Data Communications and Networking Fourth Edition

Forouzan

CW527/558-3
Computer Networks I

Student slides

Chapter 19

Network Layer:
Logical Addressing

19-1 IPv4 ADDRESSES

An IPv4 address is a 32-bit address that uniquely and universally defines the connection of a device (for example, a computer or a router) to the Internet.

Topics discussed in this section:

Address Space
Notations
Classful Addressing
Classless Addressing
Network Address Translation (NAT)

Note

An IPv4 address is 32 bits long.

An IPv6 address is 128 bits long.

Note

The IPv4 addresses are unique and universal.

Unique: No two devices on the Internet may have the same address
Universal: Addressing system must be accepted by any host that wants to connect to the Internet

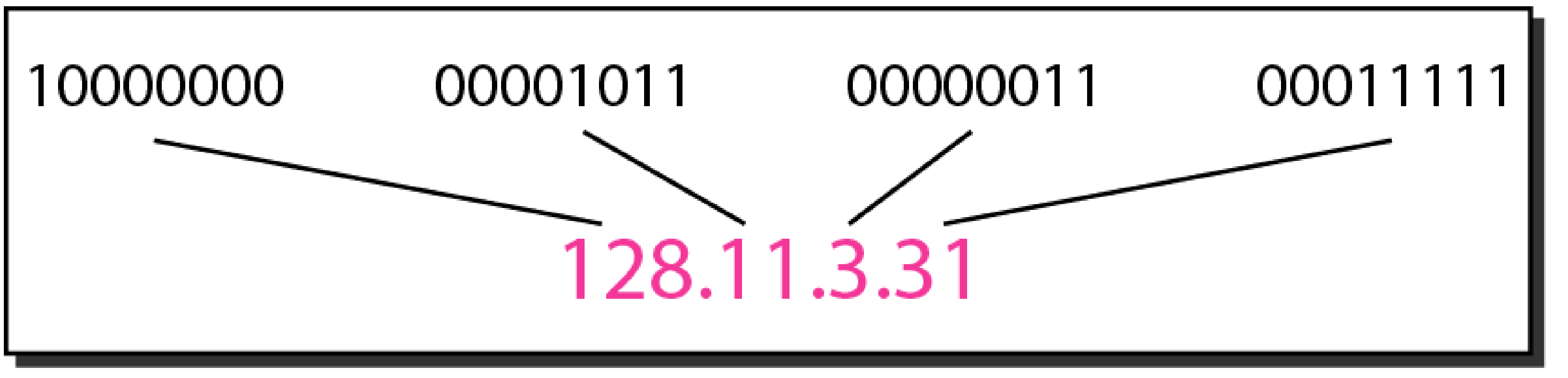
Address space = 2^n where n = number of bits

Note

The address space of IPv4 is 2^{32} or 4,294,967,296.

Figure 19.1 *Dotted-decimal notation and binary notation for an IPv4 address*

Two Notations used, binary and dot decimal



Example 19.1

Change the following IPv4 addresses from binary notation to dotted-decimal notation.

a. 10000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

Solution

Example 19.2

Change the following IPv4 addresses from dotted-decimal notation to binary notation.

a. 111.56.45.78

b. 221.34.7.82

Example 19.3

Find the error, if any, in the following IPv4 addresses.

a. 111.56.045.78

b. 221.34.7.8.20

c. 75.45.301.14

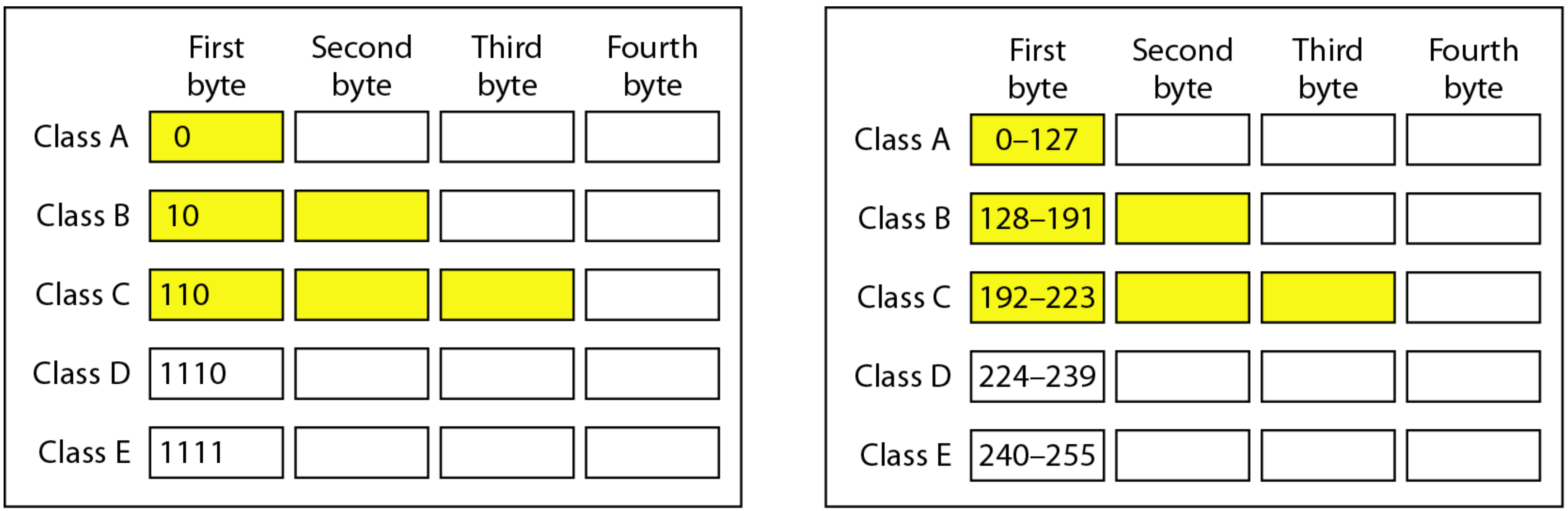
d. 11100010.23.14.67

Solution

Note

In classful addressing, the address space is divided into five classes: A, B, C, D, and E.

Figure 19.2 *Finding the classes in binary and dotted-decimal notation*



a. Binary notation

b. Dotted-decimal notation

Example 19.4

Find the class of each address.

a. <u>**0**</u>0000001 00001011 00001011 11101111

b. <u>**110**</u>00001 10000011 00011011 11111111

c. <u>**14**</u>.23.120.8

d. <u>**252**</u>.5.15.111

Solution

Table 19.1 ***Number of blocks and block size in classful IPv4 addressing***

Class	*Number of Blocks*	*Block Size*	*Application*
A	128	16,777,216	Unicast
B	16,384	65,536	Unicast
C	2,097,152	256	Unicast
D	1	268,435,456	Multicast
E	1	268,435,456	Reserved

Note

In classful addressing, a large part of the available addresses were wasted.

