Variable Length Subnet Masks

1. How does the use of fixed length subnet masks cause issues of permanently unused, or wasted, addresses?

Fixed length subnet masks often result in permanently unused addresses because each subnet on a network is required to support the same number of hosts. In an organization, it is likely that the amount of hosts needed for each subnet can vary. With a fixed length subnet mask, the amount of bits left over for hosts remains constant for each subnet. Therefore, the number of addresses available per host is constant despite a variable need. For example, if an investment bank needs 200 hosts for a subnet related to their trading platforms/employees, and only 20 hosts for a subnet related to their human resources department, the latter subnet would have 180 more unused hosts because the subnet mask length is fixed for all subnets. Permanently unused addresses can not only cause the organization to run out of addresses in the long-term, but can also hinder network performance as the broadcast domain is unnecessarily large and thus broadcast messages will take longer to successfully achieve their purpose.

2. For each scenario below, identify the number of assignable addresses and the number of unused addresses on the subnet:

- *Scenario A*: Subnet 66.114.124.0/22 is used to support 217 hosts.
- *Scenario B*: Subnet 54.88.181.128/25 is used to support 119 hosts.
- *Scenario C*: Subnet 50.63.202.48/28 is used to support 1 host.

Scenario A: Subnet 66.114.124.0/22 is used to support 217 hosts.

A 22-bit Network Identifier results in 10 bits remaining for the Host-Identifier. (32 total bits – 22-bit Network Identifier = 10-bit Host-Identifier)

2 ^ 10 = 1,024 total addresses

1024 – 2 = **1,022 total assignable addresses** (subtract one for the network address and one for the broadcast address which are not assignable).

1,022 total assignable addresses – 217 needed hosts = **805 unused addresses**

Scenario B: Subnet 54.88.181.128/25 is used to support 119 hosts.

A 25-bit Network Identifier results in 7 bits remaining for the Host-Identifier. (32 total bits – 25-bit Network Identifier = 7-bit Host-Identifier)

2 ^ 7 = 128 total addresses

128 – 2 = **126 total assignable addresses** (subtract one for the network address and one for the broadcast address which are not assignable).

126 total assignable addresses – 119 needed hosts = **7 unused addresses**

Scenario C: Subnet 50.63.202.48/28 is used to support 1 host.

A 28-bit Network Identifier results in 4 bits remaining for the Host-Identifier. (32 total bits – 28-bit Network Identifier = 4-bit Host-Identifier)

2 ^ 4 = 16 total addresses

16 – 2 = **14 total assignable addresses** (subtract one for the network address and one for the broadcast address which are not assignable).

14 total assignable addresses – 1 needed host = **13 unused addresses**

3. Why is re-allocating existing subnets to accommodate a new subnet problematic?
The re-allocation of subnets is necessary when an organization using fixed length subnet masks needs a new subnet supporting more hosts than previously anticipated and allocated for in the previous subnets. Subnets are then re-allocated and assigned a shorter network identifier to support more hosts. However, the previous subnets, which didn't require as many hosts, will now have a great number of unused addresses (refer to the response to question one for the consequences of unused addresses). Re-allocation of subnets is also a major effort for the network department of an organization because all client computers, routers, servers, firewalls, and related devices may need to be re-configured to recognize the new network identifier which can be quite costly of an effort.

4. Calculate the following for the given scenarios:

Scenario A: The organization is assigned the network described by CIDR entry 172.226.0.0/16. The organization needs two subnets, the first to support 45 hosts, and the second to support 27 hosts. The organization allocates the first subnet as 172.226.0.0/26.

a. If the organization opts to use fixed length subnet masks to allocate its subnets, what is the CIDR entry for the second subnet, and what is the second subnet's network identifier in binary?

   First subnet:
   172 → 10101100, 226 → 11100010, 0 → 00000000, 0 → 00000000
   CIDR Binary: 10101100 11100010 00000000 00000000
   Network Identifier for the 1st subnet: 10101100 11100010 00000000 00

   Increment the Subnet Identifier from the first subnet by 1.

   Second subnet (using fixed length subnet masks):
   Network Identifier for the 2nd subnet: 10101100 11100010 00000000 01
   CIDR Binary for the 2nd subnet: 10101100 11100010 00000000 01000000
   CIDR Decimal for the 2nd subnet: 172.226.0.64/26

b. If the organization opts to use VLSMs to allocate its subnets, what is the CIDR entry for the second subnet, and what is its network identifier in binary?

