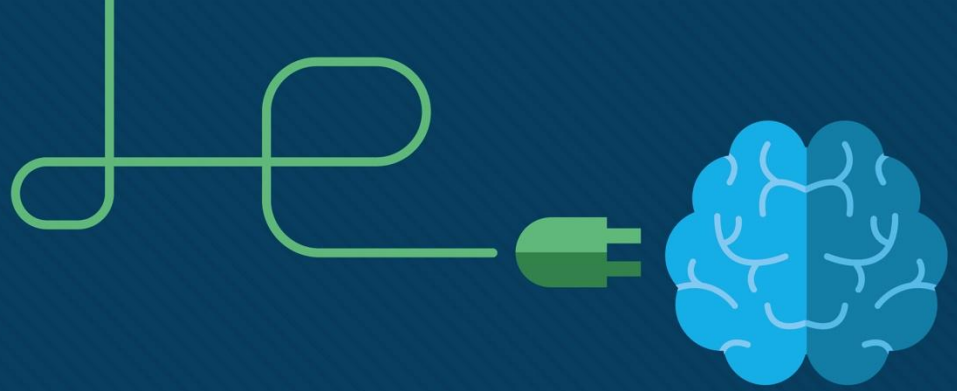


Module 5: Network Layer (Part-2)

Introduction to Networks v7.0 (ITN)

5.5 Subnetting

Subnet Mask

- A subnet mask is a **32-bit** number created by setting the host bits to all 0s and setting network bits to all 1s. In this way, the subnet mask is separated the IP address into the host address and network address. The broadcast address is always assigned to the "255" address, and a network address is always assigned to the "0" address.
- The subnet mask may be “Classfull” or “Classless”.
- A **classfull** addressing (addressed by RFC 790 in 1981) contain five classes shown in the next slide table.
- A **classless** addressing may be **Classless Inter-Domain Routing (CIDR)** or **Variable Length Subnet Mask** (VLSM)

Subnetting

Classfull Addressing

Class	range	Subnet Mask	Mask prefix	Subnet Mask in Binary (n = network, h = host)	No. of hosts
A	0-127	255.0.0.0	/ 8	nnnnnnnn.hhhhhhhh.hhhhhhhh.hhhhhhhh 11111111.00000000.00000000.00000000	16,777,214
B	127-191	255.255.0.0	/ 16	nnnnnnnn.nnnnnnnn.hhhhhhhh.hhhhhhhh 11111111.11111111.00000000.00000000	65,534
C	192-223	255.255.255.0	/ 24	nnnnnnnn.nnnnnnnn.nnnnnnnn.hhhhhhhh 11111111.11111111.11111111.00000000	254
D	224-239	For multicast applications			268,435,456
E	240-255	Reserved for future researches			268,435,456

Classfull Addressing

Example 5.4

Find the class of each address.

a. 00000001 00001011 00001011 11101111
b. 11000001 10000011 00011011 11111111
c. 14.23.120.8
d. 252.5.15.111

Solution

a. The first bit is 0. This is a class A address.
b. The first 2 bits are 1; the third bit is 0. This is a class C address.
c. The first byte is 14; the class is A.
d. The first byte is 252; the class is E.

Classless Addressing (CIDR)

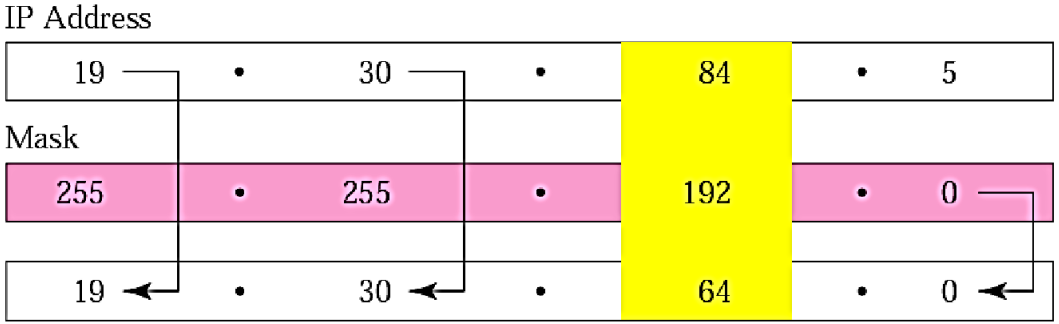
- Networks are most easily subnetted at the octet boundary of /8, /16, and /24.
- Classfull addressing **wasted** many IPv4 addresses.
- Classfull address allocation was replaced with classless addressing which ignores the rules of classes (A, B, C) to make **Classless Inter-Domain Routing (CIDR)** used in **Subnets**.
- Notice that using longer prefix lengths decreases the number of hosts per subnet.
- **Variable Length Subnet Mask** (**VLSM**) is another classless strategy, where the subnet design uses more than one mask in the same network.

