AHRAM CANADIAN UNIVERSITY

Lecture (06)
Fundamentals of MANs

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Agenda

- What is WAN?
- What is MAN?
- OSI layer1 of WANs
- OSI Layer 2 of WANs

What is WAN?

- LAN standards and protocols define how a network between two devices operates, these devices are relatively close together.
- Team *local refers to LAN*
- WAN standards and protocols define how to network between devices that are relatively far apart—in some cases, even thousands of miles apart—
- Term *wide-area refers to WAN.*

What is WAN? (2)

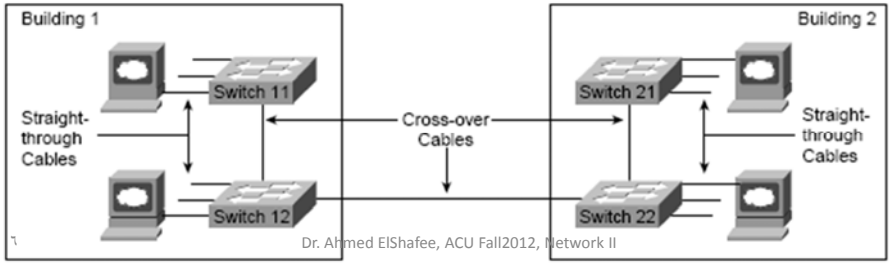
- LANs tend to reside in a single building or possibly among buildings in a campus using optical cabling approved for Ethernet.
- WAN connections typically run longer distances than Ethernet, across town or between cities.
- Often, only one or a few companies even have the rights to run cables under the ground between the sites.
- So, the people who created WAN standards needed to use different physical specifications than Ethernet to send data 1000 km or more (WAN).

What is MAN?

- Besides LANs and WANs, the term *metropolitan-area network (MAN) is* sometimes used for networks that extend between buildings and through rights-of-ways.
- The term typically implies a network that does not reach as far as a WAN, generally in a metropolitan area.
- The distinctions between LANs, MANs, and WANs are not sharp—there is no set distance that means a link is a LAN, MAN, or WAN link.

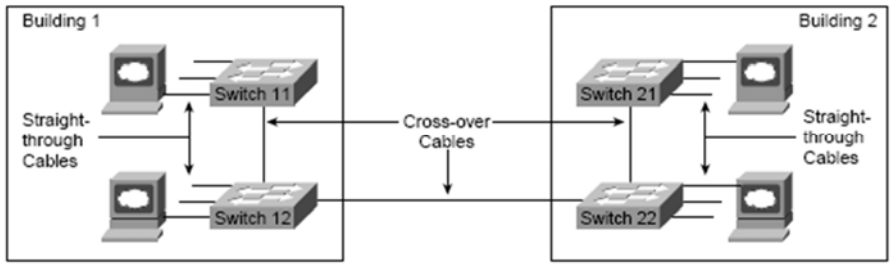
OSI layer1 of WAN

- The OSI physical layer defines the standards and protocols used to create the physical network and to send the bits across that network.
- A point-to-point WAN link acts like a trunk between two Ethernet switches in many ways.
- Below figure shows a LAN with two buildings and two switches in each building.



OSI layer1 of WAN (2)

- the trunk links between the switches uses Ethernet network layer protocol, which uses a twisted pair of wires to transmit and another twisted pair to receive, to reduce electromagnetic interference.



OSI layer1 of WAN (3)

- Now imagine that the buildings are 1000 KMs apart instead of right next to each other.
- You are immediately faced with two problems:

1. Ethernet does not support any type of cabling that allows an individual trunk to run for 1000 KMs
2. Even if Ethernet supported a 1000 KMs trunk, you do not have the rights of way needed to bury a cable over the 1000 KMs of real estate between buildings.

