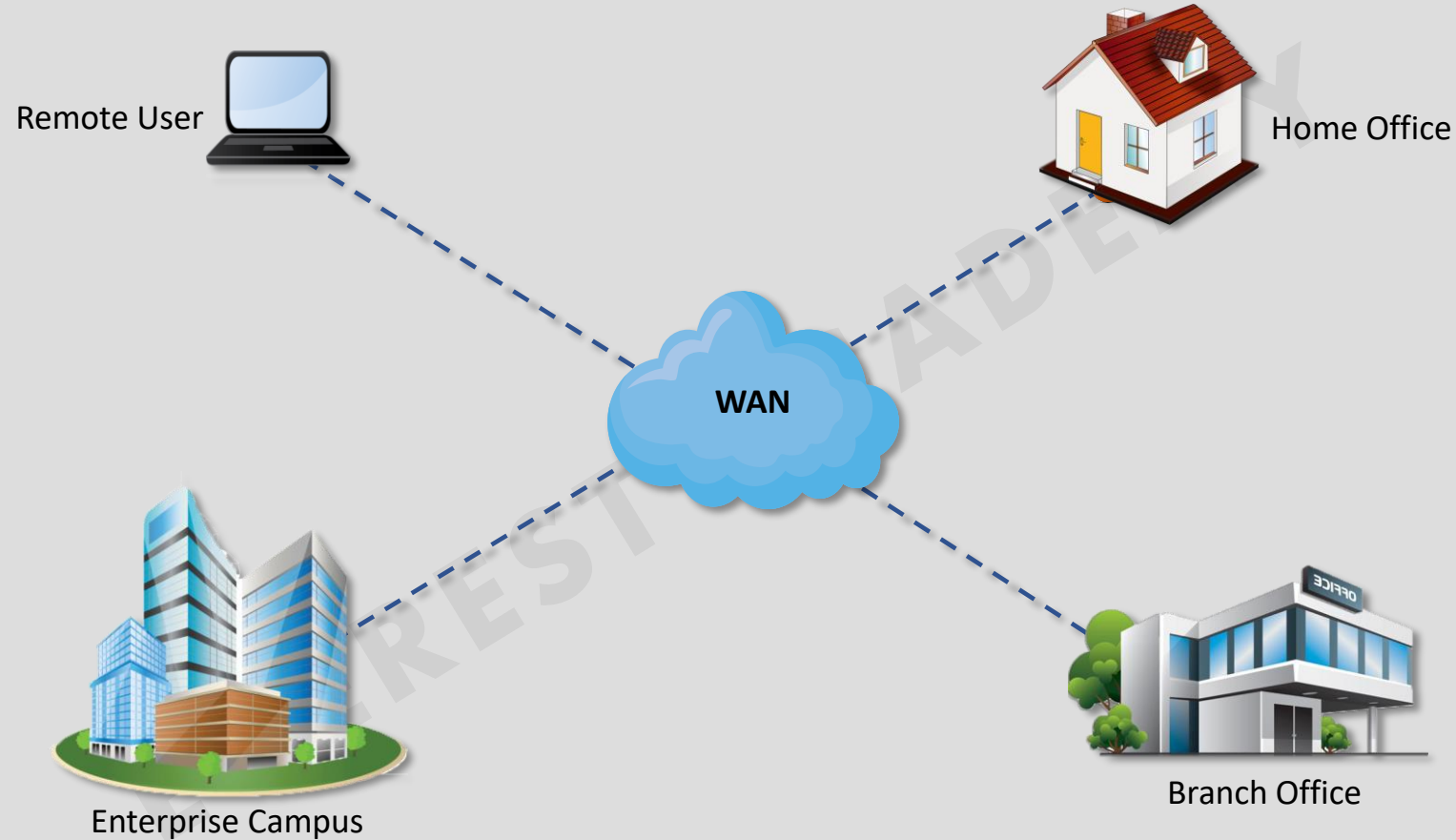


## Wide Area Network (WAN)



CCNP Service Provider

CCIE Service Provider

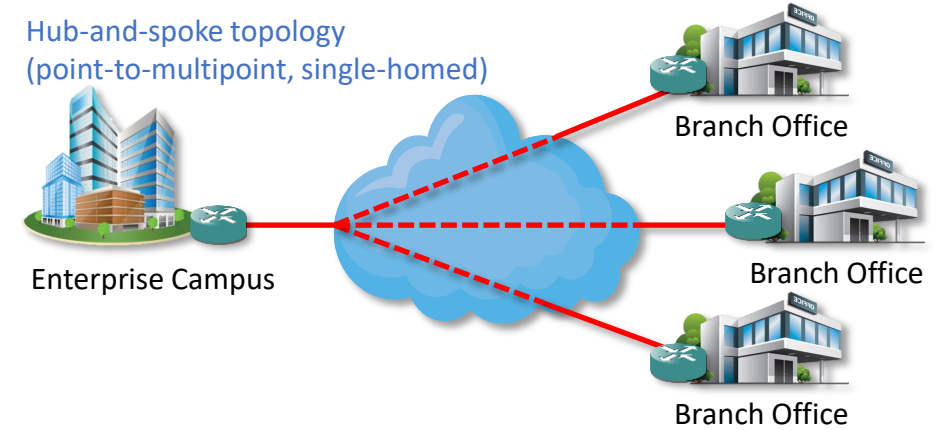


## WAN Topologies

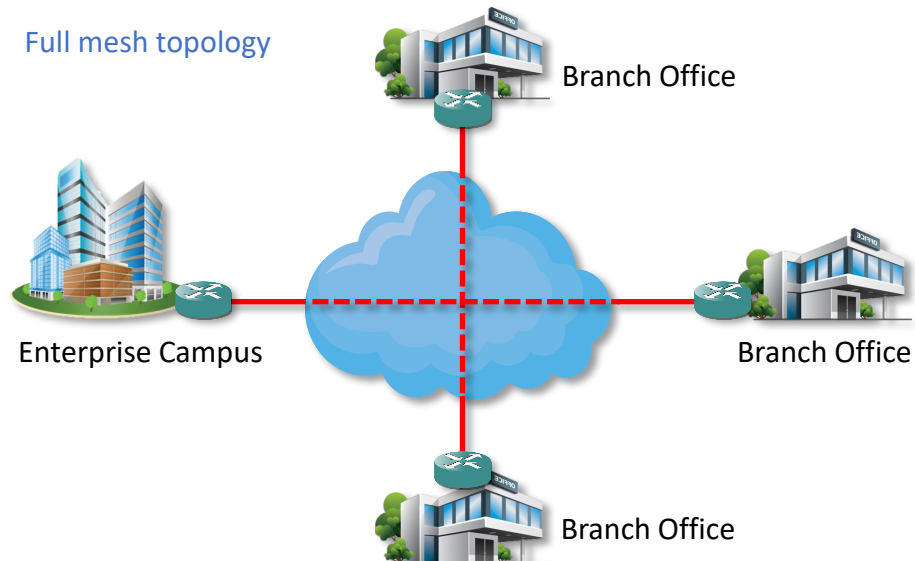
Point-to-point topology



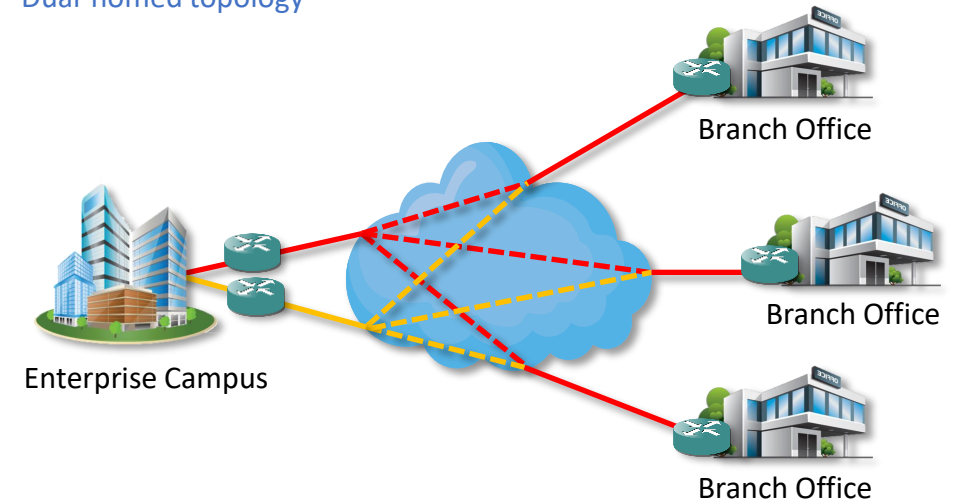
Hub-and-spoke topology  
(point-to-multipoint, single-homed)



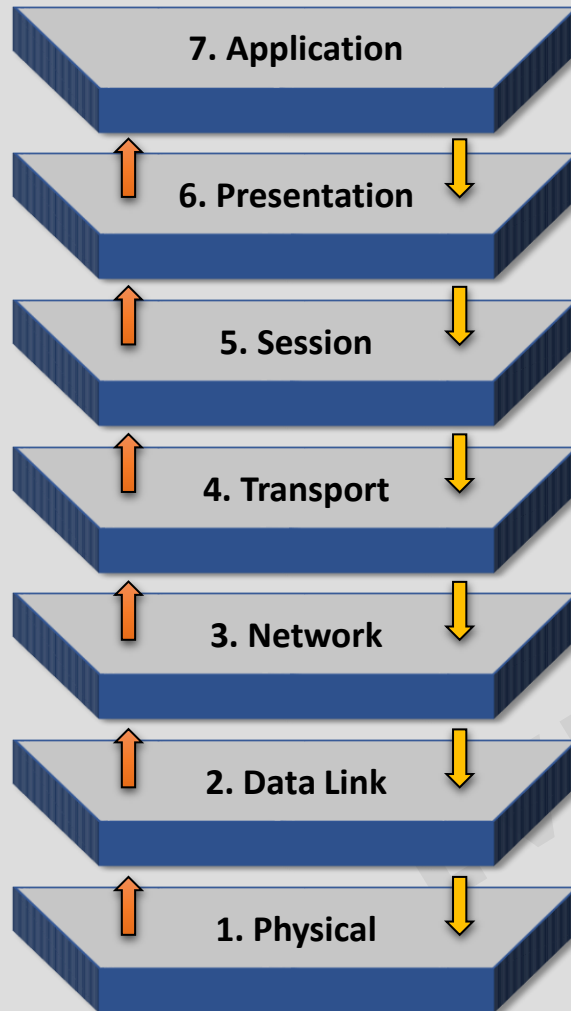
Full mesh topology



Dual-homed topology



## WAN Operations



❖ Modern WAN standards are defined and managed by a number of recognized authorities including the following:

- **TIA/EIA** : Telecommunications Industry Association and Electronic Industries Alliance.
- **ISO** : International Organization for Standardization.
- **IEEE** : Institute of Electrical and Electronics Engineers.

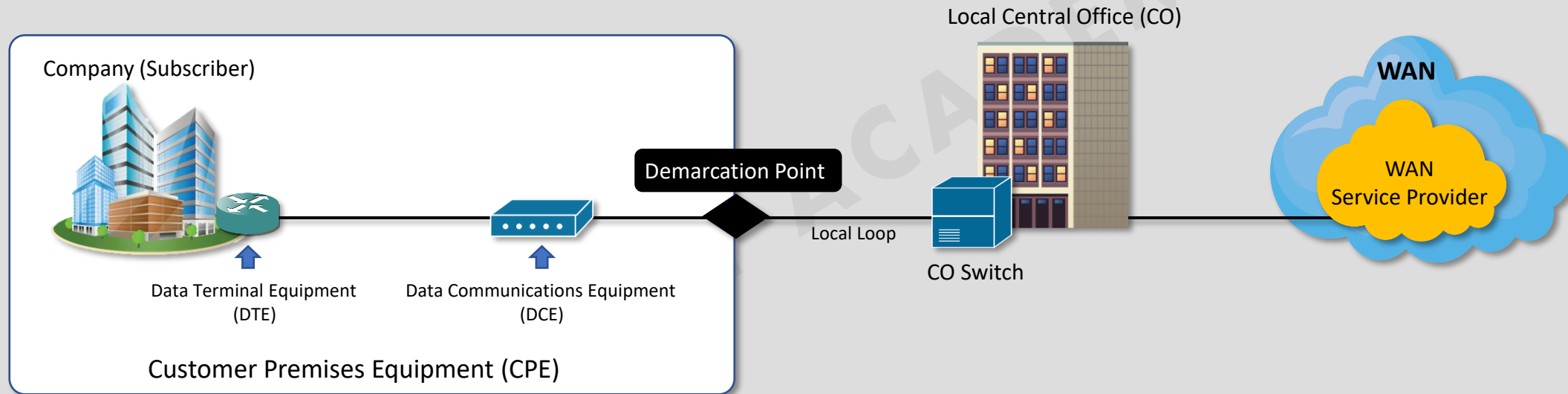


Describes how data will be encapsulated into a frame.  
HDLC, PPP, ISDN, Frame Relay, ATM, Metro Ethernet, MPLS, VSAT, Broadband (DSL, Cable Modem)

Describes the electrical, mechanical, and operational components to transmit bits

