LABORATORY WORK NO. 1

SUBNETTING, SUPERNETTING

1. Objectives

The aims of this laboratory are: to understand the structure of IP addresses and to distinguish between the default network ID and host ID for any IP addresses, to explain the function of subnet masks, to understand the concept of subnetting, supernetting, to learn how to manipulate subnet masks to configure subnets for a variety of network restrictions and needs and to configure a supernetted address space.

2. Theoretical considerations

2.1 Introduction

To successfully administer and troubleshoot IP internets, it is important to understand all aspects of IP addressing. One of the most important aspects of TCP/IP network administration is the assignment of proper IP addresses to all nodes in an IP internetwork. Although the concept of IP address assignment is simple, the actual mechanics of efficient IP address allocation using subnet techniques are somewhat complicated.

2.2 Understanding the structure of IP addresses

2.2.1 Network ID and Host ID

An IPv4 address consists of 32 bits of information. These bits are divided into four sections, referred to as octets or bytes, each containing 1 byte (8 bits). A generalized IP address is indicated with x.y.z.w.
You can depict an IP address using one of two methods:

- dotted-decimal notation, as in 172.27.102.4;
- binary notation, as in 10101100 00011011 01100110 00000100

An IP address is divided into two components: the first designates the network identifier, while the second part designates the host identifier. The network ID identifies a particular network within a large TCP/IP internetwork, the host ID identifies a TCP/IP host (a workstation, server, router or another TCP/IP device) specific to the network defined by the network ID. Every machine on the same network shares the network address part of its IP address.

Network ID	Host ID

Figure 1.1 *Network and host identifier*

2.2.2 IP address classes

The class of an address, which is determined by the value of the first octet, designates which of its 32 bits represent the default network ID. The Internet community has defined five address classes. For the small number of network processing a very large number of nodes, they created class A network. At the other extreme is class C network, which is reserved for the numerous networks with a small number of nodes. The class distinction between very large and very small is predictably called the class B network. Class D is used for multicast addresses and class E for scientific purposes.

Table 1.1 *IP address ranges*

Class	**Value of the 1st octet**	**Value of first bits**	**Number of bits in NetID**	**Number of bits in HostID**	**Address range**
A	1-127	0	8	24	1.0.0.0- 127.255.255.255
B	128-191	10	16	16	128.0.0.0-191.255.255.255
C	192-223	110	24	8	192.0.0.0-223.255.255.255
D	224-239	1110	multicast		224.0.0.0-239.255.255.255
E	240-254	1111	research		240.0.0.0-254.255.255.255

In a class A network address, the high-order bit is set to 0, the first octet is defined as the network ID, and the last three octets are used for the host ID. The network address with all 0s is reserved to designate the default route and the address 127 is reserved for diagnostics.

In a class B network, the two high-order bits are set to 10, the first two octets are assigned to the network ID and the remaining two octets are used for the host ID.

In a class C network, the three high-order bits are set to 110, the first three octets area assigned for the network ID with only one octet remaining for the host ID.

Class D addresses are for IP multicast addresses. The four high-order bits are set to 1110, the next 28 bits are used for individual IP multicast addresses. Class E addresses are experimental addresses reserved for future use. The five high-order bits in a class E address are set to 1111.

	x	y	z	w
Class A	Net ID	Host ID	Host ID	Host ID
Class B	Net ID	Net ID	Host ID	Host ID
Class C	Net ID	Net ID	Net ID	Host ID

Some IP addresses are reserved for special purposes, and network administrators should not assign these addresses to hosts:

- network address: host ID of all 0s;
- broadcast address: host ID of all 1s;
- default route: entire IP address set to all 0s;
- all 1s broadcast: entire IP address set to all 1s;
- 127.0.0.1 – reserved as loopback address, used for loopback tests.

2.2.3 Types of IP addresses

To be able to communicate on a private TCP/IP network or on the public Internet, each host on the network must be identified by an IP address. These IP addresses can be grouped into two categories: public IP addresses – globally unique addresses that are connected to the Internet, private IP addresses – confines to specific ranges that can be used by any private network but can not be seen on the public Internet.

