Chapter 6 Addressing the Network- IPv4

Objectives

- Explain the structure IP addressing and demonstrate the ability to convert between 8-bit binary and decimal numbers.
- Given an IPv4 address, classify by type and describe how it is used in the network
- Explain how addresses are assigned to networks by ISPs and within networks by administrators
- Determine the network portion of the host address and explain the role of the subnet mask in dividing networks.
- Given IPv4 addressing information and design criteria, calculate the appropriate addressing components.
- Use common testing utilities to verify and test network connectivity and operational status of the IP protocol stack on a host.

6.1 IPv4 Addresses

6.1.1 IP Addressing Structure

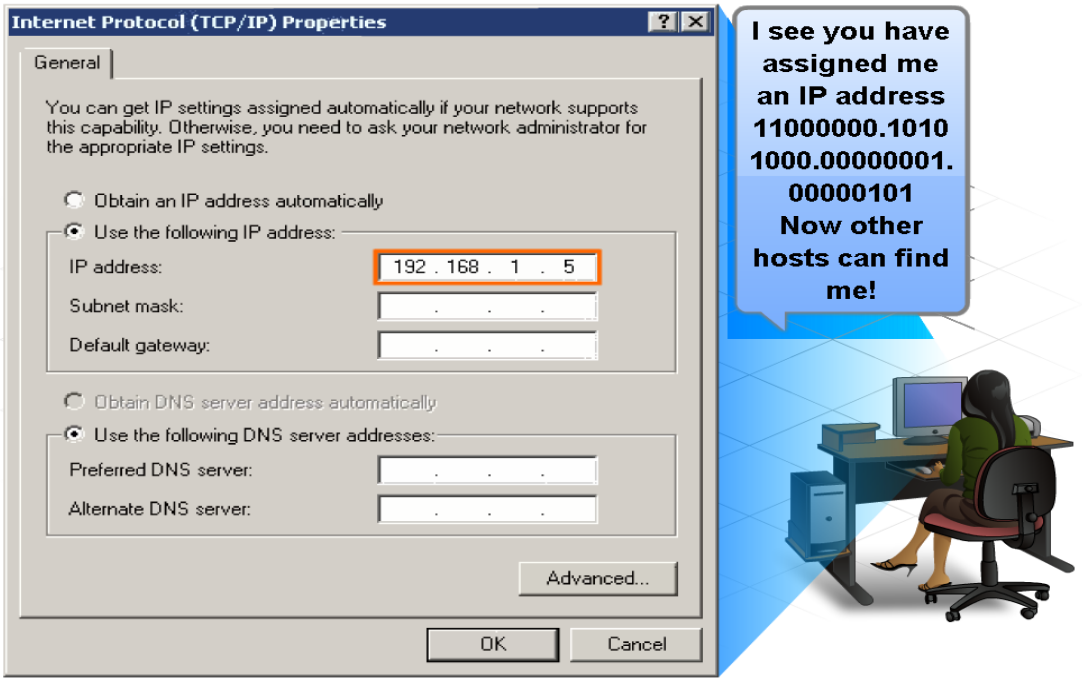
- Each device on a network must be **uniquely defined**.
- At the Network layer, the **packets** of the communication need to be identified with **source and destination addresses** of the two end systems.
- With IPv4, this means each packet has a **32-bit source address** and a **32-bit destination address** in Layer 3 header with IPv4.
- These addresses are used in the data network as **binary patterns**. Inside the devices, digital logic is applied for their interpretation.
- For the human, a string of 32 bits is difficult to interpret and remember. Therefore, a **dotted decimal format** is used to represent IPv4 addresses.

Example 1:

The address: 10101100000100000000010000010100 is expressed in dotted decimal as: 172.16.4.20

Keep in mind that devices use binary logic. The dotted decimal format is used to make it easier for people to use and remember addresses.