Classless Addressing (CIDR)

Example 5.6

What is the subnetwork address if the destination address is 19.30.84.5 and the mask is 255.255.192.0?

Solution



AND

84	0	1	0	1	0	1	0	0
192	1	1	0	0	0	0	0	0
64	0	1	0	0	0	0	0	0

AND

Classless Addressing (CIDR)
Example 5.7

A block of address is granted to a small organization. We know that one of the address is 205.15.37.39/28. What is the first address (subnet address) and the last address (broadcast)in the block

Solution

The binary representation of the given address is

11001101 00010000 00100101 00100111

If we set 32−28 rightmost bits to 0, we get

11001101 00010000 00100101 00100000

or

205.15.37.32.

If we set 32 − 28 rightmost bits to 1, we get

11001101 00010000 00100101 00101111

or

205.15.37.47

Note:

- The first address (subnet address) in the block can be found by setting the rightmost (32-n) bits to 0's.
- The last address (broadcast) in the block can be found by setting the rightmost (32-n) bits to 1's

Classless Addressing (CIDR)
Example 5.8

A company is granted the IPv4: 192.168.0.0/25, using CIDR to design the network.

Solution steps:

1. Find the subnet mask.
2. Find the number of subnets (Net).
3. Find the number of hosts in each subnet (Host).
4. Find the number of hops (Δ).
5. Write down the subnets table.
6. Draw the circuit diagram

Solution

1. The subnet mask = **/ 25** → **11111111.11111111.11111111.10000000** → **255.255.255.128**
2. Number of subnets (Net) = $2^y \rightarrow 2^1 \rightarrow 2$
3. Number of hosts in each subnet (Host) = $2^x - 2 \rightarrow 2^7 - 2 \rightarrow 126$
4. Number of hops (Δ) = 256 – 128 = 128
5. The subnets table shown in the next slide (according to the above solution):