Every IP address on the public Internet is unique. To allow networks to obtain unique addresses for the Internet, the Internet Assigned Numbers Authority (IANA) divides up the nonreserved portion of the IP address space and delegates responsibility for address allocation to a number of regional registries throughout the world.

The IANA has reserved a certain number of IP addresses that are never used on the global Internet. These IP private addresses are used for hosts that require IP connectivity but that do not need to be seen on the public networks. Host addressed with a private IP address can connect to the Internet through the use of a proxy server or a computer/router configured as Network Address Translation.

Table 1.2 *Private address ranges*

Starting Address	Ending Address
10.10.0.0	10.255.25.254
172.16.0.0	172.31.255.254
192.168.0.0	192.168.255.254

Also, an IP address can be one of the following types:

1. unicast: a unicast IP address is assigned to a single network interface attached to an IP networked. Unicast addresses are used in one-to-one communications;
2. broadcast: a broadcast IP address is designed to be processed by every IP node on the same network segment. Broadcast IP addresses are used in one-to-many communications. IP broadcast addresses can be use only as destination addresses;
3. multicast: an IP multicast address is an address on which one or multiple nodes can be listening on the same or different network segments.

2.3 Subnetting

IP networks can be divided into smaller units called subnetworks or "subnets". The administrator can subdivide the network using subnetting. This is done by "borrowing" bits from the host ID portion of the address and using them as a subnet filed.
Some of the benefits of subnetting include the following:

1. reduced network traffic **-** the smaller broadcast domains you create, the less network traffic on that network segment;
2. optimized network performance - this is a result of reduced network traffic;
3. simplified management - it's easier to identify and isolate network problems in a group of smaller connected networks than within one gigantic network;
4. spanning of large geographical distances **-** because WAN links are considerably slower and more expensive than LAN links, a single large network that spans long distances can create

problems in every arena listed above. Connecting multiple smaller networks makes the system more efficient.

2.3.1 Subnet masks

Another setting whose proper is required for TCP/IP to function is the subnet mask. It specifies how many bits are used to represent the network and the subnet portion of the address and is used by a host to determine whether the destination of a packet is on the local network or on a remote network. Subnet masks use the same format and representation techniques as IP addresses.

Network bits	Host bits	
Network bits	Subnet bits	Host bits

Figure 1.2 *Subdividing the host bits*

RFC 950 defines the use of a subnet mask as a 32-bit value that is used to distinguish the network ID from the host ID in an arbitrary IP address. The bits of the subnet mask are defined as follows: all bits that correspond to the network ID are set to 1, all bits that correspond to host ID are set to 0.

Every host on a network requires a subnet mask – either a default mask, which is used when a network has not been subnetted (and therefore consists of a single subnet), or a custom subnet mask, which is typically used when a network is divided into multiple subnets.

Table 1.3 *Default masks*

Class	**Default mask**
A	255.0.0.0
B	255.255.0.0
C	255.255.255.0

2.3.2 Process of subnetting

By manipulating subnet masks, you can customize address space to suit your network needs. Using subnetting you can subdivide networks into distinct and separate groups. Subnetting is often used to accommodate a divided physical topology or to restrict broadcast traffic on a network.

Subnetting refers to the practice of logically subdividing a network address space by extending the string of 1-bits used in the subnet mask of a network. You take bits from the host ID of IP address and reserve them to define the subnet address. This extension enables you to create multiple subnets within the original network address space.

The act of subnetting a network ID is a relatively complex procedure; although there are numerous subnet calculators available, the ability to subnet is an important skill for any TCP/IP network administrator.

Subnetting is done in two basic steps:

1. based on your design requirements, decide how many host bits you need for the proper balance between number of subnets and number of hosts per subnet;
2. based on the number of hosts bits chosen, enumerate the subnetted network IDs, including the ranges of usable IP addresses for each subnetted network ID and the broadcast address of each subnetwork.

