INFO 3605
Fundamentals of LAN Technologies
Lecture 15 - Analyzing Subnet Masks

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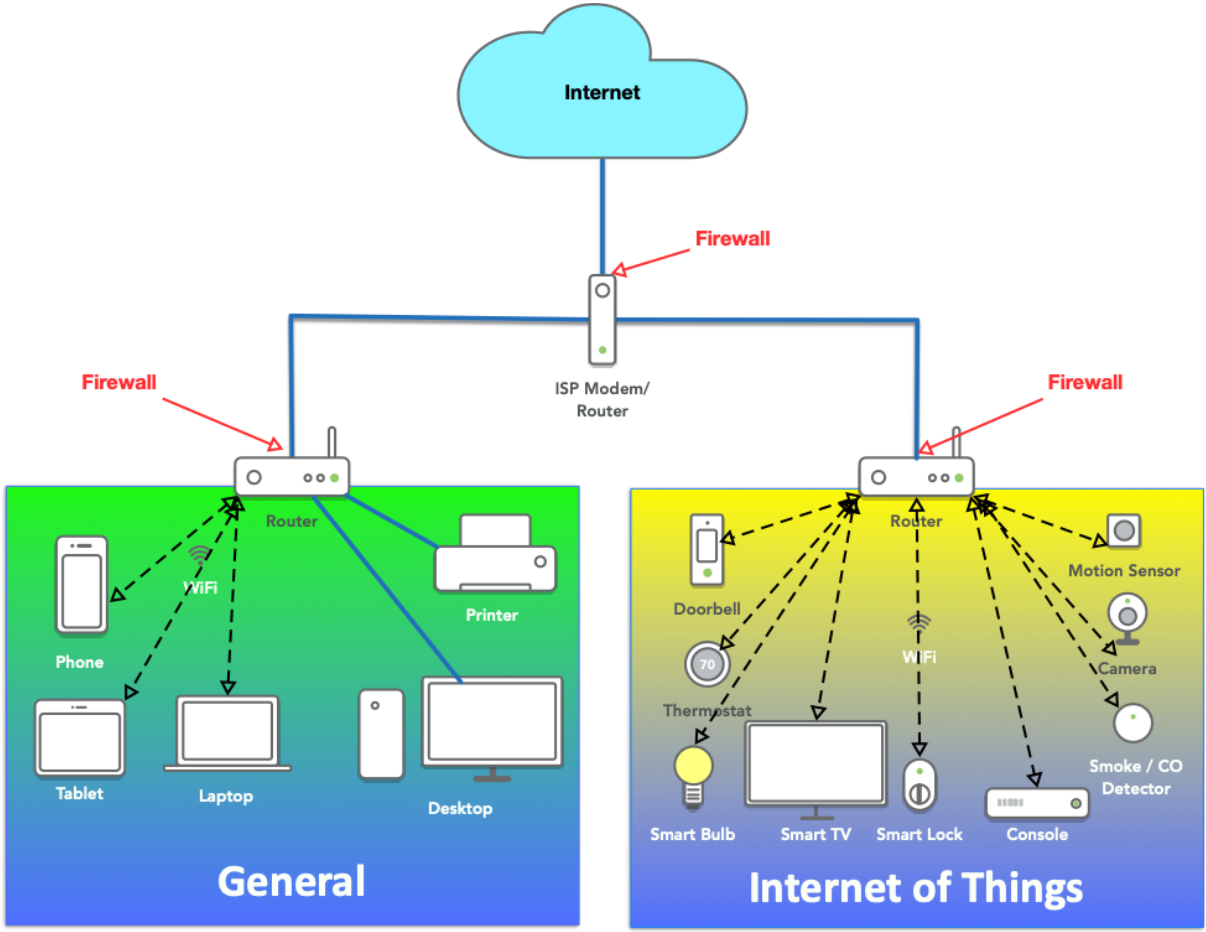
Based on Chapter 15 of Odom, Wendell. *CCENT/CCNA ICND1 100-105 official cert guide*. Indianapolis, IN: Cisco Press, 2016.

Network masks in your home network

- Typically the subnet mask is 255.255.255.0 which is a /24 network.
- How large is this home network?
- What are your network address and broadcast address?
- How can you expand this network?
- How can you split this network?
- What are the network masks?



https://www.ckd3.com/blog/2018/10/15/home-network-segmentation-a-must-in-the-iot-era

Objectives

- Configure, verify, and troubleshoot IPv4 addressing and subnetting.
- Understand the difference between classful and classless subnetting.