   Second subnet needs to support only 27 hosts.
   Host Identifier needs to be only 5 bits long (2 ^ 5 = 32 – 2 = 30 assignable addresses)
   If the Host Identifier needs to be only 5 bits long, the Network Identifier should be 27 bits long (32 total bits – 5-bit Host Identifier = 27-bit Network-Identifier)

   Network Identifier for the 2nd subnet (FLSM): 10101100 11100010 00000000 01
   Append an additional 0 to take up the 27th bit.

   Second subnet (using variable length subnet masks):
   Network Identifier for the 2nd subnet: 10101100 11100010 00000000 010
   CIDR Binary for the 2nd subnet: 10101100 11100010 00000000 01000000
   CIDR Decimal for the 2nd subnet: 172.226.0.64/27

c. Calculate the number of assignable addresses and the number of unused addresses for the second subnet for your allocation selections in part a and in part b.

Number of assignable and unused addresses using FLSM for 2nd subnet:

A 26-bit Network Identifier results in 6 bits remaining for the Host-Identifier.
(32 total bits – 26-bit Network Identifier = 6-bit Host-Identifier)

2 ^ 6 = 64 total addresses

64 – 2 = **62 total assignable addresses** (subtract one for the network address and one for the broadcast address which are not assignable).

62 total assignable addresses – 27 needed hosts = **35 unused addresses**

Number of assignable and unused addresses using VLSM for 2nd subnet:

A 27-bit Network Identifier results in 5 bits remaining for the Host-Identifier.
(32 total bits – 27-bit Network Identifier = 5-bit Host-Identifier)

2 ^ 5 = 32 total addresses

32 – 2 = **30 total assignable addresses** (subtract one for the network address and one for the broadcast address which are not assignable).

30 total assignable addresses – 27 needed hosts = **3 unused addresses**

Scenario B: The organization is assigned the network described by CIDR entry 64.91.224.0/22. The organization needs two subnets, the first to support 390 hosts, and the second to support 75 hosts. The organization allocates the first subnet as 64.91.224.0/23.

a. If the organization opts to use fixed length subnet masks to allocate its subnets, what is the CIDR entry for the second subnet, and what is the second subnet's network identifier in binary?

   First subnet:
   64 → 01000000, 91 → 01011011, 224 → 11100000, 0 → 00000000
   CIDR Binary: 01000000 01011011 11100000 00000000
   Network Identifier for the 1st subnet: 01000000 01011011 1110000

   Increment the Subnet Identifier from the first subnet by 1.

   Second subnet (using fixed length subnet masks):
   Network Identifier for the 2nd subnet: 01000000 01011011 1110001
   CIDR Binary for the 2nd subnet: 01000000 01011011 11100010 00000000
   CIDR Decimal for the 2nd subnet: 64.91.226.0/23

b. If the organization opts to use VLSMs to allocate its subnets, what is the CIDR entry for the second subnet, and what is its network identifier in binary?

   Second subnet needs to support only 75 hosts.
   Host Identifier needs to be only 7 bits long (2 ^ 7 = 128 – 2 = 126 assignable addresses)
   If the Host Identifier needs to be only 7 bits long, the Network Identifier should be 25 bits long (32 total bits – 7-bit Host Identifier = 25-bit Network-Identifier)

   Network Identifier for the 2nd subnet (FLSM): 01000000 01011011 1110001
   Append an additional 2 0s to take up the 24th and 25th bits.

   Second subnet (using variable length subnet masks):
   Network Identifier for the 2nd subnet: 01000000 01011011 11100010 0
   CIDR Binary for the 2nd subnet: 01000000 01011011 11100010 00000000
   CIDR Decimal for the 2nd subnet: 64.91.226.0/25

c. Calculate the number of assignable addresses and the number of unused addresses for the second subnet for your allocation selections in part a and in part b.

Number of assignable and unused addresses using FLSM for 2^{nd} subnet:

A 23-bit Network Identifier results in 9 bits remaining for the Host-Identifier.
(32 total bits – 23-bit Network Identifier = 9-bit Host-Identifier)

2 ^ 9 = 512 total addresses

512 – 2 = **510 total assignable addresses** (subtract one for the network address and one for the broadcast address which are not assignable).

510 total assignable addresses – 75 needed hosts = **435 unused addresses**

Number of assignable and unused addresses using VLSM for 2^{nd} subnet:

A 25-bit Network Identifier results in 7 bits remaining for the Host-Identifier.
(32 total bits – 25-bit Network Identifier = 7-bit Host-Identifier)

2 ^ 7 = 128 total addresses

128 – 2 = **126 total assignable addresses** (subtract one for the network address and one for the broadcast address which are not assignable).

