

Cisco Certified Network Associate

640-801

CCNA Certification

Adaptive Testing

1 Paper : 150 US \$ = Approx. Rs 7,500

Time Limit : 90 minutes

No. Questions : 55 – 65

Passing Score : 849/1000

Questions Format :

1. **Single Choice**
2. **Multiple Choice**
3. **Drag & Drop**
4. **Fill in the Blanks**
5. **Router Simulations**
6. **Scenario Based**

Reference Books

- ▣ **CCNA – Study Guide (640-801) by Richard Deal
TATA McGrawhill**
- OR**
- ▣ **CCNA – Intro (640-811) by Wendell Odom
Pearson Education (CiscoPress)**
- ▣ **CCNA – ICND (640-821) by Wendell Odom
Pearson Education (CiscoPress)**
- OR**
- ▣ **CCNA (640-801) by Wendell Odom
Pearson Education (CiscoPress)**

CCNA Course Overview

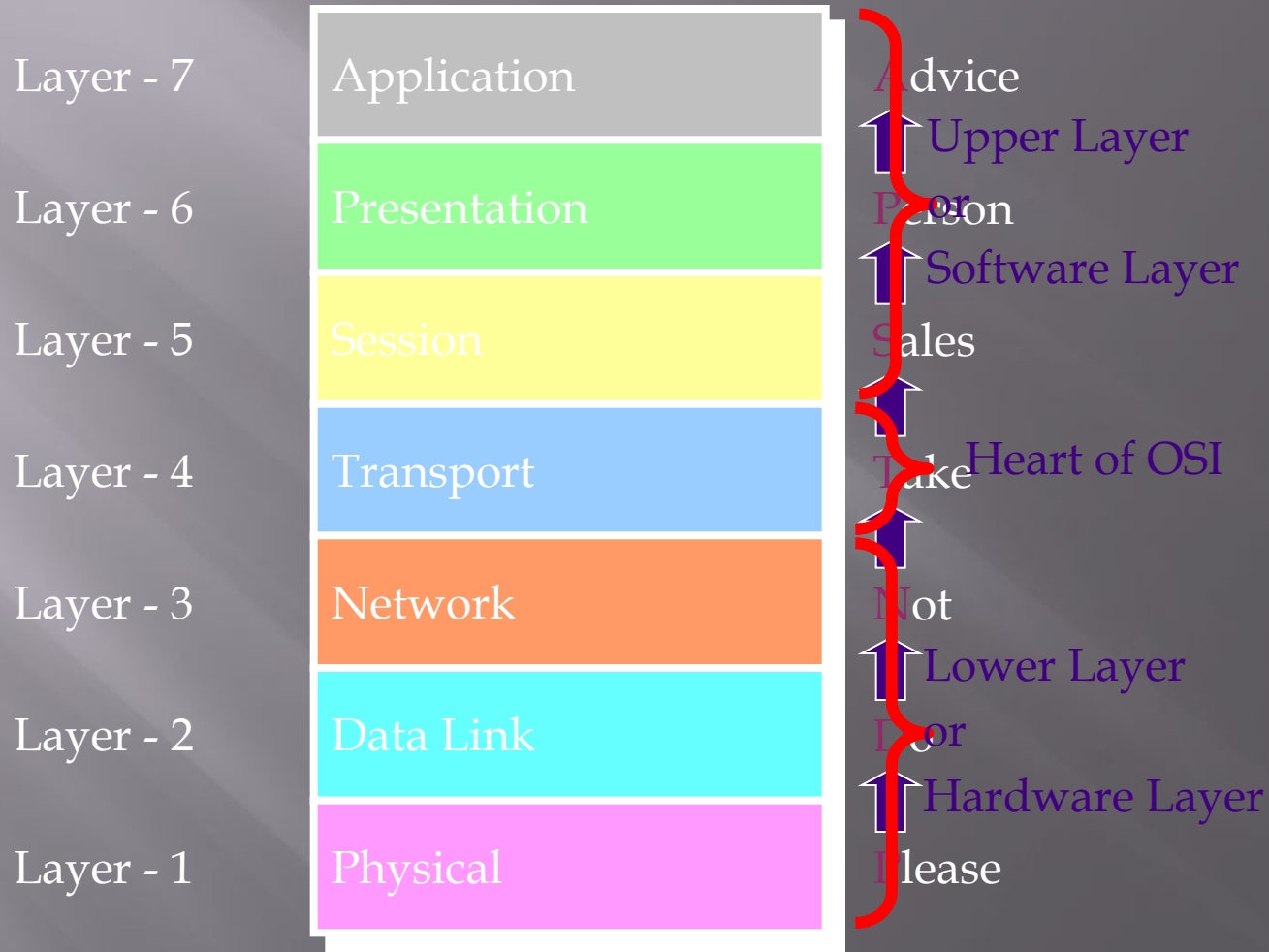
- Day 1 : OSI Layers**
- Day 2 : IP Addressing & Subnetting**
- Day 3 : Subnetting, VLSM & CIDR**
- Day 4 : Initial Configuration &
Internal & External of Routers**
- Day 5 : Wan Interface Configuration &
Static & Default Routing**
- Day 6 : Dynamic Routing : RIP & IGRP**
- Day 7 : Dynamic Routing : OSPF & EIGRP**
- Day 8 : Access List - Standard, Extended & Named**
- Day 9 : Switching**
- Day 10 : VLAN – Virtual Lan**
- Day 11 : Integrated Service Digital Network**
- Day 12 : Frame- Relay**
- Day 13 : Troubleshooting of Leased Line**
- Day 14 : Introduction of Firewall**

OSI LAYERS

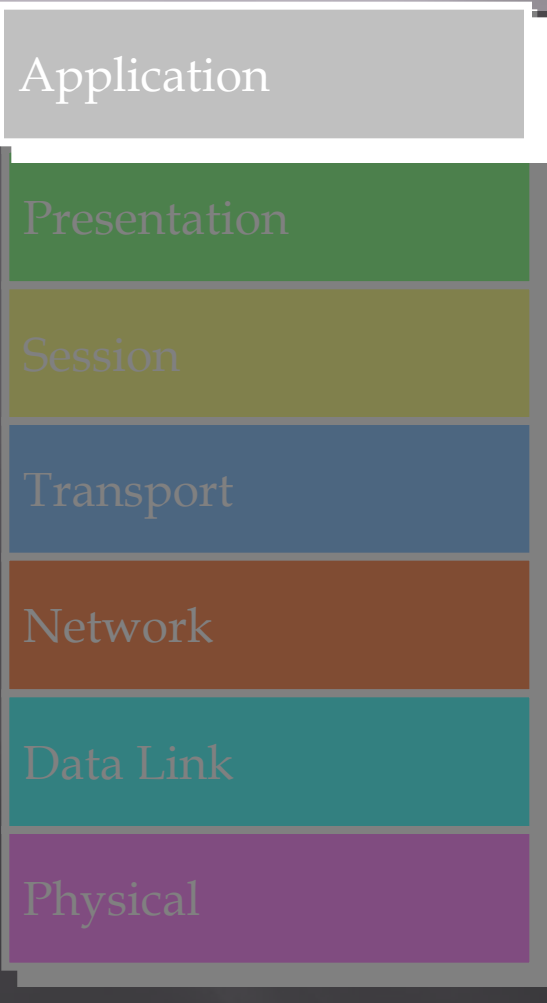
OSI Model

- **OSI means Open System Interconnect model.**
- **Developed by the International Organization for Standardization in 1974.**
- **It consists of seven layers.**
- **Each layer has a different but specific processing function.**

OSI Model Layers



Application Layer



Application Layer is responsible for providing Networking Services to user. It also known as Desktop Layer. Identification of Services is done using Port Numbers.

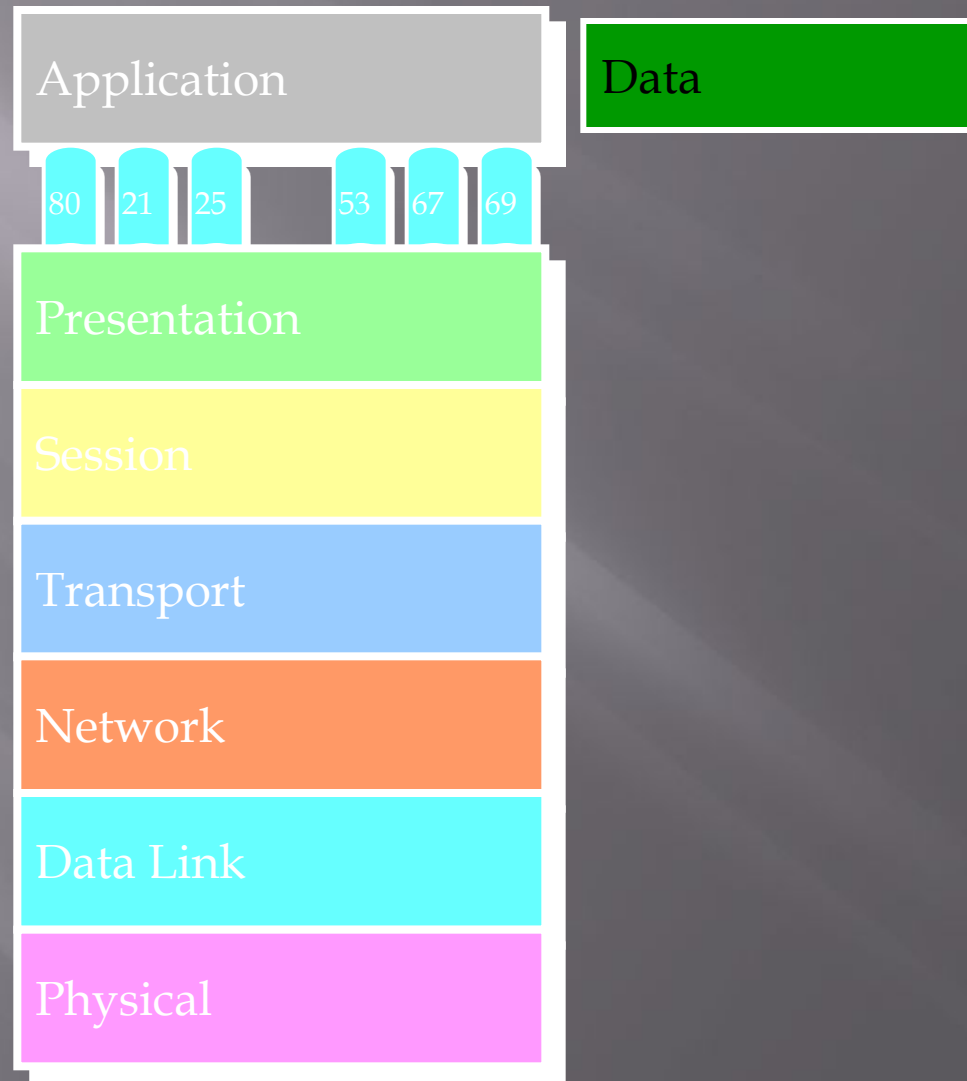
Ports are nothing but Socket i.e. Entry and Exit Point to the Layer

Total No. Ports 0 – 65535

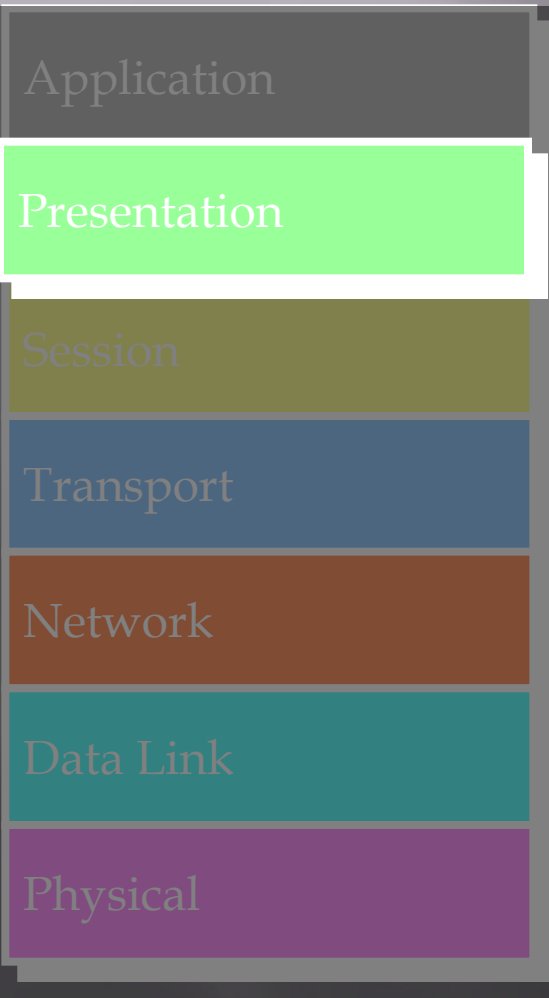
Reserved Ports 0 – 1023

Open Ports 1024 – 65535

How data flows from Application Layer



Presentation Layer



Presentation Layer is responsible for converting data into standard format.

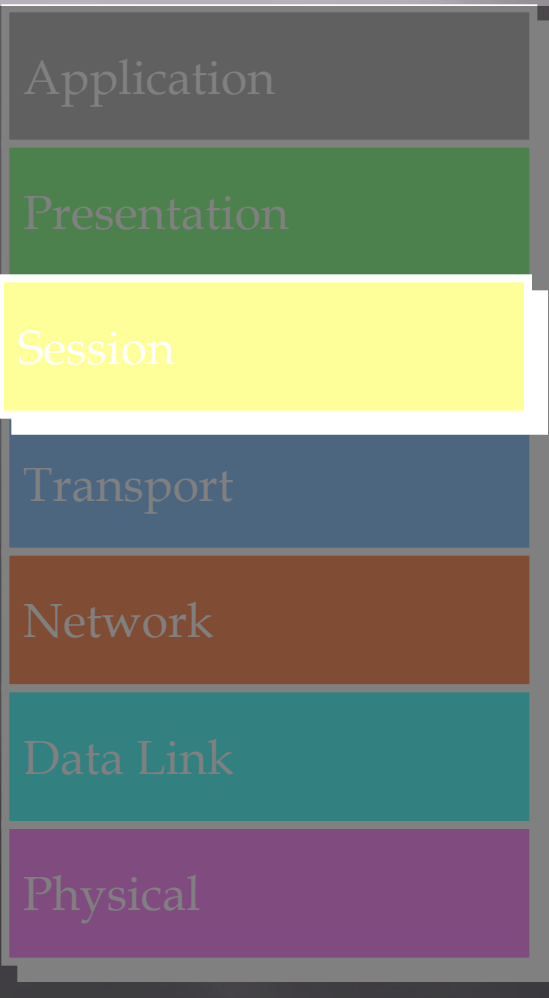
Examples : ASCII, EBCDIC, JPEG, MPEG, BMP, MIDI, WAV, MP3

Following tasks are performed at Presentation layer :

Encoding – Decoding
Encryption – Decryption
Compression – Decompression



Session Layer



Session Layer is responsible establishing, maintaining and terminating session.

Session ID also works at Session Layer.

Examples :

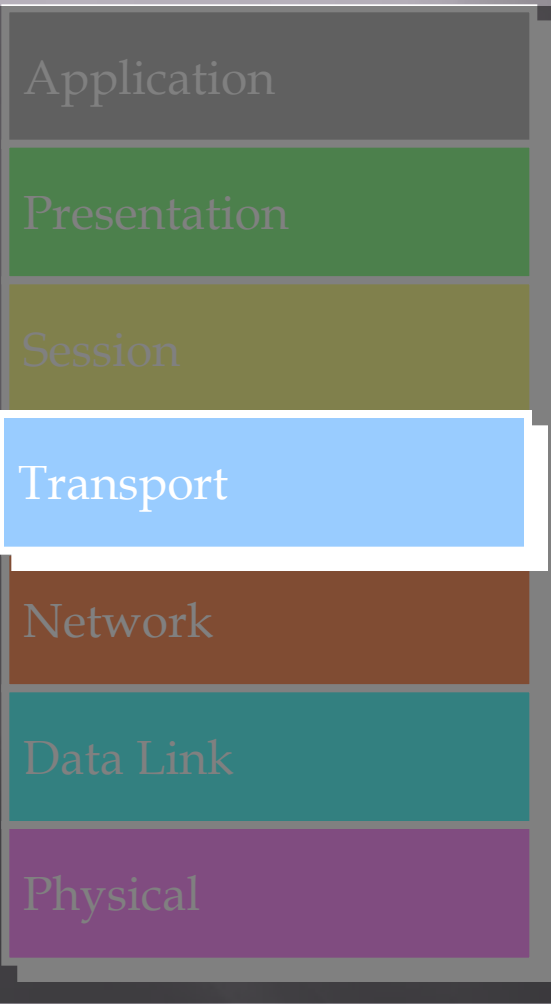
RPC □ Remote Procedure

SQL □ Structured Query

NFS □ Network File System



Transport Layer



Transport Layer is responsible for end-to-end connectivity. It is also known as heart of OSI Layers. Following task are performed at Transport Layer : -

- Identifying Service
- Multiplexing & De-multiplexing
- Segmentation
- Sequencing & Reassembling
- Flow Control
- Error Correction

Identifying Service

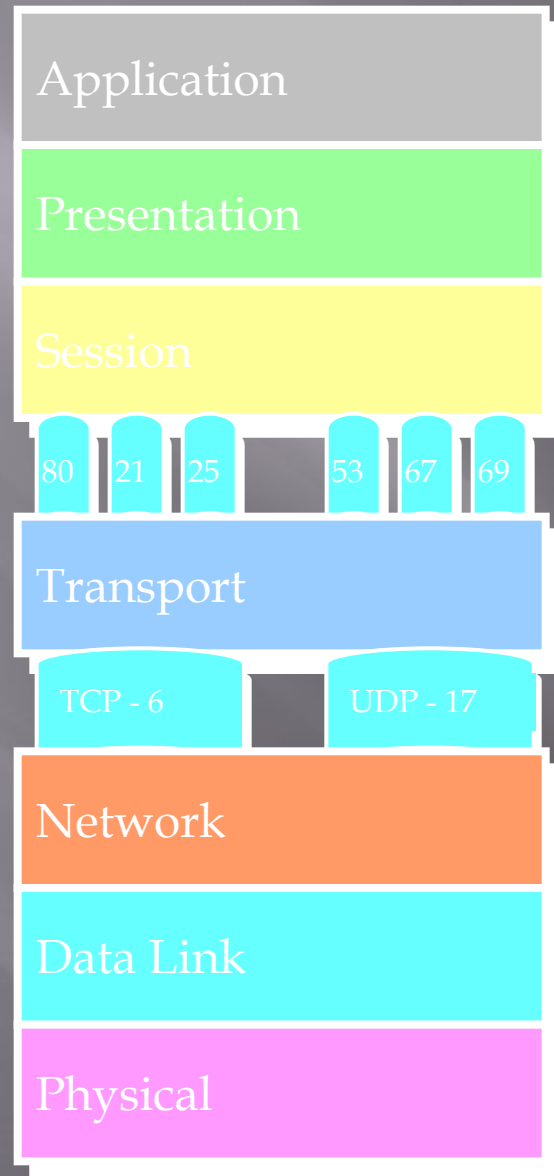
TCP

- Transmission Control Protocol
- Connection Oriented
- Acknowledgement
- Reliable
- Slower
- Port No. 6
- e.g. HTTP, FTP, SMTP

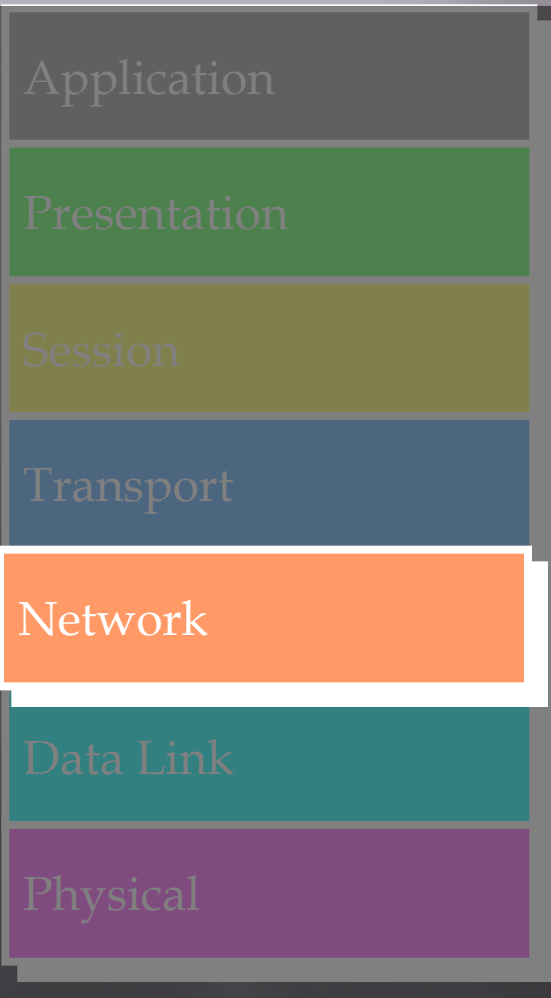
UDP

- User Datagram Protocol
- Connection Less
- No Acknowledgement
- Unreliable
- Faster
- Port No. 17
- e.g. DNS, DHCP, TFTP

Multiplexing & De-multiplexing



Network Layer

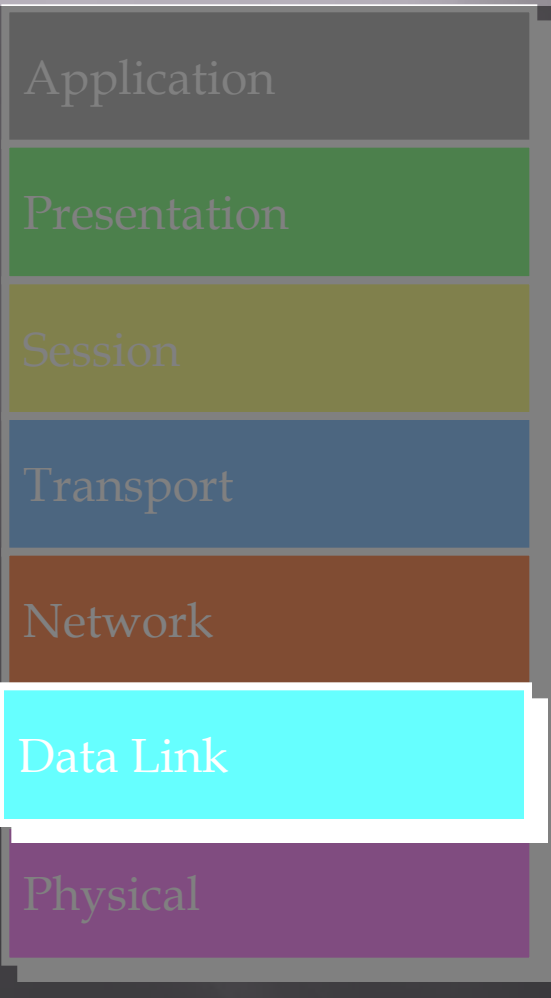


Network Layer is responsible for providing best path to data to reach destination. Logical Addressing sits on this layer. Device working on Network Layer is Router.

