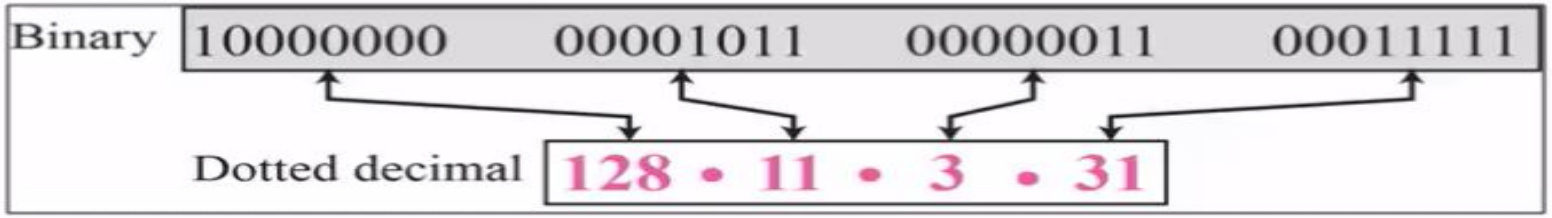
Network Layer

Introduction

- An IPv4 address is **32** bits long.
- The IPv4 addresses are unique and universal.
- The address space of IPv4 is 2^{32} (or) 4,294,967,296.
- IP Addressing is Logical Addressing.
- It works on Network Layer (Layer 3).
- 32 bits divided into 4 octets and represented in Decimal Notation.



First Octet **Second Octet** **Third Octet** **Forth Octet**

10000000. 00001011. 00000011. 00011111

Introduction

Total Addresses = 2^{32} = 4,294,967,296.

Taking Example for **First Octet** : Total 8 bits, Value will be 0's and 1's i.e. 2^8 = 256 combinations

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
0	0	0	0	0	0	0	0	=	0
0	0	0	0	0	0	0	1	=	1
0	0	0	0	0	0	1	0	=	2
0	0	0	0	0	0	1	1	=	3
0	0	0	0	0	1	0	0	=	4
1	1	1	1	1	1	1	1	=	255

Total IP Address Range

0 . 0 . 0 . 0

to

255.255.255.255

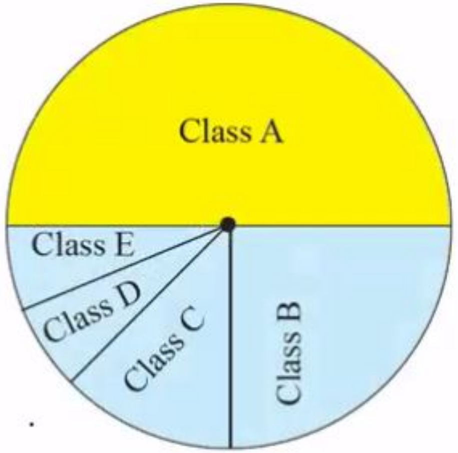
Classful Addressing

	Octet 1	Octet 2	Octet 3	Octet 4
Class A	0........			
Class B	10......			
Class C	110.....			
Class D	1110....			
Class E	1111....			

Binary notation

	Byte 1	Byte 2	Byte 3	Byte 4
Class A	0–127			
Class B	128–191			
Class C	192–223			
Class D	224–299			
Class E	240–255			

Dotted-decimal notation



Class A: 2^{31} = 2,147,483,648 addresses, 50%

Class B: 2^{30} = 1,073,741,824 addresses, 25%

Class C: 2^{29} = 536,870,912 addresses, 12.5%

Class D: 2^{28} = 268,435,456 addresses, 6.25%

Class E: 2^{28} = 268,435,456 addresses, 6.25%

Classful Addressing

- To identify the range of each class a bit called priority bit is used.
- Priority Bit is the left most bits in the **First Octet**

- CLASS A priority bit is 0
- CLASS B priority bit is 10
- CLASS C priority bit is 110
- CLASS D priority bit is 1110
- CLASS E priority bit is 1111

Classful Addressing

IP addresses of Class A

For Class A range : First bit of the first octet is reserved for the priority bit.

0xxxxxxx. xxxxxxxx. xxxxxxxx. xxxxxxxx

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
0	0	0	0	0	0	0	0	=	0
0	0	0	0	0	0	0	1	=	1
0	0	0	0	0	0	1	0	=	2
0	0	0	0	0	0	1	1	=	3
0	0	0	0	0	1	0	0	=	4
0	1	1	1	1	1	1	1	=	127

Class A Range

0 . 0 . 0 . 0 to

127.255.255.255

Exception

0.X.X.X and 127.X.X.X network are reserved

Classful Addressing

IP addresses of Class B

For Class B range : First two bits of the first octet should be reserved for the priority bit.

10xxxxxx. xxxxxxxx. xxxxxxxx. xxxxxxxx

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
1	0	0	0	0	0	0	0	=	128
1	0	0	0	0	0	0	1	=	129
1	0	0	0	0	0	1	0	=	130
1	0	0	0	0	0	1	1	=	131
1	0	0	0	0	1	0	0	=	132
1	0	1	1	1	1	1	1	=	191

Class B Range

128. 0 . 0 . 0

to

191.255.255.255

Classful Addressing

IP addresses of Class C

For Class C range : First Three bits of the first octet should be reserved for the priority bit.

110xxxxx. xxxxxxxx. xxxxxxxx. xxxxxxxx

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
1	1	0	0	0	0	0	0	=	192
1	1	0	0	0	0	0	1	=	193
1	1	0	0	0	0	1	0	=	194
1	1	0	0	0	0	1	1	=	195
1	1	0	0	0	1	0	0	=	196
1	1	0	1	1	1	1	1	=	223

Class C Range

192.0.0.0

to

223.255.255.255

Classful Addressing

IP addresses of Class D

For Class D range : First four bits of the first octet should be reserved for the priority bit.

1110xxxx. xxxxxxxx. xxxxxxxx. xxxxxxxx

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
1	1	1	0	0	0	0	0	=	224
1	1	1	0	0	0	0	1	=	225
1	1	1	0	0	0	1	0	=	226
1	1	1	0	0	0	1	1	=	227
1	1	1	0	0	1	0	0	=	228
1	1	1	0	1	1	1	1	=	239

Class D Range

224. 0 . 0 . 0

to

239.255.255.255

Classful Addressing

IP addresses of Class E

For Class E range : First four bits of the first octet should be reserved for the priority bit.

1111xxxx. xxxxxxxx. xxxxxxxx. xxxxxxxx

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
1	1	1	1	0	0	0	0	=	240
1	1	1	1	0	0	0	1	=	241
1	1	1	1	0	0	1	0	=	242
1	1	1	1	0	0	1	1	=	243
1	1	1	1	0	1	0	0	=	244
1	1	1	1	1	1	1	1	=	255

Class E Range

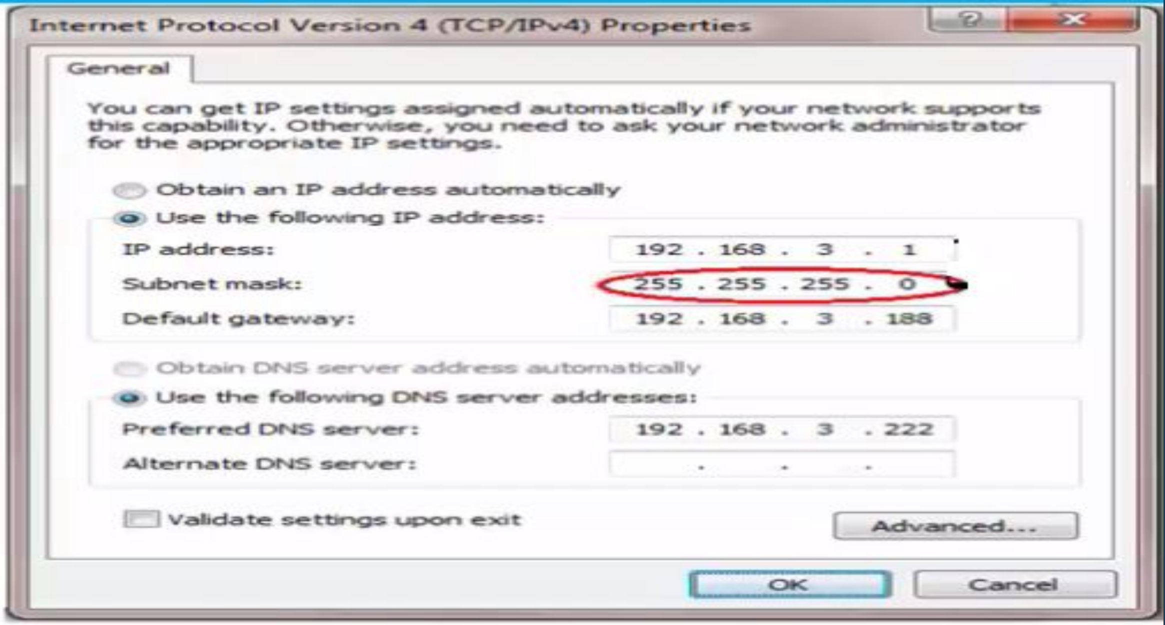
240. 0 . 0 . 0

to

255.255.255.255

Classful Addressing

IP address = 192.168.3.1



Can both systems communicate? **Cannot say with the given data**

Two (or) more systems will communicate , if they belongs to Same Network.

Network to which the system belongs will be identified using 32-bit Subnet Mask.

32-bit Subnet Mask → All 1's for Network Bits & All 0's for Host Bits

NetworkID = BOOLEAN AND (32-bit IP address , 32-bit Subnet Mask)

Systems will communicate if they both belongs to same network ID.

Classful Addressing

Subnet Mask

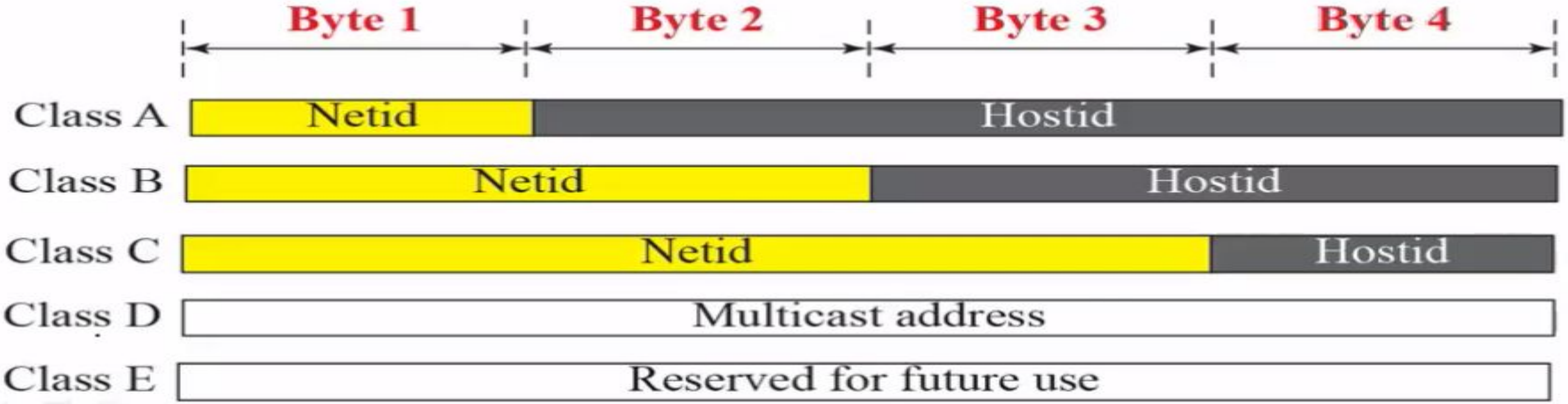
- 32-bit Subnet Mask differentiates **Network portion** and **Host Portion**.
- Subnet Mask is been given for **host Identification** of **Network ID**.
- Represented with all **1**'s in **network portion** and with all **0**'s in **host portion**.

Classful Addressing

n → no of **Network Bits**
h → no of **Host Bits**

IP address is divided into Network & Host Portion

- **CLASS A is written as** **N.H.H.H** → **n = 8 , h = 24**
- **CLASS B is written as** **N.N.H.H** → **n = 16 , h = 16**
- **CLASS C is written as** **N.N.N.H** → **n = 24 , h = 8**



Classful Addressing

- 32-bit **Subnet Mask** differentiates **Network portion** and **Host Portion**.
- Subnet Mask is been given for **host Identification** of **Network ID**.
- Represented with all **1**'s in **network portion** and with all **0**'s in **host portion**.

