CSC465 – Computer Networks Spring 2004

Dr. J. Harrison

These slides were produced almost entirely from material by Behrouz Forouzan for the text "TCP/IP Protocol Suite (2nd Edition)", McGraw Hill Publisher

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Chapter 5

Subnetting/Supernetting and Classless Addressing

Introduction

- Classful addressing results in suboptimal usage of address space
- Problem aggravated by increasing demand for addresses
  - More organizations
 - More IP-addressable devices

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CONTENTS

- **SUBNETTING**
- **SUPERNETTING**
- **CLASSLESS ADDRSSING**


SUBNETTING

## 2-Level Addressing Hierarchy

- Network is divided into several smaller subnetworks
- Each subnetwork is assigned its own network ID
- Results in an implicit 2-level hierarchy
- To reach a host on the Internet, we must first reach the network using the netid (1st part) then the host itself using the hostid (2nd part)
- However for many this is insufficient (also unsafe)
  - One network, many hosts

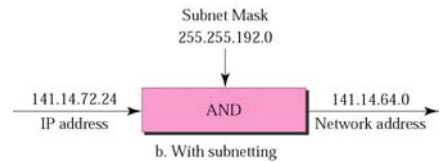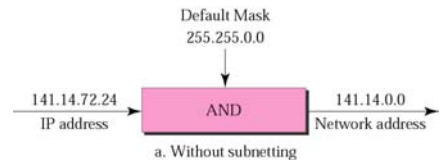## A network with two levels of hierarchy (not subnetted)
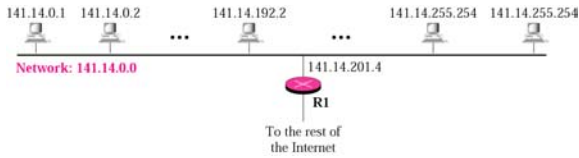
Subnetting

- Further partition the address space to create a 3rd address level: Network ID, Subnet ID and Host ID
- Delivery is three stage process
  - To Network, then Subnet and then to Host
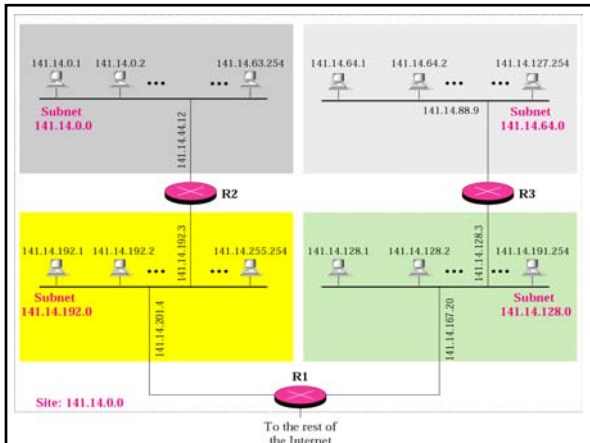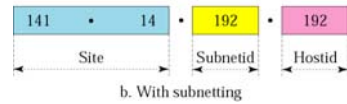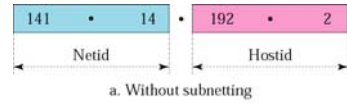
Default mask and subnet mask

Example 1

What is the subnetwork address if the destination address is 200.45.34.56 and the subnet mask is 255.255.240.0?

Solution

What is the subnetwork address if the destination address is 200.45.34.56 and the subnet mask is 255.255.240.0?

11001000 00101101 00100010 00111000

11111111 11111111 1111**0000 00000000**
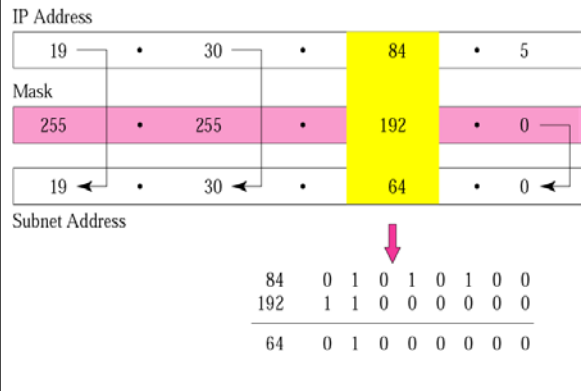
11001000 00101101 **0010**0000 00000000

The subnetwork address is **200.45.32.0**

with 2^{12}= 4096 available addresses

Example 2

What is the subnetwork address if the destination address is 19.30.80.5 and the mask is 255.255.192.0?

