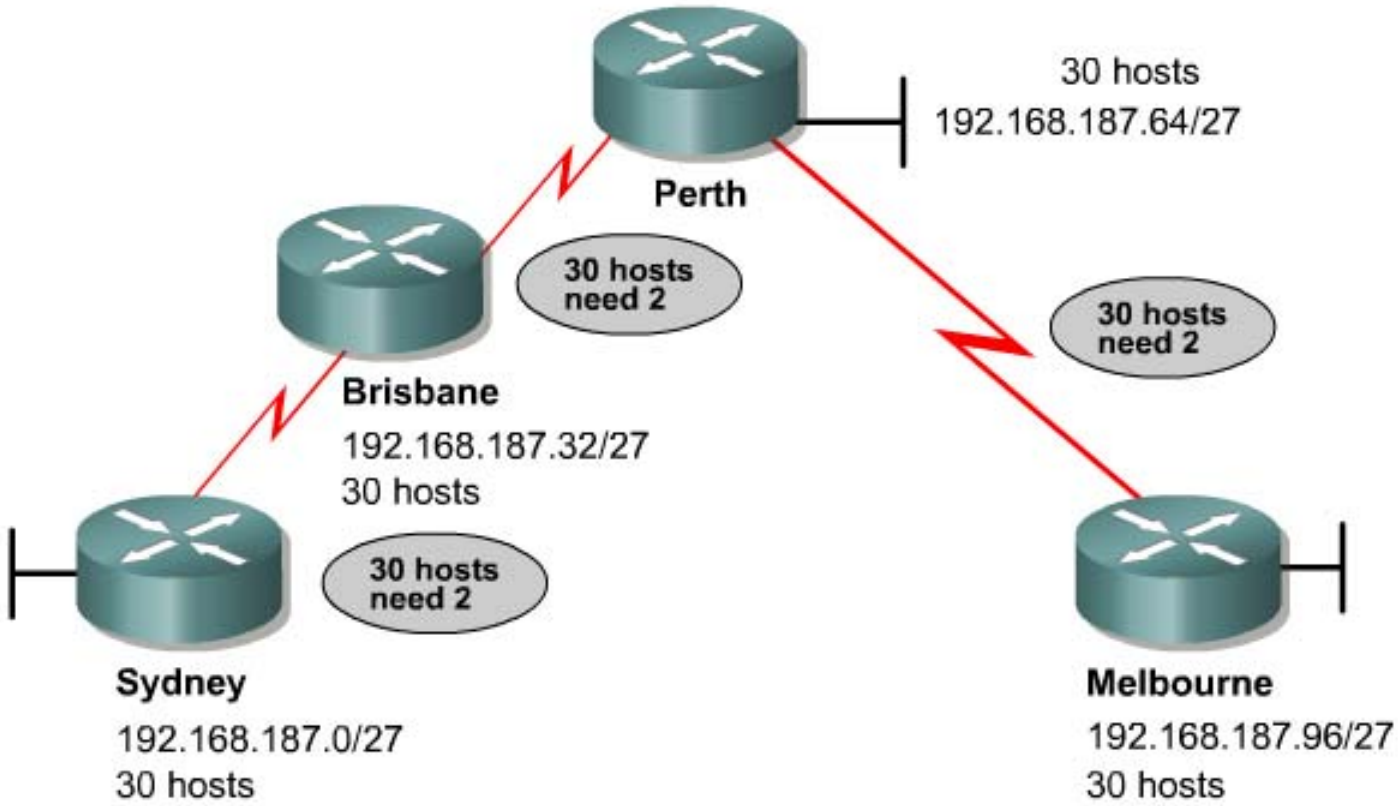
A Waste of Space

- **For example:**

Subnet Number	Subnet Address	
Subnet 0	192.168.187.0	/27
Subnet 1	192.168.187.32	/27
Subnet 2	192.168.187.64	/27
Subnet 3	192.168.187.96	/27
Subnet 4	192.168.187.128	/27
Subnet 5	192.168.187.160	/27
Subnet 6	192.168.187.192	/27
Subnet 7	192.168.187.224	/27

A Waste of Space

- **For example:**



When to Use VLSM?