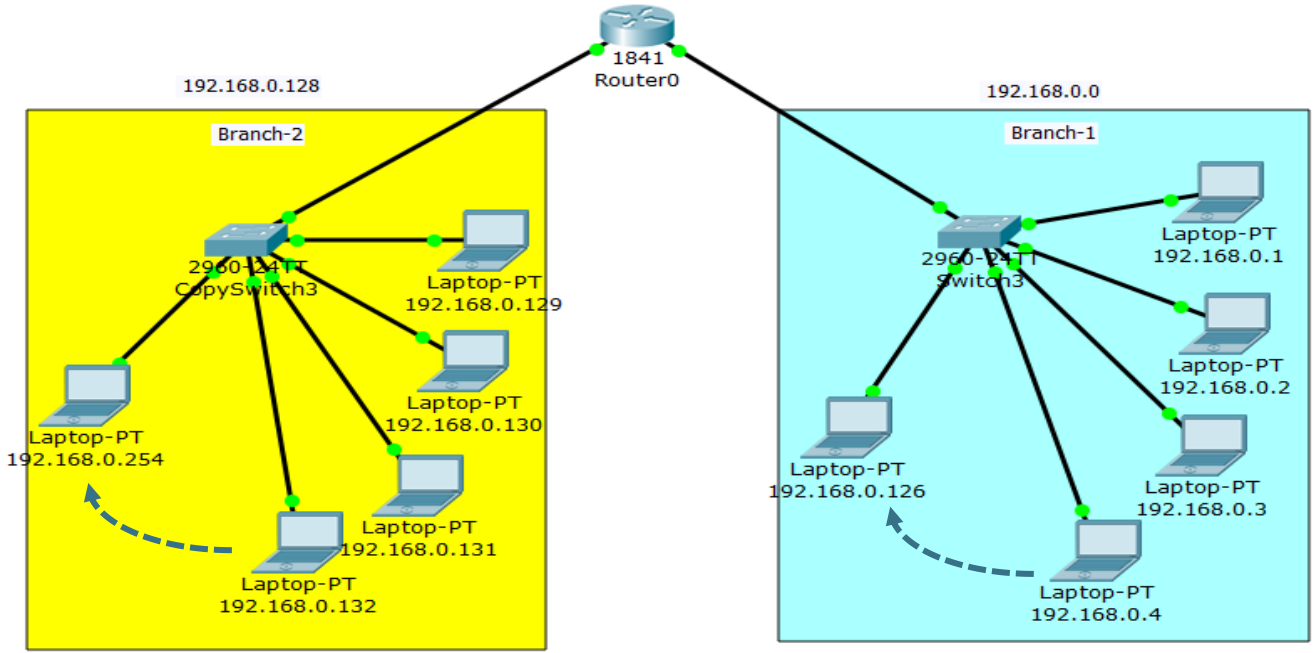
y= no. of 1's=1
x= no. of 0's=7

Subnetting

Classless Addressing (CIDR) Example 5.8 (contd.)

	Branch-1	Branch-2
Address Name	192.168.0.0	192.168.0.128
First Host	192.168.0.1	192.168.0.129
Last Host	192.168.0.126	192.168.0.254
Broadcast	192.168.0.127	192.168.0.255

Not allowed



Classless Addressing (CIDR) Homework

HOMEWORK-1: Repeat Example 5.8 for IPv4: 192.168.0.0/26.

HOMEWORK-2: Repeat Example 5.8 for IPv4: 192.168.0.0/27.

HOMEWORK-3: Repeat Example 5.8 for IPv4: 192.168.0.0/28.

HOMEWORK-4: Repeat Example 5.8 for IPv4: 172.16.0.0/16.

HOMEWORK-5: Repeat Example 5.8 for IPv4: 10.0.0.0/8.

Hint: For class B, number of ones (y) and number of zeros (x) are computed for the last two octets. For class A, x and y are computed for the last three octets.

5.6 VLSM

Classless Addressing (VLSM)

- VLSM stands for **Variable Length Subnet Mask** where the subnet design uses more than one mask in the same network.
- It is used to increase the usability of subnets as they can be of variable size.
- In the VLSM subnet division, the network administrator can divide the IP address space into subnets of different sizes, and allocate them according to individual needs on the network.
- VLSM is supported by the following protocols: **Open Shortest Path First** (OSPF), **Enhanced Interior Gateway Router Protocol** (EIGRP), **Border Gateway Protocol** (BGP), **Routing Information Protocol** (RIP), and **Intermediate to Intermediate systems** (IS-IS).

Classless Addressing (VLSM) Example 5.9

A company has the following requirements distributed in the table below, wants to get a mask address for each subnets. What are the steps involved?

Subnet name	No. of Hosts
A	14
B	30
C	20
D	6
E	2
F	2
G	2
H	2

Solution steps:

1. Find the Block size for each subnet which is a number between 1 and 255 times of two plus two:
   - no. of hosts=14 → 16
   - no. of hosts=30 → 32
   - no. of hosts=20 → 32
   - no. of hosts=6 → 8
   - no. of hosts=2 → 4

128	64	32	16	8	4	2	1

Subnet name	No. of Hosts	Block size
A	14	16
B	30	32
C	20	32
D	6	8
E	2	4
F	2	4
G	2	4
H	2	4

Classless Addressing (VLSM) Example 5.9 (contd.)