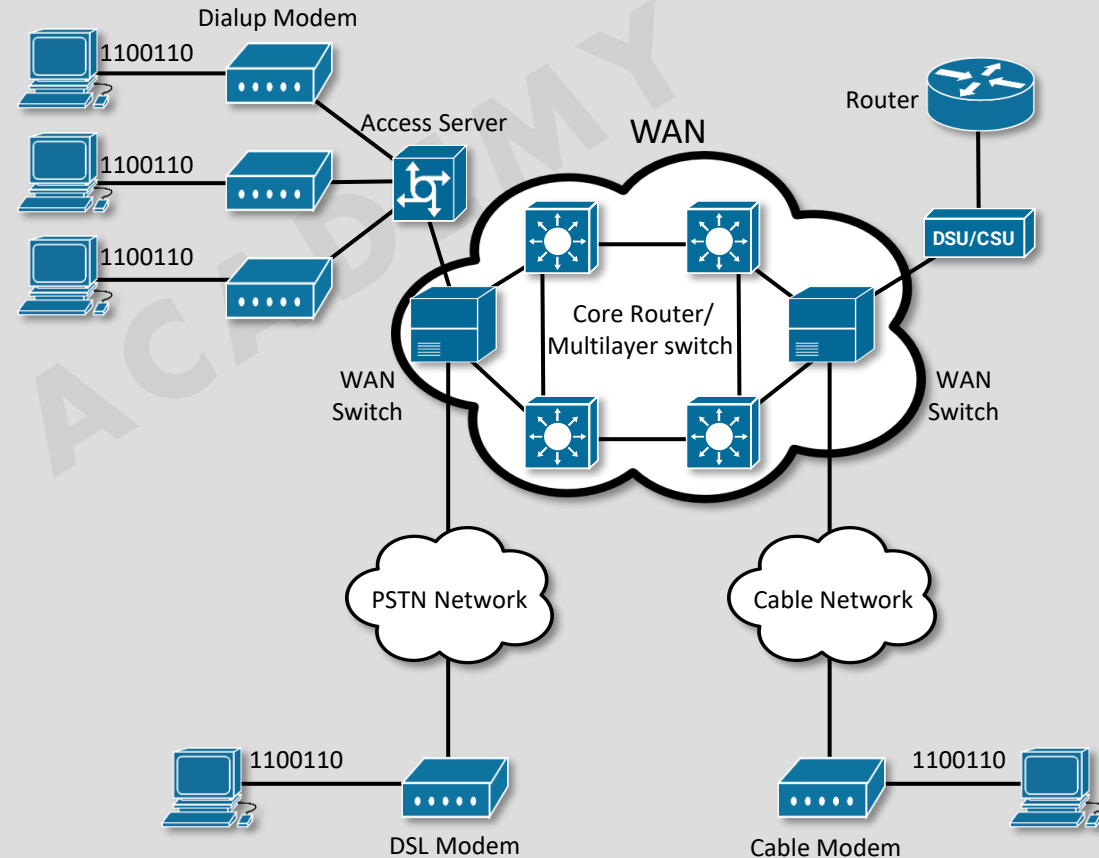


## Common WAN Terminology



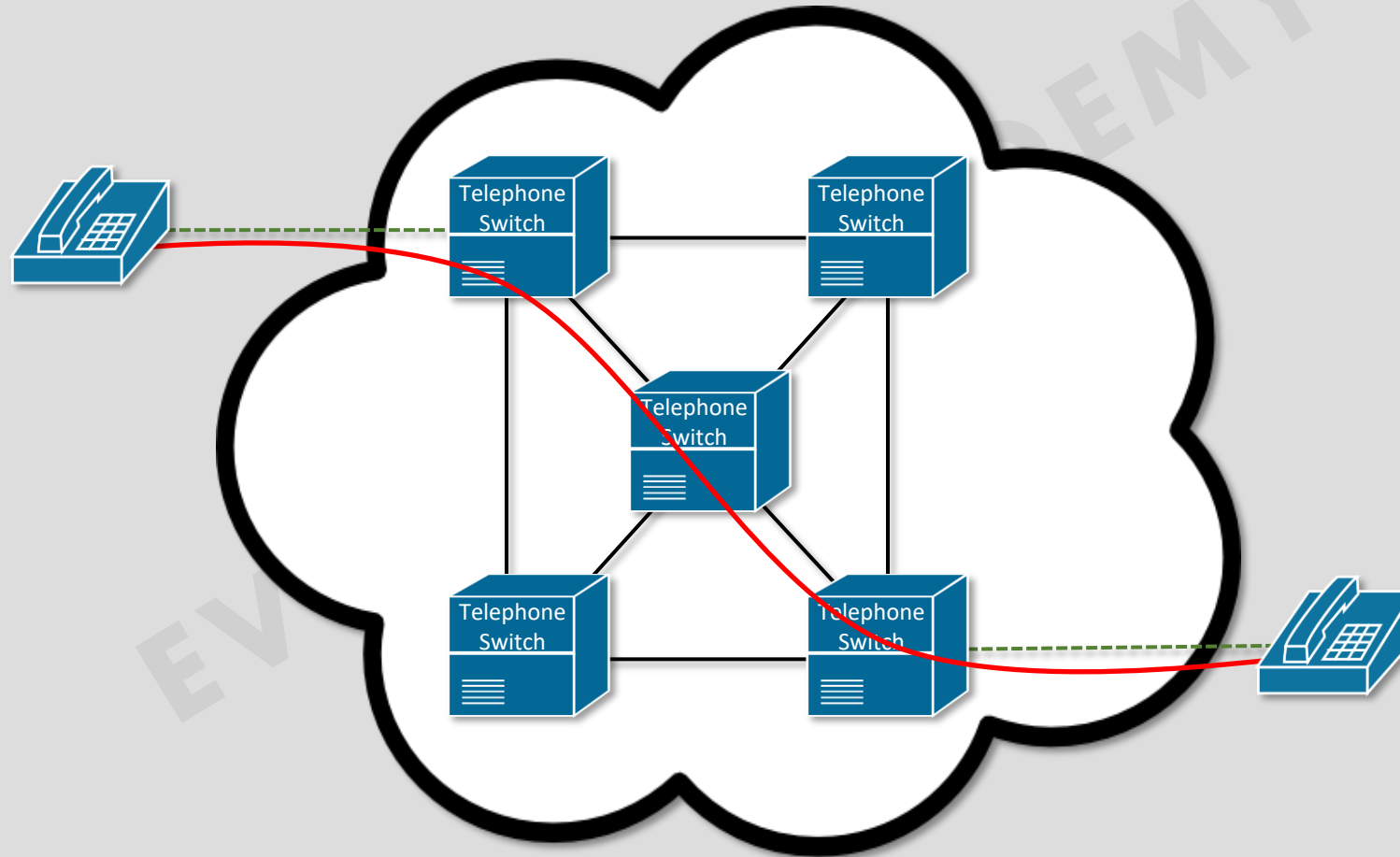
## WAN Devices

- ❑ **Dialup modem** : legacy WAN technology that converts digital signals into voice frequencies to be transmitted over the analog lines of the public telephone network.
- ❑ **Access server** : legacy WAN technology that coordinates dial-in and dial-out user communications.
- ❑ **Broadband modem** : used with high-speed DSL or cable Internet service
- ❑ **Channel Service Unit/Data Service Unit (CSU/DSU)** : used to convert digital, leased-line signals into frames that the LAN can interpret and vice versa.
- ❑ **WAN switch** : multiport internetworking device used in service provider networks
- ❑ **Router** : provides internetworking and WAN access interface ports to connect to the service provider network
- ❑ **Core router/Multilayer switch** : resides within the backbone of the WAN, supports multiple interfaces, and forwards IP packets at full line speed



## Circuit-Switched Network

- ❑ **Circuit-switched Networks** establish a dedicated circuit between source and destination before the users may communicate, such as making a telephone call.

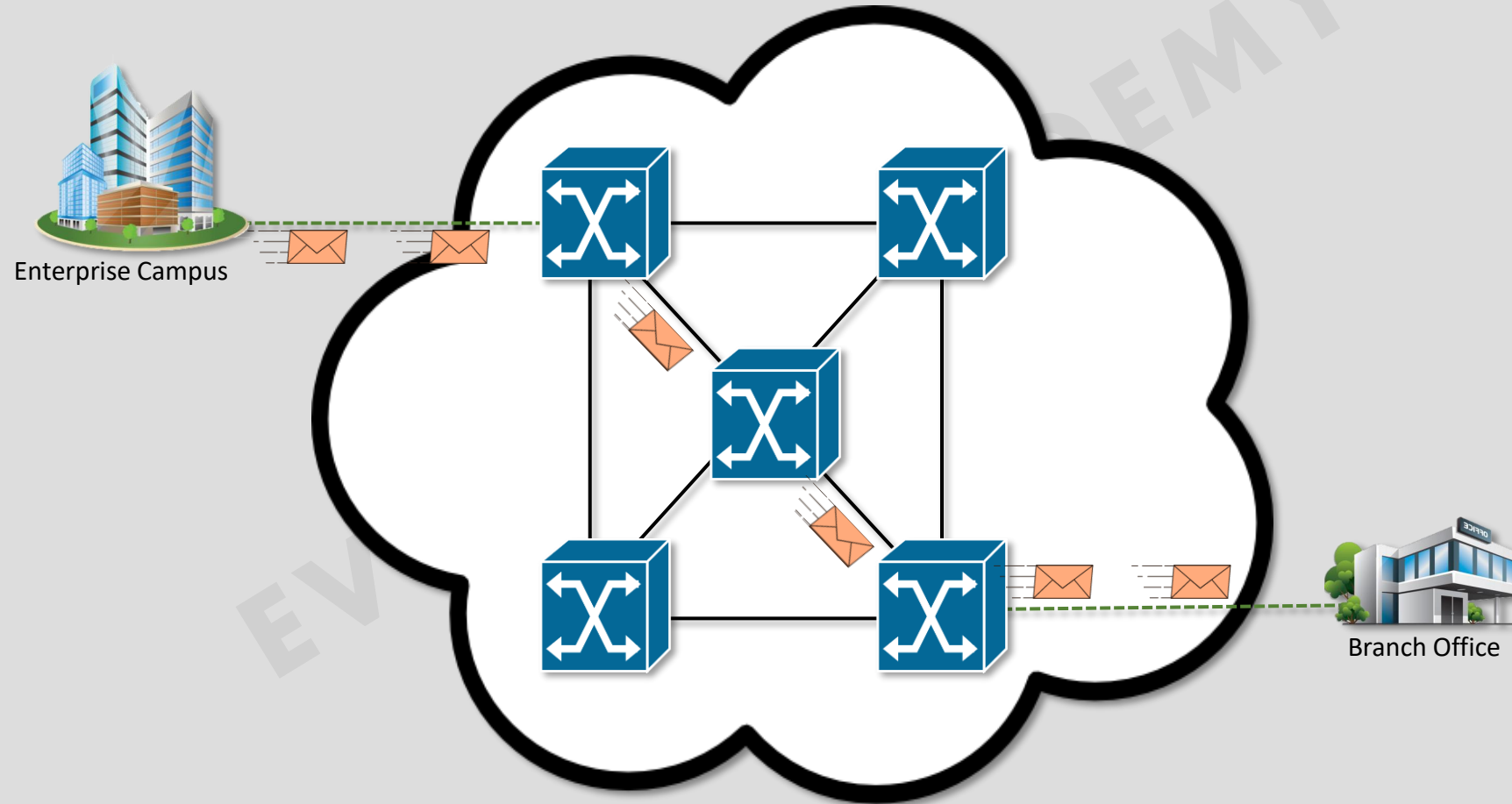


Public Switched Telephone Network (PSTN)



## Packet-Switched Network

- ❑ **Packet-Switched Networks** split traffic into packets that are routed over a shared network and do not require a dedicated circuit between source and destination.



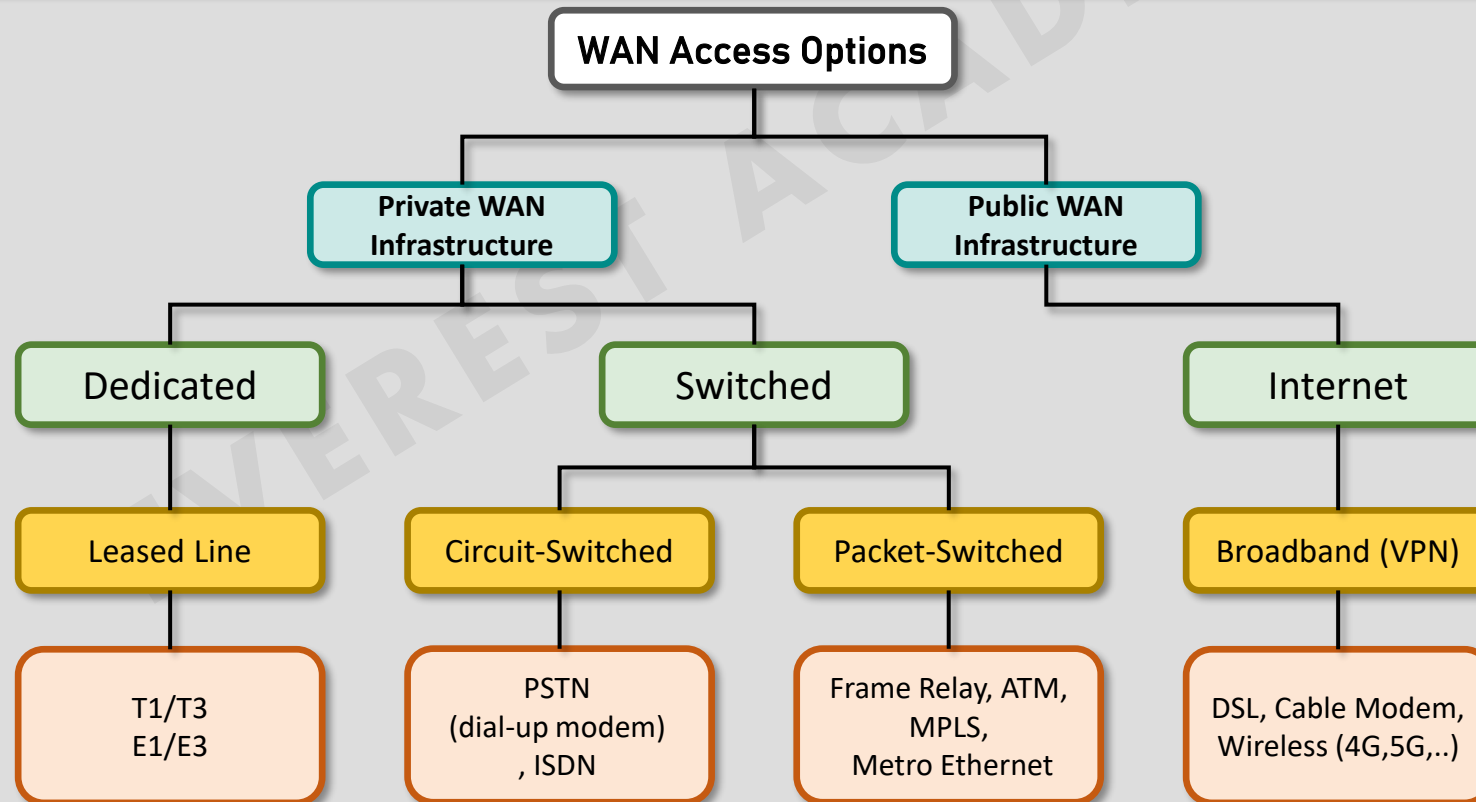
Multiprotocol Label Switching (MPLS)



## WAN Access Options

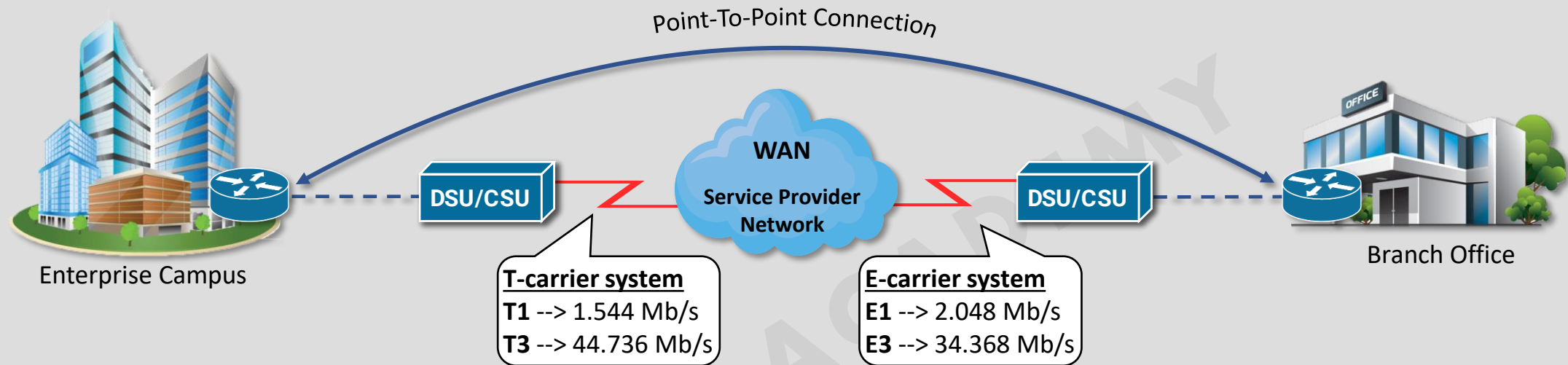
**Private WAN Infrastructure** : Service providers may offer dedicated leased lines, circuit-switched links, such as PSTN or ISDN, and packet switched links, such as Metro Ethernet, ATM, or Frame Relay.

**Public WAN Infrastructure**: Service providers provide Internet access using broadband services such as DSL, cable modem, and wireless (4G, 5G,...).





## Leased Line

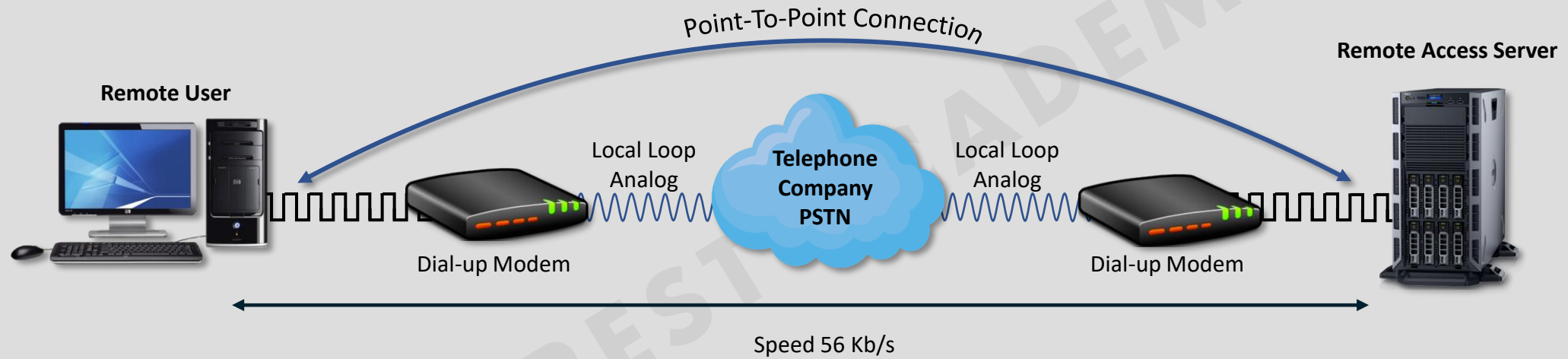


Line	Speed	Transmission Medium
T1	1.544 Mbps	2-Pair UTP
T3	44.736 Mbps	Optical Fiber
E1	2.048 Mbps	2-Pair UTP
E3	34.368 Mbps	Optical Fiber



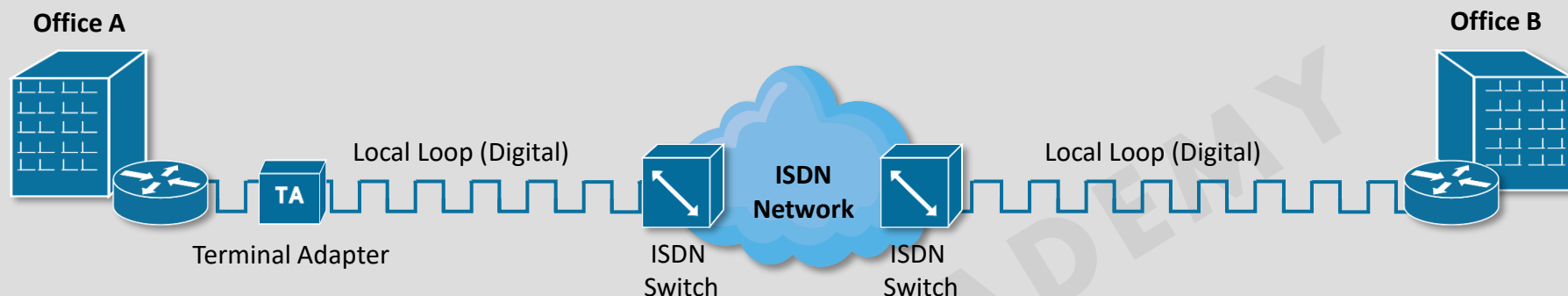
## Dial-up Lines

### Circuit Switching Technology



## Integrated Services Digital Network (ISDN)

### Circuit Switching Technology



- ❑ The connection uses **bearer channels (B)** for carrying all types of digital information in full duplex mode and a **delta channel (D)** for carrying control signaling information for the B channels.