It is divided into two parts

- Routed Protocols
e.g. IP, IPX, Apple Talk.
- Routing Protocols
e.g. RIP, IGRP, OSPF, EIGRP

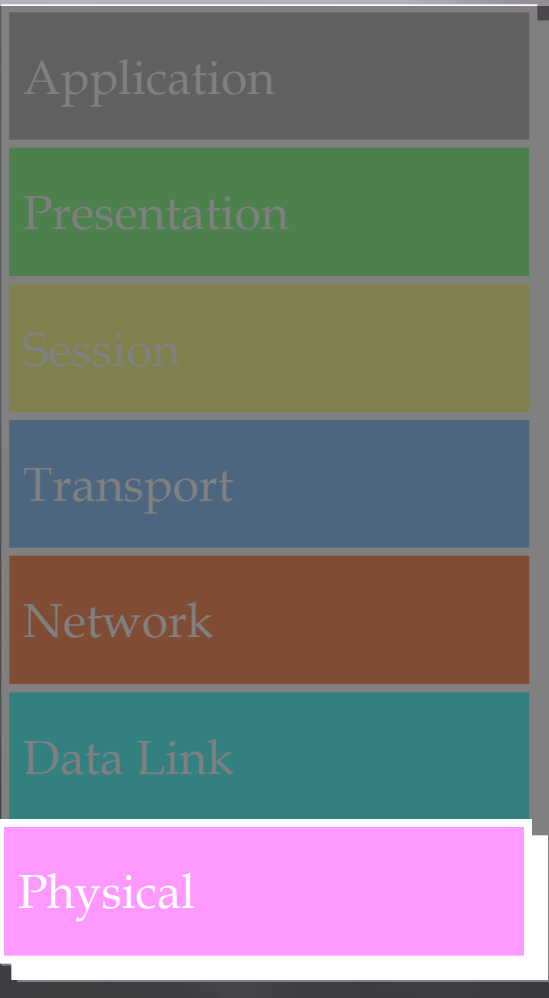
Datalink Layer



Datalink Layer is divided into two Sub Layers :

- LLC – Logical Link Control
It talks about Wan protocols e.g. PPP, HDLC, Frame-relay
- MAC – Media Access Control
It talks about Physical Address. It is 48 bit Addressing i.e. 12 digit Hexadecimal No. It is also responsible for Error Detection
Device working on Data Link Layer is Switch, Bridge, NIC.

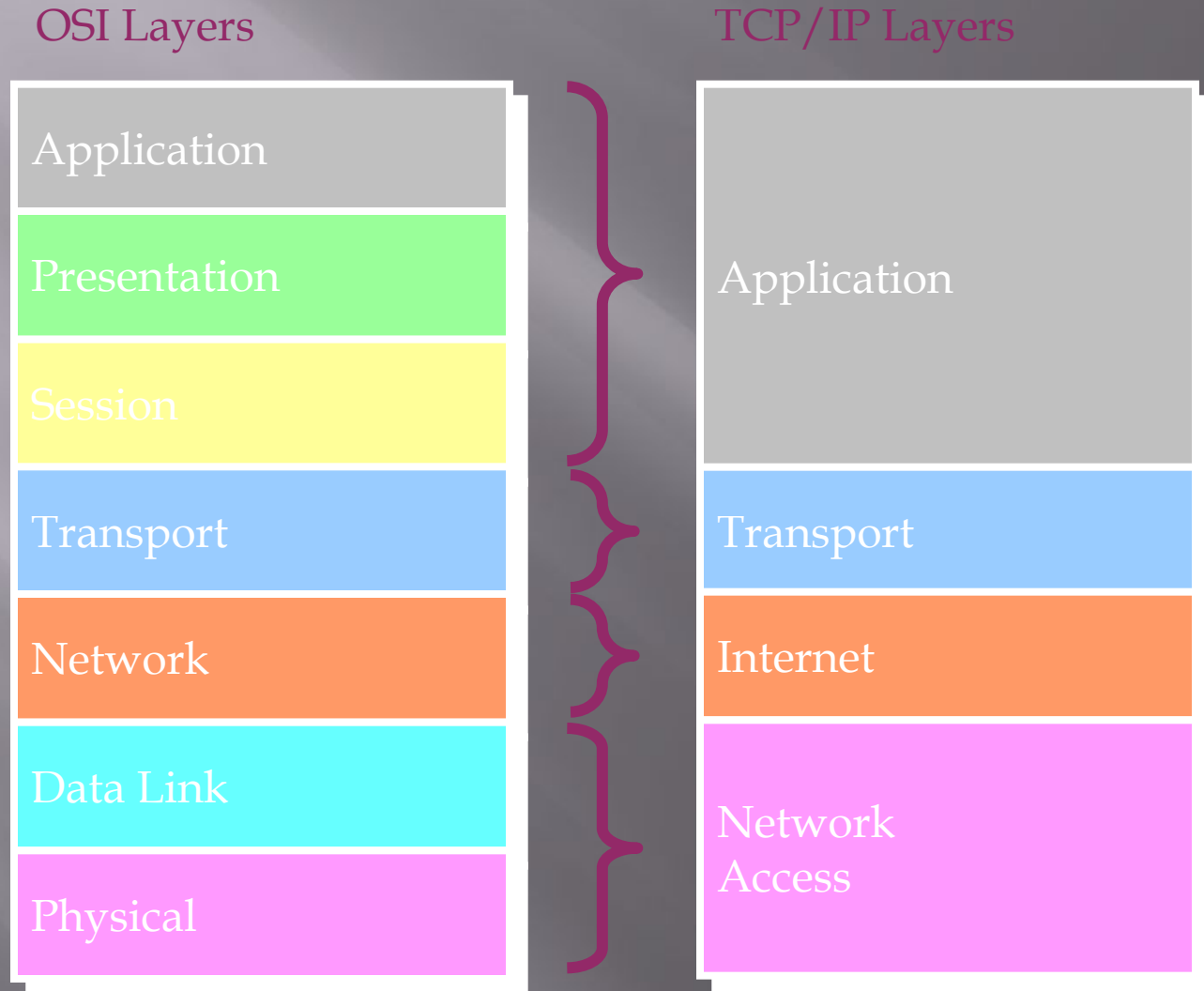
Physical Layer



Physical Layer is responsible for electrical, mechanical or procedural checks. Data will be converted in Binary that is 0's & 1's. Data will be in the form of electrical pulses if it is Coaxial or Twisted Pair cable and in the form of Light if it is Fiber Optic Cable.

Devices working at Physical Layer are Hubs, Repeaters, Cables, Modems etc.

Comparing OSI with TCP/IP Layers



IP ADDRESSING

- IP Addressing is Logical Addressing
- It works on Network Layer (Layer 3)
- Two Version of Addressing Scheme
 - IP version 4 – 32 bit addressing
 - IP version 6 – 128 bit addressing

IP version 4

- What is BIT ?

Bit is a value that will represent 0's or 1's (i.e. Binary)

01010101000001011011111100000001

- 32 bits are divided into 4 Octets known as Dotted Decimal Notation

First Octet	Second Octet	Third Octet	Forth Octet
01010101	00000101	10111111	00000001

IP version 6

- 128-bit address is divided along 16-bit boundaries, and each 16-bit block is converted to a 4-digit hexadecimal number and separated by colons (Colon-Hex Notation)

FEDC:BA98:7654:3210:FEDC:BA98:7654:3210

This discussion is out of the scope of CCNA

Binary to Decimal Conversion

Taking Example for First Octet :

Total 8 bits, Value will be 0's and 1's

i.e. $2^8 = 256$ combination

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

IP Address Classes

- Total IP Addressing Scheme is divided into 5 Classes
 - CLASS A
 - CLASS B
 - CLASS C
 - CLASS D
 - CLASS E
-
- LAN & WAN
- Multicasting & Newsgroups
- Research & Development

Priority Bits Concept

- To identify the range of each class we will be using Priority Bit Concept
- 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

CLASS A Range

For Class A range reserved first bit in first octet, the value of that bit should not change.

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

CLASS B Range

For Class B range reserved first two bit in first octet, the value of that bit should not change.

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

CLASS C Range

For Class C range reserved first three bit in first octet, the value of that bit should not change.

110xxxxx. xxxxxxxxxx. xxxxxxxxxx. xxxxxxxxxx

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

CLASS D Range

For Class D range reserved first four bit in first octet, the value of that bit should not change.

1110xxxx. xxxxxxxxxx. xxxxxxxxxx. xxxxxxxxxx

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

CLASS E Range

For Class E range reserved first four bit in first octet, the value of that bit should not change.

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

Octet Format

- IP address is divided into Network & Host Portion
- CLASS A is written as N.H.H.H
- CLASS B is written as N.N.H.H
- CLASS C is written as N.N.N.H

CLASS A – No. Networks & Host

- 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 Net)
 - = 126 Networks
- No. of Host
 - = $2^{24} - 2$ (-2 is for Network ID & Broadcast)
 - = $16777216 - 2$
 - = 16777214 Hosts/Network

CLASS A
126 Networks
&
16777214 Hosts/Nw

CLASS B – No. Networks & Host

- 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**

CLASS B
16384 Networks
&
65534 Hosts/Nw

CLASS C – No. Networks & Host

- 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**

CLASS C
2097152 Networks
&
254 Hosts/Nw

Network & Broadcast Address

- **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 lie between the Network Address and the Broadcast Address.**
- **Only Valid IP Addresses are assigned to hosts/clients**

Example - Class A

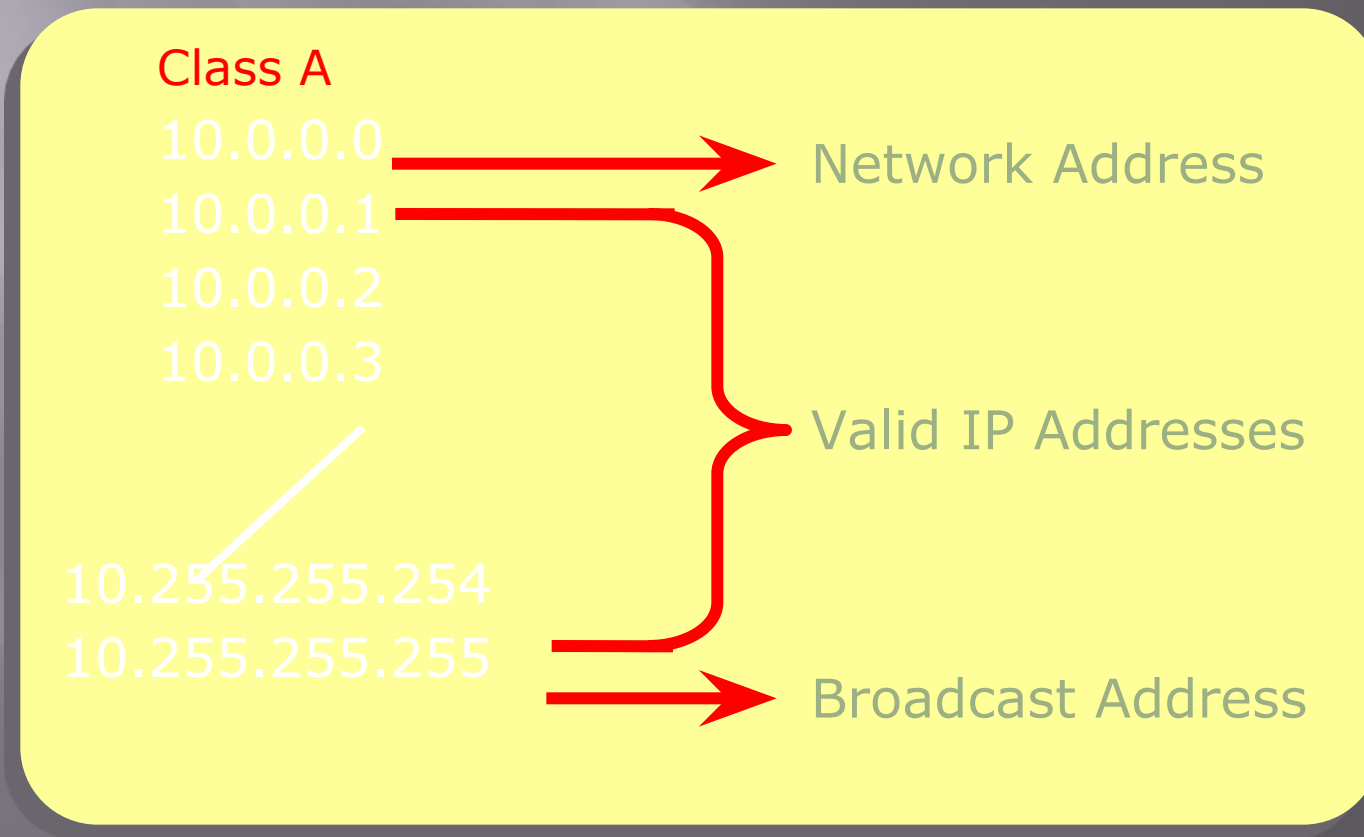
Class A : **N.H.H.H**

Network Address :

0xxxxxxx.00000000.00000000.00000000

Broadcast Address :

0xxxxxxx.11111111.11111111.11111111



Example - Class B

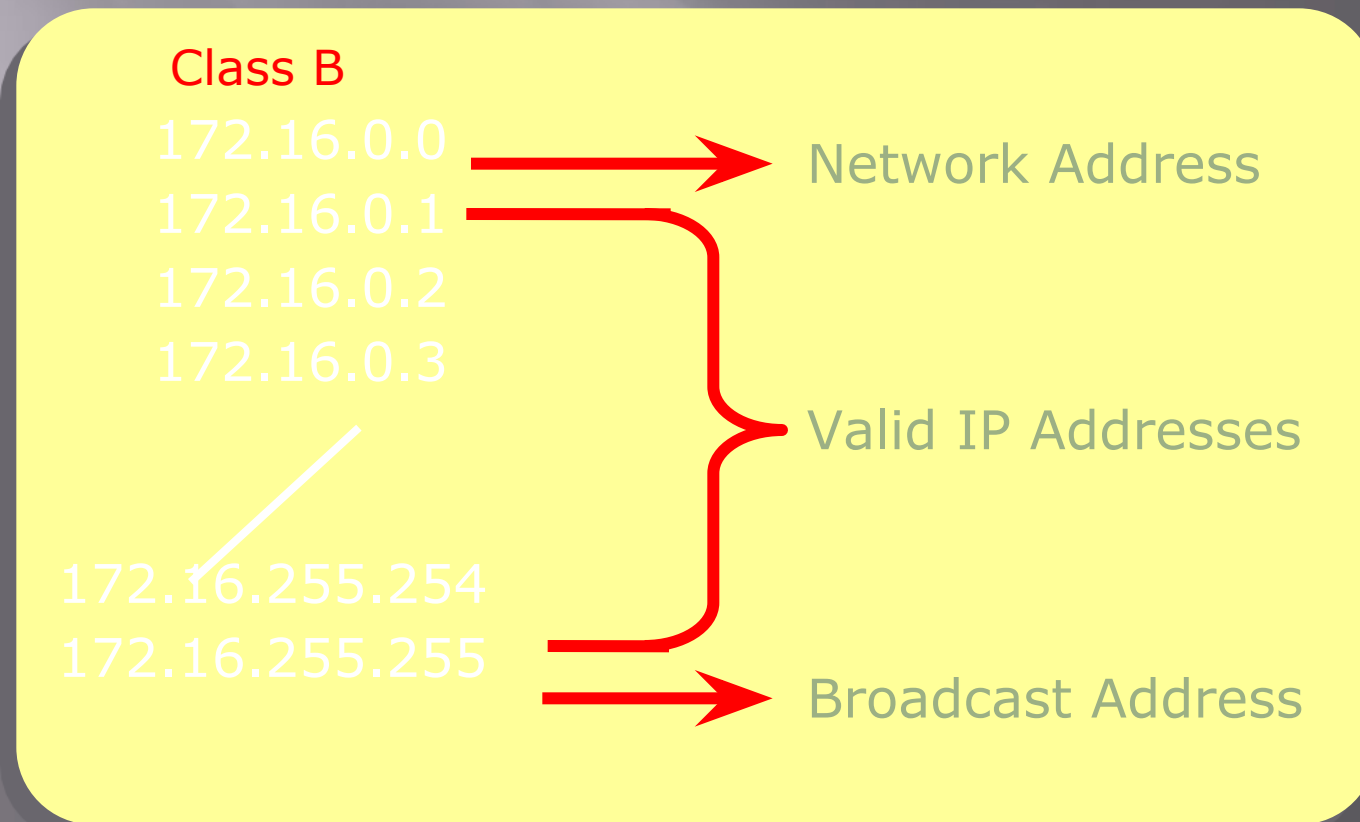
Class B : **N.N.H.H**

Network Address :

10xxxxxx.xxxxxxxx.00000000.00000000

Broadcast Address :

10xxxxxx.xxxxxxxx.11111111.11111111



Example - Class C

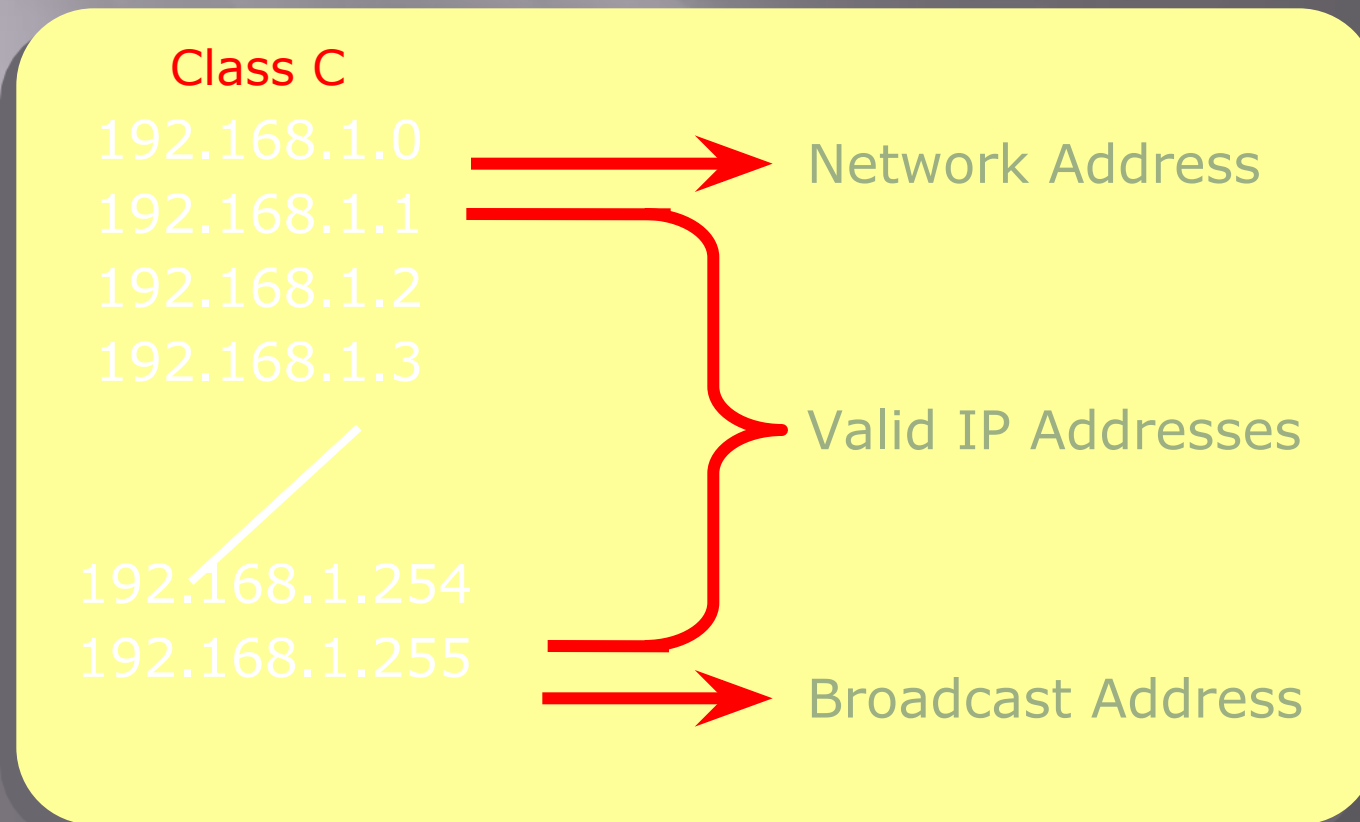
Class C : N.N.N.H

Network Address :

110xxxxx.xxxxxxxxxx.xxxxxxxxxx.00000000

Broadcast Address :

110xxxxx.xxxxxxxxxx.xxxxxxxxxx.11111111



Private Address

- 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, ATM machines, networks not connected to Internet.

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

Subnet Mask

- Subnet Mask differentiates Network portion and Host Portion
- Subnet Mask is been given for host Identification of Network ID
- Represent all Network Bit Values with 1
- Represent all Host Bit Values with 0

Subnet Mask - Examples

Class A : **N.H.H.H**

11111111.00000000.00000000.00000000

Default Subnet Mask for Class A is **255.0.0.0**

Class B : **N.N.H.H**

11111111.11111111.00000000.00000000

Default Subnet Mask for Class B is **255.255.0.0**

Class C : **N.N.N.H**

11111111.11111111.11111111.00000000

Default Subnet Mask for Class C is **255.255.255.0**

How Subnet Mask Works ?

IP Address : 192.168.1.1

Subnet Mask : 255.255.255.0

192.168.1.1 = 11000000.10101000.00000001.00000001

255.255.255.0 = 11111111.11111111.11111111.00000000

=====

192.168.1.0 = 11000000.10101000.00000000.00000000

=====

Above Calculations is done with the Help of AND operation.
The output of an AND table is only 1 if both inputs are 1.
For all other possible inputs the output is 0.

AND TABLE		
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Subnetting

- **Dividing a Single Network into Multiple Networks.**
- **Converting Host bits to Network Bits
i.e. Converting 0's into 1's**
- **Subnetting is also called as FLSM (Fixed Length Subnet Mask)**
- **Subnetting can be done in three ways.**
 - Requirement of Network
 - Requirement of Host
 - Cisco / Notation

Power table

POWER TABLE

$2^1 = 2$	$2^9 = 512$	$2^{17} = 131072$	$2^{25} = 33554432$
$2^2 = 4$	$2^{10} = 1024$	$2^{18} = 262144$	$2^{26} = 67108864$
$2^3 = 8$	$2^{11} = 2048$	$2^{19} = 524288$	$2^{27} = 134217728$
$2^4 = 16$	$2^{12} = 4096$	$2^{20} = 1048576$	$2^{28} = 268435456$
$2^5 = 32$	$2^{13} = 8192$	$2^{21} = 2097152$	$2^{29} = 536870912$
$2^6 = 64$	$2^{14} = 16384$	$2^{22} = 4194304$	$2^{30} = 1073741824$
$2^7 = 128$	$2^{15} = 32768$	$2^{23} = 8388608$	$2^{31} = 2147483648$
$2^8 = 256$	$2^{16} = 65536$	$2^{24} = 16777216$	$2^{32} = 4294967296$

Some Important Values

VALUES IN SUBNET MASK

Bit	Value	Mask
1	128	10000000
2	192	11000000
3	224	11100000
4	240	11110000
5	248	11111000
6	252	11111100
7	254	11111110
8	255	11111111

Requirement of Networks is 5 ?