Quick Quiz

- Which of the following answers lists the prefix (CIDR) format equivalent of 255.255.254.0?
  a. /19
  b. /20
  c. /23
  d. /24
  e. /25

Quick Quiz

- Which of the following answers lists the prefix (CIDR) format equivalent of 255.255.254.0?
  a. /19
  b. /20
  c. /23
  d. /24
  e. /25

Quick Quiz

- Which of the following answers lists the prefix (CIDR) format equivalent of 255.255.255.240?
  a. /26
  b. /28
  c. /27
  d. /30
  e. /29

Quick Quiz

- Which of the following answers lists the prefix (CIDR) format equivalent of 255.255.255.240?
  a. /26
  b. /28
  c. /27
  d. /30
  e. /29

Quick Quiz

- Which of the following answers lists the dotted-decimal notation (DDN) equivalent of /30?
  - a. 255.255.255.192
  - b. 255.255.255.252
  - c. 255.255.255.240
  - d. 255.255.254.0
  - e. 255.255.255.0

Quick Quiz

- Which of the following answers lists the dotted-decimal notation (DDN) equivalent of /30?
  - a. 255.255.255.192
  - b. 255.255.255.252
  - c. 255.255.255.240
  - d. 255.255.254.0
  - e. 255.255.255.0

Three Mask Formats

- Subnet masks can be written as 32-bit binary numbers, but not just any binary number.
- In particular, the binary subnet mask must follow these rules:
  - The value must not interleave 1s and 0s.
  - If 1s exist, they are on the left.
  - If 0s exist, they are on the right.
- Illegal subnet mask
  - 10101010 01010101 11110000 00001111
    - Interleaved 1s and 0s.
  - 0000000 00000000 00000000 11111111
    - 0s on left and 1s on right.

Three Mask Formats

- Two alternative subnet mask formats exist so that we humans do not have to work with 32-bit binary numbers:
  - dotted-decimal notation (DDN), converts each set of 8 bits into the decimal equivalent.
    - 11111111 00000000 00000000 00000000 → 255.0.0.0
    - 11111111 11111111 11111111 00000000 →255.255.255.0
  - The prefix format takes advantage of the rule that the subnet mask starts with some number of 1s, and then the rest of the digits are 0s.
    - lists a slash (/) followed by the number of binary 1s in the binary mask.
    - 11111111 00000000 00000000 00000000 → /8
    - 11111111 11111111 11111111 00000000 →/24
  - prefix ←→ prefix mask ←→ CIDR mask ←→ slash mask

Converting Between Binary and Prefix Masks

- Binary to prefix: Count the number of binary 1s in the binary mask, and write the total, in decimal, after a /.
- Prefix to binary: Write P binary 1s, where P is the prefix value, followed by as many binary 0s as required to create a 32-bit number.

Converting Between Binary and Prefix Masks

- Example Conversions: Binary to Prefix

Binary Mask	Logic	Prefix Mask
11111111 11111111 11000000 00000000	Count 8 + 8 + 2 = 18 binary 1s	/18
11111111 11111111 11111111 11110000	Count 8 + 8 + 8 + 4 = 28 binary 1s	/28
11111111 11111000 00000000 00000000	Count 8 + 5 = 13 binary 1s	/13

- Example Conversions: Prefix to Binary

Prefix Mask	Logic	Binary Mask
/18	Write 18 1s, then 14 0s, total 32	11111111 11111111 11000000 00000000
/28	Write 28 1s, then 4 0s, total 32	11111111 11111111 11111111 11110000
/13	Write 13 1s, then 19 0s, total 32	11111111 11111000 00000000 00000000

Converting Between Binary and DDN Masks

- A dotted-decimal number (DDN) used with IPv4 addressing contains four decimal numbers, separated by dots.
- For each octet, perform a decimal-to-binary conversion.