2. Find the Mask depending on the block size by filling1's within and after the block size number in the binary numbering system then convert it to decimal number:

Block size=16 →

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

→ 240 → / 28

Block size=32 →

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

→ 224 → /27

Number of 1's in the whole address
11111111.11111111.11111111.11110000

Block size=8 →

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

→ 248 → /29

Block size=4 →

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

→ 252 → /30

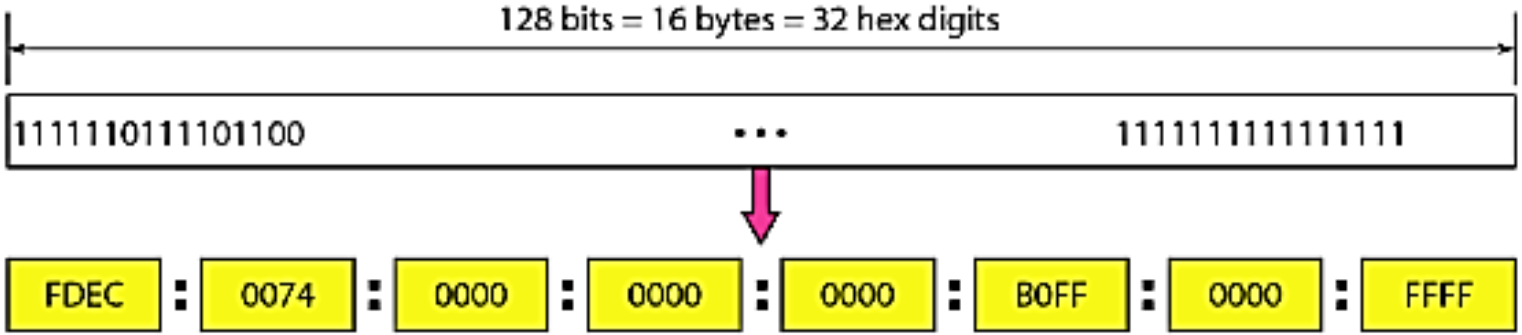
Classless Addressing (VLSM) Example 5.9 (contd.)

Subnet name	No. of Hosts	Block size	Mask	CIDR Mask
A	14	16	255.255.255.240	/ 28
B	30	32	255.255.255.224	/ 27
C	20	32	255.255.255.224	/ 27
D	6	8	255.255.255.248	/ 29
E	2	4	255.255.255.252	/ 30
F	2	4	255.255.255.252	/ 30
G	2	4	255.255.255.252	/ 30
H	2	4	255.255.255.252	/ 30

5.7 IPv6 Addressing

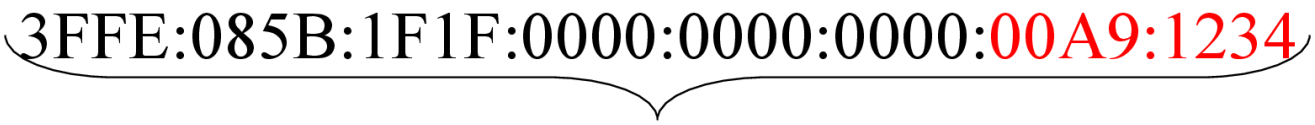
IPv6 Addressing

An IPv6 address is 128 bits long.



IPv6 address in binary and hexadecimal colon notation

128-bit IPv6 Address



8 groups of 16-bit hexadecimal numbers separated by “:”