Type of Interface	Number of <b>B channels</b>	Number of <b>D channels</b>	Descriptive
BRI	2 (64 kbps)	1 (16 kbps)	2B+D (144 kb/s)
PRI (T1)	23 (64 kbps)	1 (64 kbps)	23B+D (1.544 Mb/s)
PRI (E1)	30 (64 kbps)	1 (64 kbps)	30B+D (2.048 Mb/s)

Primary Rate Interface (PRI)

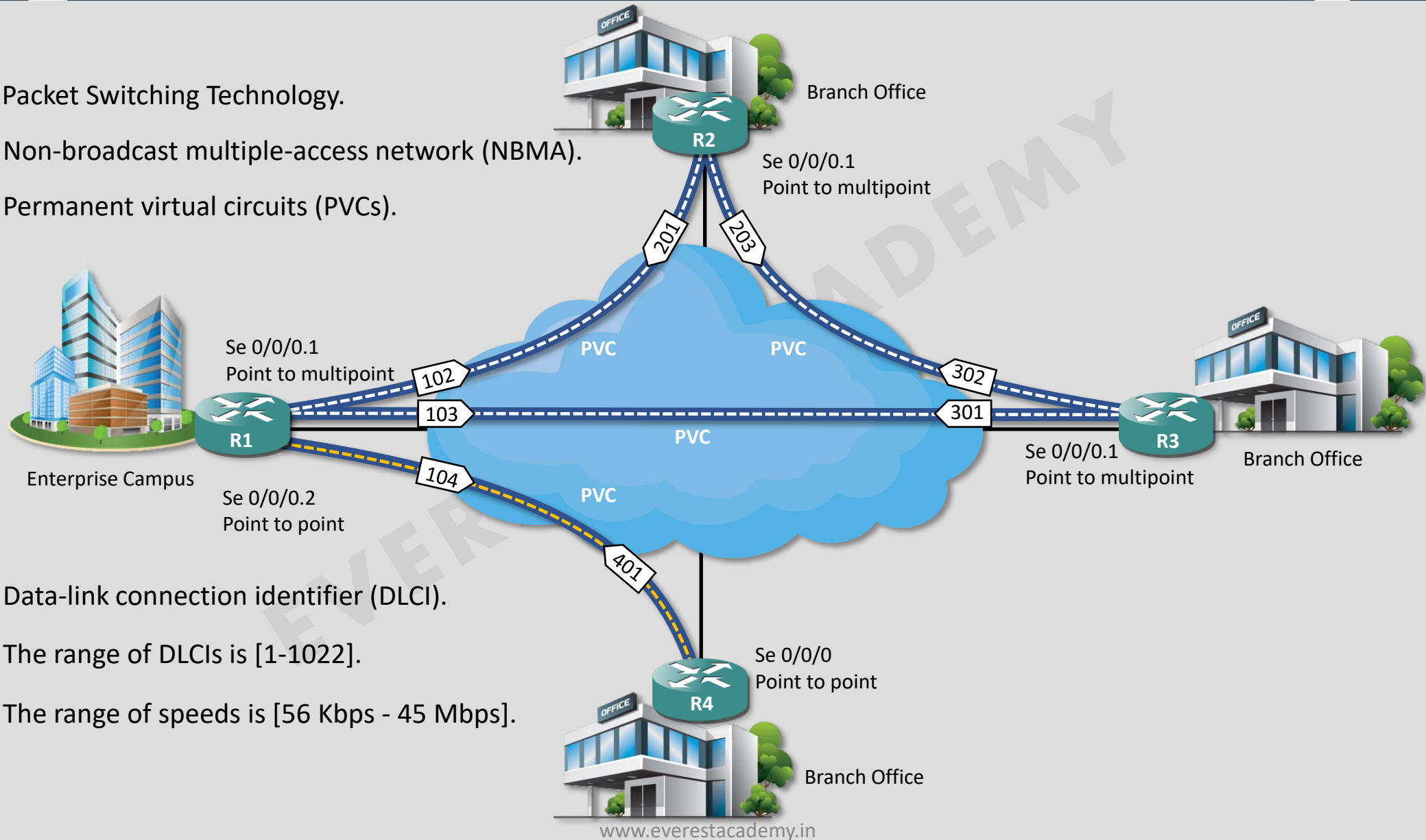


Basic Rate Interface (BRI)



## Frame Relay

- ☐ Packet Switching Technology.
- ☐ Non-broadcast multiple-access network (NBMA).
- ☐ Permanent virtual circuits (PVCs).

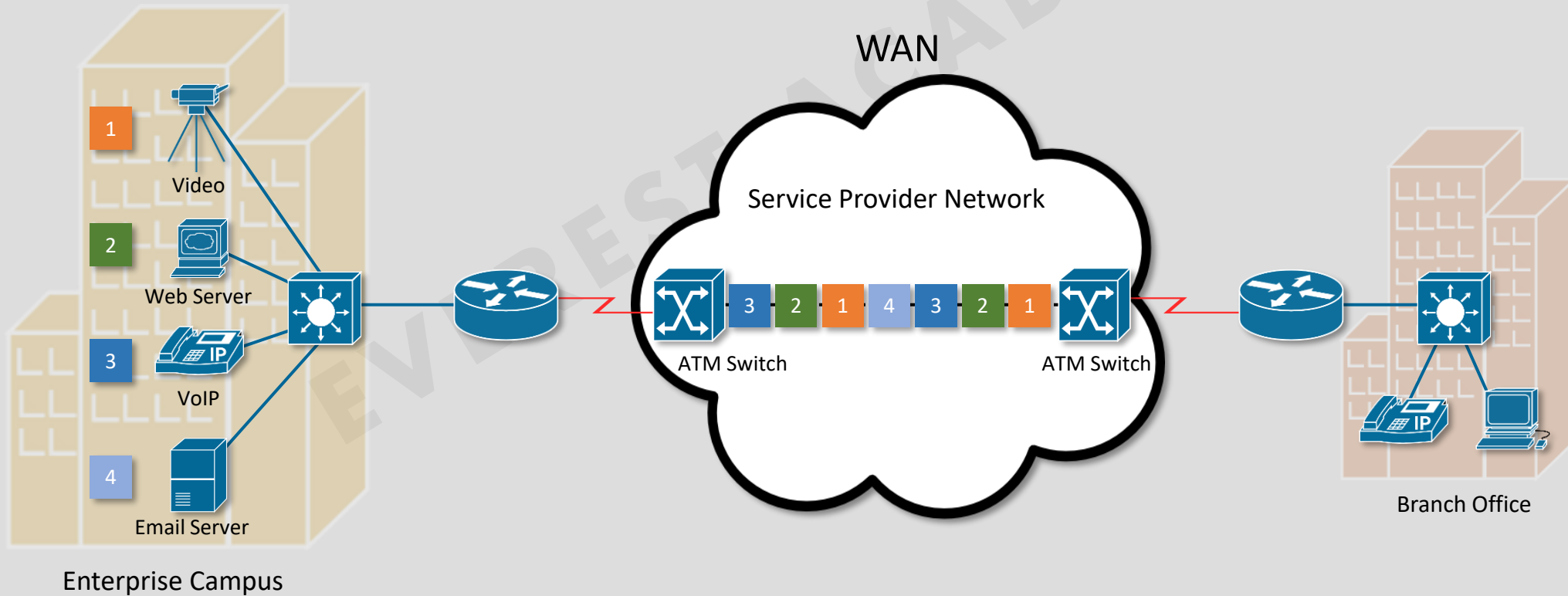


- ☐ Data-link connection identifier (DLCI).
- ☐ The range of DLCIs is [1-1022].
- ☐ The range of speeds is [56 Kbps - 45 Mbps].

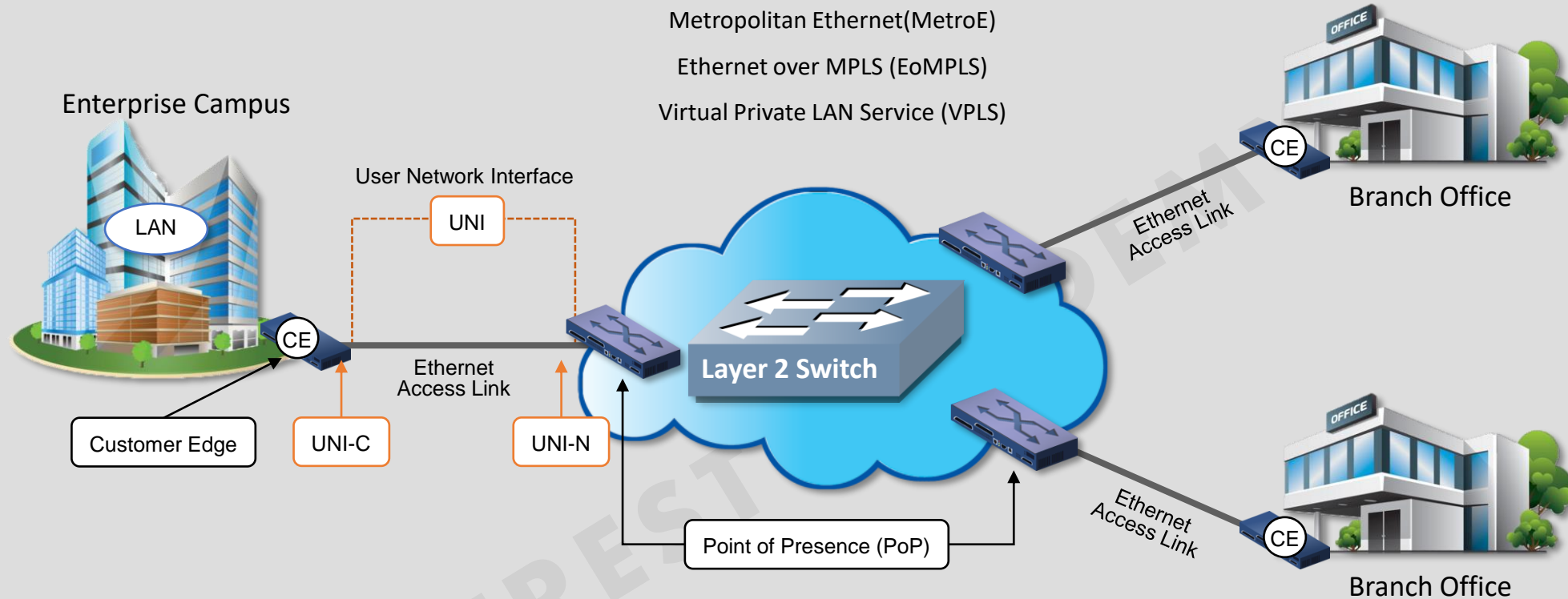


## Asynchronous Transfer Mode (ATM)

- ❑ ATM is a connection-oriented packet switching technology.
- ❑ It is built on a cell-based architecture rather than on a frame-based architecture.
- ❑ ATM cells are always a fixed length of 53 bytes.
- ❑ The ATM cell contains a 5-byte ATM header followed by 48 bytes of ATM payload.



## Metro Ethernet (MetroE)

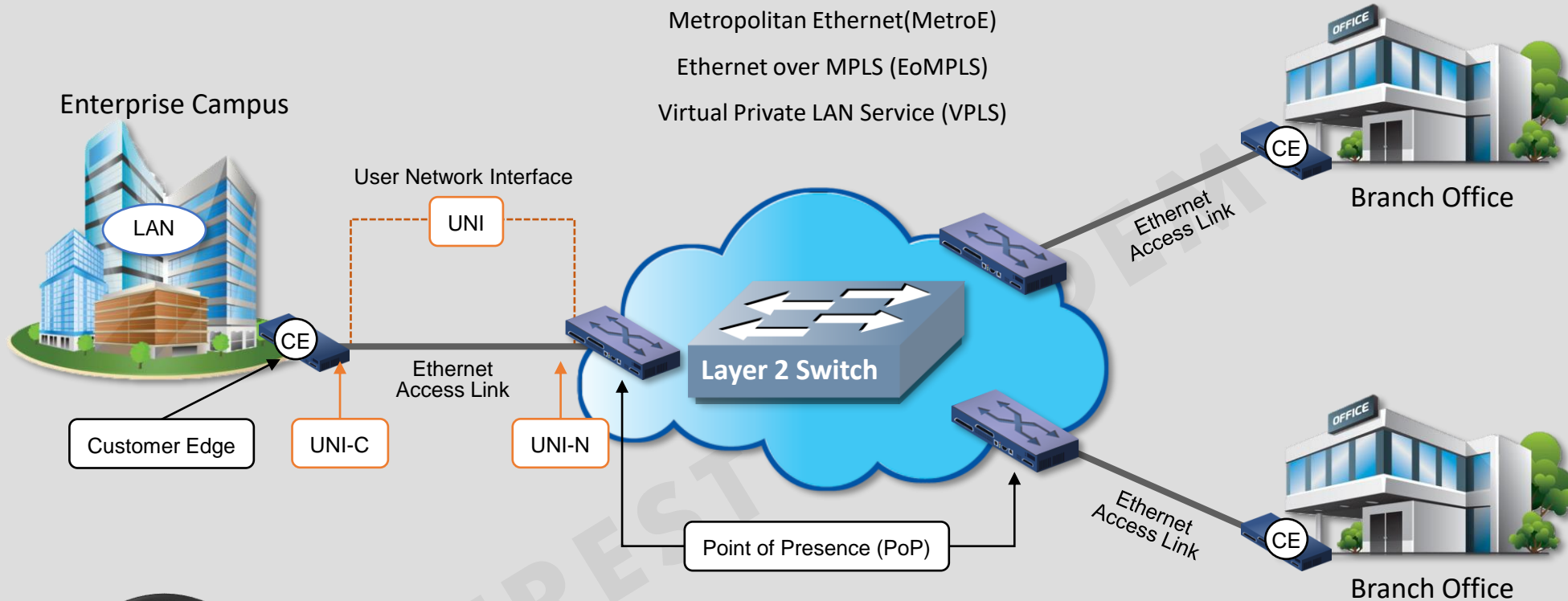


Name	Speed	Distance
100BASE-LX10	100 Mbps	10 Km
1000BASE-LX	1 Gbps	5 Km
1000BASE-LX10	1 Gbps	10 Km
<b>1000BASE-ZX</b>	<b>1 Gbps</b>	<b>100 Km</b>
10GBASE-LR	10 Gbps	10 Km
<b>10GBASE-ER</b>	<b>10 Gbps</b>	<b>40 Km</b>





## Metro Ethernet (MetroE)

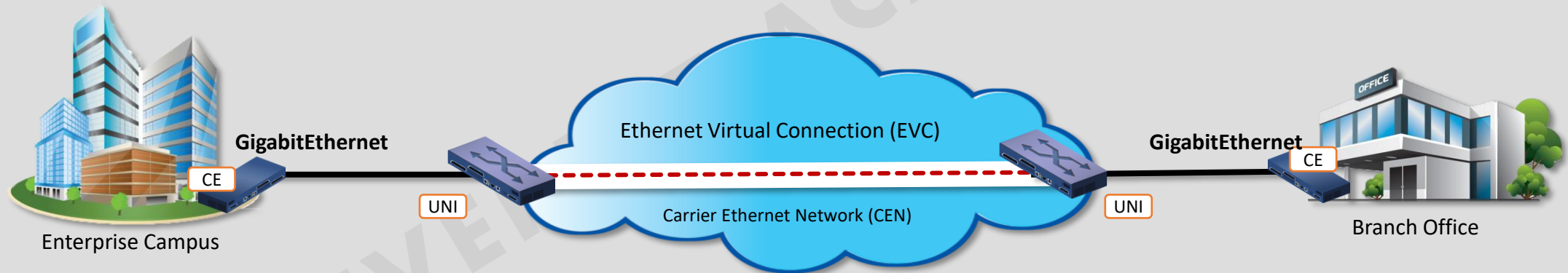


- ❑ The Metro Ethernet Forum (MEF) is a nonprofit organization that defines the scope, concepts, and terminology for deploying Ethernet services in the metro ethernet.



