ET0730

Chapter 5
Subnetting

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School of Electrical & Electronic Engineering

Objectives

- Explain the need of subnetting.
- Perform the Fixed-length Subnet Mask (FLSM) subnetting.
- Describe the limitations of FLSM.
- Explain the benefit of Variable-length Subnet Mask (VLSM)
- Perform the Variable-length Subnet Mask (VLSM) subnetting.

Outline

- What is “Subnetting”?
- How to do “Subnetting”?
- Number of Subnets
- Limitations of Fixed-length Subnet Mask (FLSM)
- Variable-Length Subnet Mask (VLSM)
- How to perform subnetting using VLSM?

What is "Subnetting"? (1)

- Very often a block of IP addresses (i.e. a range of IP addresses) is allocated to an organization.
- Example:
  - Given the IP address of 65.33.40.0/21, the address block is from 65.33.40.0 to 65.33.47.255.

Exercise:

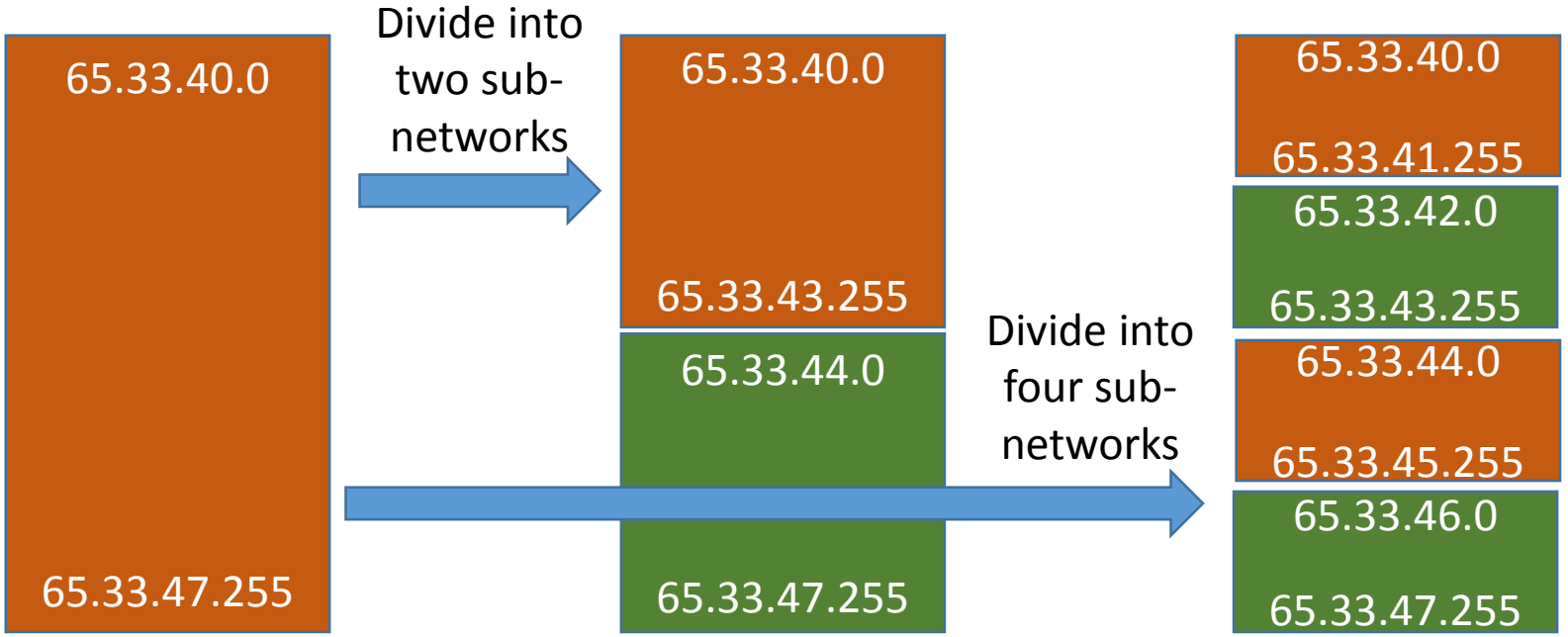
- Given the IP address of 65.33.40.0/21, prove that the address block is from 65.33.40.0 to 65.33.47.255.
- Answer:
  - Network prefix = 21, hence the IP address range is:
    - **01000001 00100001 00101**000 00000000 = **65.33.40.0**
    - **01000001 00100001 00101**000 00000001 = 65.33.40.1
    - **01000001 00100001 00101**000 00000010 = 65.33.40.2
    - Other combinations in between…
    - **01000001 00100001 00101**111 11111101 = 65.33.47.253
    - **01000001 00100001 00101**111 11111110 = 65.33.47.254
    - **01000001 00100001 00101**111 11111111 = **65.33.47.255**

Answer: (cont'd)

- Therefore, the IP address block (range) for 65.33.40.0/21 is 65.33.40.0 to 65.33.47.255.
- Notice that:
  - The first IP address, 65.33.40.0 cannot be assigned to a host since it is reserved as the Network ID.
  - The last IP address, 65.33.47.255 cannot be assigned to a host because it is reserved as broadcast IP address.

