INFO 3605
Fundamentals of LAN Technologies
Lecture 13.2 - Perspectives on IPv4 Subnetting

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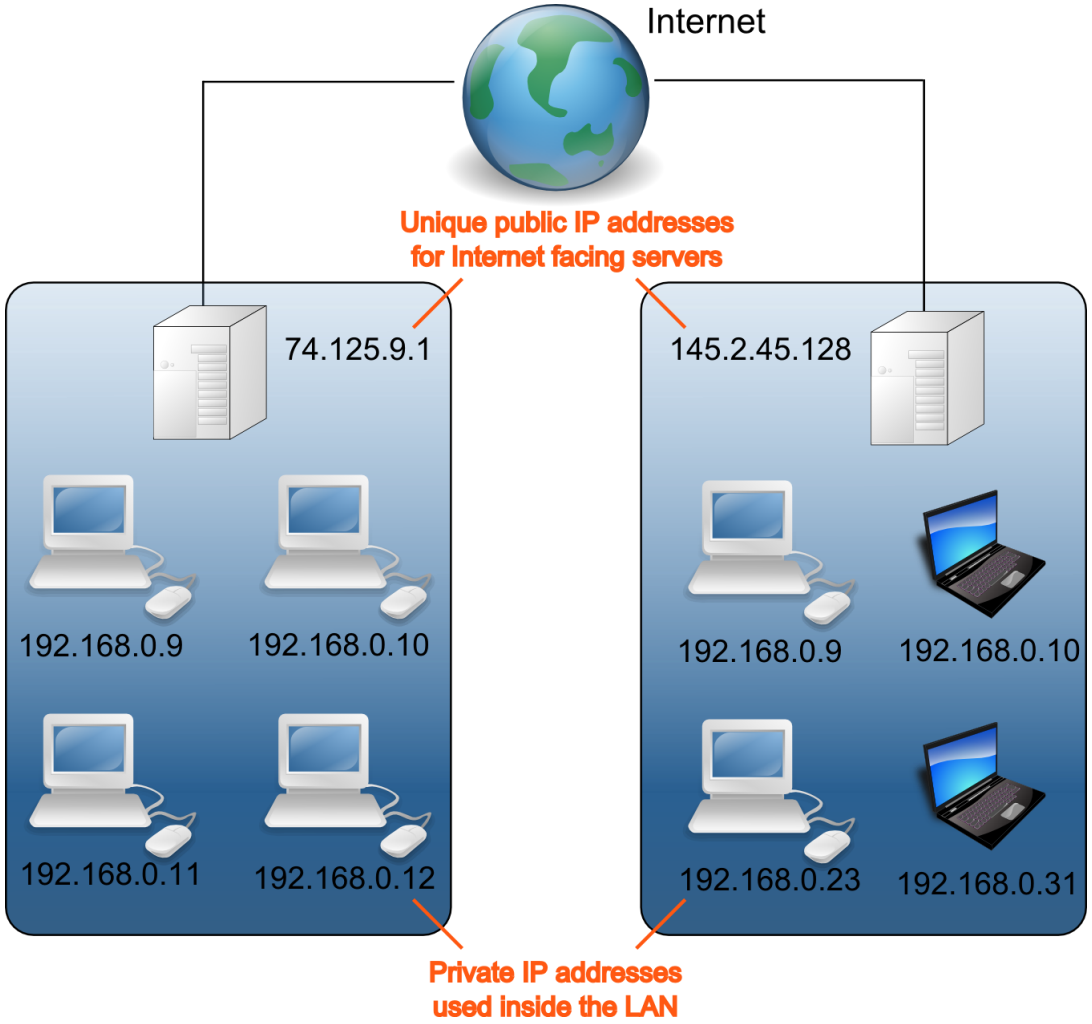
Based on Chapter 13 of Odom, Wendell. *CCENT/CCNA ICND1 100-105 official cert guide*. Indianapolis, IN: Cisco Press, 2016.

Public or Private

- Can you tell if your network uses public or private IP addressing?



Objectives

- Configure, verify, and troubleshoot IPv4 addressing and subnetting.
- Compare and contrast IPv4 address types.
- Understand unicast address types.
- Describe the need for private IPv4 addressing.

Quick Quiz

- Which of the following are private IP networks? (Choose two answers.)
  a. 172.31.0.0
  b. 172.32.0.0
  c. 192.168.255.0
  d. 192.1.168.0
  e. 11.0.0.0

Quick Quiz

- Which of the following are private IP networks? (Choose two answers.)

  a. 172.31.0.0

  b. 172.32.0.0

  c. 192.168.255.0

  d. 192.1.168.0

  e. 11.0.0.0

Quick Quiz

- Which of the following are public IP networks? (Choose three answers.)
  a. 9.0.0.0
  b. 172.30.0.0
  c. 192.168.255.0
  d. 192.1.168.0
  e. 1.0.0.0

Quick Quiz

- Which of the following are public IP networks? (Choose three answers.)

  a. 9.0.0.0

  b. 172.30.0.0

  c. 192.168.255.0

  d. 192.1.168.0

  e. 1.0.0.0

Introduction to Subnetting

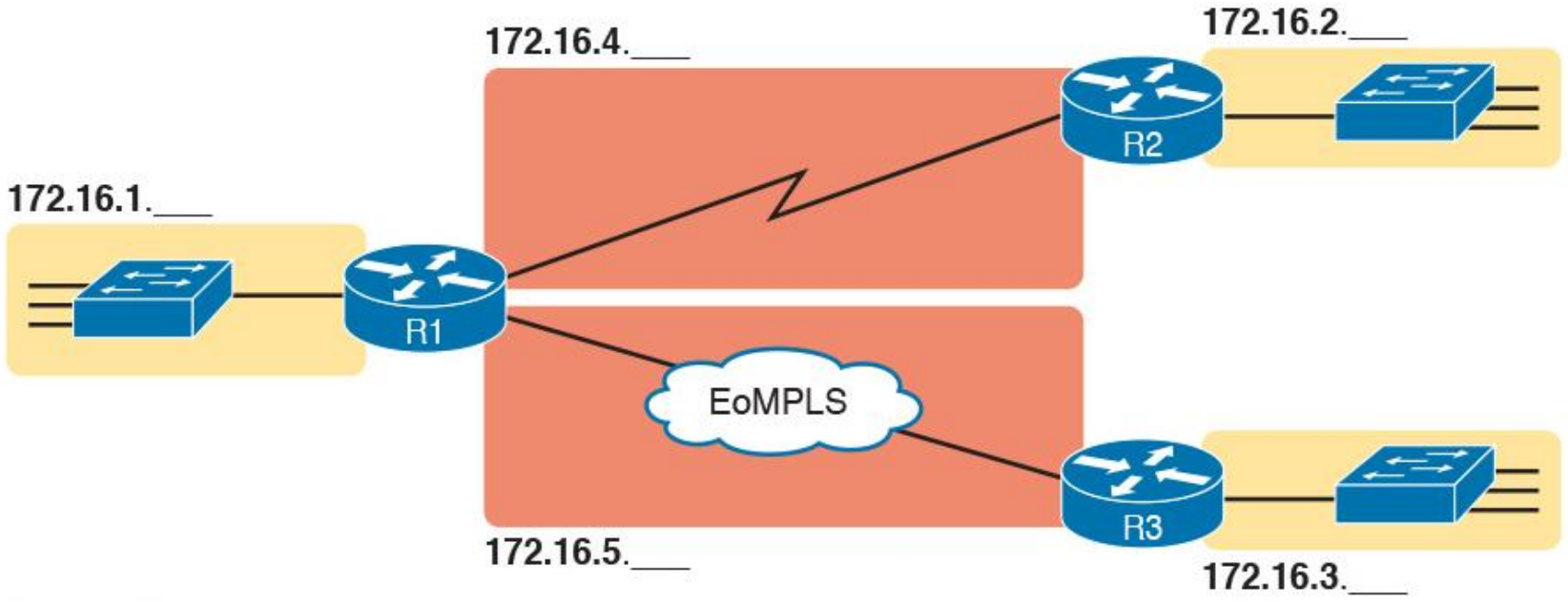
- Subnetting allows you to take a large network and split it into smaller pieces.
- These smaller networks can then be assigned to different parts of an enterprise internetwork.

Subnetting Defined Through a Simple Example

- An IP network (a Class A, B, or C network) is simply a set of consecutively numbered IP addresses that follows some preset rules.
  - Class B network 172.16.0.0 consists of all IP addresses that begin with 172.16: 172.16.0.0, 172.16.0.1, 172.16.0.2, and so on, through 172.16.255.255.
  - Class A network 10.0.0.0 includes all addresses that begin with 10.
- An IP subnet is simply a subset of a Class A, B, or C network.
  - subnet is a shortened version of the phrase subdivided network.