- VLSM can be used to prevent waste of addresses.
- To apply VLSM to the addressing problem, we will break the default network address into subnets of variable sizes:
  - Large subnets are created for addressing LANs.
  - Very small subnets are created for WAN links and other special cases.

When to Use VLSM?

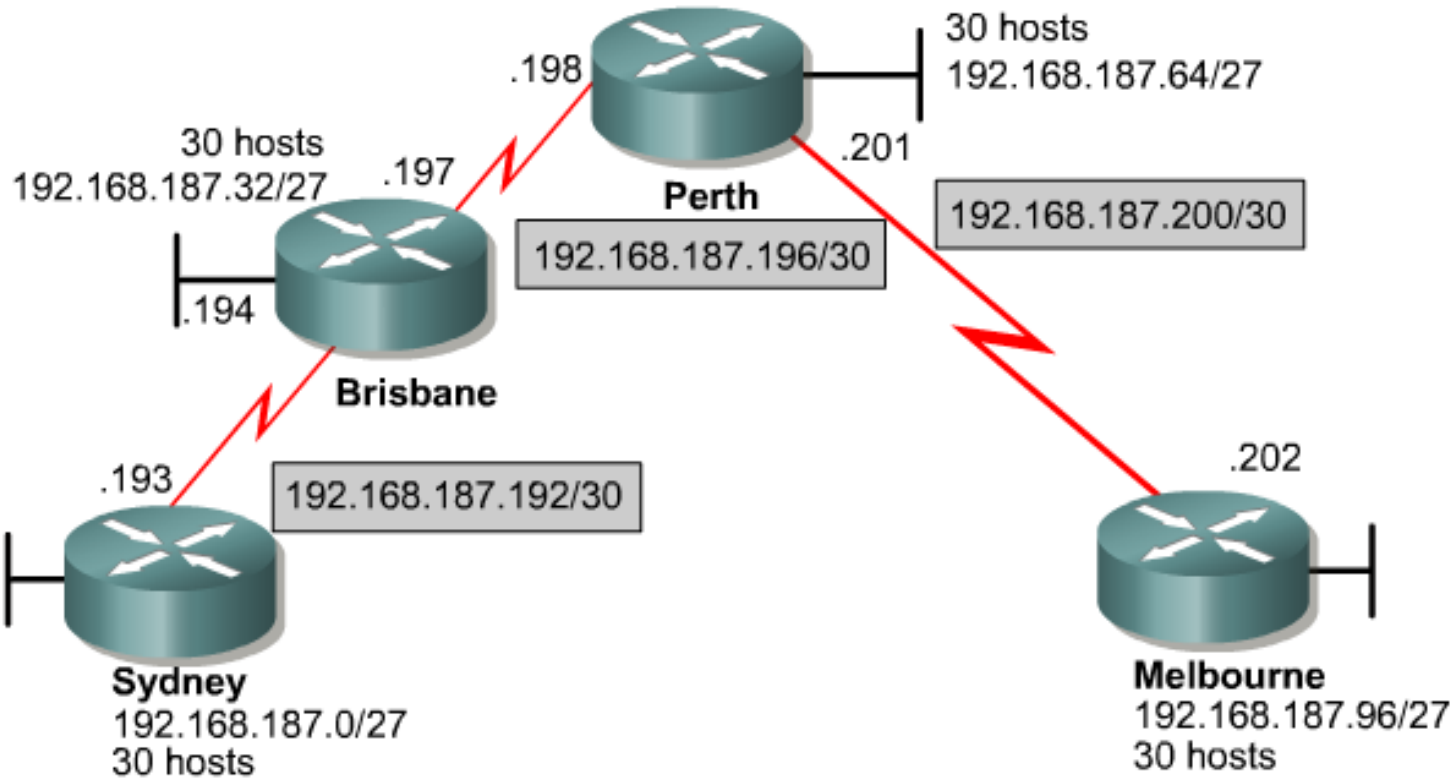
- **For example:**

Subnet Number	Subnet Address	
subnet 0	192.168.187.0	/27
subnet 1	192.168.187.32	/27
subnet 2	192.168.187.64	/27
subnet 3	192.168.187.96	/27
subnet 4	192.168.187.128	/27
subnet 5	192.168.187.160	/27
subnet 6	192.168.187.192	/27
subnet 7	192.168.187.224	/27

