Network Technologies (TCP/IP Suite)

Umar Kalim
Dept. of Communication Systems Engineering

umar.kalim@niit.edu.pk
http://www.niit.edu.pk/~umarkalim

22/03/2007

Outline

- IP: The Internet Protocol
  - Subnetting
  - Classless Interdomain Routing (CIDR)

IP Addressing

Problem:

- Address classes were too "rigid". For most organizations, Class C were too small and Class B too big. Led to inefficient use of address space, and a shortage of addresses.
- Organizations with internal routers needed to have a separate (Class C) network ID for each link.
- And then every other router in the Internet had to know about every network ID in every organization, which led to large address tables.
- Small organizations wanted Class B in case they grew to more than 255 hosts. But there were only about 16,000 Class B network IDs.

IP Addressing

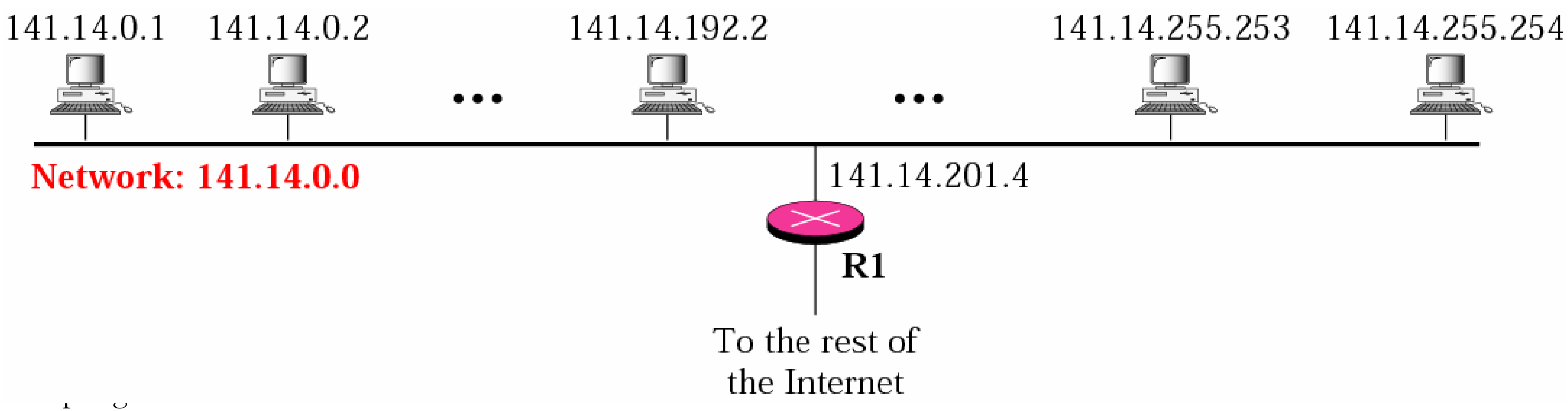
Two solutions were introduced:

- Subnetting within an organization to subdivide the organization's network ID.
- Classless Interdomain Routing (CIDR) in the Internet backbone was introduced in 1993 to provide more efficient and flexible use of IP address space.

- CIDR is also known as "supernetting" because subnetting and CIDR are basically the same idea.