Example – 1

Class C : N.N.N.H

110xxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx

Class C : 192.168.1.0

- No. of Subnet
 - = $2^n - 2 \geq \text{Req. of Subnet}$
 - = $2^3 - 2 \geq 5$ (-2 is for First & Last Subnet Range)
 - = $8 - 2$
 - = 6 Subnet
- No. of Host
 - = $2^h - 2$ (-2 is for Network ID & Broadcast ID)
 - = $2^5 - 2$
 - = $32 - 2$
 - = 30 Hosts/Subnet

Example – 1 (Continued...)

If you convert 3 Host Bits to Network Bits
6 Subnet & 30 Hosts/Subnet

Customize Subnet Mask
255.255.255.224

Subnet Range

192.168.1.32 to 192.168.1.63 ☐ MCSE .
192.168.1.64 to 192.168.1.95 ☐ CISCO .
192.168.1.96 to 192.168.1.127 ☐ FIREWALL
192.168.1.128 to 192.168.1.159 ☐ SOLARIS
192.168.1.160 to 192.168.1.191 ☐ TRAINING
192.168.1.192 to 192.168.1.223 ☐ Future Use

Requirement of Networks is 14 ?

Example – 2

Class C : N.N.N.H

110xxxxx.xxxxxxxx.xxxxxxxx.xxxxXXXX

Class C : 192.168.1.0

- No. of Subnet
 - = $2^n - 2 \geq \text{Req. of Subnet}$
 - = $2^4 - 2 \geq 14$ (-2 is for First & Last Subnet Range)
 - = $16 - 2$
 - = 14 Subnet
- No. of Host
 - = $2^h - 2$ (-2 is for Network ID & Broadcast ID)
 - = $2^4 - 2$
 - = $16 - 2$
 - = 14 Hosts/Subnet

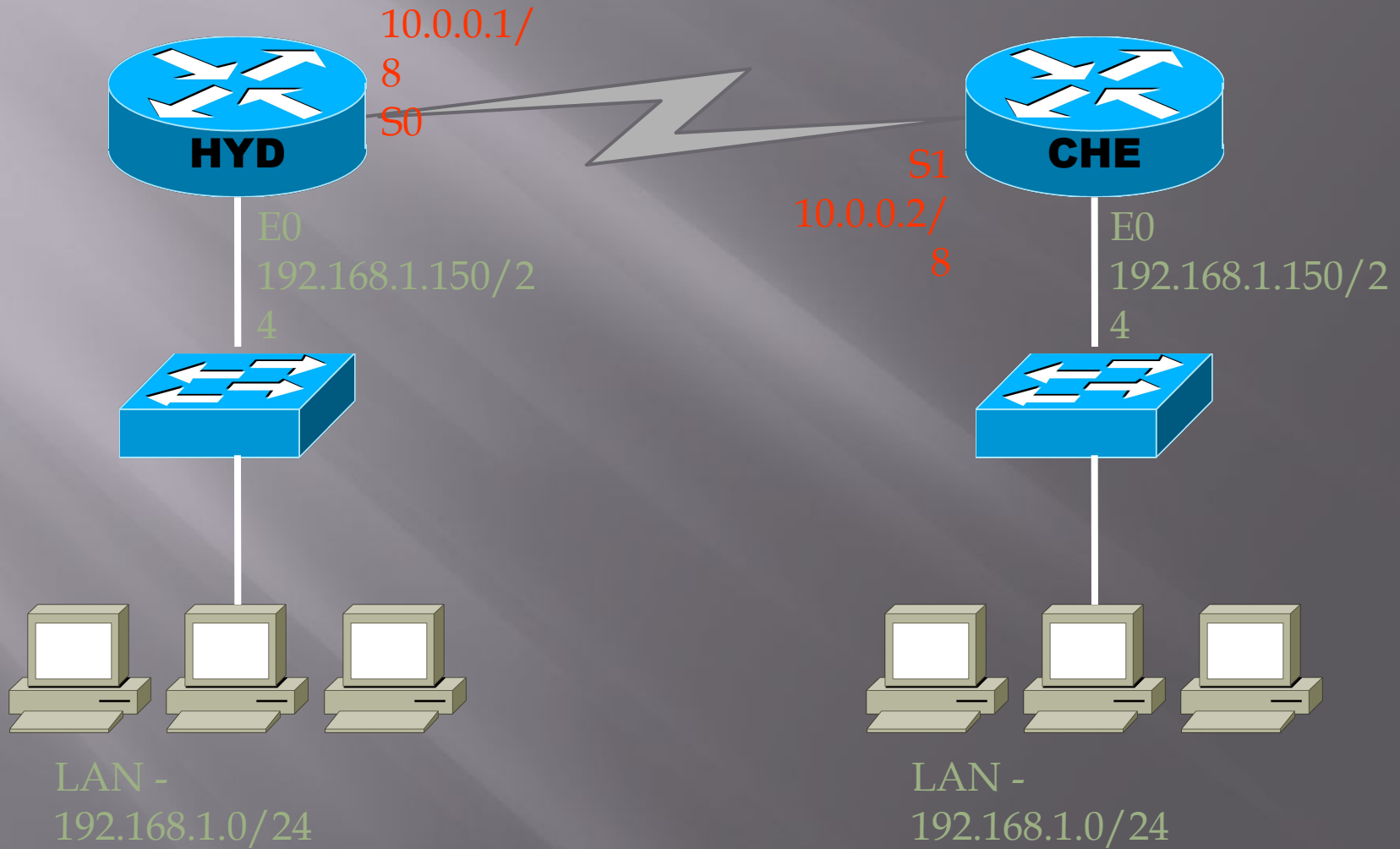
INTERNAL & EXTERNAL OF ROUTERS

What is a Router ?

- Router is device which is used to make communication between two or more different networks which are present in different geographical locations
- If you want to make communication between two or more different networks which are present in the same geographical location, what steps will you do?

Answer : Configure Software Router or you can go with CIDR concept i.e. Change Subnet Mask.

Is communication possible ?



Is communication possible ?

- Can 1.0 network in Hyderabad communicate with 1.0 network in Bombay.

Answer : No

The same networks present in different geographical location cant communicate through a router because If Network ID of both the network is same then it do the searching in the Lan only.

Which Routers to buy ?

Many companies are manufacturing Router :

- ▣ **Cisco**
- ▣ **Nortel**
- ▣ **Multicom**
- ▣ **Cyclades**
- ▣ **Juniper**
- ▣ **Dax**
- ▣ **Dlink**

But Cisco is having monopoly in the market of Routers

Cisco's Hierarchical Design Model

Cisco divided the Router into 3 Layers

- ▣ **Access Layer Router**
- ▣ **Distribution Layer Router**
- ▣ **Core Layer Router**

Access Layer Router

- Routers which are used by the Small Organization and are also known as Desktop or Company Layer Routers.

Router Series : 800, 1000, 1600, 1700, 2500



Cisco 800



Cisco 1700



Cisco 1760

Distribution Layer Router

- Routers which are used by the ISPs and are also known as ISP Layer Routers

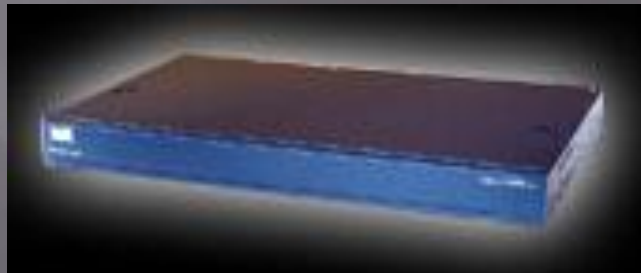
Router Series : 2600, 3200, 3600, 3700



Cisco 3600



Cisco 3700



Cisco 2600XM/2691

Core Layer Router

- Routers which are used by the Global ISPs and are also known as Backbone Routers

Router Series : 6400, 7200, 7300, 7400, 7500, 7600,
10000, 12000



Cisco 7000

Router Classification

FIXED ROUTER

- Fixed Router are just like a branded PC where modification of interfaces is not possible
- Access Layer Routers are example of Fixed Router except 1600 and 1700 series

MODULAR ROUTER

- Modular Router are just like a Assembled PC where modification of interfaces is possible
- Distribution and Core Layer Routers example of Modular Router

Example Modular Router

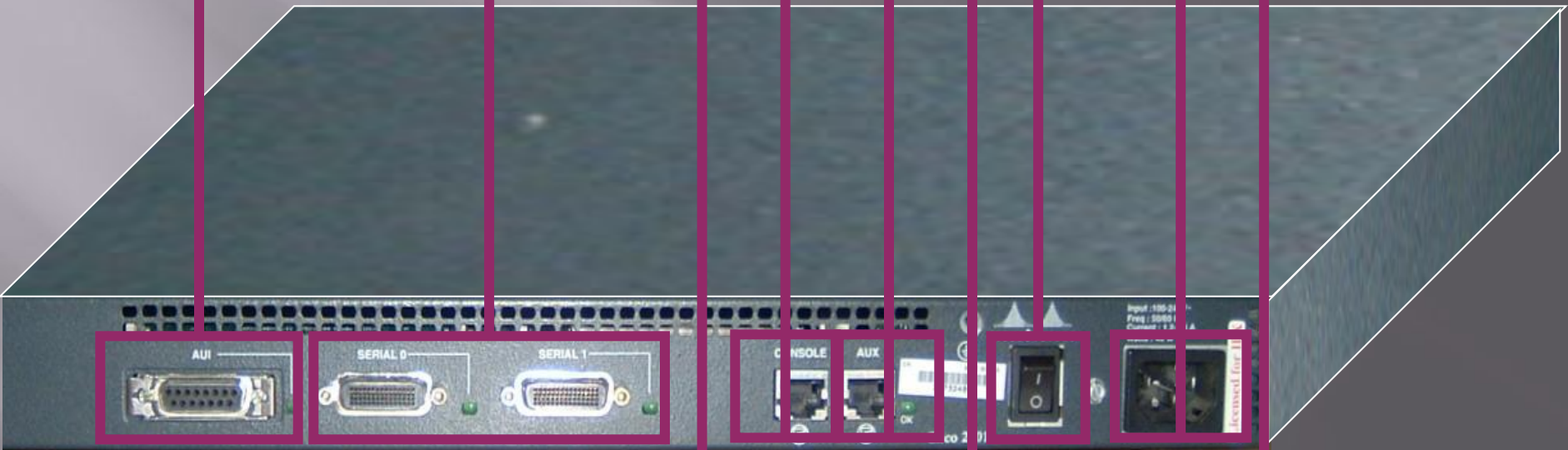


Model 2501

AUI
Attachment
Unit Interface
E0

Serial Ports
S0 and S1

Power Switch



Console
Con 0

Auxiliary
Aux 0

Power
Supply

Attachment Unit Interface

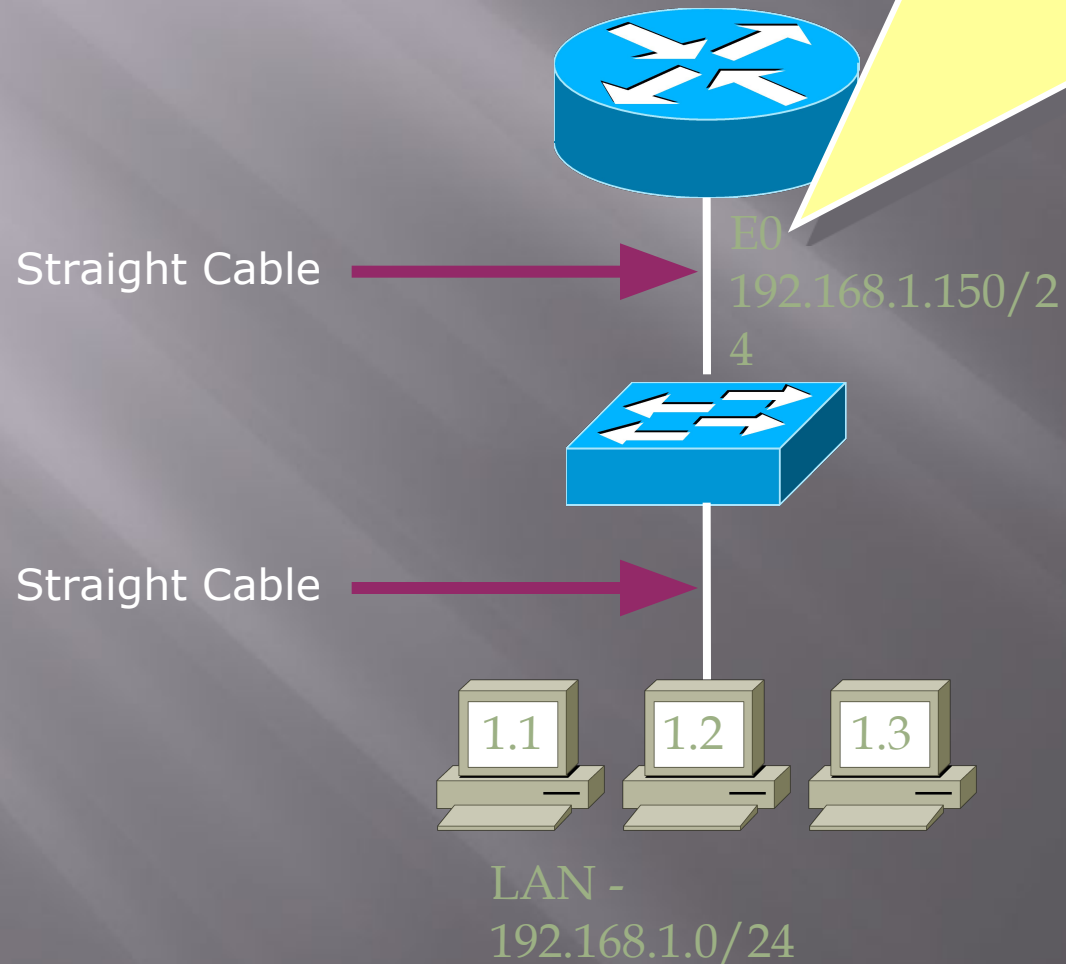
- AUI pin configuration is 15 pin female.
- It is known as Ethernet Port or LAN port or Default Gateway.
- It is used for connecting LAN to the Router.
- Transceiver is used for connection which converts 8 wires to 15 wires. i.e. RJ45 to 15 pin converter.

Transceiver

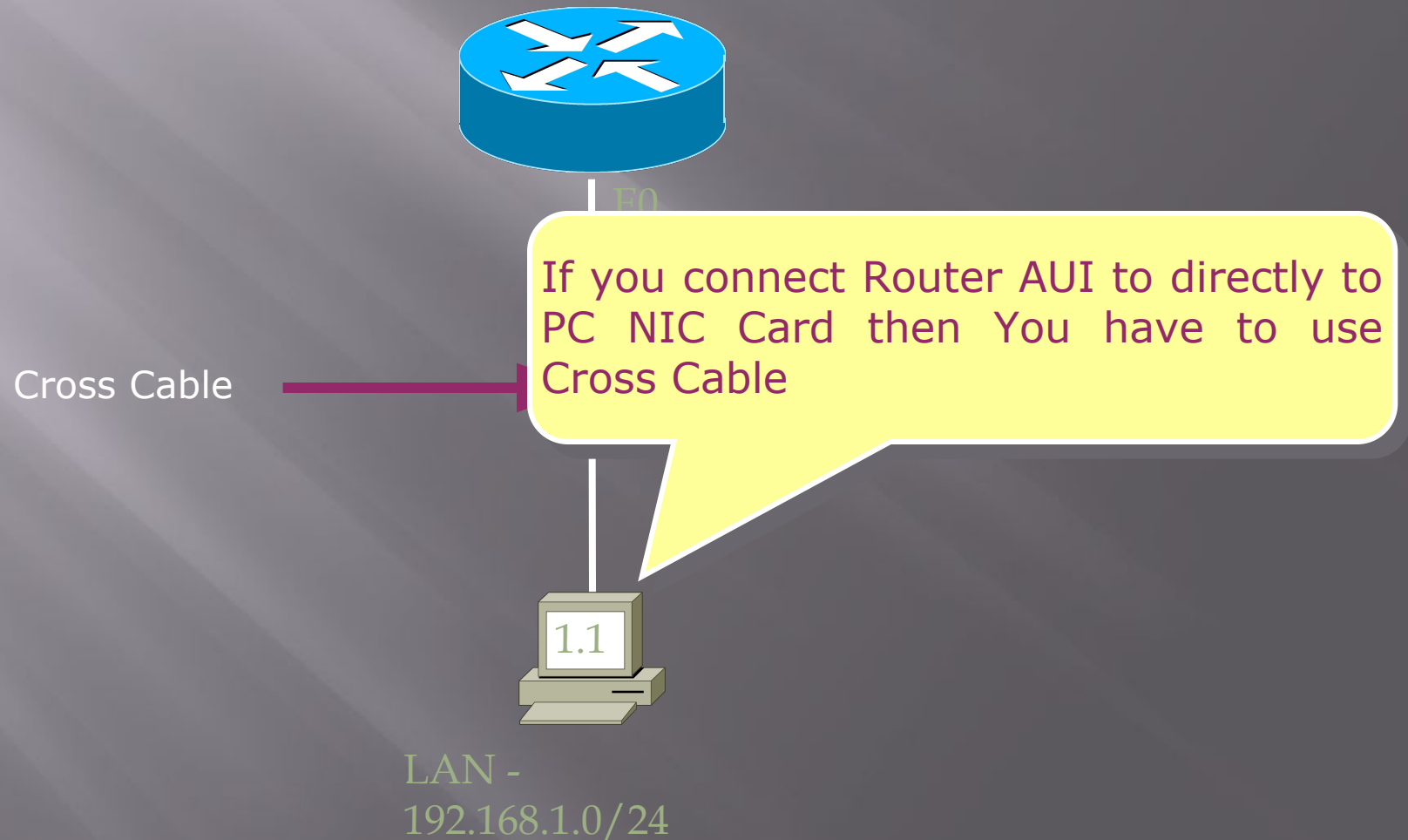


Attachment Unit Interface

An IP address needs to be assigned to this interface and it should be in the same network as of the LAN.



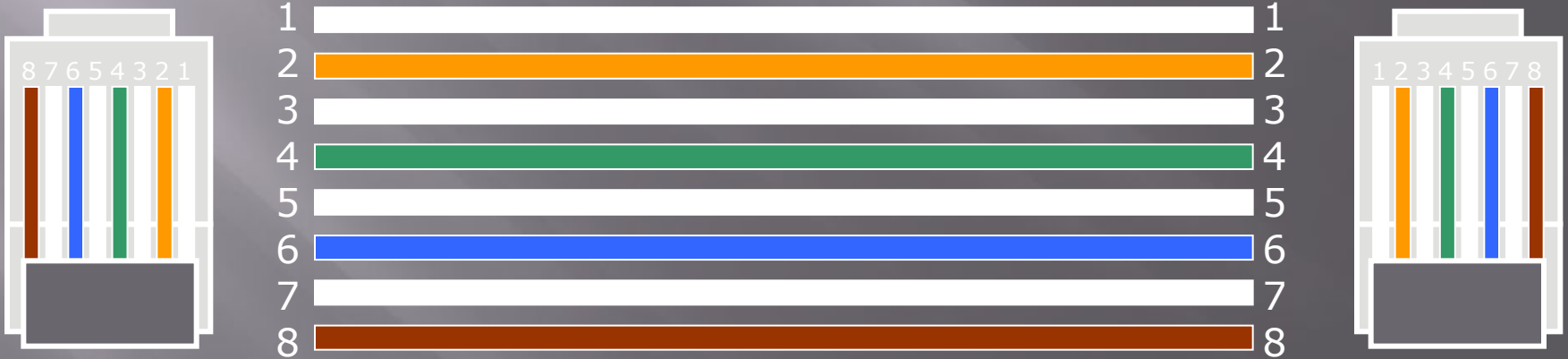
Attachment Unit Interface



Crimping of Twisted pair Cable

- Straight cable

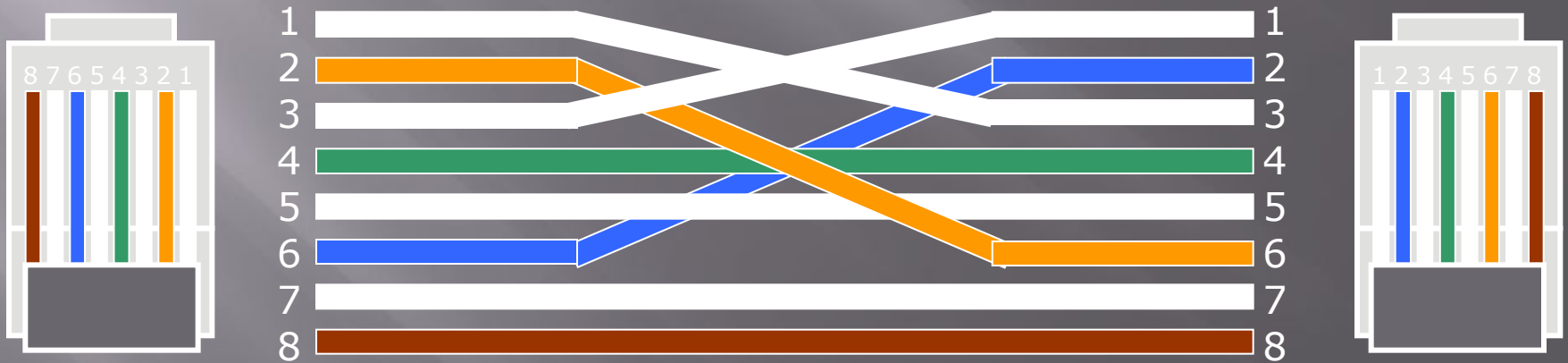
It is used between unlike device (dissimilar devices) e.g.
Hub to PC, Switch to PC, Hub to Router



Crimping of Twisted pair Cable

- Cross cable

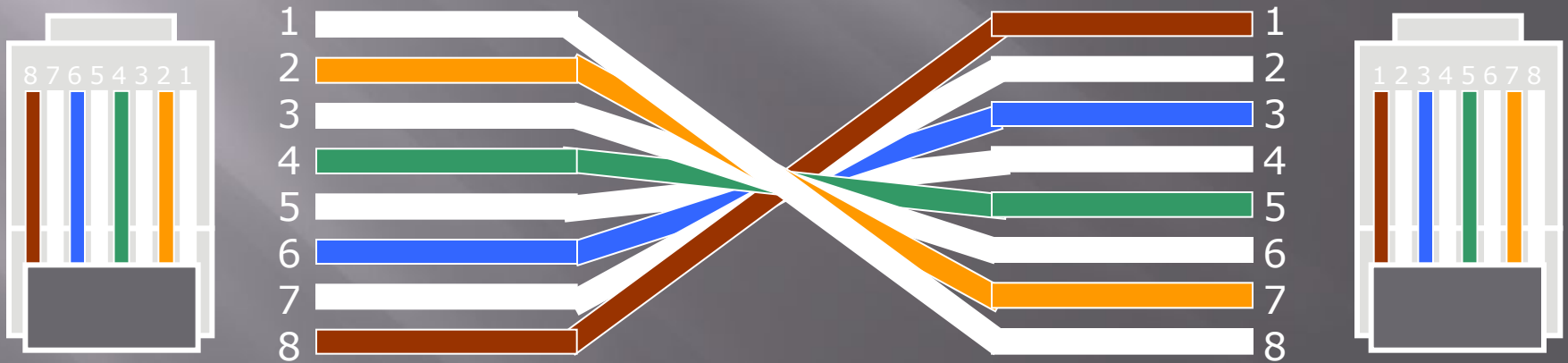
It is used between like device (Similar devices) e.g.
Hub to HUB, PC to PC, Switch to Switch, HUB to Switch,
exception is PC to Router



Crimping of Twisted pair Cable

- Rollover Cable

It is used for connecting Router Console Port to PC Com Ports or Serial ports.