2.3.2.1 Example 1

Write the subnet, broadcast address and valid host range for the following: address 172.16.0.0 with mask 255.255.192.0.

Step1. Determining the class of the IP address

172.16.0.0 is a class B address. In a class B address the first two octets are used for network ID, the last two octets are used for host ID. The default mask for class B addresses is 255.255.0.0.

Step2. Determining the number of host bits

To determine the number of host bits perform an analysis of the subnet mask.

255.255.192.0 ⇔ 11111111 11111111 11000000 00000000

Number of bits used for host ID = 14

Number of bits used for subnetting = 2

Note: Because addresses with the two patterns (network ID, host ID) of all 0s and all 1s are reserved, the actual maximum usable number of host/subnetworks is calculated with minus 2.

Number of hosts in a subnet = 2^{14}–2 = 16382 hosts
Number of subnets = 2^{2}-2 = 2 subnets

Step3. Defining the subnetted network IDs

Subnet	Binary representation	Subnetted network ID
1	10101100.0001000.01000000.00000000	172.16.64.0
2	10101100.0001000.10000000.00000000	172.16.128.0

Step4. Defining the IP address ranges for each subnetted network ID

Subnet	Binary representation	Range of IP addresses
1	10101100.0001000.01000000.00000001	172.16.64.1 –
	10101100.0001000.01111111.11111110	172.16.127.254
2	10101100.0001000.10000000.00000001	172.16.128.1 –
	10101100.0001000.10111111.11111110	172.16.192.254

Subnet	Binary representation	Broadcast address
1	10101100.0001000.01111111.11111111	172.16.64.255
2	10101100.0001000.10111111.11111111	172.16.128.255

2.3.2.2 Example 2

You have the following address 193.1.1.0. You need to define 6 subnets and 25 hosts in a subnet. Determine the network mask, the subnetted networks IDs, the range of IP addresses for each subnetted network and the broadcast address for each subnetted network.

Step1. Determining the class of the IP address

193.1.1.0 is a class C address. In a class C address, the first three octets are used for network ID, the last octet is used for host ID. The default mask for class C addresses is 255.255.255.0.

Step2. Determining the number of host and subnet bits

Need to define 6 subnets, need 3 bits
Need to define 25 hosts/subnet, need 5 bits

Step3. Defining the mask

Because we are working with a class C address, we can use for subnetting only the last octet. So, the mask will be: 255.255.255.11100000 ⇔ 255.255.255.224
Step4. Defining the subnetted network IDs

Subnet	Binary representation	Subnetted network ID
1	193.1.1.00100000	193.1.1.32
2	193.1.1.01000000	193.1.1.64
3	193.1.1.01100000	193.1.1.96
4	193.1.1.10000000	193.1.1.128
5	193.1.1.10100000	193.1.1.160
6	193.1.1.11000000	193.1.1.192

Step5. Defining the IP address ranges for each subnetted network ID

Subnet	Binary representation	Range of IP addresses
1	193.1.1.00100001	193.1.1.33-193.1.1.62
	193.1.1.00111110	
2	193.1.1.01000001	193.1.1.65-193.1.1.94
	193.1.1.01011110	
3	193.1.1.01100001	193.1.1.97-193.1.1.126
	193.1.1.01111110	
4	193.1.1.10000001	193.1.1.129-193.1.1.158
	193.1.1.10011110	
5	193.1.1.10100001	193.1.1.161-193.1.1.190
	193.1.1.10111110	
6	193.1.1.11000001	193.1.1.193-193.1.1.222
	193.1.1.11011110	

Step6. Defining the broadcast address for each subnetted network

Subnet	Binary representation	Broadcast address
1	193.1.1.00<u>11111</u>	193.1.1.63
2	193.1.1.01<u>11111</u>	193.1.1.95
3	193.1.1.01<u>11111</u>	193.1.1.127
4	193.1.1.10<u>11111</u>	193.1.1.159
5	193.1.1.10<u>11111</u>	193.1.1.191
6	193.1.1.11<u>11111</u>	193.1.1.223

2.4 Supernetting, CIDR

Classless Interdomain Routing (CIDR) was introduced to improve both address space utilization and routing scalability in the Internet. It was needed because of the rapid growth of the Internet and growth of the IP routing tables held in the Internet routers.