Converting E s

- Binary table:

Decimal Value	Binary Value	Decimal Value	Binary Value	Decimal Value	Binary Value	Decimal Value	Binary Value
0	00000000	32	00100000	64	01000000	96	01100000
1	00000001	33	00100001	65	01000001	97	01100001
2	00000010	34	00100010	66	01000010	98	01100010
3	00000011	35	00100011	67	01000011	99	01100011
4	00000100	36	00100100	68	01000100	100	01100100
5	00000101	37	00100101	69	01000101	101	01100101
6	00000110	38	00100110	70	01000110	102	01100110
7	00000111	39	00100111	71	01000111	103	01100111
8	00001000	40	00101000	72	01001000	104	01101000
9	00001001	41	00101001	73	01001001	105	01101001
10	00001010	42	00101010	74	01001010	106	01101010
11	00001011	43	00101011	75	01001011	107	01101011
12	00001100	44	00101100	76	01001100	108	01101100
13	00001101	45	00101101	77	01001101	109	01101101
14	00001110	46	00101110	78	01001110	110	01101110
15	00001111	47	00101111	79	01001111	111	01101111
16	00010000	48	00110000	80	01010000	112	01110000
17	00010001	49	00110001	81	01010001	113	01110001
18	00010010	50	00110010	82	01010010	114	01110010
19	00010011	51	00110011	83	01010011	115	01110011
20	00010100	52	00110100	84	01010100	116	01110100
21	00010101	53	00110101	85	01010101	117	01110101

Converting Between Binary and DDN Masks

- Nine possible values in a decimal mask:

Binary Mask Octet	Decimal Equivalent	Number of Binary 1s
00000000	0	0
10000000	128	1
11000000	192	2
11100000	224	3
11110000	240	4
11111000	248	5
11111100	252	6
11111110	254	7
11111111	255	8

Converting Between Binary and DDN Masks

- **Binary to decimal:**
  - Organize the bits into four sets of eight.
  - For each octet, find the binary value in the table and write down the corresponding decimal value

Binary Mask	Logic	Decimal Mask
11111111 11111111 11000000 00000000	11111111 maps to 255 11000000 maps to 192 00000000 maps to 0	255.255.192.0
11111111 11111111 11111111 11110000	11111111 maps to 255 11110000 maps to 240	255.255.255.240
11111111 11111000 00000000 00000000	11111111 maps to 255 11111000 maps to 248 00000000 maps to 0	255.248.0.0

Converting Between Binary and DDN Masks

- **Decimal to binary:**
  - For each octet, find the decimal value in the table and write down the corresponding 8-bit binary value.

Decimal Mask	Logic	Binary Mask
255.255.192.0	255 maps to 11111111 192 maps to 11000000 0 maps to 00000000	11111111 11111111 11000000 00000000
255.255.255.240	255 maps to 11111111 240 maps to 11110000	11111111 11111111 11111111 11110000
255.248.0.0	255 maps to 11111111 248 maps to 11111000 0 maps to 00000000	11111111 11111000 00000000 00000000

Converting Between Binary and DDN Masks

- **Binary Table:**
- Use as a fall back or base case.

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
128	64	32	16	8	4	2	1	=	192
1	1	0	0	0	0	0	0		

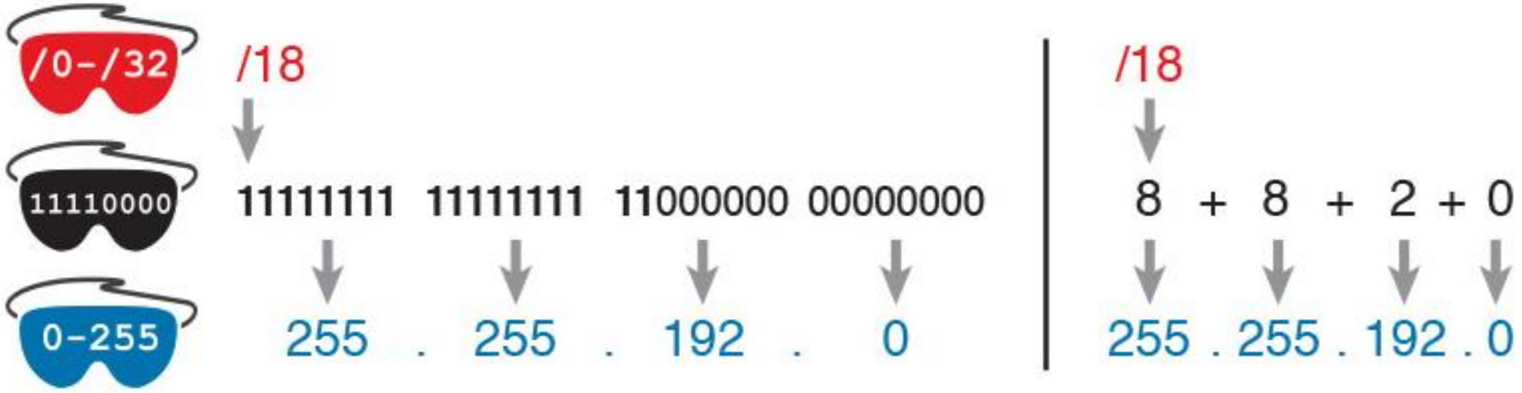
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
128	64	32	16	8	4	2	1	=	168
1	0	1	0	1	0	0	0		