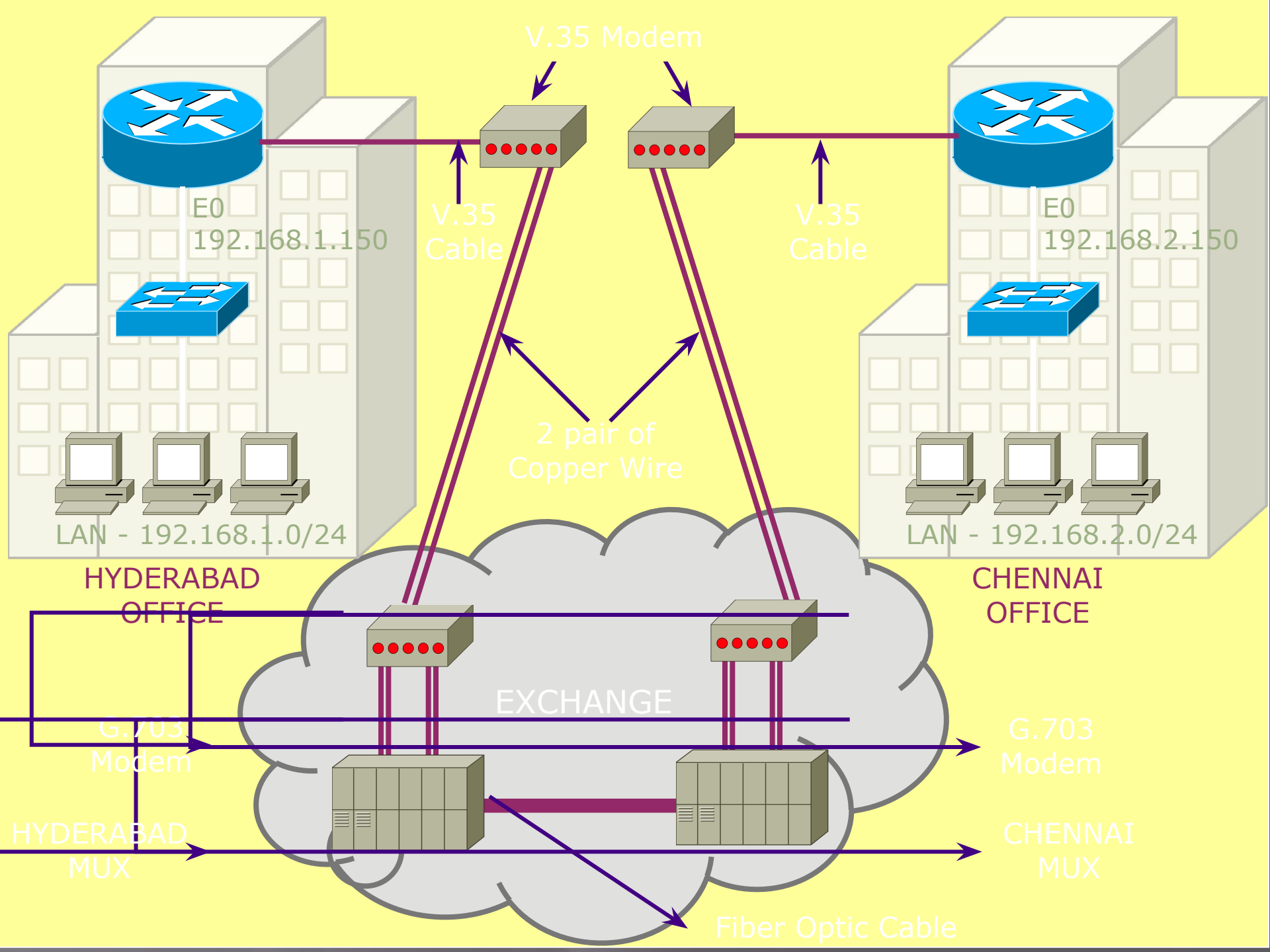


Serial Port

- Serial pin configuration is 60 pin configuration female (i.e. 15 pins and 4 rows) and Smart Serial pin configuration is 26 pin configuration female.
- It is known as WAN Port
- It is used for connecting to Remote Location to the Router.
- V.35 cable is having 60 pin configuration male at one end and on the other end 18 pin configuration male.

V.35 Cable

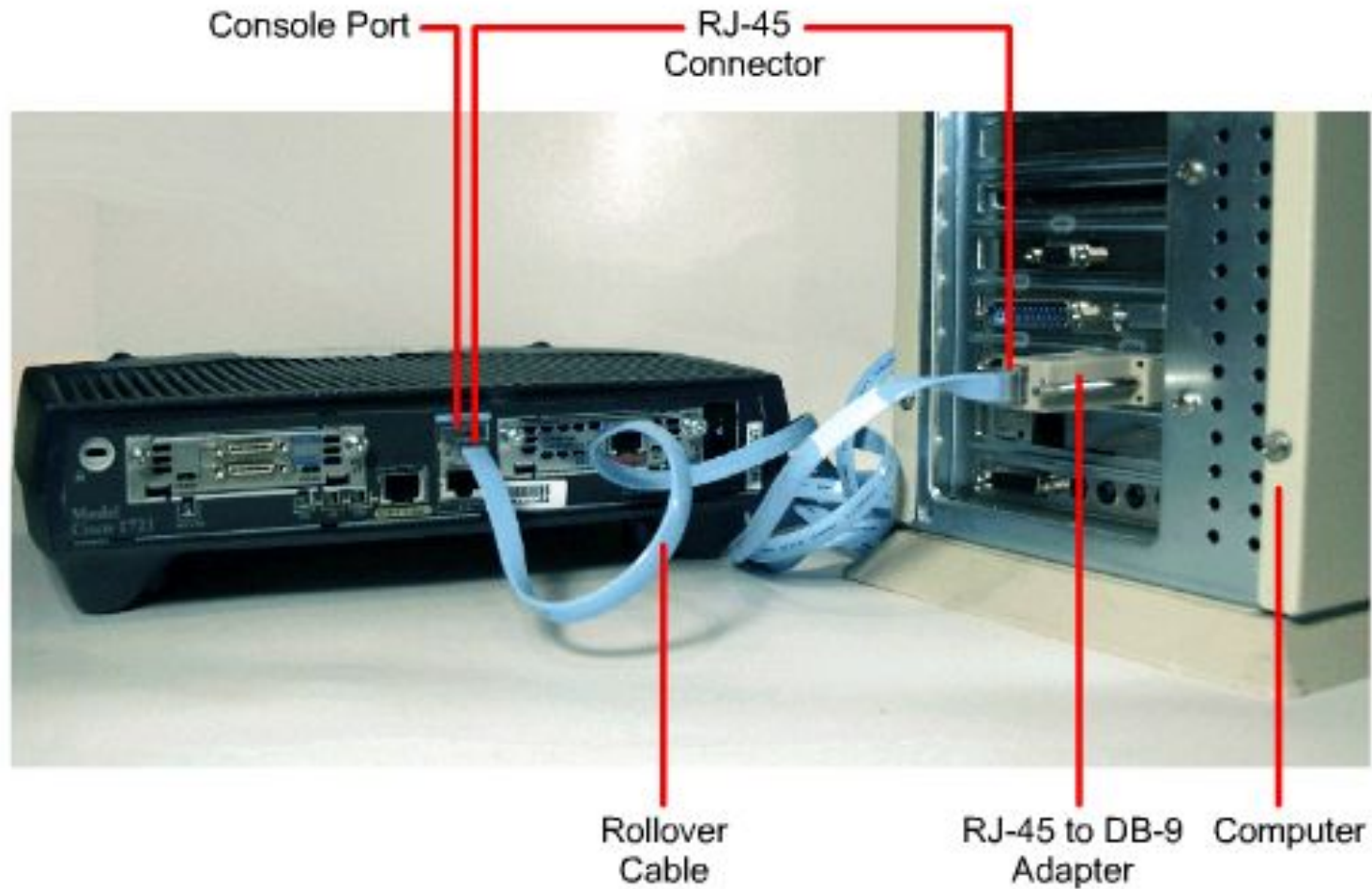




Console Port

- It is known as Local Administrative Port
- It is generally used for Initial Configuration, Password Recovery and Local Administration of the Router. It is RJ45 Port
- IMP : It is the most delicate port on the Router because of it make less use of Console Port.

Console Connectivity



Console Connectivity

- Connect a rollover cable to the router console port (RJ-45 connector).
- Connect the other end of the rollover cable to the RJ-45 to DB-9 adapter
- Attach the female DB-9 adapter to a PC Serial Port.
- Open Emulation Software

DB9 Converter



Other Ports

- **Auxiliary port**

It is known as Remote Administrative Port.

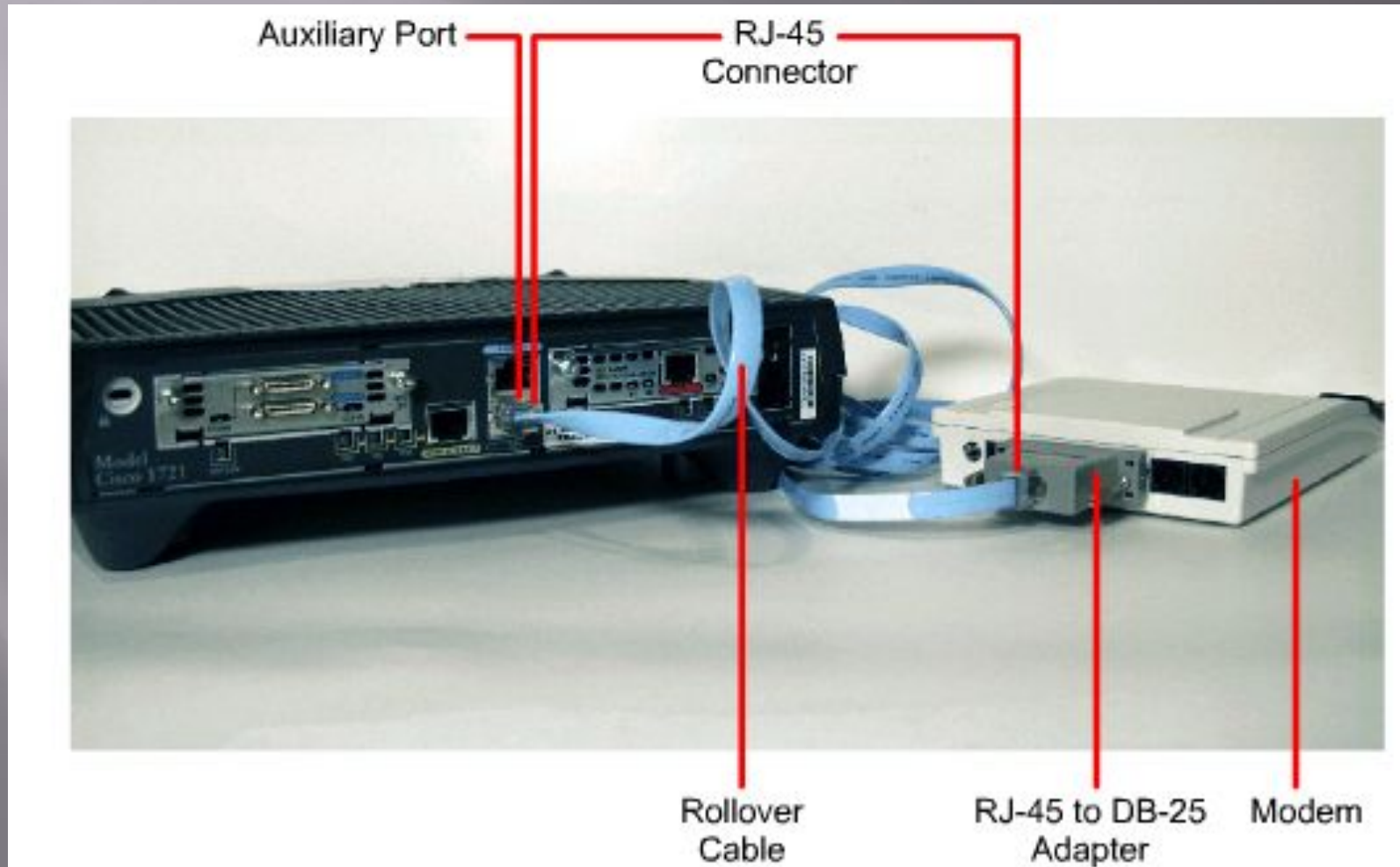
- **BRI Port**

Basic Rate Interface used to connect ISDN to the Router. It is RJ45 Port. It is available on 2503 and 2520 model router.

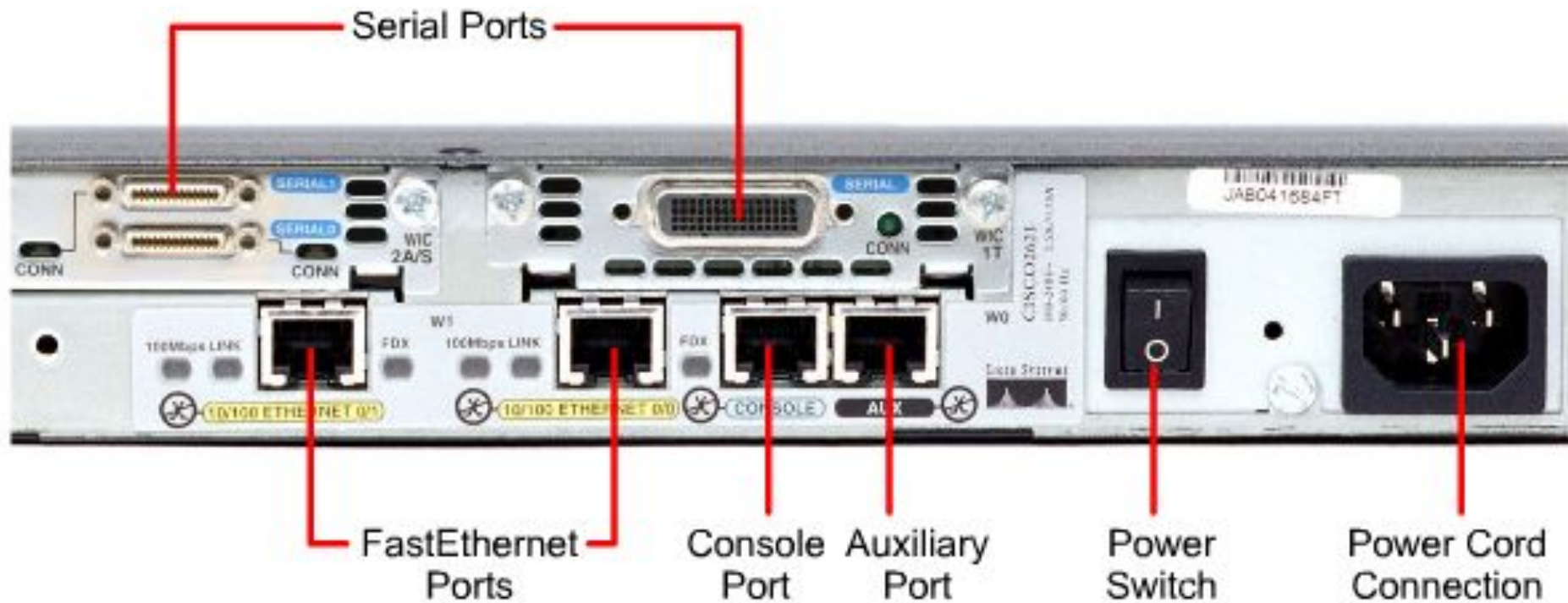
- **10 Base T Port**

It is RJ45 Port and used for connecting LAN to Router. Its job same as AUI Port but here no need for Transceiver. It is available 2520 model router.

Auxiliary Connectivity



2601 Model Router



Brief Overview

- ▣ **WAN interfaces**
 - Serial interface (S0, S1 etc) – 60 pin/26 pin(smart serial)
 - ISDN interface(BRI0 etc) – RJ45

- ▣ **LAN interfaces - Ethernet**
 - AUI (Attachment Unit Interface) (E0)– 15 pin
 - 10bT – RJ45

- ▣ **Administration interfaces**
 - Console – RJ45 - Local
 - Auxiliary – RJ45 - Remote

Internal Components

- ▣ **ROM**

A bootstrap program is located here. It is same as BIOS of the PC. Bootstrap program current version is 11.0

- ▣ **Flash**

Internetwork Operating System (IOS) developed by Cisco is stored here. IOS is Command line interface and current version is 13.0

Internal Components

- ▣ **NVRAM**

Non volatile RAM, similar to Hard Disk

It is also known as Permanent Storage or Startup Configuration. Generally size of NVRAM is 32 KB.

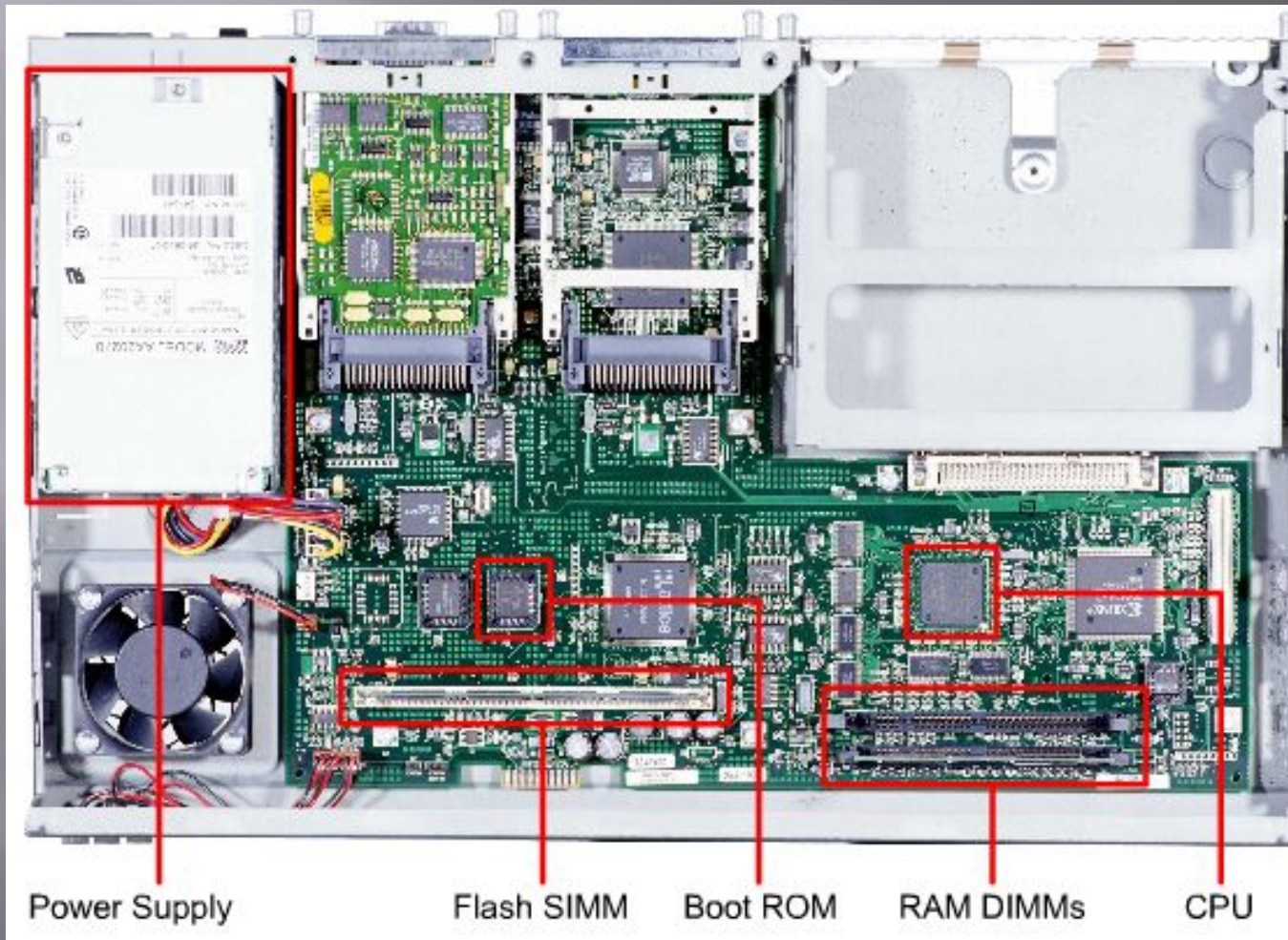
- ▣ **RAM**

It is also known as Temporary Storage or running Configuration. Minimum size of RAM is 2MB. RAM is greater than NVRAM in the Router.