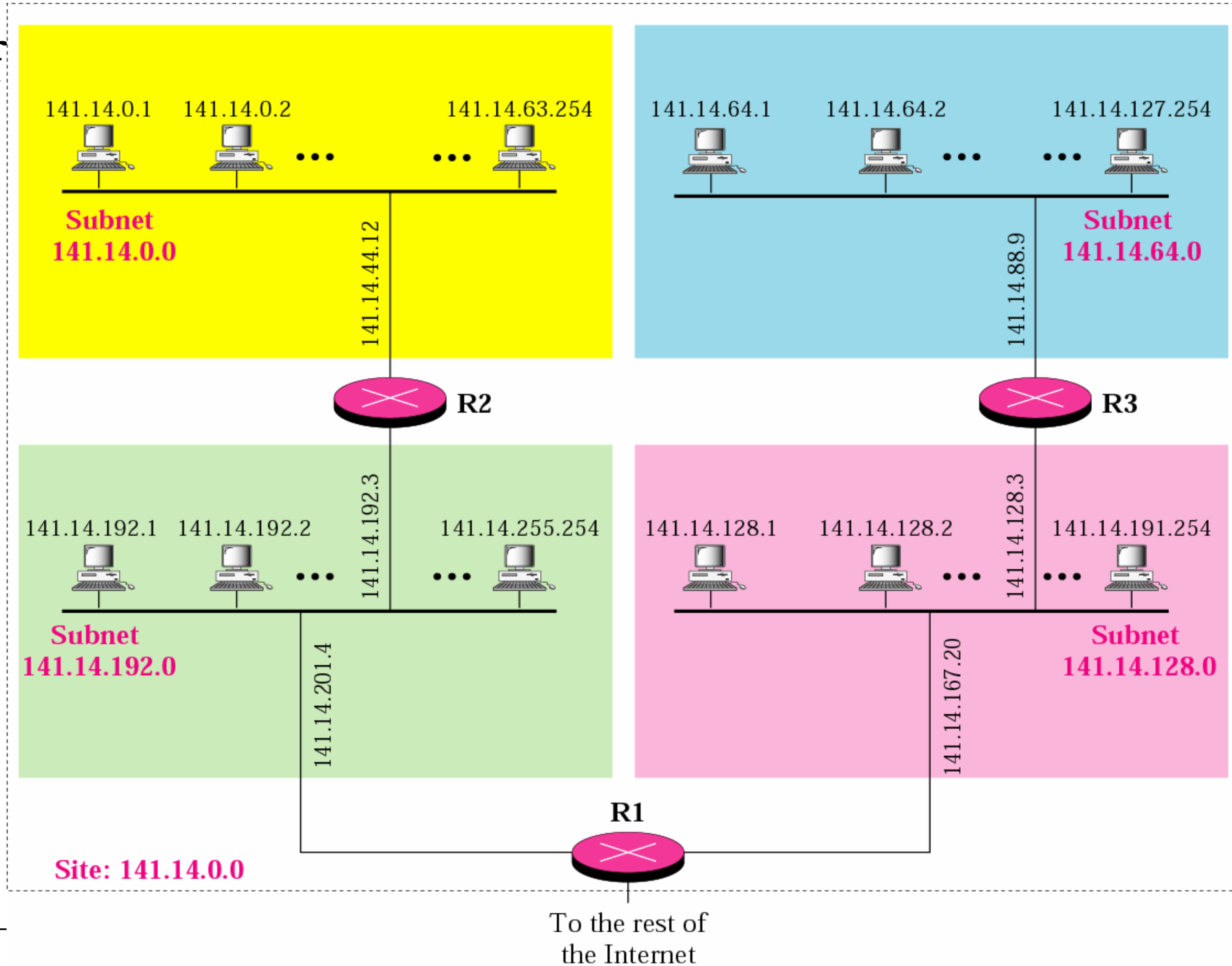
Subnetting

- A network is divided into several smaller sub-networks
  - Each subnetwork has its own network address
- Conventionally we have two levels of hierarchy
  - To reach the host, we must first reach the network



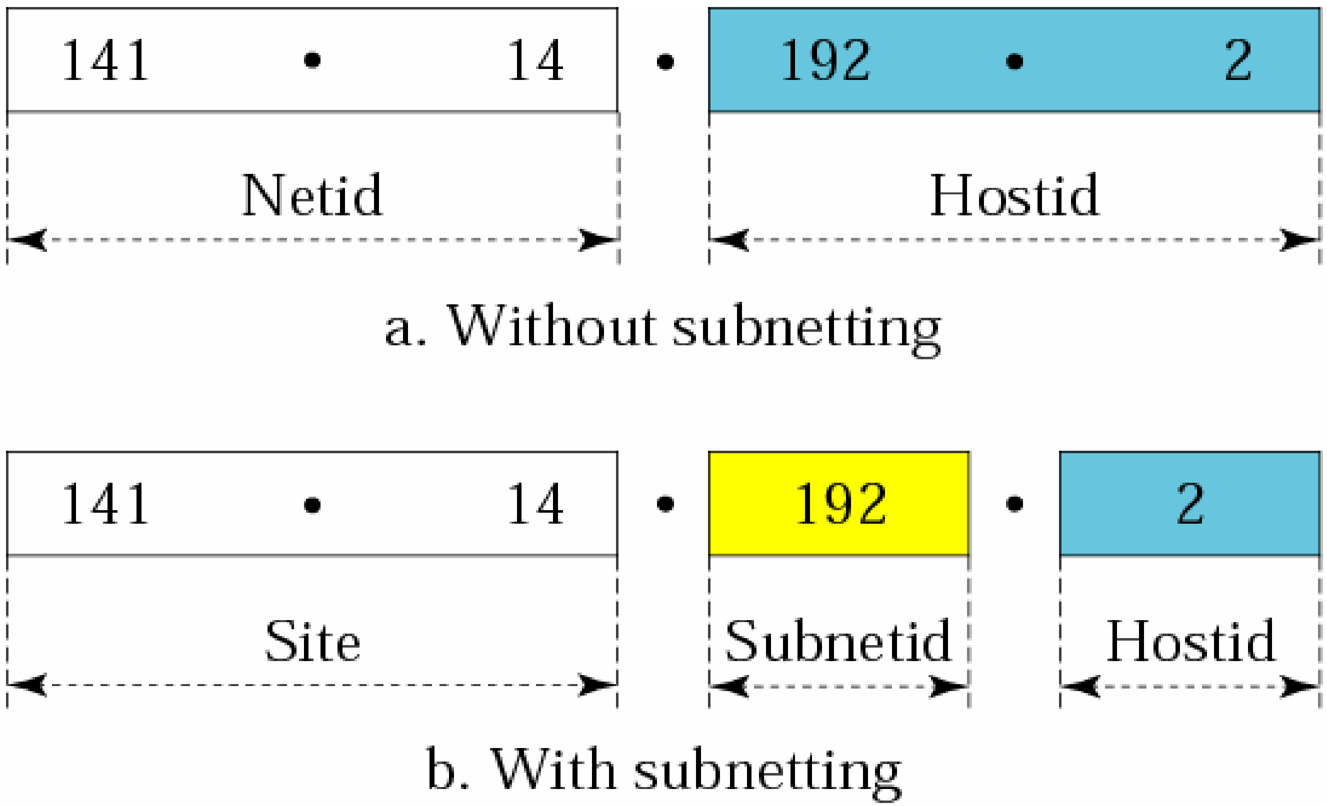
Subnetting

- The rest of the Internet is not aware that sub-networks exist
- Levels: site, subnet, host