Table 19.2 ***Default masks for classful addressing***

Class	*Binary*	*Dotted-Decimal*	*CIDR*
A	**11111111** 00000000 00000000 00000000	**255**.0.0.0	/8
B	**11111111 11111111** 00000000 00000000	**255**.**255**.0.0	/16
C	**11111111 11111111 11111111** 00000000	**255**.**255**.**255**.0	/24

Slash notation or CIDR notation

CIDR Classless Interdomain Routing

Note

Classful addressing, which is almost obsolete, is replaced with classless addressing.

The Internet authorities imposed three restrictions on classless address blocks

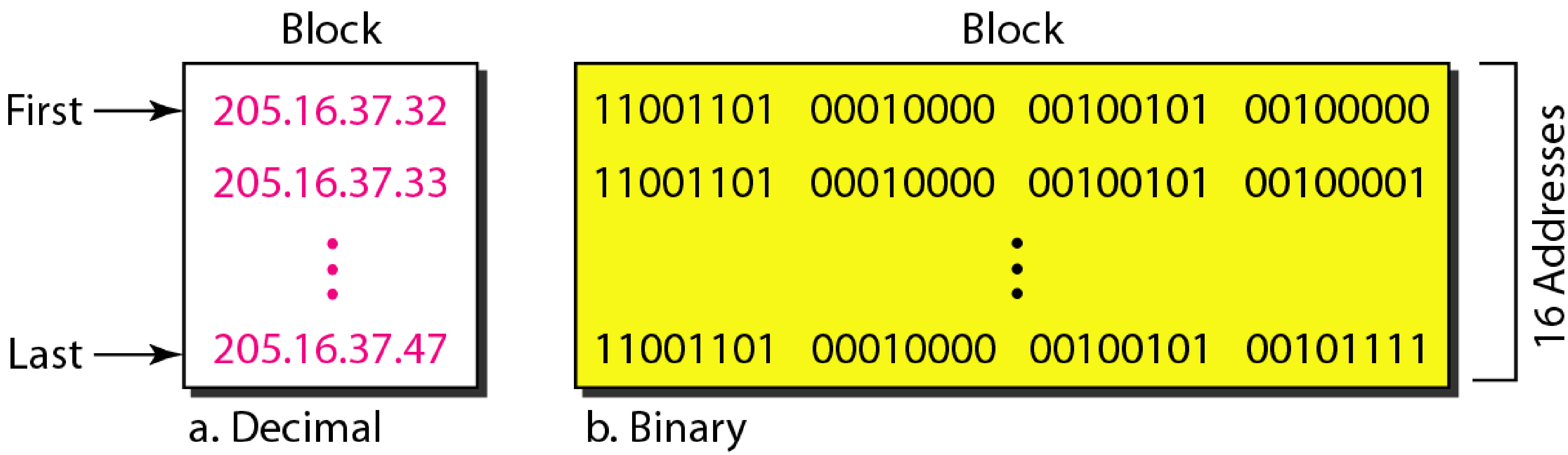
- **The addresses in a block must be contiguous**
- **The number of addresses in a block must be a power of 2 (ie 2,4,8,16,..)**
- **The first address must be evenly divisible by the number of addresses**

Example 19.5

Figure 19.3 shows a block of addresses, in both binary and dotted-decimal notation, granted to a small business that needs 16 addresses.

We can see that the restrictions are applied to this block. The addresses are contiguous. The number of addresses is a power of 2 ($16 = 2^4$), and the first address is divisible by 16. The first address, when converted to a decimal number, is 3,440,387,360, which when divided by 16 results in 215,024,210.

Figure 19.3 *A block of 16 addresses granted to a small organization*



The addresses are contiguous
The number of addresses is a power of 2 ($2^4 = 16$)
The first address when converted to decimal is 3,440,387,360 and when divided by 16 results in 215,024,210

Note

In IPv4 addressing, a block of addresses can be defined as
x.y.z.t /*n*
in which x.y.z.t defines one of the addresses and the /*n* defines the mask.

n leftmost bits are 1's and 32 – n rightmost bits are 0's

Note

The first address in the block can be found by setting the rightmost $32 - n$ bits to 0s.

Example 19.6

A block of addresses is granted to a small organization. We know that one of the addresses is 205.16.37.39/28. What is the first address in the block?

Solution

Note

The last address in the block can be found by setting the rightmost 32 − n bits to 1s.

Example 19.7

Find the last address for the block in Example 19.6.

Solution

Note

The number of addresses in the block can be found by using the formula 2^{32-n}.

Example 19.8

Find the number of addresses in Example 19.6.

Solution

Example 19.9

Another way to find the first address, the last address, and the number of addresses is to represent the mask as a 32-bit binary (or 8-digit hexadecimal) number. This is particularly useful when we are writing a program to find these pieces of information. In Example 19.5 the /28 can be represented as

11111111 11111111 11111111 11110000

(twenty-eight 1s and four 0s).

Find

a. The first address

b. The last address

c. The number of addresses.

Solution

a. ***The first address can be found by ANDing the given addresses with the mask. ANDing here is done bit by bit. The result of ANDing 2 bits is 1 if both bits are 1s; the result is 0 otherwise.***

Address:	11001101	00010000	00100101	00100111
Mask:	**11111111**	**11111111**	**11111111**	**11110000**
First address:	11001101	00010000	00100101	00100000

Example 19.9 (continued)

b. ***The last address can be found by ORing the given addresses with the complement of the mask. ORing here is done bit by bit. The result of ORing 2 bits is 0 if both bits are 0s; the result is 1 otherwise. The complement of a number is found by changing each 1 to 0 and each 0 to 1.***