Subnet Number	Subnet Address	
sub-subnet 0	192.168.187.192	/30
sub-subnet 1	192.168.187.196	/30
sub-subnet 2	192.168.187.200	/30
sub-subnet 3	192.168.187.204	/30
sub-subnet 4	192.168.187.208	/30
sub-subnet 5	192.168.187.212	/30
sub-subnet 6	192.168.187.216	/30
sub-subnet 7	192.168.187.220	/30

When to Use VLSM?

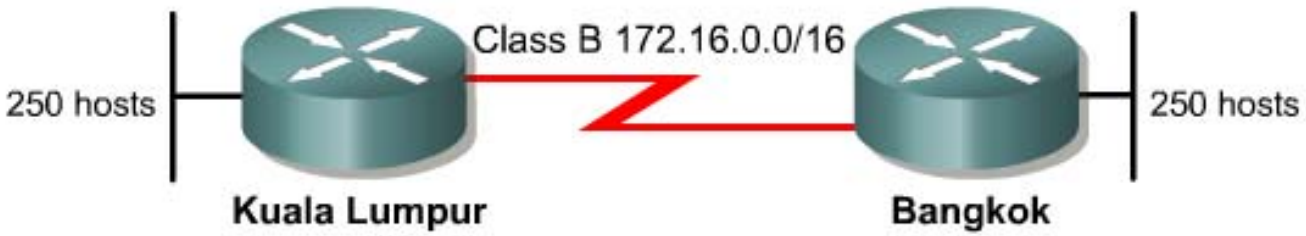
- **For example:**



Notice the /27 bit masks for the LANs, and the /30 for the serial links

Calculating Subnets with VLSM

- Look at the example in below which illustrates how to calculate subnets with VLSM.



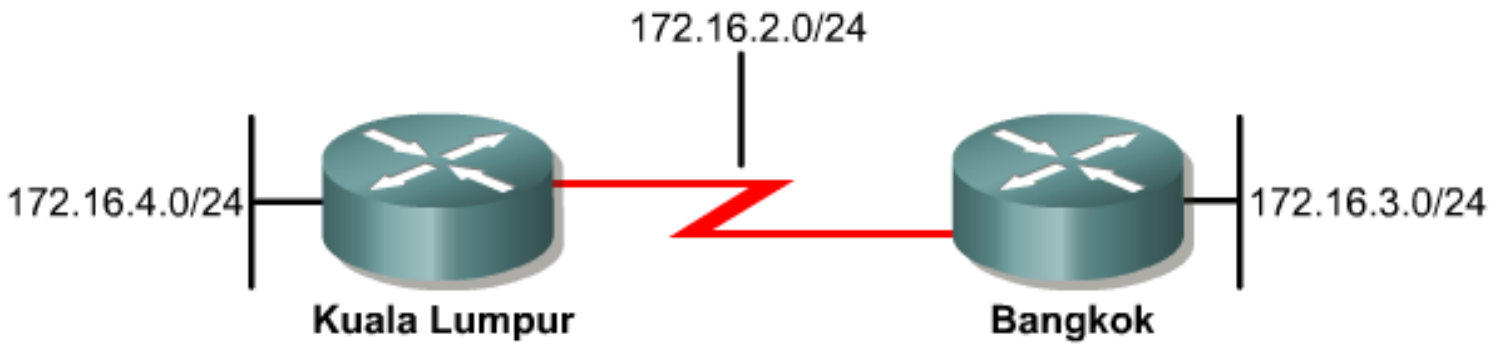
Each LAN must support over 250 hosts. The Class B network 172.16.0.0/16 can be subnetted with a 24-bit mask (255.255.255.0) to create large enough subnets for each LAN.

