Chapter 9: Subnetting IP Networks

Introduction to Networks
Chapter 9

9.0 Introduction
9.1 Subnetting an IPv4 Network
9.2 Addressing Schemes
9.3 Design Considerations for IPv6
9.4 Summary
Chapter 9: Objectives

Upon completion of this chapter, you will be able to:

- Explain why routing is necessary for hosts on different networks to communicate.
- Describe IP as a communication protocol used to identify a single device on a network.
- Given a network and a subnet mask, calculate the number of host addresses available.
- Calculate the necessary subnet mask in order to accommodate the requirements of a network.
- Describe the benefits of variable length subnet masking (VLSM).
- Explain how IPv6 address assignments are implemented in a business network.
9.1 Subnetting an IPv4 Network
Network Segmentation

Reasons for Subnetting

**Subnetting** is the process of segmenting a network into multiple smaller network spaces called subnetworks or subnets.

- Large networks must be segmented into smaller subnetworks, creating smaller groups of devices and services to:
  - Control traffic by containing broadcast traffic within each subnetwork.
  - Reduce overall network traffic and improve network performance.

**Communication Between Subnets**

- A router is necessary for devices on different networks and subnets to communicate.
- Each router interface must have an IPv4 host address that belongs to the network or subnet that the router interface is connected.
- Devices on a network and subnet use the router interface attached to their LAN as their default gateway.
IP Subnetting is FUNdamental

The Plan

Planning the Network

Student LAN  Faculty LAN  Admin LAN

Planning requires decisions on each subnet in terms of size, the number of hosts per subnet, and how host addresses will be assigned.
Subnetting an IPv4 Network

Basic Subnetting

- Borrowing Bits to Create Subnets
- Borrowing 1 bit \(2^1 = 2\) subnets

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Borrowing 1 Bit from the host portion creates 2 subnets with the same subnet mask.

**Subnet 0**
- Network: 192.168.1.0-127/25
- Mask: 255.255.255.128

**Subnet 1**
- Network: 192.168.1.128-255/25
- Mask: 255.255.255.128
Subnetting an IPv4 Network

Subnets in Use

Subnet 0
Network 192.168.1.0-127/25

Subnet 1
Network 192.168.1.128-255/25
Subnetting an IPv4 Network

Subnetting Formulas

Calculate number of subnets

Subnets = \(2^n\)
(where \(n\) = bits borrowed)

\[
\begin{array}{cccccc}
192 & . & 168 & . & 1 & . & 0 000 0000
\end{array}
\]

1 bit was borrowed

\(2^1 = 2\) subnets

Calculate number of hosts

Hosts = \(2^n\)
(where \(n\) = host bits remaining)

\[
\begin{array}{cccccccc}
192 & . & 168 & . & 1 & . & 0 & 000 0000
\end{array}
\]

7 bits remain in host field

\(2^7 = 128\) addresses per subnet
\(2^7 - 2 = 126\) valid hosts per subnet
Subnetting an IPv4 Network

Creating 4 Subnets

Borrowing 2 bits to create 4 subnets. \(2^2 = 4\) subnets

Creating 4 Subnets

<table>
<thead>
<tr>
<th>Original</th>
<th>Mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.168.1.00</td>
<td>255.255.255.00</td>
</tr>
</tbody>
</table>

Borrowing 2 bits creates 4 subnets:

- **Net 0**: 192.168.1.00/26
- **Net 1**: 192.168.1.01/26
- **Net 2**: 192.168.1.10/26
- **Net 3**: 192.168.1.11/26

All 4 subnets use the same mask:

<table>
<thead>
<tr>
<th>Mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>255.255.255.11</td>
</tr>
</tbody>
</table>
## Subnetting an IPv4 Network

### Creating Eight Subnets

Borrowing 3 bits to **Create 8 Subnets.** \(2^3 = 8\) subnets

<table>
<thead>
<tr>
<th>Network</th>
<th>First</th>
<th>Last</th>
<th>Broadcast</th>
<th>Subnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net 0</td>
<td>192.168.1.0</td>
<td>192.168.1.31</td>
<td>192.168.1.32</td>
<td>192.168.1.1.0</td>
</tr>
<tr>
<td>Net 1</td>
<td>192.168.1.32</td>
<td>192.168.1.63</td>
<td>192.168.1.64</td>
<td>192.168.1.1.1</td>
</tr>
<tr>
<td>Net 2</td>
<td>192.168.1.64</td>
<td>192.168.1.95</td>
<td>192.168.1.96</td>
<td>192.168.1.1.32</td>
</tr>
<tr>
<td>Net 3</td>
<td>192.168.1.96</td>
<td>192.168.1.127</td>
<td>192.168.1.128</td>
<td>192.168.1.1.33</td>
</tr>
</tbody>
</table>
Subnetting an IPv4 Network

Creating Eight Subnets (Cont.)