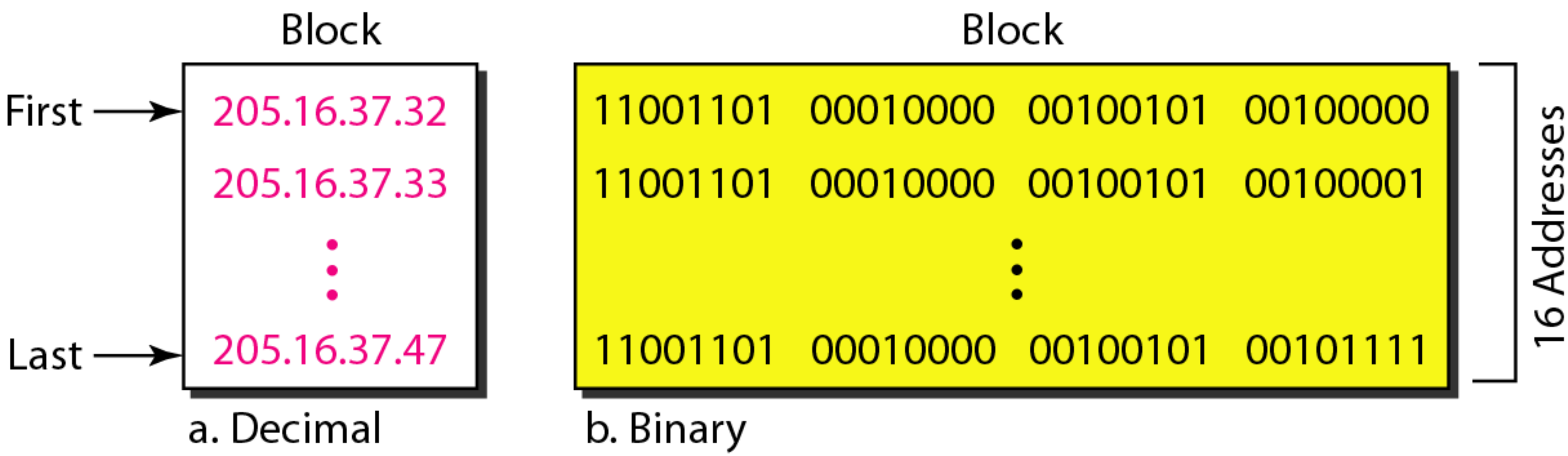
Address:	11001101	00010000	00100101	00100111
Mask complement:	**00000000**	**00000000**	**00000000**	**00001111**
Last address:	11001101	00010000	00100101	00101111

Example 19.9 (continued)

c. ***The number of addresses can be found by complementing the mask, interpreting it as a decimal number, and adding 1 to it.***

Mask complement:	**000000000 00000000 00000000 00001111**
Number of addresses:	15 + 1 = 16

Figure 19.4 *A network configuration for the block 205.16.37.32/28*



Note

The first address in a block is normally not assigned to any device; it is used as the network address that represents the organization to the rest of the world.

Figure 19.5 *Two levels of hierarchy in an IPv4 address*

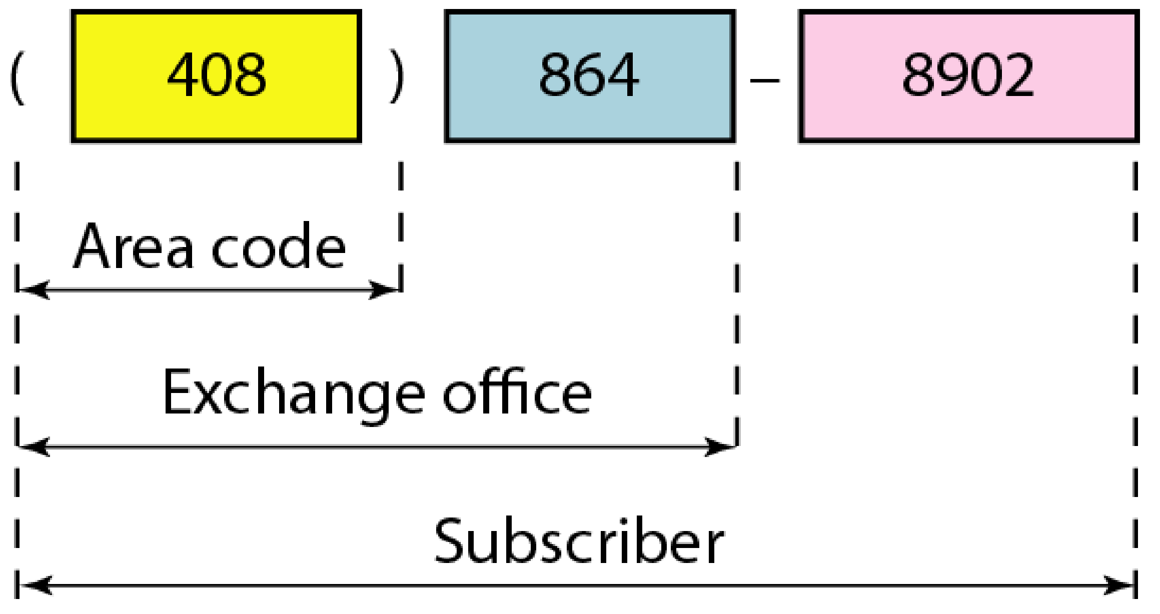
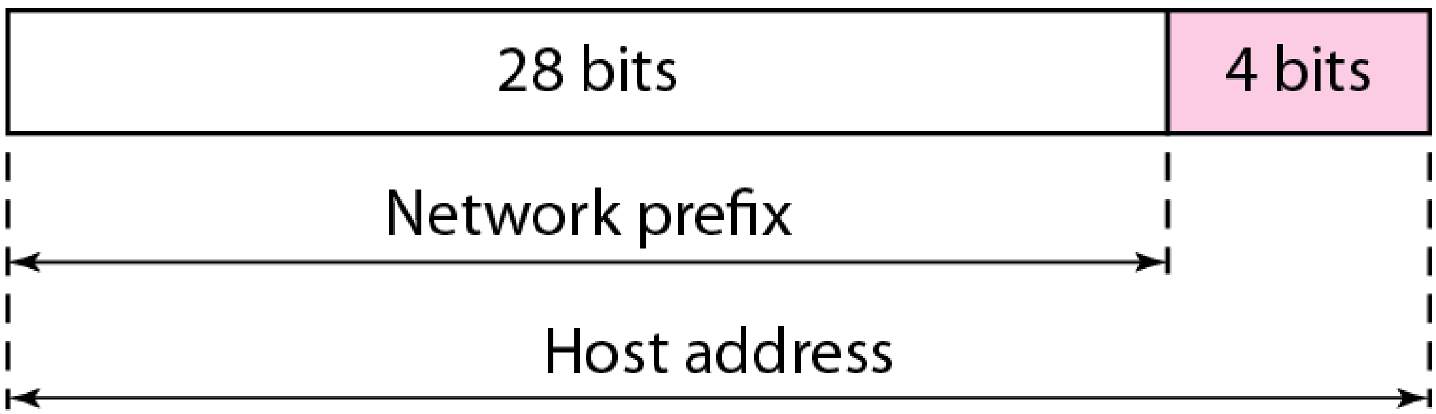