OSI layer1 of WAN (4)

- To create such long links, or circuits, the actual physical cabling is owned, installed, and managed by a company that has the right of way to run cables under streets.
- Because a company that needs to send data over the WAN circuit does not actually own the cable or line, it is called a *leased line.*
- *Companies that can provide leased WAN lines typically started* life as the local telephone company called "Telco"
- In many countries, the telephone company is still a government-regulated or government-controlled monopoly

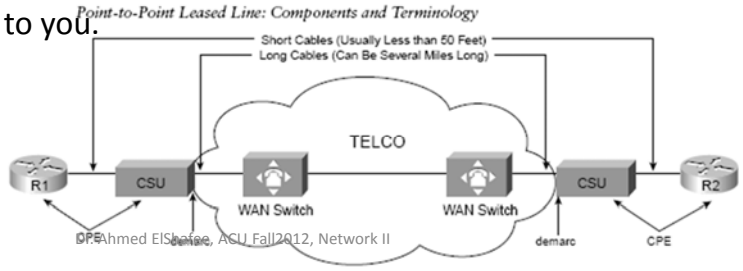
OSI layer1 of WAN (5)

- Point-to-point WAN links provide basic connectivity between two points.
- It is similar to what you would have if you made a phone call between two sites but you never hung up.
- The two devices on either end of the WAN circuit could send and receive bits between each other any time they want, without needing to dial a phone number.
- It is called a *leased circuit or leased line because you have* the exclusive right to use that circuit, as long as you keep paying for it.

OSI layer1 of WAN (6)

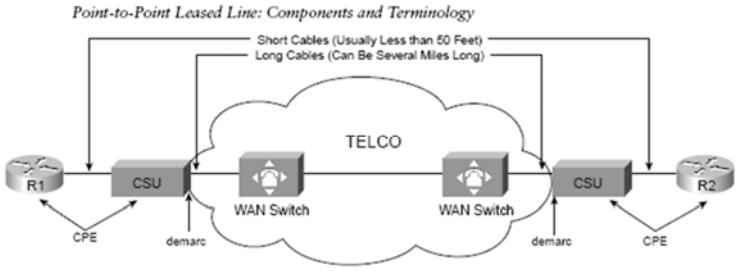
WAN Connections from the Customer Viewpoint

- Below figure presents WAN leased line acts as if the telco gave you two twisted pairs of wires between the two sites on each end of the line.
- Teelco has built a large network already and even runs extra cables from the local central office (CO) to your building.
- When you ask for leased line, it just dedicate some pre-installed line to you.



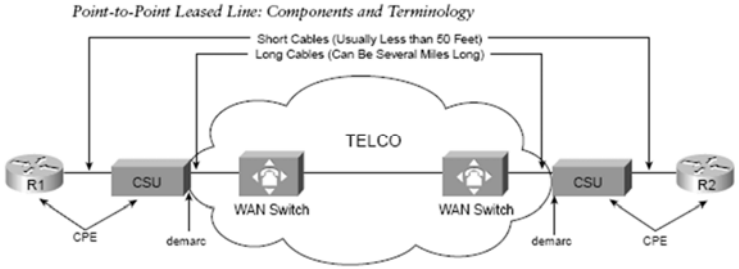
OSI layer1 of WAN (7)

- Typically routers are connected to Channel Service Unit or Digital Service Unit "CSU/DSU" using short cable.
- In other cases router comes with internally integrated CSU
- Router + CSU called CPE "*customer premises equipment"* which refers to equipments in customer side.



OSI layer1 of WAN (8)

- A direct line is connected from CSU to nearest CO connecting to WAN switch.
- The same happened in the other end.
- Between WAN switches, there may be different COs, and different WAN switches uses different technologies.