Subnetting Defined Through a Simple Example

- Subnet Plan Document
- Used when an engineer subnets Class B network 172.16.0.0.
- The design shows five subnets: one for each of the three LANs and one each for the two WAN links.

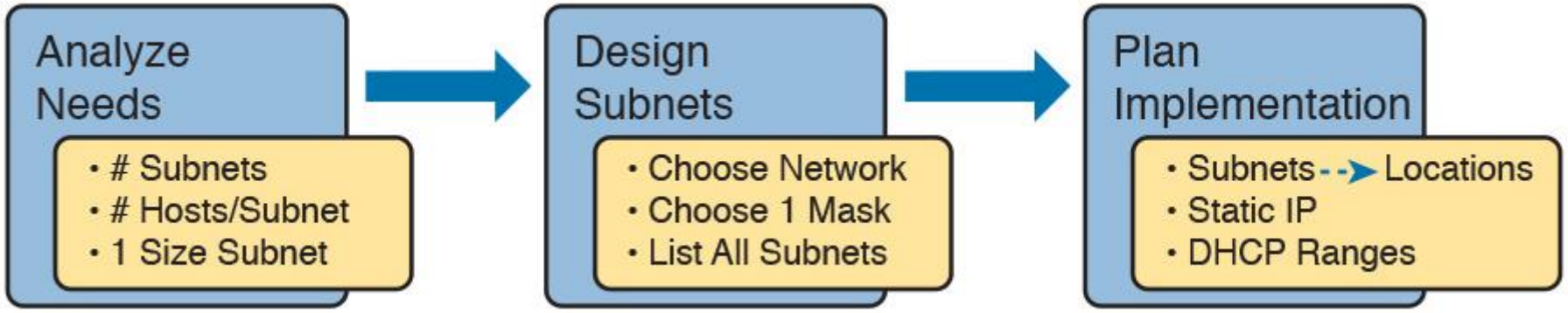


Subnet Design:

Class B 172.16.0.0
First 2 Octets are Equal

Operational View Versus Design View of Subnetting

- To fully understand IP addressing and subnetting, you need to think about subnetting from both a design and operational perspective.
  - **Operational perspective**: in most cases understand how an existing network operates or interpreting the existing design.
  - **Design perspective**: plan design and create your own network based on organizational requirements and allow others to easier understand the design. **Greenfield**.



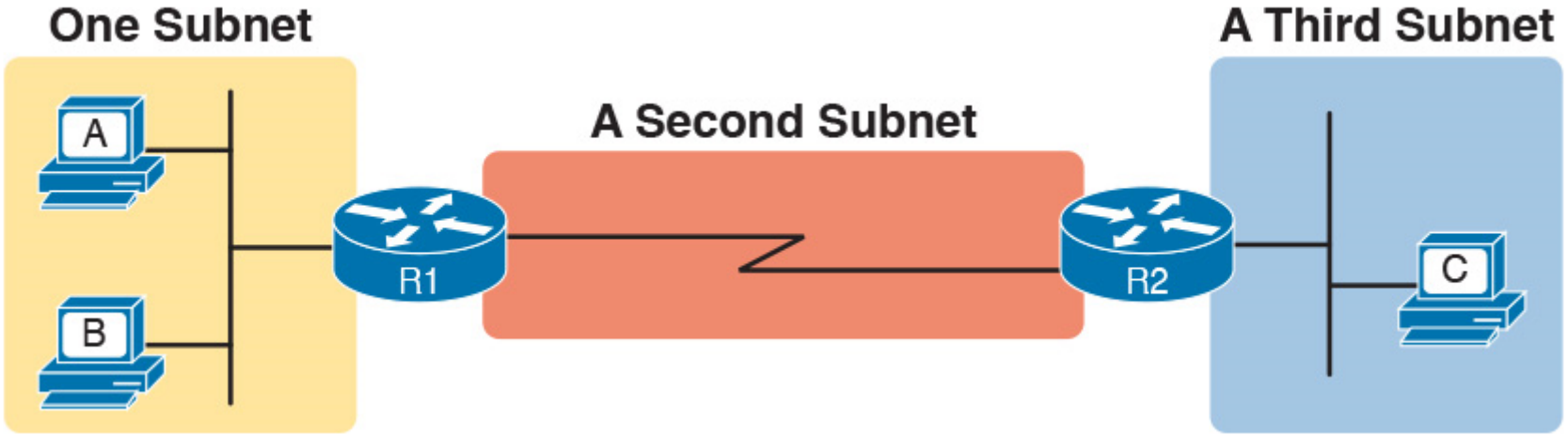
Analyze Subnetting and Addressing Needs

- Four basic questions that can be used to analyze the addressing and subnetting needs for any new or changing enterprise network:

1. Which hosts should be grouped together into a subnet?
2. How many subnets does this network require?
3. How many host IP addresses does each subnet require?
4. Will we use a single subnet size for simplicity, or not?

Rules About Which Hosts Are in Which Subnet

- The IP addresses must be assigned according to some basic rules, and for good reasons.
- The rules are as follows:
  - Addresses in the same subnet are not separated by a router.
  - Addresses in different subnets are separated by at least one router.

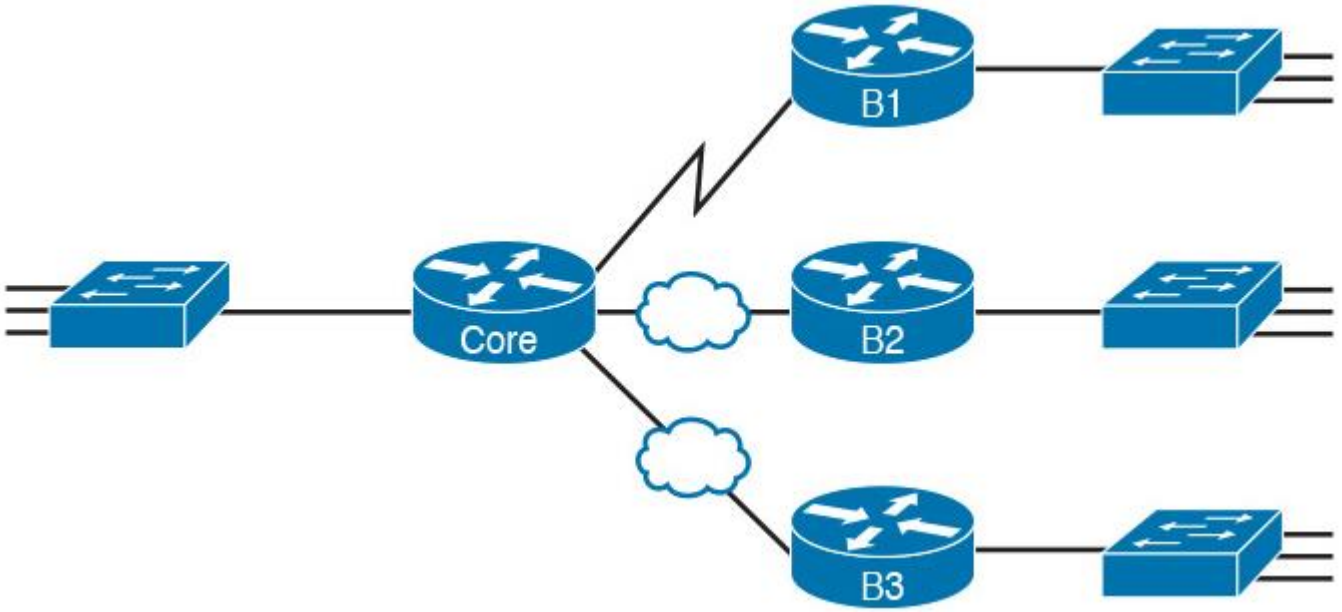


Determining the Number of Subnets

- The engineer must think about the internetwork as documented and count the locations that need a subnet.
- For the types of links discussed in this course (CCNA), you should plan for one subnet for every:
  - VLAN
  - Point-to-point serial link
  - Ethernet emulation WAN link (EoMPLS)
  - Tunneling pair (in ICND2)
  - For each Point to Multipoint pair (MPLS, in ICND2)