## Ethernet Virtual Connection (EVC)

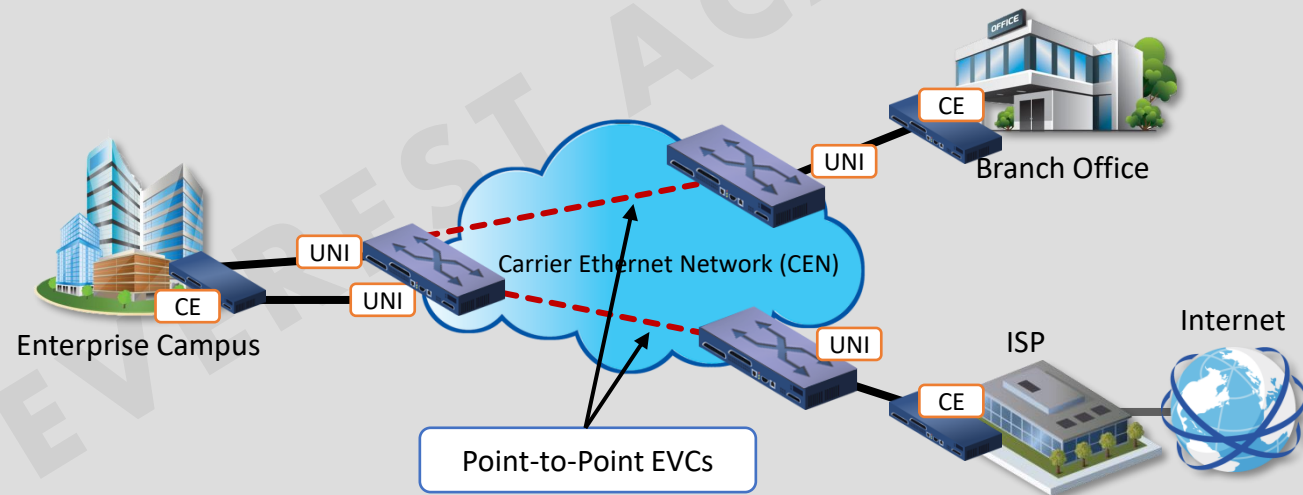
- ❑ An EVC is an association of two or more UNIs that limits the exchange of Service Frames to UNIs in the Ethernet Virtual Connection (EVC).
- ❑ A given UNI can support more than one EVC.
  - Point-to-Point EVC
  - Point-to-Multipoint EVC
  - Multipoint-to-Multipoint EVC





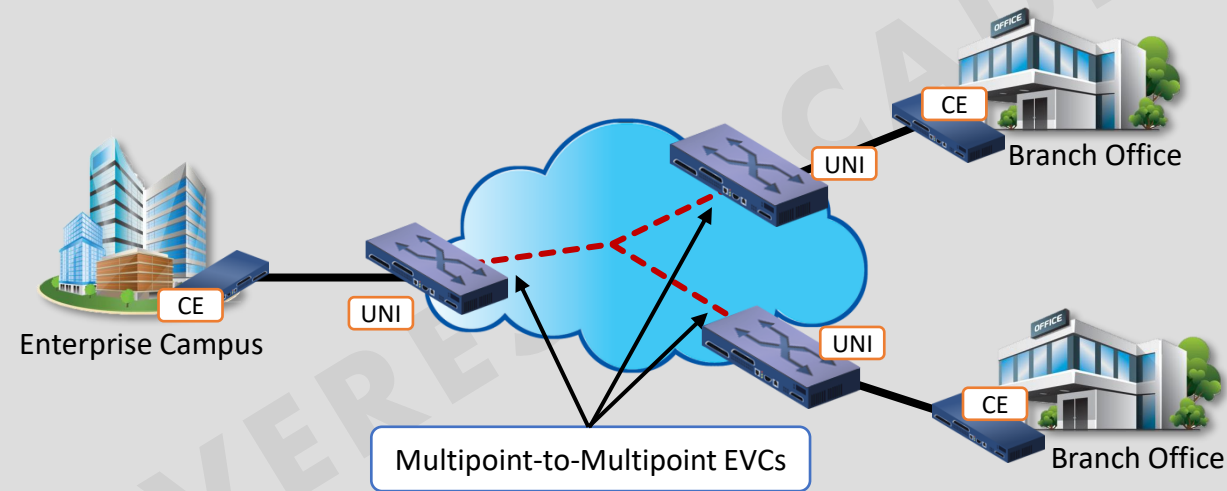
## E-Line (Point-to-Point EVC)

- ❑ **An E-Line** is a service type for connecting exactly 2 UNIs where those 2 UNIs can communicate only with one another.
- ❑ **E-Lines** are used to create, among other solutions:
  - Private lines .
  - Ethernet Internet access.
  - Replacement for Frame Relay and ATM services.
- ❑ **E-Lines** are the most popular Carrier Ethernet service due to their simplicity.



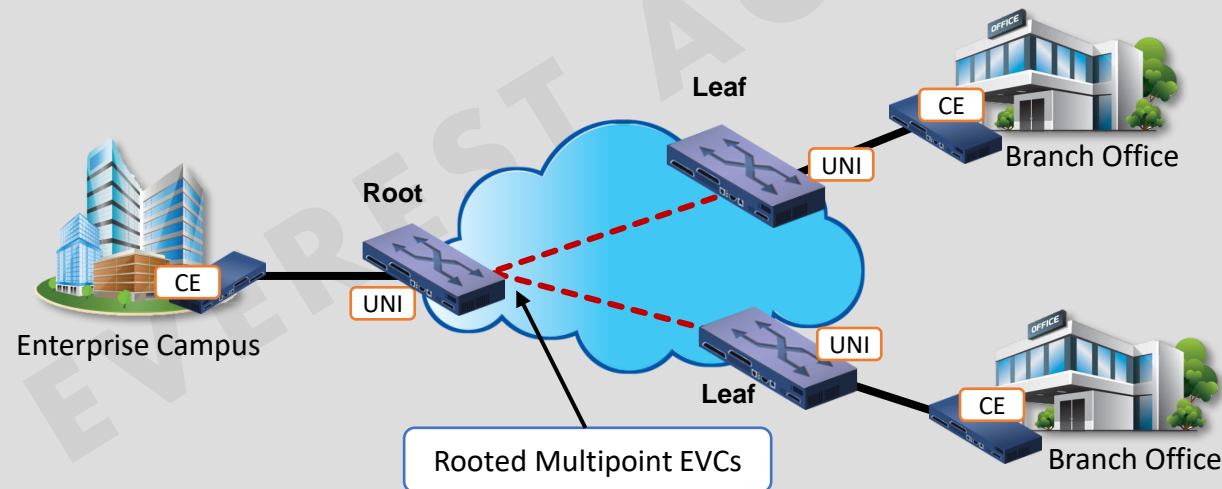
## *E-LAN (Multipoint-to-Multipoint EVC)*

- ❑ **An E-LAN** is a multipoint-to-multipoint service that connects a number of UNIs (2 or more) providing full mesh connectivity for those sites.
- ❑ **Each UNI** can communicate with any other UNI that is connected to that Ethernet service.

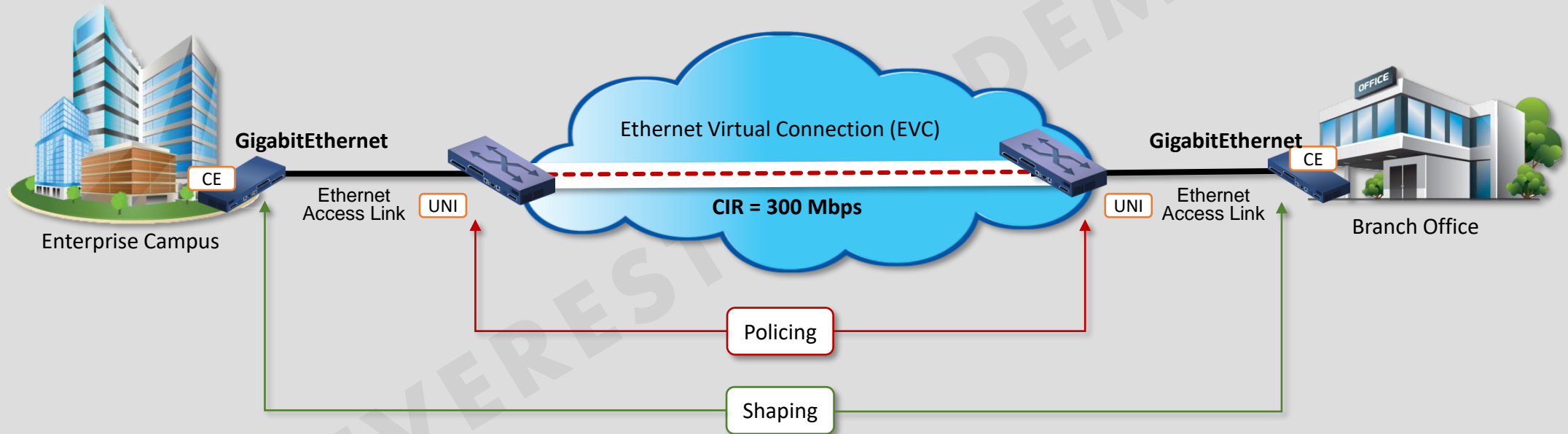


## E-Tree (Point-to-Multipoint)

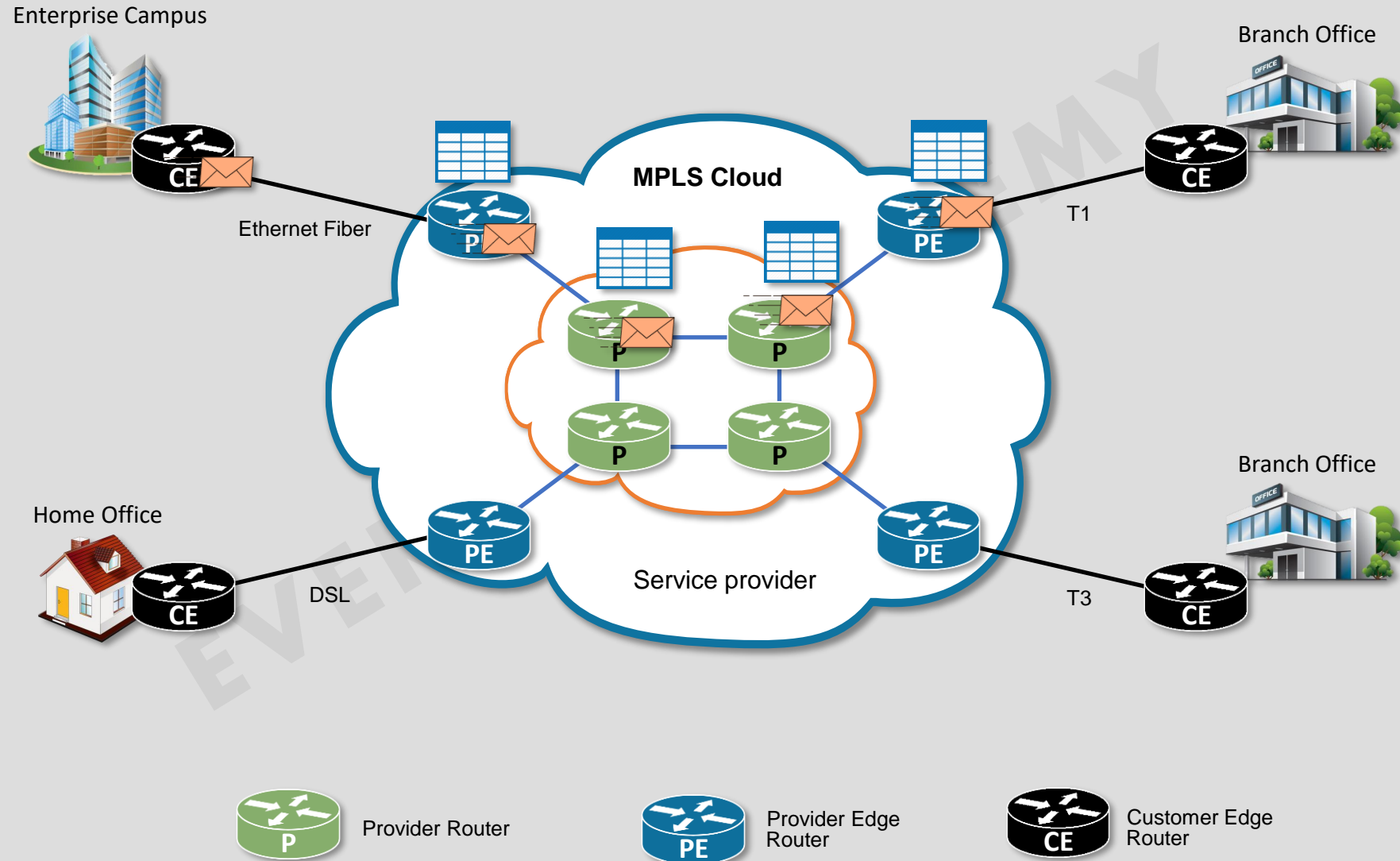
- ❑ **An E-Tree** is a rooted multipoint service that connects a number of UNIs providing sites with hub and spoke multipoint connectivity
- ❑ **Each UNI** is designated as either root or leaf.
- ❑ **A root UNI** can communicate with any leaf UNI, while a leaf UNI can communicate only with a root UNI.
  - Provides traffic separation between users (Leaf UNIs).



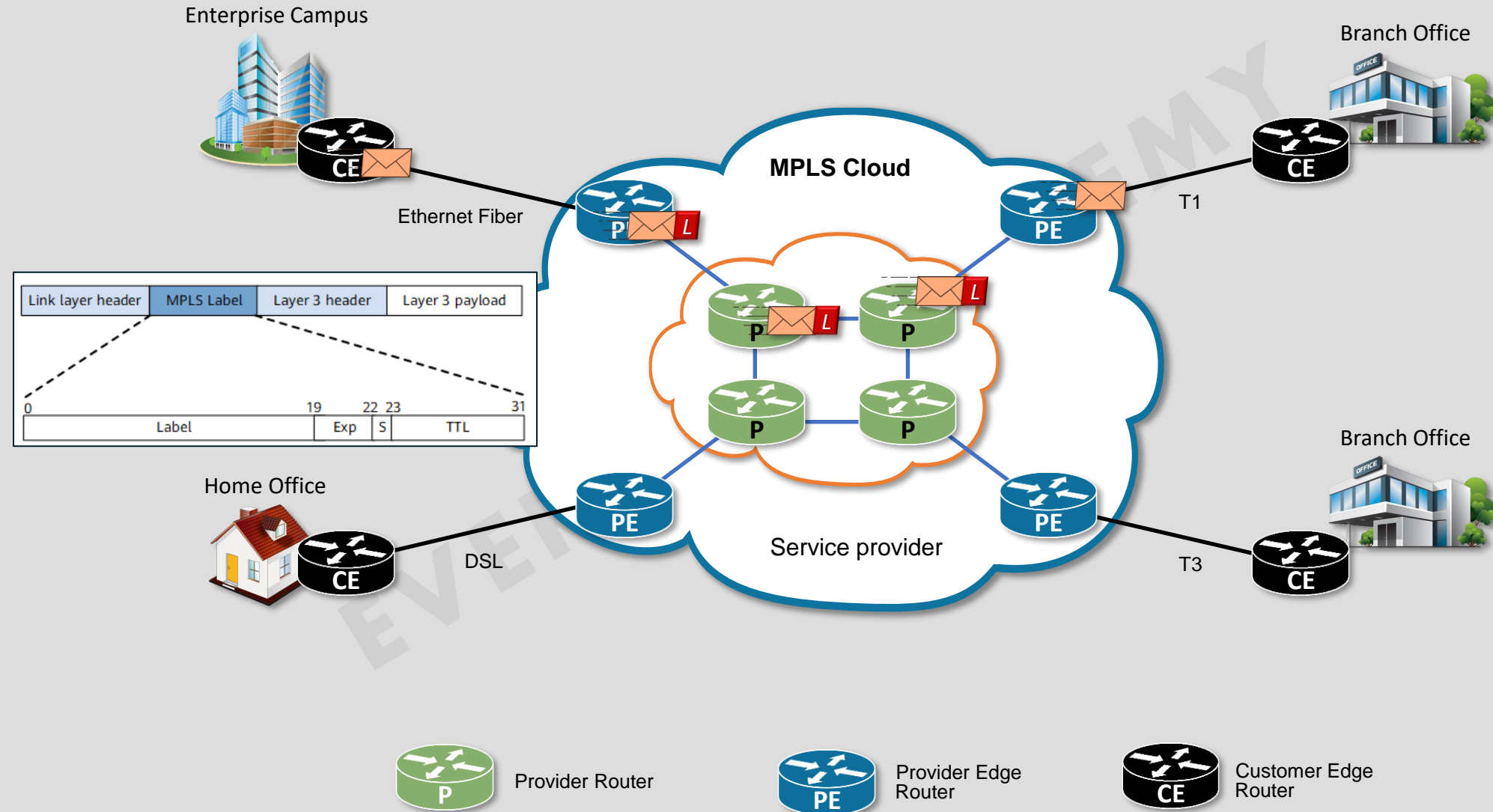
## Committed Information Rate (CIR)



## Multiprotocol Label Switching (MPLS)



## Multiprotocol Label Switching (MPLS)



## Layer 3 with MPLS VPN

CE1# show ip ospf neighbor

Neighbor ID	Pri	State	Dead Time	Address	Interface
192.168.1.1	1	FULL/DR	00:00:36	192.168.1.1	FastEthernet0/0