Example 2:



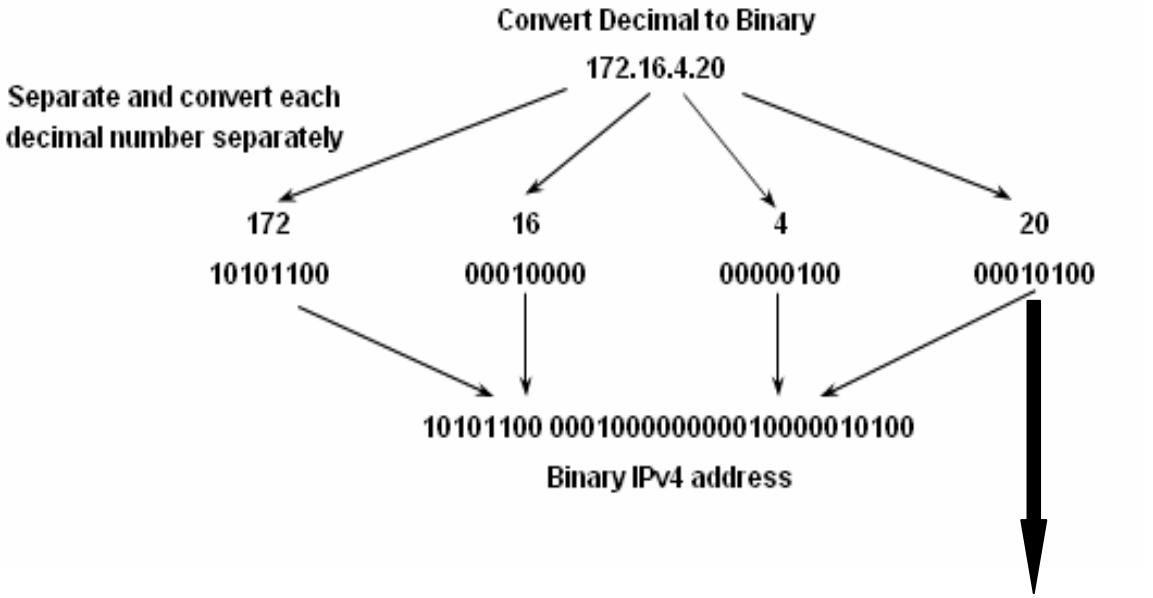
IP version 4 (IPv4) is the current form of addressing used on the Internet.

6.1.2 Knowing the Numbers – Binary to Decimal Conversion

To understand the operation of a device in a network, we need to look at addresses and other data the way the device does - in binary notation. This means that we need to have some skill in binary to decimal conversion.

Data represented in binary may represent many different forms of data to the human network. In this discussion, we refer to binary as it relates to IPv4 addressing. This means that we look at each byte (octet) as a decimal number in the range of 0 to 255.

Binary Numbering System



2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
0	0	0	1	0	1	0	0

Converting decimal to 8-bit binary

Positional Notation in the base 10 number system

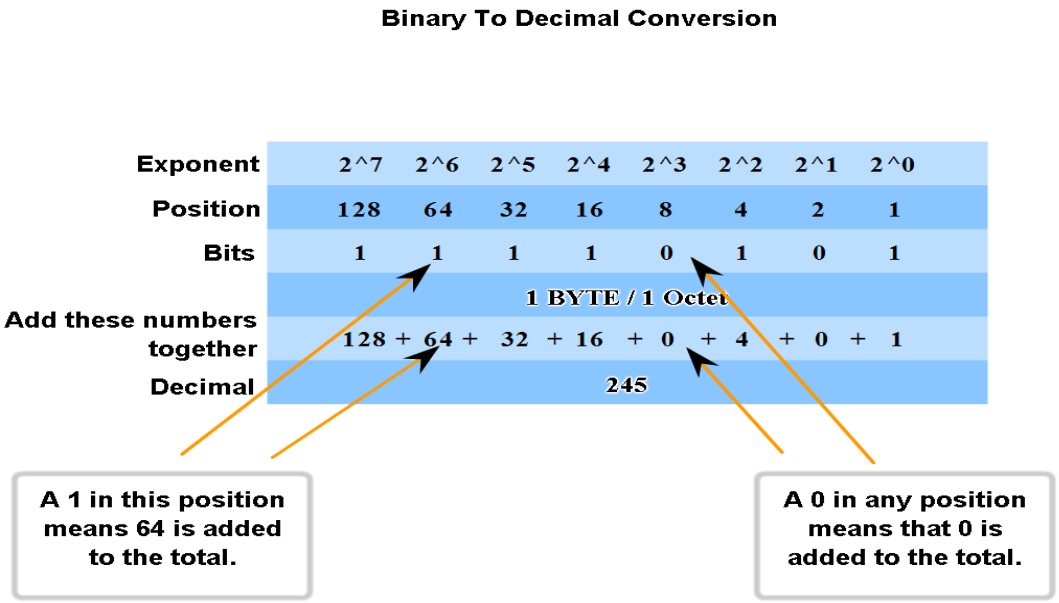
Learning to convert binary to decimal requires an understanding of the mathematical basis of a numbering system called positional notation. Positional notation means that a digit represents different values depending on the position it occupies. More specifically, the value that a digit represents is that value multiplied by the power of the base, or radix, represented by the position the digit occupies.