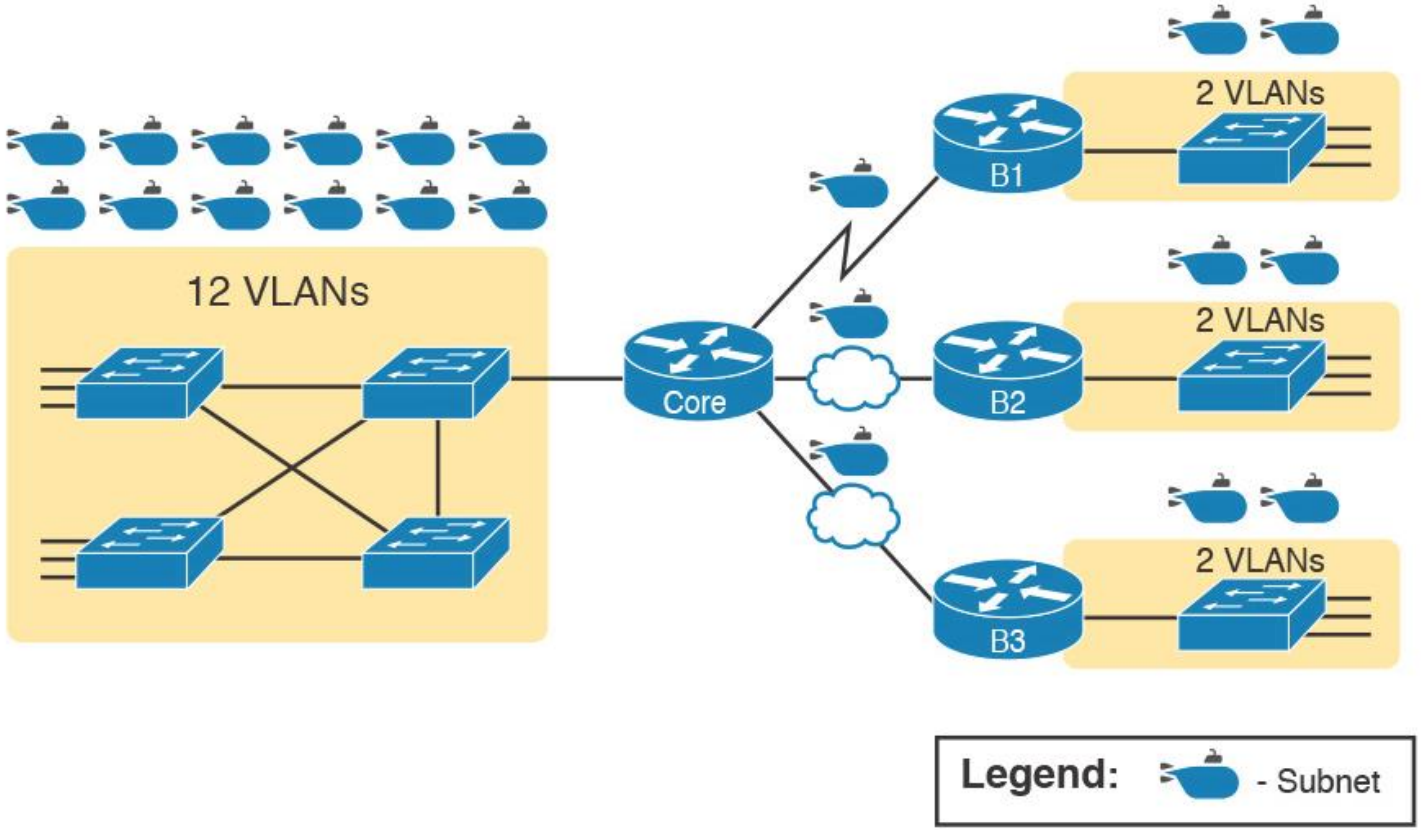
Determining the Number of Subnets

- Four-Site Internetwork with Small Central Site
- Difficult to predict but:
  - At least 3 subnets for the WAN links.
  - A subnet for each LAN site **BUT**
    - each LAN can have multiple VLANs.



Determining the Number of Subnets

- Four-Site Internetwork with Larger Central Site
- Includes VLANS.
- Total of 21 subnets.
  - 12 VLANs left of Core
  - 2 VLANs off B1
  - 2 VLANs off B2
  - 2 VLANs off B3
  - 3 VLANs for point to point WAN links.
- What about expansion?

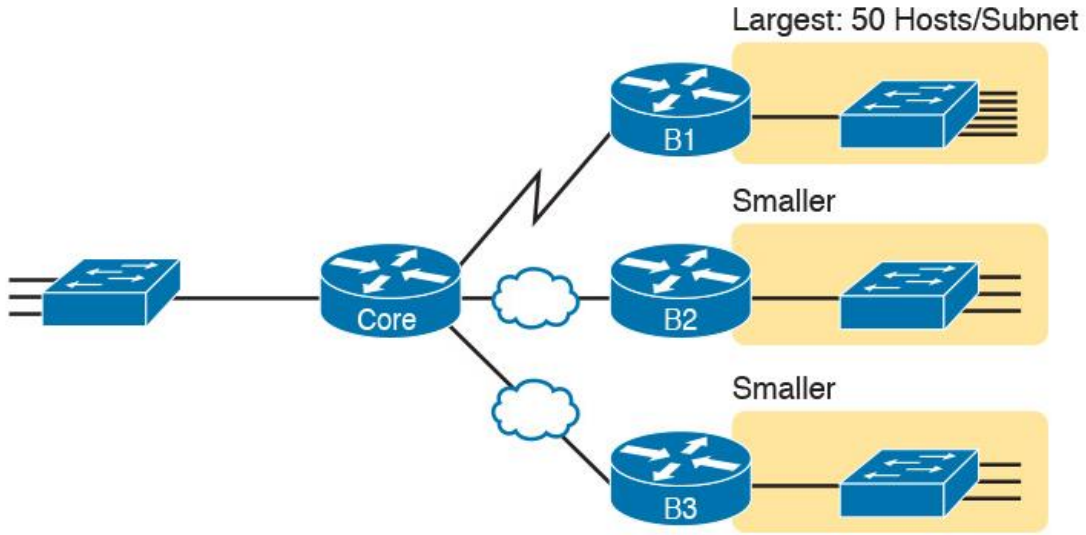


Determining the Number of Hosts per Subnet

- Every device that connects to a subnet needs an IP address.
- For a totally new network, you can look at business plans—numbers of people at the site, devices on order, etc.
- When expanding an existing network to add new sites, you can use existing sites as a point of comparison, and then find out which sites will get bigger or smaller.
- Also include the router interface IP address in each subnet and the switch IP address used to remotely manage the switch.

Determining the Number of Hosts per Subnet

- Some planners use typical sites for planning purposes.
- E.g. Sales offices, marketing offices, accounts offices. All of which can have local and remote sites.
- Large Branch B1 with 50 Hosts/Subnet



One Size Subnet Fits All—Or Not

- In implementing can use a simpler design by using a one-size-subnet-fits-all philosophy.
- A subnet's size, or length, is simply the number of usable IP addresses in the subnet.
- A subnetting design can either use one size subnet, or varied sizes of subnets, with pros and cons for each choice.

Defining the Size of a Subnet

- The engineer assigns each subnet a subnet mask, and that mask, among other things, defines the size of that subnet.
- The mask sets aside a number of host bits whose purpose is to number different host IP addresses in that subnet.
- Typically it will be 2^x IPs with **x** being the number of bits.
- If x are host bits (H), it will be 2^H unique IPs.
- Actual subnet size is 2^H - 2 and not 2^H.
- Each subnet reserves:
  - the numerically lowest value for the **subnet number** and
  - the numerically highest value as the **subnet broadcast address**.

