CSG 1105 / 5130 - Applied Communications

Week 6 Tutorial

Objectives

- To learn the benefits of subnets in a network
- To learn about the different classes of networks
- To learn subnet calculations
- To learn about supernets

By the end of this workshop you should be able to

- Explain the benefits of implementing multiple subnets in a network
- Be able to distinguish between class A, B and C networks
- Determine key information on a network
  - Binary calculations
  - Class
  - Network prefix determination
  - Host number determination
  - Number of subnets in the network
  - Number of hosts per subnet
  - Host IP address range
  - Broadcast address
- Explain and determine a supernet comprised of subnets

Optional Downloads

- Binary capable calculator (software or hardware)
- A recording of this Tutorial from blackboard; discussions are held in class and clarifications are made too.

Preface - What are Subnets?

A subnet is a logical division of a network by increasing the number of bits related to the network prefix. An IP address is comprised of two parts, the **Network Prefix** and the **Host Number**. The Network Prefix is described as the common, identical, most-significant bit-group in the IP address. This means that the Network Prefix is the part of the IP address which does not change, and it is specified by the subnet mask applied to the network. The Host Number occupies the field called a Rest Field which is the unique identifier for that particular host, or network interface.

The Network Prefix is specified by the bit-length of the prefix, and is usually placed at the end of the network in a numeric form between 0 an 32, which is the Classless Inter-Domain Routing (CIDR) number. For example, 192.168.0.0/24 is the prefix for a network starting at that address. These four numbers specify how much of the address is the Network Prefix. As IP addresses are comprised of 4 sets of 8 bits, having a /24 means that the first 24 bits of an IP address is it's Network Prefix, ie for 192.168.0.1/24, the network prefix is 192.168.0, and the Host Number is .1. The /24 represents a subnet mask of 255.255.255.0, which is calculated by adding the number of bits turned **on** in each of the four numbers, 8+8+8+0=24.

Benefits of Subnets

The benefits of a subnet vary from each implementation. When in a large organisation or for the Internet the allocation of address spaces are crucial to optimise the number of clients available for use in the network. It can also increase routing efficiency and allows a more modular management of the network as a whole (for security or routing purposes). They can also be used to improve the arrangement of the logical hierarchy of a network, providing a method to partition the network into branches.

Binary - Counting and Converting

When counting in binary there are only two values, 0 and 1. As we read from the right to the left of the binary sequence we double the value of the previous bit (a bit is a single number). In networking, we always deal with 8-bit values, leading us to a range of numbers from 0 to 255. For the value of 0, the binary is `00000000`, for 255, the binary is `11111111`, and for half-way at 128, we have `10000000`. The binary values for a subnet mask will always be a block of 1's followed by a block of 0's. The 0's designate that the following bits are the host number.

To calculate the binary representation of the numbers you can either use a calculator which can convert decimal to binary, or you can work it out manually. We'll work out how to determine the binary representation for 192.168.0.1 below.

To convert to binary from decimal the simplest way is to know how to count in binary first: 0, 1, 2, 4, 8, 16, 32, 64, 128 etc. You simply keep doubling the value or work out 2^n where n represents any number to apply as a power (2^2=4 etc.). The highest we'll need to use in networking is 128. Once you know the pattern of binary, you then take your decimal number (ie, 192) and compare it to the largest binary number (ie, 128). If it is equal to or larger than it you can note down a 1 value and subtract the binary number from our decimal, 192-128=64. Once you reach a decimal value that is smaller than the binary, simply note a 0 until it is once again larger. You then repeat this process, see below:

192 > 128 therefore 192 - 128 = 64	1
64 = 64 therefore 64 - 64 = 0	1
0 < 32 therefore	0
0 < 16 therefore	0
0 < 8 therefore	0
0 < 4 therefore	0
0 < 2 therefore	0
0 < 1 therefore	0

Then, arrange the binary from the first subtraction on the left to our final on the right and we have the binary code `11000000`, which is 192 in binary.

To go backwards from binary to decimal, simply add the binary value back into the decimal starting from the right. ie, for 11000000 it would be 64 + 128 = 192.

Classes - A, B or C?

IP Addresses are divided into three classes of addresses, and these are based on the leading, most-significant bits in the binary representation of the network address. The values are characterised as follows:

Class	Leading Bits	Size of Network Prefix	Size of Host Number	Start Address	Last Address
Class A	0	8	24	0.0.0.0	127.255.255.255
Class B	10	16	16	128.0.0.0	191.255.255.255
Class C	110	24	0	192.0.0.0	223.255.255.255

There are more classes higher than these but they are not defined and are uncommon to see. Today, classful addresses are only used in private networks are not used on the internet since the introduction of subnet masks.