Example:

245 = (2 * 10^2) + (4 * 10^1) + (5 * 10^0) or 245 = (2 * 100) + (4 * 10) + (5 * 1)

Converting 8-bit binary to decimal

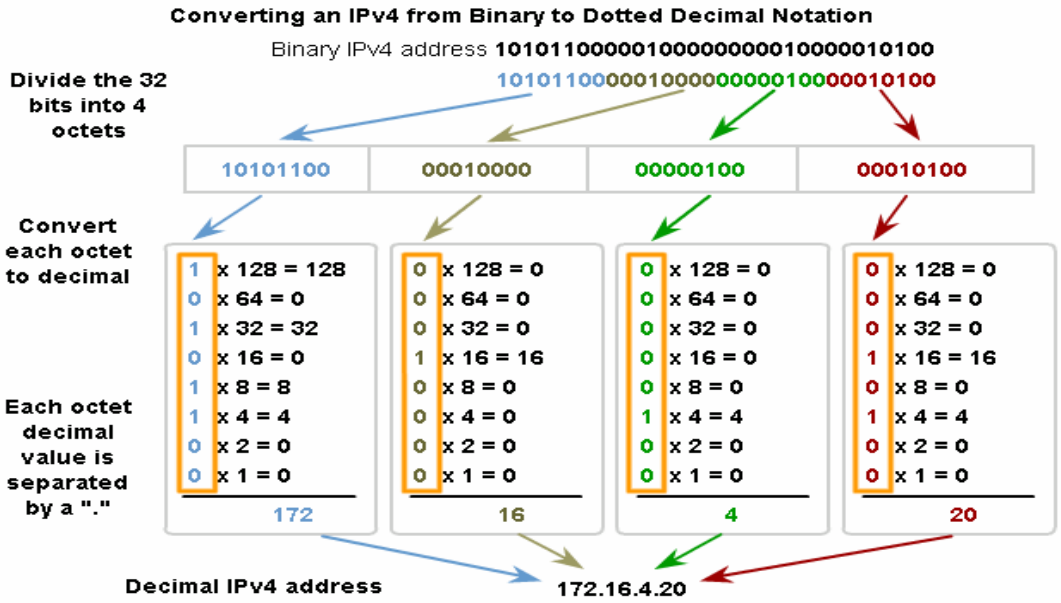
Example 1:



11110101 in Binary = Decimal Number 245

Example 2: Binary IPv4 address 10101100000100000000010000010100

Decimal IPv4 address 172.16.4.20



Practice converting decimal to 8-bit binary

Decimal to Binary Conversion Activity

Given a decimal value, enter the correct binary values for each positon.