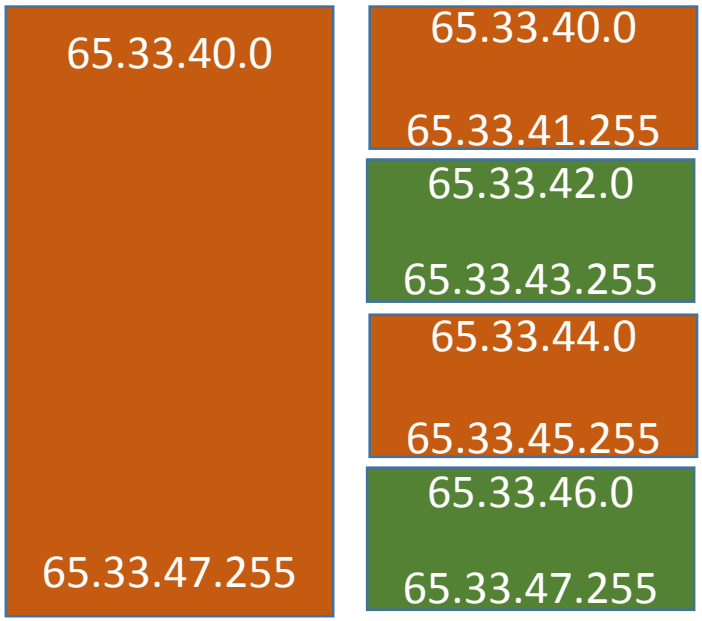
What is "Subnetting"? (2)

- Subnetting is the process of dividing a single address block into multiple logical networks.
- Each network can then be assigned to a different department or functional group.
- Example:



What is “Subnetting”? (3)

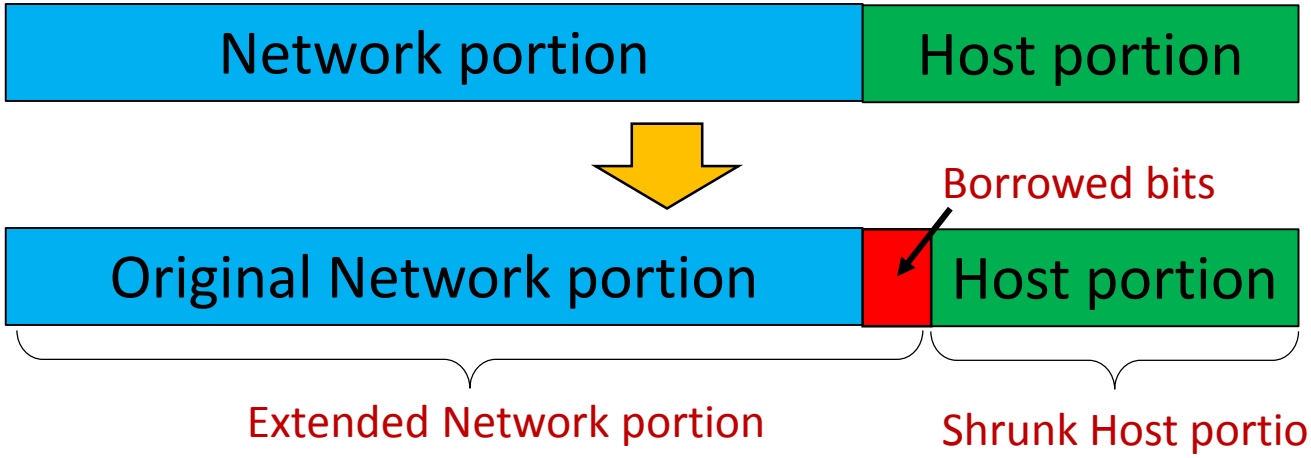
- The more subnets the address block is divided into, the smaller each subnet gets.
- Each subnet’s first IP address and last IP address are the Network ID and Broadcast Address respectively which cannot be assigned to hosts.
  - The overall number of available host addresses will be reduced.



Two addresses cannot be assigned to hosts

Eight addresses cannot be assigned to hosts

How to do “Subnetting”?



- To do subnetting, we “borrow” bits from the Host portion of the IP address block.
- The “borrowed bits” become part of the Network portion.
- The number of bits to be “borrowed”, *m*, depends on the number of subnets to be created.

$2^m \geq$ number of subnet

Example:

- Divide the address block 65.33.40.0/21 into 4 subnets. For each subnet, specify the:
  - network ID,
  - first and last valid host addresses, and
  - broadcast address.