<table>
<thead>
<tr>
<th>Network</th>
<th>192.168.1.128</th>
<th>192.168.1.129</th>
<th>192.168.1.158</th>
<th>192.168.1.159</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd</td>
<td></td>
<td></td>
<td>192.168.1.224</td>
<td></td>
</tr>
<tr>
<td>4th</td>
<td></td>
<td></td>
<td>192.168.1.225</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Network</th>
<th>192.168.1.128</th>
<th>192.168.1.158</th>
<th>192.168.1.159</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>192.168.1.160</td>
<td>192.168.1.161</td>
<td>192.168.1.190</td>
</tr>
<tr>
<td>2nd</td>
<td>192.168.1.191</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Network</th>
<th>192.168.1.128</th>
<th>192.168.1.158</th>
<th>192.168.1.159</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>192.168.1.160</td>
<td>192.168.1.161</td>
<td>192.168.1.191</td>
</tr>
<tr>
<td>2nd</td>
<td>192.168.1.192</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Subnetting an IPv4 Network
Creating Eight Subnets (Cont.)

Subnet Allocation

- 192.168.1.0/27
- 192.168.1.12/27
- 192.168.1.34/27
- PC2
- 192.168.1.32/27
- 0.33
- G0/1
- R1
- 192.168.1.64/27
- 0.65
- S0/0/0
- PC3
- 192.168.1.96/27
- 0.97
- G0/0
- R2
- 192.168.1.128/27
- 0.129
- G0/1
- 192.168.1.98/27
- 192.168.1.130/27
- PC4
Determining the Subnet Mask

Subnetting Based on Host Requirements

Two considerations when planning subnets:
- Number of subnets required
- Number of host addresses required

Formula to determine number of usable hosts: \(2^n - 2\)
- \(2^n\) (where \(n\) is the number of remaining host bits) is used to calculate the number of hosts.
- \(-2\) (The subnetwork ID and broadcast address cannot be used on each subnet.)
Determining the Subnet Mask
Subnetting Network-Based Requirements

Calculate the number of subnets:

- $2^n$ (where $n$ is the number of bits borrowed)
- Subnet needed for each department.
Determining the Subnet Mask

Subnetting To Meet Network Requirements

- Balance the required number of subnets and hosts for the largest subnet.
- Design the addressing scheme to accommodate the maximum number of hosts for each subnet.
- Allow for growth in each subnet.
Determining the Subnet Mask

Subnetting To Meet Network Requirements

Subnets and Addresses

10101100.00010000.000000 00.00000000 172.16.0.0/22

0 10101100.00010000.000000 00.00000000 172.16.0.0/26
1 10101100.00010000.000000 00.01000000 172.16.0.64/26
2 10101100.00010000.000000 00.10000000 172.16.0.128/26
3 10101100.00010000.000000 00.11000000 172.16.0.192/26
4 10101100.00010000.000000 01.00000000 172.16.1.0/26
5 10101100.00010000.000000 01.01000000 172.16.1.64/26
6 10101100.00010000.000000 01.10000000 172.16.1.128/26

Nets 7 – 14 not shown

15 10101100.00010000.000000 11.10000000 172.16.3.128/26
16 10101100.00010000.000000 11.11000000 172.16.3.192/26

\[2^4 = 16\]
\[2^6 - 2 = 62\]
subnets

Hosts per subnet
Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses

- Traditional subnetting – Uses the same number of addresses is allocated for each subnet.
- Subnets that require fewer addresses have unused (wasted) addresses; for example, WAN links only need two addresses.
Benefits of Variable Length Subnet Masking

Variable Length Subnet Masks (VLSM)

- The variable-length subnet mask (VLSM) or subnetting a subnet provides more efficient use of addresses.
- VLSM allows a network space to be divided in unequal parts.
- Subnet mask varies, depending on how many bits have been borrowed for a particular subnet.
- Network is first subnetted, and then the subnets are resubnetted.
Benefits of Variable Length Subnet Masking
Basic VLSM