Class = A

Class A : N.H.H.H

Default Subnet Mask =11111111.00000000.00000000.00000000

Default Subnet Mask in Decimal Representation= 255.0.0.0

Class = B

Class A : N. N.H.H

Default Subnet Mask =11111111. 11111111.00000000.00000000

Default Subnet Mask in Decimal Representation= 255. 255.0.0

Class = C

Class A : N. N. N.H

Default Subnet Mask =11111111. 11111111. 11111111.00000000

Default Subnet Mask in Decimal Representation= 255. 255.255.0

Classful Addressing

How to compute the Network Id using IP address & Subnet Mask ?

IP Address : 192.168.1.1
Subnet Mask : 255.255.255.0

ANDING PROCESS :

192.168.1.1 = 11000000.10101000.00000001.00000001
255.255.255.0 = 11111111.11111111.11111111.00000000
====================================
192.168.1.0 = 11000000.10101000.00000001.00000000
====================================

The output of an AND table is 1 if both its inputs are 1.

Classful Addressing

Class A

- Class A Octet Format is **N.H.H.H**
- **Network bits : 8** **Host bits : 24**

- **No. of Networks**

  = 2^{8-1} (-1 is Priority Bit for Class A)

  = 2^7

  = 128 – 2 (-2 is for 0 & 127 Network)

  = 126 Networks

- **No. of Host**

  = $2^{24} - 2$ (-2 is for Network ID & Broadcast ID)

  = 16777216 - 2

  = 16777214 Hosts/Network

Classful Addressing

Class B

- **Class B Octet Format is N.N.H.H**
- **Network bits : 16** **Host bits : 16**

- **No. of Networks**
  - = 2^{16-2} (-2 is Priority Bit for Class B)
  - = 2^{14}
  - = 16384 Networks

- **No. of Host**
  - = $2^{16} - 2$ (-2 is for Network ID & Broadcast ID)
  - = 65536 - 2
  - = 65534 Hosts/Network

Classful Addressing

Class C

- Class C Octet Format is **N.N.N.H**
- **Network bits : 24** **Host bits : 8**

- **No. of Networks**
  = 2^{24-3} (-3 is Priority Bit for Class C)
  = 2^{21}
  = 2097152 Networks

- **No. of Host**
  = $2^{8} - 2$ (-2 is for Network ID & Broadcast ID)
  = 256 - 2
  = 254 Hosts/Network

Classful Addressing

NOTE

- The **network address** is represented with **all bits as ZERO** in the **host portion** of the address
- The **broadcast address** is represented with **all bits as ONES** in the **host portion** of the address
- Valid IP Addresses lies **between** the Network Address and the Broadcast Address.
- Only Valid IP Addresses are assigned to hosts.

Classful Addressing

Private IP addresses

- There are certain addresses in **each class of IP address** that are reserved for **LAN**.
- These addresses are called private addresses.
- They can be used for: home & office networks, networks **not connected to Internet**.
- All the remaining addresses are called as **Public addresses**.

Class A

10.0.0.0 to 10.255.255.255

Class B

172.16.0.0 to 172.31.255.255

Class C

192.168.0.0 to 192.168.255.255

Classful Addressing

Summary of Classful IP addressing

Sno	Class	First Octet	First IP	Last IP	%	Total IP's	Network bits & Host bits	Default Subnet Mask	Total Networks	Hosts/Network
1	A	0XXXXXXX	0.0.0.0	127.255.255.255	50%	2^{31}	N.H.H.H [n=8 , h=24]	255.0.0.0	2^{7}-2 = 126	2^{24} - 2 = 16777214
2	B	10XXXXXX	128.0.0.0	191.255.255.255	25%	2^{30}	N.N.H.H [n=16, h=16]	255.255.0.0	2^{14} = 16384	2^{16} - 2 = 65534
3	C	110XXXXX	192.0.0.0	223.255.255.255	12.5%	2^{29}	N.N.N.H [n=24 , h=8]	255.255.255.0	2^{21} = 2097152	2^{8} - 2 = 254
4	D	1110XXXX	224.0.0.0	239.255.255.255	6.25%	2^{28}	Not Applicable	Not Applicable	Not Applicable	Not Applicable
5	E	1111XXXX	240.0.0.0	255.255.255.255	6.25%	2^{28}	Not Applicable	Not Applicable	Not Applicable	Not Applicable

Sno	Class	First Octet	Network bits & Host bits	Default Subnet Mask	Total Networks	Hosts/Network
1	A	0XXXXXXX	N.H.H.H [n=8,h=24]	255.0.0.0	126	16777214
2	B	10XXXXXX	N.N.H.H [n=16,h=16]	255.255.0.0	16384	65534
3	C	110XXXXX	N.N.N.H [n=24,h=8]	255.255.255.0	2097152	254

Total Computers = 5 * 20 =100

Requirement → Want to connect all 100 computers to Internet

Which **Class of IP addresses** will be assigned by ISP provider **?** Class "C" IP addresses

Can I include **all 100 computers** in a **single network ?** **YES**

No of Networks = 1
No of Hosts = 100

Solution :- Get 100 IP addresses of Class C from ISP [192.168.1.1 to 192.168.1.100]

SNO	DEPARTMENT	No of Computers	STARTING IP	ENDING IP
1	HR	20	192.168.1.1	192.168.1.20
2	MARKETING	20	192.168.1.21	192.168.1.40
3	SALES	20	192.168.1.41	192.168.1.60
4	MANUFACTURING	20	192.168.1.61	192.168.1.80
5	CORPORATE	20	192.168.1.81	192.168.1.100

How many **IP's wasted** for ISP provider**?**

100 IP addresses→ My Organization → DEFENCE
154 IP addresses→ Other Company → TERRORIST

In Network 192.168.1.0 → Only 100 used among 254 hosts → 154 IP addresses **wasted**.

Sno	Class	First Octet	Network bits & Host bits	Default Subnet Mask	Total Networks	Hosts/Network
1	A	0XXXXXXX	N.H.H.H [n=8,h=24]	255.0.0.0	126	16777214
2	B	10XXXXXX	N.N.H.H [n=16,h=16]	255.255.0.0	16384	65534
3	C	110XXXXX	N.N.N.H [n=24,h=8]	255.255.255.0	2097152	254

Total Computers = 5 * 20 =100

Requirement → Want to connect all 100 computers to Internet

Which **Class of IP addresses** will be assigned by ISP provider ? **Class "C" IP addresses**

Can I include **all 100 computers** in a **single network** ? **NO**

No of Networks = 5
No of Hosts = 20

Solution :-
Get 20IP addresses of 5 different networks in Class C.

Sno	Network	IP addresses
1	192.168.1.0	20
2	192.168.2.0	20
3	192.168.3.0	20
4	192.168.4.0	20
5	192.168.5.0	20

SNO	DEPARTMENT	No of Computers	STARTING IP	ENDING IP	IP addr wasted
1	HR	20	192.168.1.1	192.168.1.20	254-20 = 234
2	MARKETING	20	192.168.2.1	192.168.2.20	254-20 = 234
3	SALES	20	192.168.3.1	192.168.3.20	254-20 = 234
4	MANUFACTURING	20	192.168.4.1	192.168.4.20	254-20 = 234
5	CORPORATE	20	192.168.5.1	192.168.5.20	254-20 = 234
					Total wasted = 1170

Sno	Class	First Octet	Network bits & Host bits	Default Subnet Mask	Total Networks	Hosts/Network
1	A	0XXXXXXX	N.H.H.H [n=8,h=24]	255.0.0.0	126	16777214
2	B	10XXXXXX	N.N.H.H [n=16,h=16]	255.255.0.0	16384	65534
3	C	110XXXXX	N.N.N.H [n=24,h=8]	255.255.255.0	2097152	254

Problems with **Classful** IP addressing → Wastage of IP addresses.

Solution → **Classless** IP addressing

No Fixed Subnet Mask [**Default Subnet Mask will not be used**]

Subnet Mask can be **customized** to meet our requirement.

Uses **Subnetting** → Converts the **Host** Bits into **Network** Bits

Uses **Supernetting** → Converts the **Network** Bits into **Host** Bits

Classful IP addressing → Used till 1993

Classless IP addressing → Introduced in 1993 and is currently in use.

Subnetting

- Dividing a Single Network into Multiple Networks by converting Host Bits to Network Bits in a Subnet Mask.

- Subnetting is also called as FLSM → Fixed Length Subnet Mask.

- We go for Subnetting to meet the requirement. [No of Networks (or) Hosts/Network]

Sno	Class	First Octet	Network bits & Host bits	Default Subnet Mask	Total Networks	Hosts/Network
1	A	0XXXXXXX	N.H.H.H [n=8,h=24]	255.0.0.0	126	16777214
2	B	10XXXXXX	N.N.H.H [n=16,h=16]	255.255.0.0	16384	65534
3	C	110XXXXX	N.N.N.H [n=24,h=8]	255.255.255.0	2097152	254

Details of my Organization

Total Departments = 5

Computers in each department = 20

Total Computers = 5 * 20 =100

Requirement → Want to connect all 100 computers to Internet

Which **Class of IP addresses** will be assigned by ISP provider **?** Class "C" IP addresses

Can I include **all 100 computers** in a **single network ?** NO

No of Networks = 5
No of Hosts = 20

Solution :-

❖ Get 100 IP addresses belongs to **same network** of **Class C** and use **Subnetting** to find the **Customized subnet mask**.

❖ Which will make each department as a separate network and will not allow Inter department communication by assigning **different Network ID** to each network.

Default Subnet Mask = [11111111. 11111111.11111111.00000000]

Customized Subnet Mask= [11111111. 11111111.11111111.<u>111</u>00000]

Class C : N.N.N.H [n=24 bits, h=8 bits] [254 hosts /Network]

Default Subnet Mask = [11111111. 11111111. 11111111.00000000]

Take Single Network in Class C : 192.168.1.0

No. of Subnets =

= $2^n - 2 \geq$ Req. of Subnet [-2 is for First & Last Subnet Range]

= $2^n - 2 \geq 5$ =

= $2^n \geq 7$

= $n = 3$

= 3 Host Bits will be converted into Network Bits

$n = 24 + \underline{3} = 27$ bits

$h = 8 - \underline{3} = 5$ bits

- No. of Hosts=

= $2^h - 2$ [-2 is for Network ID & Broadcast ID]

= $2^5 - 2$

= $32 - 2$

= 30 Hosts/Subnet

My Requirement

No of Networks = 5

No of Hosts = 20

2 Subnets to be ignored:-

First Subnet → Because it consists of **Network ID** IP-address. [IP address with all host bits 0's]

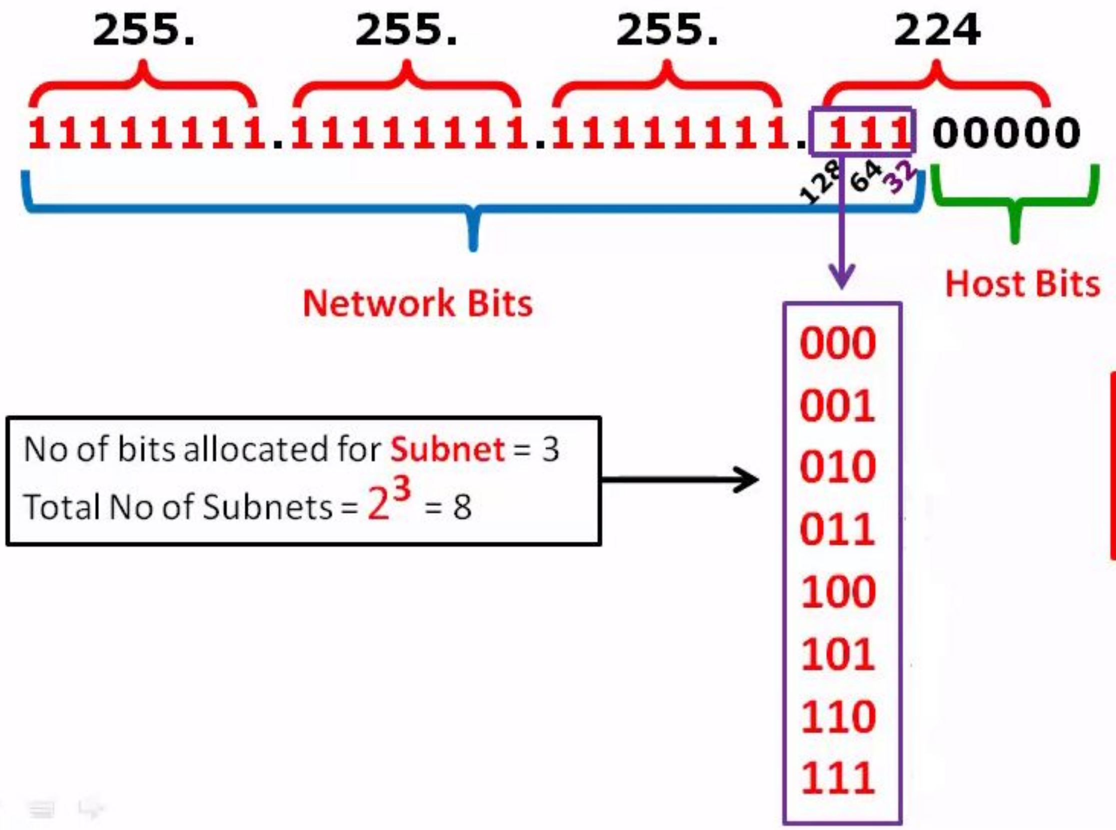
Last Subnet → Because it consists of **Broadcast ID** IP-address[IP address with all host bits 1's]