CE2# show ip ospf neighbor

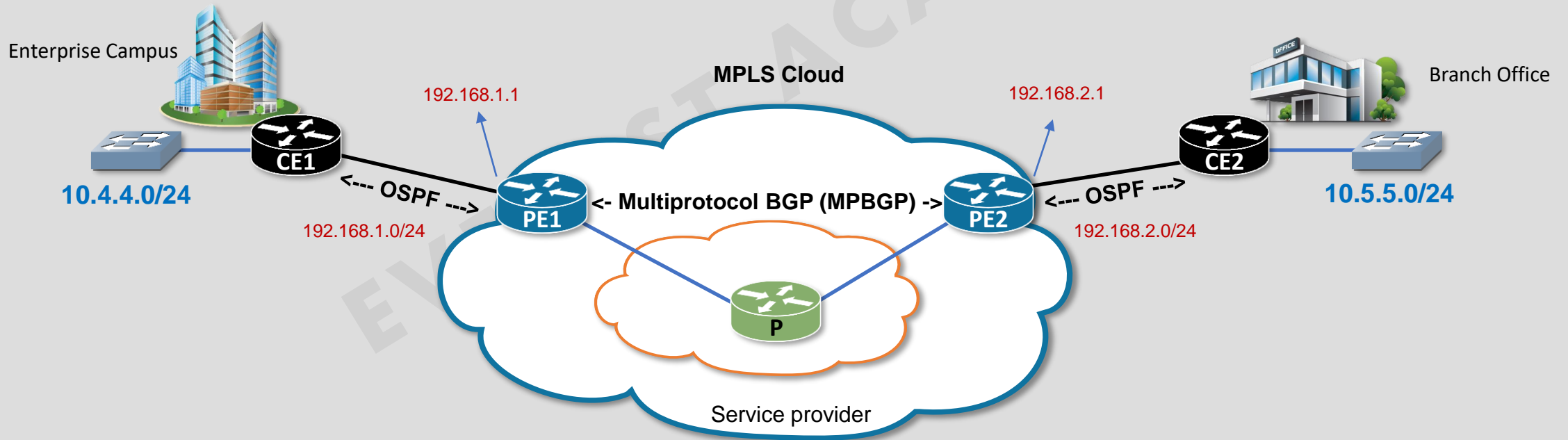
Neighbor ID	Pri	State	Dead Time	Address	Interface
192.168.2.1	1	FULL/DR	00:00:38	192.168.2.1	FastEthernet0/0

CE1# show ip route ospf

O IA 10.5.5.0/24 [110/3] via 192.168.1.1, 00:02:30, FastEthernet0/0  
O IA 192.168.2.0/24 [110/2] via 192.168.1.1, 00:04:37, FastEthernet0/0

CE2# show ip route ospf

O IA 10.4.4.0/24 [110/3] via 192.168.2.1, 00:10:48, FastEthernet0/0  
O IA 192.168.1.0/24 [110/2] via 192.168.2.1, 00:10:48, FastEthernet0/0

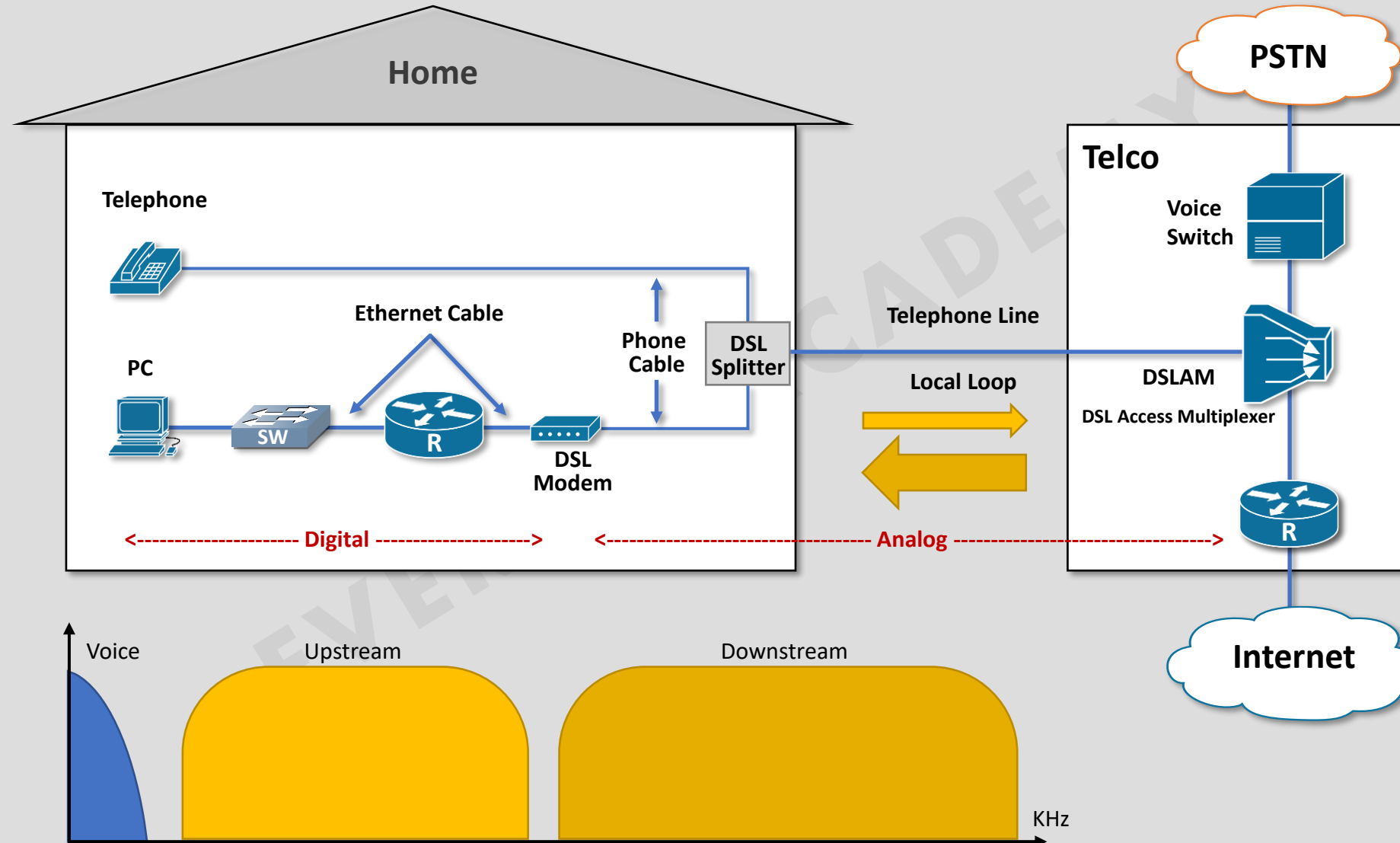


## Digital Subscriber Line (DSL)



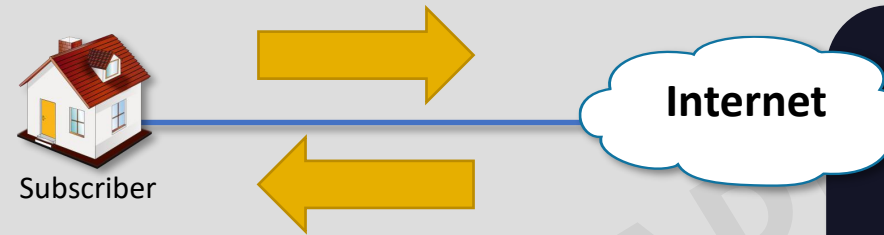


## Digital Subscriber Line (DSL)



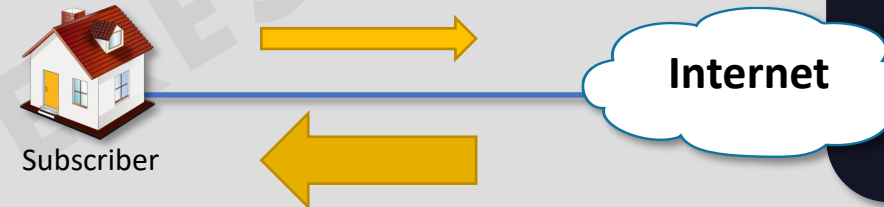
## DSL Technologies

### ❑ Symmetric Digital Subscriber line (SDSL):

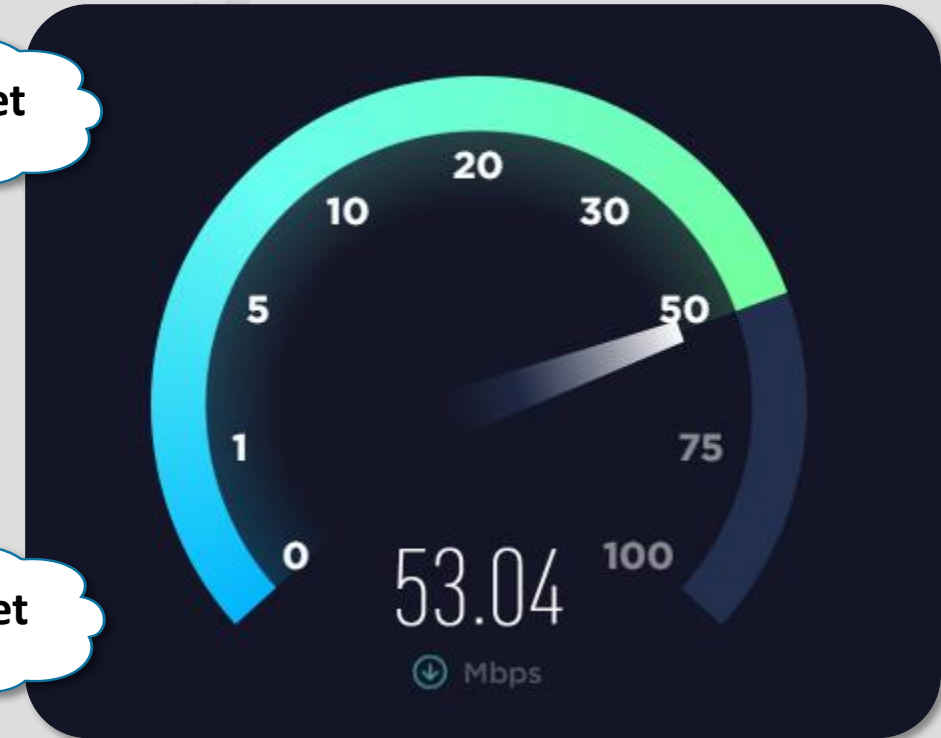


- High bit rate digital subscriber line (HDSL), 1,544 kbit/s and 2,048 kbit/s

### ❑ Asymmetric Digital Subscriber line (ADSL) :



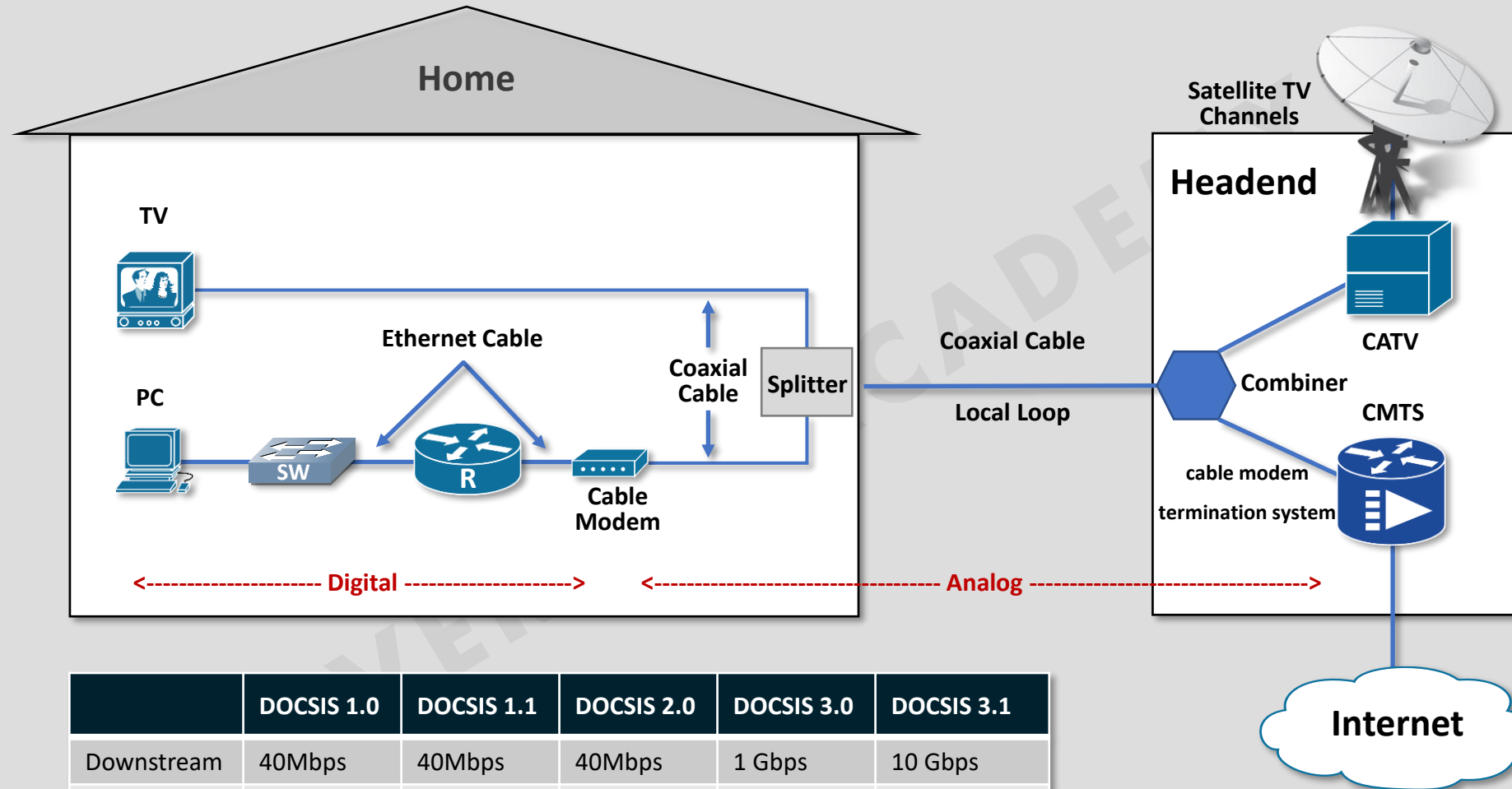
- Asymmetric digital subscriber line (ADSL), up to 8 Mbit/s and 800 kbit/s
- Asymmetric digital subscriber line 2 (ADSL2), up to 12 Mbit/s and 3.5 Mbit/s
- Asymmetric digital subscriber line 2 plus (ADSL2+), up to 24 Mbit/s and 3.5 Mbit/s
- Very-high-bit-rate digital subscriber line (VDSL), up to 54 Mbit/s and 16 Mbit/s