Solution (1)

- 65.33.40.0 =

  01000001 00100001 00101000 00000000

- Network prefix = /21, therefore the subnet mask is

  11111111 11111111 11111000 00000000

  = 255.255.248.0

- Number of subnets = 4, so m=2 (i.e. borrow 2 bits)
- Borrowing 2 bits from the Host portion, the new subnet mask is

  11111111 11111111 11111**11**0 00000000

  = 255.255.254.0

Borrow 2 bits from the Host portion

Solution (2)

- Subnet #1 IP address block:

  01000001 00100001 00101**00**0 00000000

  01000001 00100001 00101**00**0 00000001

  Other combinations …

  01000001 00100001 00101**00**1 11111110

  01000001 00100001 00101**00**1 11111111

IP address block of Subnet #1

- Subnet #1's Network ID =

  01000001 00100001 00101**00**0 00000000 = 65.33.40.0/23

- Subnet #1's first valid host address =

  01000001 00100001 00101**00**0 00000001 = 65.33.40.1

- Subnet #1's last valid host address =

  01000001 00100001 00101**00**1 11111110 = 65.33.41.254

- Subnet #1's broadcast address =

  01000001 00100001 00101**00**1 11111111 = 65.33.41.255

Take note of the network prefix. It has changed from /21 to /23.

Solution (3)

- Subnet #2 IP address block:

  01000001 00100001 00101**01**0 00000000

  01000001 00100001 00101**01**0 00000001

  Other combinations …

  01000001 00100001 00101**01**1 11111110

  01000001 00100001 00101**01**1 11111111

  IP address block of Subnet #2

- Subnet #2's Network ID =
  01000001 00100001 00101**01**0 00000000 = 65.33.42.0/23
- Subnet #2's first valid host address =
  01000001 00100001 00101**01**0 00000001 = 65.33.42.1
- Subnet #2's last valid host address =
  01000001 00100001 00101**01**1 11111110 = 65.33.43.254
- Subnet #2's broadcast address =
  01000001 00100001 00101**01**1 11111111 = 65.33.43.255

Solution (4)

- Subnet #3 IP address block:

  01000001 00100001 00101**10**0 00000000
  01000001 00100001 00101**10**0 00000001
  Other combinations …
  01000001 00100001 00101**10**1 11111110
  01000001 00100001 00101**10**1 11111111

  IP address block of Subnet #3

- Subnet #3's Network ID =
  01000001 00100001 00101**10**0 00000000 = 65.33.44.0/23
- Subnet #3's first valid host address =
  01000001 00100001 00101**10**0 00000001 = 65.33.44.1
- Subnet #3's last valid host address =
  01000001 00100001 00101**10**1 11111110 = 65.33.45.254
- Subnet #3's broadcast address =
  01000001 00100001 00101**10**1 11111111 = 65.33.45.255

Solution (5)

- Subnet #4 IP address block:

  01000001 00100001 00101**11**0 00000000

  01000001 00100001 00101**11**0 00000001

  Other combinations …

  01000001 00100001 00101**11**1 11111110

  01000001 00100001 00101**11**1 11111111

  IP address block of Subnet #4

- Subnet #4's Network ID = 01000001 00100001 00101**11**0 00000000 = 65.33.46.0/23
- Subnet #4's first valid host address = 01000001 00100001 00101**11**0 00000001 = 65.33.46.1
- Subnet #4's last valid host address = 01000001 00100001 00101**11**1 11111110 = 65.33.47.254
- Subnet #4's broadcast address = 01000001 00100001 00101**11**1 11111111 = 65.33.47.255

Solution (6) - Summary

Subnet #	Network ID	Valid Host Addresses	Broadcast Address
1	65.33.40.0/23	65.33.40.1 to 65.33.41.254	65.33.41.255
2	65.33.42.0/23	65.33.42.1 to 65.33.43.254	65.33.43.255
3	65.33.44.0/23	65.33.44.1 to 65.33.45.254	65.33.45.255
4	65.33.46.0/23	65.33.46.1 to 65.33.47.254	65.33.47.255

Exercise (*Lab 5- Section A*)

Divide the address block 200.15.11.0/24 into 4 subnets.

- (i) How many host addresses are there in each subnet?
- (ii) For each subnet, specify the:
  - network ID,
  - first and last valid host addresses, and
  - broadcast address.