Calculating Subnets with VLSM

Subnetted Class B as 255.255.255.0

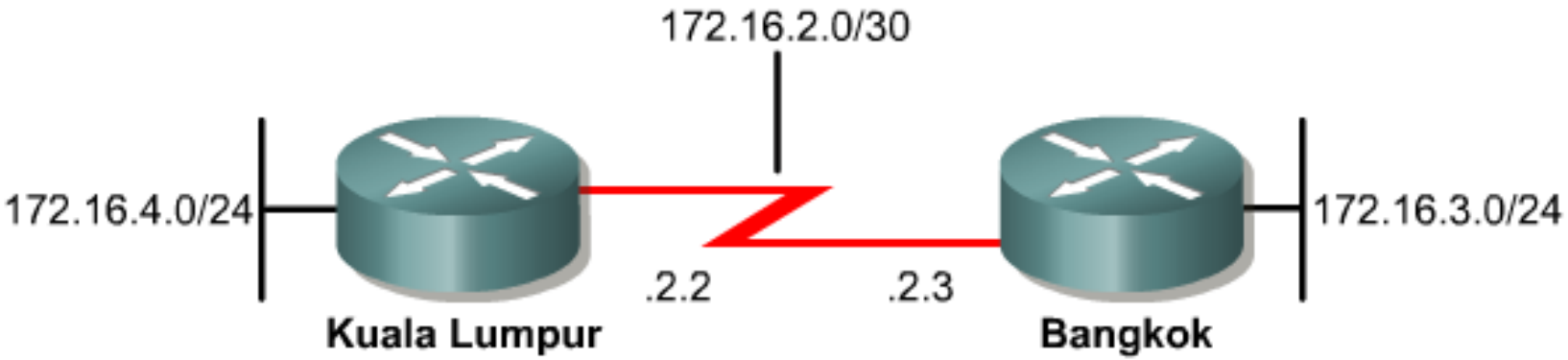
#	ID	Range	Broadcast
0	172.16.0.0	172.16.0.1 - 172.16.0.254	172.16.0.255
1	172.16.1.0	172.16.1.1 - 172.16.1.254	172.16.1.255
2	172.16.2.0	172.16.2.1 - 172.16.2.254	172.16.2.255
3	172.16.3.0	172.16.3.1 - 172.16.3.254	172.16.3.255
4	172.16.4.0	172.16.4.1 - 172.16.4.254	172.16.4.255
5	172.16.5.0	172.16.5.1 - 172.16.5.254	172.16.5.255
6	172.16.6.0	172.16.6.1 - 172.16.6.254	172.16.6.255
7	172.16.7.0	172.16.7.1 - 172.16.7.254	172.16.7.255
8	172.16.8.0	172.16.8.1 - 172.16.8.254	172.16.8.255
9	172.16.9.0	172.16.9.1 - 172.16.9.254	172.16.9.255
10	172.16.10.0	172.16.10.1 - 172.16.10.254	172.16.10.255
11	172.16.11.0	172.16.11.1 - 172.16.11.254	172.16.11.255
12	172.16.12.0	172.16.12.1 - 172.16.12.254	172.16.12.255
13	172.16.13.0	172.16.13.1 - 172.16.13.254	172.16.13.255
14	172.16.14.0	172.16.14.1 - 172.16.14.254	172.16.14.255
15	172.16.15.0	172.16.15.1 - 172.16.15.254	172.16.15.255

Calculating Subnets with VLSM



Each Link can support over 250 hosts, but the WAN link only needs two, one for each router interface. Therefore, 252 addresses would be wasted.