Default Subnet Mask for Class C IP Address

[11111111. 11111111.11111111.00000000] → 255.255.255.0

Customized Subnet Mask after Subnetting

[11111111. 11111111.11111111.11100000] → 255.255.255.224



No of bits allocated for **Subnet** = 3

Total No of Subnets = 2^3 = 8

My Requirement

No of Networks = 5

No of Hosts = 20

My Requirement

No of Networks = 5

No of Hosts = 20

No of bits allocated for **Subnet** = 3

Total No of Subnets = 2^3 = 8

Hosts per Subnet = $2^5 - 2$ = 30

SUBNETS	Starting IP address	Ending IP address	Valid/Invalid	NETWORK ID	Subnet Mask
1	192.168.1.**000**00000 192.168.1.**0**	192.168.1.**000**11111 192.168.1.**31**	INVALID bcoz of Network ID	192.168.1.**000**	IP address/27
2	192.168.1.**001**00000 192.168.1.**32**	192.168.1.**001**11111 192.168.1.**63**	VALID	192.168.1.**001**	IP address/27
3	192.168.1.**010**00000 192.168.1.**64**	192.168.1.**010**11111 192.168.1.**95**	VALID	192.168.1.**010**	IP address/27
4	192.168.1.**011**00000 192.168.1.**96**	192.168.1.**011**11111 192.168.1.**127**	VALID	192.168.1.**011**	IP address/27
5	192.168.1.**100**00000 192.168.1.**128**	192.168.1.**100**11111 192.168.1.**159**	VALID	192.168.1.**100**	IP address/27
6	192.168.1.**101**00000 192.168.1.**160**	192.168.1.**101**11111 192.168.1.**191**	VALID	192.168.1.**101**	IP address/27
7	192.168.1.**110**00000 192.168.1.**192**	192.168.1.**110**11111 192.168.1.**223**	VALID	192.168.1.**110**	IP address/27
8	192.168.1.**111**00000 192.168.1.**224**	192.168.1.**111**11111 192.168.1.**255**	INVALID bcoz of Broadcast ID	192.168.1.**111**	IP address/27

PROBLEM : 1

Calculate the no of subnets, Hosts/Subnet, and Range of IP addresses for class "C" IP address 192.168.1.0/29.

Class C : N.N.N.H [n=24, h = 8]

IP Address : 110xxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx

Default Subnet Mask : 11111111. 11111111. 11111111.00000000

Class C : 192.168.1.0/29

Customized subnet Mask : 11111111. 11111111. 11111111. 11111000

Extra Network Bits used for Subnetting = n = 29 – 24 = 5

- **No. of Subnets**

  = $2^n - 2$

  = $2^5 - 2$ **(-2 is for First & Last Subnet Range)**

  = **30 Subnets**

- **No. of Hosts/Subnet [h=8–5=3]**

  = $2^h - 2$ **(-2 is for Network ID & Broadcast ID)**

  = $2^3 - 2$

  = **6 Hosts/Subnet**

- **Customize Subnet Mask =**

$$\underbrace{11111111}_{255}.\underbrace{11111111}_{255}.\underbrace{11111111}_{255}.\underbrace{11111}_{248}000$$

128 64 32 16 8

- **Range of Networks**

Network ID		Broadcast ID	
192.168.1.0	–	192.168.1.7	x
192.168.1.8	–	192.168.1.15	
192.168.1.16	–	192.168.1.23	
192.168.1.24	–	192.168.1.31	
192.168.1.240	–	192.168.1.247	
192.168.1.248	–	192.168.1.255	x

Valid Subnets

PROBLEM : 2

Calculate the no of subnets, Hosts/Subnet, and Range of IP addresses for class "C" IP address 192.168.1.0/28.

Class C : N.N.N.H [n=24, h = 8]

IP Address : 110xxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx

Default Subnet Mask : 11111111. 11111111. 11111111.00000000

Class C : 192.168.1.0/ 28

Customized subnet Mask : 11111111. 11111111. 11111111.1111 0000

Extra Network Bits used for Subnetting = n = 28 – 24 = 4

- **No. of Subnets**

  = $2^n - 2$

  = $2^4 - 2$ (-2 is for First & Last Subnet Range)

  = 14 Subnets

- **No. of Hosts/Subnet [h=8–4=4]**

  = $2^h - 2$ (-2 is for Network ID & Broadcast ID)

  = $2^4 - 2$

  = 14 Hosts/Subnet

- **Customize Subnet Mask =**

255.	255.	255.	240
11111111.	11111111.	11111111.	11110000
			128 64 32 16

- **Range of Networks**

Network ID		Broadcast ID	
192.168.1.0	–	192.168.1.15	X
192.168.1.16	–	192.168.1.31	Valid Subnets
192.168.1.32	–	192.168.1.47	
192.168.1.48	–	192.168.1.63	
192.168.1.224	–	192.168.1.239	
192.168.1.240	–	192.168.1.255	X

PROBLEM : 3

Calculate the no of Hosts/Subnet, and Range of IP addresses for class "B" with Network ID 172.16.0.0 for a requirement of 2 subnets.

Class B : N.N.H.H [n=16, h = 16]
IP Address : 10xxxxxx.xxxxxxxx. xxxxxxxx.xxxxxxxx
Default Subnet Mask : 11111111. 11111111.00000000.00000000
Network ID : 172.16.0.0
Networks = 16384 and Hosts/Network = 65534

Customized Subnet Mask : 11111111. 11111111. 11000000.00000000

Requirement = 2 subnets

- **No. of Subnets**
  = $2^n - 2 \geq$ Req. of Subnet [-2 is for First & Last Subnet Range]
  = $2^n - 2 \geq 2$
  = $2^n \geq 4$
  = n=2

2 Host Bits to be converted into Network Bits

n = 16 + 2 = 18 bits | h = 16 - 2 = 14 bits

- **No. of Hosts/Subnet [h=16−2=14]**
  = $2^h - 2$ (-2 is for Network ID & Broadcast ID)
  = $2^{14} - 2$
  = 16382 Hosts/Subnet

- **Customize Subnet Mask =**

255. 255. 192. 0

11111111.11111111.11000000. 00000000

128 64

- **Range of Networks**

Network ID		Broadcast ID	
172.16.0.0	–	172.16.63.255	x
172.16.64.0	–	172.16.127.255	Valid
172.16.128.0	–	172.16.191.255	Valid
172.16.192.0	–	172.16.255.255	x

Sno	Class	First Octet	Network bits & Host bits	Default Subnet Mask	Total Networks	Hosts/Network
1	A	0XXXXXXX	N.H.H.H [n=8,h=24]	255.0.0.0	126	16777214
2	B	10XXXXXX	N.N.H.H [n=16,h=16]	255.255.0.0	16384	65534
3	C	110XXXXX	N.N.N.H [n=24,h=8]	255.255.255.0	2097152	254

Requirement for My Organization

Total Networks = 1 [All hosts belongs to same Network]

Total Hosts = 1000

Total IP-addresses Required = 1000

Internet Service Provider [ISP Provider]

- ❖Which **Class IP** will be selected to fulfill my requirement ? Class B
- ❖Total No of Hosts per Network in Class B = **65534**
- ❖What is the Network ID = 172.68.0.0 [n=16, h=16]
- ❖Total IP addresses allotted = 1000
- ❖How many IP addresses are remaining in that Network = 65534-1000 = 64534 IP's
- ❖Can ISP provider allocate the remaining 64534 IP's to other customers ? NO
- ❖Total IP addresses wasted in the allocation = 64534 [**98% of IP's wasted**]
- ❖Is it a proper allocation ? NO
- ❖What is the Solution to overcome this kind of allocations ? SUPERNETTING

How SUPERNETTING provides Solution

Total Hosts per Subnet in Class C = 254

$\boxed{254 * 4 = \mathbf{1016} > \mathbf{1000}}$

It Simply Combines 4 Class "C" Networks of 254 hosts into a Single Network of 1016 Hosts.

Conversion will be done → By Converting 2-Network Bit into Host Bit. [00,01,10,11]

Supernetting

❖It is reverse (inverse) of Subnetting

❖Combining of Multiple Networks to Single Networks

❖Converting Network Bits to Hosts Bits [Converting 1's into 0's]

❖Supernetting is also called as CIDR [Classless Inter Domain Routing]

Subnetting → Conversion of **Host Bits** to **Network Bits** [**0** → **1** in **Subnet Mask**]

Supernetting → Conversion of **Network Bits** to **Host Bits** [**1** → **0** in **Subnet Mask**]

Requirement for My Organization

Total Networks = 1 [All hosts belongs to same Network]

Total Hosts = 1000

Class C : N.N.N.H [n=24 h = 8]

IP Address : 110xxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx

Default Subnet Mask : 11111111. 11111111. 11111111.00000000

Default Subnet Mask : 255.255.255.0

Class C : 192.168.0.0

- **No. of Host**

$= 2^h - 2 \geq$ Req. of Host [-2 is for Network ID & Broadcast ID]

$= 2^h - 2 \geq 1000$

$= 2^h \geq 1002$

$= h = 10$ bits

What would be total no of network bits ?

$n = 32 - 10 = 22$ bits

Customized Subnet Mask : 11111111. 11111111.111111<u>00</u>.00000000

Customized Subnet Mask : 255.255.252.0

Default Values	New Values
n = 24	n = 22
h = 8	h = 10

Supernetting

1000 IP addresses allocated are : 192.168.4.0 to 192.168.7.255

4 class C addresses combined to form a single network.

- **Customize Subnet Mask =**

255.	**255.**	**252.**	**0**
11111111.	**11111111.**	**11111100.**	**00000000**

128 64 32 16 8 4

- **Range of Networks**

Network ID		**Broadcast ID**
192.168.0.0	**–**	**192.168.3.255**
192.168.4.0	**–**	**192.168.7.255**
192.168.8.0	**–**	**192.168.11.255**
192.168.12.0	**–**	**192.168.15.255**
192.168.248.0	**–**	**192.168.251.255**
192.168.252.0	**–**	**192.168.255.255**

Valid Subnets

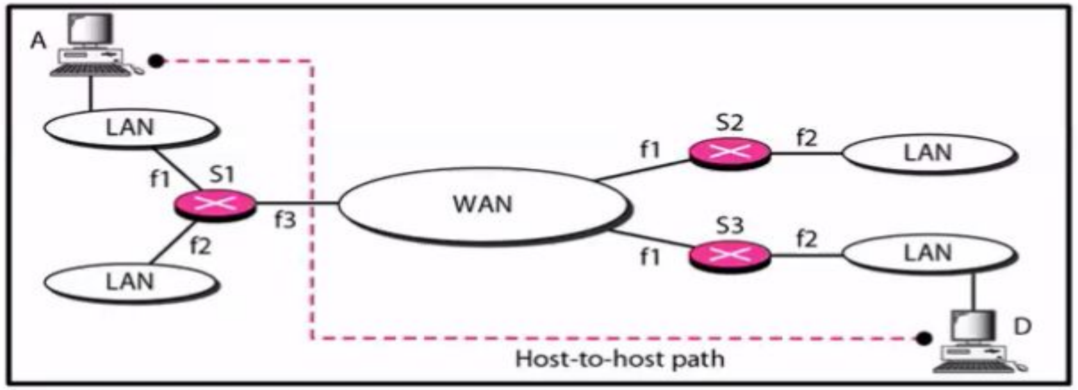
Introduction

When do we need ***Switch*** **?** [**Data Link Layer** Device works on MAC address]