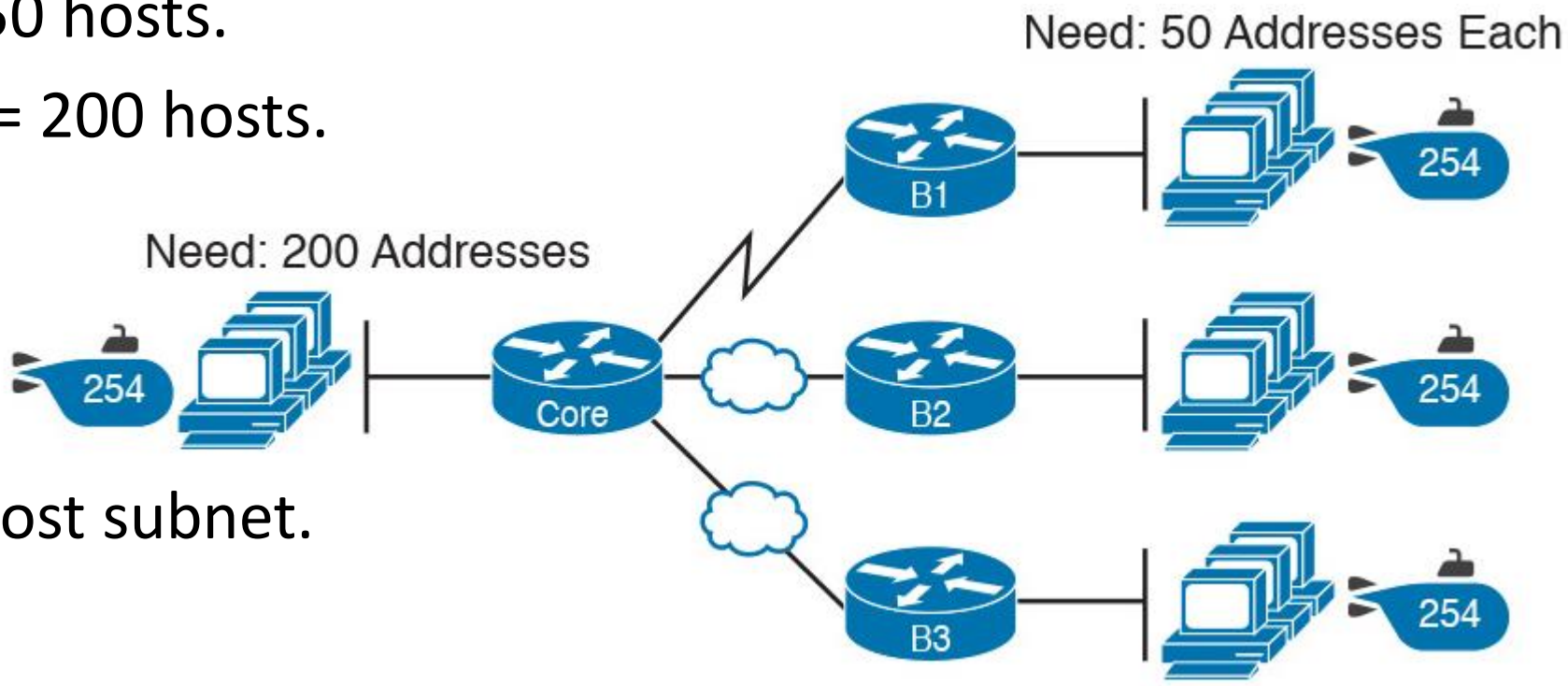
subnet number ←→ subnet ID ←→ subnet address

One-Size Subnet Fits All

- To choose to use a single-size subnet in an enterprise network, you must use the same mask for all subnets.
- What mask can we use?
- Use a mask that supports the largest sized network.
- Therefore the H (hosts) bits value must be large enough that $\mathbf{2^H - 2}$ is larger than (or equal to) the number of IP addresses required in the largest subnet.

One-Size Subnet Fits All

- Network Using One Subnet Size
- Branch LAN = 50 hosts.
- Main site LAN = 200 hosts.
- $2^7 - 2 = 126$
- $2^8 - 2 = 254$
- 254 > 200
- Will use 8 bit host subnet.



One-Size Subnet Fits All

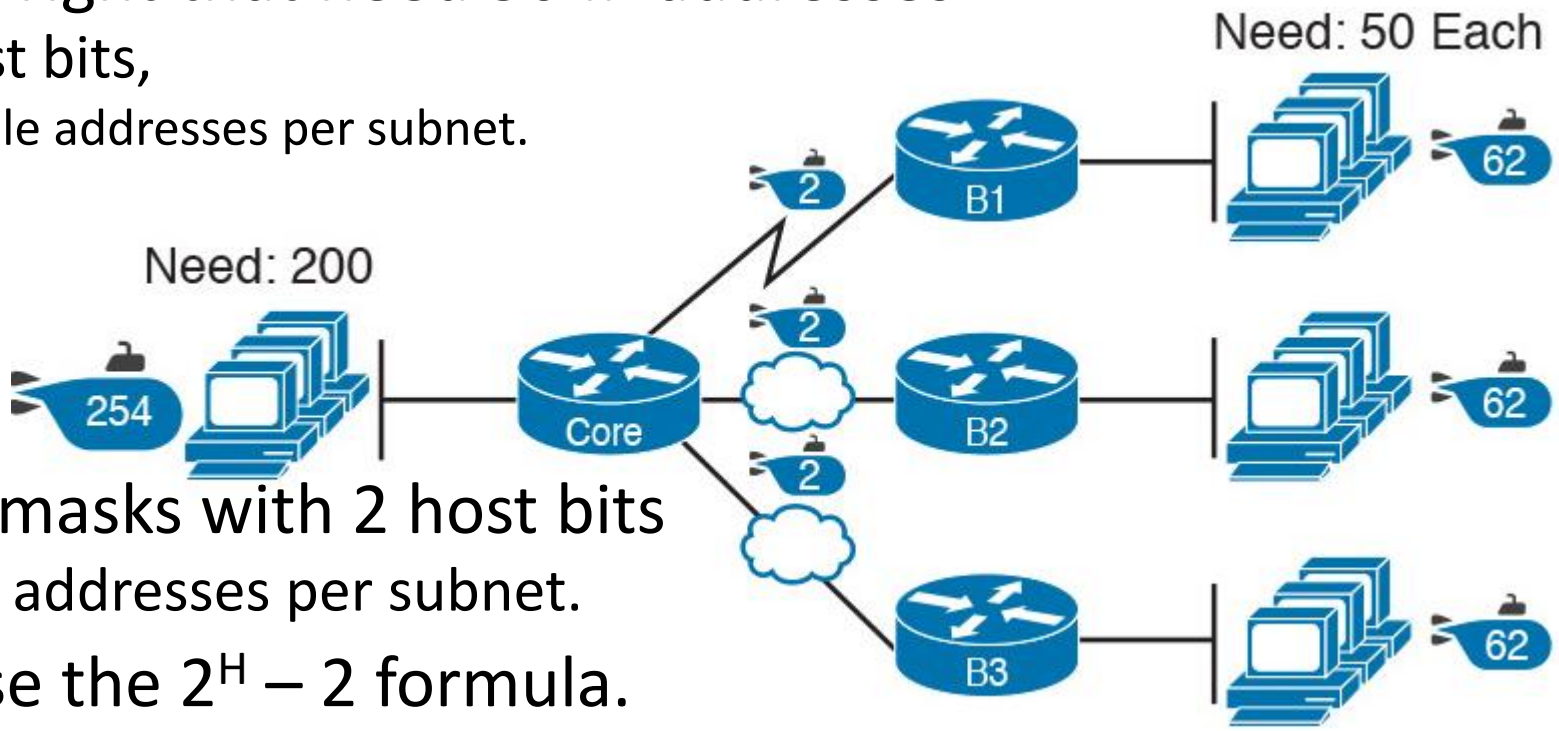
- Advantages:
  - Operational simplicity.
    - Everyone can get used to using one mask.
  - Allow for expansion.
- Disadvantages:
  - Wastes IP addresses.
  - If you are expanding your main site, by this design, **ALL** smaller sites must use a larger subnet.
    - i.e. if 200 expands to 260, need 9 bits ($2^9 – 2 = 510$) for each subnetwork.

Multiple Subnet Sizes (Variable-Length Subnet Masks)

- To create multiple sizes of subnets in one Class A, B, or C network, the engineer must create some subnets using one mask, some with another, and so on.
- Different masks mean different numbers of host bits, and a different number of hosts in some subnets based on the $2^H - 2$ formula.

Multiple Subnet Sizes (Variable-Length Subnet Masks)

- Three Masks, Three Subnet Sizes
- The subnets on the right that need 50 IP addresses
  - Subnets with 6 host bits,
    - $2^6 – 2 = 62$ available addresses per subnet.



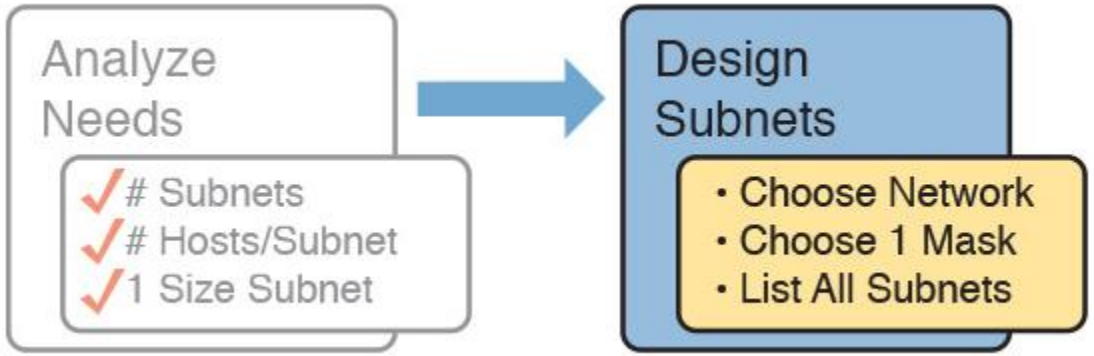
- The WAN links use masks with 2 host bits
  - $2^2 – 2 = 2$ available addresses per subnet.
- All subnets must use the $2^H – 2$ formula.