## Cable Modem



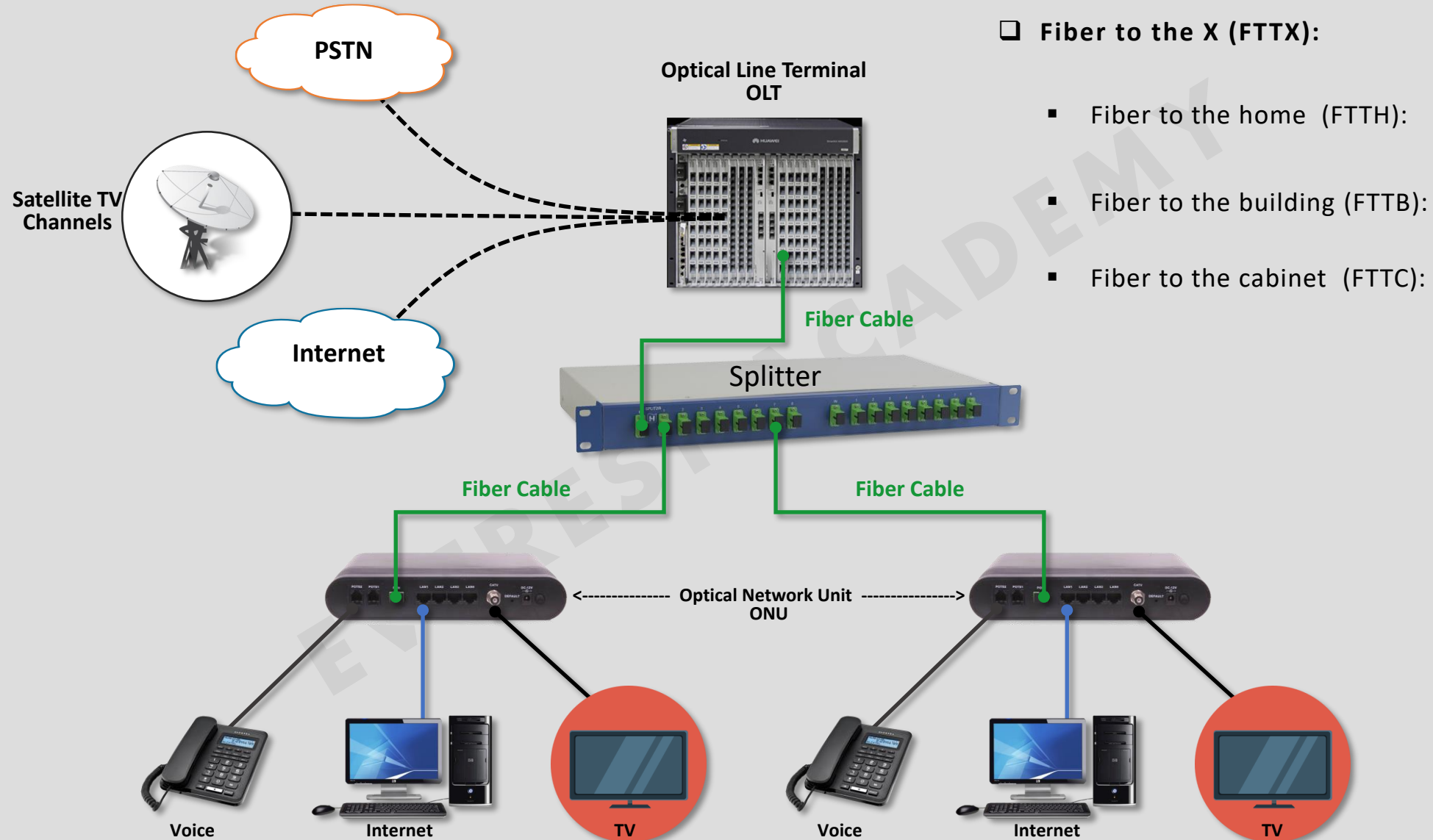
## Cable Modem



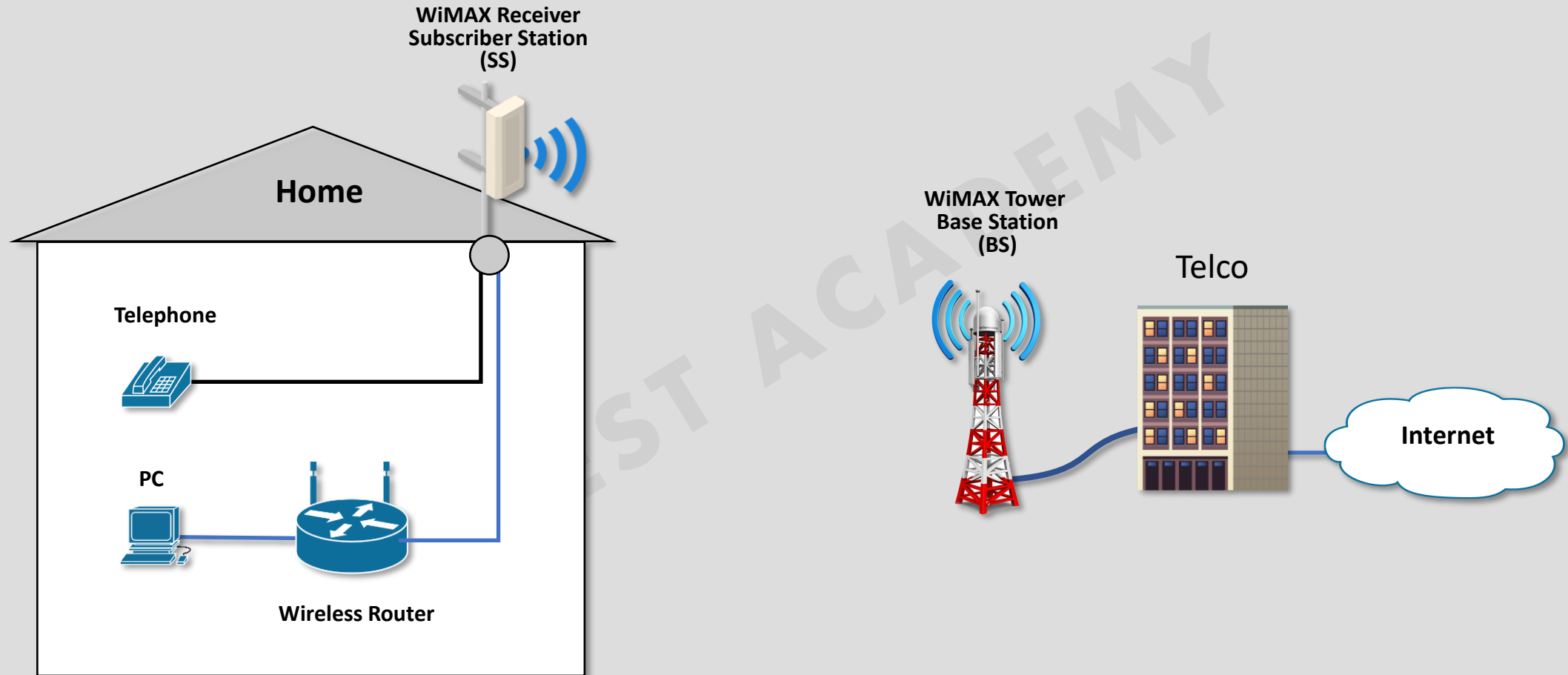
- Data Over Cable Service Interface Specification (DOCSIS).