Answer (1)

(i)

- Number of bits to borrow = 2
- Number of bits in host portion
  = 32 – 24 – 2 = 6
- Number of host addresses per subnet
  = 2^6 – 2 = 62

(ii)

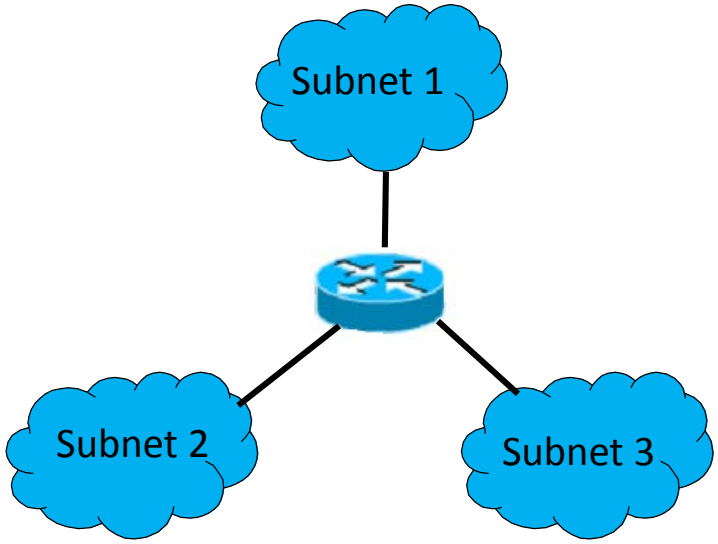
- Follow the procedures in the example to derive the Network ID, valid host addresses and broadcast address. See next slide for answers.

Answer (2)

Subnet #	Network ID	Valid Host Addresses	Broadcast Address
1	200.15.11.0/26	200.15.11.1 to 200.15.11.62	200.15.11.63
2	200.15.11.64 /26	200.15.11.65 to 200.15.11.126	200.15.11.127
3	200.15.11.128/26	200.15.11.129 to 200.15.11.190	200.15.11.191
4	200.15.11.192/26	200.15.11.193 to 200.15.11.254	200.15.11.255

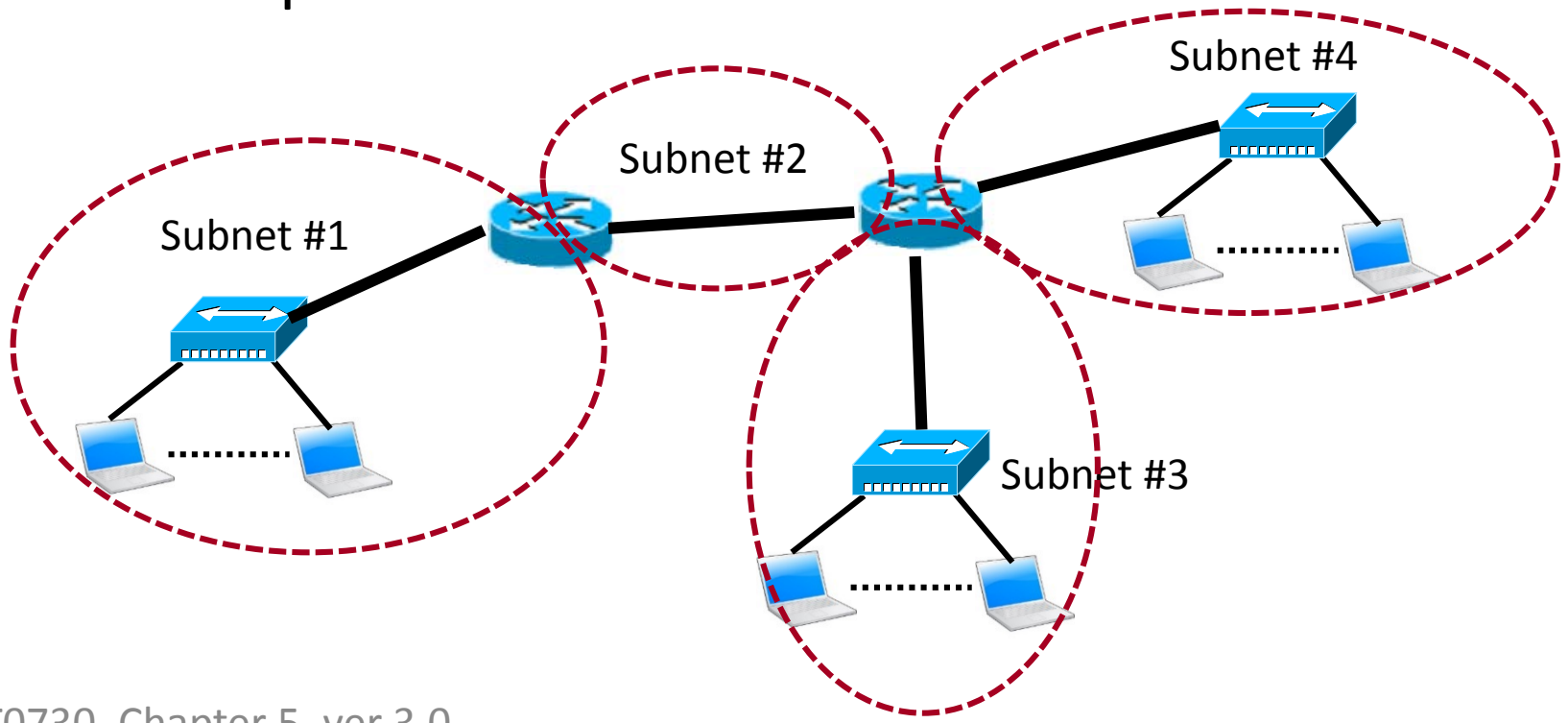
Number of Subnets (1)

- Routers link up subnets. Each interface of router is connected to a different subnet.
- No two interfaces of a router should have overlapping IP address spaces.