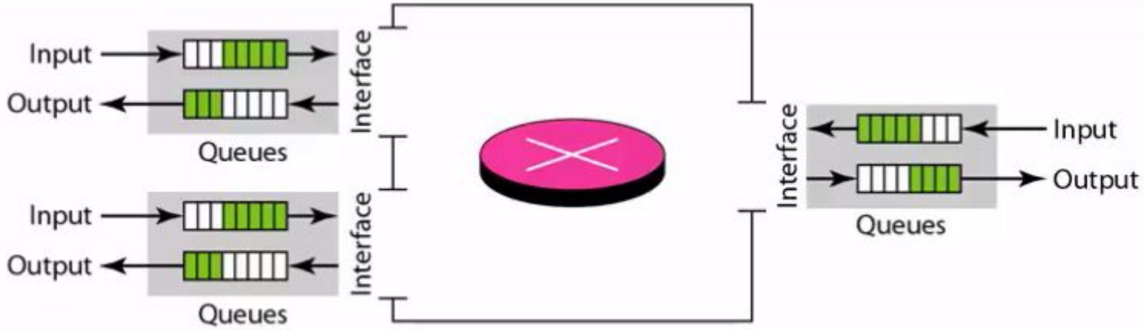
To allow Communication between 2 systems in the ***Same Network****.*

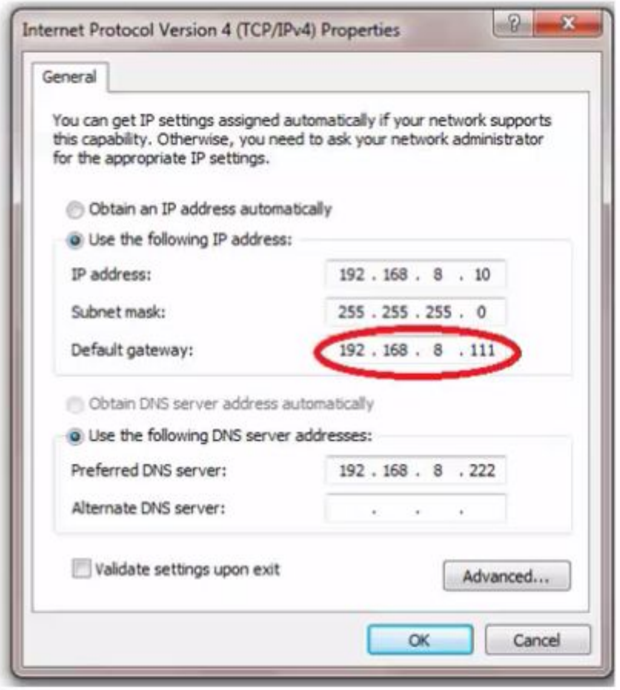
When do we need ***Router*** **?** [**Network Layer** Device works on **IP address**]

To Communication between 2 Systems belongs to ***Different Networks****.*



Introduction

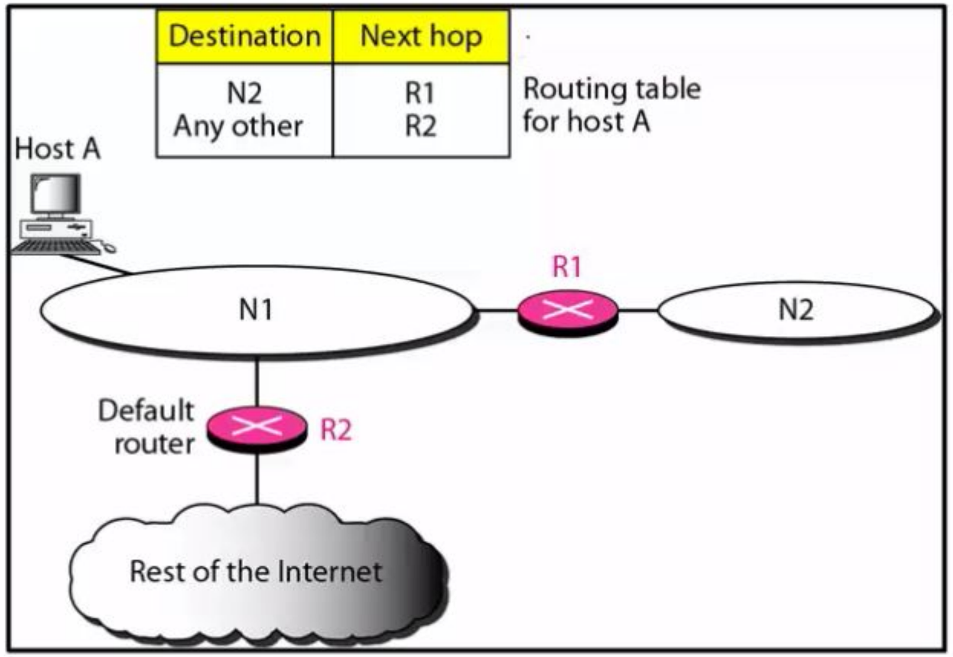




Introduction

Default Method

In Default Method, Routing Table will be **very small**. Because we have only one entry for Internet.



Introduction

Forwarding Process

Forwarding	→ *Place a packet in its route to its destination.*
Routing	→ *refers to the way* ***routing tables are created*** *to help* ***Forwarding****.*
Routing Protocols	→ *Used to* ***continuously update*** *the routing tables.*

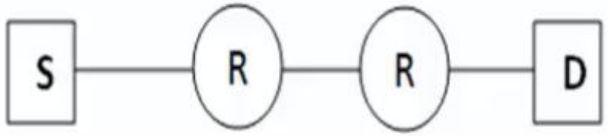
As we are using ***Classless IP addressing****, we need to have* ***at least 4 columns in a routing table****.*

Mask	*Network Address*	*Next Hop*	*Interface*
/26	180.70.65.192	—	m2
/25	180.70.65.128	—	m0
/24	201.4.22.0	—	m3
/22	201.4.16.0	....	m1
Any	Any	180.70.65.200	m2

Steps to perform in Search:-

1. Select the entry with the **Highest Mask** in the Routing Table.
2. Apply the Mask to the Destination Address to compute **Network Id**. If Network Id matches, forward the packet to the Next Hop in the select row.
3. If Network Id doesn't match → Select the **Next Highest Mask & Repeat the Process**.
4. If all entry's fail & Default Route exists → Forward the packet to the Default Route.
5. If No Default Route Exists → Discard the Packet & Send ICMP Destination Unreachable to Sender.

Assume that source S and destination D are connected through two intermediate routers labeled R. Determine how many times each packet has to visit the network layer and the data link layer during a transmission from S to D.



a) Network layer – 4 times and Data link layer-4 times

b) Network layer – 4 times and Data link layer-3 times

c) Network layer – 4 times and Data link layer-6 times

d) Network layer – 2 times and Data link layer-6 times

The routing table of a router is shown below:

Destination	Subnet Mask	Interface
128.75.43.0	255.255.255.0	Eth0
128.75.43.0	255.255.255.128	Eth1
192.12.17.5	255.255.255.255	Eth3
Default		Eth2

On which interface will the router forward packets addressed to destinations 128.75.43.16 and 192.12.17.10 respectively ?

a) Eth1 and Eth2

b) Eth0 and Eth2

c) Eth0 and Eth3

d) Eth1 and Eth3

Introduction

Types of Routing Tables

Static Routing Table

- *The Network Administrator enters the route for* ***each destination*** ***manually*** *in to the table.*
- *It is feasible for a small network , Not suitable for Internet.*

Dynamic Routing Table

- *Routing Table will get updated automatically if there is any change in the network.*
- *Implemented using Dynamic Routing Protocols : RIP, OSPF, and BGP.*
- *Internet is using Dynamic Routing Protocols to update the Routing Tables automatically.*

Introduction

Format of the Routing Table

Mask	Network address	Next-hop address	Interface	Flags	Reference count	Use
....	....	....	....	....	....	....

Mask → This Mask has to be applied to the Destination to find the **Network Id**

Network Address → It indicates the **Network Id** to which the packet is finally delivered.

Next-hop Address → It indicates the address of the **next Router** to which the packet has to be forwarded.

Interface → It indicates the name of the interface. [8-port Router → 8 Interfaces → Can connect to 8 Networks]

FLAGS [Set/Unset]

U → Up → Indicates that the Router is up and running.

G → Gateway → Means that Destination is in another network [indirect delivery].

H → Host-Specific → Entry in Network Address is Host-Specific address [Complete IP address of Host]

D → Added by Redirection → ICMP redirection message provided the new routing entry.

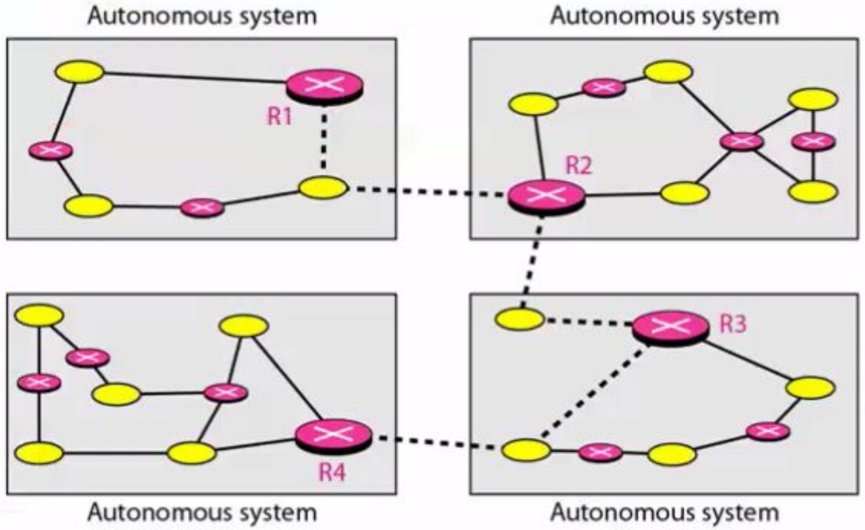
M → Modified by Redirection → ICMP redirection message updated the existing routing entry.

Reference Count → This field provides the no of users **currently** using this route. [at the moment]

Use → It shows the no of packets transmitted through this router for the **Corresponding Destination**.

Introduction

1. As Internet is large network, one routing protocol cannot handle the task of updating the routing tables of all routers.
2. For this reason, an **Internet is divided into Autonomous Systems**. [Domain] [Microsoft, SBI, Infosys]
3. Autonomous System → Group of networks and routers under the control of Single Administration.
4. Intra domain Routing → Routing **inside** an autonomous system.
5. Inter domain Routing → Routing **between** autonomous systems.

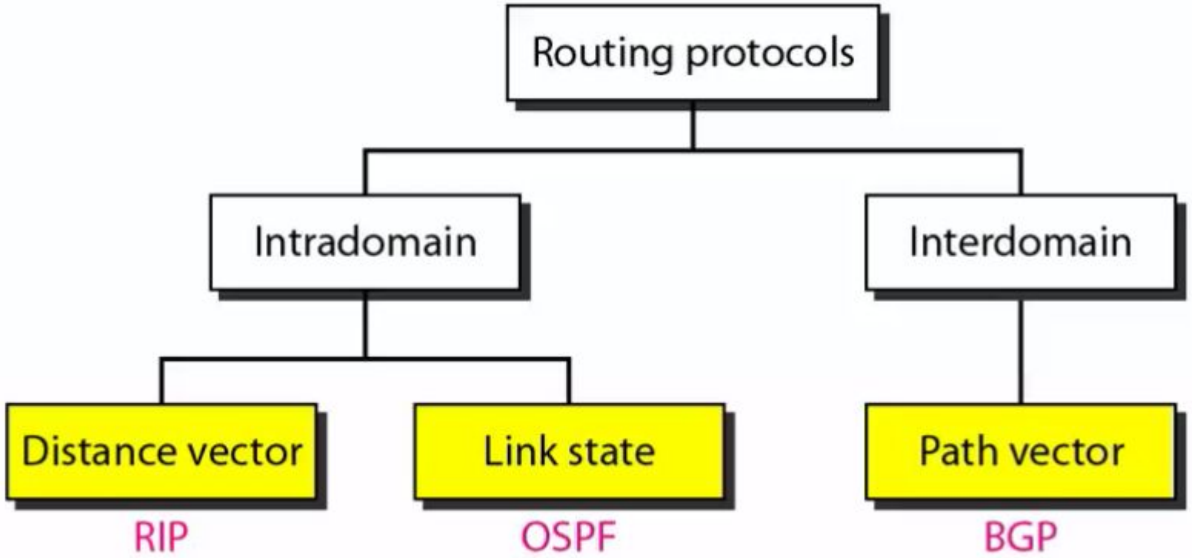


Each Autonomous System → Can choose **one (or) more** intra domain routing protocols.

