Module 5: Number Systems

Instructor Materials

Introduction to Networks v7.0
(ITN)

What to Expect in this Module

- To facilitate learning, the following features within the GUI may be included in this module:

Feature	Description
Animations	Expose learners to new skills and concepts.
Videos	Expose learners to new skills and concepts.
Check Your Understanding(CYU)	Per topic online quiz to help learners gauge content understanding.
Interactive Activities	A variety of formats to help learners gauge content understanding.
Syntax Checker	Small simulations that expose learners to Cisco command line to practice configuration skills.
PT Activity	Simulation and modeling activities designed to explore, acquire, reinforce, and expand skills.

Module Objectives

Module Title: Number Systems

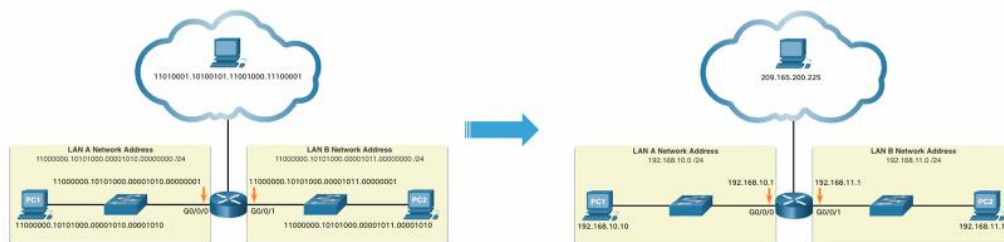**Module Objective**: Calculate numbers between decimal, binary, and hexadecimal systems.

Topic Title	Topic Objective
Binary Number System	Calculate numbers between decimal and binary systems.
Hexadecimal Number System	Calculate numbers between decimal and hexadecimal systems.

5.1 Binary Number System

Binary and IPv4 Addresses

- Binary numbering system consists of 1s and 0s, called bits
- Decimal numbering system consists of digits 0 through 9
- Hosts, servers, and network equipment using binary addressing to identify each other.
- Each address is made up of a string of 32 bits, divided into four sections called octets.
- Each octet contains 8 bits (or 1 byte) separated by a dot.
- For ease of use by people, this dotted notation is converted to dotted decimal.

Binary Positional Notation

- Positional notation means that a digit represents different values depending on the "position" the digit occupies in the sequence of numbers.
- The decimal positional notation system operates as shown in the tables below.

Radix	10	10	10	10
Position in Number	3	2	1	0
Calculate	(10^3)	(10^2)	(10^1)	(10^0)
Position Value	1000	100	10	1

	Thousands	Hundreds	Tens	Ones
Positional Value	1000	100	10	1
Decimal Number (1234)	1	2	3	4
Calculate	1 x 1000	2 x 100	3 x 10	4 x 1
Add them up…	1000	+ 200	+ 30	+ 4
Result	1,234			

Binary Number System
Binary Positional Notation (Cont.)

The binary positional notation system operates as shown in the tables below.

Radix	2	2	2	2	2	2	2	2
Position in Number	7	6	5	4	3	2	1	0
Calculate	(2^7)	(2^6)	(2^5)	(2^4)	(2^3)	(2^2)	(2^1)	(2^0)
Position Value	128	64	32	16	8	4	2	1

Positional Value	128	64	32	16	8	4	2	1
Binary Number (11000000)	1	1	0	0	0	0	0	0
Calculate	1x128	1x64	0x32	0x16	0x8	0x4	0x2	0x1
Add Them Up…	128	+ 64	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0
Result	192							

Binary Number System
Convert Binary to Decimal

Convert 11000000.10101000.00001011.00001010 to decimal.

| Positional Value	128	64	32	16	8	4	2	1
Binary Number (11000000)	1	1	0	0	0	0	0	0
Calculate	1x128	1x64	0x32	0x16	0x8	0x4	0x2	0x1
Add Them Up…	128	+ 64	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	→ 192
Binary Number (10101000)	1	0	1	0	1	0	0	0
Calculate	1x128	0x64	1x32	0x16	1x8	0x4	0x2	0x1
Add Them Up…	128	+ 0	+ 32	+ 0	+ 8	+ 0	+ 0	+ 0	→ 168
Binary Number (00001011)	0	0	0	0	1	0	1	1
Calculate	0x128	0x64	0x32	0x16	1x8	0x4	1x2	1x1
Add Them Up…	0	+ 0	+ 0	+ 0	+ 8	+ 0	+ 2	+ 1	→ 11
Binary Number (00001010)	0	0	0	0	1	0	1	0
Calculate	0x128	0x64	0x32	0x16	1x8	0x4	1x2	0x1
Add Them Up…	0	+ 0	+ 0	+ 0	+ 8	+ 0	+ 2	+ 0	→ 10

192.168.11.10

Binary Number System
Decimal to Binary Conversion

The binary positional value table is useful in converting a dotted decimal IPv4 address to binary.