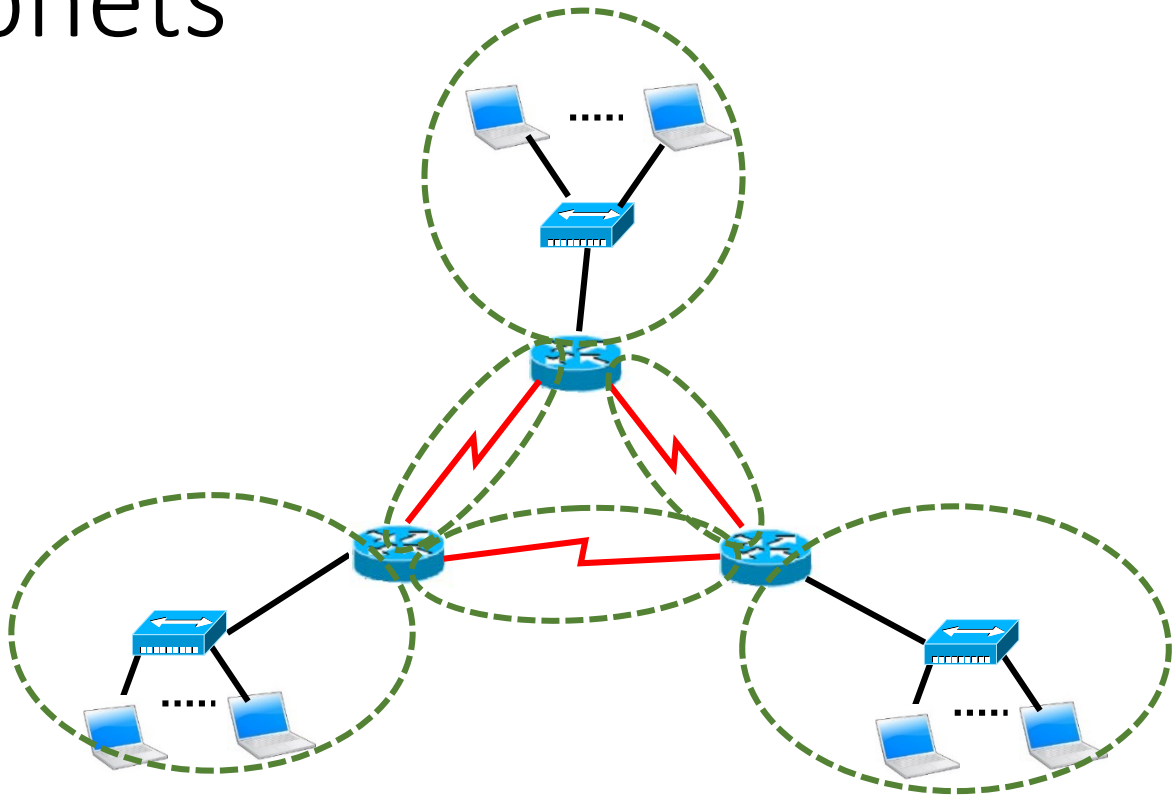


Number of Subnets (2)

- Interconnection between routers is also considered a subnet.
- Example: Determine the number