Figure 19.6 *A frame in a character-oriented protocol*

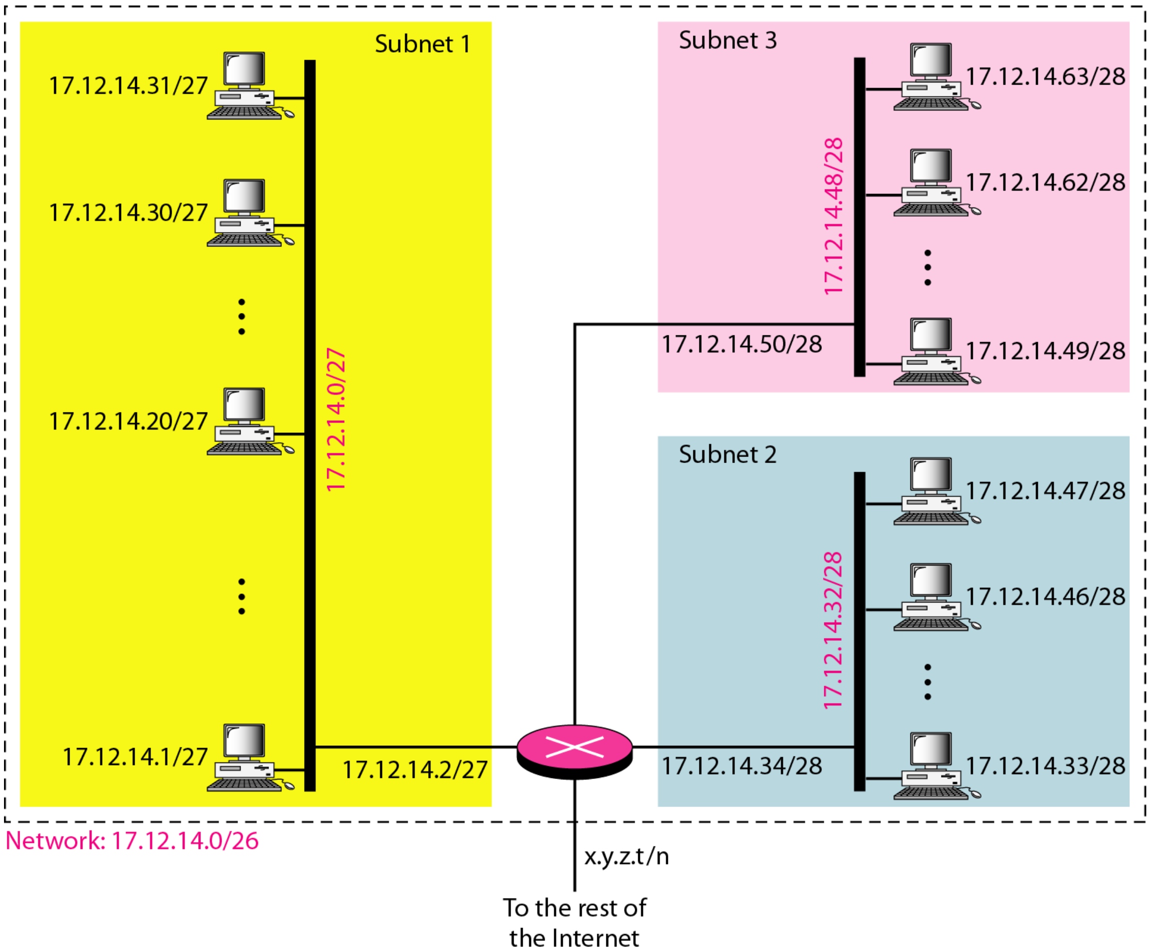


The prefix is common to all addresses in the network the suffix changes from one device to another

Note

Each address in the block can be considered as a two-level hierarchical structure: the leftmost *n* bits (prefix) define the network; the rightmost 32 − n bits define the host.

Figure 19.7 *Configuration and addresses in a subnetted network*



Given a block of 64 addresses

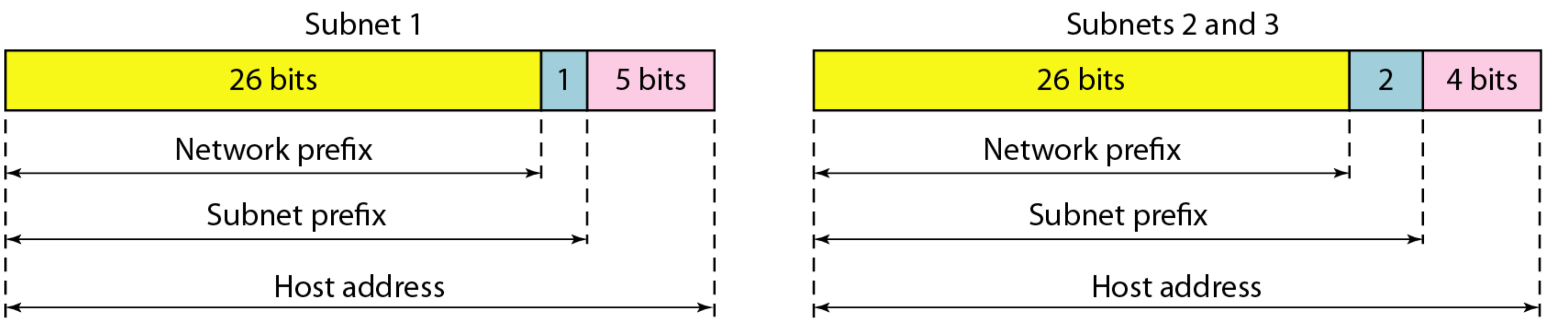
Subnet the block into a block of 32 and 2 blocks of 16

Write out the range of addresses in each block

What is the address of each subnet

What is the broadcast address of each subnet

Figure 19.8 *Three-level hierarchy in an IPv4 address*



Address allocation: ICANN Internet Corporation for Assigned Names and Numbers, ICANN don't deal with organisations they only deal with ISP's.

The Internet Assigned Numbers Authority (IANA)

FROM: Wikipedia

ICANN

ICANN is an acronym for the Internet Corporation for Assigned Names and Numbers, a global multi-stakeholder organization that was created an 1998 and empowered through actions by the U.S. government and its Department of Commerce. ICANN is the main Internet governance institution. Its primary responsibility is to manage the Internet's core infrastructure, which consists of IP addresses, domain names, and root servers. It coordinates the Internet's DNS, IP addresses and autonomous system numbers, which involves a continued management of these evolving systems and the protocols that underly them.