Decimal Value	209							
Exponent	2^7th	2^6th	2^5th	2^4th	2^3rd	2^2nd	2^1st	2^0
Position	128	64	32	16	8	4	2	1
Bit								

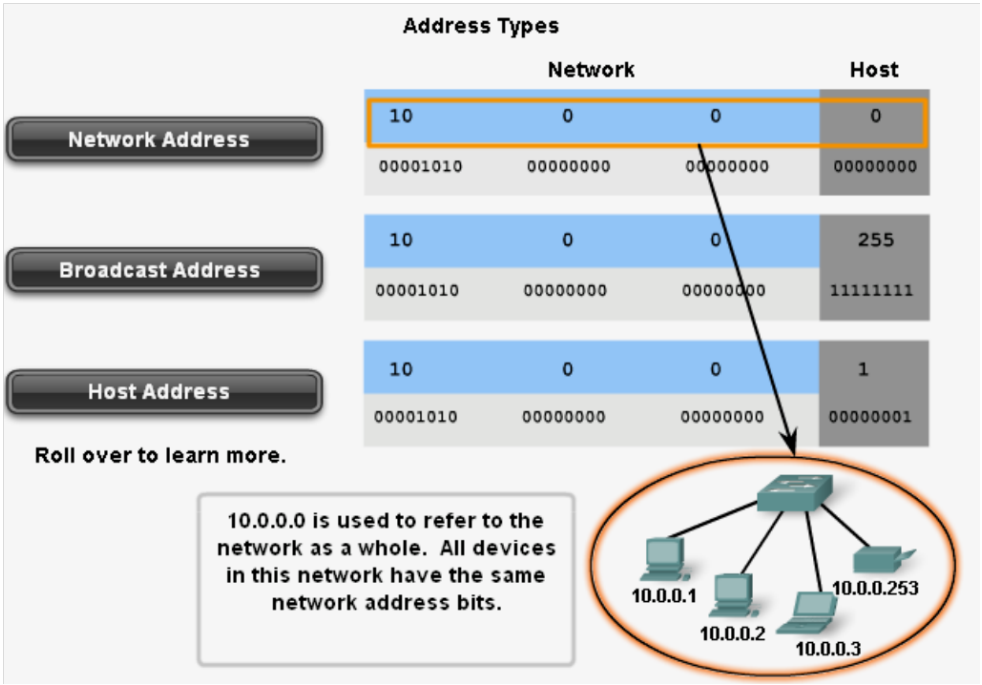
Enter numbers for these 8 positions.

6.2 Addresses for Different Purposes

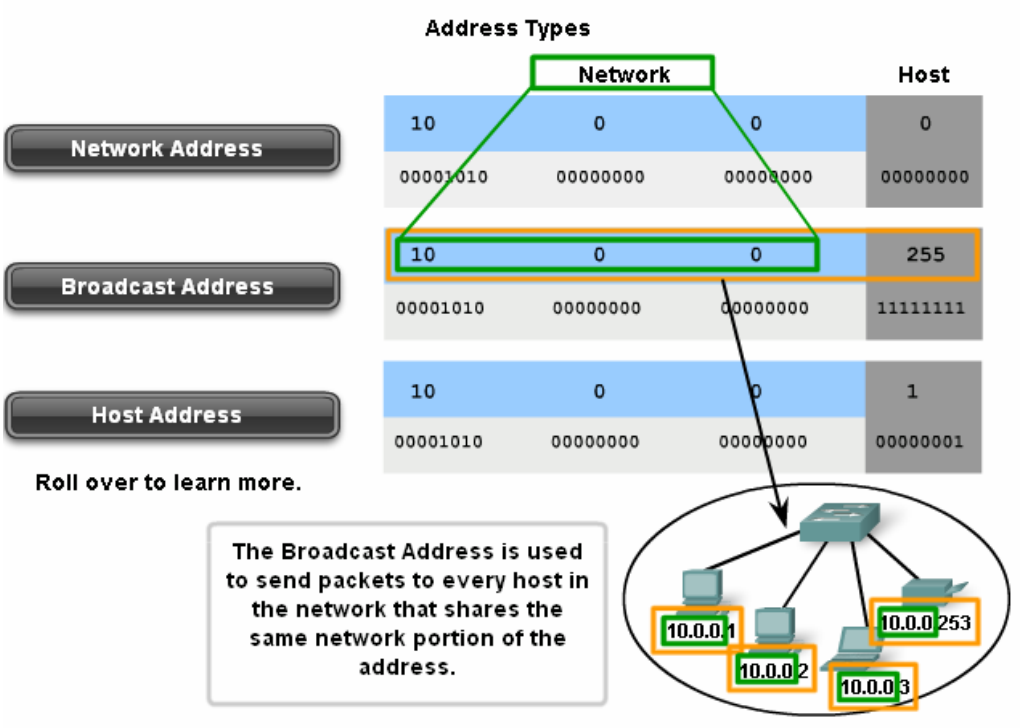
6.2.1 Types of addresses in an IPv4 Network