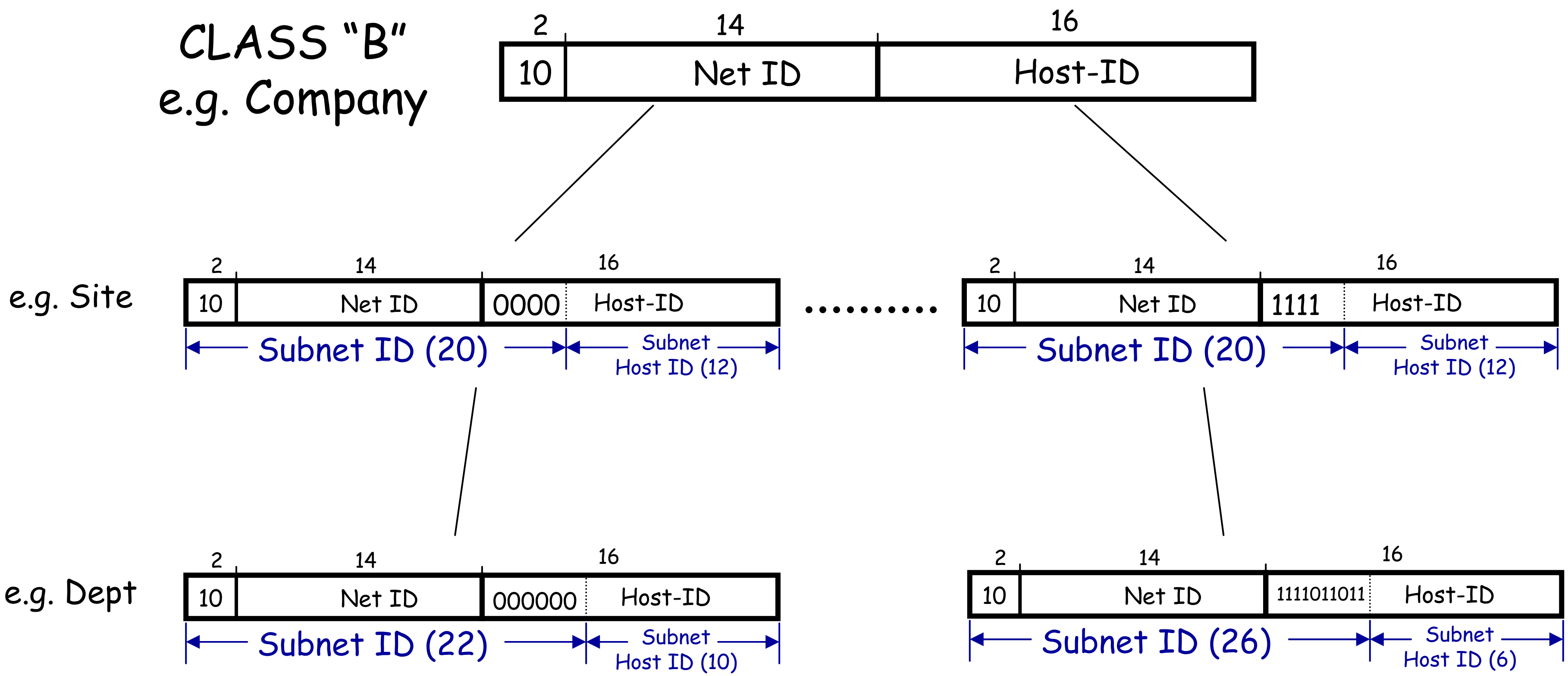


Subnetting

- Routing now involves delivery to the site, then the subnet and finally the host



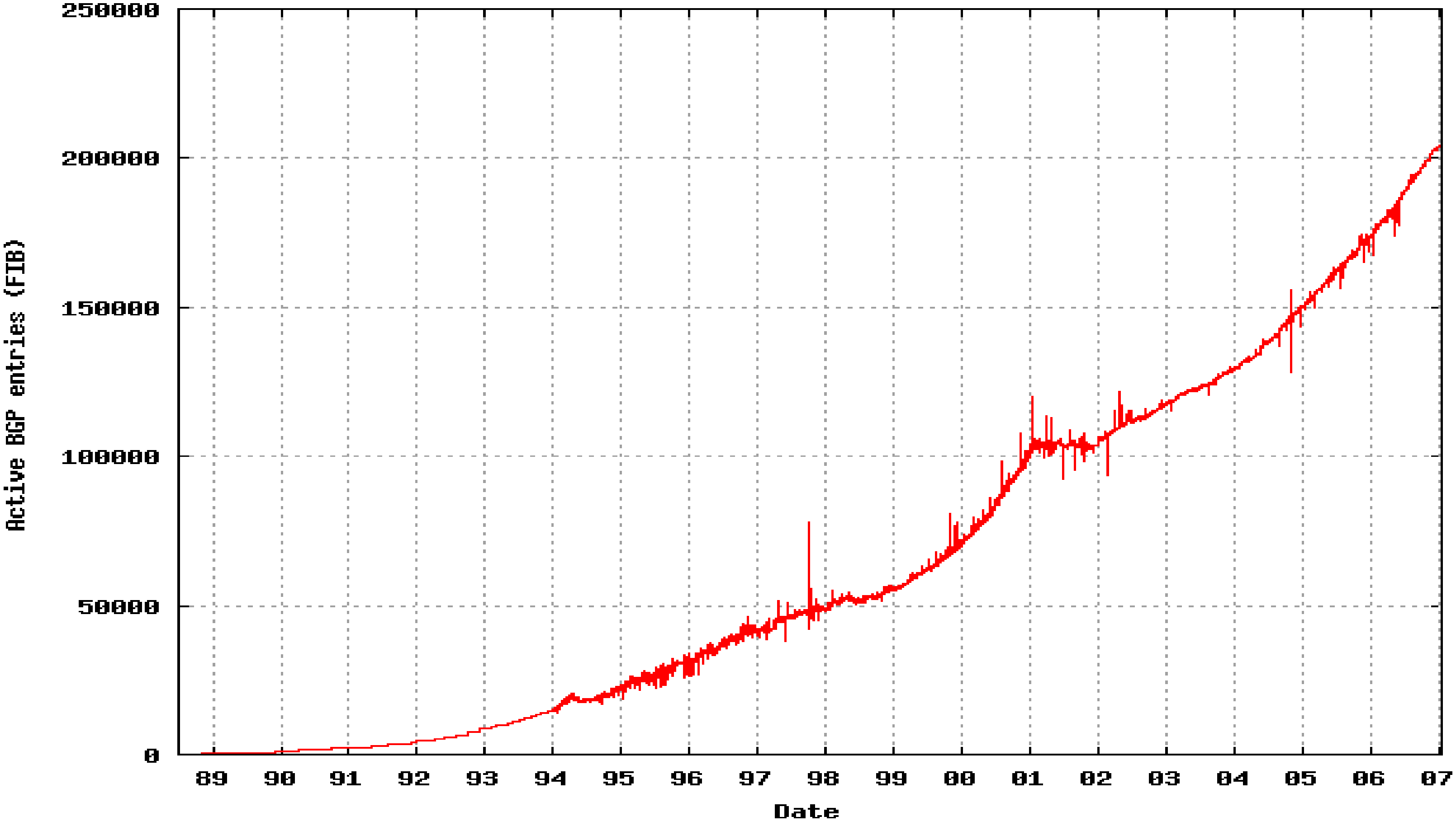
Subnetting


CLASS "B"
e.g. Company
2
14
16
10
Net ID
Host-ID
e.g. Site
2
14
16
10
Net ID
0000
Host-ID
Subnet ID (20)
Subnet
Host ID (12)
....
2
14
16
10
Net ID
1111
Host-ID
Subnet ID (20)
Subnet
Host ID (12)
e.g. Dept
2
14
16
10
Net ID
000000
Host-ID
Subnet ID (22)
Subnet
Host ID (10)
2
14
16
10
Net ID
1111011011
Host-ID
Subnet ID (26)
Subnet
Host ID (6)