CIDR moves way from the traditional IP classes (Class A, Class B, Class C, and so on). CIDR uses a supernetted subnet mask to express the range of network Ids. A supernetted subnet mask is less specific and contains fewer network ID bits than a classful subnet mask.
An IP network is represented by a prefix, which is an IP address and some indication of the length of the mask. Length means the number of left-most contiguous mask bits that are set to 1. So network 172.16.0.0 255.255.0.0 can be represented as 172.16.0.0/16.

We have an example of 8 sequential class C networks ID starting with network ID 223.1.184.0, ending with network ID 223.1.191.0.

Starting network ID	223.1.184.0	<u>11011111.00000001.10111</u>000.00000000
Ending network ID	223.1.191.0	<u>11011111.00000001.10111</u>111.00000000

Notice that the first 21 bits of the range of networks IDs are the same. The last 3 bits of the third octet vary over all possible values from 000 through 111.

This range of networks IDs can be aggregated with the network ID and the mask listed below.

Network ID	223.1.184.0
Mask	11111111.11111111.11111000.00000000
Mask	255.255.248.0
Network prefix length	/21

Also, let's have another example: an ISP (Internet Service Provider) owns network 172.16.0.0/16, the ISP can offer 172.16.1.0/24, 172.16.2.0/24, and so on to customers. Yet, when advertising to other providers, the ISP only needs to advertise 172.16.0.0/16.

Dropping the classes makes forwarding more complicated. Each routing table entry is extended by giving it a 32-bit mask. Thus, there is now a single routing table for all networks consisting of an array of (IP address, subnet mask, and outgoing line) triples. When a packet comes in, its destination IP address is first extracted. Then (conceptually) the routing table is scanned entry by entry, masking the destination address and comparing it to the table entry looking for a match. It is possible that multiple entries (with different subnet mask lengths) match, in which case the longest mask is used. Thus, if there is a match for a /20 mask and a /24 mask, the /24 entry is used.

3. Lab activity

3.1 Write the subnet, broadcast address, and valid host range for 172.16.10.33 255.255.255.240.
3.2 Write the subnet, broadcast address, and valid host range for 192.168.100.7 with 4 bits of subnetting.
3.3 Your ISP has assigned you 2 class C network addresses, 131.107.10.0 and 131.107.11.0 to accommodate your network's 400 hosts. Which network address and subnet mask (expressed as a network prefix) can you assign to this address space so that your routers and hosts view these 2 networks as a single network?
3.4 Your network address is 143.16.0.0 and subnet mask is 255.255.254.0. You also know an IP address from your network, address 143.16.19.215.

1) How many bits are used for subnetting?

2) Compute the address of the subnet in which your IP address 143.16.19.215 is located?
3) Determine the range of IP addresses for the subnet computed at 2).
4) Which is the maximum number of hosts in a subnet?
5) Which is the maximum number of subnets?
6) You have the addresses 143.16.0.24, 143.16.7.12. To which subnet to they belong to?
7) Determine the broadcast address for the second subnet.
8) Determine the address of the fourth subnet.

3.5 Your ISP has addresses available stating at 194.24.0.0. Suppose that company A needs 2048 addresses and is assigned the addresses 194.24.0.0 through 194.27.7.255 along with mask 255.255.248.0. Next, company B asks for 4096 addresses, since a block of 4096 addresses must lie on a 4096-byte boundary, they cannot be given addresses starting at 194.24.8.0. Instead, they get 194.24.16.0 through 194.24.31.255 along with subnet mask 255.255.240.0. Now the company C asks for 1024 addresses and is assigned addresses 194.24.8.0 through 194.24.11.255 and mask 255.255.252.0. The routing tables are updated with the three assigned entries.
Where (which company) will be sent a packet addressed to 194.24.17.4?

Notes