Within the address range of each IPv4 network, we have three types of addresses:

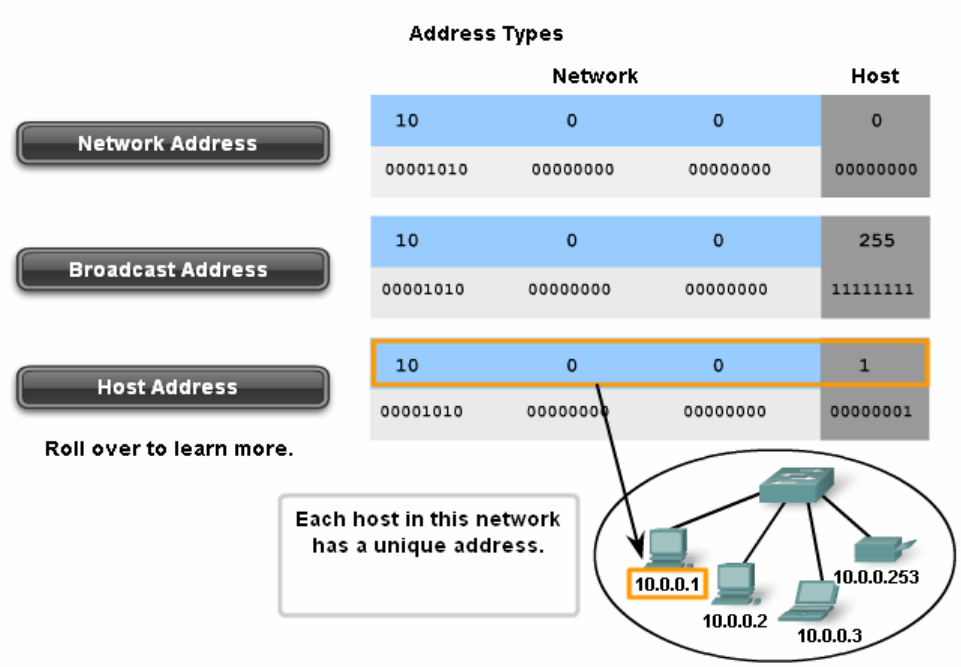
Network address - The network address is a standard way to refer to a network (e.g. 10.0.0.0).



Broadcast address - A special address used to send data to all hosts in the network. The broadcast address uses the highest address in the network range. This is the address in which the bits in the host portion are all 1s.



Host addresses - The addresses assigned to the end devices in the network



Network Prefixes

An important question is: How do we know how many bits represent the network portion and how many bits represent the host portion? When we express an IPv4 network address, we add a prefix length to the network address. For example, in 172.16.4.0 /24, the /24 is the prefix length - it tells us that the first 24 bits are the network address. This leaves the remaining 8 bits, the last octet, as the host portion.

The subnet is another entity that is used to specify the network portion of an IPv4 address to the network devices. The subnet mask consists of 32 bits, just as the address does, and uses 1s and 0s to indicate which bits of the address are network bits and which bits are hosts bits.

Using Different Prefixes for the 172.16.4.0 Network

Network	Network address	Host range	Broadcast address
172.16.4.0 /24	172.16.4.0	172.16.4.1 - 172.16.4.254	172.16.4.255
172.16.4.0 /25	172.16.4.0	172.16.4.1 - 172.16.4.126	172.16.4.127
172.16.4.0 /26	172.16.4.0	172.16.4.1 - 172.16.4.62	172.16.4.63
172.16.4.0 /27	172.16.4.0	172.16.4.1 - 172.16.4.30	172.16.4.31