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
128	64	32	16	8	4	2	1	=	10
0	0	0	0	1	0	1	0		

http://www.certiology.com/wp-content/uploads/2015/09/tabal2.png

Converting Between Prefix and DDN Masks

- To move from decimal to prefix, first convert decimal to binary and then from binary to prefix.
- Conversion from Prefix to Decimal: Full Binary Versus Shorthand



Converting Between Prefix and DDN Masks

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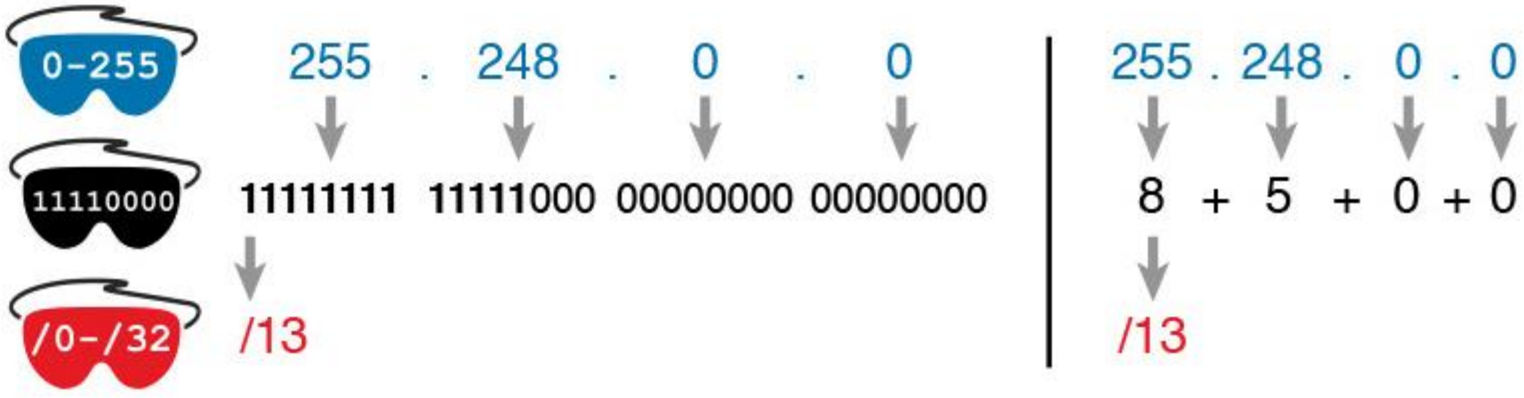


Converting Bet

- 33 legal subnet masks.