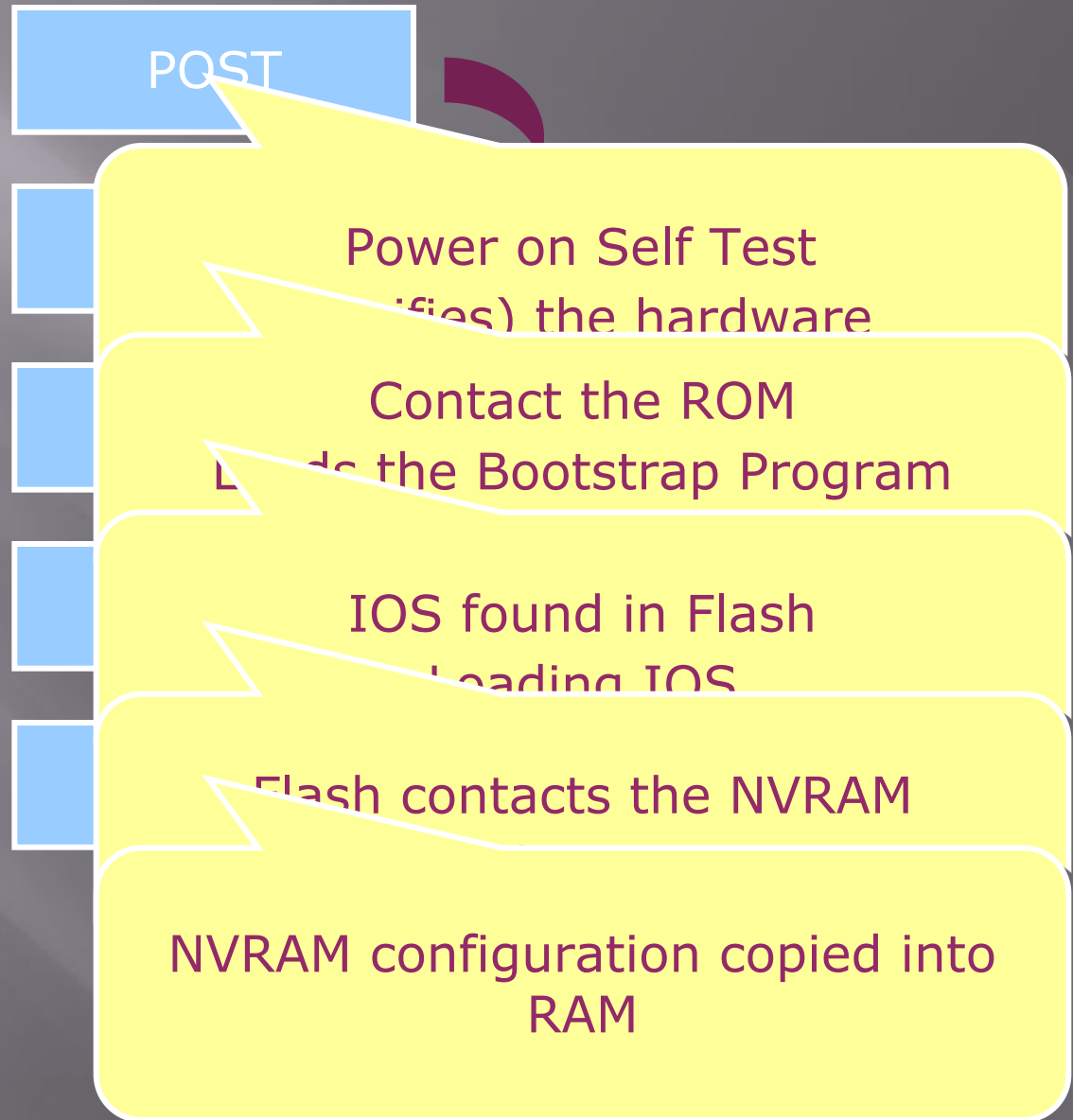
- ▣ **Processor**

Motorola Processor 70 Mhz, RISC based processor

Internal Components

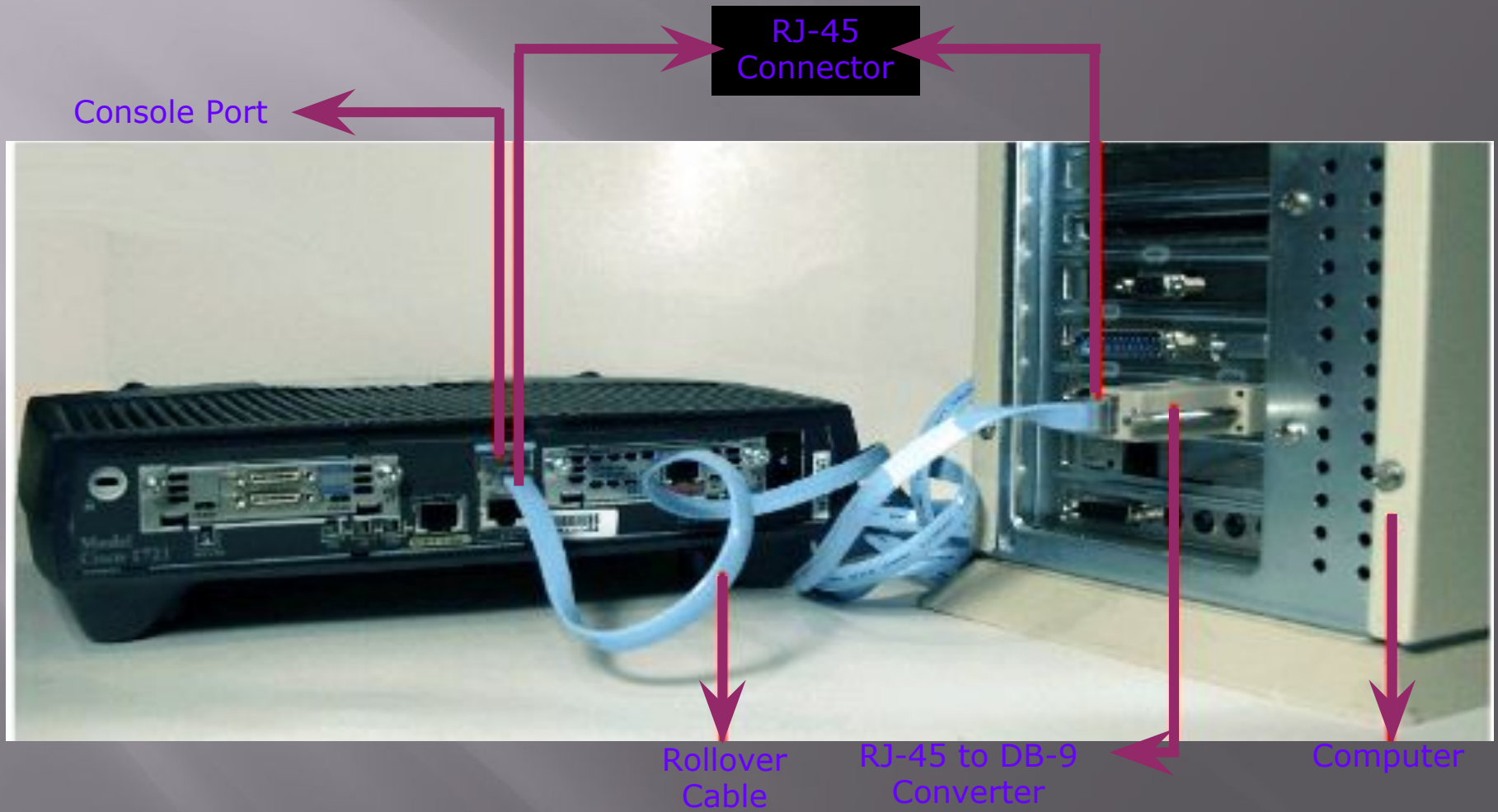


Boot sequence



INITIAL CONFIGURATION

Console Connectivity



Console Connectivity

- Connect a rollover cable to the router console port (RJ-45 connector).
- Connect the other end of the rollover cable to the RJ-45 to DB-9 adapter
- Attach the female DB-9 adapter to a PC Serial Port.
- Open emulation software on the PC.

Emulation Software

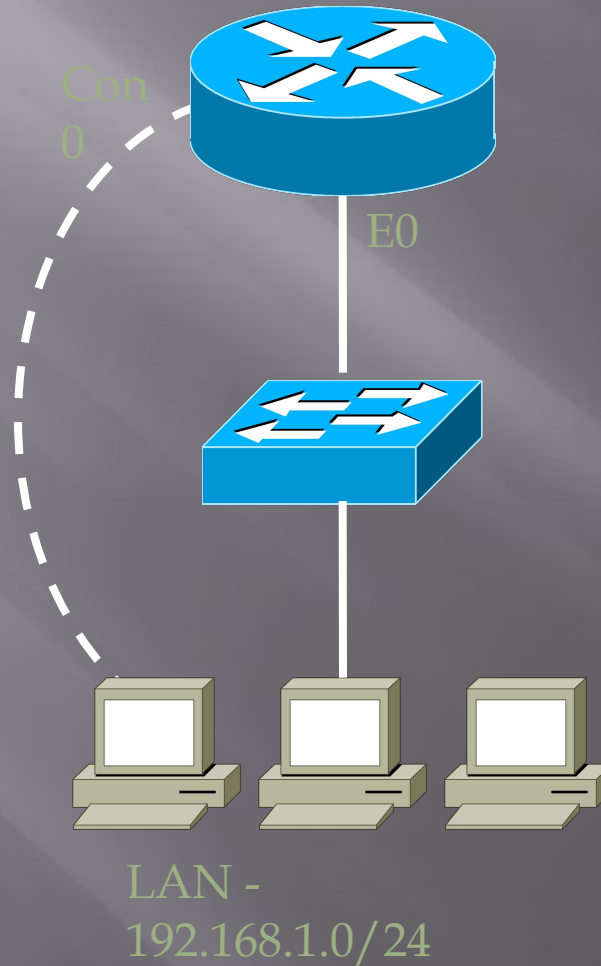
WINDOWS

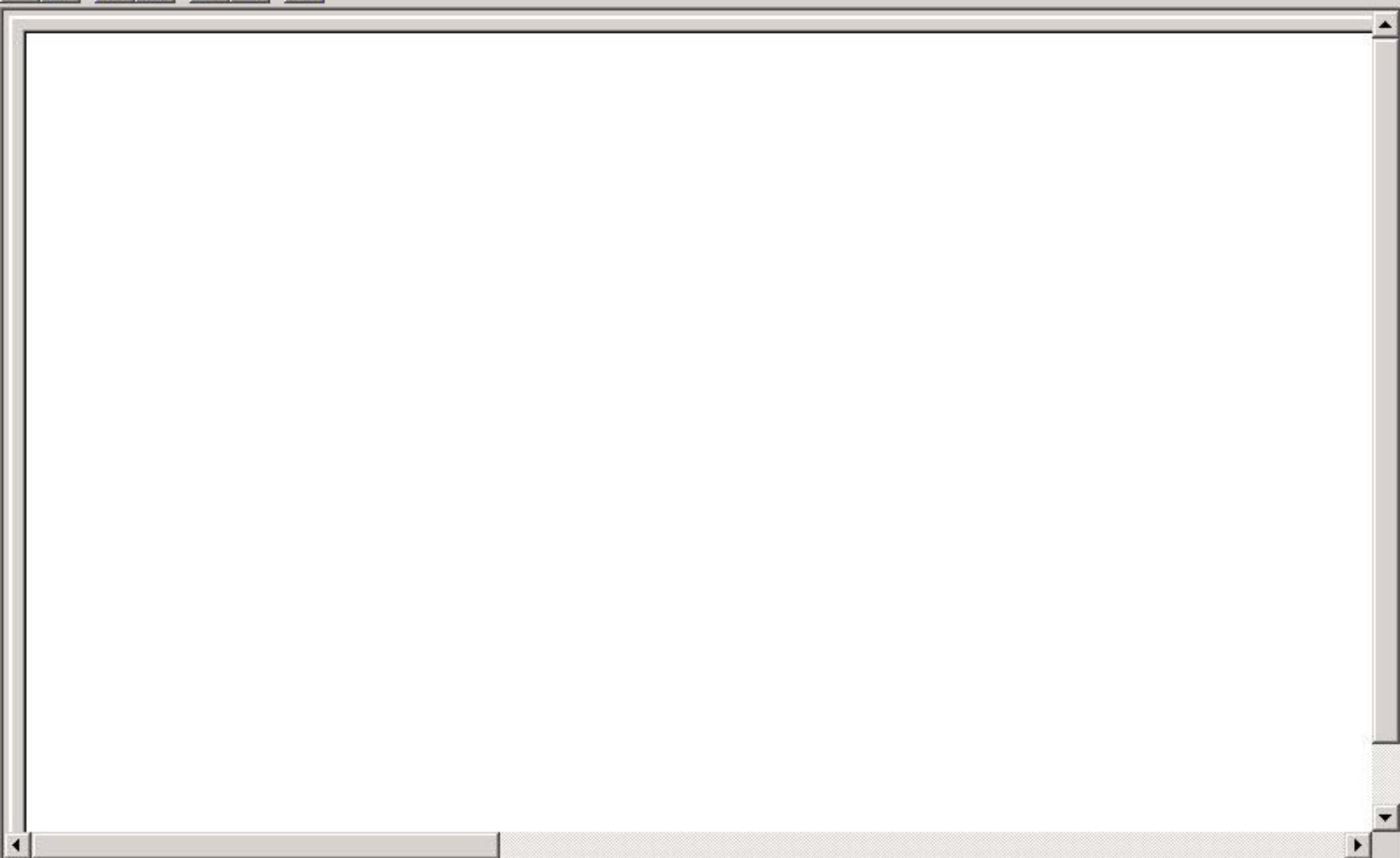
- Start □ Programs □ Accessories □ Communications □ HyperTerminal □ HyperTerminal.
- Give the Connection Name & Select Any Icon
- Select Serial (Com) Port where Router is Connected.
- In Port Settings □ Click on Restore Defaults

LINUX

- # minicom -s

Console Connectivity





Connected 0:01:20

Auto detect

Auto detect

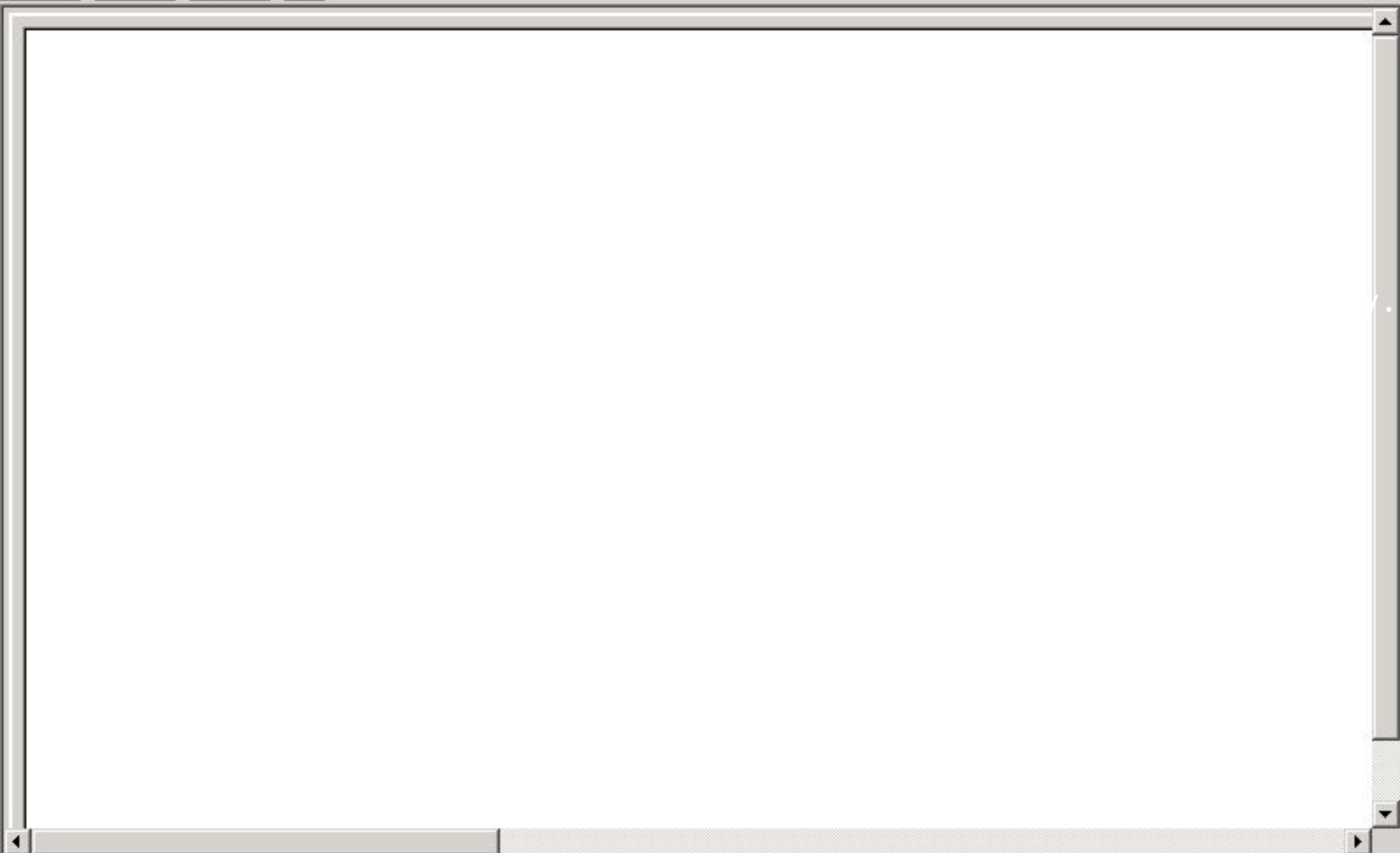
SCROLL

CAPS

NUM

Capture

Print echo



Connected 0:01:20

Auto detect

Auto detect

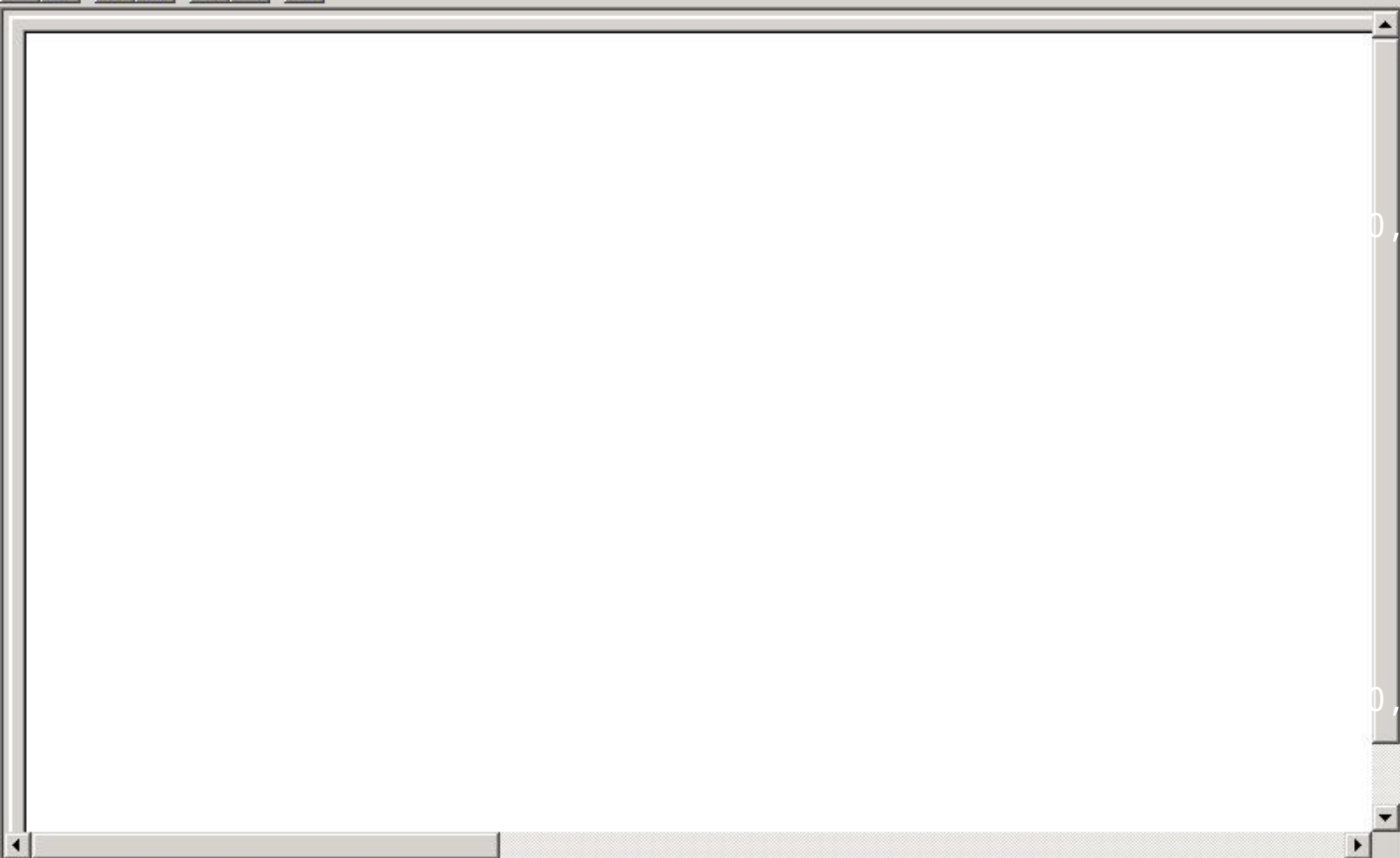
SCROLL

CAPS

NUM

Capture

Print echo



Connected 0:01:20

Auto detect

Auto detect

SCROLL

CAPS

NUM

Capture

Print echo



Setting Telnet password

```
Router(config)# line vty 0 4
```

Setting Console password

```
Router(config)# line con 0
```

```
Router(config-line)# login
```

```
Router(config-line)# password <password>
```

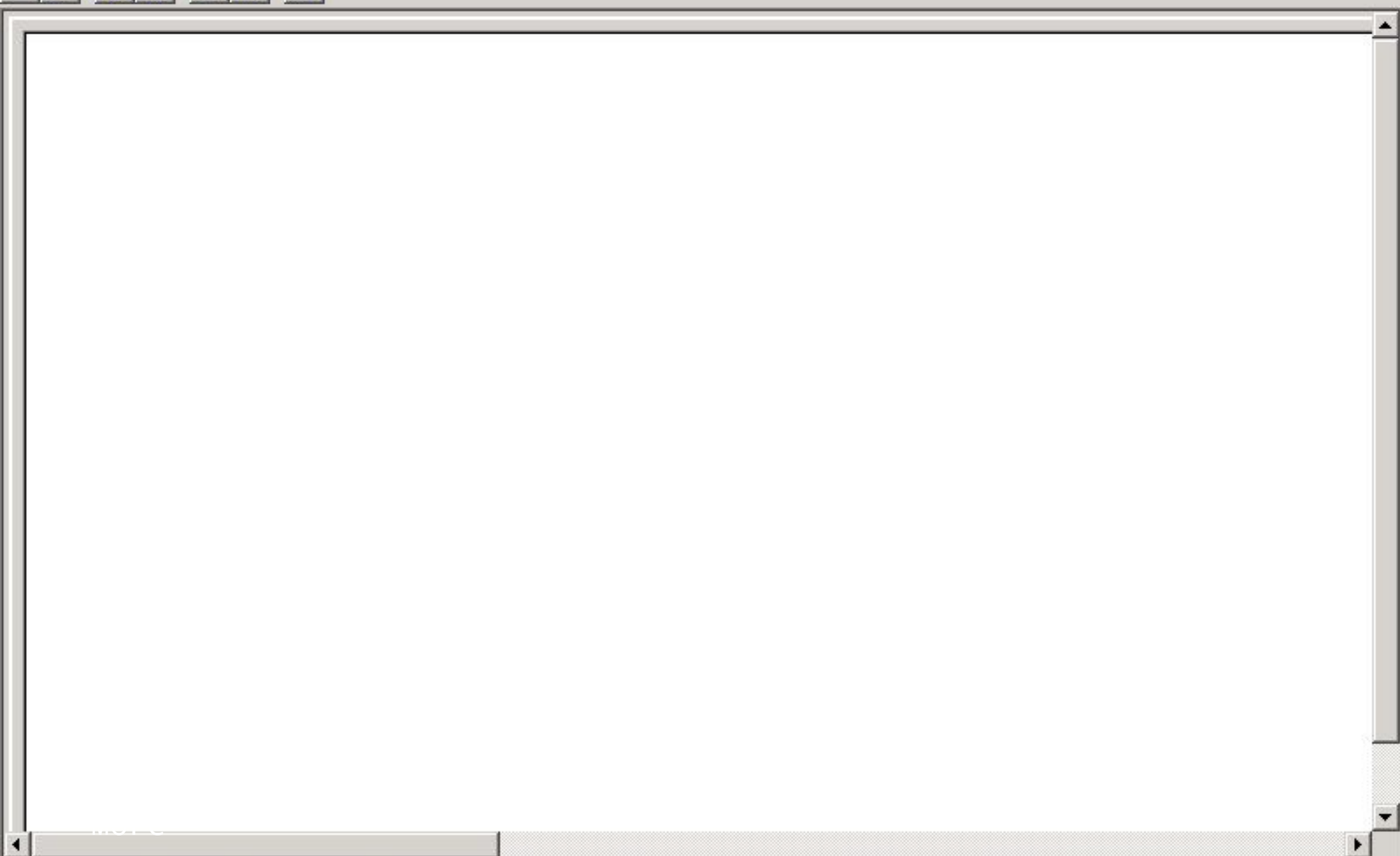
```
ig-line 0 200m  
Router(config)# line con 0  
Router(config-line)# no shutdown
```