IPv4 Subnetting - The Network Prefix & Host Number

To determine the network prefix of a subnet we need two pieces of information, the IP address and the subnet mask. To calculate the network prefix of an address we perform a process called **bitwise AND** on the binary representation of the IP address compared to it's subnet mask. A bitwise AND is the same as a **logical AND** working on the binary values bit-by-bit. The AND process is a method of determining if our value for the network prefix will be 1 or 0 for that bit. As the name suggests, the bit will be 1 only if that relevant bit is 1 in the IP address AND the subnet mask, if either of them are 0 or both are 0 the resulting bit in the network prefix will also be 0. A table showing the outcomes in the middle cells below:

Subnet Mask > **IP Address V**	**0**	**1**
0	0	0
1	0	1

Firstly, we'll need to convert our IP address and subnet mask into binary - use the method above or a calculator to help. We'll work with the address 192.168.0.166 and subnet mask 255.255.255.0. Then you simply need to compare the bit directly beneath the other to determine the network prefix and host number. The host number is any bits left over by the subnet mask (ie where the subnet

	Binary Form	**Decimal Form**
IP Address	`11000000.10101000.00000000.10100110`	`192.168.0.166`
Subnet Mask	`11111111.11111111.11111111.00000000`	`255.255.255.0`
Network Prefix	`11000000.10101000.00000000.00000000`	`192.168.0.0`
Host Number	`00000000.00000000.00000000.10100110`	`0.0.0.166`

mask is **not** 255).

Looking at that table above, the we can see that by simply taking the first 3 numbers from the IP address we have the Network Prefix, and the last number is the host number. But it is not always that simple, lets change the subnet mask to now be 255.255.255.192, we'll analyse this in a bit-

	Binary Form	**Decimal Form**
IP Address	`11000000.10101000.00000000.10100110`	`192.168.0.166`
Subnet Mask	`11111111.11111111.11111111.11000000`	`255.255.255.192`
Network Prefix	`11000000.10101000.00000000.10000000`	`192.168.0.128`
Host Number	`00000000.00000000.00000000.00100110`	`0.0.0.38`

wise operation below:

We now see that the Host Number has changed as the network prefix is now larger. By increasing the values in a subnet mask we are splitting our network into smaller subnets. We we increased to 255.255.255.192 (/26) we have made four separate subnets, instead of the single network we originally had.

Number of Subnets and Hosts in a Network
We can easily determine how many subnets and hosts per subnet exist by looking at the binary form of our subnet masks. The easiest way to do this is to look at how many bits are 'borrowed' by the subnet mask in the last 8-bits of the address. Let's take the subnet masks of 255.255.255.0 (/24) and 255.255.255.192 (/26) for example.

Subnet Mask	Binary Form
255.255.255.0	11111111.11111111.11111111.00000000
255.255.255.192	11111111.11111111.11111111.11000000

Here we can visually see that 2 additional bits has been 'borrowed' into the subnet mask when we go to the .192 mask. To determine how many subnets we now have we can simply raise 2 to the power of this borrowed number, ie, $2^2 = 4$. When using the subnet mask of 255.255.255.192 we have 4 possible subnets.

The number of hosts is equally as easy to calculate. Simply take the remaining 0 bits, in this case 6, and raise 2 to that power, then subtract 2 (for the start address and broadcast addresses), ie, $2^6-2 = 62$. So in each subnet we have a possible 62 host addresses, one broadcast address and the network start address.

The network start address is the first available value in that subnet, so for 192.168.0.0/26 our start address is 192.168.0.0, this address is reserved and cannot be used. We then know that we have 62 hosts in this network and as such we can tell our last host address would be 192.168.0.62. Our host range therefore must be 192.168.0.1 - 192.168.0.62. The broadcast address in any network is always one number higher than the last host address, meaning that our broadcast address would be 192.168.0.63. From this point, we can then tell our next subnets start address - 192.168.0.64.

Supernets - What are they?
A supernet is an IP network which has been formed by two or more subnets with common CIDR network prefixes. They are calculated by comparing the bit values of the subnets and finding a common bit-pattern, from which a new network prefix is determined.

A supernet is a method of reducing the number of networks contained in a routing table on a router, and therefore on the Internet routing tables. It allows multiple networks to be aggregated into one single supernet to be advertised to other routers.

It does have some risks in that each brand of router can implement it in their own way, it can create inefficient routes on the internet as not all subnets may be contained in this supernet and the ability to detect a routing loop is severely diminished.