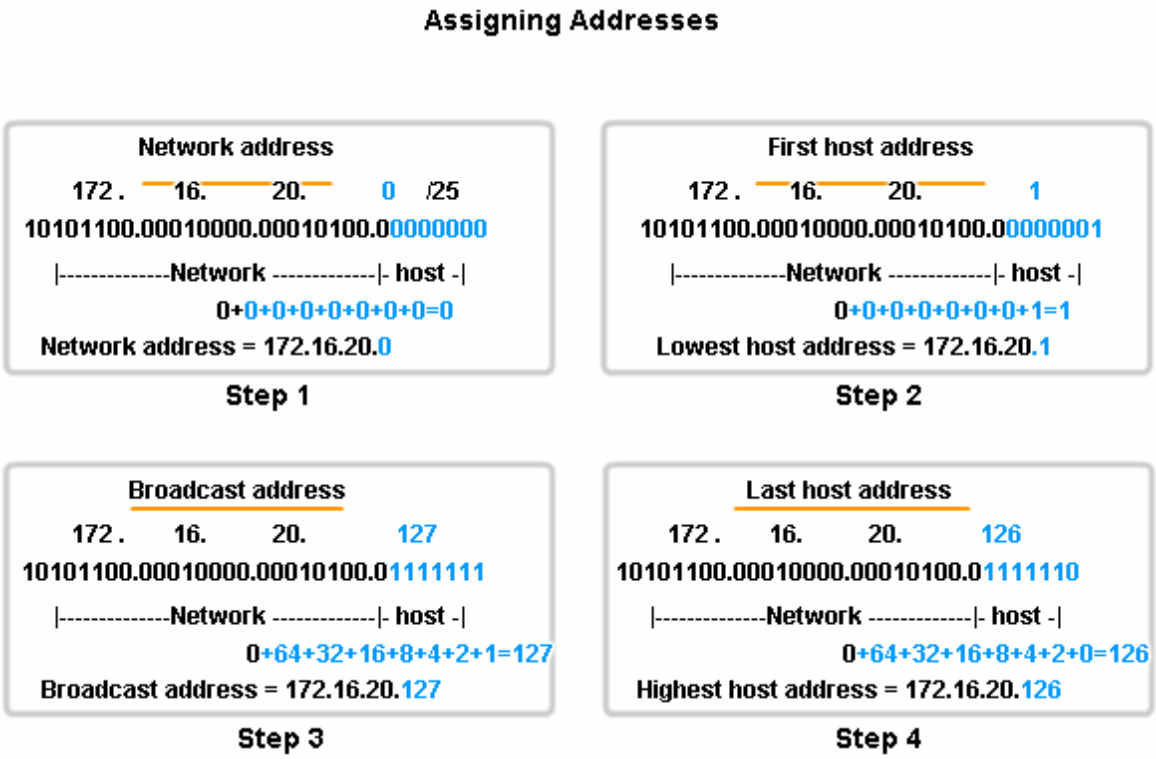
SAME NETWORK ADDRESS ALL PREFIXES

DIFFERENT BROADCAST ADDRESS EACH PREFIX

6.2.2 Calculating Network, Hosts and Broadcast Addresses

At this point, you may be wondering: How do we calculate these addresses? This calculation process requires us to look at these addresses in binary. How do we calculate these addresses?

In the example network divisions, we need to look at the octet of the address where the prefix divides the network portion from the host portion. In all of these examples, it is the last octet. See the figure for an example of the address assignment for the 172.16.20.0/25 network.



6.2.3 Unicast, Broadcast, Multicast- Types of communication

In an IPv4 network, the hosts can communicate one of three different ways:

Unicast - the process of sending a packet from one host to an individual host.
Broadcast - the process of sending a packet from one host to all hosts in the network.
Multicast - the process of sending a packet from one host to a selected group of hosts.

These three types of communication are used for different purposes in the data networks. In all three cases, the IPv4 address of the originating host is placed in the packet header as the source address.

Unicast Transmission

Unicast communication is used for the normal host-to-host communication in both a client/server and a peer-to-peer network. In an IPv4 network, the unicast address applied to an end device is referred to as the host address. For unicast communication, the host addresses assigned to the two end devices are used as the source and destination IPv4 addresses (Figure 1).

During the encapsulation process, the source host places its IPv4 address in the unicast packet header as the source host address and the IPv4 address of the destination host in the packet header as the destination address.