Setting the Enable password

```
Router(config)#enable password <password>
```

```
Router(config)#enable secret <password>
```



Connected 0:01:20

Auto detect

Auto detect

SCROLL

CAPS

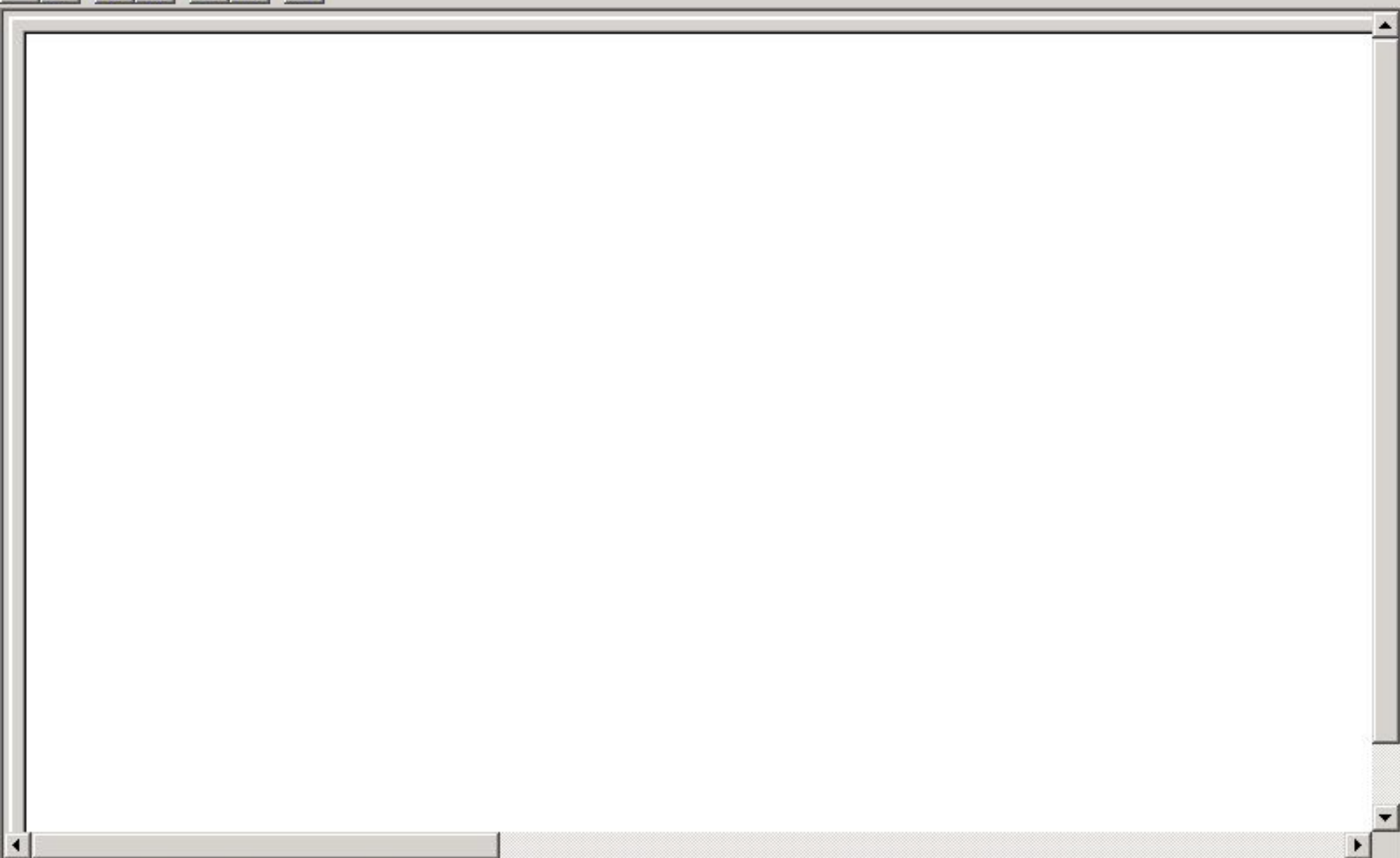
NUM

Capture

Print echo



```
!  
line vty 0  
  login  
  password zoom  
!  
end  
Hyderabad# show version  
Cisco Internetwork Operating System Software  
IOS (tm) 2500 Software (C2500-JS-L), Version 12.1(17), RELEASE SOFTWARE  
Copyright (c) 1986-1999 by cisco Systems, Inc.  
Compiled Mon 04-Jan-99 17:27 by ashah  
Image text-base: 0x03040148, data-base: 0x00001000  
  
ROM: System Bootstrap, Version 11.0(10c), SOFTWARE  
BOOTFLASH: 3000 Bootstrap Software (IGS-BOOT-R), Version 11.0(10c),  
RELEASE SOFTWARE (fc1)  
  
Hyderabad uptime is 1 hour, 28 minutes  
System restarted by power-on  
System image file is "flash:/c2500-ipx-ip.bin", booted via flash  
--More--
```

Connected 0:01:20

Auto detect

Auto detect

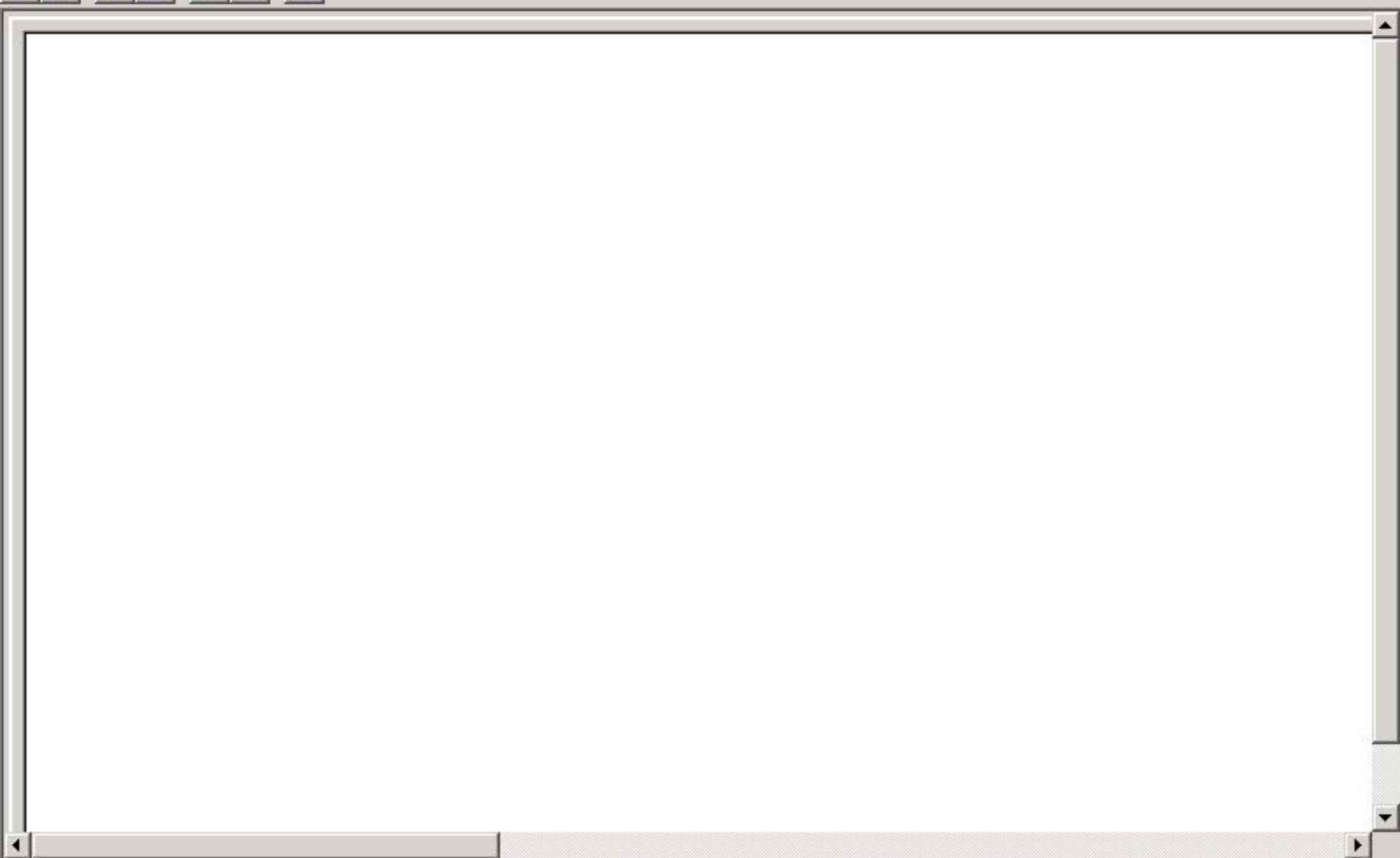
SCROLL

CAPS

NUM

Capture

Print echo



Connected 0:01:20

Auto detect

Auto detect

SCROLL

CAPS

NUM

Capture

Print echo

WAN INTERFACE CONFIGURATION

Encapsulation

PPP

- Point to Point Protocol
- Open Standard Protocol (works with same and different company Routers i.e. Cisco-Nortel, Cisco-Multicom.
- Supports Authentication
- Supports Compression

HDLC

- High level Data link Control
- Vendor proprietary Protocol (works with same company Router only, i.e. Cisco-Cisco, Nortel-Nortel, etc.)
- No Support for Authentication
- No Support for Compression

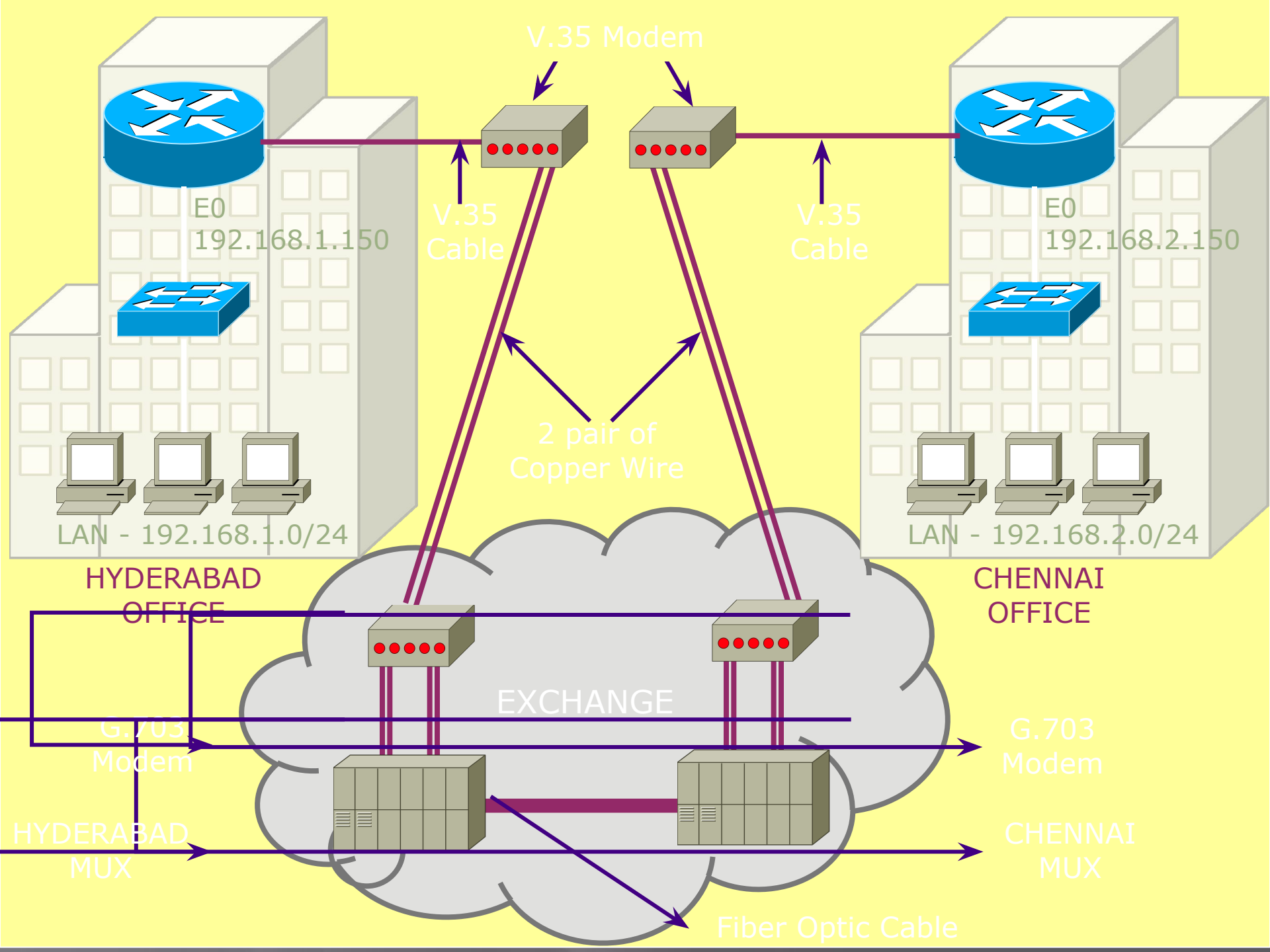
Device Classification

DCE

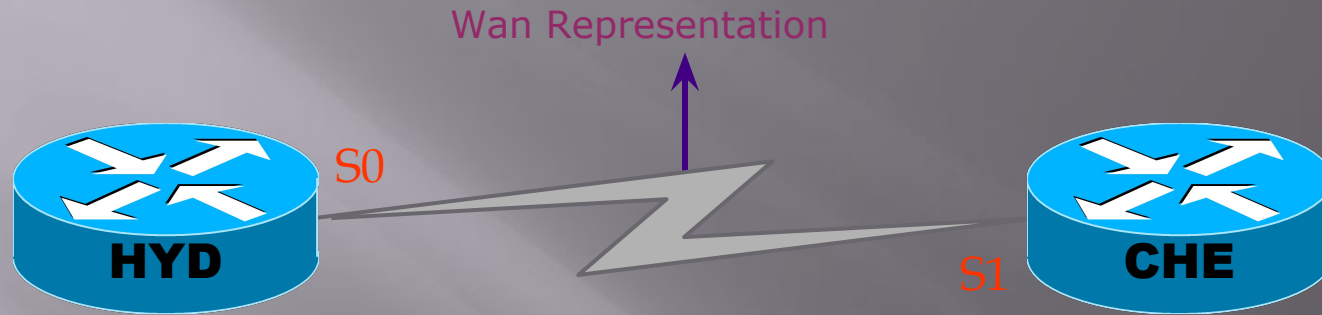
- Data Communication Equipment
- Generate clocking (i.e. Speed).
- Master
- Example of DCE device in Leased line setup : V.35 & G.703 Modem & Exchange (Modem & MUX)
- Example of DCE device in Dial up setup : Dialup Modem

DTE

- Data Termination Equipment
- Accept clocking (i.e. Speed).
- Slave
- Example of DTE device in Leased line setup : Router
- Example of DTE device in Dial up setup : Computer



Lab Setup

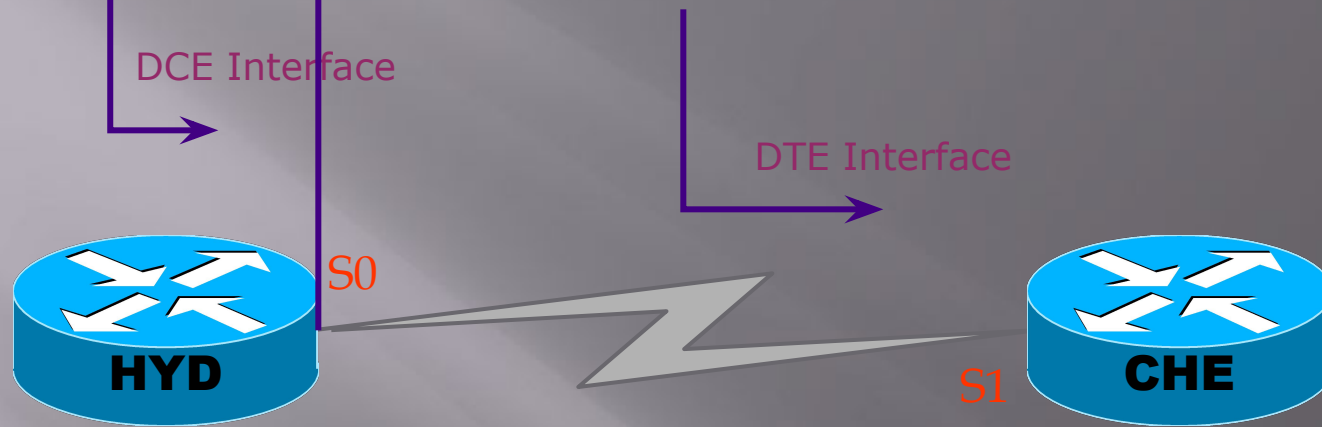


- In the labs we are using Back to Back Cable, this cable emulates copper wire, modems and MUX, i.e. it is acting as Exchange.
- Without DCE & DTE device communication is not possible.