IP Address

| 19 | • | 30 | • | 84 | • | 5 |

Mask

| 255 | • | 255 | • | 192 | • | 0 |

| 19 | • | 30 | • | 64 | • | 0 |

Subnet Address

84	0 1 0 1 0 1 0 0
192	1 1 0 0 0 0 0 0
64	0 1 0 0 0 0 0 0

Comparison of a default mask and a subnet mask

255.255.0.0

| Default Mask | 11111111 | 11111111 | 00000000 | 00000000 |
| | | 16 | | |

255.255.224.0

| Subnet Mask | 11111111 | 11111111 | 111 | 00000 | 00000000 |
| | | 3 | | 13 | |

The number of 1's in a default mask is predetermined. (8, 16, 24)

Subnet mask has more ones than default mask.

Note

The number of subnets must be a power of 2.

Example 3

A company is granted the site address 201.70.64.0 (class C). The company needs six subnets. What is the subnet mask? Design the subnets.

Solution

The number of 1s in the default mask is 24 (class C).

The company needs six subnets. This number 6 is not a power of 2. The next number that is a power of 2 is 8 (2^3). We need 3 more 1s in the subnet mask. The total number of 1s in the subnet mask is 27 (24 + 3).

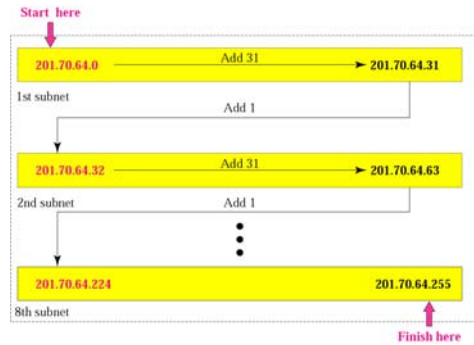The total number of 0s is 5 (32 − 27). The subnet mask is:

11111111 11111111 11111111 11100000

or

255.255.255.224

The number of subnets is 8.
The number of addresses in each subnet
is 2^5 (5 is the number of 0s) or 32.

Example 3

Example 4

A company is granted the site address
181.56.0.0 (class B). The company needs
1000 subnets. Design the subnets.

Solution

The number of 1s in the default mask is 16
(class B).

The company needs 1000 subnets. This
number is not a power of 2. The next number
that is a power of 2 is 1024 (2^{10}). We need 10
more 1s in the subnet mask.

The total number of 1s in the subnet mask is
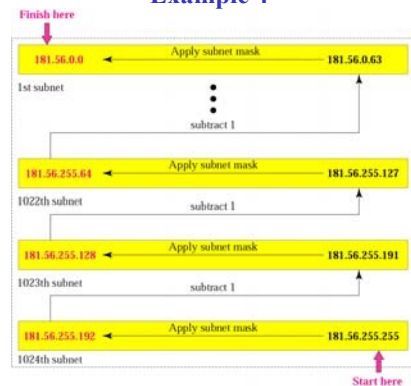26 (16 + 10).