One-Size Subnet Fits All (Mostly)

- Initially network design can be done with classful networks.
- With classless design we go into the realm of different network sizes used different subnet sizes.
- variable-length subnet masks (VLSM), allows you to used different masks for different subnets in the **same classful IP network.**

Make Design Choices

- Input to the Design Phase, and Design Questions to Answer
- Subnet Design:
  - Choose Network
  - Choose 1 Mask
  - List All Subnets

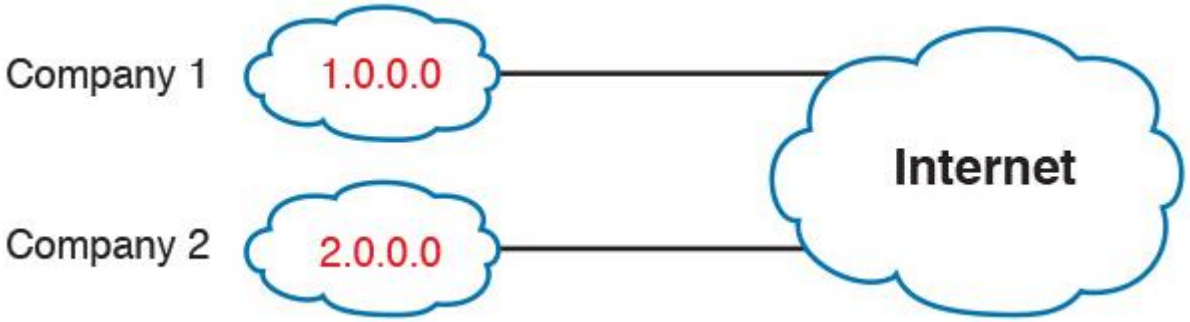


Choose a Classful Network

- In the original design companies used registered public classful IP networks when implementing TCP/IP **inside** the company.
- By the mid- 1990s, an alternative became more popular: private IP networks.

Public IP Networks

- Two Companies with Unique Public IP Networks
- No one else should be using these IP addresses.
- Similar to your post office analogy.
  - Cannot have two people with the same postal address.

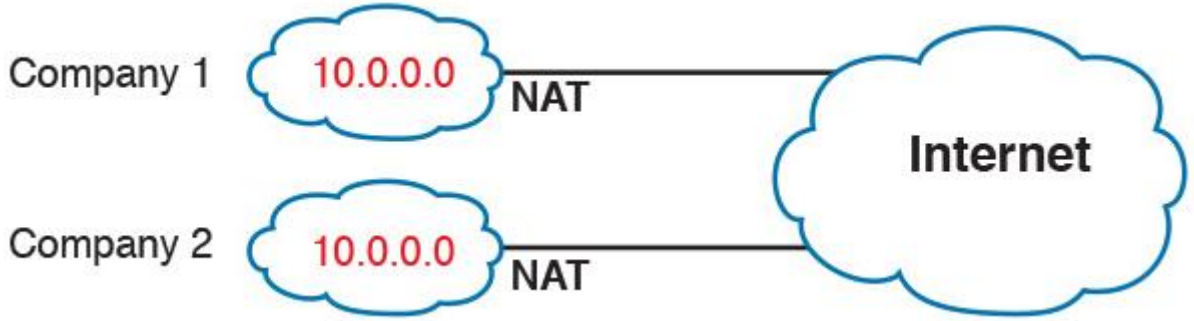


Growth Exhausts the Public IP Address Space

- The Internet community worked hard during the 1990s to solve the problem, coming up with several solutions, including the following:
  - A new version of IP (IPv6), with much larger addresses (128 bit).
  - Assigning a subset of a public IP network to each company, instead of an entire public IP network, to reduce waste.
  - Network Address Translation (NAT), which allows the use of private IP networks.
- Focusing on third option of Private IP networks and NAT.

Growth Exhausts the Public IP Address Space

- Reusing the Same Private Network 10.0.0.0 with NAT
- Both companies can:
  - use the same classful IP network (10.0.0.0).
  - implement their subnet design internal to their respective enterprise internetworks, without discussing their plans.
  - use the exact same IP addresses inside network 10.0.0.0.
  - communicate with each other through the Internet.



Private IP Networks

- Request For Comments (RFC) 1918 defines the set of private IP networks.
- By definition, these private IP networks:
  - Will never be assigned to an organization as a public IP network.
  - Can be used by organizations that will use NAT when sending packets into the Internet.
  - Can also be used by organizations that never need to send packets into the Internet.
  - Will not be routed publicly.

Class of Networks	Private IP Networks	Number of Networks
A	10.0.0.0	1
B	172.16.0.0 through 172.31.0.0	16
C	192.168.0.0 through 192.168.255.0	256

Choosing an IP Network During the Design Phase

- After the choice to use a private IP network has been made, just pick one that has enough IP addresses.
- You can have a small internetwork and still choose to use private Class A network 10.0.0.0.
- It might seem wasteful to choose a Class A network that has over 16 million IP addresses, especially if you only need a few hundred.
- The methods to subnet a public IP network versus a private IP network are the same.

Choose the Mask

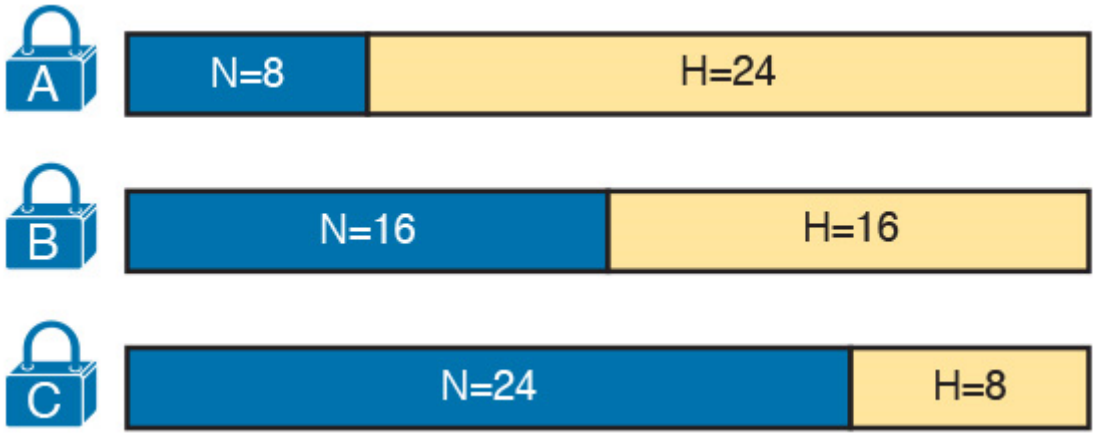
- When designing your network, core components to know at this point:
  - The number of subnets required.
  - The number of hosts/subnet required.
  - A decision was made to use only one mask for all subnets, so that all subnets are the same size (same number of hosts/subnet).
  - The classful IP network number that will be subnetted.

Classful IP Networks Before Subnetting

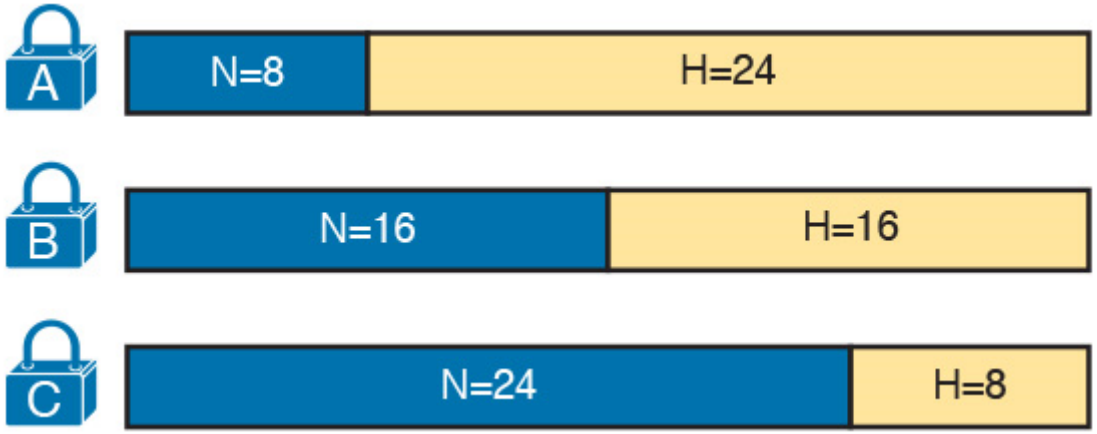
- When looking at an unsubnetted classful network, the addresses in a network have only two parts:
  - the network part and
  - host part.
- Comparing any two addresses in the classful network:
  - The addresses have the same value in the network part.
  - The addresses have different values in the host part.