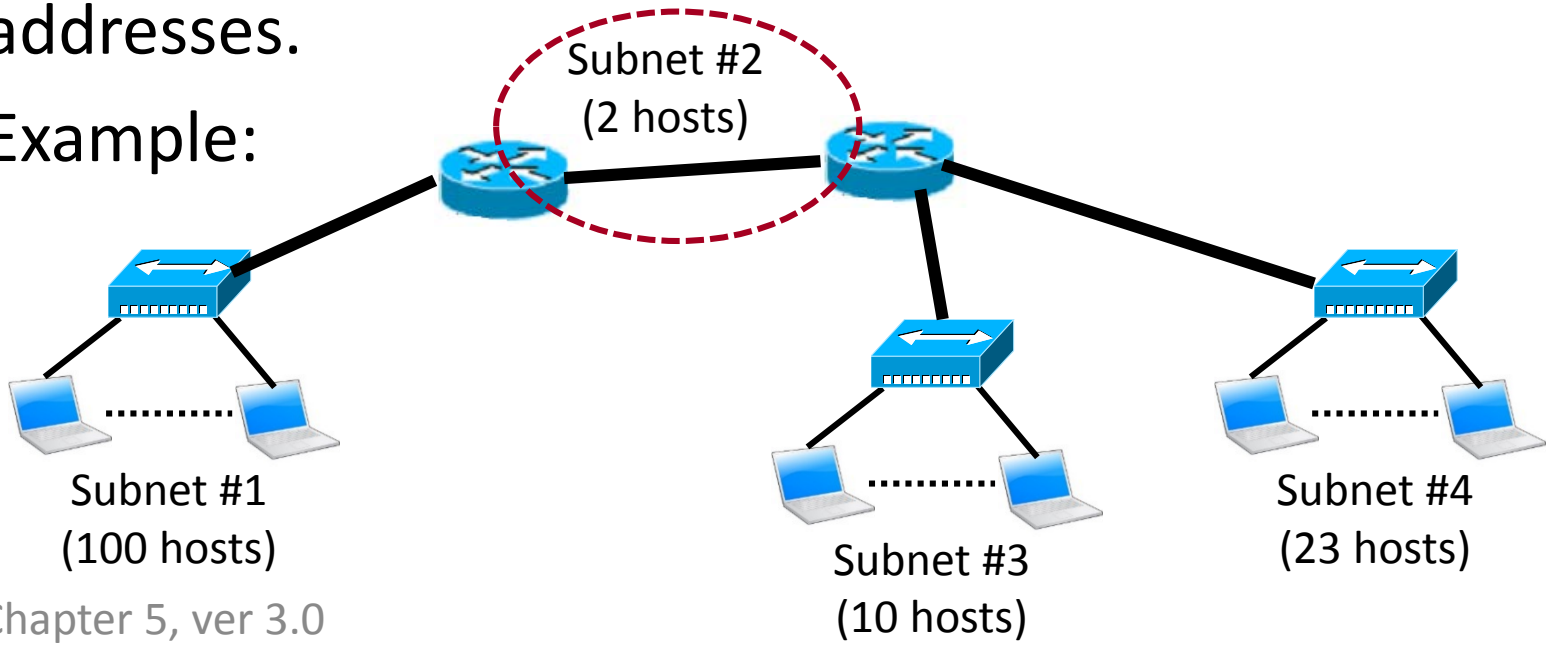
Exercise: Determine the number of subnets



- How many subnets are there?
- Answer: 6

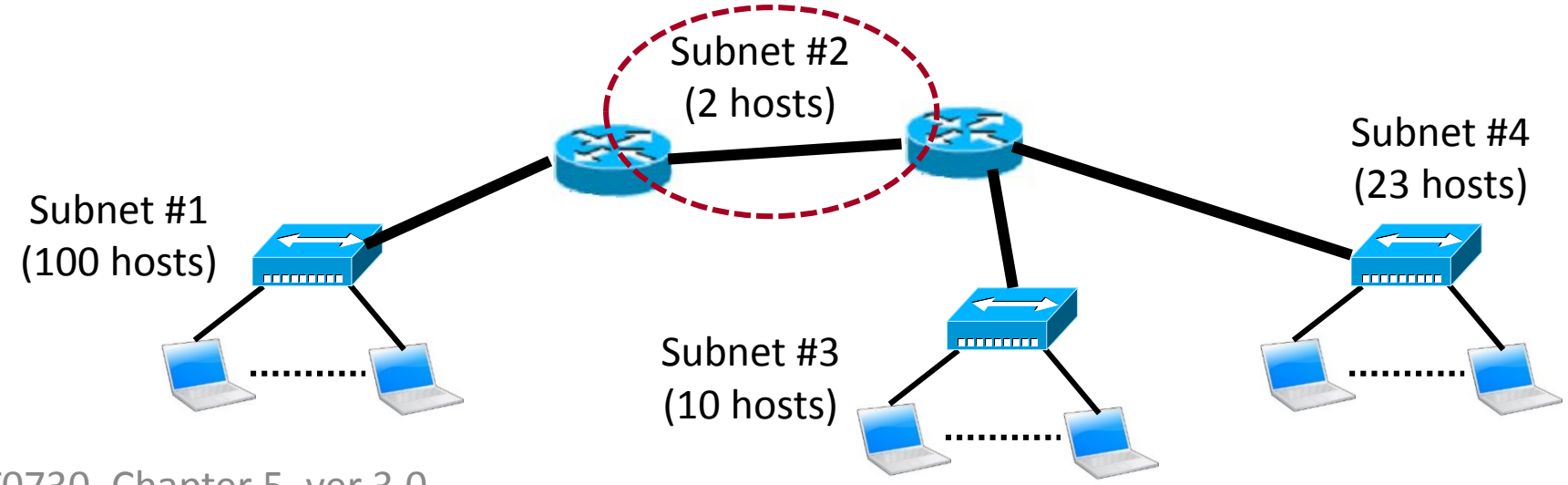
Limitations of Fixed-length Subnet Mask (1)

- The subnetting example and exercise assume that each subnet has equal number of hosts.
  - i.e. **Fixed-length Subnet Mask (FLSM).**
- But in reality, some subnets need to support more hosts, while some subnets needs very few host addresses.
- Example:



Limitations of Fixed-length Subnet Mask (2)

- FLSM assigns same number of bits in the host portion for any subnet, regardless of the number of hosts in the subnets.
  - This results in very wasteful, unused IP addresses.
- Example: Subnet #2 needs only 2 host addresses (one for each router interface), but 7-bit host portion will be used for al subnets because Subnet #1 needs 100 host addresses.