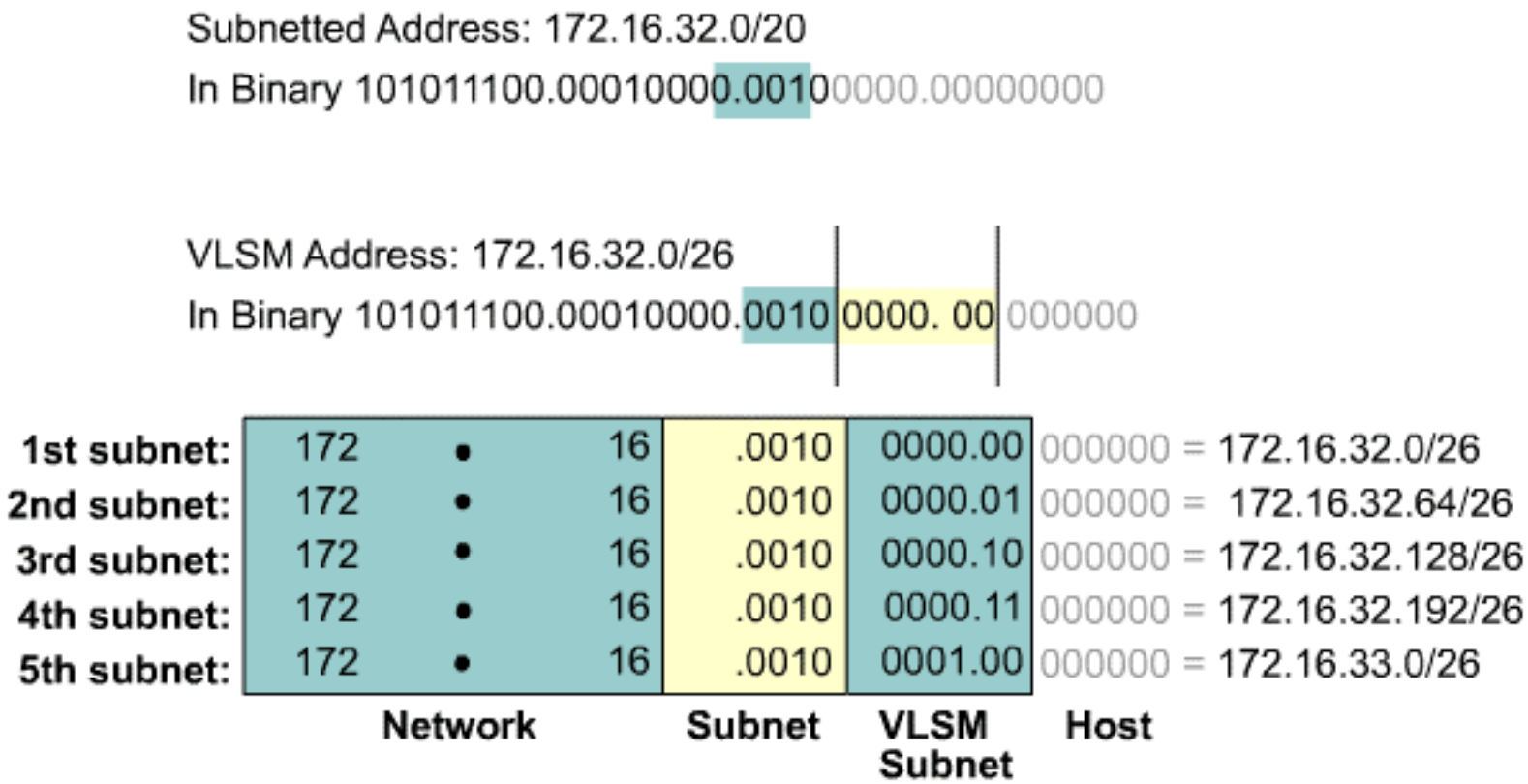
Calculating Subnets with VLSM