While ICANN has its roots in the U.S. government, it is now, and continues to strive to be, an international, community-driven organization (also known as ICANN globalisation). Their management of an interoperable Internet covers 180 million domain names, the allocation of more than 4 billion network addresses, and the support of approximately a trillion DNS look-ups everyday across 240 countries. ICANN collaborates with companies, individuals, and governments to ensure the continued success of the Internet. It holds meetings three times a year, switching the international location for each meeting; one of these serves as the annual general meeting when the new ICANN Board members take their seats.

The Internet Assigned Numbers Authority (IANA) is a department of ICANN

Dialup: Addresses assigned dynamically. Problem today with xDSl and the use of home networks

Table 19.3 ***Addresses for private networks***

Range			*Total*
10.0.0.0	to	10.255.255.255	2^{24}
172.16.0.0	to	172.31.255.255	2^{20}
192.168.0.0	to	192.168.255.255	2^{16}

Figure 19.10 *A NAT implementation*

Quick solution

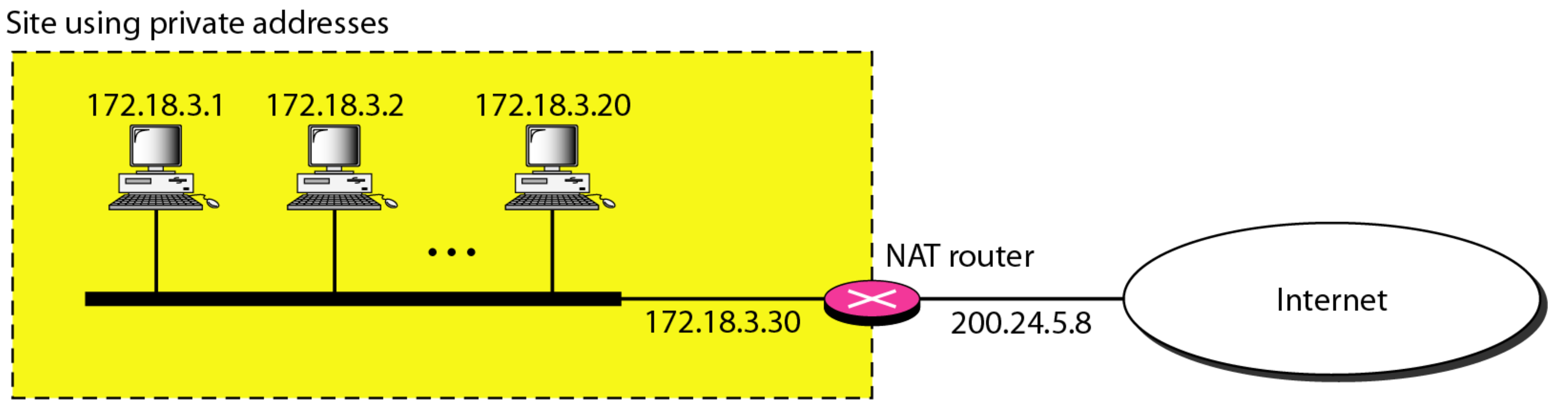


Figure 19.11 *Addresses in a NAT*

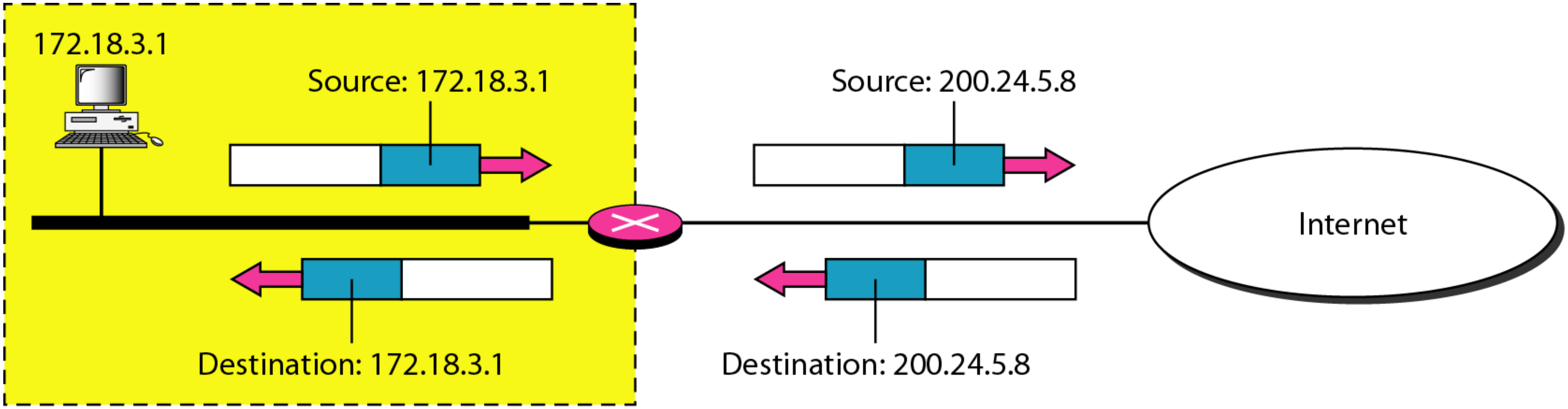
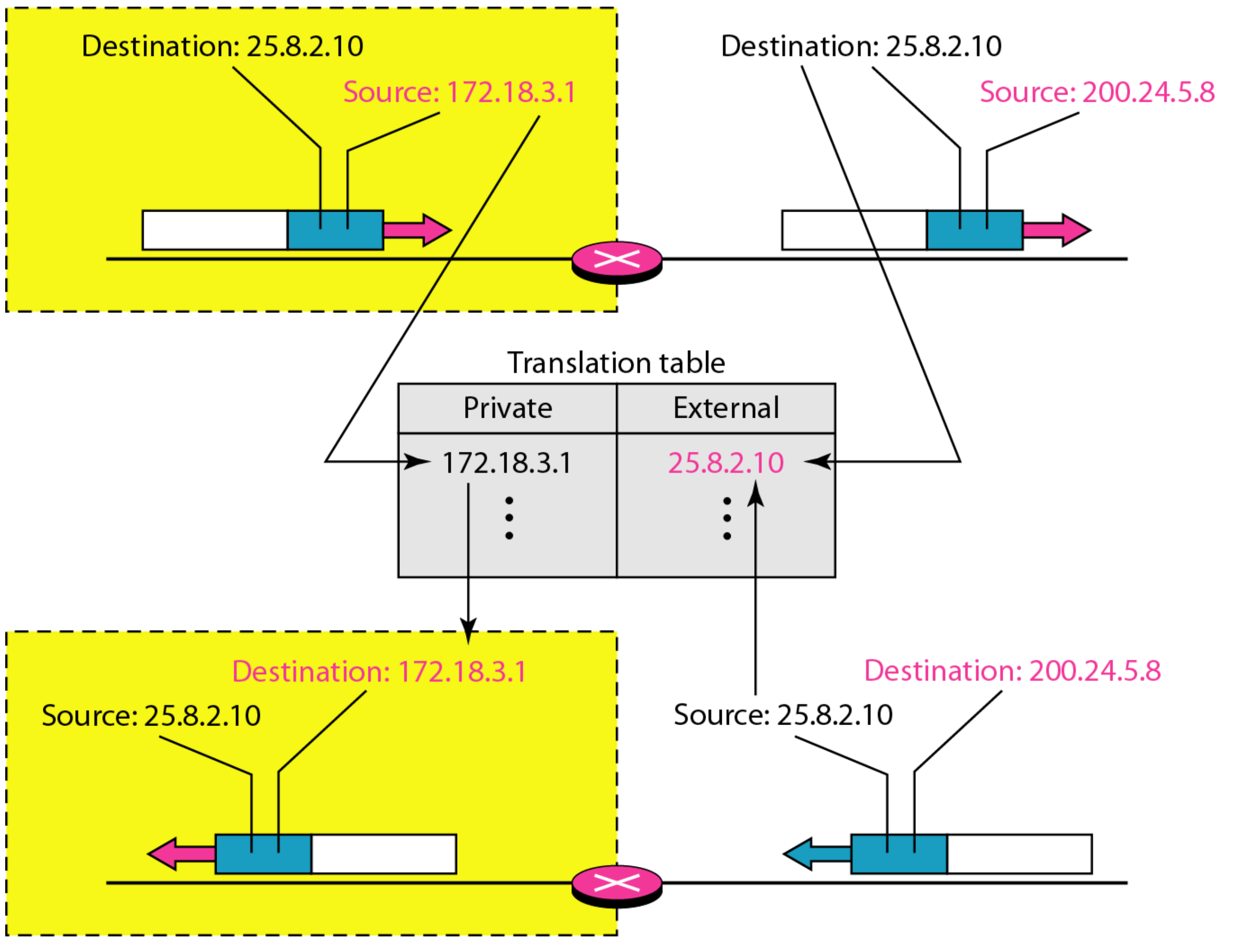