OSI layer1 of WAN (9)

WAN Cabling Standards

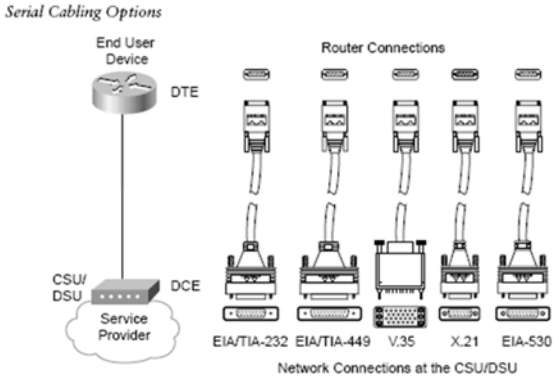
There are two type of WAN links (serial links)

- synchronous serial interfaces
- asynchronous serial interfaces

Most common serial WAN links are synchronous

OSI layer1 of WAN (10)

1. Router 2 CSU



WAN Interface Cable Standards

Standard Connectors (into CSU/DSU)	Standards Body	Number of Pins on the Connector
EIA/TIA-232	TIA	25
EIA/TIA-449	TIA	37
EIA/TIA-530	TIA	25
V.35	ITU	34
X.21	ITU	15

OSI layer1 of WAN (11)

2. CSU to CO

- The cable between the CSU/DSU and the telco CO typically uses an RJ-48 connector to connect to the CSU/DSU;
- the RJ-48 connector has the same size and shape as the RJ-45 connector used for Ethernet cables.

OSI layer1 of WAN (12)

- The cables and physical connector types each have differing limits on the speed of serial data transmission.
- Generally, the shorter the length of the cable is, the closer it can get to the maximum speed allowed for that cable and connector

Maximum Speeds for Various Cables

Data (bps)	Distance (Meters) EIA/TIA-232	Distance (Meters) EIA/TIA-449, V.35, X.21, EIA-530
2400	60	1250
4800	30	625
9600	15	312
19,200	15	156
38,400	15	78
115,200	3.7	—
T1 (1.544 Mbps)	—	15

OSI layer1 of WAN (13)

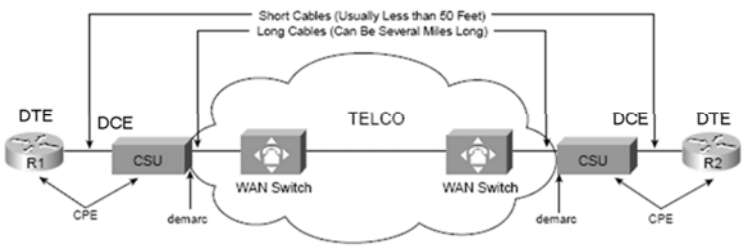
Clock Rates, DCE, and DTE

- When a network engineer needs to add a point-to-point leased line between two routers, he contacts a service provider and orders the circuit.
- As part of that process, the customer specifies how fast the circuit should run, in kilobits per second (kbps).
- While the circuit is being set up by the telco, the engineer purchases two CSU/DSUs, installs one at each site, and configures each CSU/DSU.
- He also cables each router to the respective CSU/DSU using the cables shown in the previous section.
- Eventually, the telco installs the new line into the customer premises, and the line can be connected to the CSU/DSUs

OSI layer1 of WAN (14)

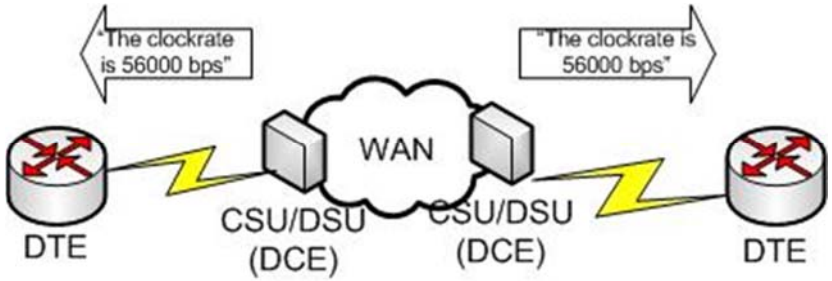
- *clock rate, bandwidth, link speed* all refer to the same thing
- One of the most important isssue is that the two CSU/DSUs are configured to operate at that same speed.
- To do so, one device provides a clocking signal to the other device which simply react, sending and receiving data at the correct rate.