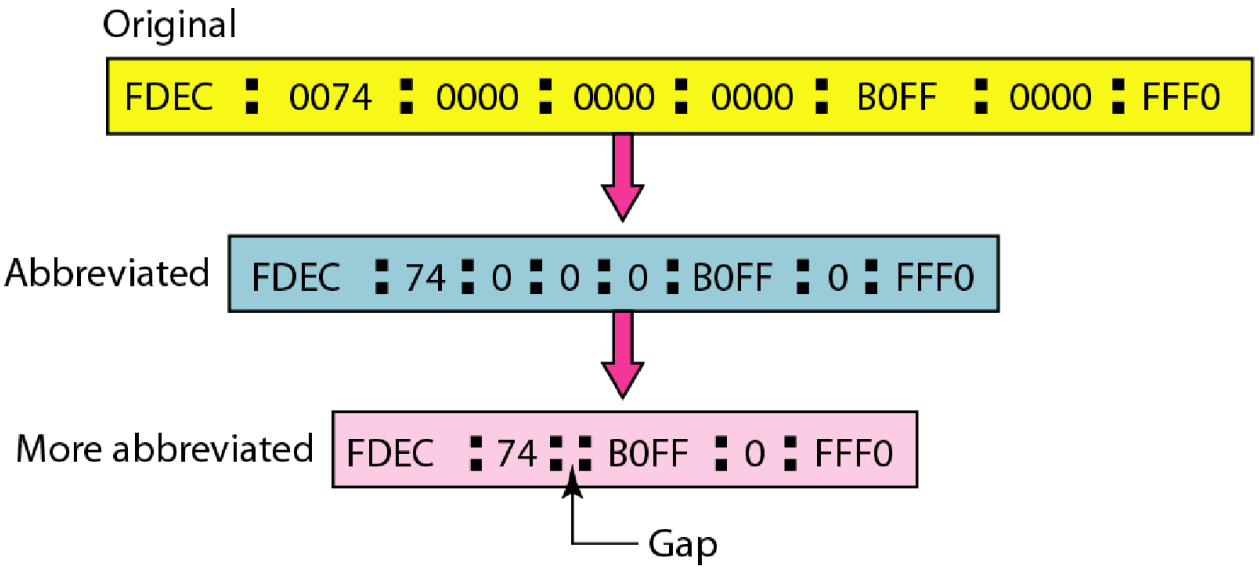
Leading zeros can be removed

3FFE:85B:1F1F::A9:1234

:: = all zeros in one or more group of 16-bit hexadecimal numbers

IPv6 Addressing

Abbreviated IPv6 addresses



IPv6 Addressing
Example 5.10

Expand the address 0:15::1:12:1213 to its original.

Solution

We first need to align the left side of the double colon to the left of the original pattern and the right side of the double colon to the right of the original pattern to find how many 0s we need to replace the double colon.

```
xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
  0:   15:                    :    1:   12:1213
```

This means that the original address is.

```
0000:0015:0000:0000:0000:0001:0012:1213
```

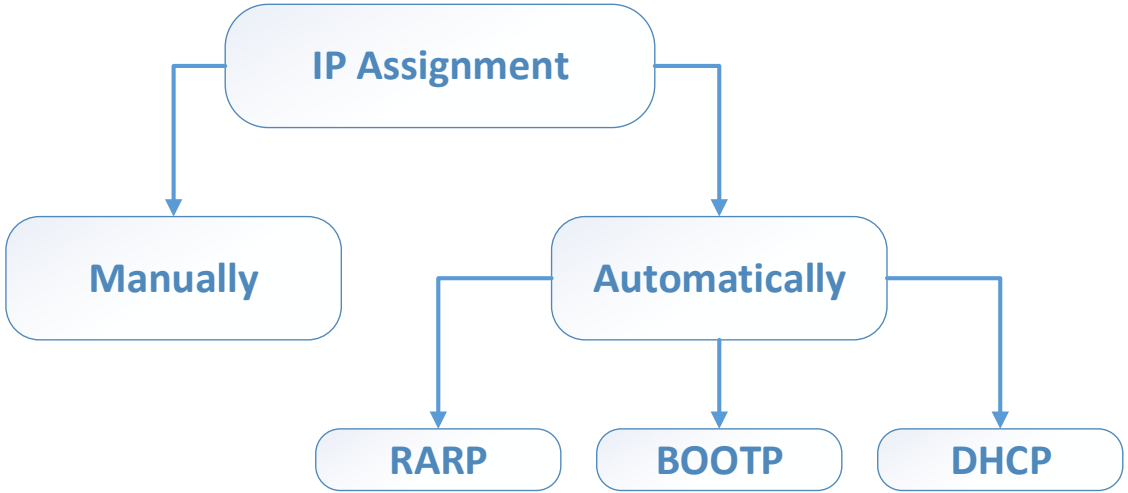
5.8 IP Address Assignment

Manually and Automatically

- IP assignment can be either be manually or automatically.
- A static IP address can be useful for remote access systems, like virtual private networks (VPNs) and proxy servers. Unlike dynamic IP addresses, which most devices use, static IPs don't change.