Subnetting

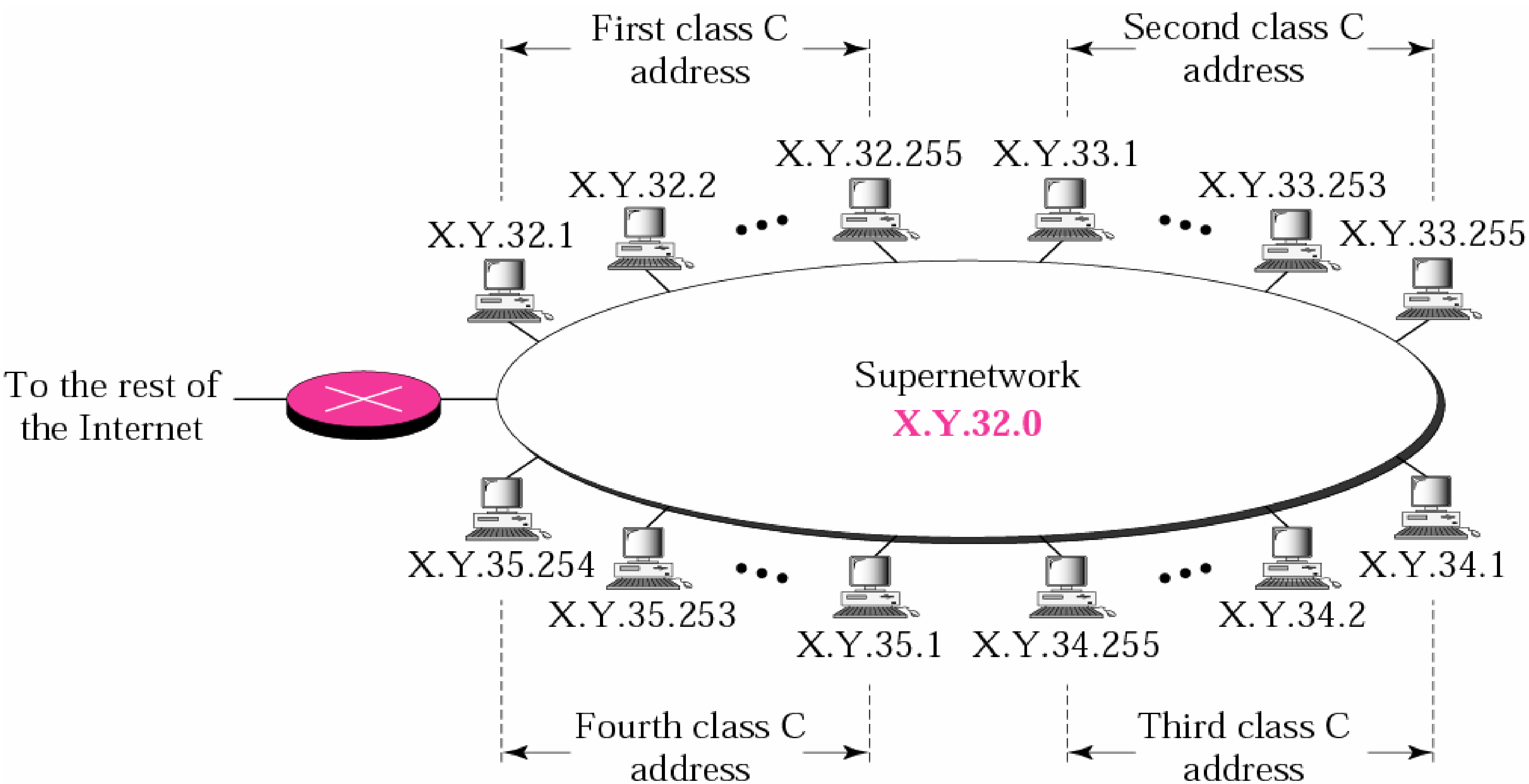
- Subnetting is a form of hierarchical routing.
- Subnets are usually represented via an address plus a subnet mask or "netmask".
  - 171.64.15.0/24, or just 171.64.15/24.

Size of the Routing Table at the core of the Internet



Source: http://www.cidr-report.org/

Supernetting



Address Assignment

- If a subnet consists of 100 Class C networks and if these addresses are randomly chosen
  - The routers external to the supernet requires 100 entries (one for each Class C network) for the supernet
- It would be desirable if only 1 entry is required
- This can be achieved by carefully assigning addresses

Address Assignment

- 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

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

a)198.47.32.0 198.47.33.0 198.47.34.0

b)198.47.32.0 198.47.42.0 198.47.52.0 198.47.62.0

c)198.47.31.0 198.47.32.0 198.47.33.0 198.47.34.0

d)198.47.32.0 198.47.33.0 198.47.34.0 198.47.35.0

Solution

a)198.47.32.0 198.47.33.0 198.47.34.0

Not acceptable. #blocks not a power of 2.

b)198.47.32.0 198.47.42.0 198.47.52.0 198.47.62.0

Not acceptable. Not contagious.

c)198.47.31.0 198.47.32.0 198.47.33.0 198.47.34.0

Not acceptable. 3rd byte of 1st address not divisible by 4.

d)198.47.32.0 198.47.33.0 198.47.34.0 198.47.35.0

Acceptable.