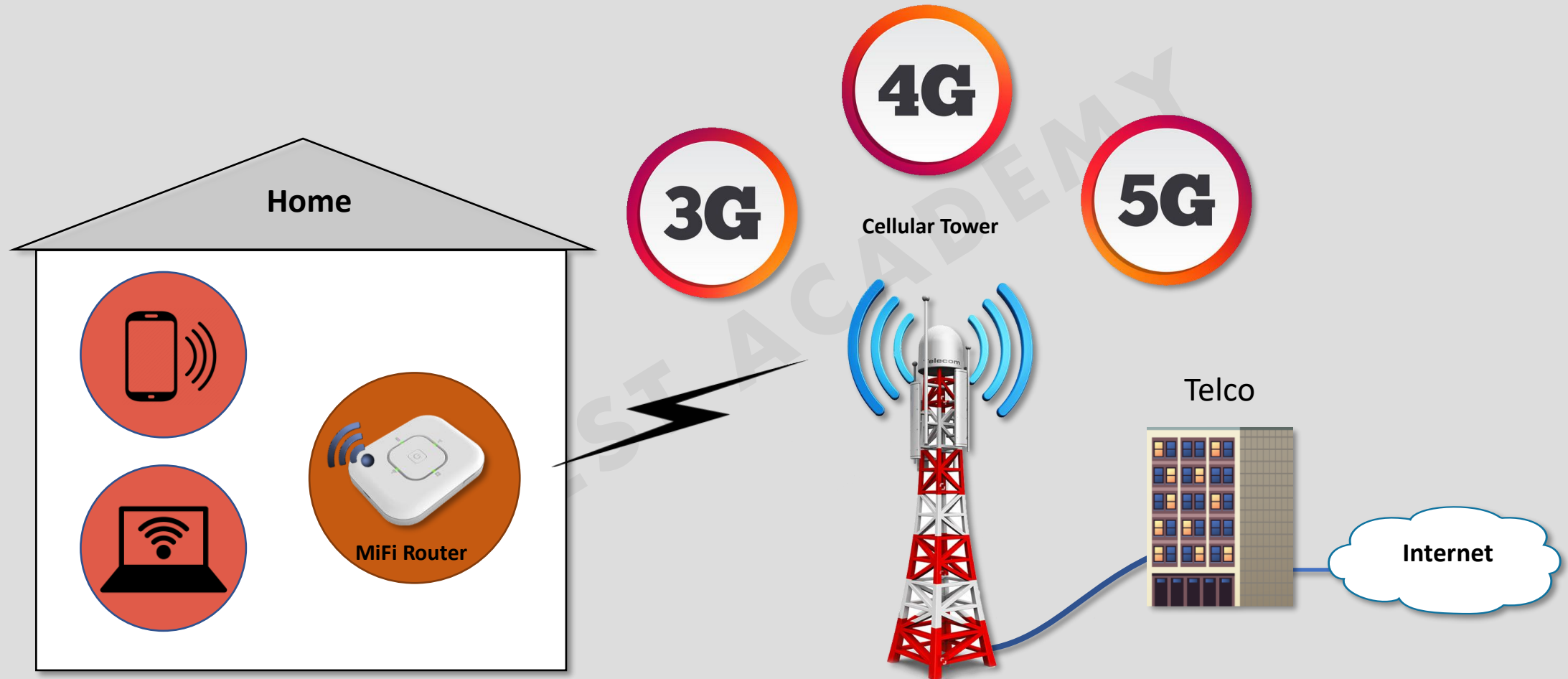
## Fiber Optic Internet



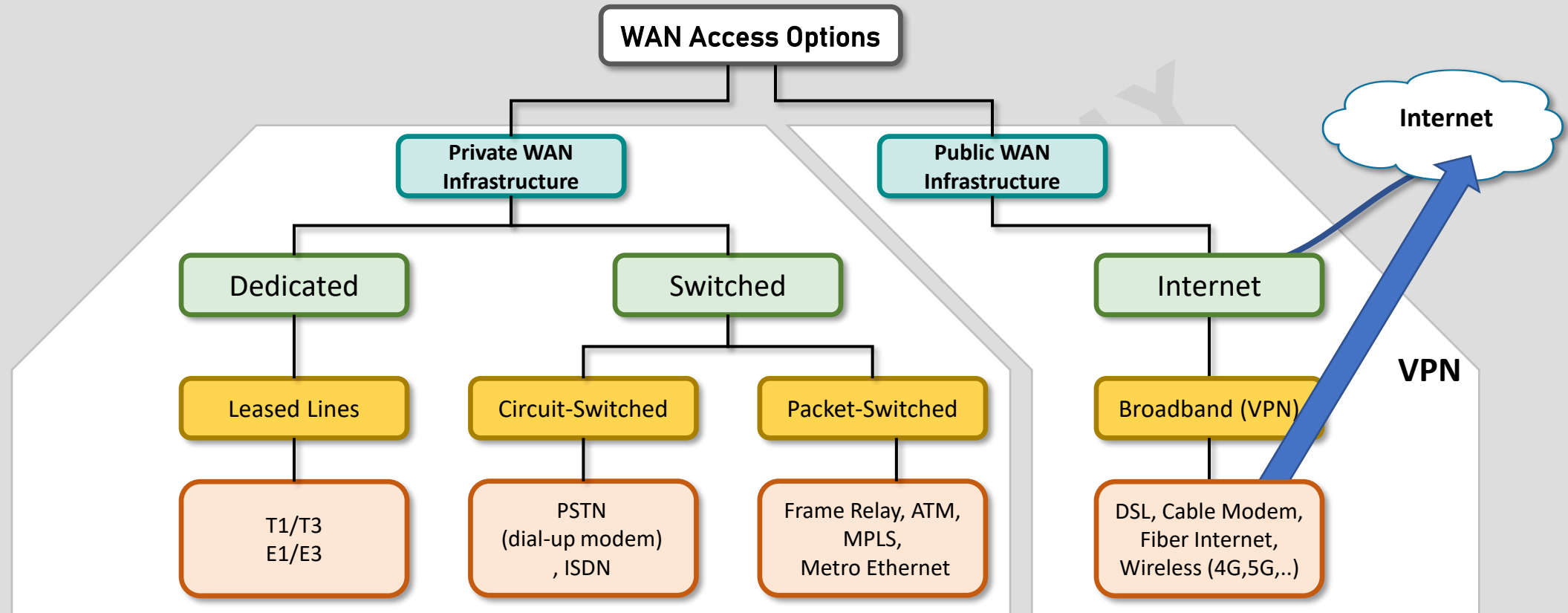
## WiMAX



## 3G/4G/5G (Cellular Network)

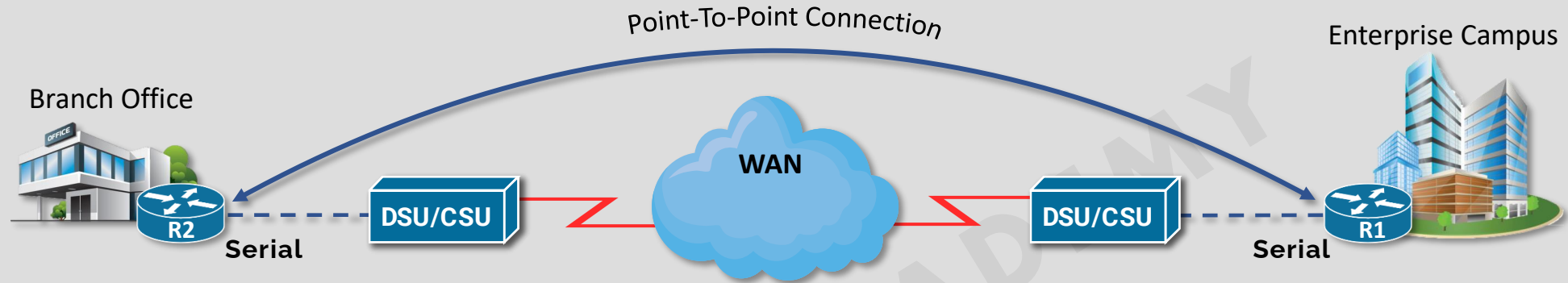


## Internet VPNs





## Cisco HDLC Encapsulation

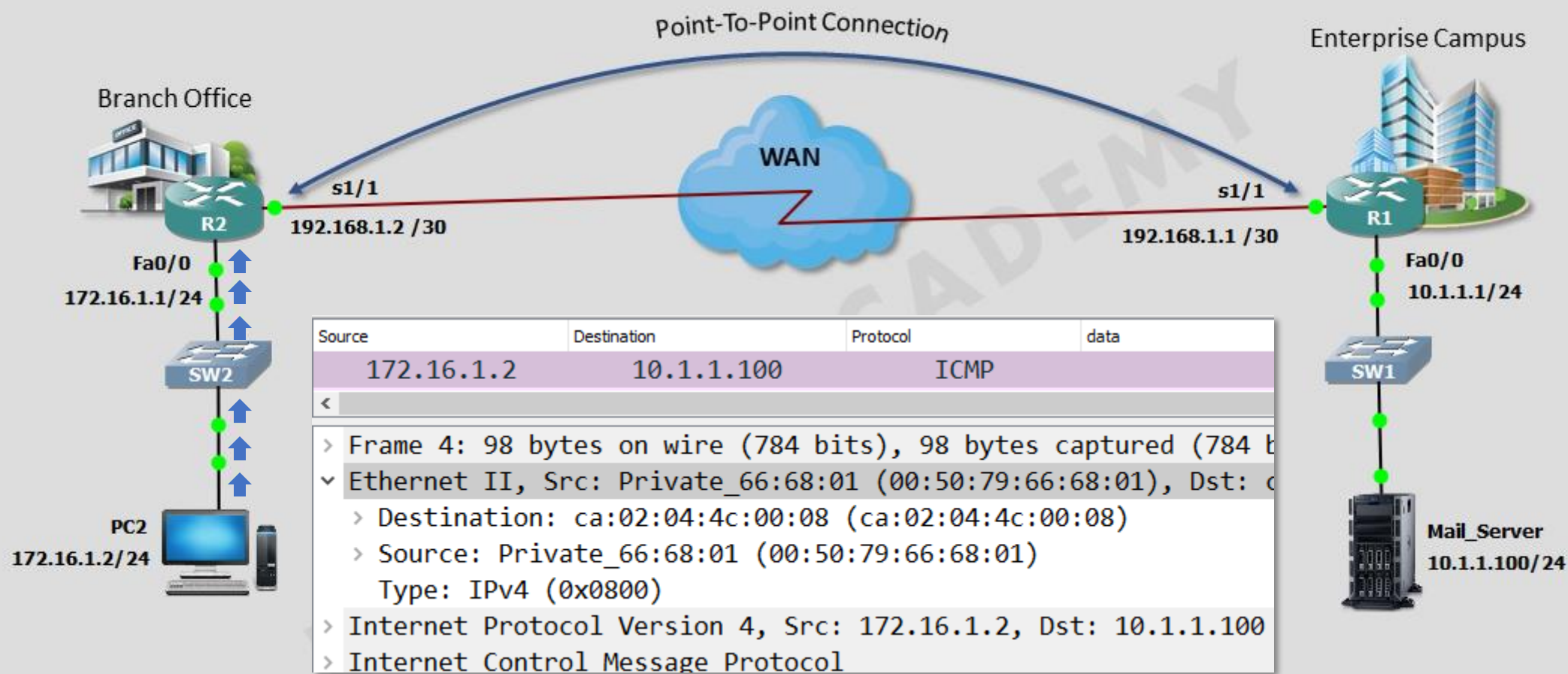


### ■ Cisco HDLC

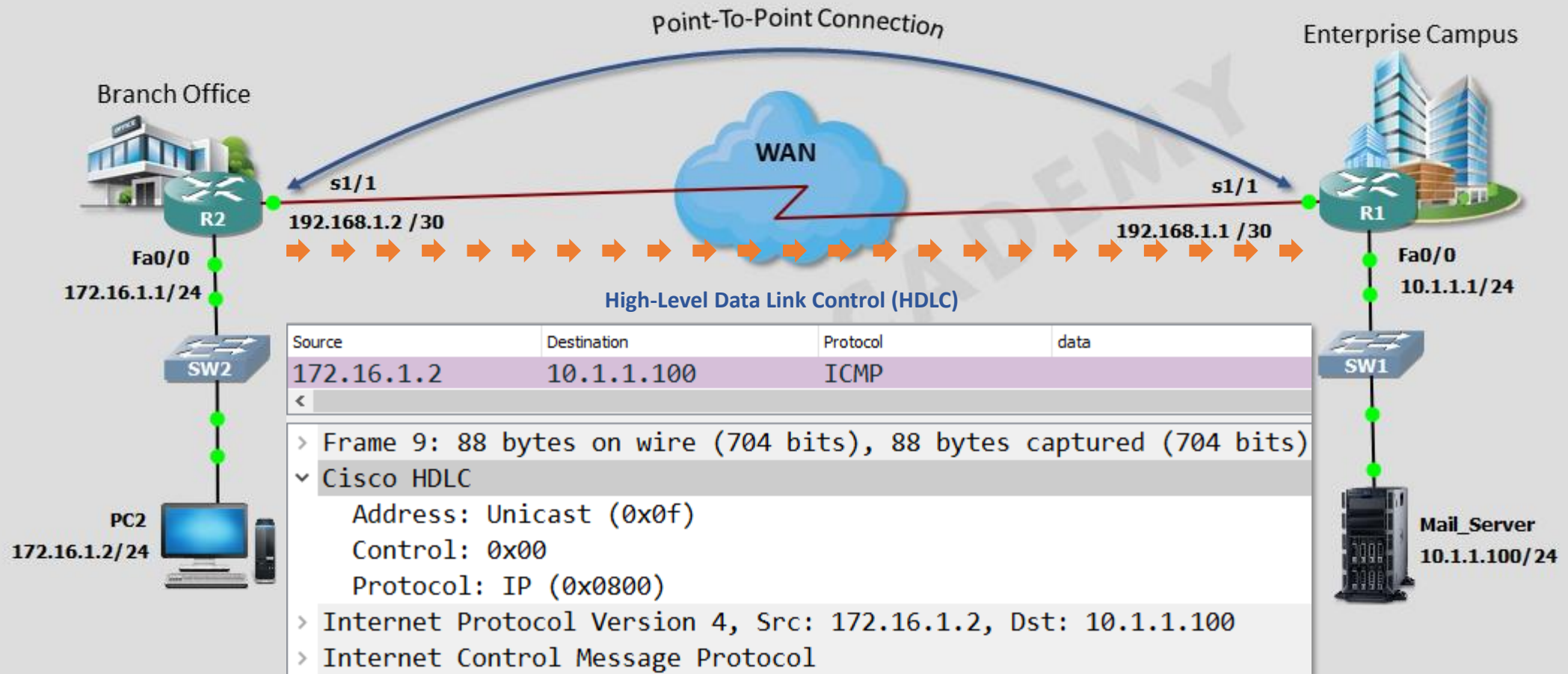
Flag	Address	Control	Protocol	Data	FCS	Flag
0x7E = 126	0x0F (unicast), 0x8F (broadcast)	0x00	IPv4 : 0x0800 IPv6 : 0x86dd CDP : 0x2000			0x7E = 126



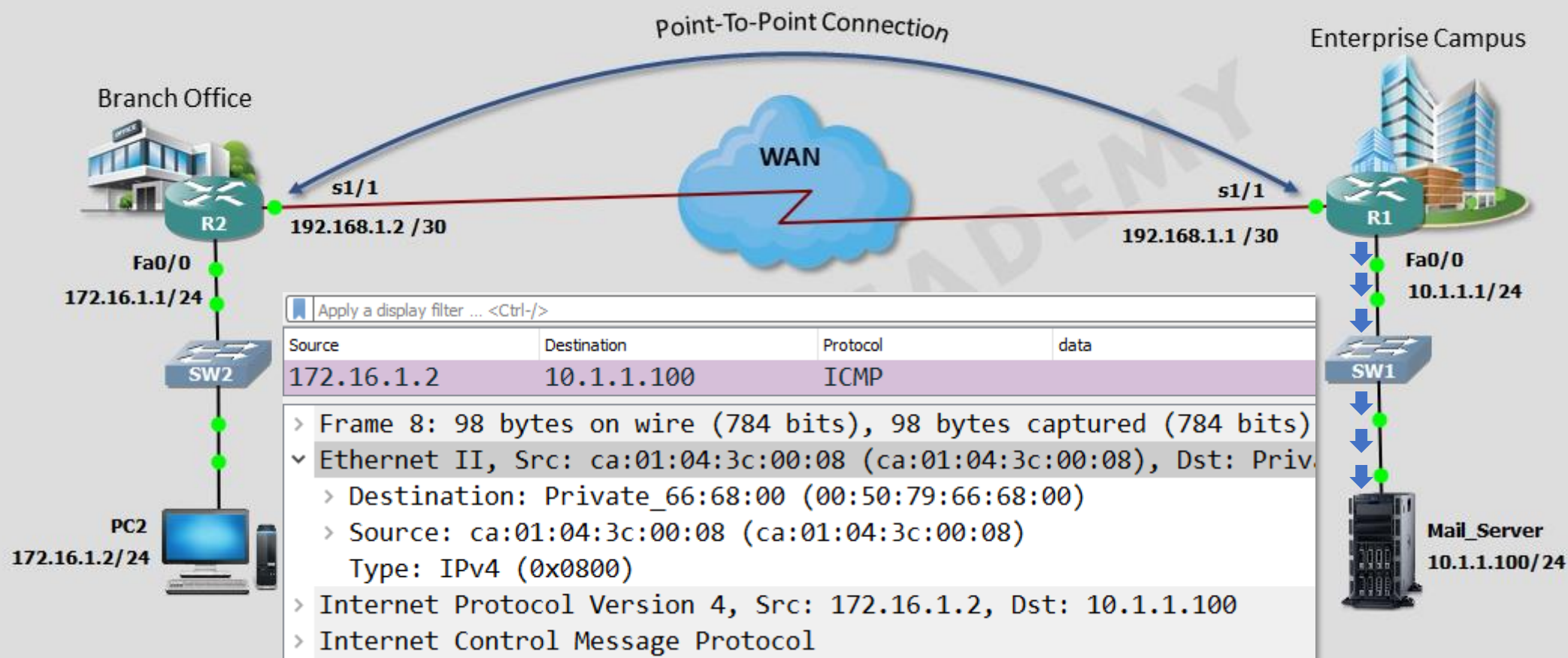
## Cisco HDLC Encapsulation



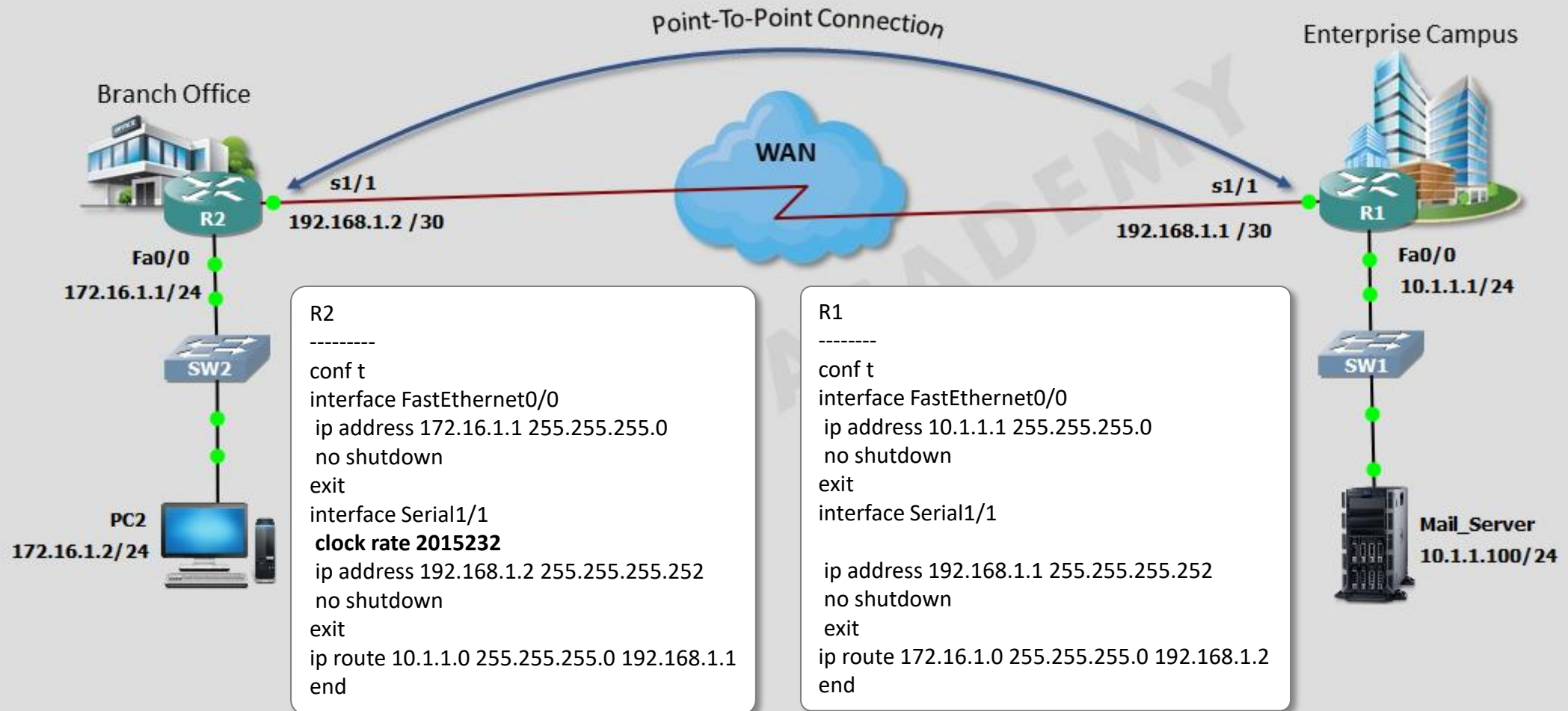
# Cisco HDLC Encapsulation



## Cisco HDLC Encapsulation

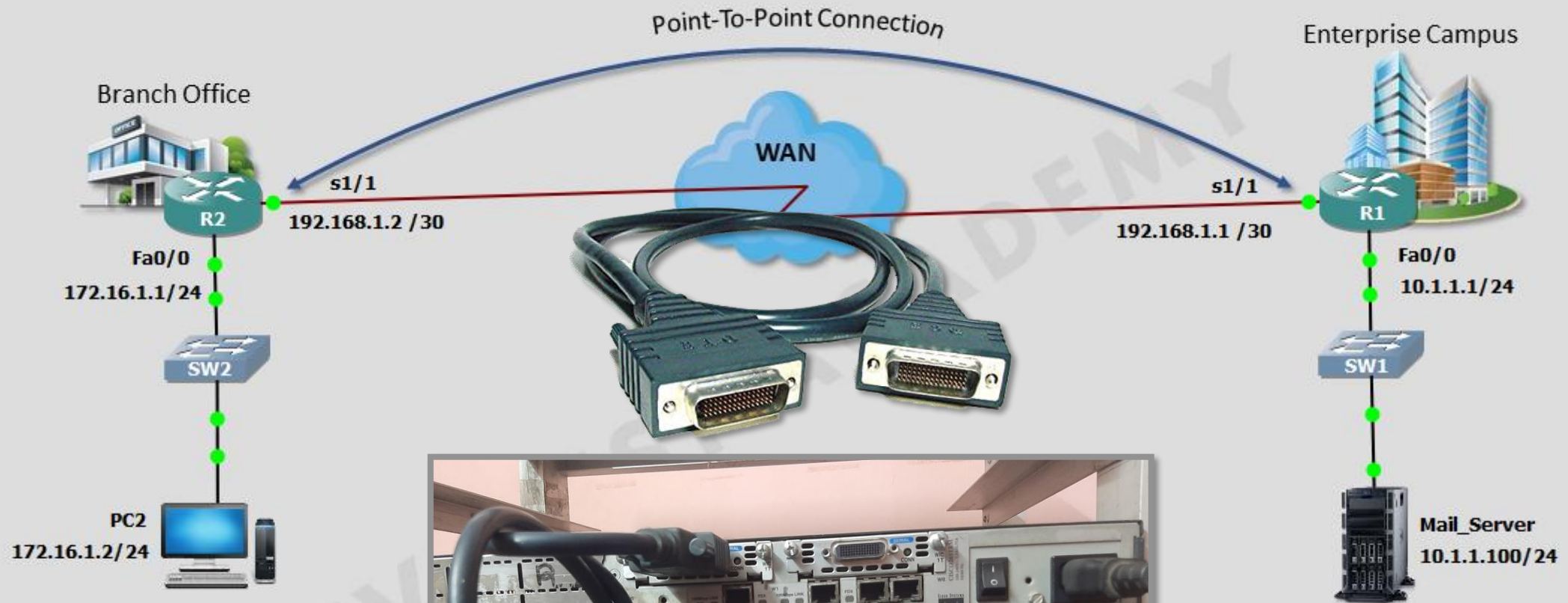


# Cisco HDLC Encapsulation





## Cisco HDLC Encapsulation

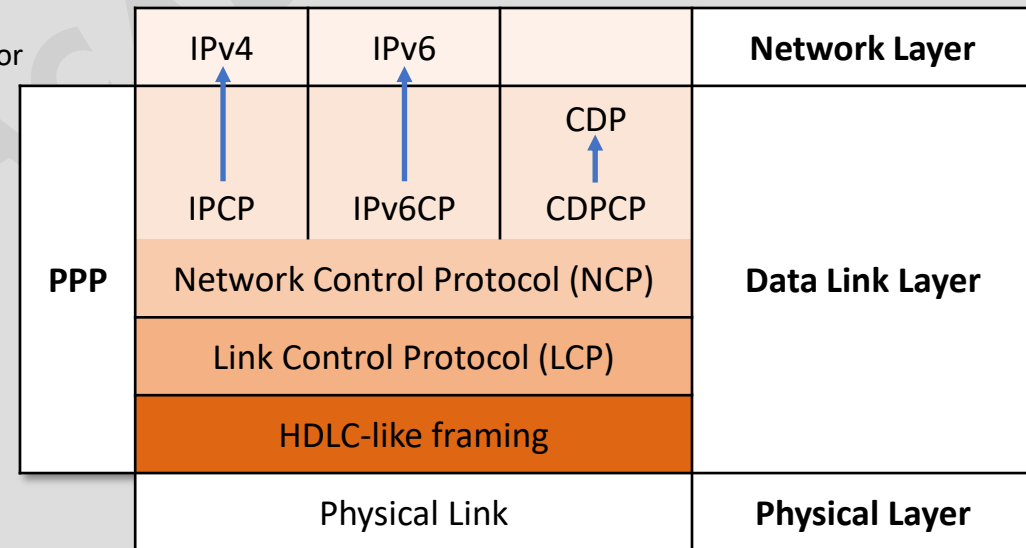


## Point-to-Point Protocol (PPP)

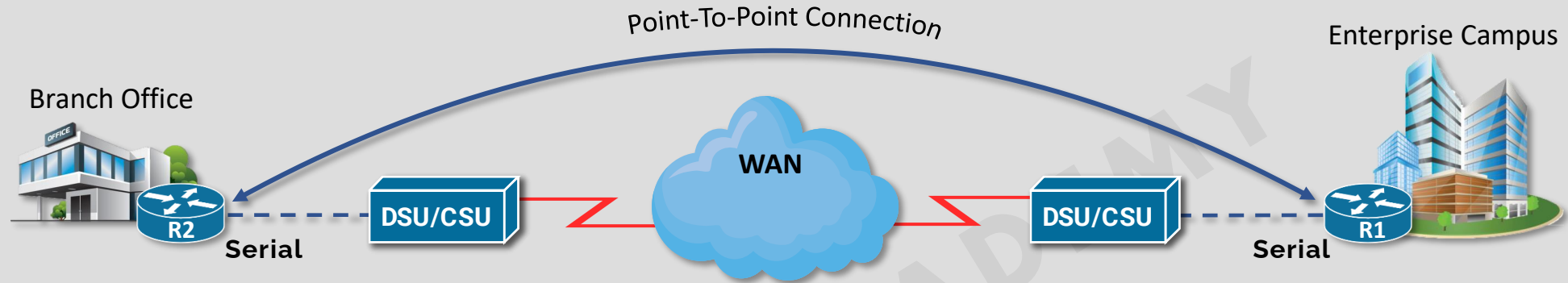
- ❑ **PPP** is a protocol that is able to handle **authentication**, **compression**, and **error detection**; **monitor link quality**; and logically **bundle multiple serial connections together** to share the load.

- ❑ **PPP components:**

1. Frame format (encapsulation).
2. Link Control Protocol (LCP).
  - Authentication method used (PPP Authentication Procedure [PAP] or Challenge-Handshake Authentication Protocol [CHAP]), if any.
  - Compression.
  - Callback phone.
  - Multilink.
  - Error detection.
3. Family of Network Control Protocols (NCPs) .
  - IPCP: controls IPv4.
  - IPv6CP: Controls IPv6.
  - CDPCP: Controls Cisco Discovery Protocol (CDP).