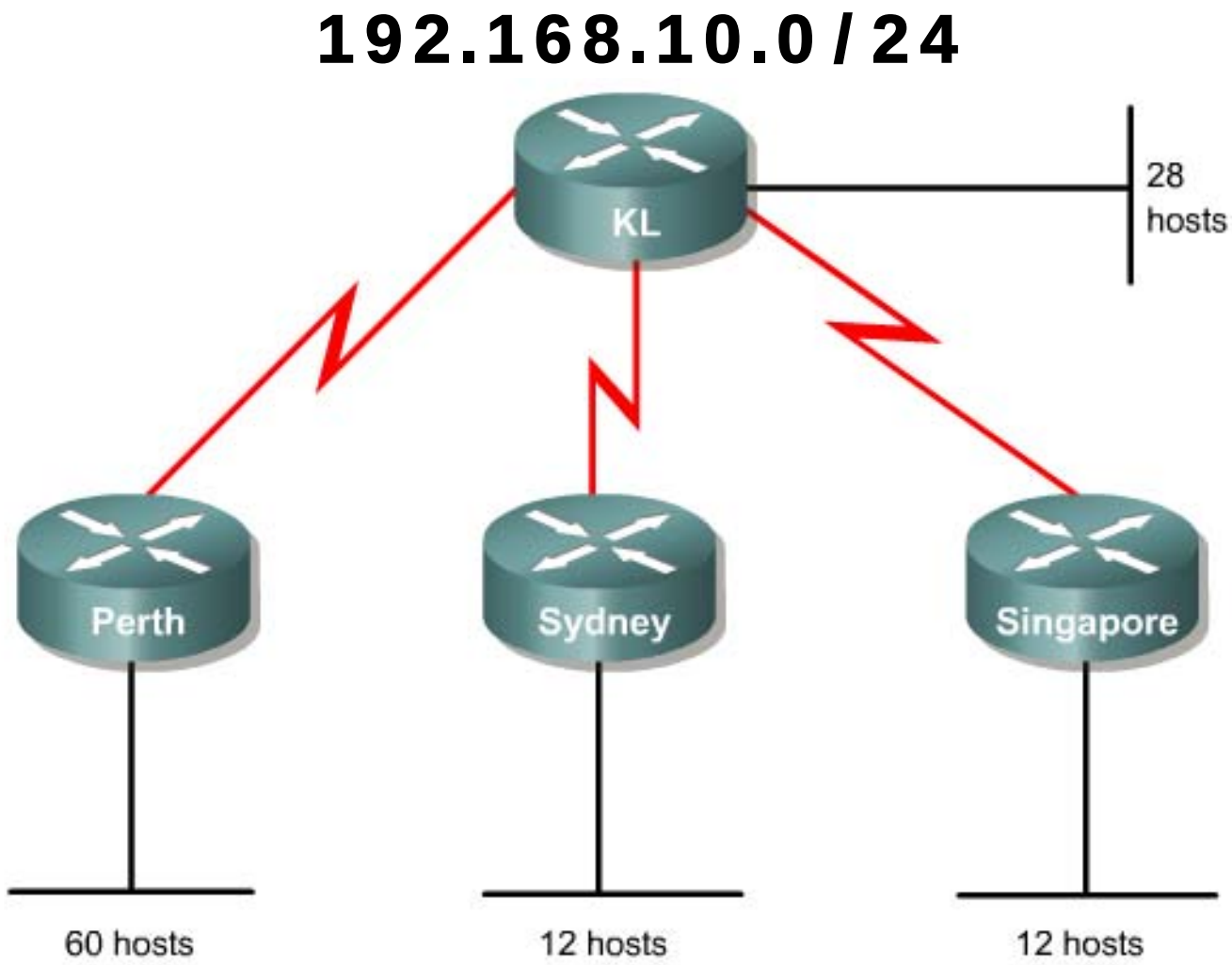
The /30 means that fewer addresses are lost.