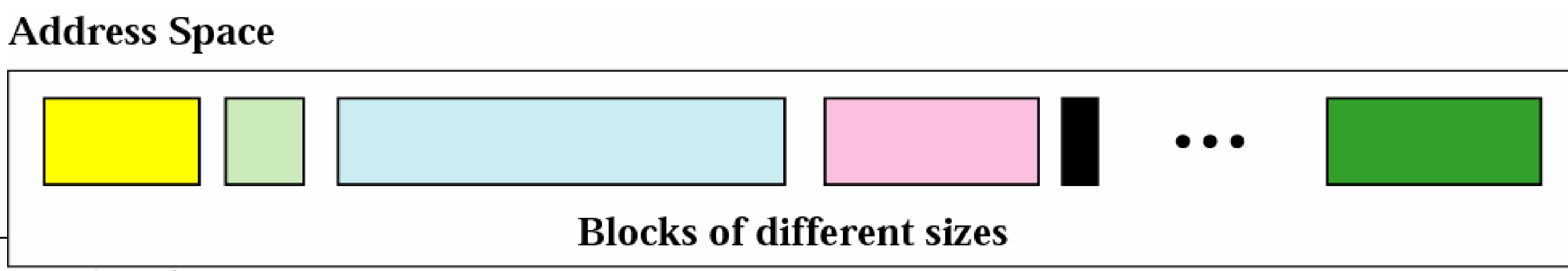
Supernet Mask

- For classful addressing we know the default masks and hence the range
- For subnets, the first address (of the subnet) and the subnet mask define the range of addresses
- For supernets we again need the mask to define the range of addresses

Questions?

Classless addressing

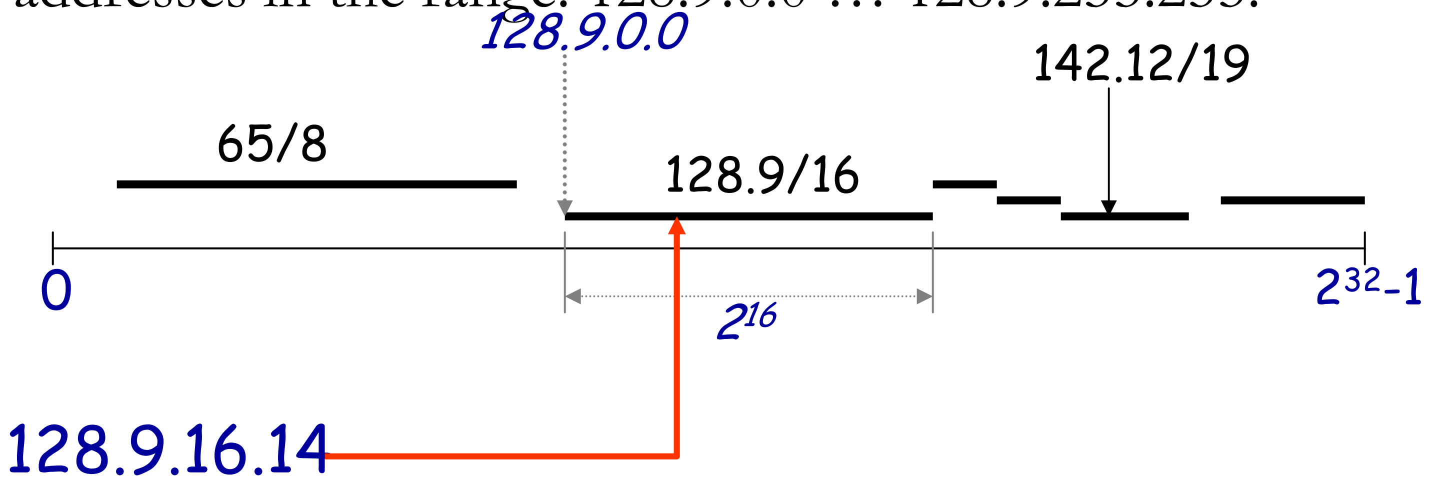
- In classless addressing variable-length blocks are assigned that belong to no class
- In this architecture, the entire address space (2^{32} addresses) is divided into blocks of different sizes
  - Block of 2 addresses
  - Block of 128 addresses etc



Classless Interdomain Routing (CIDR)

Addressing

- The IP address space is broken into line segments.
- Each line segment is described by a *prefix*.
- A prefix is of the form x/y where x indicates the prefix of all addresses in the line segment, and y indicates the length of the segment.
- e.g. The prefix 128.9/16 represents the line segment containing addresses in the range: 128.9.0.0 … 128.9.255.255.



Restrictions

- Number of addresses in the block must be a power of 2
  - 2, 4, 8, 16, 32, ….
- The first address must be evenly divisible by the number of addresses
  - If a block has 4 addresses, the first address must be divisible by 4
    - *If a block has 256 addresses or less (check the right most byte only)*
    - *If a block has 65536 addresses or less (check the two right most bytes only)*

Example 1

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

a. 205.16.37.32 ***b.190.16.42.44***
c. 17.17.33.80 ***d.123.45.24.52***

Solution

Only two are eligible (a and c). 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 2

Which of the following can be the beginning address of a block that contains 256 addresses?

a.205.16.37.32

b.190.16.42.0

c.17.17.32.0

d.123.45.24.52

Solution

In this case, the right-most byte must be 0. Only two addresses are eligible (b and c).

Example 3

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

a. 205.16.37.32 ***b.190.16.42.0***

c. 17.17.32.0 ***d.123.45.24.52***

Solution

In this case, we need to check two bytes because 1024 = 4 × 256. The right-most byte must be divisible by 256. The second byte (from the right) must be divisible by 4. Only one address is eligible (c).