## PPP Encapsulation



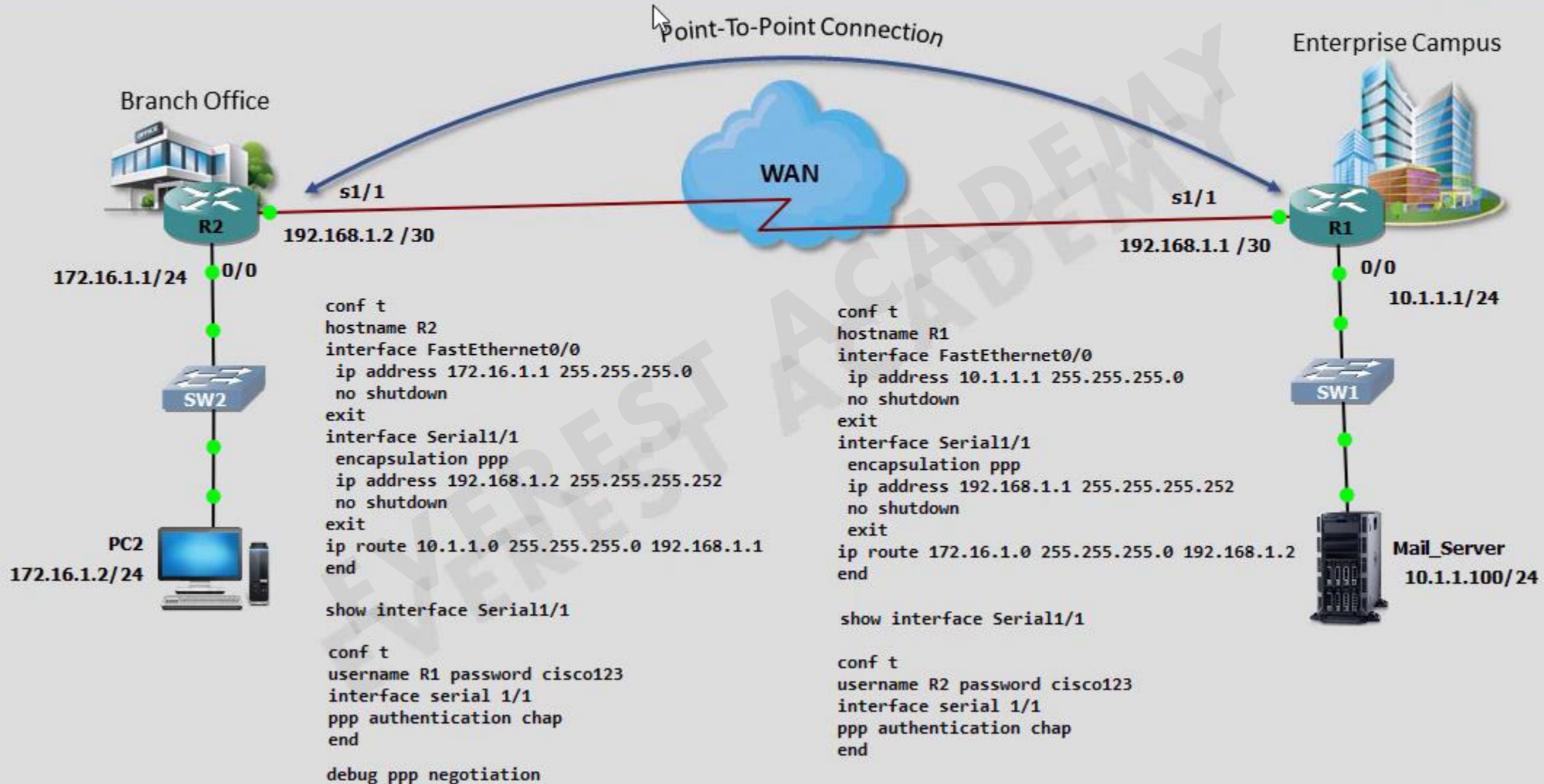
### PPP General Frame Format

Flag	Address	Control	Protocol	Data	FCS	Flag
0x7E = 126	0xFF = 255	0x03	IPv4 : 0x0021 IPv6 : 0x0057 CDP : 0x0207			0x7E = 126

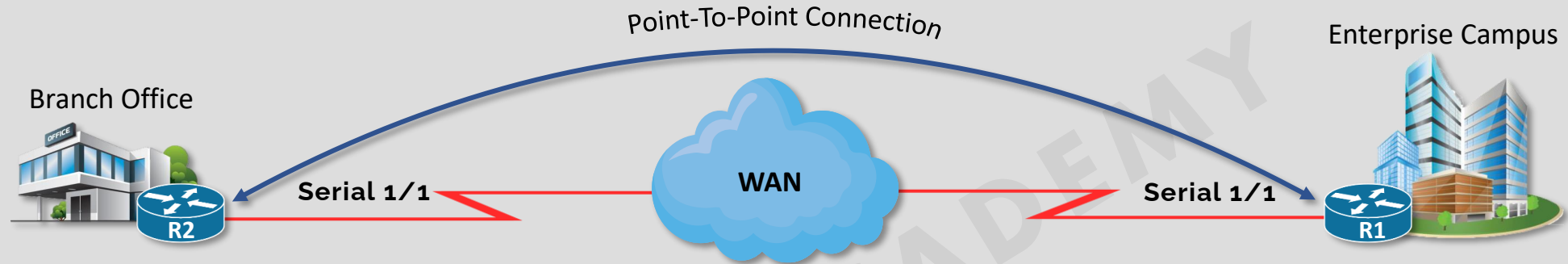




## PPP Authentication Protocols



## PPP Authentication Protocols

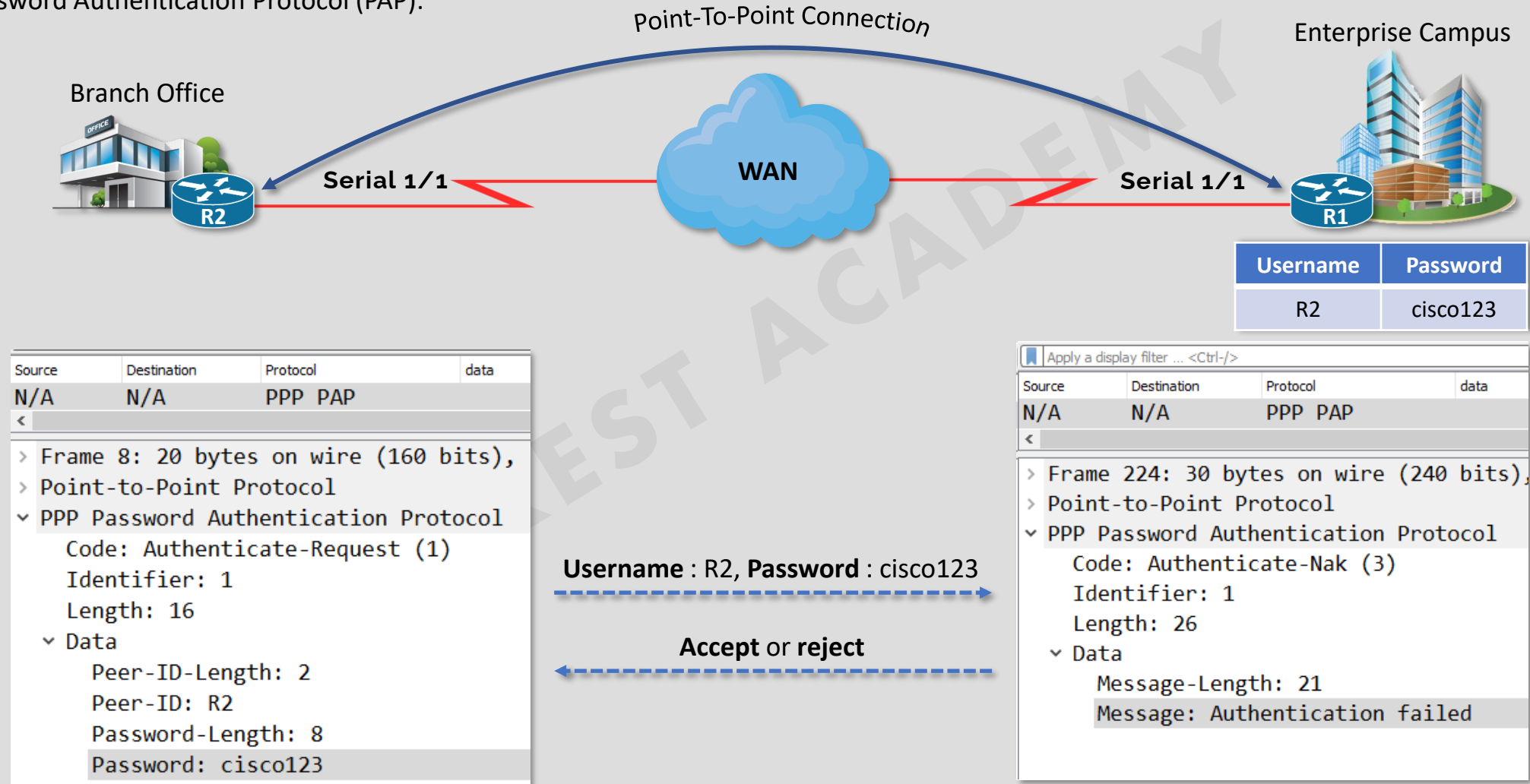


- ☐ Password Authentication Protocol (PAP):
- ☐ Challenge Handshake Authentication Protocol (CHAP):



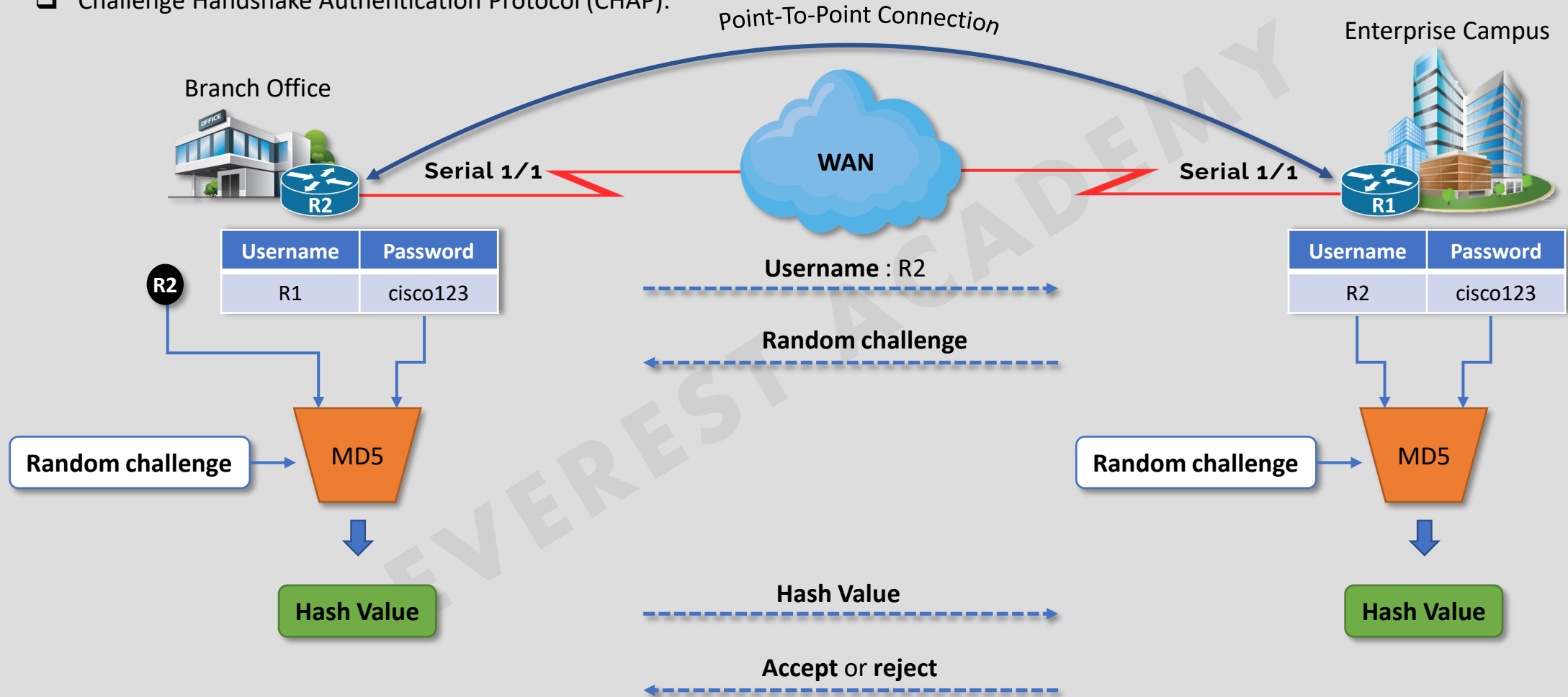
## PPP Authentication Protocols

### ❑ Password Authentication Protocol (PAP):



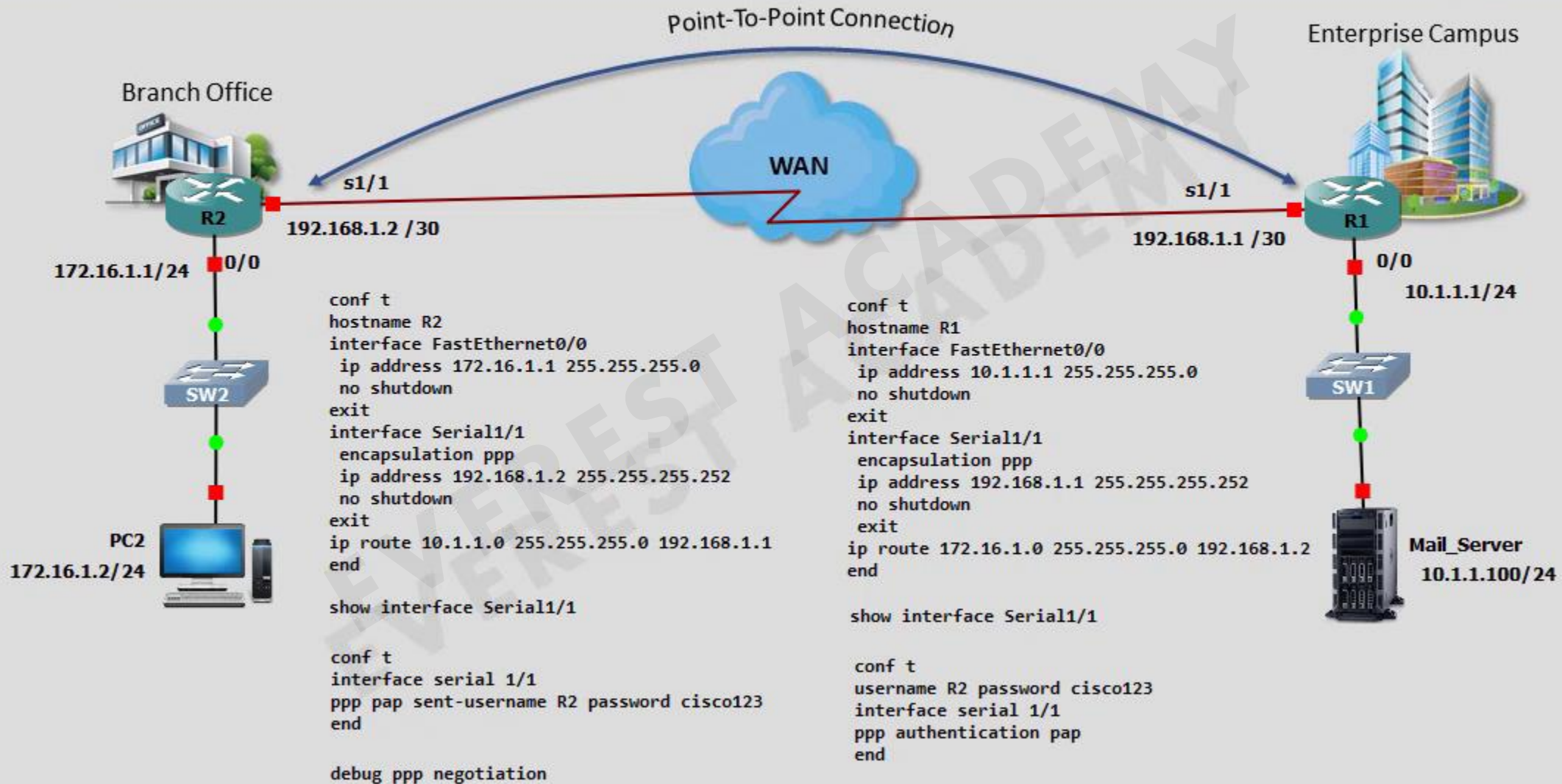
## PPP Authentication Protocols

### ❑ Challenge Handshake Authentication Protocol (CHAP):





## PPP Authentication Protocols



## PPP Authentication Protocols