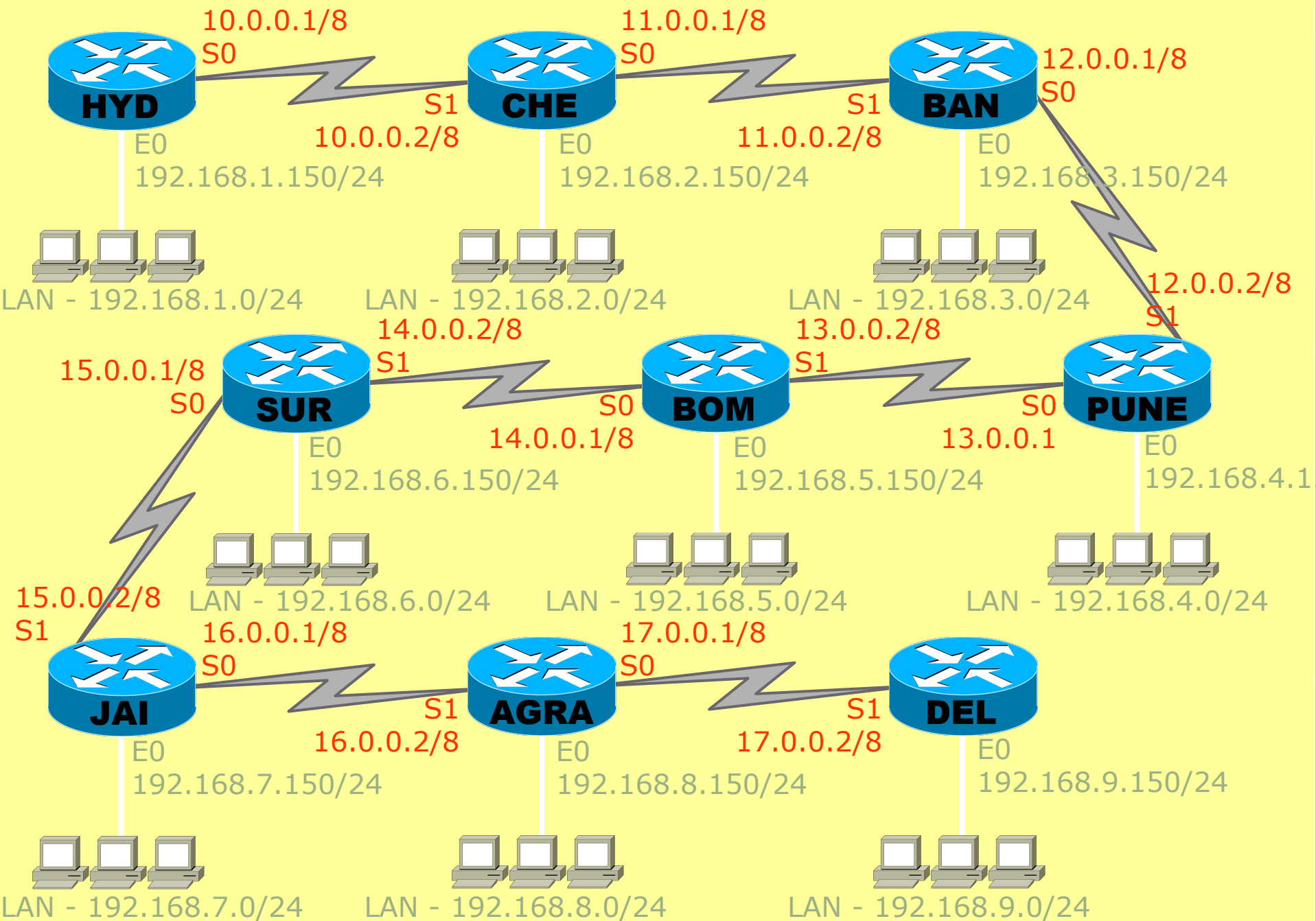
V.35 Back to Back Cable



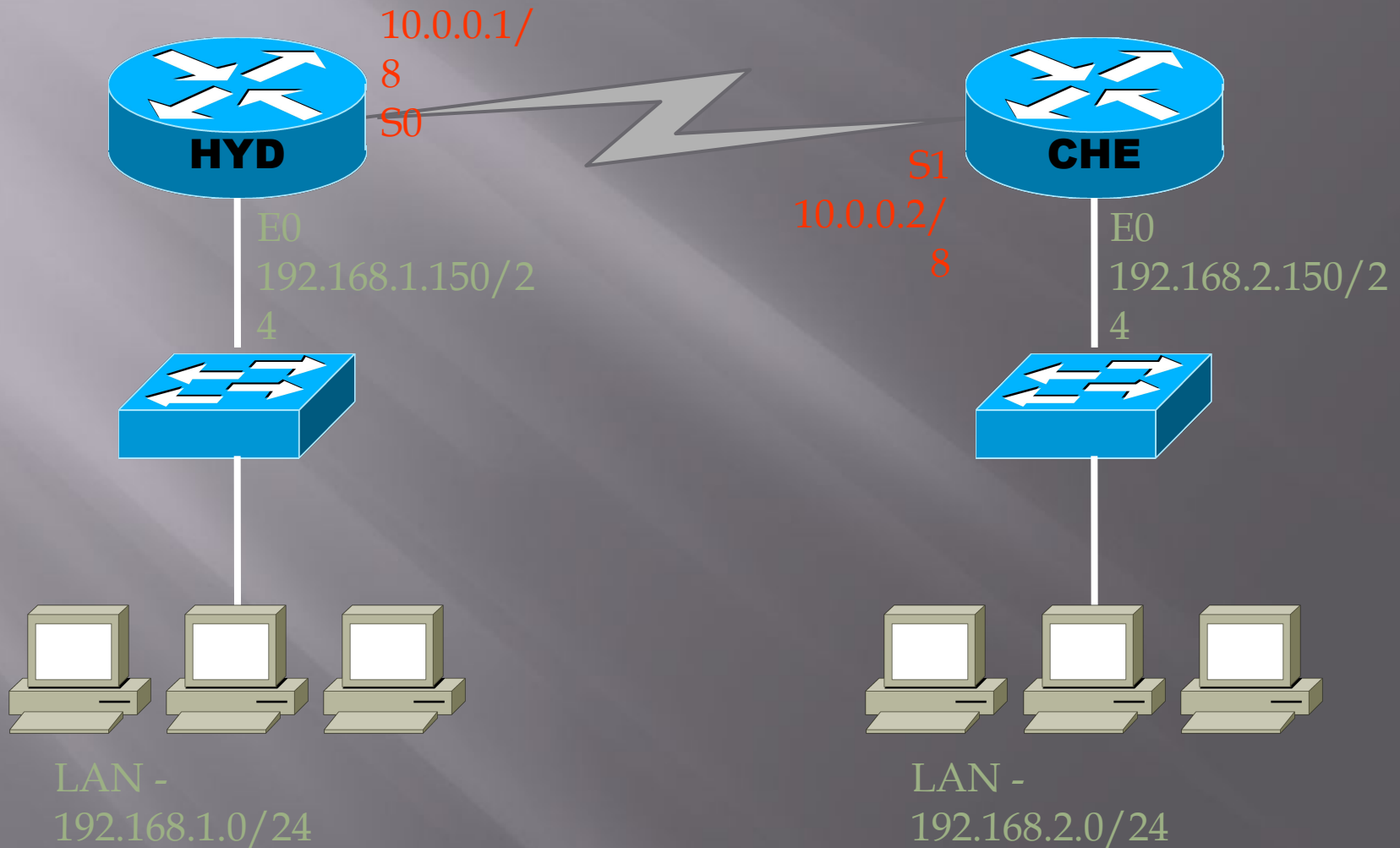
Lab Setup



- In labs Scenario if Exchange is not coming in between the Routers so who will generate clocking ?
Here for Lab Setup we will convert one Router to DCE device which connected to DCE interface.
- How can you tell which end is the DTE and which end is the DCE?
- Look at the label on the cable one will be DCE & one will be DTE. On DCE interface you had to give Clock rate command.



Wan Interface Configuration





Microsoft Windows 2000 [Version 5.00.2195]

(C) Copyright 1985-2000 Microsoft Corp.

C:\> telnet 192.168.1.150

Connecting

=====

Welcome to Hyderabad Router

=====

User Access Verification

password : ****

Hyderabad> enable

password : ****

Hyderabad#show controllers S 0

HD unit 0, idb = 0xB7574, driver structure at 0xBC2F8

buffer size 1524 HD unit 0, V.35 DCE cable

cpb = 0x1, eda = 0x4940, cda = 0x4800

RX ring with 16 entries at 0x4014800

00 bd_ptr=0x4800 pak=0x0BE054 ds=0x401B6A8 status=80 pak_size=0

01 bd_ptr=0x4814 pak=0x0BED04 ds=0x401E5B0 status=80 pak_size=0

02 bd_ptr=0x4828 pak=0x0BE224 ds=0x401BD60 status=80 pak_size=0

03 bd_ptr=0x483C pak=0x0BEED4 ds=0x401EC68 status=80 pak_size=0

--More--

```
04 bd_ptr=0x4850 pak=0x0BEB34 ds=0x401DEF8 status=80 pak_size=0
05 bd_ptr=0x4864 pak=0x0BF0A4 ds=0x401F320 status=80 pak_size=0
06 bd_ptr=0x4878 pak=0x0BDE84 ds=0x401AFF0 status=80 pak_size=0
07 bd_ptr=0x488C pak=0x0BE794 ds=0x401D188 status=80 pak_size=0
08 bd_ptr=0x48A0 pak=0x0BDCB4 ds=0x401A938 status=80 pak_size=0
09 bd_ptr=0x48B4 pak=0x0BE964 ds=0x401D840 status=80 pak_size=0
10 bd_ptr=0x48C8 pak=0x0BE3F4 ds=0x401C418 status=80 pak_size=0
11 bd_ptr=0x48DC pak=0x0BDAE4 ds=0x401A280 status=80 pak_size=0
12 bd_ptr=0x48F0 pak=0x0BD914 ds=0x4019BC8 status=80 pak_size=0
13 bd_ptr=0x4904 pak=0x0BD744 ds=0x4019510 status=80 pak_size=0
14 bd_ptr=0x4918 pak=0x0BD574 ds=0x4018E58 status=80 pak_size=0
15 bd_ptr=0x492C pak=0x0BD3A4 ds=0x40187A0 status=80 pak_size=0
16 bd_ptr=0x4940 pak=0x0BD1D4 ds=0x40180E8 status=80 pak_size=0
cpb = 0x1, eda = 0x5014, cda = 0x5014
TX ring with 2 entries at 0x4015000
00 bd_ptr=0x5000 pak=0x000000 ds=0x4031838 status=80 pak_size=22
01 bd_ptr=0x5014 pak=0x000000 ds=0x000000 status=80 pak_size=0
02 bd_ptr=0x5028 pak=0x000000 ds=0x000000 status=80 pak_size=0
0 missed datagrams, 0 overruns
0 bad datagram encapsulations, 0 memory errors
0 transmitter underruns
0 residual bit errors
Hyderabad#
```

Microsoft Windows 2000 [Version 5.00.2195]

(C) Copyright 1985-2000 Microsoft Corp.

C:\> telnet 192.168.2.150

Connecting

=====

Welcome to Chennai Router

=====

User Access Verification

password : ****

Chennai> enable

password : ****

Chennai#show controllers S 1

HD unit 0, idb = 0xB7574, driver structure at 0xBC2F8

buffer size 1524 HD unit 0, V.35 DTE cable

cpb = 0xE1, eda = 0x4814, cda = 0x4828

RX ring with 16 entries at 0xE14800

00 bd_ptr=0x4800 pak=0x0BEB34 ds=0xE1DEF8 status=80 pak_size=13

01 bd_ptr=0x4814 pak=0x0BF0A4 ds=0xE1F320 status=80 pak_size=13

02 bd_ptr=0x4828 pak=0x0BED04 ds=0xE1E5B0 status=80 pak_size=0

03 bd_ptr=0x483C pak=0x0BE964 ds=0xE1D840 status=80 pak_size=0

--More--

04	bd_ptr=0x4850	pak=0x0BE794	ds=0xE1D188	status=80	pak_size=0
05	bd_ptr=0x4864	pak=0x0BE5C4	ds=0xE1CAD0	status=80	pak_size=0
06	bd_ptr=0x4878	pak=0x0BE3F4	ds=0xE1C418	status=80	pak_size=0
07	bd_ptr=0x488C	pak=0x0BE224	ds=0xE1BD60	status=80	pak_size=0
08	bd_ptr=0x48A0	pak=0x0BE054	ds=0xE1B6A8	status=80	pak_size=0
09	bd_ptr=0x48B4	pak=0x0BDE84	ds=0xE1AFF0	status=80	pak_size=0
10	bd_ptr=0x48C8	pak=0x0BDCB4	ds=0xE1A938	status=80	pak_size=0
11	bd_ptr=0x48DC	pak=0x0BDAE4	ds=0xE1A280	status=80	pak_size=0
12	bd_ptr=0x48F0	pak=0x0BD914	ds=0xE19BC8	status=80	pak_size=0
13	bd_ptr=0x4904	pak=0x0BD744	ds=0xE19510	status=80	pak_size=0
14	bd_ptr=0x4918	pak=0x0BD574	ds=0xE18E58	status=80	pak_size=0
15	bd_ptr=0x492C	pak=0x0BD3A4	ds=0xE187A0	status=80	pak_size=0
16	bd_ptr=0x4940	pak=0x0BD1D4	ds=0xE180E8	status=80	pak_size=0

cpb = 0xE1, eda = 0x5028, cda = 0x5028

TX ring with 2 entries at 0xE15000

00	bd_ptr=0x5000	pak=0x000000	ds=0xE31964	status=80	pak_size=13
01	bd_ptr=0x5014	pak=0x000000	ds=0xE31964	status=80	pak_size=13
02	bd_ptr=0x5028	pak=0x000000	ds=0x000000	status=80	pak_size=0

0 missed datagrams, 0 overruns

0 bad datagram encapsulations, 0 memory errors

0 transmitter underruns

0 residual bit errors

Chennai#

Microsoft Windows 2000 [Version 5.00.2195]

(C) Copyright 1985-2000 Microsoft Corp.

C:\> telnet 192.168.1.150

Connecting

=====

Welcome to Hy

=====

User Access V

password : **

Hyderabad> ena

password : **

Hyderabad# conf t

Enter configuration commands, one per line. End with CNTL/Z.

Hyderabad(config)# interface serial 0

Hyderabad(config-if)# ip address 10.0.0.1 255.0.0.0

Hyderabad(config-if)# no shutdown

Hyderabad(config-if)# clockrate 64000

Hyderabad(config-if)# encapsulation hdlc

Hyderabad(config-if)# exit

Hyderabad(config)#

Configuring Serial interface

Router(config)#interface serial <no>

Router(config-if)#ip address <address> <mask>

Router(config-if)#no shutdown

Router(config-if)#clockrate <clock rate>

Router(config-if)#encapsulation {ppp|hdlc}

Microsoft Windows 2000 [Version 5.00.2195]

(C) Copyright 1985-2000 Microsoft Corp.

C:\> telnet 192.168.2.150

Connecting

=====

Welcome to Chennai

=====

User Access Verification

password : ****

Chennai> enable

password : ****

Chennai# configure terminal

Enter configuration commands, one per line. End with CNTL/Z.

Chennai(config)# interface serial 1

Chennai(config-if)# ip address 10.0.0.2 255.0.0.0

Chennai(config-if)# no shutdown

Chennai(config-if)# encapsulation hdslc

Chennai(config-if)# exit

Chennai(config)#

Configuring Serial interface

Router(config)#interface serial <no>

Router(config-if)#ip address <address> <mask>

Router(config-if)#no shutdown

Router(config-if)#clockrate <clock rate>

Router(config-if)#encapsulation {ppp|hdlc}

Microsoft Windows 2000 [Version 5.00.2195]

(C) Copyright 1985-2000 Microsoft Corp.

C:\> telnet 192.168.1.150

Connecting

=====

Welcome to Hyderabad Router

=====

User Access Verification

password : ****

Hyderabad> enable

password : ****

Hyderabad#configure terminal

Enter configuration commands, one per line. End with CNTL/Z.

Hyderabad(config)# interface serial 0

Hyderabad(config-if)# ip address 10.0.0.1 255.0.0.0

Hyderabad(config-if)# no shutdown

Hyderabad(config-if)# clockrate 64000

Hyderabad(config-if)# encapsulation hdlc

Hyderabad(config-if)# exit

Hyderabad(config)# exit

Hyderabad# show int s0

```
Serial0 is up, line protocol is up
Hardware is HD64570
Internet address is 10.0.0.1/8
MTU 1500 bytes,BW 1544 Kbit,DLY 20000 usec,rely 255/255,load 1/255
Encapsulation HDLC, loopback not set, keepalive set (10 sec)
Last input 00:05:29, output 00:00:03, output hang never
Last clearing of "show interface" counters never
Input queue: 0/75/0 (size/max/drops); Total output drops: 0
```

Serial0 is up, line protocol is up

Implies, all configurations and the connectivity are fine.

```
0 output errors, 0 collisions, 132 interface resets
0 output buffer failures, 0 output buffers swapped out
325 carrier transitions
DCD=up DSR=up DTR=up RTS=up CTS=up
```

Hyderabad# show int s0

```
Serial0 is administratively down, line protocol is down
Hardware is HD64570
Internet address is 10.0.0.1/8
MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec, rely 255/255, load 1/255
Encapsulation HDLC, loopback not set, keepalive set (10 sec)
Last input 00:01:27, output 00:01:20, output hang never
Last clearing of "show interface" counters never
Input queue: 0/75/0 (size/max/drops); Total output drops: 0
```

Serial0 is administratively down, line protocol is down

Implies, No Shut (Layer1 command) has not been given on
the local routers interface.

```
0 output errors, 0 collisions, 131 interface resets
0 output buffer failures, 0 output buffers swapped out
325 carrier transitions
DCD=up DSR=up DTR=down RTS=down CTS=up
```

```
Hyderabad# show int s0
```

```
Serial0 is up, line protocol is down
Hardware is HD64570
Internet address is 10.0.0.1/8
MTU 1500 bytes,BW 1544 Kbit,DLY 20000 usec,rely 255/255,load 1/255
Encapsulation HDLC, loopback not set, keepalive set (10 sec)
Last input 00:07:56, output 00:00:05, output hang never
Last clearing of "show interface" counters never
Input queue: 0/75/0 (size/max/drops); Total output drops: 0
```

Serial0 is up, line protocol is down

Implies , Encapsulation or Clock Rate (Layer2 commands)

have not been given or encapsulation on both the routers are different.

```
0 output errors, 0 collisions, 138 interface resets
0 output buffer failures, 0 output buffers swapped out
341 carrier transitions
DCD=up DSR=up DTR=up RTS=up CTS=up
```

```
Hyderabad# show int s0
```



```
Serial0 is down, line protocol is down
Hardware is HD64570
Internet address is 10.0.0.1/8
MTU 1500 bytes,BW 1544 Kbit,DLY 20000 usec,rely 255/255,load 1/255
Encapsulation HDLC, loopback not set, keepalive set (10 sec)
Last input 00:12:40, output 00:00:08, output hang never
Last clearing of "show interface" counters never
Input queue: 0/75/0 (size/max/drops); Total output drops: 0
```

Serial0 is down, line protocol is down

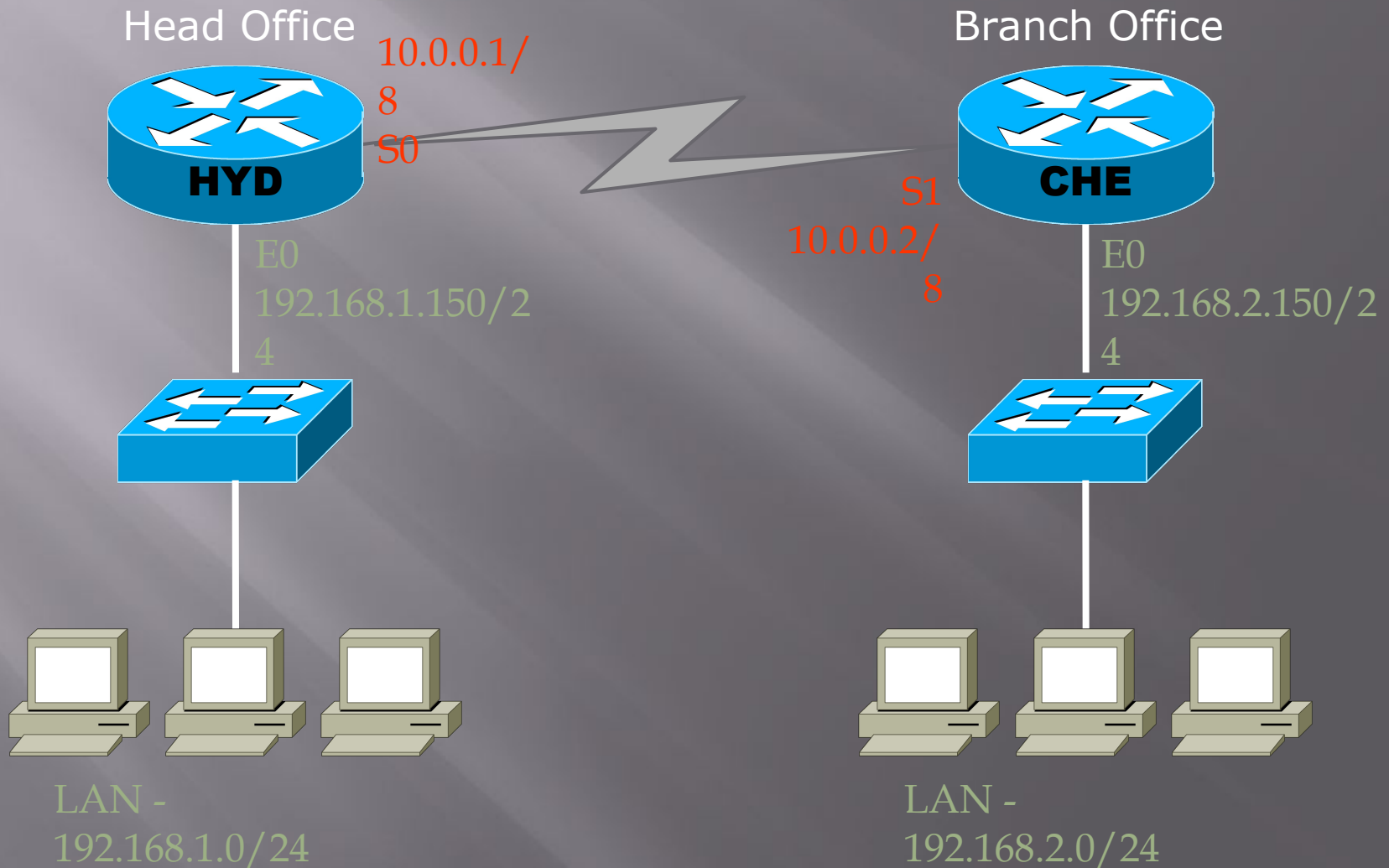
Implies , No Shut has not been given on the remote routers
interface or some problem with the physical connectivity.

```
0 output errors, 0 collisions, 147 interface resets
0 output buffer failures, 0 output buffers swapped out
370 carrier transitions
DCD=down DSR=down DTR=up RTS=up CTS=down
```

Hyderabad#

STATIC ROUTING

Routing Network Diagram



Rules of Routing

- Head Office Ethernet interface should be in the same network as your Head office LAN and similarly on Branch Office side. Show Diagram
- Head Office Serial S0 and Branch Office Serial S1 should be in same network. Show Diagram
- Head Office LAN and Branch Office LAN should be in different Network. Show Diagram
- All interfaces of Router should be in different network. Show Diagram

Types of Routing

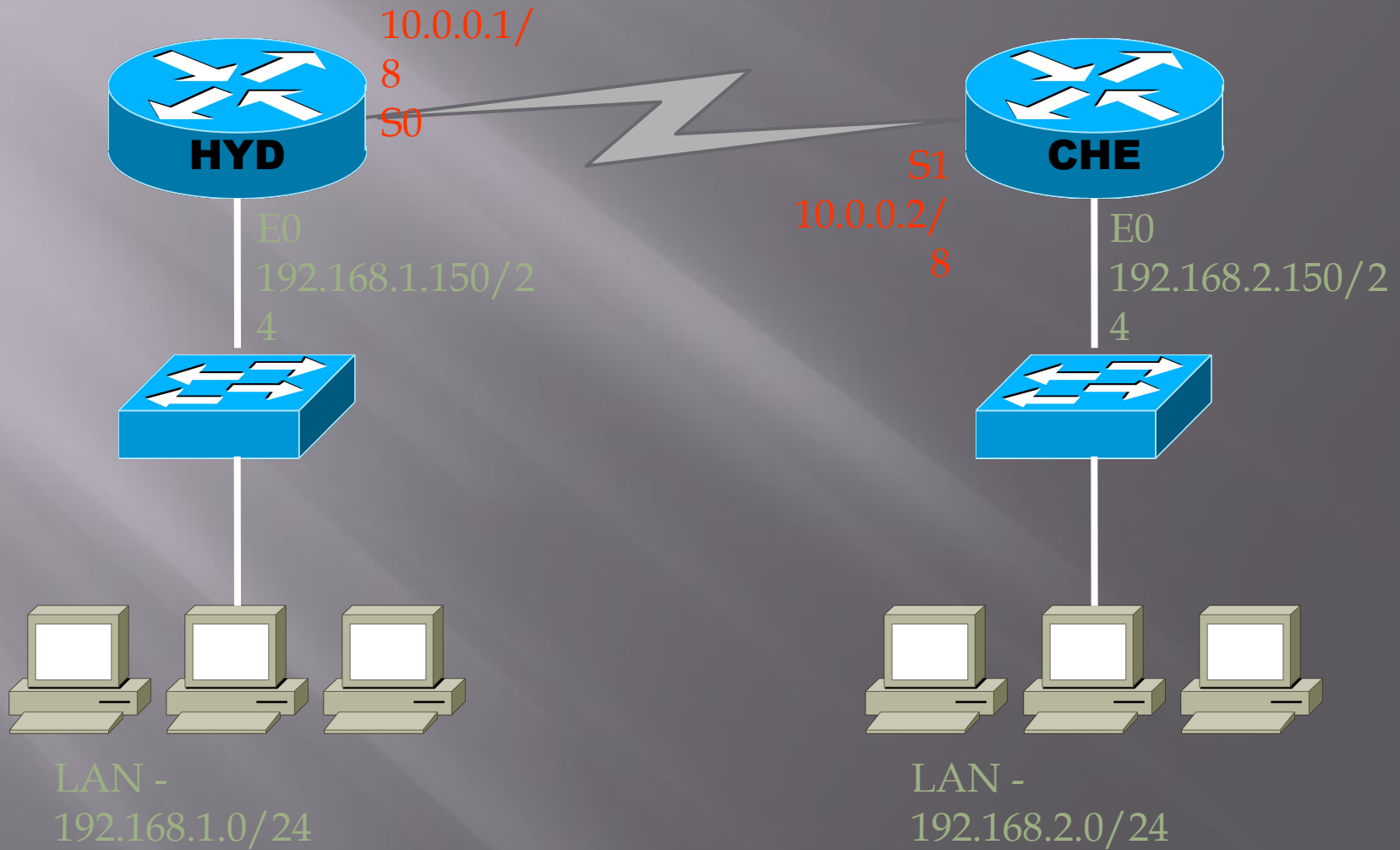
- Static Routing
- Default Routing
- Dynamic Routing

Static Routing

- It is configured by Administrator manually.
- Mandatory need of Destination Network ID
- It is Secure & fast
- Used for Small organization which have network of 10-15 Routers.
- Administrative distance for Static Router is 0 and 1.