Masks

- In classful addressing the masks are implicit
- For classless addressing we need the masks

x.y.z.t/n

Terminology

- Prefix ~ netID
  - The common part of the address
- Prefix Length ~ length (in # of bits) of the prefix
  - denoted by /n

Prefix lengths

/n	Mask	/n	Mask	/n	Mask	/n	Mask
/1	128.0.0.0	/9	255.128.0.0	/17	255.255.128.0	/25	255.255.255.128
/2	192.0.0.0	/10	255.192.0.0	/18	255.255.192.0	/26	255.255.255.192
/3	224.0.0.0	/11	255.224.0.0	/19	255.255.224.0	/27	255.255.255.224
/4	240.0.0.0	/12	255.240.0.0	/20	255.255.240.0	/28	255.255.255.240
/5	248.0.0.0	/13	255.248.0.0	/21	255.255.248.0	/29	255.255.255.248
/6	252.0.0.0	/14	255.252.0.0	/22	255.255.252.0	/30	255.255.255.252
/7	254.0.0.0	/15	255.254.0.0	/23	255.255.254.0	/31	255.255.255.254
/8	255.0.0.0	/16	255.255.0.0	/24	255.255.255.0	/32	255.255.255.255

- Classful addressing is a special case of classless addressing

Terminology

- Suffix ~ hostID
- Suffix length ~ length (in # of bits) of the suffix
  - calculated by (32-n)

Finding the block

- Given the address and the mask
  - We can find the first address
  - the last address and
  - the number of addresses

Finding the first address

What is the first address in the block if one of the addresses is 167.199.170.82/27?

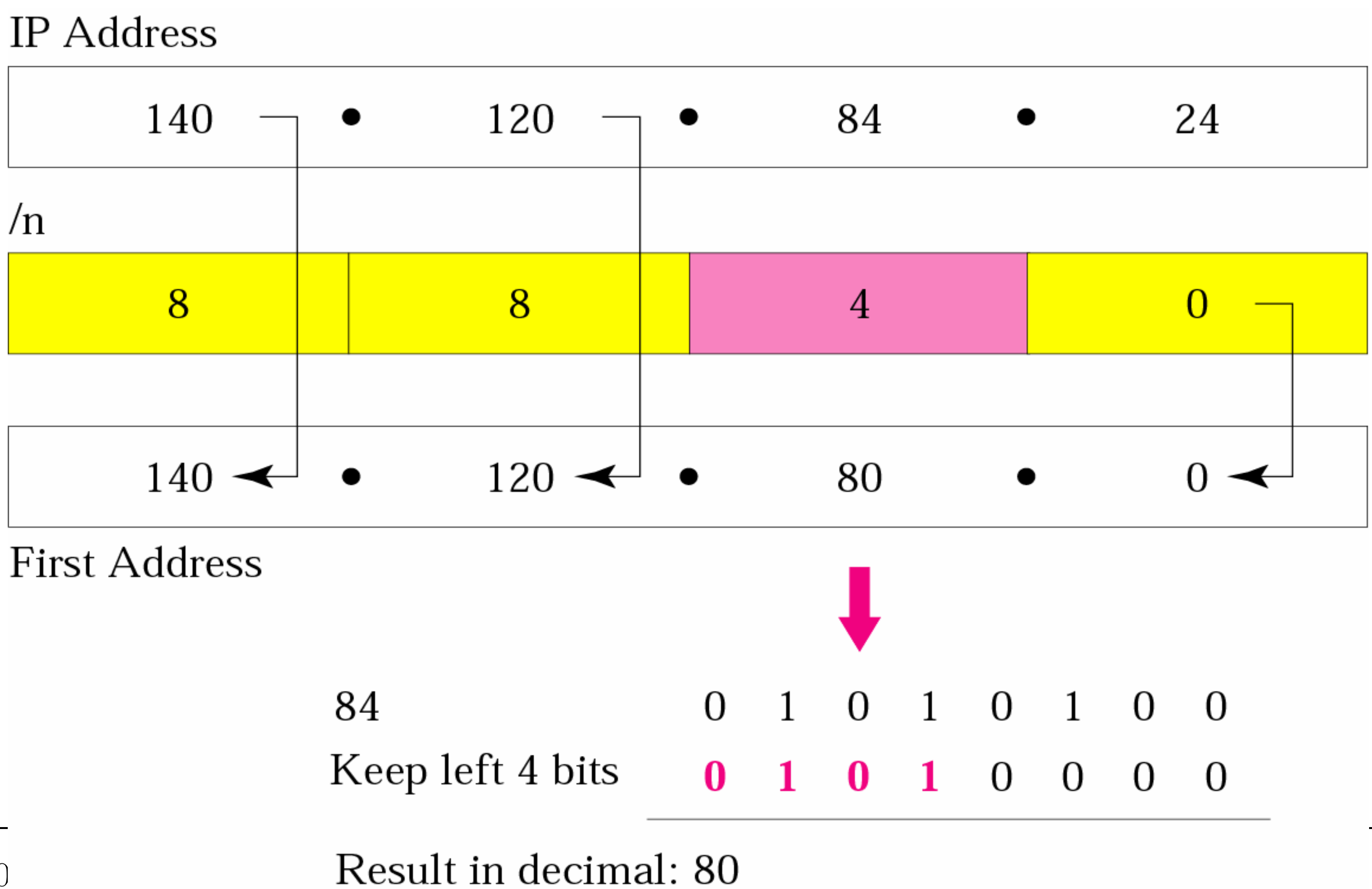
Solution

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 following shows the process:

Address in binary: ***10100111 11000111 10101010 01010010***
Keep the left 27 bits: ***10100111 11000111 10101010 01000000***
Result in CIDR notation: 167.199.170.64/27

Finding the first address

What is the first address in the block if one of the addresses is 140.120.84.24/20?



	128	64	32	16	8	4	2	1
Write 84 as sum of:	0	64	0	16	0	4	0	0
Select only leftmost 4:	0	64	0	16				
Add to find the result:	80							

Finding the last address in the block

- To the first address, add the number of addresses, minus one OR
- Add the first address to the complement of the mask

Example 1

Find the number of addresses in the block if one of the addresses is 140.120.84.24/20.

Solution

The prefix length is 20. The number of addresses in the block is 2^{32-20} or 2^{12} or 4096. Note that this is a large block with 4096 addresses.

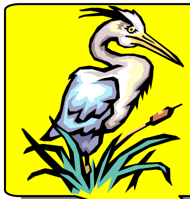
Example 2

Find the last address in the block if one of the addresses is 140.120.84.24/20.

Solution

We found in the previous examples that the first address is 140.120.80.0/20 and the number of addresses is 4096. To find the last address, we need to add 4095 (4096 − 1) to the first address.