Classful IP Networks Before Subnetting

- Format of Unsubnetted Class A, B, and C Networks
- N and H represent the number of network and host bits, respectively.
- IP class rules define the number of network octets (1, 2, or 3) for Classes A, B, and C, respectively.



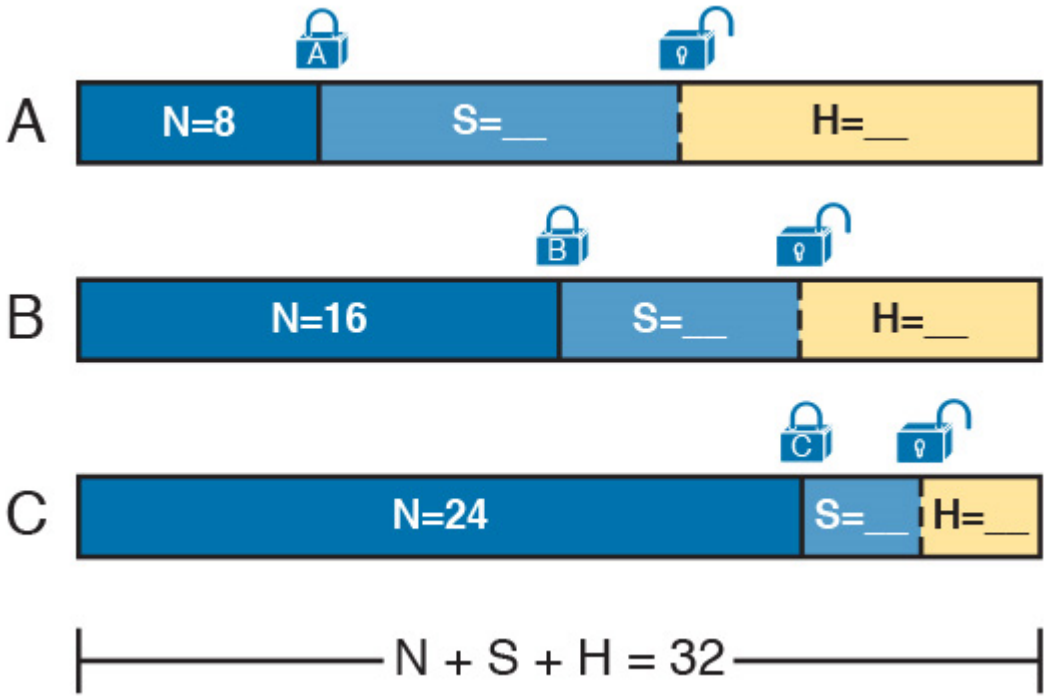
Classful IP Networks Before Subnetting



- In particular, the size of an unsubnetted Class A, B, or C network is as follows:
  - Class A: $2^{24} - 2 = 16{,}777{,}214$
  - Class B: $2^{16} - 2 = 65{,}534$
  - Class C: $2^{8} - 2 = 254$

Borrowing Host Bits to Create Subnet Bits

- Concept of Borrowing Host Bits
- To subnet a network, the designer thinks about the network and host parts.
- The engineer adds a third part in the middle: the subnet part.
- The designer cannot change the size of the network part or the size of the entire address (32 bits).
- To create a subnet part of the address structure, the engineer borrows bits from the host part.

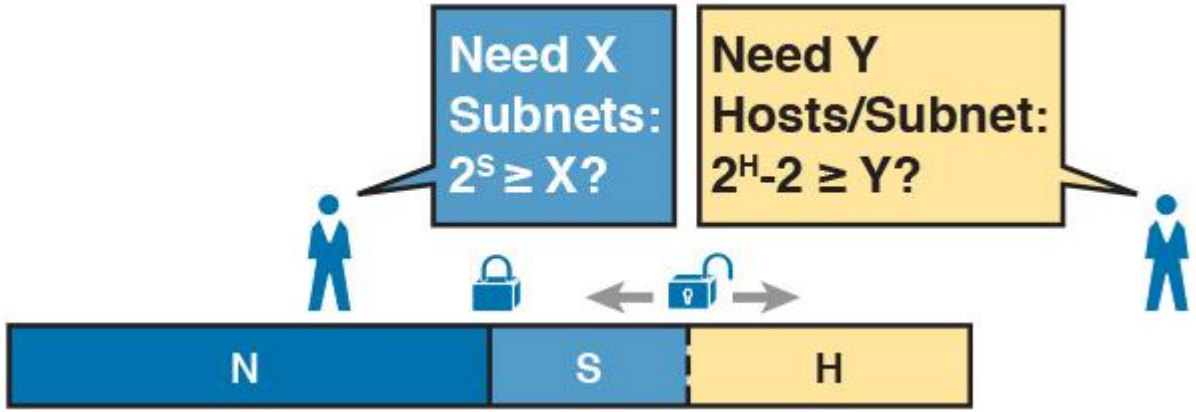


Choosing Enough Subnet and Host Bits

- Where should we place the dashed line to create our subnets?
- Need information from the requirements gathered in the early stages of the planning process:
  - Number of subnets required.
  - Number of hosts/subnet.
- With 1 subnet bit, you can number 2^1 or 2 subnets.
- With 2 bits, 2^2 or 4 subnets, with 3 bits, 2^3 or 8 subnets, etc.
- The number of subnet bits must be large enough to uniquely number all the subnets, as determined during the planning process.

Choosing Enough Subnet and Host Bits

- Borrowing Enough Subnet and Host Bits
- 2^S must be more than the number of required subnets.
- $2^H – 2$ must be more than the required number of hosts/subnet.



Example Design: 172.16.0.0, 200 Subnets, 200 Hosts

- Planning requirements:
  - Use a single mask for all subnets.
  - Plan for 200 subnets.
  - Plan for 200 host IP addresses per subnet.
  - Use private Class B network 172.16.0.0.
  - [200 x 200 = 40,000 IPs] < [2^8 x 2^8 = 65,536]

Example Design: 172.16.0.0, 200 Subnets, 200 Hosts

- **How many subnet (S) bits do I need to number 200 subnets?**
- S = 7 is not large enough ($2^7 = 128$), but S = 8 is enough ($2^8 = 256$). So, you need at least 8 subnet bits.

- **How many host (H) bits do I need to number 200 hosts per subnet?**
- H = 7 is not large enough ($2^7 – 2 = 126$), but H = 8 is enough ($2^8 – 2 = 254$).

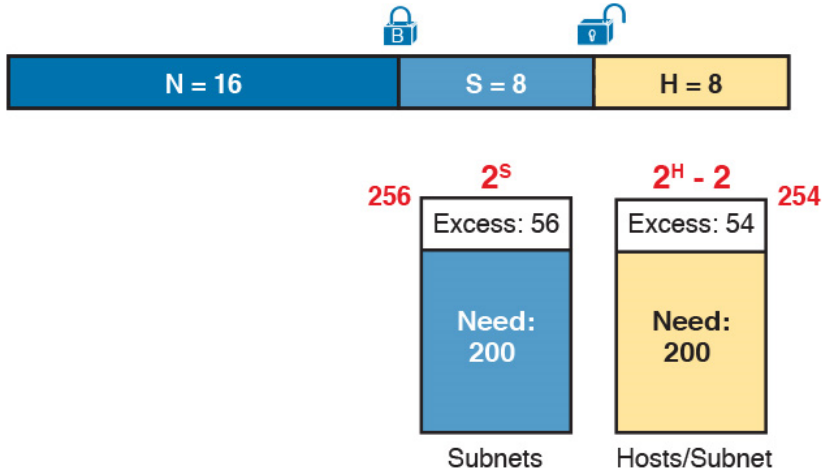
Example Design: 172.16.0.0, 200 Subnets, 200 Hosts

- First Ten Subnets, Plus the Last Few, from 172.16.0.0, 255.255.255.0

Subnet Number	IP Addresses	Broadcast Address
172.16.0.0	172.16.0.1 – 172.16.0.254	172.16.0.255
172.16.1.0	172.16.1.1 – 172.16.1.254	172.16.1.255
172.16.2.0	172.16.2.1 – 172.16.2.254	172.16.2.255
172.16.3.0	172.16.3.1 – 172.16.3.254	172.16.3.255
172.16.4.0	172.16.4.1 – 172.16.4.254	172.16.4.255
172.16.5.0	172.16.5.1 – 172.16.5.254	172.16.5.255
172.16.6.0	172.16.6.1 – 172.16.6.254	172.16.6.255
172.16.7.0	172.16.7.1 – 172.16.7.254	172.16.7.255
172.16.8.0	172.16.8.1 – 172.16.8.254	172.16.8.255
172.16.9.0	172.16.9.1 – 172.16.9.254	172.16.9.255
Skipping many…		
172.16.254.0	172.16.254.1 – 172.16.254.254	172.16.254.255
172.16.255.0	172.16.255.1 – 172.16.255.254	172.16.255.255