Supernet Calculations
Supernet calculations are done in the same fashion as calculating the network prefix of a subnet. You compare the different subnets starting address and find where the common pattern finishes and then create a network with 0's replacing the remaining slots. You can then also use this to determine the new subnet mask. Let's look at this below:

A router has the following networks connected to it, let's determine their supernet:

192.168.144.0
192.168.145.0
192.168.146.0
192.168.147.0
192.168.148.0

We need to convert these to binary values and then compare their higher order bits (left most bits) until we see the common pattern stop. See the table below showing this visually:

Address	First Octect	Second Octect	Third Octect	Fourth Octect
192.168.148.0	11000000	10101000	10010100	00000000
192.168.149.0	11000000	10101000	10010101	00000000
192.168.150.0	11000000	10101000	10010110	00000000
192.168.151.0	11000000	10101000	10010111	00000000
192.168.152.0	11000000	10101000	10011000	00000000

We can see that the common pattern ends after the first half of the third octect. We can then deduce that the supernet address will have this common pattern, followed by entirely zeros, as we can see below:

First Octect	Second Octet	Third Octet	Fourth Octet	Address	Subnet Mask
11000000	10101000	10010000	00000000	192.168.144.0	/20

Therefore, our summarised route is 192.168.144.0/20 with a subnet mask of 255.255.240.0.

We can see the risk involved with implementing this however, as this would also contain the networks 192.168.144.0, 192.168.145.0, 192.168.146.0 and 192.168.147.0, even though they are not connected to this router.

Complete the challenges on the next page.

Challenges
Attempt to complete these questions below without looking through the document for the answers; for the calculation questions, feel free to look back for guidance.
Answers are found on the last page of the document.

1. What does CIDR stand for?
2. What is a the Network Prefix?
3. What is the Host Number?
4. Convert the following numbers into binary:
    1. 172
    2. 224
    3. 48
    4. 101
    5. 207
5. Convert the following binary values into numbers:
    1. `10100101`
    2. `01101001`
    3. `01100011`
    4. `11110001`
    5. `11101011`
6. Convert the following IP addresses & CIDR subnet masks into binary and find the Network Prefix and Host Number:
    1. `10.0.0.16 / 27`
    2. `172.16.8.155 / 26`
    3. `192.168.23.44 / 24`
    4. `201.110.33.18 / 29`
7. Looking at the following binary subnet masks, how many subnets and hosts per subnet will there be?
    1. `11111111.11111111.11111111.00000000`
    2. `11111111.11111111.11111111.11110000`
    3. `11111111.11111111.11111111.11000000`
    4. `11111111.11111111.11111111.11111100`
8. Looking at the following IP addresses determine the network start address, IP range and broadcast address for each of their respective subnets:
    1. `192.168.0.45 / 24`
    2. `192.168.0.45 / 25`
    3. `192.168.5.133 / 26`
    4. `10.0.0.197 / 27`
9. What is the summary address for the following routes? (all /24)
    1. 172.16.18.0
    2. 172.16.19.0
    3. 172.16.20.0
    4. 172.16.21.0
    5. 172.16.25.0
10. What unused networks are also contained in this route summary above?
11. What networks are contained in the following route summary? 10.100.96.0/20

Answers

1. Classless Inter-Domain Routing
2. A network prefix is the first allocated bits usually around /24 representing the network.
3. A host number is the remaining bits in a network address after determining the network prefix.
4. Binary numbers:
    1. 10101100
    2. 11100000
    3. 00110000
    4. 01100101
    5. 11001111
5. Numbers:
    1. 165
    2. 105
    3. 99
    4. 241
    5. 235
6. Network Prefixes & Host Numbers
    1. Prefix: 10.0.0.0 & Host: 16
    2. Prefix: 172.16.8.128 & Host: 37
    3. Prefix: 192.168.23.0 & Host: 44
    4. Prefix: 201.110.33.16 & Host: 2
7. Subnets & Hosts
    1. Subnets: 1 & Hosts: 254
    2. Subnets: 16 & Hosts: 14
    3. Subnets: 8 & Hosts: 30
    4. Subnets: 64 & Hosts: 2
8. Network, Host address range & Broadcast
    1. Network: 192.168.0.0/24, Host range: 192.168.0.1 - 192.168.0.254, Broadcast: 192.168.0.255
    2. Network: 192.168.0.0/24, Host range: 192.168.0.1 - 192.168.0.126, Broadcast: 192.168.0.127
    3. Network: 192.168.5.128/26, Host range: 192.168.5.129 - 192.168.5.190, Broadcast: 192.168.0.191
    4. Network: 10.0.0.192/27, Host range: 10.0.0.193 - 10.0.0.222, Broadcast: 10.0.0.223
9. Supernet: 172.16.16.0/20
10. Other networks: 172.16.16.0, 172.16.17.0, 172.16.22.0, 172.16.23.0, 172.16.24.0, 172.16.26.0, 172.16.27.0, 172.16.28.0, 172.16.29.0, 172.16.30.0, 172.16.31.0
11. 10.100.96.0, 10.100.97.0, 10.100.98.0, 10.100.99.0, 10.100.100.0, 10.100.101.0, 10.100.102.0, 10.100.103.0, 10.100.104.0, 10.100.105.0, 10.100.106.0, 10.100.107.0, 10.100.108.0, 10.100.109.0, 10.100.110.0, 10.100.111.0