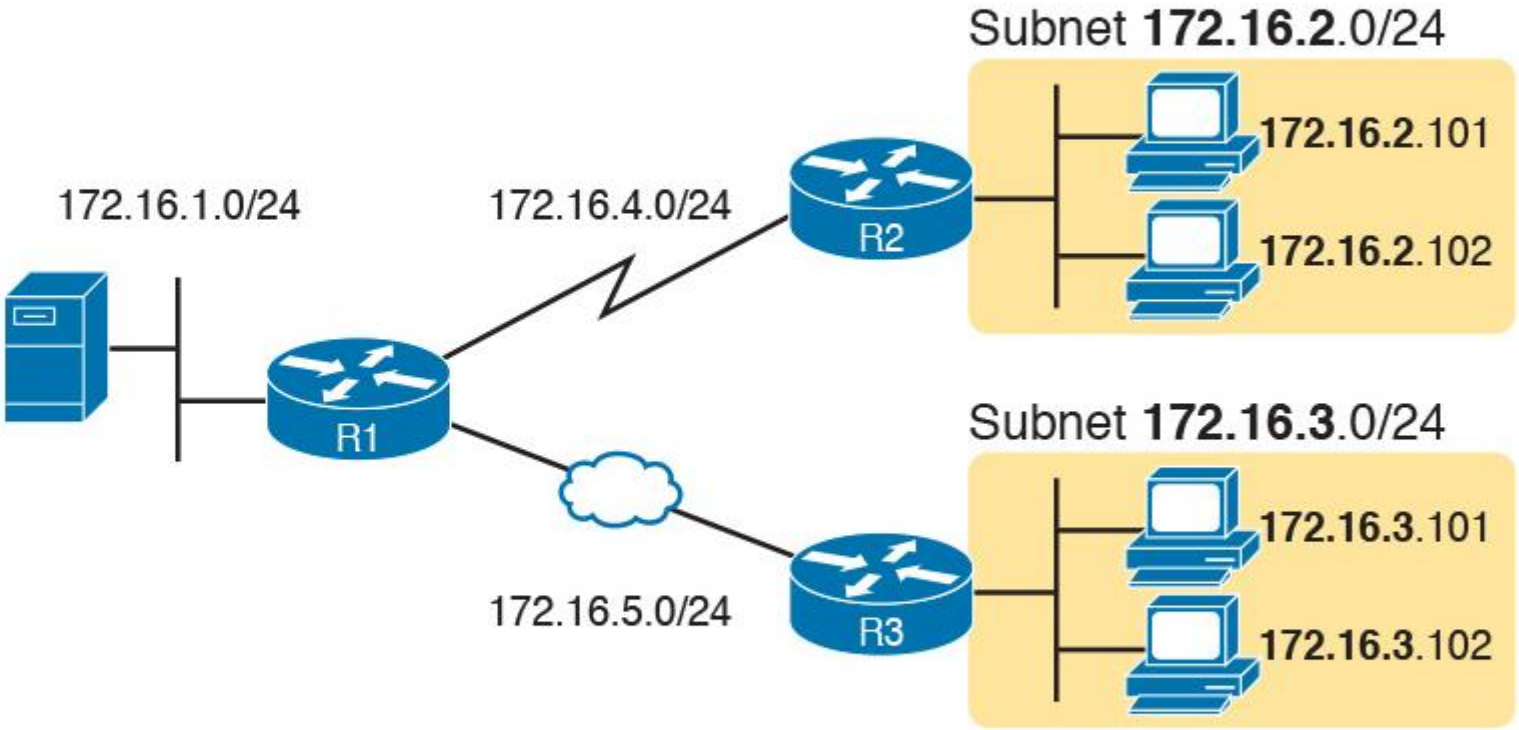
Decimal	Prefix	Binary
0.0.0.0	/0	00000000 00000000 00000000 00000000
128.0.0.0	/1	10000000 00000000 00000000 00000000
192.0.0.0	/2	11000000 00000000 00000000 00000000
224.0.0.0	/3	11100000 00000000 00000000 00000000
240.0.0.0	/4	11110000 00000000 00000000 00000000
248.0.0.0	/5	11111000 00000000 00000000 00000000
252.0.0.0	/6	11111100 00000000 00000000 00000000
254.0.0.0	/7	11111110 00000000 00000000 00000000
255.0.0.0	/8	11111111 00000000 00000000 00000000
255.128.0.0	/9	11111111 10000000 00000000 00000000
255.192.0.0	/10	11111111 11000000 00000000 00000000
255.224.0.0	/11	11111111 11100000 00000000 00000000
255.240.0.0	/12	11111111 11110000 00000000 00000000
255.248.0.0	/13	11111111 11111000 00000000 00000000
255.252.0.0	/14	11111111 11111100 00000000 00000000
255.254.0.0	/15	11111111 11111110 00000000 00000000
255.255.0.0	/16	11111111 11111111 00000000 00000000
255.255.128.0	/17	11111111 11111111 10000000 00000000
255.255.192.0	/18	11111111 11111111 11000000 00000000
255.255.224.0	/19	11111111 11111111 11100000 00000000

Identifying Subnet Design Choices Using Masks

- The subnet mask plays several roles.
- One purpose is defining the prefix part of the IP addresses in a subnet.
  - The prefix part must be the same value for all addresses in a subnet.

Identifying Subnet Design Choices Using Masks

- Simple Subnet Design, with Mask /24
- The prefix part of the addresses is 24 bits (3 octets) long.