Figure 19.12 *NAT address translation (using one IP address)*



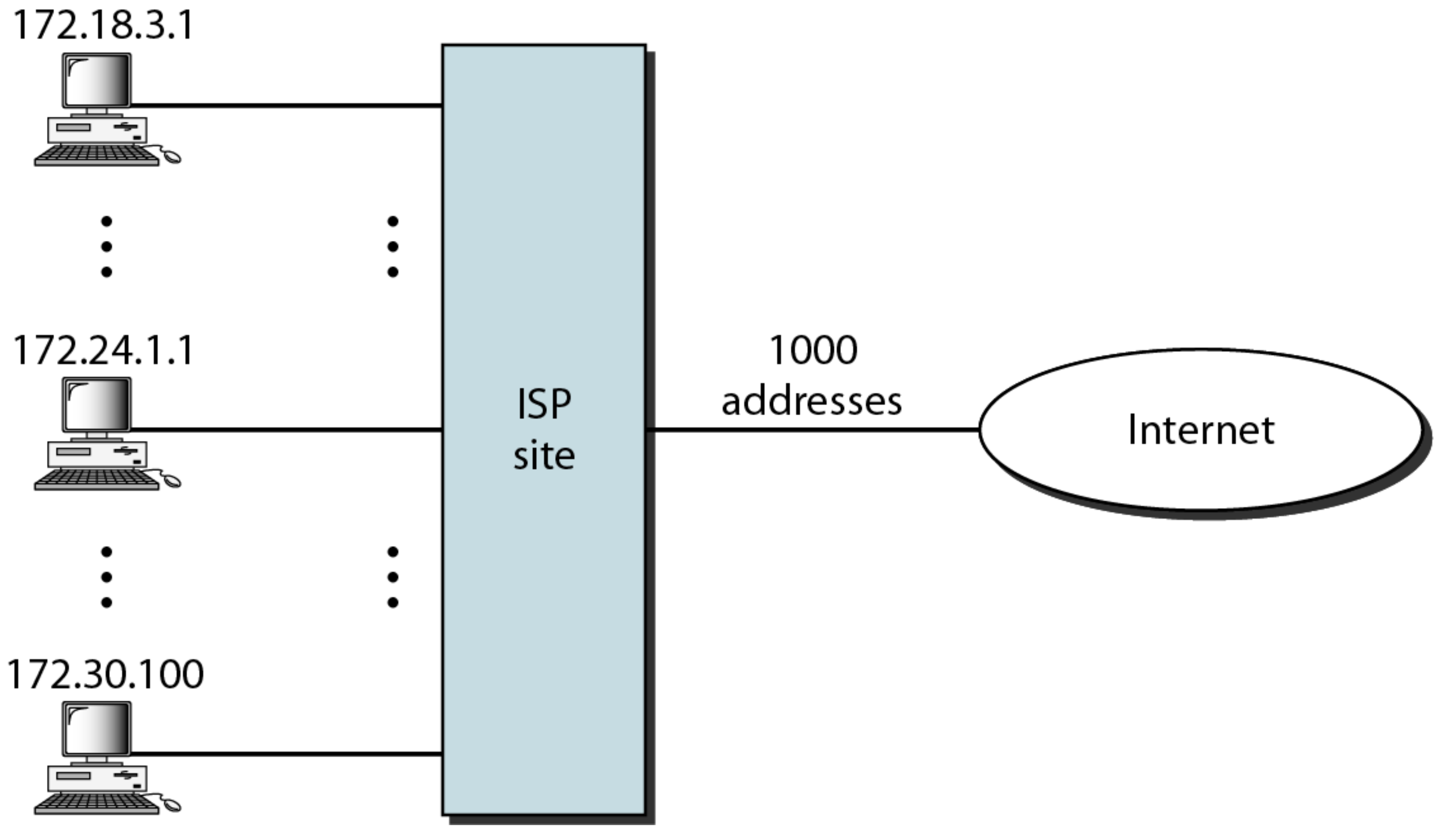
Only one private network host can access the same external host. To remove this restriction the NAT router uses a pool of addresses. E.g. if we had four global addresses then four private hosts could access the same external host at the same time. Because each pair of addresses defines a connection.
Can only have four connections to the same external host
A private network host can NOT access more than one server program on the same external host (eg HTTP, FTP, etc.)