Only **one inter domain routing protocol** has to be chosen for routing between autonomous systems.

Introduction

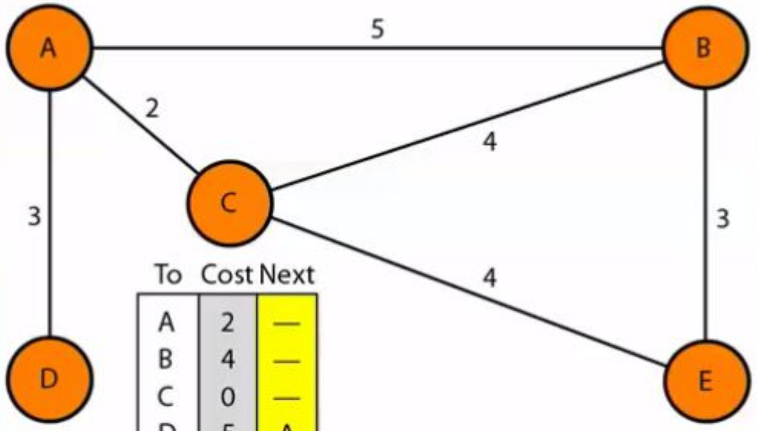
The following Routing Protocols will be discussed in detail :-



RIP → *Routing Information Protocol*
OSPF → *Open Shortest Path First Protocol*
BGP → *Border Gateway Protocol*

Distance Vector Routing

- In Distance Vector Routing, least-cost route between any 2 nodes the route with minimum distance.
- Each node maintains a minimum distance to every node.
- Each node shares its routing table **only with its neighbors** periodically &when there is a change.



To	Cost	Next
A	0	—
B	5	—
C	2	—
D	3	—
E	6	C

A's table

To	Cost	Next
A	5	—
B	0	—
C	4	—
D	8	A
E	3	—

B's table

To	Cost	Next
A	3	—
B	8	A
C	5	A
D	0	—
E	9	A

D's table

To	Cost	Next
A	2	—
B	4	—
C	0	—
D	5	A
E	4	—

C's table

To	Cost	Next
A	6	C
B	3	—
C	4	—
D	9	C
E	0	—

E's table

Distance Vector Routing

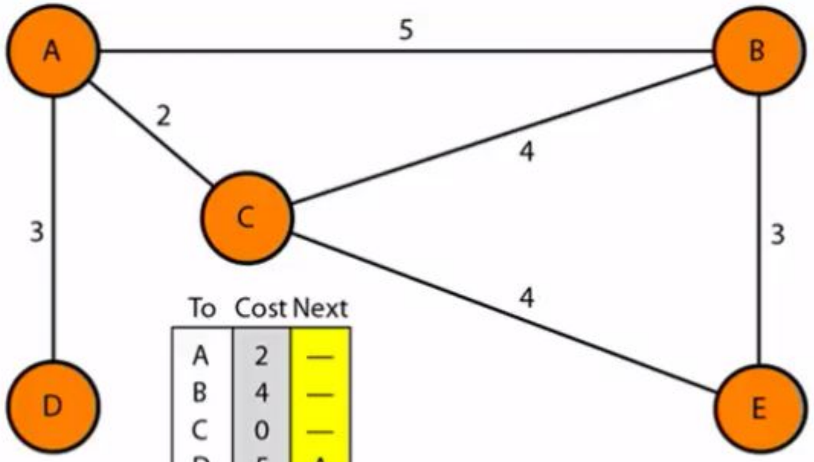
How tables were constructed **initially** ?

In the beginning:-

1. Each node finds the distance to its immediate neighbors.
2. Constructs the table & Shares it with its neighbors
3. Every node receives a 2 column table from all his neighbors.
4. Finally node uses the tables received from all neighbors to calculate the min distance to all nodes.

To	Cost	Next
A	0	—
B	5	—
C	2	—
D	3	—
E	∞	

A's table



To	Cost	Next
A	5	—
B	0	—
C	4	—
D	∞	
E	3	—

B's table

To	Cost	Next
A	3	—
B	∞	
C	∞	
D	0	—
E	∞	

D's table

To	Cost	Next
A	2	—
B	4	—
C	0	—
D	5	A
E	4	—

C's table

To	Cost	Next
A	∞	
B	3	B
C	4	C
D	∞	
E	0	D

E's table

Distance Vector Routing

Node "A" updating its table after receiving a table from its neighbor "C"

To	Cost
A	2
B	4
C	0
D	∞
E	4

Received from C

Add 2 to table

A to C = 2

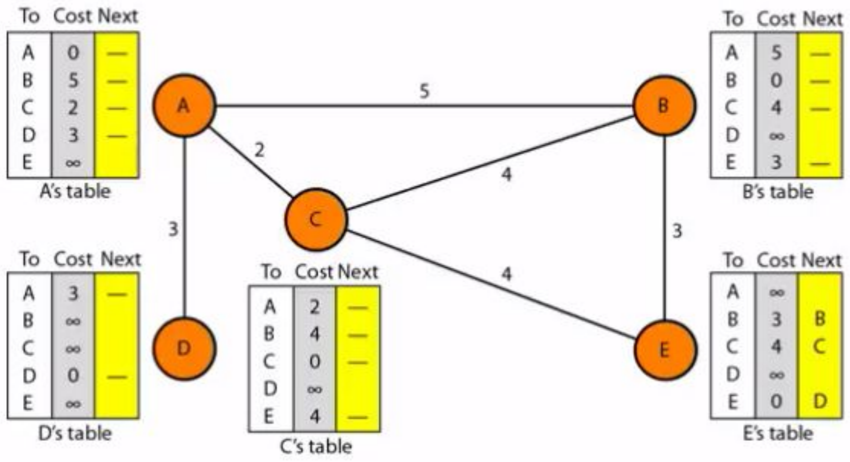
To	Cost	Next
A	4	C
B	6	C
C	2	C
D	∞	C
E	6	C

A's modified table

Compare

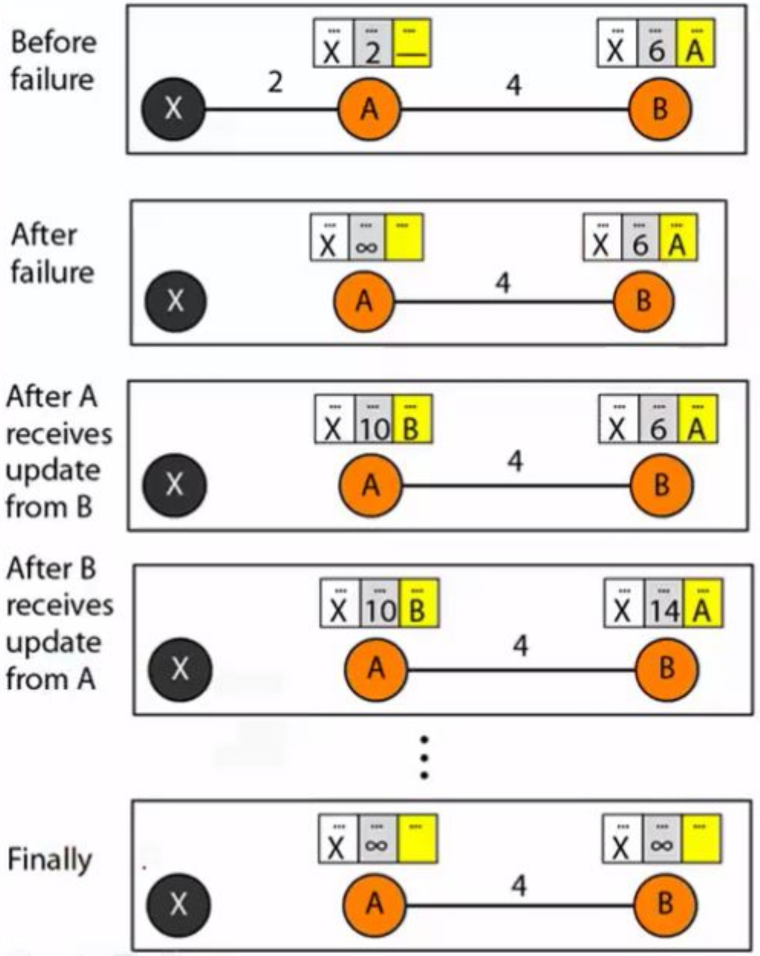
To	Cost	Next
A	0	—
B	5	—
C	2	—
D	3	—
E	∞	—

A's old table



Distance Vector Routing

Problem with Distance Vector Routing :-Two-Node Loop Instability



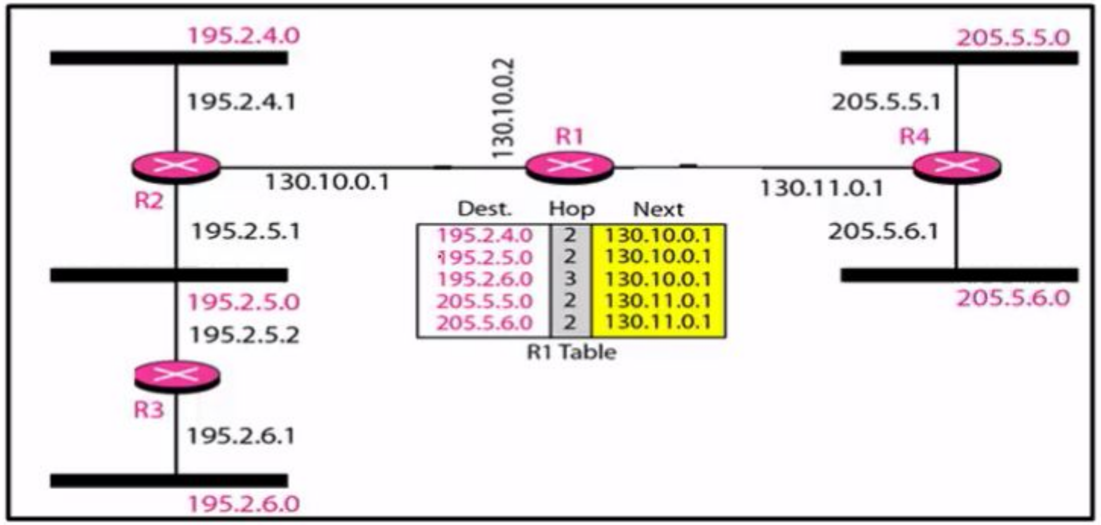
Solutions

1. Split Horizon
2. Split Horizon & Poison Reverse

Routing Information Protocol [RIP]

- RIP is an **intra domain routing protocol** used inside an Autonomous System.
- RIP implements **Distance Vector Routing** directly with some consideration.

1. Autonomous System → Routers & Networks [Links]
2. Routers will have routing tables and Networks [Links] do not have routing tables.
3. Destination Address in a routing table is a Network. [First Column → Network Address]
4. Metric Used by RIP → **No of Links** [hop count]
5. Infinity = 16. [Any route in an Autonomous System <= 15 hops]
6. Next-Node Column → Defines the address of the router to which the packet has to be sent.