Identifying Subnet Design Choices Using Masks

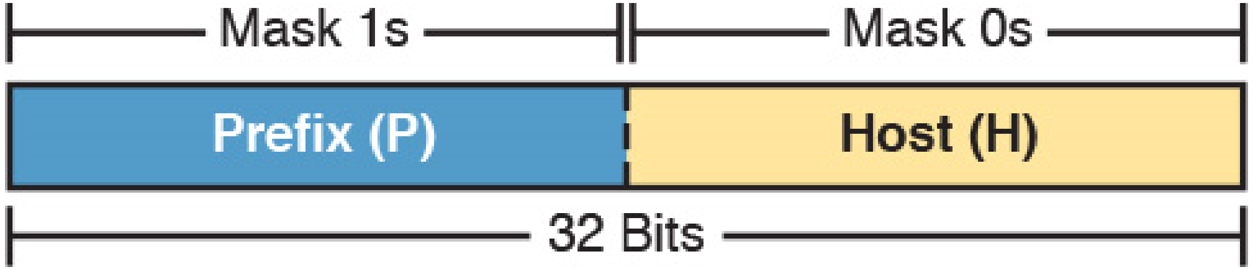
- Other uses for a subnet mask:
  - Defines the size of the prefix (combined network and subnet) part of the addresses in a subnet.
  - Defines the size of the host part of the addresses in the subnet.
  - Can be used to calculate the number of hosts in the subnet.
  - Provides a means for the network designer to communicate the design details—the number of subnet and host bits—to the devices in the network.
  - Under certain assumptions, can be used to calculate the number of subnets in the entire classful network.
  - Can be used in binary calculations of both the subnet ID and the subnet broadcast address.

Masks Divide the Subnet’s Addresses into Two Parts

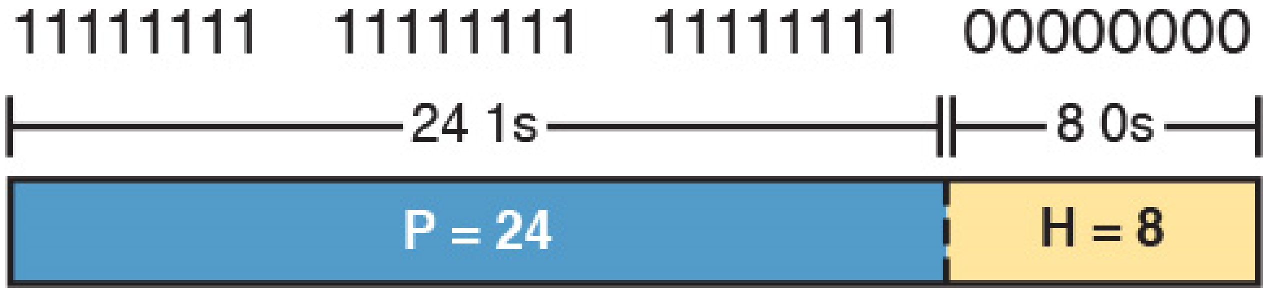
- The subnet mask subdivides the IP addresses in a subnet into two parts: the prefix, or subnet part, and the host part.
- All IP addresses in the same subnet have the same value in the prefix part of their addresses.
  - Prefix (subnet) part: Equal in all addresses in the same subnet.
  - Host part: Different in all addresses in the same subnet.