The total number of 0s is 6 (32 − 26).
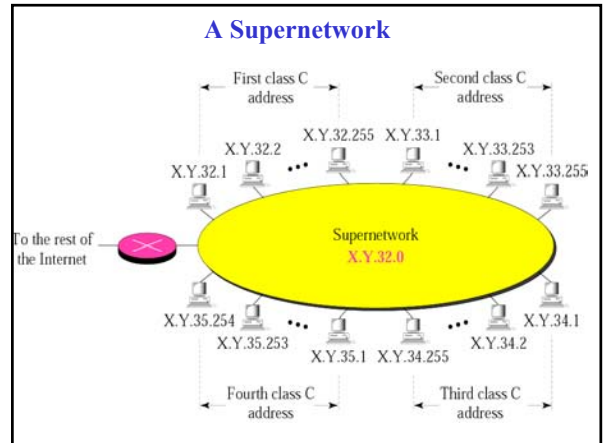
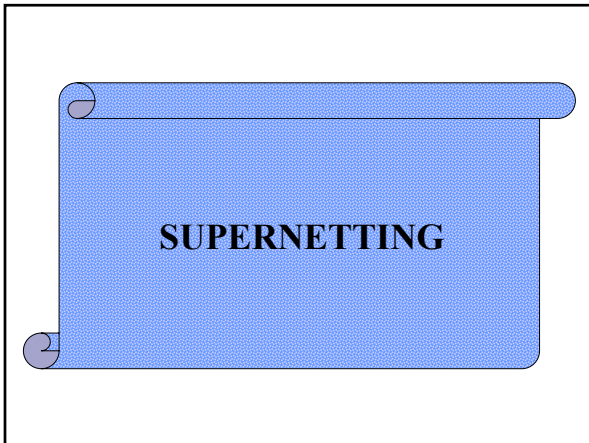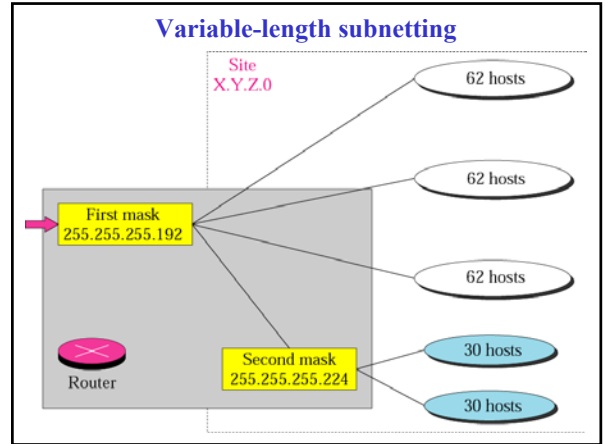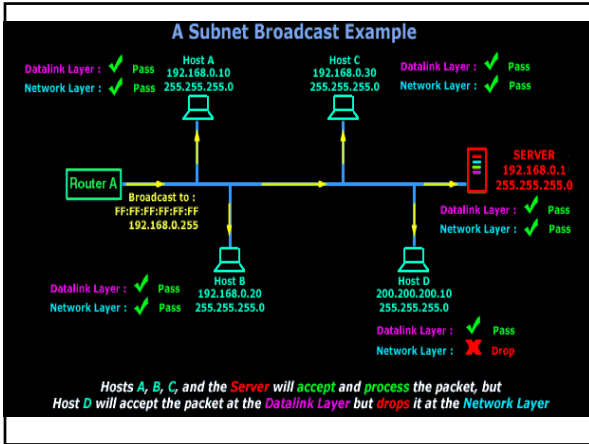---

The mask is

11111111 11111111 11111111 11000000

or

255.255.255.192.

The number of subnets is 1024.
The number of addresses in each subnet is 2^6
(6 is the number of 0s) or 64.

Example 4

A Subnet Broadcast Example

Datalink Layer : ✓ Pass   Host A 192.168.0.10 255.255.255.0   Host C 192.168.0.30 255.255.255.0   Datalink Layer : ✓ Pass
Network Layer : ✓ Pass   Network Layer : ✓ Pass

Router A

Broadcast to : FF:FF:FF:FF:FF:FF 192.168.0.255

SERVER 192.168.0.1 255.255.255.0

Datalink Layer : ✓ Pass
Network Layer : ✓ Pass

Datalink Layer : ✓ Pass   Host B 192.168.0.20 255.255.255.0
Network Layer : ✓ Pass

Host D 200.200.200.10 255.255.255.0

Datalink Layer : ✓ Pass
Network Layer : ✗ Drop

Hosts A, B, C, and the Server will accept and process the packet, but Host D will accept the packet at the Datalink Layer but drops it at the Network Layer

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Variable-length subnetting

Site X.Y.Z.0

First mask 255.255.255.192

62 hosts
62 hosts
62 hosts
30 hosts
30 hosts

Second mask 255.255.255.224

Router

SUPERNETTING

A Supernetwork

First class C address
Second class C address

X.Y.32.255 X.Y.33.1

X.Y.32.2   X.Y.33.253
X.Y.32.1   X.Y.33.255

To the rest of the Internet

Supernetwork X.Y.32.0

X.Y.35.254   X.Y.34.1
X.Y.35.253   X.Y.34.2
X.Y.35.1 X.Y.34.255

Fourth class C address
Third class C address

Rules:

** The number of blocks must be a power of 2 (1, 2, 4, 8, 16, . . .).

** The blocks must be contiguous in the address space (no gaps between the blocks).

** The third byte of the first address in the superblock must be evenly divisible by the number of blocks. In other words, if the number of blocks is *N*, the third byte must be divisible by *N*.