- Setting up a static IP address is a simple process on most operating systems.

- Assigning an IP address automatically depends on protocols responsible for this operation most of these protocols shown in flowchart:



Manually

How to set a static IP address on Windows 10 and 11

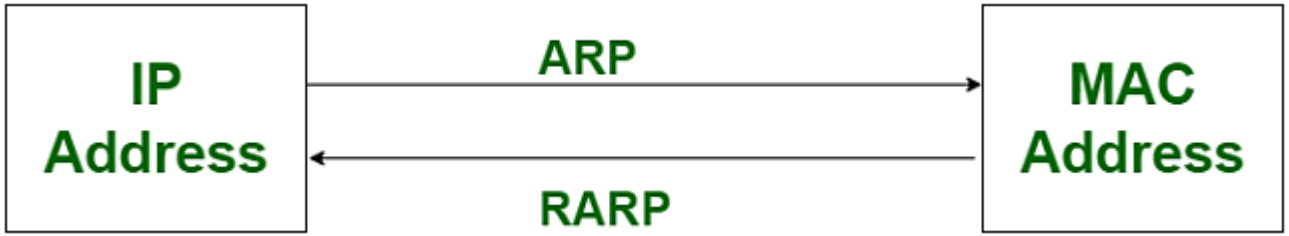
1. Open “Settings” on your computer.
2. Select “Network and internet.”
3. Select your current connection.
4. Select “Manage known networks” > “Properties” > “IP settings.”
5. Select “Edit.”
6. Select “Manual.”
7. Select “IPv4” and switch it to “On.”
8. Input the IP address you want to be static.
9. In the “Subnet prefix length” field, input “24.”
10. Type “ipconfig/all” into the window and input your gateway information.
11. Select “Save.”

Automatically-RARP

- **Reverse Address Resolution Protocol** (RARP) is a protocol a physical machine in a local area network (LAN) can use to request its IP address. It does this by sending the device's physical address to a specialized RARP server that is on the same LAN and is actively listening for RARP requests.

- **ARP,** uses an IP address to find an own MAC address

- **RARP,** uses the MAC address to find the own IP address



Automatically-RARP

RARP request & reply

1. Diskless workstations will send a RARP request, which is a Layer-2 broadcast.

2. Only a RARP server can respond to a RARP request.

3. RARP servers maintain a table of MAC to IP address mappings for RARP clients.

4. During the boot process, RARP clients call the RARP server to obtain their IP configuration information.

ARP/RARP Message Structure

0-15 bits		16-31 bits
Hardware Type		Protocol Type
HLen (1 byte)	PLen (1 byte)	operation
Sender HA (bytes 1-4)		
Sender HA (bytes 5-6)		Sender PA (bytes 1-2)
Sender PA (bytes 3-4)		Target HA (bytes 1-2)
Target HA (bytes 3-6)		
Target PA (bytes 1-4)		
RARP Header Structure		