Masks Divide the Subnet's Addresses into Two Parts

- Prefix (Subnet) and Host Parts Defined by Masks 1s and 0s

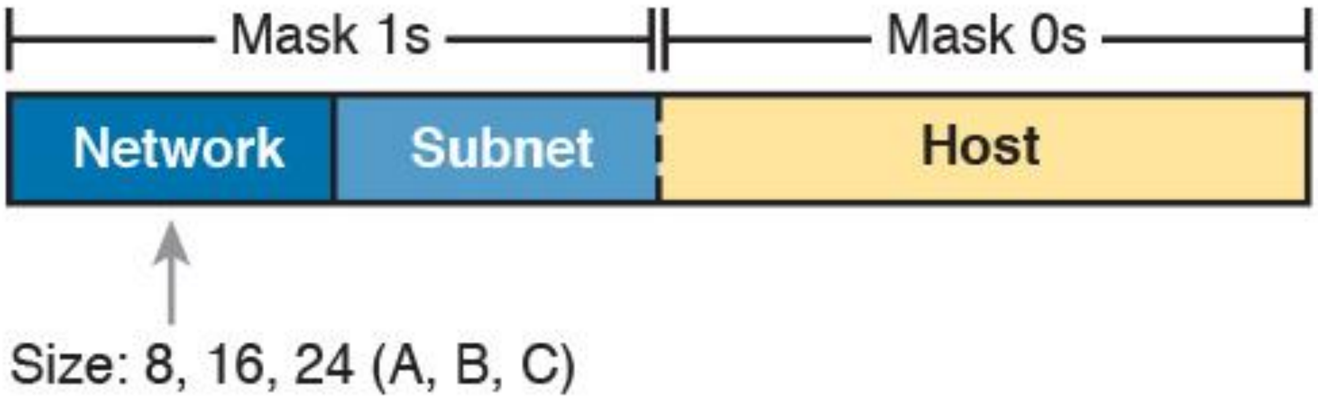


- Mask 255.255.255.0: P=24, H=8



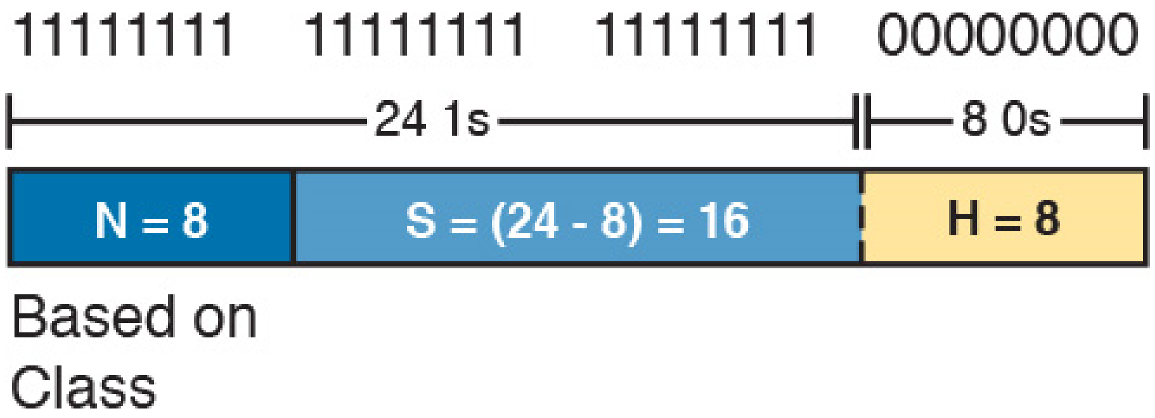
Masks and Class Divide Addresses into Three Parts

- Apply Class A, B, and C rules to the address format to define the network part at the beginning of the address.
- This added logic divides the prefix into two parts: the network part and the subnet part.
- Class Concepts Applied to Create Three Parts



Masks and Class Divide Addresses into Three Parts

- Subnet 10.1.1.0, Mask 255.255.255.0: N=8, S=16, H=8
- subnet uses mask 255.255.255.0, and the addresses are all in Class A network 10.0.0.0.

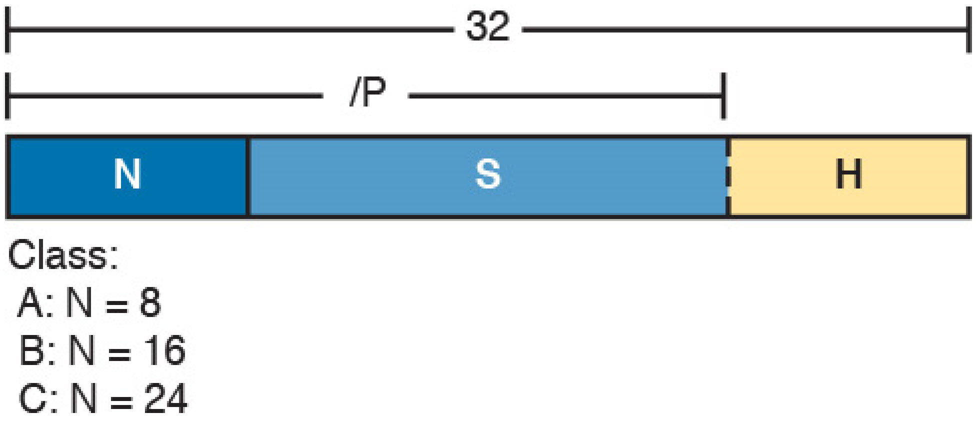


Classless and Classful Addressing

- **Classful** addressing means that you think about Class A, B, and C rules, so the prefix is separated into the network and subnet parts.
  - The concept that an IPv4 address has three parts—network, subnet, and host—as defined by the mask and Class A, B, and C rules.
  - **Follow** class rules.
- **Classless** addressing means that you ignore the Class A, B, and C rules and treat the prefix part as one part.
  - The concept that an IPv4 address has two parts—the prefix part plus the host part—as defined by the mask, with no consideration of the class (A, B, or C).
  - **Ignore** class rules.