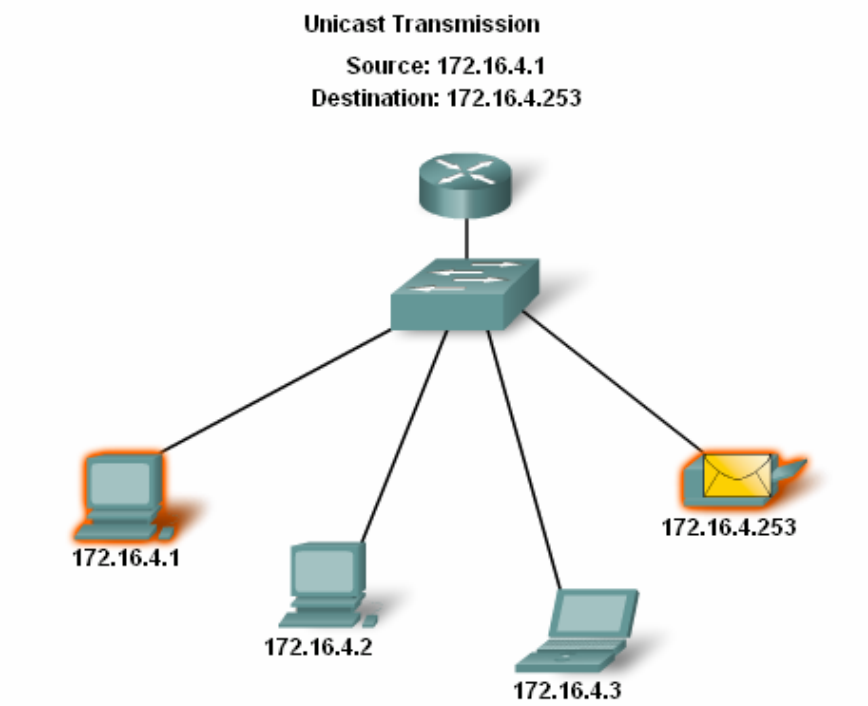


Figure 1: Unicast Transmission.

Broadcast Transmission

Some examples for using broadcast transmission are:

- Mapping upper layer addresses to lower layer addresses
- Requesting an address
- Exchanging routing information by routing protocols

When a host needs information, the host sends a request, called a query, to the broadcast address. All hosts in the network receive and process this query. One or more of the hosts with the requested information will respond, typically using unicast. Similarly, when a host needs to send information to the hosts on a network, it creates and sends a broadcast packet with the information.

Directed Broadcast

A directed broadcast is sent to all hosts on a specific network. This type of broadcast is useful for sending a broadcast to all hosts on a non-local network. For example, for a host outside of the network to communicate with the hosts within the 172.16.4.0 /24 network, the destination address of the packet would be 172.16.4.255.

Limited Broadcast

The limited broadcast is used for communication that is limited to the hosts on the local network (Figure 2). These packets use a destination IPv4 address 255.255.255.255. Routers do not forward this broadcast. Packets addressed to the limited broadcast address will only appear on the local network. For this reason, an IPv4 network is also referred to as a broadcast domain.