126 total assignable addresses – 75 needed hosts = **51 unused addresses**

Scenario C: The organization is assigned the network described by CIDR entry 98.136.241.128/25. The organization needs two subnets, the first to support 25 hosts, and the second to support 18 hosts. The organization allocates the first subnet as 98.136.241.128/27.

a. If the organization opts to use fixed length subnet masks to allocate its subnets, what is the CIDR entry for the second subnet, and what is the second subnet's network identifier in binary?

   First subnet:
   98 → 01100010, 136 → 10001000, 241 → 11110001, 128 → 10000000
   CIDR Binary: 01100010 10001000 11110001 10000000
   Network Identifier for the 1st subnet: 01100010 10001000 11110001 100

   Increment the Subnet Identifier from the first subnet by 1.

   Second subnet (using fixed length subnet masks):
   Network Identifier for the 2nd subnet: 01100010 10001000 11110001 101
   CIDR Binary for the 2nd subnet: 01100010 10001000 11110001 10100000
   CIDR Decimal for the 2nd subnet: 98.136.241.160/27

b. If the organization opts to use VLSMs to allocate its subnets, what is the CIDR entry for the second subnet, and what is its network identifier in binary?

   Second subnet needs to support only 18 hosts.
   Host Identifier needs to be 5 bits long (2 ^ 5 = 32 – 2 = 30 assignable addresses)
   A 4-bit Host Identifier would not be sufficient as it would only have 14 assignable addresses (2 ^ 4 = 16 – 2 = 14 assignable addresses)
   If the Host Identifier needs to be only 5 bits long, the Network Identifier should be 27 bits long (32 total bits – 5-bit Host Identifier = 27-bit Network-Identifier)

   Since the length of the Network-Identifier is already 27 using the fixed length subnet mask and is not changing, a variable length subnet mask would take on the same values as the fixed length subnet mask.

   Second subnet (using variable length subnet masks):
   Network Identifier for the 2nd subnet: 01100010 10001000 11110001 101
   CIDR Binary for the 2nd subnet: 01100010 10001000 11110001 10100000
   CIDR Decimal for the 2nd subnet: 98.136.241.160/27

c. Calculate the number of assignable addresses and the number of unused addresses for the second subnet for your allocation selections in part a and in part b.

Number of assignable and unused addresses using FLSM for 2^{nd} subnet:

A 27-bit Network Identifier results in 5 bits remaining for the Host-Identifier.
(32 total bits – 27-bit Network Identifier = 5-bit Host-Identifier)

2 ^ 5 = 32 total addresses

32 – 2 = **30 total assignable addresses** (subtract one for the network address and one for the broadcast address which are not assignable).

30 total assignable addresses – 18 needed hosts = **12 unused addresses**

Number of assignable and unused addresses using VLSM for 2^{nd} subnet:

A 27-bit Network Identifier results in 5 bits remaining for the Host-Identifier.
(32 total bits – 27-bit Network Identifier = 5-bit Host-Identifier)

2 ^ 5 = 32 total addresses

32 – 2 = **30 total assignable addresses** (subtract one for the network address and one for the broadcast address which are not assignable).

30 total assignable addresses – 18 needed hosts = **12 unused addresses**

7. For scenarios A, B, and C in step 6, does use of VLSMs significantly reduce the number of unused addresses in the second subnet?

Scenario A

For Scenario A, the use of VLSMs reduces the number of unused addresses from 35 unused addresses to 3 unused addresses. This reduction in addresses is not drastic because the difference in Network-Identifier length bits is only 1 bit because the difference of the number of hosts needed between the first and second host is also not drastic (18 more hosts in subnet 1). The location of the additional Subnet Identifier bit utilized in VLSM is also later in the address (in the 27^{th} bit). This means that the number of restricted available hosts is not as significant had the additional Subnet Identifier bit occurred earlier in the address given the remaining number of bits for the hosts. Additionally, reducing the number of unused hosts in the second subnet via VLSM to just 3 may actually create a future risk if the organization expands past the originally intended 27 hosts and is not recommended as networks are often destined to grow in user base.

Scenario B

For Scenario B, the use of VLSMs significantly reduces the number of unused addresses from 435 unused addresses to just 51 unused addresses. This reduction in addresses is drastic because the difference in Network-Identifier length bits is 2 bits because the difference of the number of hosts needed between the first and second host is also drastic (315 more hosts in subnet 1). The location of the additional two Subnet Identifier bits utilized in VLSM, is also earlier in the address (in the 24^{th} and 25^{th} bit). This means that the number of restricted available hosts is more significant compared to if the additional Subnet Identifier bits occurred later in the address given the remaining number of bits for the hosts.