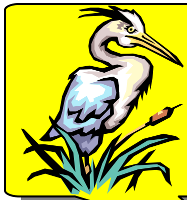
See Next Slide



Note:

In classless addressing, the last address in the block does not necessarily end in 255.

Subnetting in classless addressing



Note:

In fixed-length subnetting, the number of subnets is a power of 2.

Subnet mask

- We need to increase the prefix length
- If we need ***s*** number of subnets
  - As $s = 2^{\text{number of extra 1s}}$
  - => number of extra 1s = $\log_2 s$

Example 1

An organization is granted the block 130.34.12.64/26. The organization needs 4 subnets. What is the subnet prefix length?

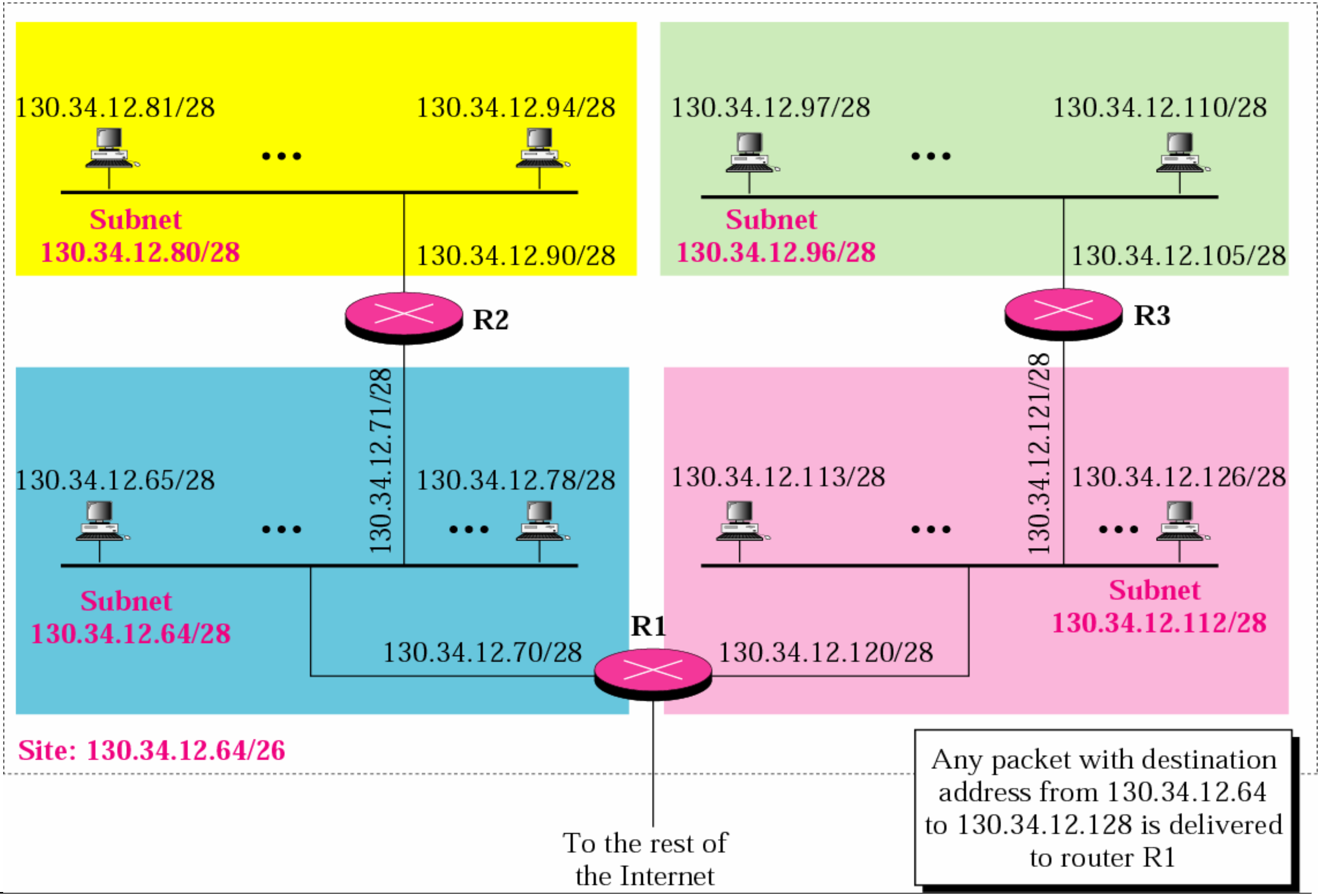
Solution

We need 4 subnets, which means we need to add two more 1s ($\log_2 4 = 2$) to the site prefix. The subnet prefix is then /28.

Example 2

What are the subnet addresses and the range of addresses for each subnet in the previous example?

See Next Slide


130.34.12.81/28
130.34.12.94/28
Subnet
130.34.12.80/28
130.34.12.90/28
130.34.12.97/28
130.34.12.110/28
Subnet
130.34.12.96/28
130.34.12.105/28
R2
R3
130.34.12.71/28
130.34.12.121/28
130.34.12.65/28
130.34.12.78/28
130.34.12.113/28
130.34.12.126/28
Subnet
130.34.12.64/28
Subnet
130.34.12.112/28
R1
130.34.12.70/28
130.34.12.120/28
Site: 130.34.12.64/26
To the rest of the Internet
Any packet with destination address from 130.34.12.64 to 130.34.12.128 is delivered to router R1

Example 2

The site has $2^{32-26} = 64$ addresses. Each subnet has $2^{32-28} = 16$ addresses. Now let us find the first and last address in each subnet.

1. The first address in the first subnet is 130.34.12.64/28, using the procedure we showed in the previous examples. Note that the first address of the first subnet is the first address of the block. The last address of the subnet can be found by adding 15 (16 − 1) to the first address. The last address is 130.34.12.79/28.

See Next Slide

Example 2

2.The first address in the second subnet is 130.34.12.80/28; it is found by adding 1 to the last address of the previous subnet. Again adding 15 to the first address, we obtain the last address, 130.34.12.95/28.