Example Design: 172.16.0.0, 200 Subnets, 200 Hosts

- Only one possible mask meets all the requirements in this case.
  - the number of network bits (N) must be 16, because the design uses a Class B network.
  - the mask needs at least 8 subnet bits, and at least 8 host bits.
- Example Mask Choice, N = 16, S = 8, H = 8



Example Design: 172.16.0.0, 200 Subnets, **300** Hosts

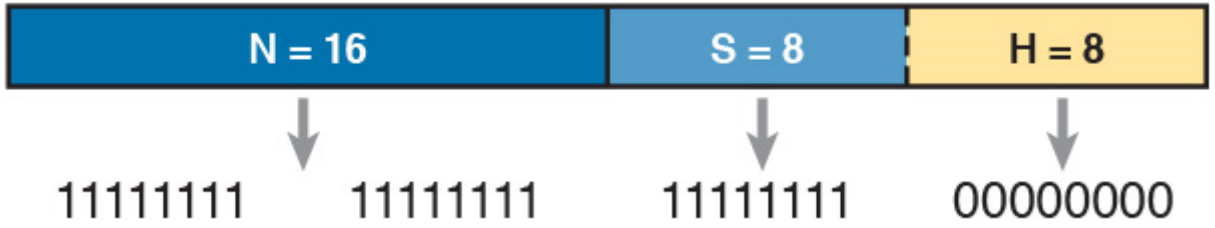
- Planning requirements:
  - Use a single mask for all subnets.
  - Plan for 200 subnets.
  - Plan for **300** host IP addresses per subnet.
  - Use private Class B network 172.16.0.0.
  - [200 x 300 = 60,000 IPs] < [2^8 x 2^8 = 65,536]
- Will this work?
  - S = 7 bits [(2^7 = 128) < 200].
  - H = 9 bits [(2^9 = 512) > 300].
- No…
  - We have 16 bits to both S and H but not enough for S.
- How can this be solved?
  - Use a larger class network: Class A

Masks and Mask Formats

- The subnet mask is a 32-bit binary number with a number of binary 1s on the left and with binary 0s on the right.
- The number of binary 0s equals the number of host bits.
- This is how the mask communicates the idea of the size of the host part of the addresses in a subnet.
- Subnet mask bits created from:
  - Classfull network bits and
  - Number of subnet bits.

Masks and Mask Formats

- Creating the Subnet Mask—Binary—Class B Network



- Represented in dotted-decimal notation (DDN) like IP addresses.
- Briefer prefix notation.

Build a List of All Subnets

- We have your subnets, but what do they look like?
- A subnet consists of a group of consecutive numbers.
- Most of these numbers can be used as IP addresses by hosts.
- Each subnet reserves the first and last numbers in the group, and these two numbers cannot be used as IP addresses.

Build a List of All Subnets

- **Subnet number:** Also called the subnet ID or subnet address, this number identifies the subnet. It is the numerically smallest number in the subnet. It cannot be used as an IP address by a host.
- **Subnet broadcast:** Also called the subnet broadcast address or directed broadcast address, this is the last (numerically highest) number in the subnet. It also cannot be used as an IP address by a host.
- **IP addresses:** All the numbers between the subnet ID and the subnet broadcast address can be used as a host IP address.

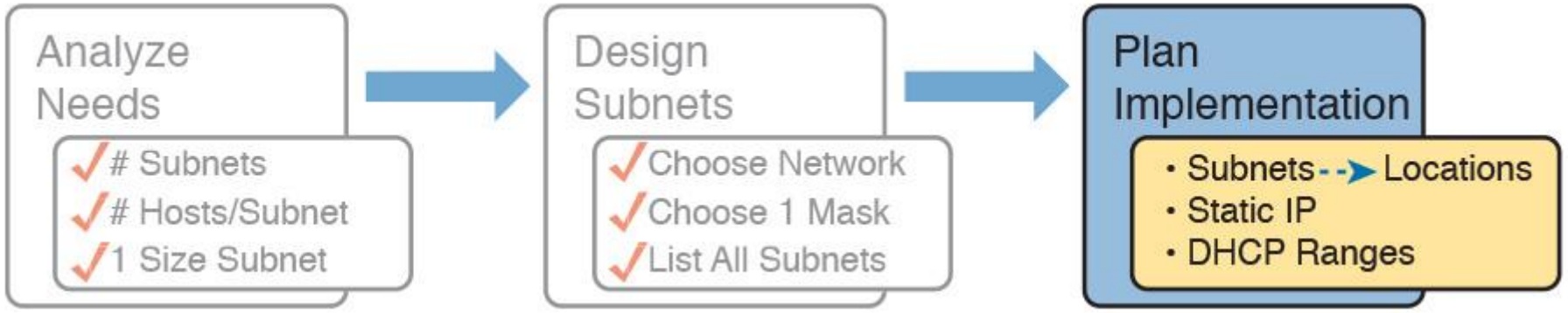
Build a List of All Subnets

- Network 172.16.0.0 (Class B)
- Mask 255.255.255.0 (for all subnets)

Subnet Number	IP Addresses	Broadcast Address
172.16.0.0	172.16.0.1 – 172.16.0.254	172.16.0.255
172.16.1.0	172.16.1.1 – 172.16.1.254	172.16.1.255
172.16.2.0	172.16.2.1 – 172.16.2.254	172.16.2.255
172.16.3.0	172.16.3.1 – 172.16.3.254	172.16.3.255
172.16.4.0	172.16.4.1 – 172.16.4.254	172.16.4.255
172.16.5.0	172.16.5.1 – 172.16.5.254	172.16.5.255
172.16.6.0	172.16.6.1 – 172.16.6.254	172.16.6.255
172.16.7.0	172.16.7.1 – 172.16.7.254	172.16.7.255
172.16.8.0	172.16.8.1 – 172.16.8.254	172.16.8.255
172.16.9.0	172.16.9.1 – 172.16.9.254	172.16.9.255
Skipping many…		
172.16.254.0	172.16.254.1 – 172.16.254.254	172.16.254.255
172.16.255.0	172.16.255.1 – 172.16.255.254	172.16.255.255

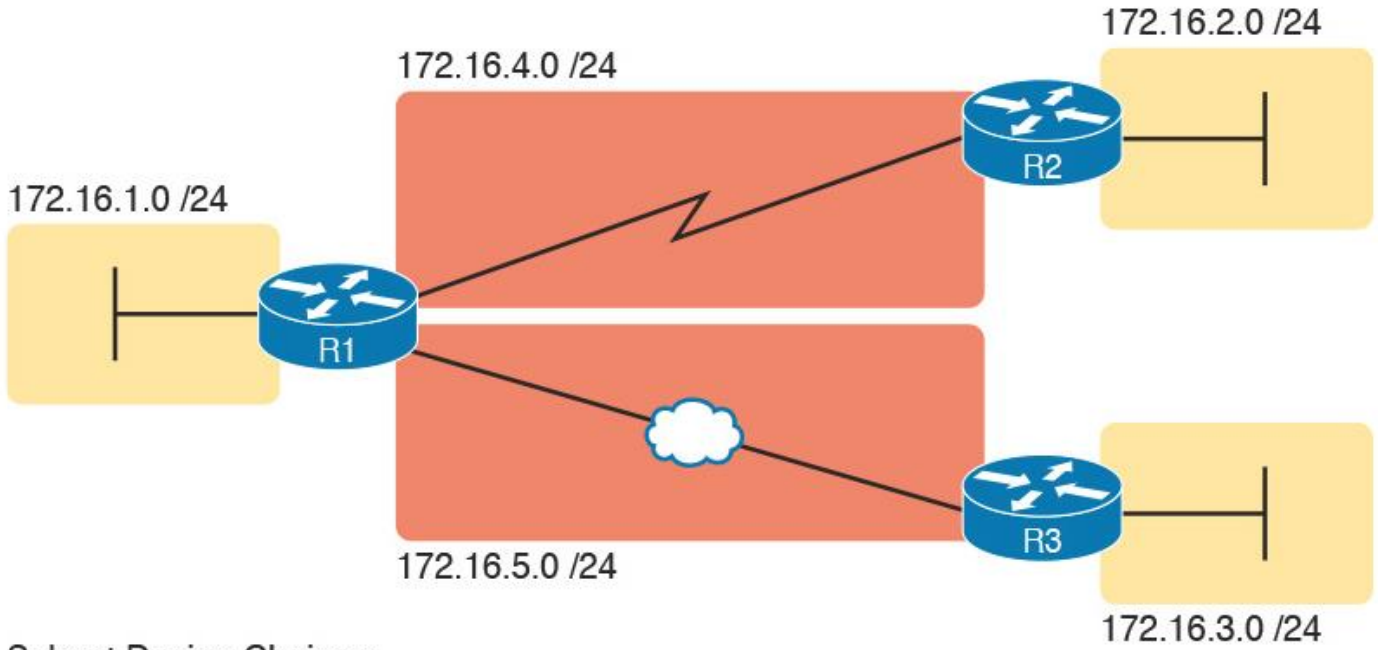
Plan the Implementation

- Before configuring the devices on each subnet need to know:
  - Where to use each subnet.
  - Are there VLANS on the site.
  - Static IP addresses that needs to be set on devices.
  - What range of IP addresses should be configured in the DHCP server?