Scenario C

For Scenario C, the use of VLSMs does not reduce the number of unused addresses. This reduction in addresses is non-existent because the Network-Identifier length bits did not change, largely because the difference of the number of hosts needed between the first and second host is minimal (7 more hosts in subnet 1).

9. Imagine that an organization is assigned the IP address block defined by 237.118.0.0/15, and that the organization needs one subnet that supports 400 hosts and another that supports 77 hosts.

a. How many bits are used by each subnet identifier?

   The number of bits used for the first Subnet Identifier is 8 bits. (Network Identifier for the subnet spans 23 bits and the Network Identifier for the organization spans 15 bits).

   The number of bits used for the second Subnet Identifier is 10 bits. (Network Identifier for the subnet spans 25 bits and the Network Identifier for the organization spans 15 bits).

b. What are the subnet masks of each subnet in binary and in dotted decimal notation?

   First subnet: 11101101 01110110 0000000
   Since the Network Identifier of the first subnet spans 23 bits, the Subnet Mask is filled with 23 1s and 9 0s: 11111111 11111111 11111110 00000000

   Subnet Mask of 1st Subnet (Binary): 11111111 11111111 11111110 00000000

   11111111 → 255
   11111111 → 255
   11111110 → 254
   00000000 → 0

   Subnet Mask of 1st Subnet (Decimal): 255.255.254.0

   Second subnet: 11101101 01110110 00000010 0
   Since the Network Identifier of the second subnet spans 25 bits, the Subnet Mask is filled with 25 1s and 7 0s: 11111111 11111111 11111111 10000000

   Subnet Mask of 2nd Subnet (Binary): 11111111 11111111 11111111 10000000

   11111111 → 255
   11111111 → 255
   11111111 → 255
   10000000 → 128

   Subnet Mask of 2nd Subnet (Decimal): 255.255.255.128

c. How many hosts could each subnet support?

Because the Network Identifier of the first subnet spans 23 bits, there are 9 bits remaining for the Host-Identifier.
(32 total bits – 23-bit Network Identifier = 9-bit Host-Identifier)

2 ^ 9 = 512 total addresses

512 – 2 = **510 total assignable addresses for the first subnet** (subtract one for the network address and one for the broadcast address which are not assignable).

Because the Network Identifier of the second subnet spans 25 bits, there are 7 bits remaining for the Host-Identifier.
(32 total bits – 25-bit Network Identifier = 7-bit Host-Identifier)

2 ^ 7 = 128 total addresses

128 – 2 = **126 total assignable addresses for the first subnet** (subtract one for the network address and one for the broadcast address which are not assignable).

d. What are the network addresses of each subnet in dotted decimal notation?

The first subnet's Network Identifier is 11101101 01110110 0000000. To derive the Network Address, append 0s to the Network Identifier until the 32 bits are filled.

Network Address of the 1st subnet (binary): 11101101 01110110 00000000 00000000

11101101 → 237
01110110 → 118
00000000 → 0
00000000 → 0

Network Address of the 1st subnet (decimal): 237.118.0.0

The second subnet's Network Identifier is 11101101 01110110 00000010 0. To derive the Network Address, append 0s to the Network Identifier until the 32 bits are filled.

Network Address of the 2nd subnet (binary): 11101101 01110110 00000010 00000000

11101101 → 237
01110110 → 118
00000000 → 0
00000000 → 0

Network Address of the 2nd subnet (decimal): 237.118.0.0

e. What are the broadcast addresses of each subnet in binary and dotted decimal notation?

The first subnet's Network Identifier is 11101101 01110110 0000000. To derive the Broadcast Address, append 1s to the Network Identifier until the 32 bits are filled.

Broadcast Address of the 1st subnet (binary): 11101101 01110110 00000001 11111111

11101101 → 237
01110110 → 118
00000001 → 1
11111111→ 255

Broadcast Address of the 1st subnet (decimal): 237.118.1.255

The second subnet's Network Identifier is 11101101 01110110 00000010 0. To derive the Broadcast Address, append 1s to the Network Identifier until the 32 bits are filled.

Broadcast Address of the 2nd subnet (binary): 11101101 01110110 00000010 01111111

11101101 → 237
01110110 → 118
00000010 → 2
01111111 → 127

Broadcast Address of the 2nd subnet (decimal): 237.118.2.127

f. What are the ranges of assignable IP addresses for each subnet, in dotted decimal notation?

   We increment the network address by 1 to start the range, and we decrement the broadcast address by 1 to end the range.

   The range of assignable IP addresses for the first subnet are 237.118.0.1 through 237.118.1.254.

   The range of assignable IP addresses for the second subnet are 237.118.0.1 through 237.118.2.126.