Calculations Based on the IPv4 Address Format

- **Hosts in the subnet:** $2^H - 2$, where H is the number of host bits.
- **Subnets in the network:** 2^S, where S is the number of subnet bits.
  - Only use this formula if only one mask is used throughout the network.
- Keeping in mind that IPv4 addresses are 32 bits long,
  - the two parts with classless addressing must add up to 32 (P + H = 32), and
  - with classful addressing, the three parts must add up to 32 (N + S + H = 32).



Calculations Based on the IPv4 Address Format

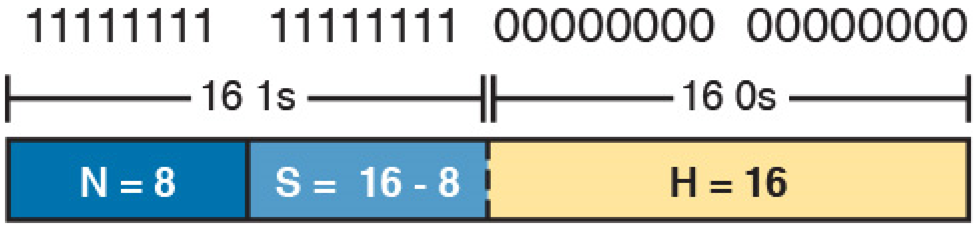
- Step 1. Convert the mask to prefix format (/P) as needed. (See the earlier section “Practice Converting Subnet Masks” for review.)
- Step 2. Determine N based on the class. (See Chapter 14, “Analyzing Classful IPv4 Networks,” for review.)
- Step 3. Calculate S = P – N.
- Step 4. Calculate H = 32 – P.
- Step 5. Calculate hosts/subnet: $2^H – 2$.

Calculations Based on the IPv4 Address Format

- Steps to finding the information in your network:
  - **Step 1.** Convert the mask to prefix format (/P) as needed
  - **Step 2.** Determine N based on the class
  - **Step 3.** Calculate S = P – N.
  - **Step 4.** Calculate H = 32 – P.
  - **Step 5.** Calculate hosts/subnet: $2^H - 2$.
  - **Step 6.** Calculate number of subnet: 2^S.

Calculations Based on the IPv4 Address Format

- Consider the case of IP address 8.1.4.5 with mask 255.255.0.0. Following the process:
  - **Step 1.** 255.255.0.0 = /16, so P=16.
  - **Step 2.** 8.1.4.5 is in the range 1–126 in the first octet, so it is Class A; so N=8.
  - **Step 3.** S = P – N = 16 – 8 = 8.
  - **Step 4.** H = 32 – P = 32 – 16 = 16.
  - **Step 5.** 2^{16} – 2 = 65,534 hosts/subnet.
  - **Step 6.** 2^{8} = 256 subnets.



What do you know now?

- Working at the help desk, you receive a call and learn a user's PC IP address and mask (10.55.66.77, mask 255.255.255.0). When thinking about this using classful logic, you determine the number of network (N), subnet (S), and host (H) bits. Which of the following is true in this case?
  a. N=12
  b. S=12
  c. H=8
  d. S=8
  e. N=24

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What do you know now?

- Working at the help desk, you receive a call and learn a user’s PC IP address and mask (192.168.9.1/27). When thinking about this using classful logic, you determine the number of network (N), subnet (S), and host (H) bits. Which of the following is true in this case?
  a. N=24
  b. S=24
  c. H=8
  d. H=7

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    a. N=24
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    c. H=8
    d. H=7

What do you know now?

- Which of the following statements is true about classless IP addressing concepts?
  a. Uses a 128-bit IP address
  b. Applies only for Class A and B networks
  c. Separates IP addresses into network, subnet, and host parts
  d. Ignores Class A, B, and C network rules

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Summary

- Rules for binary subnet mask values.
- Rules to convert between binary and prefix masks.
- Nine possible values in a decimal subnet mask.
- Rules to convert between binary and DDN masks.
- Some functions of a subnet mask.
- Comparisons of IP addresses in the same subnet.
- Two-part classless view of an IP address.
- Three-part classful view of an IP address.
- Definitions of classful addressing and classless addressing.
- Formal steps to analyse masks and calculate values.

End of Lecture 15, Further Reading, References

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