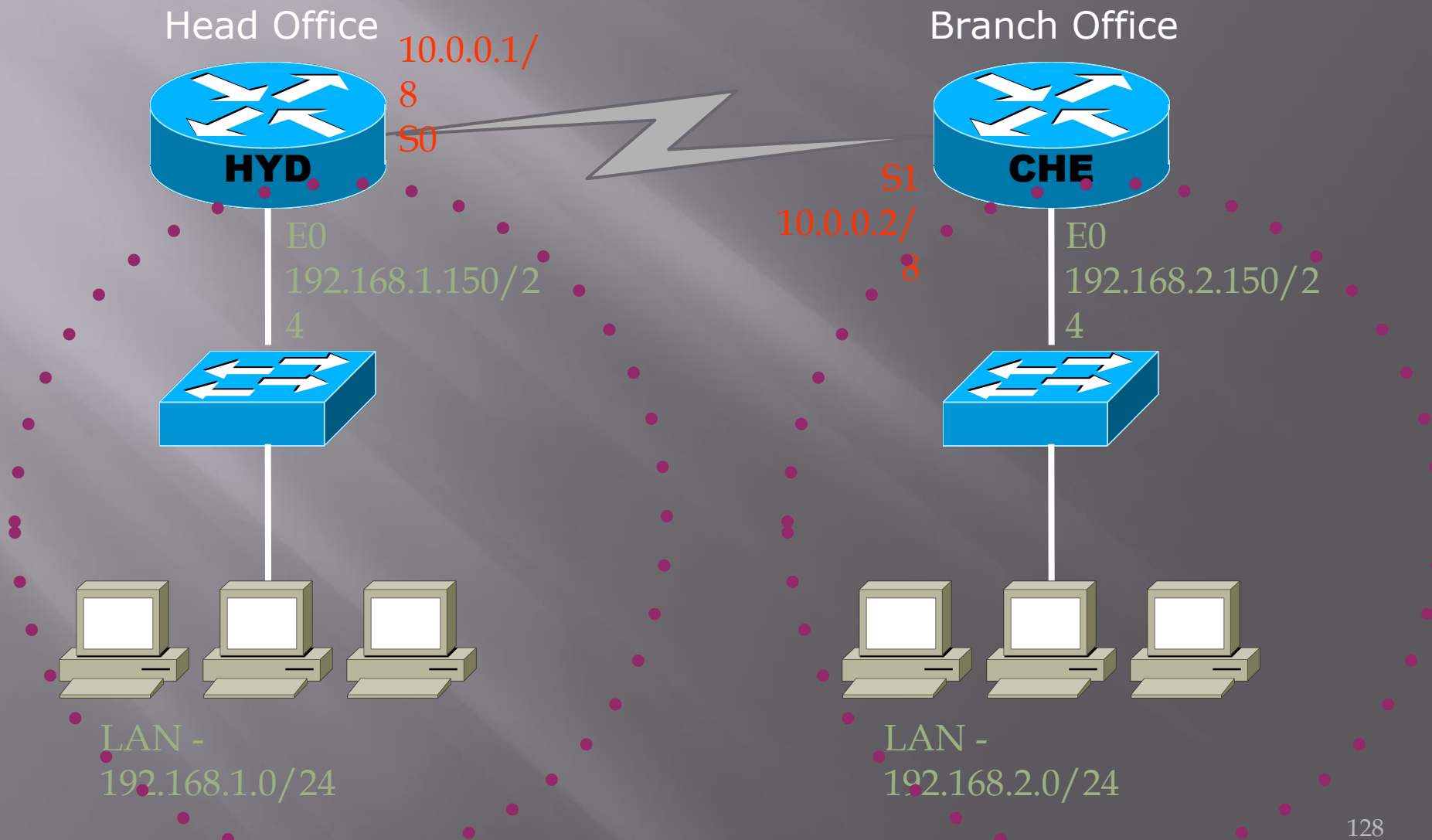
It is the “trustworthiness” of the routing information. Lesser Administrative distance higher the preference.

Static Routing Network Diagram

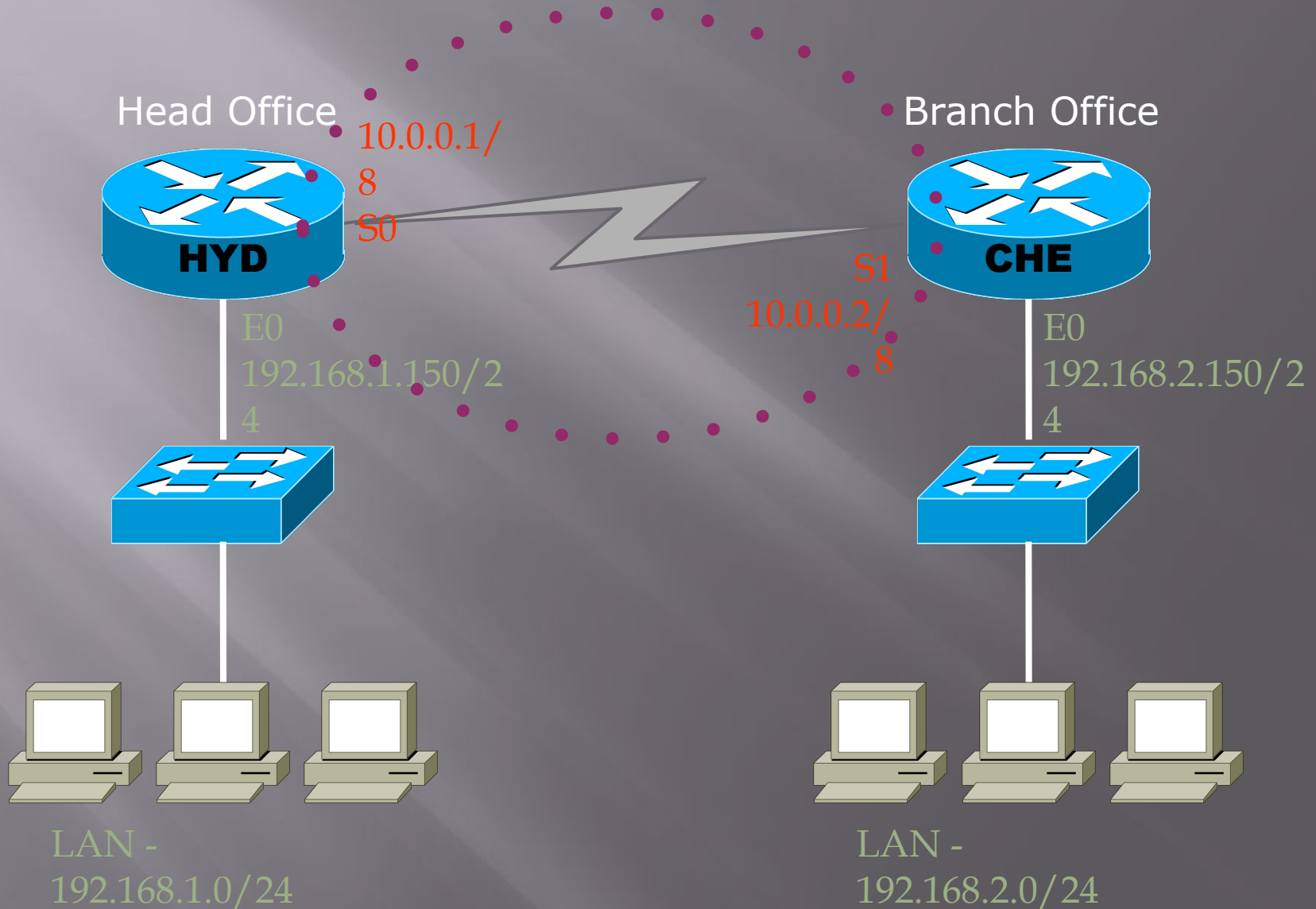




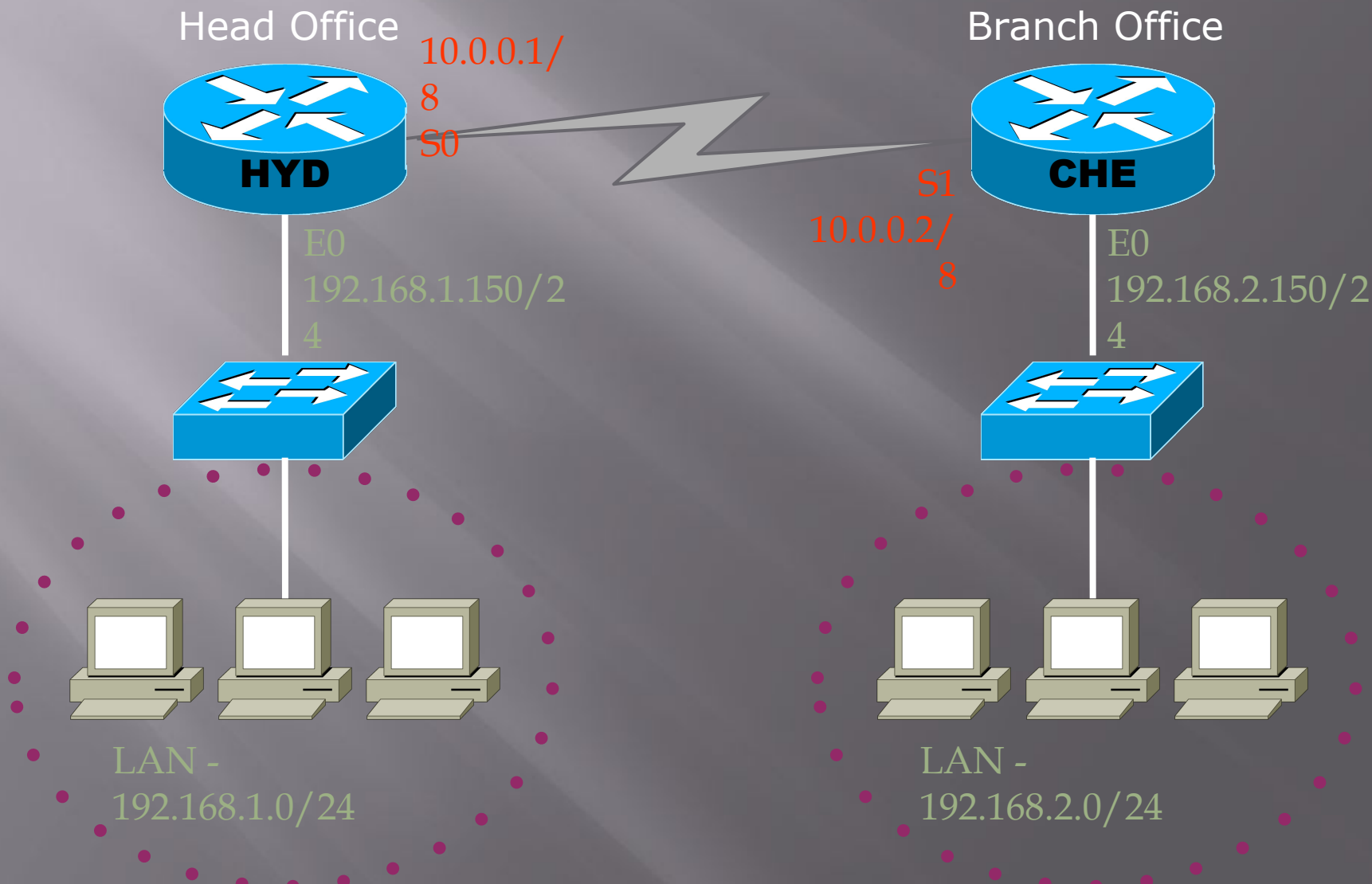
Routing Network Diagram



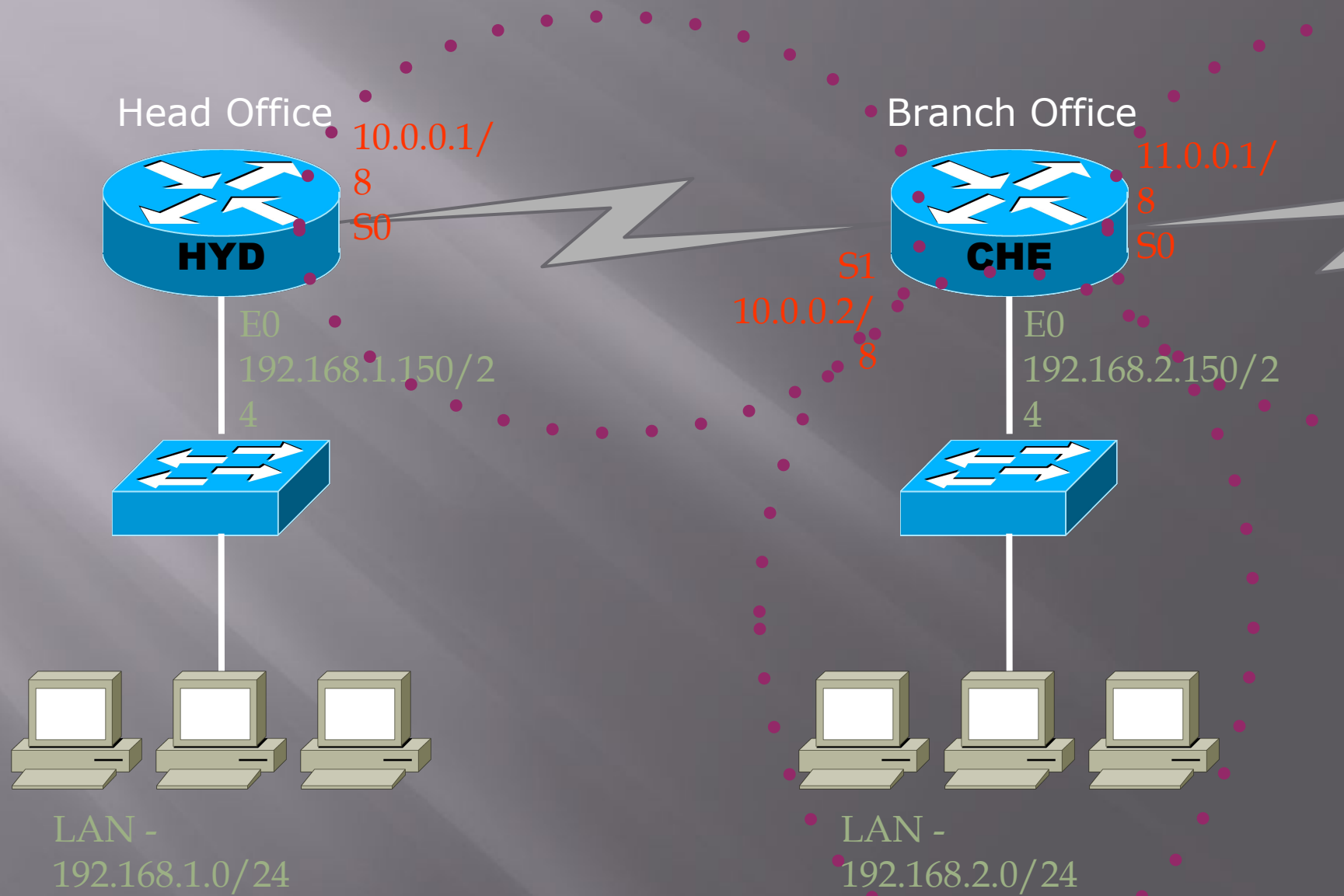
Routing Network Diagram



Routing Network Diagram



Routing Network Diagram



Microsoft Windows 2000 [Version 5.00.2195]

(C) Copyright 1985-2000 Microsoft Corp.

C:\> telnet 192.168.1.150

Connecting

=====

Welcome to Hyderabad Router

=====

User Access Verification

password : ****

Hyderabad> enable

password : ****

Hyderabad#configure terminal

Enter configuration commands, one per line. End with CNTL/Z.

Hyderabad(config)# interface serial 0

Hyderabad(config-if)# ip address 10.0.0.1 255.0.0.0

Hyderabad(config-if)# no shut

Hyderabad(config-if)# clockrate 64000

Hyderabad(config-if)# encapsulation hdlc

Hyderabad(config-if)# exit

Hyderabad(config)# exit

Hyderabad#

Diagram

Microsoft Windows 2000 [Version 5.00.2195]

(C) Copyright 1985-2000 Microsoft Corp.

C:\> telnet 192.168.1.150

Connecting

=====

Welcome to Hyderabad Router

=====

User Access Verification

password : ****

Hyderabad> enable

password : ****

Hyderabad#configure terminal

Enter configuration commands, one per line. End with CNTL/Z.

Hyderabad(config)# interface serial 0

Hyderabad(config-if)# ip address 10.0.0.1 255.0.0.0

Hyderabad(config-if)# no shut

Hyderabad(config-if)# clockrate 64000

Hyderabad(config-if)# encapsulation hdlc

Hyderabad(config-if)# exit

Hyderabad(config)# exit

Hyderabad#

Diagram

Hyderabad# show ip route
 Default gateway is not set

Host	Gateway	Last Use	Total Uses	Interface
ICMP redirect cache is empty				

Hyderabad#configure terminal
 Enter configuration commands, one per line. End with CNTL/Z.
 Hyderabad(config)# ip routing
 Hyderabad(config)# ^Z
 Hyderabad# show

Enabling Routing
 Router(config)#ip routing

Codes: C - connected, B - BGP
 D - EIGRP, E - Enter area
 N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
 E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
 i- IS-IS, L1-IS-IS level-1, L2-IS-IS level-2,*- candidate default
 U - per-user static route, o - ODR

Gateway of last resort is not set

C 192.168.1.0/24 is directly connected, Ethernet0
 C 10.0.0.0/8 is directly connected, Serial0
 Hyderabad#

Diagram

```
Hyderabad#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Hyderabad(config)#ip route 192.168.2.0 255.255.255.0 10.0.0.2
Hyderabad(config)#
Hyderabad#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
```

Configuring Static Route

```
Router(config)# ip route <Destination Network ID>
<Destination Subnet Mask>
<Next-hop IP address >
```

Or

```
Gateway Router(config)# ip route <Destination Network ID>
<Destination Subnet Mask>
<Exit interface type><interface number>
```

```
C 1
S 192.168.2.0/24
C 10.0.0.0/8 is directly connected, Serial0
```

S – for Static Routing

1 is nothing but
Administrative Distance

Diagram

Microsoft Windows 2000 [Version 5.00.2195]

(C) Copyright 1985-2000 Microsoft Corp.

C:\> telnet 192.168.2.150

Connecting

=====

Welcome to Chennai Router

=====

User Access Verification

password : ****

Chennai> enable

password : ****

Chennai# configure terminal

Enter configuration commands, one per line. End with CNTL/Z.

Chennai(config)# interface serial 1

Chennai(config-if)# ip address 10.0.0.2 255.0.0.0

Chennai(config-if)# no shut

Chennai(config-if)# encapsulation hdlc

Chennai(config-if)# exit

Chennai(config)# exit

Chennai#

Chennai#

Diagram

Microsoft Windows 2000 [Version 5.00.2195]

(C) Copyright 1985-2000 Microsoft Corp.

C:\> telnet 192.168.2.150

Connecting

=====

Welcome to Chennai Router

=====

User Access Verification

password : ****

Chennai> enable

password : ****

Chennai# configure terminal

Enter configuration commands, one per line. End with CNTL/Z.

Chennai(config)# interface serial 1

Chennai(config-if)# ip address 10.0.0.2 255.0.0.0

Chennai(config-if)# no shut

Chennai(config-if)# encapsulation hdlc

Chennai(config-if)# exit

Chennai(config)# exit

Chennai#

Chennai#

Diagram

```
Chennai# show ip route
Default gateway is not set
```

```
Host          Gateway      Last Use    Total Uses  Interface
ICMP redirect cache is empty
Chennai# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Chennai(config)# ip routing
Chennai(config)# ^Z
Chennai# show ip
```

Enabling Routing

```
Codes: C - connected, R - RIB-failure, B - BGP
       D - EIGRP, E - External, I - IS-IS, O - ODR
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1-IS-IS level-1, L2-IS-IS level-2, *- candidate default
       U - per-user static route, o - ODR

Router(config)#ip routing
```

```
Gateway of last resort is not set
```

```
C    192.168.2.0/24 is directly connected, Ethernet0
C    10.0.0.0/8 is directly connected, Serial1
Chennai#
```

Diagram

```
Chennai# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Chennai(config)# ip route 192.168.1.0 255.255.255.0 S1
Chennai(config)#
Chennai# show ip
Codes: C
```

Configuring Static Route

```
Router(config)# ip route <Destination Network ID>
<Destination Subnet Mask>
<Next-hop IP address >
```

Or

```
Gateway Router(config)# ip route <Destination Network ID>
<Destination Subnet Mask>
<Exit interface type><interface number>
```

```
C 1
S 192
C 0.0.0.0/8 is directly connected, Serial1
```

S – for Static Routing If is directly connected
Administrative Distance is 0

Diagram

Hyderabad#configure terminal

Enter configuration commands, one per line. End with CNTL/Z.

Hyderabad(config)# ip route 192.168.2.0 255.255.255.0 10.0.0.2

Hyderabad(config)# ^Z

Hyderabad# show ip route

Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
i - IS-IS, L1-IS-IS level-1, L2-IS-IS level-2,* - candidate default
U - per-user static route, o - ODR

Gateway of last resort is not set

C 192.168.1.0/24 is directly connected, Ethernet0

S 192.168.2.0/24 [1/0] via 10.0.0.2

C 10.0.0.0/8 is directly connected, Serial0

Hyderabad# ping 192.168.2.1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2 seconds:

!!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 40/43/44 ms

Hyderabad#

Diagram

Chennai# configure terminal

Enter configuration commands, one per line. End with CNTL/Z.

Chennai(config)# ip route 192.168.1.0 255.255.255.0 S1

Chennai(config)# ^Z

Chennai# show ip route

Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
i - IS-IS, L1-IS-IS level-1, L2-IS-IS level-2, *- candidate default
U - per-user static route, o - ODR

Gateway of last resort is not set

C 192.168.2.0/24 is directly connected, Ethernet0

S 192.168.1.0 is directly connected, Serial1

C 10.0.0.0/8 is directly connected, Serial1

Chennai# ping 192.168.1.1

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 192.168.1.1, timeout is 2 seconds:

!!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 40/42/44 ms

Chennai#

Diagram

Static Routing Network Diagram