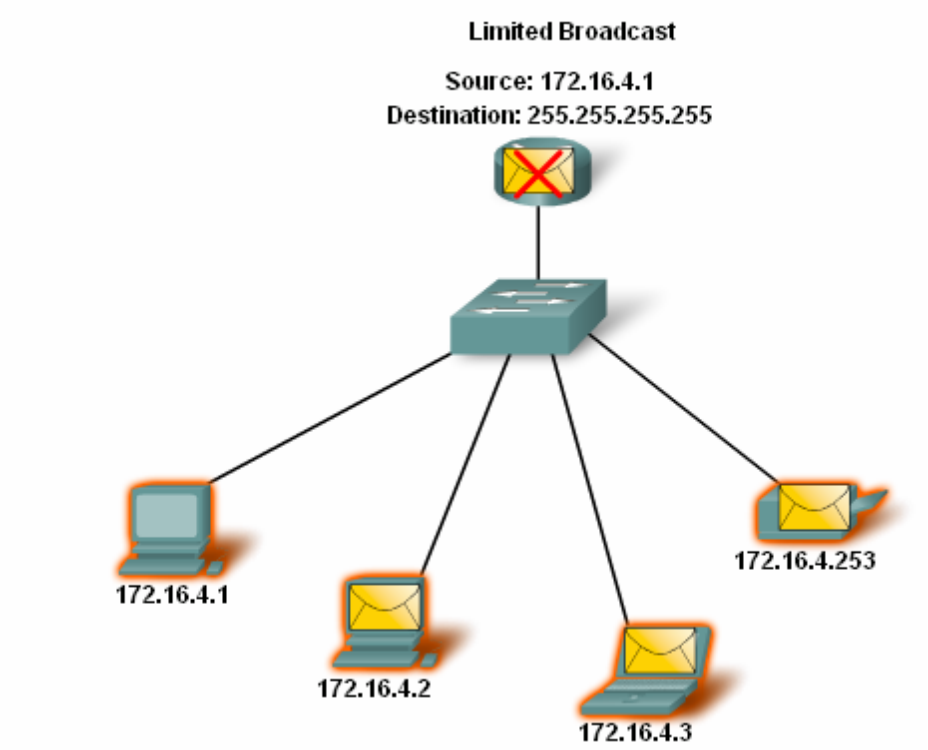


Figure 2: Limited Broadcast.

Multicast Transmission

Multicast transmission is designed to conserve the bandwidth of the IPv4 network. It reduces traffic by allowing a host to send a single packet to a selected set of hosts.

Some examples of multicast transmission are:

- Video and audio broadcasts
- Routing information exchange by routing protocols
- Distribution of software

Multicast Clients

Hosts that wish to receive particular multicast data are called multicast clients. The multicast clients use services initiated by a client program to subscribe to the multicast group.

Each multicast group is represented by a single IPv4 multicast destination address. IPv4 has set aside a special block of addresses from 224.0.0.0 to 239.255.255.255 for multicast groups addressing.

6.2.4 Reserved IPv4 Address Ranges

Expressed in dotted decimal format, the IPv4 address range is 0.0.0.0 to 255.255.255.255. As you have already seen, not all of these addresses can be used as host addresses for unicast communication.

Experimental Addresses

One major block of addresses reserved for special purposes is the IPv4 experimental address range 240.0.0.0 to 255.255.255.254. Currently, these addresses are listed as reserved for future use (RFC 3330). This suggests that they could be converted to usable addresses. Currently, they cannot be used in IPv4 networks. However, these addresses could be used for research or experimentation.

Multicast Addresses

As previously shown, another major block of addresses reserved for special purposes is the IPv4 multicast address range 224.0.0.0 to 239.255.255.255. Additionally, the multicast address range is subdivided into different types of addresses: reserved link local addresses and globally scoped addresses.

The IPv4 multicast addresses 224.0.0.0 to 224.0.0.255 are reserved link local addresses. These addresses are to be used for multicast groups on a local network. Packets to these destinations are always transmitted with a time-to-live (TTL) value of 1.

The globally scoped addresses are 224.0.1.0 to 238.255.255.255. They may be used to multicast data across the Internet. For example, 224.0.1.1 has been reserved for Network Time Protocol (NTP) to synchronize the time-of-day clocks of network devices.

Host Addresses

After accounting for the ranges reserved for experimental addresses and multicast addresses, this leaves an address range of 0.0.0.0 to 223.255.255.255 that could be used for IPv4 hosts. However, within this range are many addresses that are already reserved for special purposes.

Reserved IPv4 Address Ranges

Type of Address	Usage	Reserved IPv4 Address Range	RFC
Host Address	used for IPv4 hosts	0.0.0.0 to 223.255.255.255	790
Multicast Addresses	used for multicast groups on a local network	224.0.0.0 to 239.255.255.255	1700
Experimental Addresses	• used for research or experimentation • cannot currently be used for hosts in IPv4 networks	240.0.0.0 to 255.255.255.254	1700 3330

Figure 3.

Note: RFC is (Request for Comments) documents