Dest.	Hop	Next
195.2.4.0	2	130.10.0.1
195.2.5.0	2	130.10.0.1
195.2.6.0	3	130.10.0.1
205.5.5.0	2	130.11.0.1
205.5.6.0	2	130.11.0.1

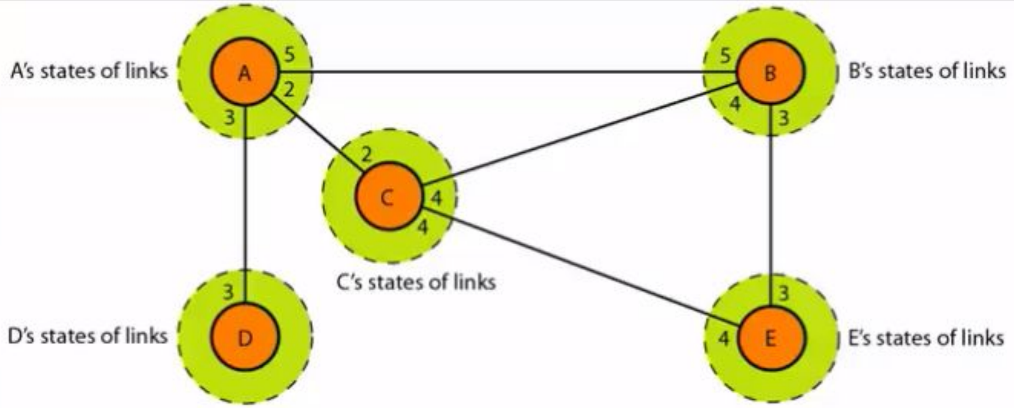
R1 Table

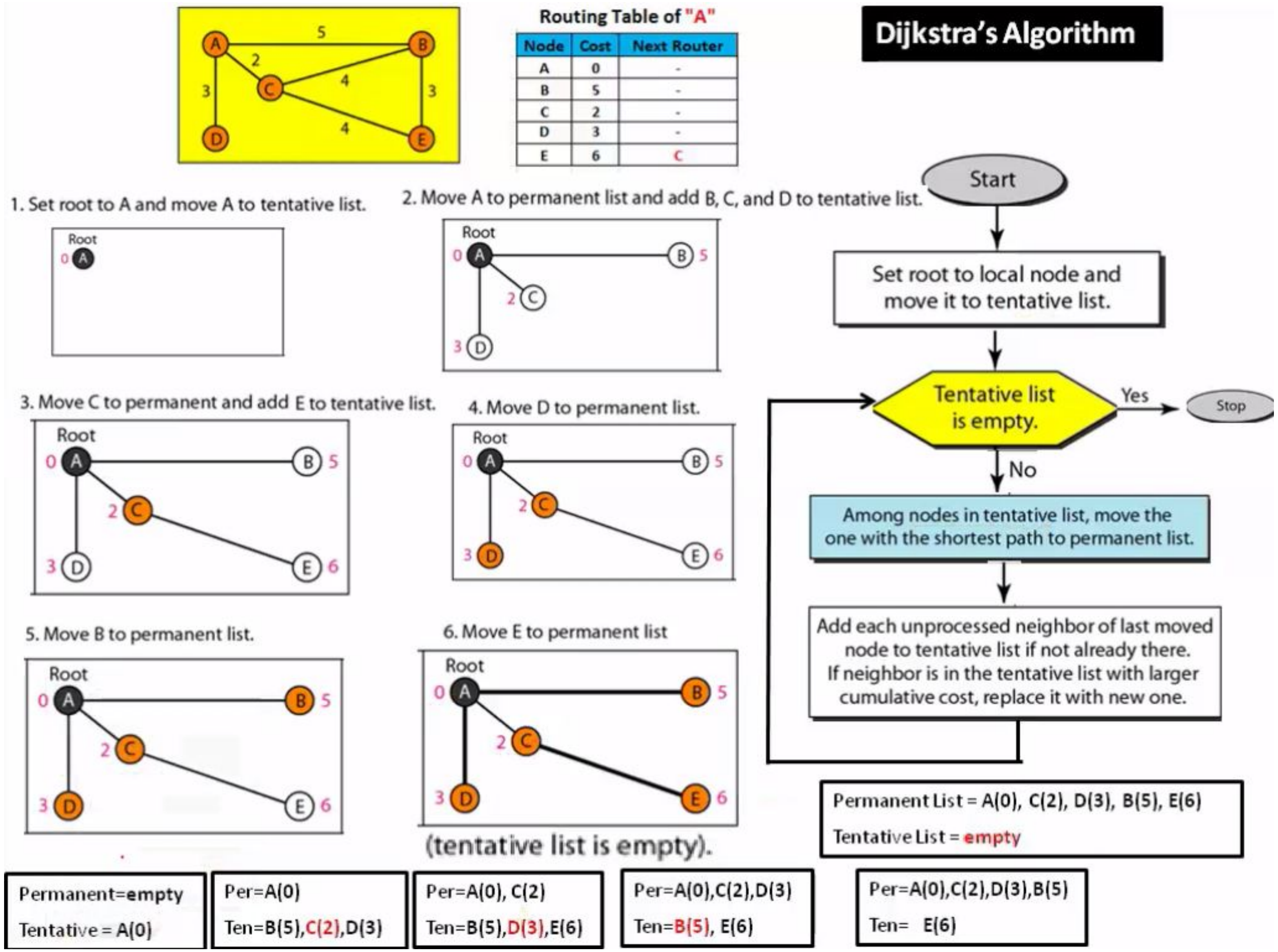
Link State Routing

Link State Routing Algorithm creates the Initial Routing tables using the following Steps:-

1. Each node constructs a Link State Packet [**LSP**].
2. Each node **broadcast** the constructed Link State Packet **LSP** to all nodes using Flooding.
3. Every node will receive the Link State Packets of all other nodes.
4. Each node constructs the **Shortest Path Tree** to all nodes using **Dijkstra's algorithm**.
5. Each node will create the Routing Table using the Constructed Shortest Path Tree.

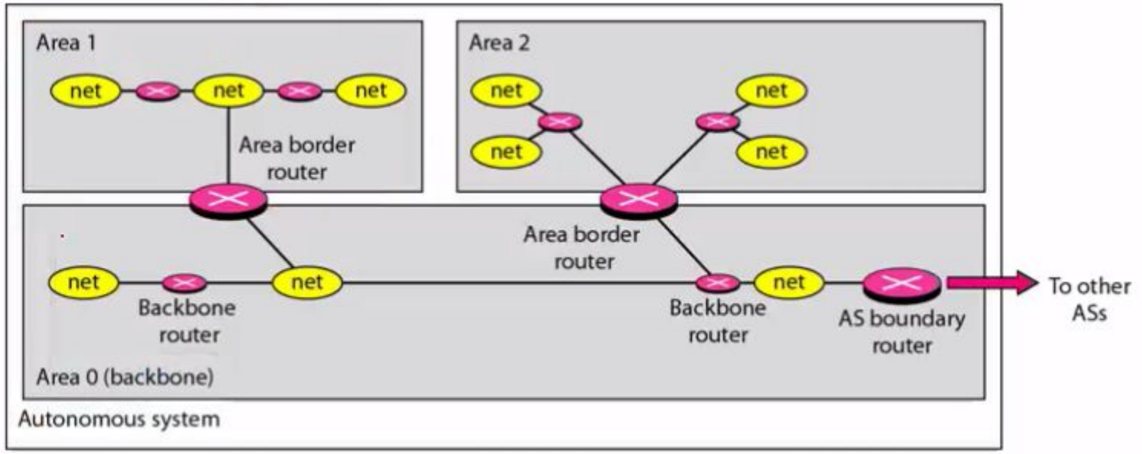
A	
Seq no	
Age	
B	5
C	2
D	3




Dijkstra's Algorithm
Routing Table of "A"
Node | Cost | Next Router
A | 0 | -
B | 5 | -
C | 2 | -
D | 3 | -
E | 6 | C
Start
Set root to local node and move it to tentative list.
Tentative list is empty.
Yes
Stop
No
Among nodes in tentative list, move the one with the shortest path to permanent list.
Add each unprocessed neighbor of last moved node to tentative list if not already there. If neighbor is in the tentative list with larger cumulative cost, replace it with new one.
1. Set root to A and move A to tentative list.
2. Move A to permanent list and add B, C, and D to tentative list.
3. Move C to permanent and add E to tentative list.
4. Move D to permanent list.
5. Move B to permanent list.
6. Move E to permanent list
(tentative list is empty).
Permanent List = A(0), C(2), D(3), B(5), E(6)
Tentative List = empty
Permanent=empty
Tentative = A(0)
Per=A(0)
Ten=B(5),C(2),D(3)
Per=A(0), C(2)
Ten=B(5),D(3),E(6)
Per=A(0),C(2),D(3)
Ten=B(5), E(6)
Per=A(0),C(2),D(3),B(5)
Ten= E(6)

OSPF

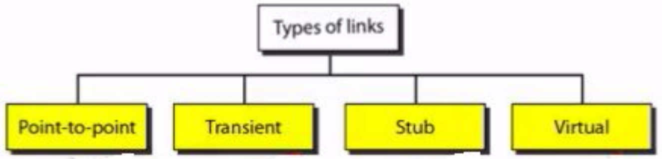
- **O**pen **S**hortest **P**ath **F**irst Protocol is an Intra domain protocol based on Link State Routing.
- OSPF divides an **Autonomous System** into **Areas**.
- Among **all the Areas**, **One Area** → will be designed as **Back Bone Area**
- The Routers inside the Back Bone Area → will be called as **Back Bone Routers.**
- All Areas inside the Autonomous System must be connected to the Back Bone Area.
- An **Area** is a collection of Networks, Hosts, and Routers.
- All Networks inside an Area must be connected.
- Routers insider the Area flood the area with routing information.
- At the border of an Area, special routers called Area Border Routers are used.

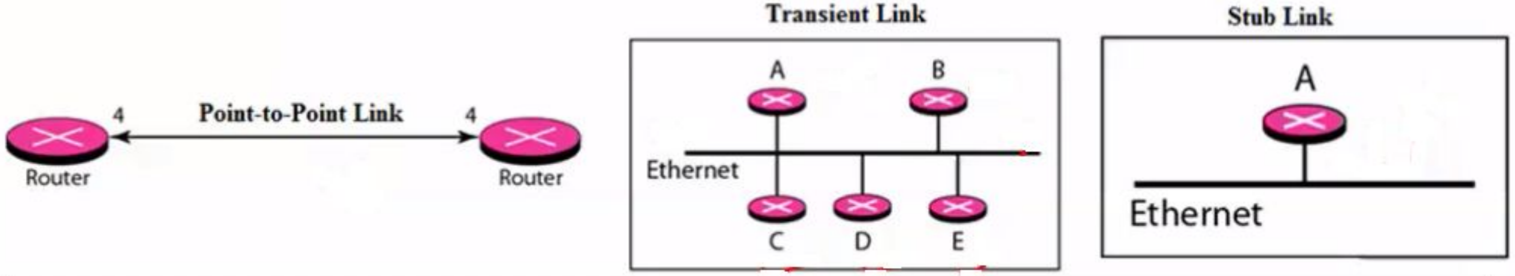


OSPF

Metric Used by OSPF → **Cost** to **each Route** based on required Service [Min Delay, Max Throughput, e.t.c]

Types of Links → **Connection** is called as a **Link**.





Point-to-Point Link → Link connecting Only 2 Routers. [Dedicated Link]

Transient Link → Link connecting Multiple Routers. [data packets can enter through any Router and Leave through any Router]

Stub Link → Network that is connected to Only One Router. [data packets will enter & leave the same Router]

Virtual Link → When the link between 2 routers is broken, the Administrator will create a Virtual Link between them, using a longer path that probably goes through several routers.

Path Vector Routing

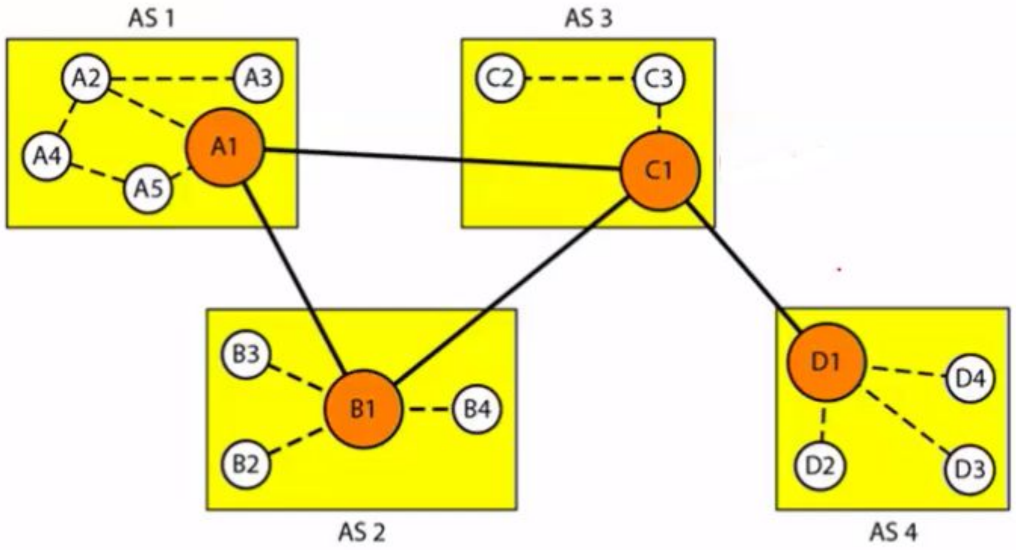
- Path Vector Routing is an **Inter Doman Routing Protocol** [Between Autonomous Systems→ AS]
- **Speaker Node** → One node in Autonomous Systems acts on behalf of the entire Autonomous System
- Speaker Node in AS creates a routing table and advertises it to Speaker Nodes in other AS's.
- The Idea is same as Distance Vector Routing with the following differences:-
  1. The Communication is allowed **Only Speaker Nodes** in neighboring Autonomous Systems.
  2. Advertisement → Advertises the **Path** [not the distance in Distance Vector Routing]