Variable-Length Subnet Mask

- The solution to the FLSM's problem is to use "Variable-length Subnet Mask" (VLSM).
- VLSM is in fact "subnetting subnets".
  - i.e. Further subnetting a subnet.
- VLSM allows us to divide an IP address block into subnets of different sizes.
  - We can then define subnets according to the host counts, thus avoiding wasting large numbers of addresses as in FLSM.

Variable-Length Subnet Mask (VLSM)

Independent Learning Activity

In this activity, you are to:

1. Find out how to do subnetting using VLSM. (Read the lecture slides from 27 - 38).
2. Continue Lab 5 Part B - ***Subnetting using VLSM***.
3. Show your VLSI subnetting design scheme to your lecturer.
4. Complete Lab 5.

Note: "Subnetting using VLSM" will be tested.

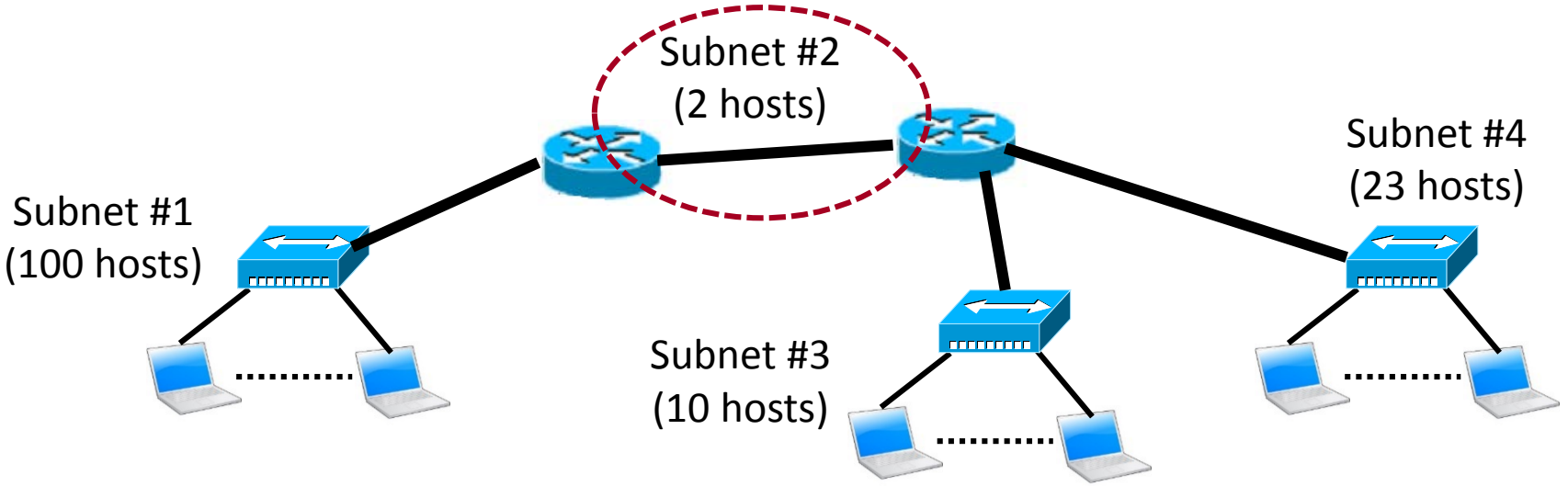
How to perform subnetting using VLSM?

- To perform VLSM subnetting, follow these steps:

1. Re-order the subnets according to number of host addresses needed, in descending order.
   - i.e. Subnet that needs the largest number of hosts addresses comes on top.
2. For each subnet, calculate the number bits needed in the host portion, n, such that **$(2^n-2) \geq$ number of host addresses needed**.
3. Allocate a block of 2^n IP addresses to that subnet. Reserve the first IP address as the Network ID, and last IP address as the Broadcast Address. The rest are valid host addresses.
4. Repeat Step 3 for each subnet, with an IP address block starting immediately after the Broadcast Address of the previous subnet.

Example

- Given the network topology shown below and a block of IP address 65.33.40.0/21, design VLSM subnetting for the four subnets.



Solution (1)

1. Rank the subnets according to number of host addresses needed, in descending order.
2. For each subnet, calculate the number of bits in the host portion.