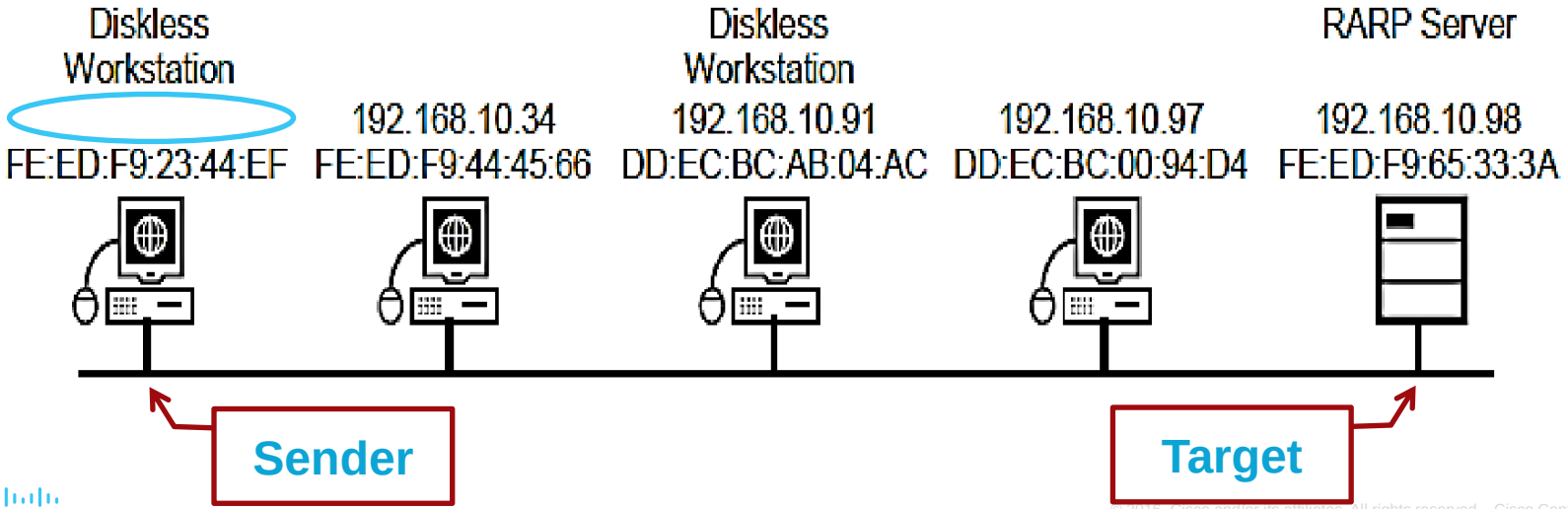
Automatically-RARP

Field	Description
Hardware Type	Specifies a hardware interface type for which the sender requires a response.
Protocol Type	Specifies the type of high-level protocol address the sender has supplied.
HLen	Hardware address length.
PLen	Protocol address length.
Operation	The values are as follows: 1 ARP request. 2 ARP response. 3 RARP request. 4 RARP response. 5 Dynamic RARP request. 6 Dynamic RARP reply. 7 Dynamic RARP error. 8 InARP request. 9 InARP reply.
Sender (HA) Hardware Address	HLen bytes in length.
Sender (PA) Protocol Address	PLen bytes in length.
Target (HA) Hardware Address	HLen bytes in length.
Target (PA) Protocol Address	PLen bytes in length.

Automatically-RARP

Example 5-11

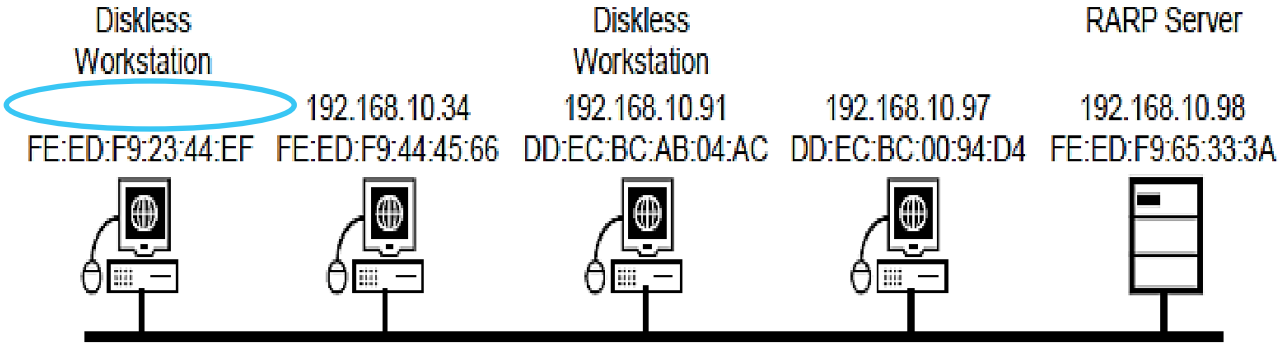
For the network shown below, write down the RARP request and RARP reply for the diskless workstation having a MAC address (FE:ED:F9:23:44:EF) to get an IP (192.168.10.36).