Dest.	Path
A1	AS1
A2	AS1
A3	AS1
A4	AS1
A5	AS1

A1 Table

Dest.	Path
B1	AS2
B2	AS2
B3	AS2
B4	AS2

B1 Table



Dest.	Path
C1	AS3
C2	AS3
C3	AS3

C1 Table

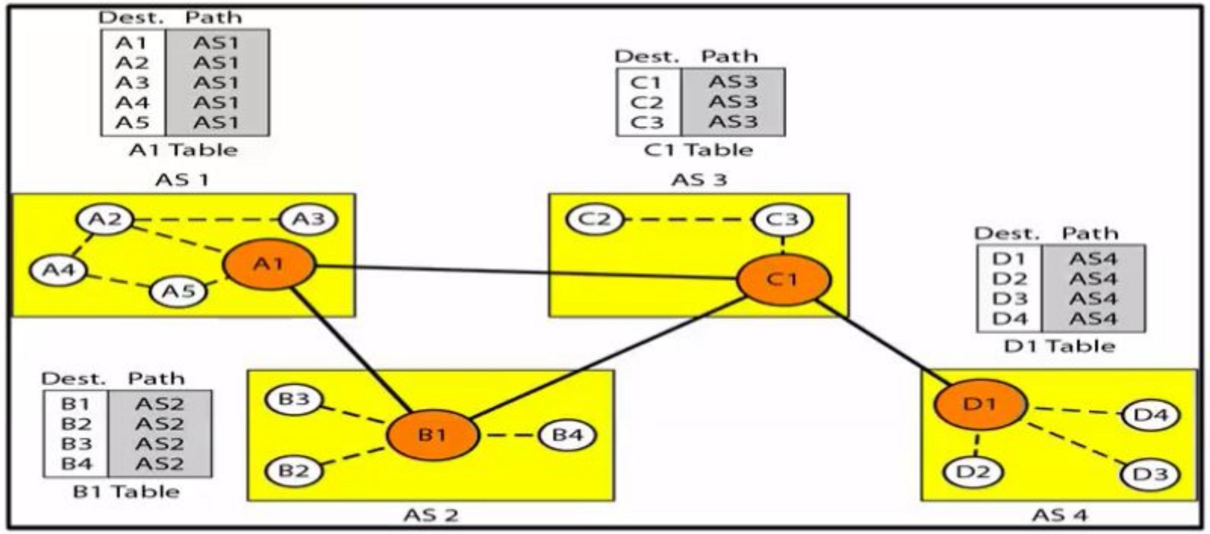
Dest.	Path
D1	AS4
D2	AS4
D3	AS4
D4	AS4

D1 Table

Path Vector Routing

How **Speaker Node** constructs the **Routing Table** with **Paths** ?

Sharing with **Immediate neighbors**



Dest.	Path
A1	AS1
…	
A5	AS1
B1	AS1-AS2
…	…
B4	AS1-AS2
C1	AS1-AS3
…	…
C3	AS1-AS3
D1	AS1-AS2-AS4
…	…
D4	AS1-AS2-AS4

A1 Table

Dest.	Path
A1	AS2-AS1
…	
A5	AS2-AS1
B1	AS2
…	…
B4	AS2
C1	AS2-AS3
…	…
C3	AS2-AS3
D1	AS2-AS3-AS4
…	…
D4	AS2-AS3-AS4

B1 Table

Dest.	Path
A1	AS3-AS1
…	
A5	AS3-AS1
B1	AS3-AS2
…	…
B4	AS3-AS2
C1	AS3
…	…
C3	AS3
D1	AS3-AS4
…	…
D4	AS3-AS4

C1 Table

Dest.	Path
A1	AS4-AS3-AS1
…	
A5	AS4-AS3-AS1
B1	AS4-AS3-AS2
…	…
B4	AS4-AS3-AS2
C1	AS4-AS3
…	…
C3	AS4-AS3
D1	AS4
…	…
D4	AS4

D1 Table

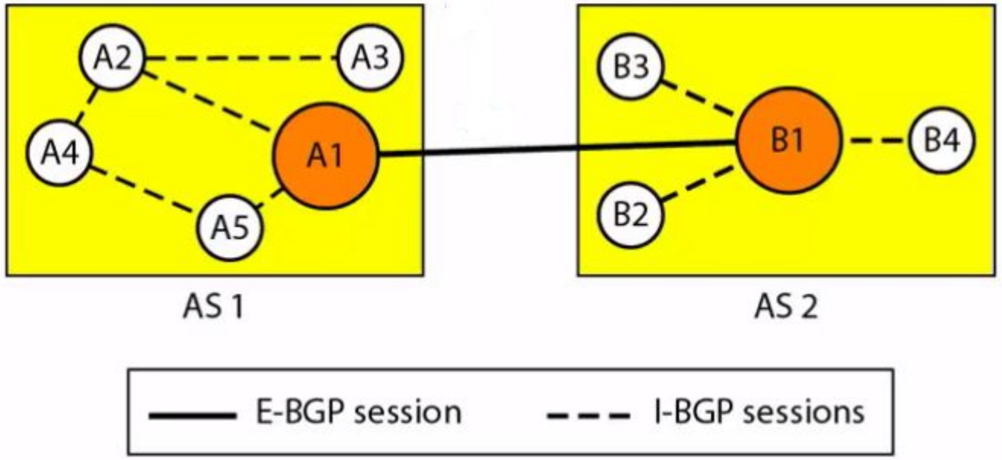
BGP

- Border Gateway Protocol is an Inter Domain Protocol using Path Vector Routing

- **BGP Session** → The exchange of routing information between 2 routers takes place in a **Session**.

- 2 Types of BGP Sessions
  1. External BGP Session
  2. Internal BGP Session

External BGP Session:- Session between **2 Speaker Nodes** of 2 different Autonomous Systems.
Internal BGP Session:- Session between **2 Routers** of Same Autonomous System.



<u>Count to infinity</u> is a problem associated with

a) Link state routing protocol

b) Distance vector routing protocol

c) DNS while resolving host name

d) TCP for congestion control

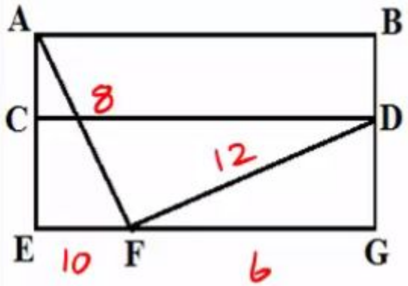
Two popular routing algorithm are distance vector (DV) and kink state (LS) routing. Which of the following are true?

(S1) Count to infinity is a problem only with DV and not LS routing.

(S2) In LS, the shortest path algorithm is run only at one node.

(S3) In DV, the shortest path algorithm is run only at one node.

(S4) DV require lesser number of network messages than LS.



Routing table of A	
A	0
B	40
C	14
D	17
E	21
F	9
G	24

Routing table of E	
A	24
B	27
C	7
D	20
E	0
F	11
G	22

Routing table of D	
A	20
B	8
C	30
D	0
E	14
F	7
G	22

Routing table of G	
A	21
B	24
C	22
D	19
E	22
F	10
G	0

Which one of the following options represents the updated routing table of F?

a)

A	8
B	20
C	17
D	12
E	10
F	0
G	6

b)

A	21
B	8
C	7
D	19
E	14
F	0
G	22

c)

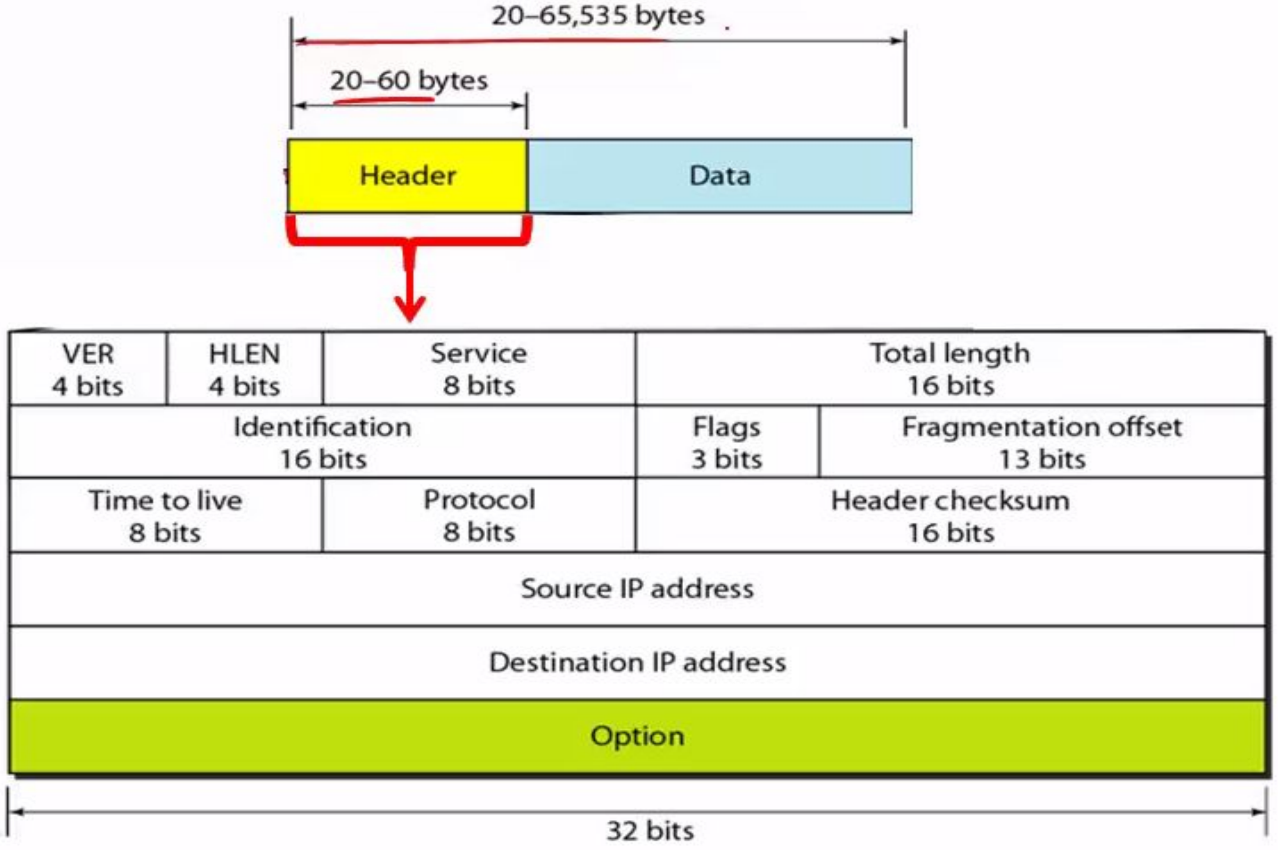
A	8
B	20
C	17
D	12
E	10
F	16
G	6

d)