Using both IP address and port number

Table 19.4 ***Five-column translation table***

Private Address	*Private Port*	*External Address*	*External Port*	*Transport Protocol*
172.18.3.1	1400	25.8.3.2	80	TCP
172.18.3.2	1401	25.8.3.2	80	TCP
. . .	. . .	. . .	. . .	. . .

Figure 19.13 *An ISP and NAT*



19-2 IPv6 ADDRESSES

Despite all short-term solutions, address depletion is still a long-term problem for the Internet. This and other problems in the IP protocol itself have been the motivation for IPv6.

Topics discussed in this section:

Structure
Address Space

Note

An IPv6 address is 128 bits long.

Figure 19.14 *IPv6 address in binary and hexadecimal colon notation*

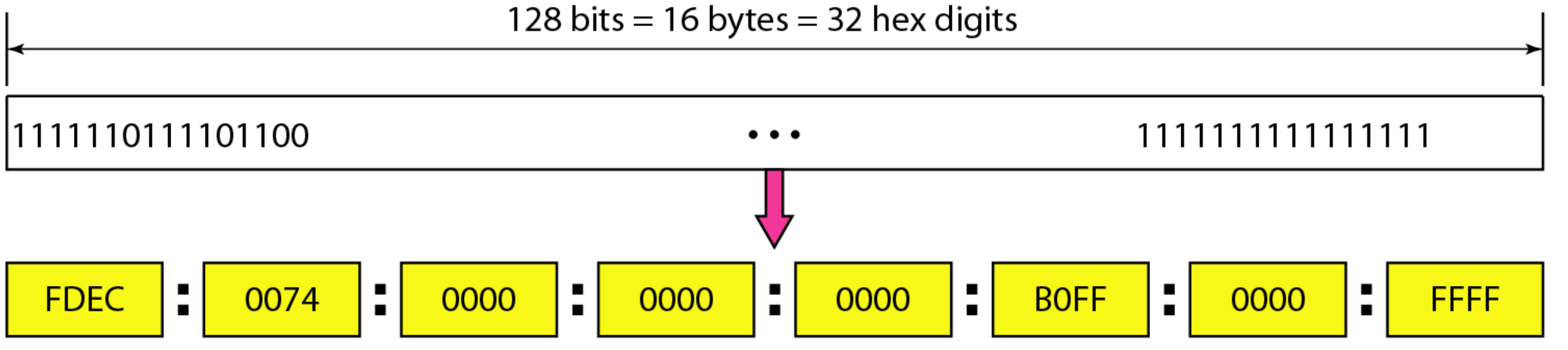
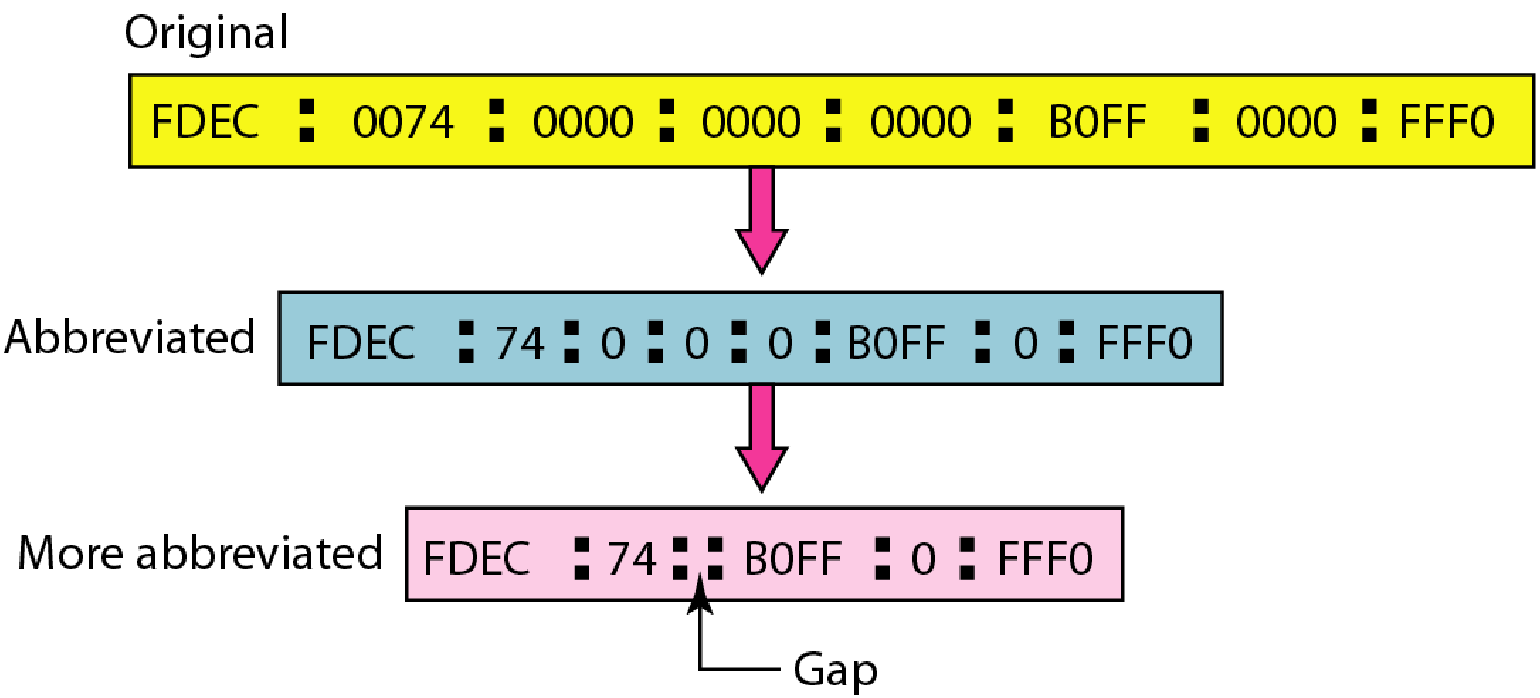


Figure 19.15 *Abbreviated IPv6 addresses*



Example 19.11

Expand the address 0:15::1:12:1213 to its original.