3. Similarly, we find the first address of the third subnet to be 130.34.12.96/28 and the last to be 130.34.12.111/28.

4. Similarly, we find the first address of the fourth subnet to be 130.34.12.112/28 and the last to be 130.34.12.127/28.

Example 3

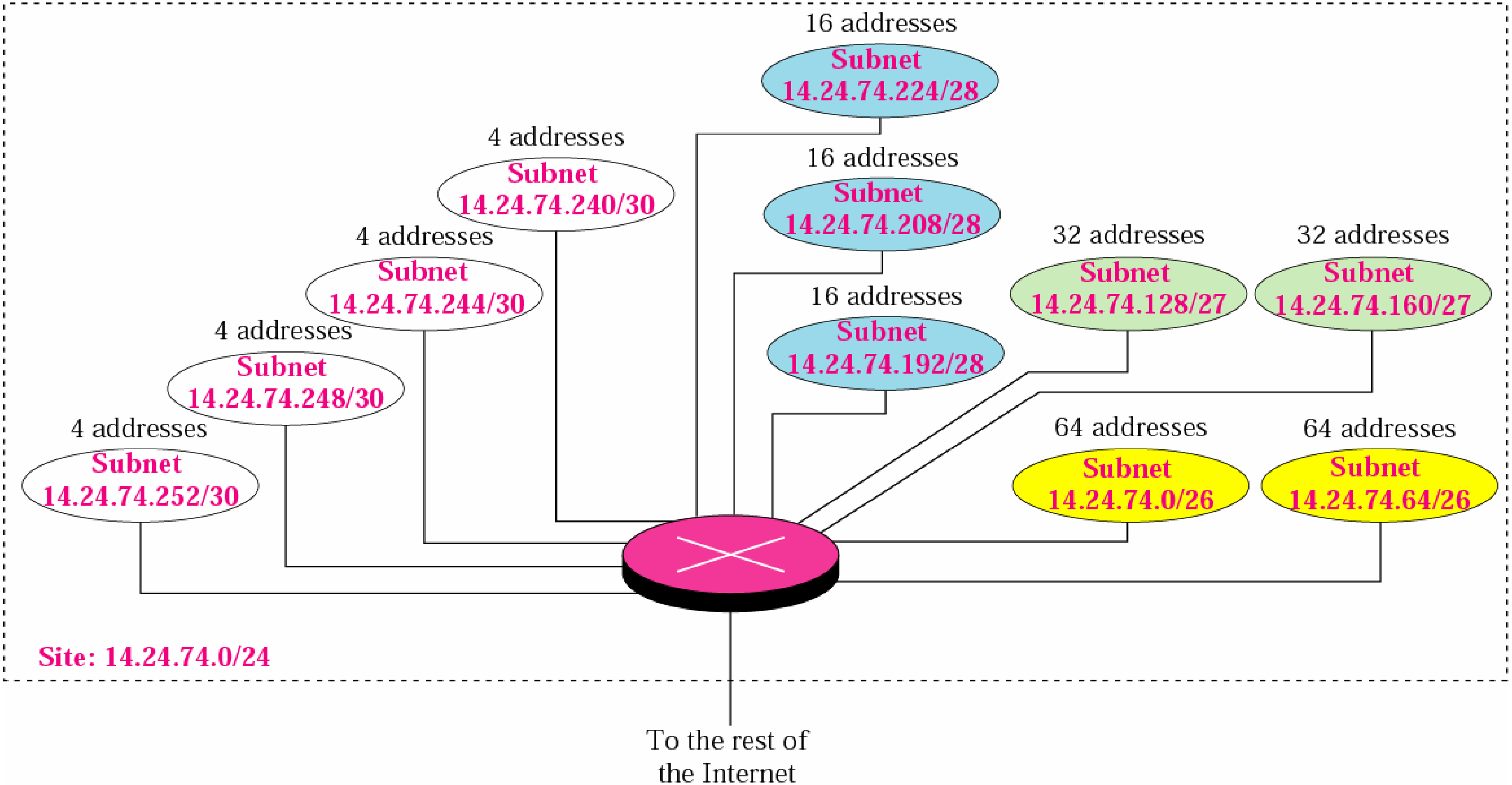
An organization is granted a block of addresses with the beginning address 14.24.74.0/24. There are $2^{32-24} = 256$ addresses in this block. The organization needs to have 11 subnets as shown below:

- a. ***two subnets, each with 64 addresses.***
- b. ***two subnets, each with 32 addresses.***
- c. ***three subnets, each with 16 addresses.***
- d. ***four subnets, each with 4 addresses.***

Design the subnets.

See Next Slide For One Solution

Example 3


16 addresses
Subnet
14.24.74.224/28
4 addresses
Subnet
14.24.74.240/30
16 addresses
Subnet
14.24.74.208/28
4 addresses
Subnet
14.24.74.244/30
32 addresses
Subnet
14.24.74.128/27
32 addresses
Subnet
14.24.74.160/27
16 addresses
Subnet
14.24.74.192/28
4 addresses
Subnet
14.24.74.248/30
4 addresses
Subnet
14.24.74.252/30
64 addresses
Subnet
14.24.74.0/26
64 addresses
Subnet
14.24.74.64/26
Site: 14.24.74.0/24
To the rest of
the Internet

Example 3

1. ***We use the first 128 addresses for the first two subnets, each with 64 addresses. Note that the mask for each network is /26. The subnet address for each subnet is given in the figure.***

2. ***We use the next 64 addresses for the next two subnets, each with 32 addresses. Note that the mask for each network is /27. The subnet address for each subnet is given in the figure.***

See Next Slide

Example 3

3. ***We use the next 48 addresses for the next three subnets, each with 16 addresses. Note that the mask for each network is /28. The subnet address for each subnet is given in the figure.***

4. ***We use the last 16 addresses for the last four subnets, each with 4 addresses. Note that the mask for each network is /30. The subnet address for each subnet is given in the figure.***

Address allocation

- Responsibility of ICANN
  - Internet Corporation for Assigned Names and Addresses
- Addresses are not allocated to organizations
- Rather they are assigned to ISPs
- ISPs distribute them to customers
  - On need to need basis

Questions?