Calculating Subnets with VLSM

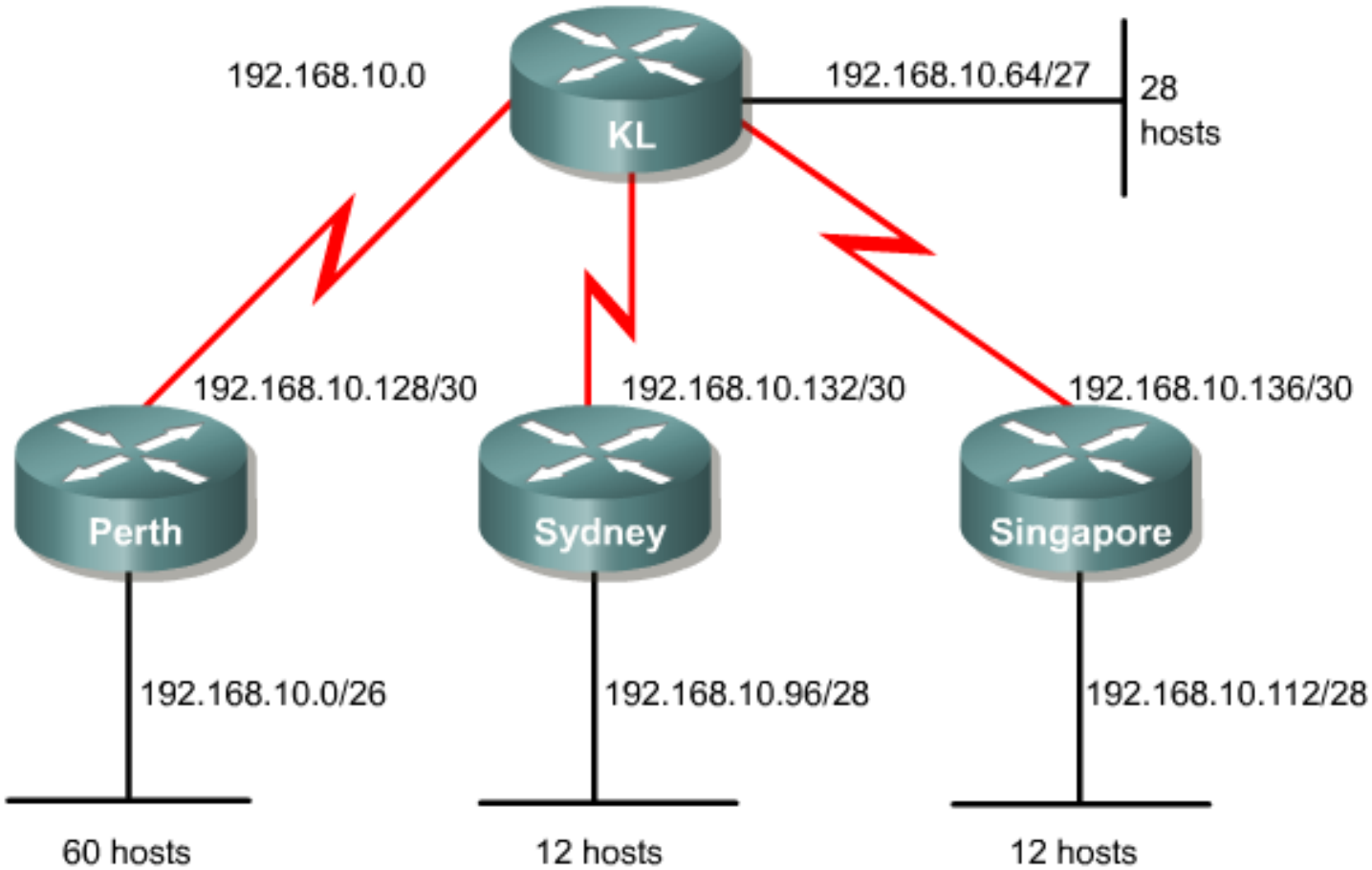
- The following illustrates calculating subnets with VLSM.