- Start in the 128 position (the most significant bit). Is the decimal number of the octet (n) equal to or greater than 128?
- If no, record a binary 0 in the 128 positional value and move to the 64 positional value.
- If yes, record a binary 1 in the 128 positional value, subtract 128 from the decimal number, and move to the 64 positional value.
- Repeat these steps through the 1 positional value.
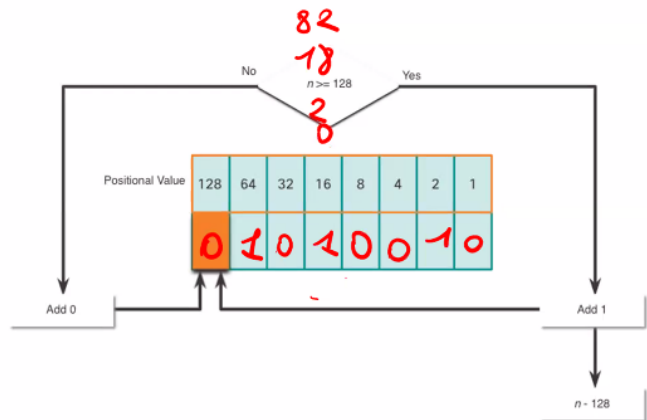
82
18
n >= 128
No   Yes
2
8

Positional Value	128	64	32	16	8	4	2	1
	0	1	0	1	0	0	1	0

Add 0   Add 1

n - 128

Binary Number System
Decimal to Binary Conversion Example

- Convert decimal 168 to binary

Is 168 > 128?
- Yes, enter 1 in 128 position and subtract 128 (168-128=40)

Is 40 > 64?
- No, enter 0 in 64 position and move on

Is 40 > 32?
- Yes, enter 1 in 32 position and subtract 32 (40-32=8)

Is 8 > 16?
- No, enter 0 in 16 position and move on

Is 8 > 8?
- Equal. Enter 1 in 8 position and subtract 8 (8-8=0)

No values left. Enter 0 in remaining binary positions

128	64	32	16	8	4	2	1
1	0	1	0	1	0	0	0

Decimal 168 is written as 10101000 in binary

IPv4 Addresses

- Routers and computers only understand binary, while humans work in decimal. It is important for you to gain a thorough understanding of these two numbering systems and how they are used in networking.

192	·	168	·	10	·	10
11000000		10101000		00001010		00001010
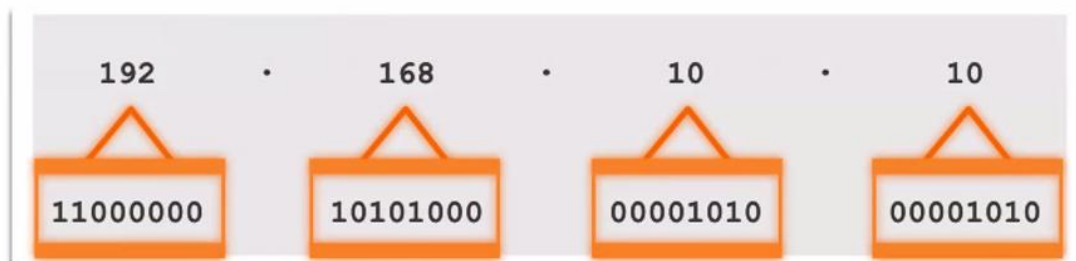
Hexadecimal and IPv6 Addresses

- To understand IPv6 addresses, you must be able to convert hexadecimal to decimal and vice versa.
- Hexadecimal is a base sixteen numbering system, using the digits 0 through 9 and letters A to F.
- It is easier to express a value as a single hexadecimal digit than as four binary bit.
- Hexadecimal is used to represent IPv6 addresses and MAC addresses.

Decimal	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Hexadecimal and IPv6 Addresses (Cont.)

- IPv6 addresses are 128 bits in length. Every 4 bits is represented by a single hexadecimal digit. That makes the IPv6 address a total of 32 hexadecimal values.
- The figure shows the preferred method of writing out an IPv6 address, with each X representing four hexadecimal values.
- Each four hexadecimal character group is referred to as a hextet.
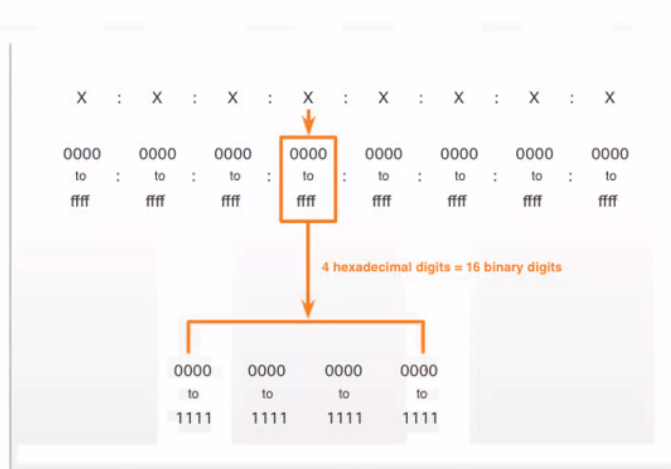
Decimal to Hexadecimal Conversions

Follow the steps listed to convert decimal numbers to hexadecimal values:
- Convert the decimal number to 8-bit binary strings.
- Divide the binary strings in groups of four starting from the rightmost position.
- Convert each four binary numbers into their equivalent hexadecimal digit.

For example, 168 converted into hex using the three-step process.
- 168 in binary is 10101000.
- 10101000 in two groups of four binary digits is 1010 and 1000.
- 1010 is hex A and 1000 is hex 8, so 168 is A8 in hexadecimal.

Hexadecimal to Decimal Conversions

Follow the steps listed to convert hexadecimal numbers to decimal values:
- Convert the hexadecimal number to 4-bit binary strings.
- Create 8-bit binary grouping starting from the rightmost position.
- Convert each 8-bit binary grouping into their equivalent decimal digit.

For example, D2 converted into decimal using the three-step process:
- D2 in 4-bit binary strings is 1101 and 0010.
- 1101 and 0010 is 11010010 in an 8-bit grouping.
- 11010010 in binary is equivalent to 210 in decimal, so D2 is 210 is decimal

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