Automatically-RARP

RARP: Request Generation

Computer FE:ED:F9:23:44:EF generates a RARP request.

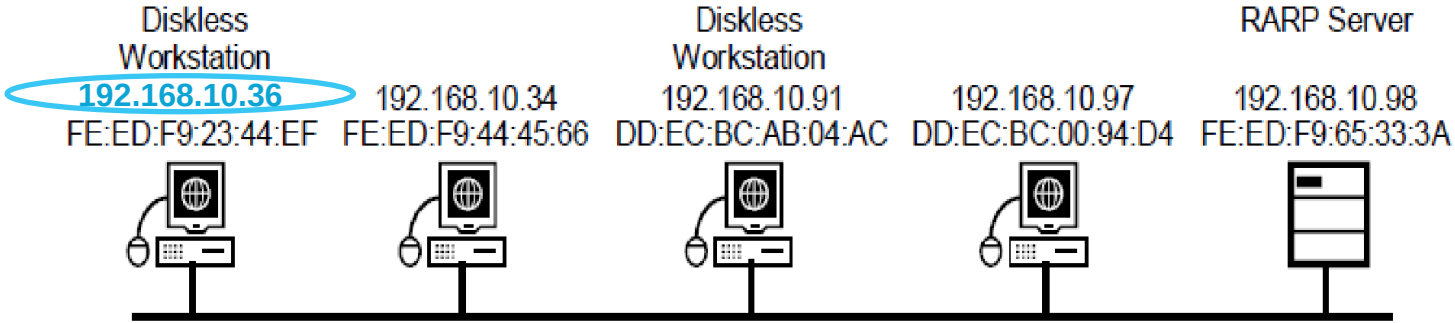


Frame header	1		0800_{16}
Source MAC	48	32	3
FE:ED:F9:23:44:EF	FE:ED:F9:23:		
Destination MAC	44:EF		Undefined
FF: FF: FF: FF: FF: FF	Undefined		FF:FF:
Field Type	FF: FF: FF: FF		
0X8035 (Ethernet)	Undefined		

Automatically-RARP

Reply Generation

The RARP server creates a RARP reply message for the requesting client



Frame header	2		0800_{16}
Source MAC	48	32	4
FE:ED:F9:65:33:3A	FE:ED:F9:23:		
Destination MAC	44:EF		192.168.
FE: ED: F9: 23: 44: EF	10.36		FE:ED:
Field Type	F9: 65: 33: 3A		
0X8035 (Ethernet)	192.168. 10.98		

Automatically-BOOTP

- **Bootstrap Protocol** (BOOTP) provides a dynamic method for associating workstations with servers. It also provides a dynamic method for assigning workstation Internet Protocol (IP) addresses and initial program load (IPL) sources.
- BOOTP is a TCP/IP protocol. It allows a client to find its IP address and the name of a load file from a server on the network. A client uses BOOTP to find this information without intervention from the user of the client.
  - Client sends a bootrequest packet - a Layer 3 broadcast (255.255.255.255)
  - BOOTP server responds with a bootreply packet containing client's IP address and gateway IP address.

Automatically-DHCP

Dynamic Host Configuration Protocol (DHCP) is a client/server protocol that automatically provides an Internet Protocol (IP) host with its IP address and other related configuration information such as the subnet mask and default gateway.

- Like BOOTP:
  - Client sends an IP broadcast datagram.
  - DHCP server returns packet containing IP address of client and gateway.
- Unlike BOOTP:
  - Server can return additional information and provide a complete IP configuration:
    - Subnet mask
    - Domain Name Server address

DHCP - Benefits

- Low maintenance
- Provides complete IP configuration
- Easy to renumber your network - just change the address range covered by the DHCP server

Automatically-DHCP