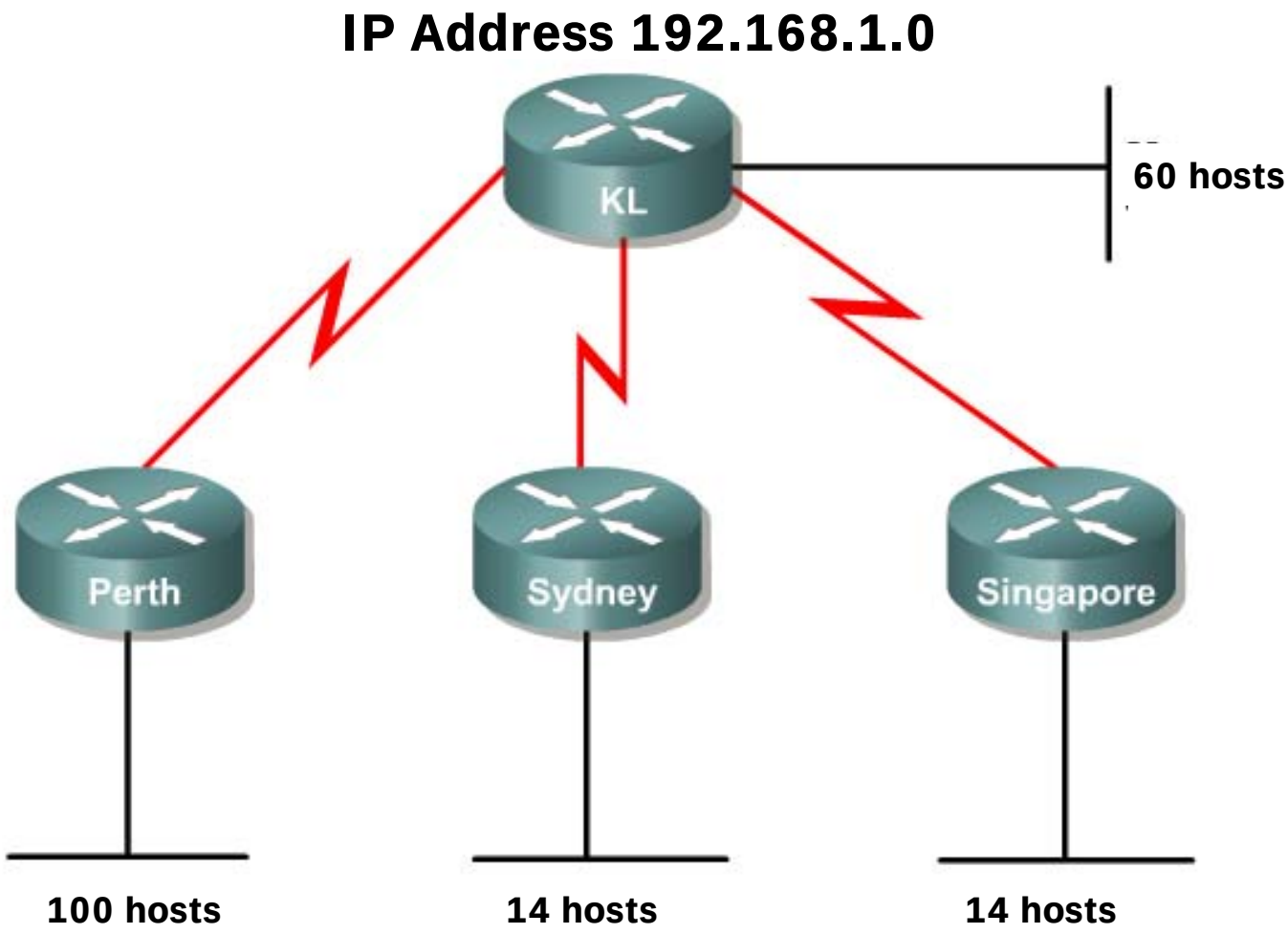
A Working VLSM Example



A Working VLSM Example



Examples


IP Address 192.168.1.0
KL
60 hosts
Perth
Sydney
Singapore
100 hosts
14 hosts
14 hosts

Good luck with this module!