![VLSM Subnetting Scheme](image)
Benefits of Variable Length Subnet Masking

VLSM in Practice

- Using VLSM subnets, the LAN and WAN segments in example below can be addressed with minimum waste.
- Each LANs will be assigned a subnet with /27 mask.
- Each WAN link will be assigned a subnet with /30 mask.
### Benefits of Variable Length Subnet Masking

#### VLSM Chart

<table>
<thead>
<tr>
<th>Network</th>
<th>/27</th>
<th>Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bldg A</td>
<td>.0</td>
<td>.1 - .30</td>
</tr>
<tr>
<td>Bldg B</td>
<td>.32</td>
<td>.33 - .62</td>
</tr>
<tr>
<td>Bldg C</td>
<td>.64</td>
<td>.65 - .94</td>
</tr>
<tr>
<td>Bldg D</td>
<td>.96</td>
<td>.97 - .126</td>
</tr>
<tr>
<td>Unused</td>
<td>.128</td>
<td>.129 - .158</td>
</tr>
<tr>
<td>Unused</td>
<td>.160</td>
<td>.161 - .190</td>
</tr>
<tr>
<td>Unused</td>
<td>.192</td>
<td>.193 - .222</td>
</tr>
<tr>
<td>.224</td>
<td></td>
<td>.225 - .254</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Network</th>
<th>/30</th>
<th>Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAN R1–R2</td>
<td>.224</td>
<td>.225 - .226</td>
</tr>
<tr>
<td>WAN R2–R3</td>
<td>.228</td>
<td>.229 - .230</td>
</tr>
<tr>
<td>WAN R3–R4</td>
<td>.232</td>
<td>.233 - .234</td>
</tr>
<tr>
<td>Unused</td>
<td>.236</td>
<td>.237 - .238</td>
</tr>
<tr>
<td>Unused</td>
<td>.240</td>
<td>.241 - .242</td>
</tr>
<tr>
<td>Unused</td>
<td>.244</td>
<td>.245 - .246</td>
</tr>
<tr>
<td>Unused</td>
<td>.248</td>
<td>.249 - .250</td>
</tr>
<tr>
<td>Unused</td>
<td>.252</td>
<td>.253 - .254</td>
</tr>
</tbody>
</table>
9.2 Addressing Schemes
Structured Design
Planning to Address the Network

Allocation of network addresses should be planned and documented for the purposes of:

- Preventing duplication of addresses
- Providing and controlling access
- Monitoring security and performance

Client addresses – Usually dynamically assigned using the Dynamic Host Configuration Protocol (DHCP).

### Sample Network Addressing Plan

<table>
<thead>
<tr>
<th>Use</th>
<th>First</th>
<th>Last</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Devices</td>
<td>.1</td>
<td>.229</td>
</tr>
<tr>
<td>Servers</td>
<td>.230</td>
<td>.239</td>
</tr>
<tr>
<td>Printers</td>
<td>.240</td>
<td>.249</td>
</tr>
<tr>
<td>Intermediary Devices</td>
<td>.250</td>
<td>.253</td>
</tr>
<tr>
<td>Gateway (router LAN interface)</td>
<td>.254</td>
<td></td>
</tr>
</tbody>
</table>
9.3 Design Considerations for IPv6
Subnetting an IPv6 Network

Subnetting Using the Subnet ID

An IPv6 Network Space is subnetted to support hierarchical, logical design of the network
Subnetting an IPv6 Network
IPV6 Subnet Allocation

IPv6 Subnetting
Address Block: 2001:0DB8:ACAD::/48

5 subnets allocated from 65,536 available subnets

IPv6 Subnet Allocation

PC1
.10

PC2
.10

PC3
.10

PC4
.10

R1

2001:0DB8:ACAD:0001::/64
G0/0

R2

2001:0DB8:ACAD:0003::/64
G0/1
S0/0/0

2001:0DB8:ACAD:0004::/64
G0/0

2001:0DB8:ACAD:0005::/64
G0/1
S0/0/0
Subnetting an IPv6 Network

Subnetting into the Interface ID

IPv6 bits can be borrowed from the interface ID to create additional IPv6 subnets.
9.3 Summary
Chapter 9: Summary

In this chapter, you learned that:

- Subnetting is the process of segmenting a network, by dividing it into multiple smaller network spaces.
- Subnetting a subnet, or using VLSM, was designed to avoid wasting addresses.
- IPv6 address space is subnetted to support the hierarchical, logical design of the network.
- Size, location, use, and access requirements are all considerations in the address planning process.
- IP networks must be tested to verify connectivity and operational performance.