Assigning Subnets to Different Locations

- Example of Subnets Assigned to Different Locations



Subnet Design Choices:

Class B 172.16.0.0 /24 (255.255.255.0)

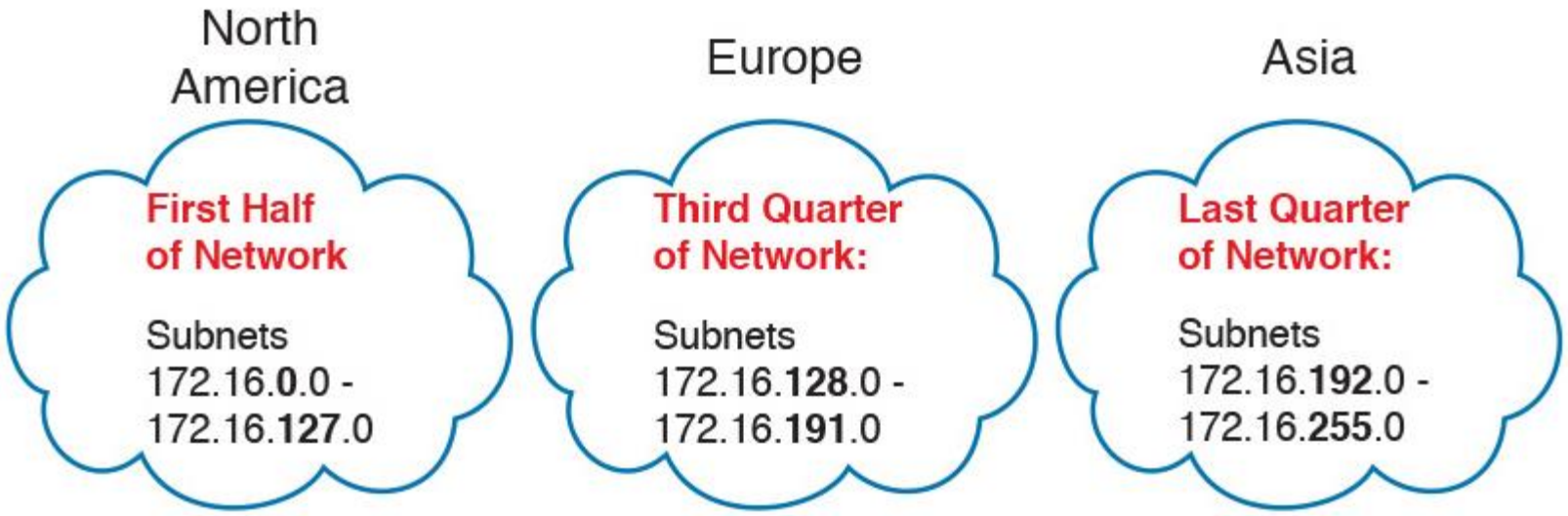
Assigning Subnets to Different Locations

1. Look at your network diagram,
2. identify each location that needs a subnet,
3. pick one from the table you made of all the possible subnets.
4. Then, track it so that you know which ones you use where, using a spreadsheet or some other purpose-built subnet-planning tool.

- Other Planning steps:
    1. Assign all LAN subnets lower numbers.
    2. WAN subnets higher numbers.
    3. Separate into organisational divisions.

Assigning Subnets to Different Locations

- Reserving 50 Percent of Subnets for North America and 25 Percent Each for Europe and Asia

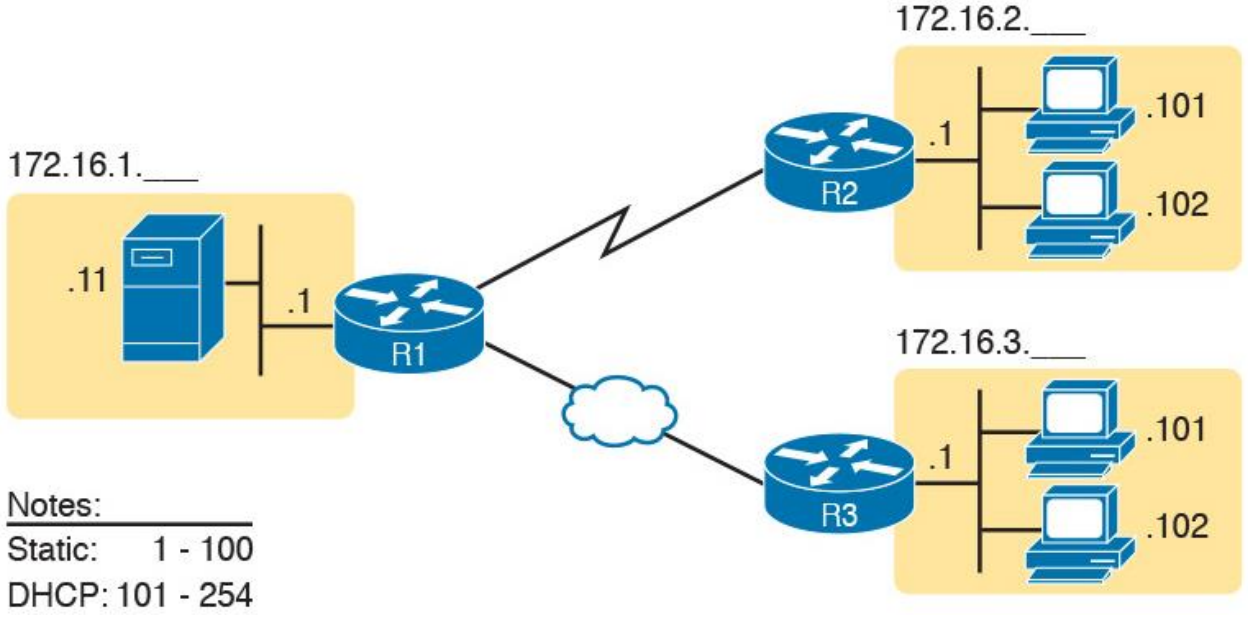


Choose Static and Dynamic Ranges per Subnet

- Devices receive their IP address and mask assignment in one of two ways:
  - dynamically by using Dynamic Host Configuration Protocol (DHCP) or
  - statically through configuration.
- For DHCP to work, the network engineer must tell the DHCP server the subnets for which it must assign IP addresses.
- Configuration limits the DHCP server to only a subset of the addresses in the subnet.

Choose Static and Dynamic Ranges per Subnet

- Static from the Low End and DHCP from the High End
- All three routers with statically assigned IP addresses that end in .1
- static IP address is assigned to the server on the left, with address 172.16.1.11
- each LAN has two PCs that use DHCP to dynamically lease their IP addresses from .101 to .254.



What do you know now?

- Before Class B network 172.16.0.0 is subnetted by a network engineer, what parts of the structure of the IP addresses in this network already exist, with a specific size? (Choose two answers.)
  a. Network
  b. Subnet
  c. Host
  d. Broadcast

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What do you know now?

- A network engineer spends time thinking about the entire Class B network 172.16.0.0, and how to subnet that network. He then chooses how to subnet this Class B network and creates an addressing and subnetting plan, on paper, showing his choices. If you compare his thoughts about this network before subnetting the network, to his thoughts about this network after mentally subnetting the network, which of the following occurred to the parts of the structure of addresses in this network?
  a. The subnet part got smaller.
  b. The host part got smaller.
  c. The network part got smaller.
  d. The host part was removed.
  e. The network part was removed

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Summary

- Key facts about subnets.
- Rules about what places in a network topology need a subnet.
- Location of the network, subnet and host parts of an IPv4 address.
- Features that extend the life of IPv4.
- Formats of Class A, B, and C addresses when not subnetted.
- Formats of Class A, B and C addresses when subnetted.
- General logic when choosing the size of the subnet and host parts of addresses in a subnet.
- Items that together define a subnet.

End of Lecture 13.2, Further Reading, References

- Odom, Wendell. *CCENT/CCNA ICND1 100-105 official cert guide*. Indianapolis, IN: Cisco Press, 2016.