Example 5

A company needs 600 addresses. Which of the following set of class C blocks can be used to form a supernet for this company?

198.47.32.0 198.47.33.0 198.47.34.0

198.47.32.0 198.47.42.0 198.47.52.0 198.47.62.0

198.47.31.0 198.47.32.0 198.47.33.0 198.47.52.0

198.47.32.0 198.47.33.0 198.47.34.0 198.47.35.0

1: No, there are only three blocks.

2: No, the blocks are not contiguous.

3: No, 31 in the first block is not divisible by 4.

4: Yes, all three requirements are fulfilled.
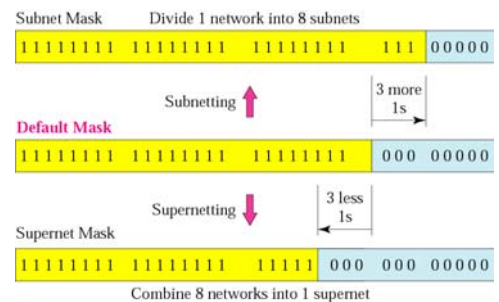

Note

In subnetting,
we need the first address of the
subnet and the *subnet mask* to
define the range of addresses.

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Figure 5-12

Comparison of subnet, default, and supernet masks

Example 6

We need to make a supernetwork out of 16 class C blocks. What is the supernet mask?

Solution

We need 16 blocks. For 16 blocks we need to change four 1s to 0s in the default mask. So the mask is

11111111 11111111 1110**0000** 00000000

or

255.255.240.0 (240/16 = 15)

Example 7

A supernet has a first address of 205.16.32.0 and a supernet mask of 255.255.248.0. A router receives three packets with the following destination addresses:

205.16.37.44
205.16.42.56
205.17.33.76

Which packet belongs to the supernet?

We apply the supernet mask to see if we can find the beginning address.

205.16.37.44   AND 255.255.248.0   ➜   205.16.32.0

205.16.42.56   AND 255.255.248.0   ➜   205.16.40.0

205.17.33.76   AND 255.255.248.0   ➜   205.17.32.0

Only the first address belongs to this supernet.

Example 8

A supernet has a first address of 205.16.32.0 and a supernet mask of 255.255.248.0.

How many blocks are in this supernet and what is the range of addresses?

Example 8

A supernet has a first address of 205.16.32.0 and a supernet mask of 255.255.248.0. How many blocks are in this supernet and what is the range of addresses?

Solution

The supernet has 21 1s. The default mask has 24 1s. Since the difference is 3, there are 2^3 or 8 blocks in this supernet. The blocks are 205.16.32.0 to 205.16.39.0. The first address is 205.16.32.0. The last address is 205.16.39.255.

5.3

CLASSLESS ADDRESSING

Figure 5-13

Variable-length blocks

Address Space

Blocks of different sizes

Number of Addresses in a Block

There is only one condition on the number of addresses in a block; it must be a power of 2 (2, 4, 8, . . .). A household may be given a block of 2 addresses. A small business may be given 16 addresses. A large organization may be given 1024 addresses.

Beginning Address

The beginning address must be evenly divisible by the number of addresses. For example, if a block contains 4 addresses, the beginning address must be divisible by 4. If the block has less than 256 addresses, we need to check only the rightmost byte. If it has less than 65,536 addresses, we need to check only the two rightmost bytes, and so on.

Example 9

Which of the following can be the beginning address of a block that contains 16 addresses?

205.16.37.32
190.16.42.44
17.17.33.80
123.45.24.52

Solution

The address 205.16.37.32 is eligible because 32 is divisible by 16. The address 17.17.33.80 is eligible because 80 is divisible by 16.

Example 10

Which of the following can be the beginning address of a block that contains 1024 addresses?

205.16.37.32
190.16.42.0
17.17.32.0
123.45.24.52

Solution

To be divisible by 1024, the rightmost byte of an address should be 0 and the second rightmost byte must be divisible by 4. Only the address 17.17.32.0 meets this condition.

Figure 5-14

Slash notation

$$A.B.C.D/n$$

Note

Slash notation is also called
CIDR
notation.

Example 11

A small organization is given a block with the beginning address and the prefix length **205.16.37.24/29** (in slash notation).

What is the range of the block?

Solution

The beginning address is 205.16.37.24. To find the last address we keep the first 29 bits and change the last 3 bits to 1s.