Solution

Example 19.11

Expand the address 0:15::1:12:1213 to its original.

Solution

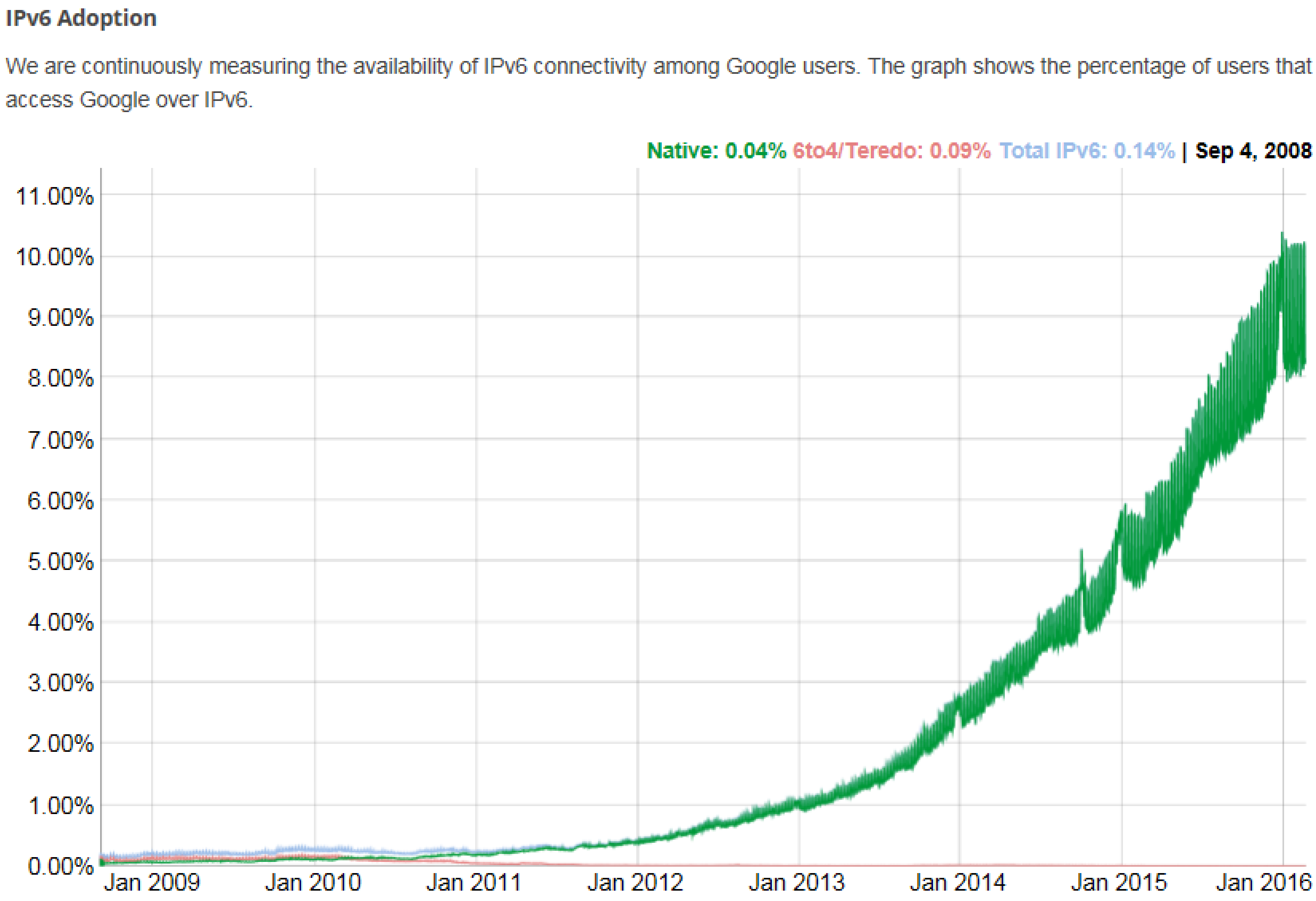
We first need to align the left side of the double colon to the left of the original pattern and the right side of the double colon to the right of the original pattern to find how many 0s we need to replace the double colon.

```
xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
   0:  15:                 :   1:  12:1213
```

This means that the original address is.

```
0000:0015:0000:0000:0000:0001:0012:1213
```

IPv6 Usage among Google users (01 Mar 2016)



Regional Internet Registries

There are five RIRs:

- AFRINIC
- APNIC
- ARIN
- LACNIC
- RIPE NCC

Regional Internet Registries map

https://www.nro.net/about-the-nro/regional-internet-registries

Regional Internet Registries

Internet identifiers are coordinated globally, so that each identifier is uniquely assigned to only one party – thus enabling successful and reliable communication among parties on the Internet. For Internet numbers (which include, most notably, Internet Protocol or IP addresses), a global registration system is facilitated by the coordinated activities of five Regional Internet Registries (RIRs).

The evolution of the RIR system was a result of the Internet community's desire for the administration of Internet number resources in accordance with practices and policies established cooperatively by those using the resources.

Each RIR operates as a not-for-profit, member-based association in its respective region in accordance with the laws of the country in which it is located. The five RIRs are as follows: AFRINIC (established 2005, serving Africa and based in Mauritius), APNIC (established 1993, serving Asia Pacific region and based in Australia), ARIN (established 1997, serving the United States, Canada, many Caribbean and North Atlantic islands and based in the United States), LACNIC (established 2002, serving Latin America and the Caribbean and based in Uruguay) and the RIPE NCC (established 1992, serving Europe, Central Asia and the Middle East and based in The Netherlands).

The RIRs are governed by Boards elected by their members and are funded by fees paid by the participating organizations. They operate according to policies developed by the community via open, inclusive, bottom-up Policy Development Processes.

The Role of Regional Internet Registries

Within their respective regions, RIRs provide services for the administration, management, distribution and registration of Internet number resources; specifically IPv4 addresses, IPv6 addresses, and Autonomous System numbers. Services are based, in part, upon policies that the communities of each RIR develop in a multi-stakeholder, bottom up approach that is open to all interested parties. The Policy Development Process within each RIR region defines the way these policies are developed and adopted.

The key services the RIRs provide are administration of the Internet number resources to help ensure uniqueness, responsible distribution, ensuring that resources go to those with a demonstrated need for them, and global publication of all allocations and assignments.

https://www.nro.net/about-the-nro/regional-internet-registries