Subnet #	Number of host addresses needed	Number of bits needed in the host portion
Subnet #1	100	7 (because 2^7-2 = 126 ≥ 100)
Subnet #4	23	5 (because 2^5-2 = 30 ≥ 23)
Subnet #3	10	4 (because 2^4-2 = 14 ≥ 10)
Subnet #2	2	2 (because 2^2-2 = 2 ≥ 2)

Solution (2)

3. IP Address Block = 65.33.40.0/21

- For Subnet #1,
  - Number of bits in Host portion = 7
  - Number of bits in Network portion = 25
  - Subnet mask =
    11111111 11111111 11111111 10000000
    = 255.255.255.128

Solution (3)

- Subnet #1 IP address block:

  01000001 00100001 00101000 00000000
  01000001 00100001 00101000 00000001
  Other combinations …
  01000001 00100001 00101000 01111110
  01000001 00100001 00101000 01111111

IP address block of Subnet #1

- Subnet #1's Network ID =
  01000001 00100001 00101000 00000000 = 65.33.40.0/25
- Subnet #1's first valid host address =
  01000001 00100001 00101000 00000001 = 65.33.40.1
- Subnet #1's last valid host address =
  01000001 00100001 00101000 01111110 = 65.33.40.126
- Subnet #1's broadcast address =
  01000001 00100001 00101000 01111111 = 65.33.40.127

Take note of the network prefix, /25.

Solution (4)

- For Subnet #4,
  - Broadcast Address of previous subnet = 65.33.40.127, therefore the starting IP Address Block for Subnet #4 is 65.33.40.128.
  - Number of bits in Host portion = 5
  - Number of bits in Network portion = 27
  - Subnet mask =

    11111111 11111111 11111111 11100000

    = 255.255.255.224

Solution (5)

- Subnet #4 IP address block:

  01000001 00100001 00101000 10000000
  01000001 00100001 00101000 10000001
  Other combinations …
  01000001 00100001 00101000 10011110
  01000001 00100001 00101000 10011111

IP address block of Subnet #4

- Subnet #4's Network ID =
  01000001 00100001 00101000 10000000 = 65.33.40.128/27
- Subnet #4's first valid host address =
  01000001 00100001 00101000 10000001 = 65.33.40.129
- Subnet #4's last valid host address =
  01000001 00100001 00101000 10011110 = 65.33.40.158
- Subnet #4's broadcast address =
  01000001 00100001 00101000 10011111 = 65.33.40.159

Take note of the network prefix, /27.

Solution (6)

- For Subnet #3,
  - Broadcast Address of previous subnet = 65.33.40.159, therefore the starting IP Address Block for Subnet #4 is 65.33.40.160.
  - Number of bits in Host portion = 4
  - Number of bits in Network portion = 28
  - Subnet mask =

    11111111 11111111 11111111 11110000

    = 255.255.255.240

Solution (7)

- Subnet #3 IP address block:

  01000001 00100001 00101000 10100000
  01000001 00100001 00101000 10100001
  Other combinations …
  01000001 00100001 00101000 10101110
  01000001 00100001 00101000 10101111

IP address block of Subnet #3

- Subnet #3's Network ID =
  01000001 00100001 00101000 10100000 = 65.33.40.160/28
- Subnet #3's first valid host address =
  01000001 00100001 00101000 10100001 = 65.33.40.161
- Subnet #3's last valid host address =
  01000001 00100001 00101000 10101110 = 65.33.40.174
- Subnet #3's broadcast address =
  01000001 00100001 00101000 10101111 = 65.33.40.175

Take note of the network prefix, /28.

Solution (8)

- For Subnet #2,
  - Broadcast Address of previous subnet = 65.33.40.175, therefore the starting IP Address Block for Subnet #4 is 65.33.40.176.
  - Number of bits in Host portion = 2
  - Number of bits in Network portion = 30
  - Subnet mask =

    11111111 11111111 11111111 11111100

    = 255.255.255.252

Solution (9)

- Subnet #2 IP address block:

  01000001 00100001 00101000 10110000
  01000001 00100001 00101000 10110001
  01000001 00100001 00101000 10110010
  01000001 00100001 00101000 10110011

  } IP address block of Subnet #2

- Subnet #2's Network ID =
  01000001 00100001 00101000 10110000 = 65.33.40.176/30
- Subnet #2's first valid host address =
  01000001 00100001 00101000 10110001 = 65.33.40.177
- Subnet #2's last valid host address =
  01000001 00100001 00101000 10110010 = 65.33.40.178
- Subnet #2's broadcast address =
  01000001 00100001 00101000 10110011 = 65.33.40.179

Take note of the network prefix, /30.

Solution (10) - Summary

Subnet #	Network ID	Valid Host Addresses	Broadcast Address
1	65.33.40.0/25	65.33.40.1 to 65.33.40.126	65.33.40.127
4	65.33.40.128/27	65.33.40.129 to 65.33.40.158	65.33.40.159
3	65.33.40.160/28	65.33.40.161 to 65.33.40.174	65.33.40.175
2	65.33.40.176/30	65.33.40.177 to 65.33.40.178	65.33.40.179
Future	IP address block from 65.33.40.180 to 65.33.47.255 is kept for future expansion.		

Questions & Answers