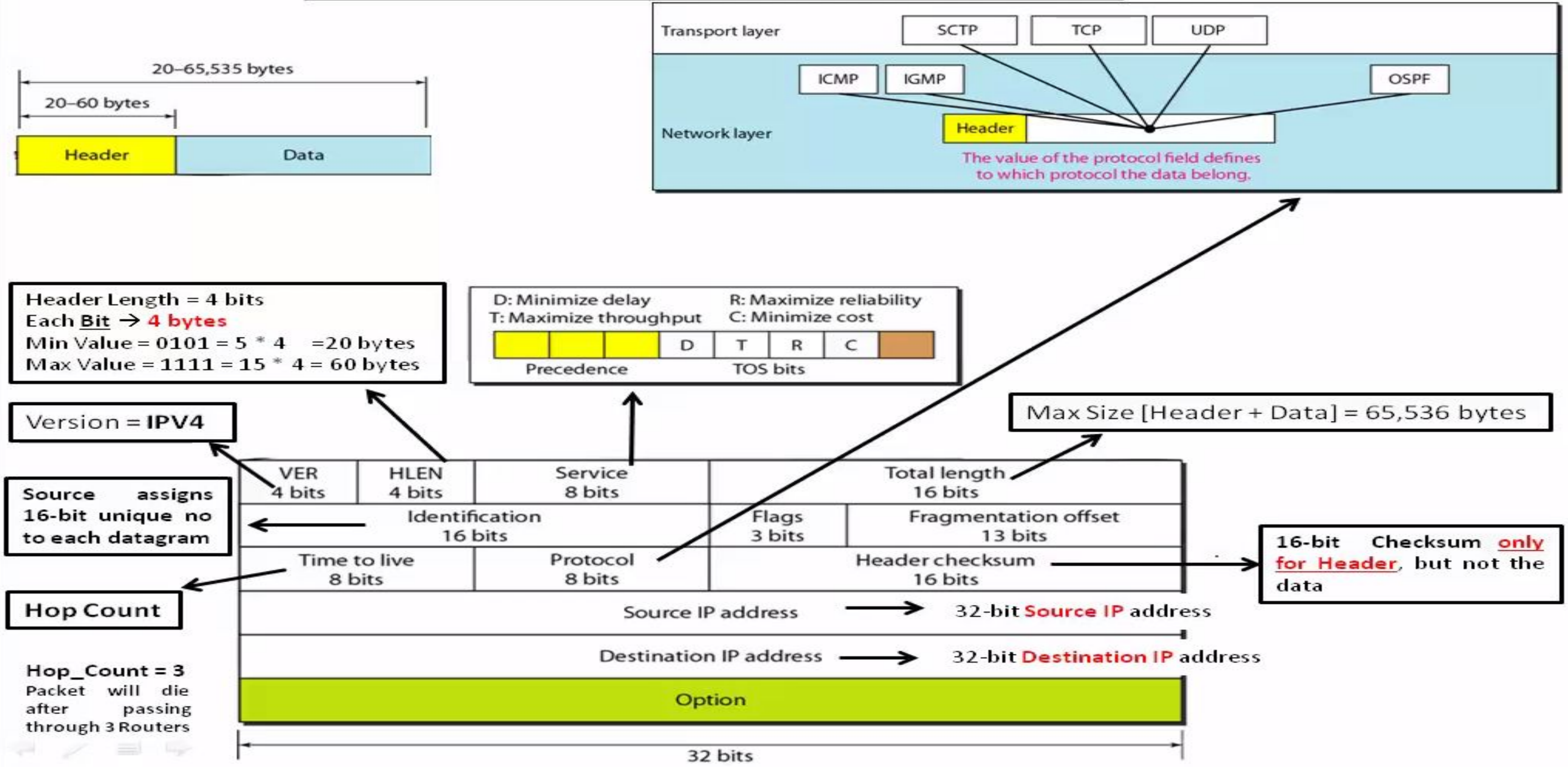
A	8
B	8
C	7
D	12
E	10
F	16
G	6

IPV4

- *IPV4 is an* ***unreliable*** *and* ***connectionless*** *datagram protocol.*
- *Packets in IPV4 are called as* ***datagrams****.*
- *IPV4 datagram format is as follows :-*

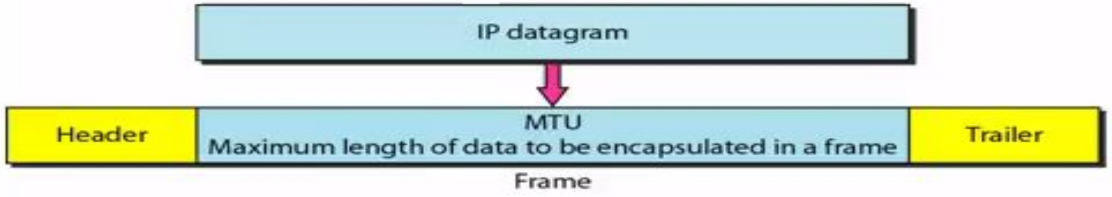


Detailed Understanding of IP Header [20 to 60 bytes]



Detailed Understanding of FLAGS & FRAGMENT OFFSET in IP Header

- ❖A datagram has to travel through **different Networks**. [LAN's]
- ❖The Maximum Size of Frame depends on the Underlying Physical Network.
- ❖Maximum Size of Frame in ETHERNET = 1500 bytes
- ❖Maximum Size of Frame in TOKEN RING = 4464 bytes
- ❖In IPV4, a datagram can be fragmented by Source Host (or) any Router in the Path.
- ❖Reassembling of the datagram will be done at Destination Only. [bcoz each datagram routes Independently]



Detailed Understanding of FLAGS & FRAGMENT OFFSET in IP Header

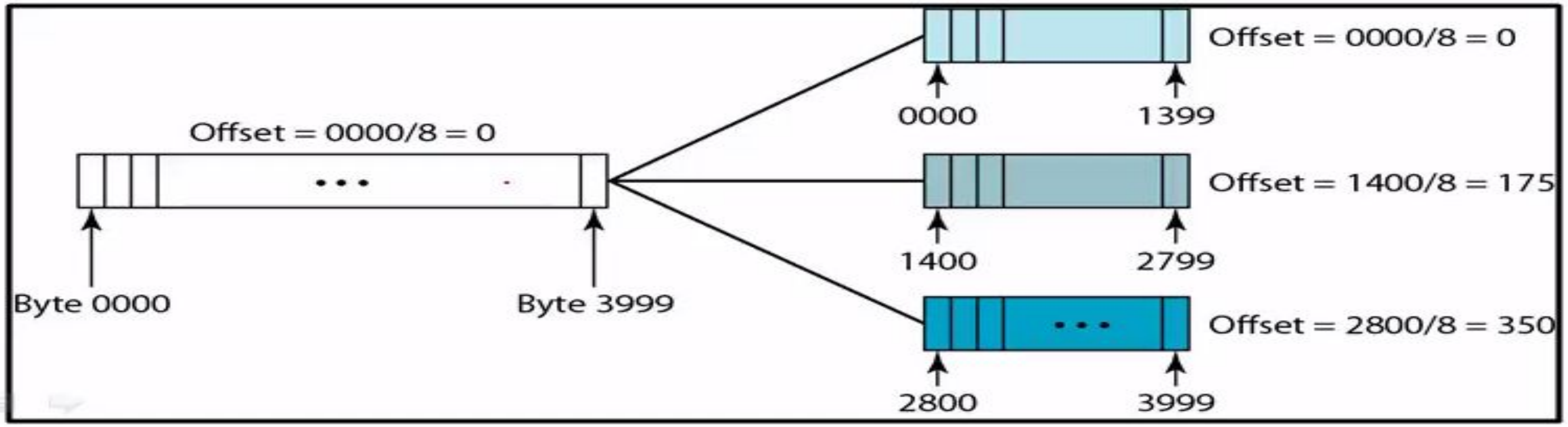
<table>
<tr><td>VER
4 bits</td><td>HLEN
4 bits</td><td>Service
8 bits</td><td colspan="2">Total length
16 bits</td></tr>
<tr><td colspan="3">Identification
16 bits</td><td>Flags
3 bits</td><td>Fragmentation offset
13 bits</td></tr>
<tr><td colspan="2">Time to live
8 bits</td><td>Protocol
8 bits</td><td colspan="2">Header checksum
16 bits</td></tr>
<tr><td colspan="5">Source IP address</td></tr>
<tr><td colspan="5">Destination IP address</td></tr>
<tr><td colspan="5">Option</td></tr>
</table>

3 Bit Flag =

	D	M

D → 1 → Do Not Fragment
M → 1 → More Fragment
M → 0 → No More Fragment

Fragment Offset [13-bits] → Relative Position of this fragment with respect to **whole datagram.**

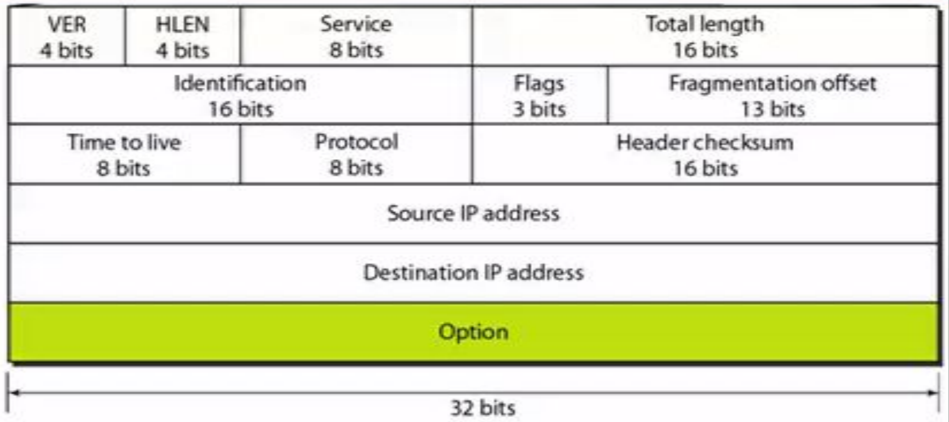


IPV4

3 Bits Flag = | | D | M |

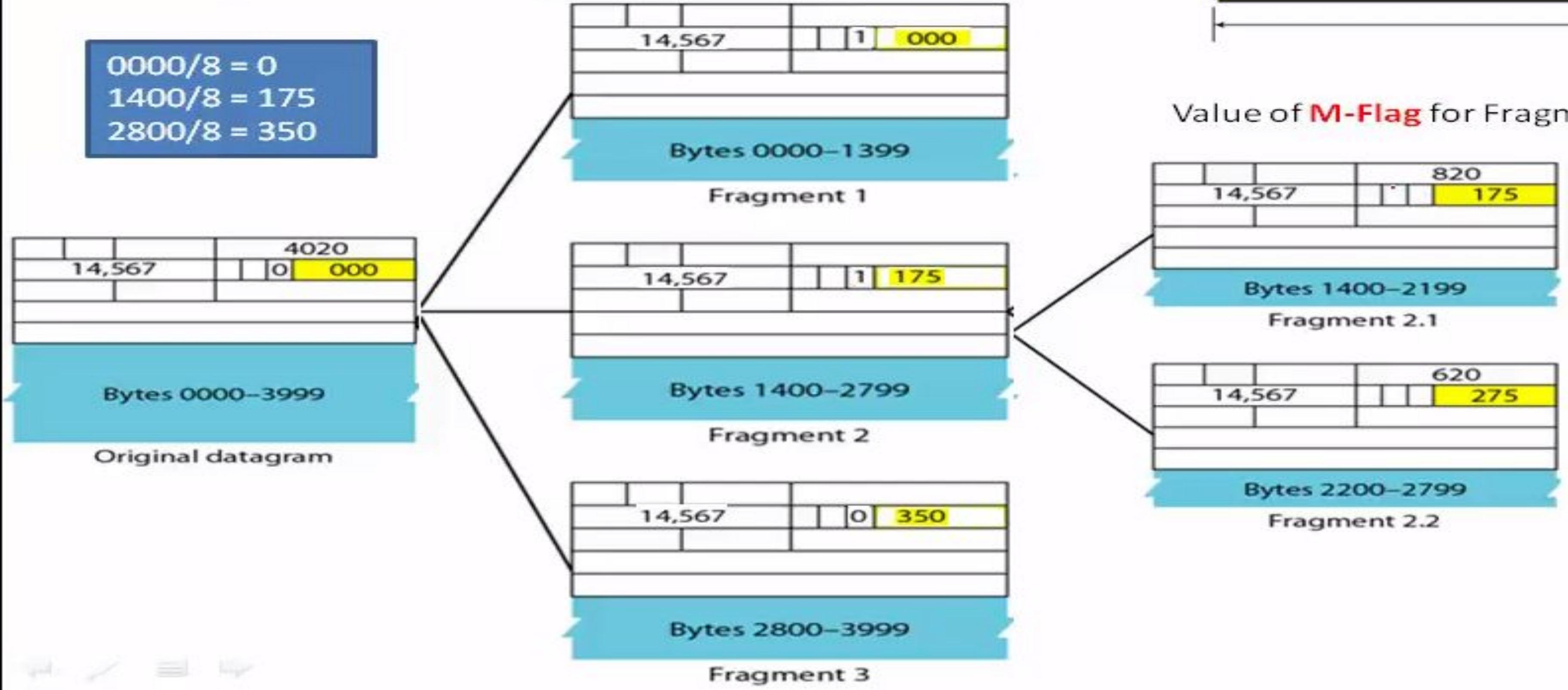
D → 1 → Do Not Fragment
M → 1 → More Fragment
M → 0 → No More Fragment

Fragment Offset [13-bits]
Relative Position of this fragment with respect to **whole datagram.**



Value of **Fragment Offset** for Fragments ?

Value of **M-Flag** for Fragments ?



IPV4

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32 bits

Options of IP Header [Max = 40 bytes]

1. Record Route
2. Strict Source Route
3. Loose Source Route
4. Time Stamp

In the TCP/IP protocol suite, which one of the following is NOT part of the IP header?

a) Fragment offset

b) Source IP address

c) Destination IP address

d) Destination port number

One of the header fields in an IP datagram is the Time to Live (TTL) field. Which of the following statements best explains the need for this field?

a) It can be used to prioritize packets

b) It can be used to reduce delays

c) It can be used to optimize throughput

d) It can be used to prevent packet looping