Beginning: **11001111 00010000 00100101 00011**000
Ending   : **11001111 00010000 00100101 00011**111

There are only 8 addresses in this block.

Example 12

We can find the range of addresses in Example 11 by another method. We can argue that the length of the suffix is $32 - 29$ or 3. So there are $2^3 = 8$ addresses in this block. If the first address is 205.16.37.24, the last address is 205.16.37.31 ($24 + 7 = 31$).

Note

A block in classes A, B, and C can easily be represented in slash notation as
A.B.C.D/ *n*
where *n* is
either 8 (class A), 16 (class B), or 24 (class C).

Example 13

What is the network address if one of the addresses is 167.199.170.82/27?

Solution

The prefix length is 27, which means that we must keep the first 27 bits as is and change the remaining bits (5) to 0s. The 5 bits affect only the last byte. The last byte is 01010010. Changing the last 5 bits to 0s, we get 01000000 or 64. The network address is 167.199.170.64/27.

Example 14

An organization is granted the block 130.34.12.64/26. The organization needs to have four subnets. What are the subnet addresses and the range of addresses for each subnet?

Solution

The suffix length is 6. This means the total number of addresses in the block is 64 (2^6). If we create four subnets, each subnet will have 16 addresses.

Solution (Continued)

Let us first find the subnet prefix (subnet mask). We need four subnets, which means we need to add two more 1s to the site prefix. The subnet prefix is then /28.

Subnet 1: 130.34.12.64/28 to 130.34.12.79/28.
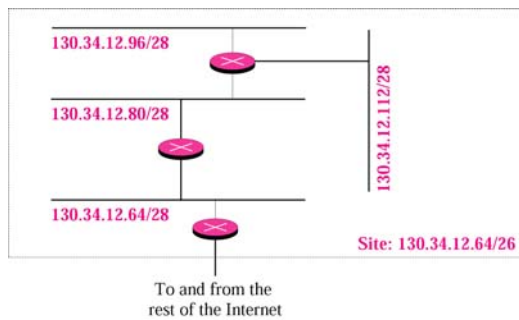
Subnet 2 : 130.34.12.80/28 to 130.34.12.95/28.

Subnet 3: 130.34.12.96/28 to 130.34.12.111/28.

Subnet 4: 130.34.12.112/28 to 130.34.12.127/28.

See Figure 5.15

Figure 5-15

Example 14

130.34.12.96/28

130.34.12.80/28

130.34.12.64/28

130.34.12.112/28

Site: 130.34.12.64/26

To and from the rest of the Internet

Example 15

An ISP is granted a block of addresses starting with 190.100.0.0/16. The ISP needs to distribute these addresses to three groups of customers as follows:

1. The first group has 64 customers; each needs 256 addresses.

2. The second group has 128 customers; each needs 128 addresses.

3. The third group has 128 customers; each needs 64 addresses.

Design the subblocks and give the slash notation for each subblock. Find out how many addresses are still available after these allocations.

Solution   {00000000.00000000}-{00111111.11111111}
Group 1

For this group, each customer needs 256 addresses. This means the suffix length is 8 ($2^8 = 256$). The prefix length is then $32 - 8 = 24$.

01: 190.100.0.0/24 ➔ 190.100.0.255/24

02: 190.100.1.0/24 ➔ 190.100.1.255/24

………………………………..

64: 190.100.63.0/24 ➔ 190.100.63.255/24

Total = $64 \times 256 = 16,384$

(Continued)   {01000000.00000000}-{01111111.11111111}
Group 2

For this group, each customer needs 128 addresses. This means the suffix length is 7 ($2^7 = 128$). The prefix length is then $32 - 7 = 25$. The addresses are:

001: 190.100.64.0/25   ➔ 190.100.64.127/25

002: 190.100.64.128/25   ➔ 190.100.64.255/25

003: 190.100.127.128/25 ➔ 190.100.127.255/25

Total = $128 \times 128 = 16,384$

Group 3

For this group, each customer needs 64 addresses. This means the suffix length is 6 ($2^6 = 64$). The prefix length is then $32 - 6 = 26$.

001:190.100.128.0/26 ➜ 190.100.128.63/26

002:190.100.128.64/26 ➜ 190.100.128.127/26

………………………….

128:190.100.159.192/26 ➜ 190.100.159.255/26

Total = 128 × 64 = 8,192

Number of granted addresses: 65,536

Number of allocated addresses: 40,960

Number of available addresses: 24,576