Point-to-Point Leased Line: Components and Terminology



OSI layer1 of WAN (15)

- The device that provides clocking, typically the CSU, is considered to be the *data communications equipment (DCE).*
- The device receiving clocking, typically the router, is referred to as *data terminal equipment (DTE).*



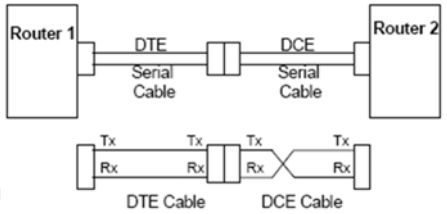
OSI layer1 of WAN (16)

- So when network engineer buys a serial cable for his router, he may buy
  - DCE cable if his router acts as DCE device
  - DTE cable if his router acts as DTE device (typical)

OSI layer1 of WAN (18)

Back-to-back serial link

- You can buy two routers, a DTE serial cable for one router, and a DCE serial cable for the other and connect the two cables together.
- The router with the DCE cable in it can be configured to provide clocking— meaning that you do not need a CSU/DSU. So, you can build a WAN in your home lab,(The DCE cable has a female connector, and the DTE has a male connector, so they can be connected.)



OSI layer1 of WAN (19)

- **Link Speeds Offered by Telcos**
- So, years ago, the telcos of the world developed a standard for sending voice using digital transmissions.
- Digital signaling inside their networks allowed for the growth of more profitable data services, such as leased lines.
- They used Pulse Code Modulation
- PCM defines that an incoming analog voice signal should be sampled 8000 times per second, and each sample should be represented by an 8-bit code.
- So, 64,000 bits were needed to represent 1 second of voice.

OSI layer1 of WAN (20)

- So the baseline transmission speed was 64 kbps because that was the necessary bandwidth for a single voice call.
- The term *digital signal level 0 (DS0) refers to the standard for a single 64-kbps line.*
- Later the telcos starting selling data services—in other words, leased lines.
- The phone companies could sell a DS0 service at 64 kbps.
- telco decided to just sell 7 of every 8 bits that could be sent over a DS0—and 7/8 of 64 kbps is 56 kbps. (ECC)
- Today many telcos do not use that bit, so they can offer the full 64-kbps channel.

OSI layer1 of WAN (21)

- Then Telco starts duplicating DS0 to offer wider band width

WAN Speed Summary

Type of Line	Name of Signalling Type	Bit Rate
56	DS0*	56 kbps
64	DS0	64 kbps
T1	DS1	1.544 Mbps (24 DS0s, plus 8 kbps overhead
T3	DS3	44.736 Mbps (28 DS1s, plus management overhead)
E1	ZM	2.048 Mbps (32 DS0s)
E3	M3	34.064 Mbps (16 E1s, plus management overhead)
J1	Y1	2.048 Mbps (32 DS0s; Japanese standard)

*DS0, with 1 robbed bit out of 8

OSI Layer 2 of WANs

- WAN protocols used on point-to-point serial links provide the basic function of data delivery across that one link.
- The two most popular data-link protocols used on point-to-point links are
  - High-Level Data Link Control (HDLC) and
  - Point-to-Point Protocol (PPP).
- The two most popular data-link protocols used on multi points-to-multi points link is
  - Frame Relay

OSI Layer 2 of WANs (2)

1. HDLC

HDLC performs OSI Layer 2 functions,

- **Arbitration—**Determines when it is appropriate to use the physical medium
- **Addressing—**Ensures that the correct recipient(s) receives and processes the data that is sent
- **Error detection—**Determines whether the data made the trip across the physical medium successfully
- **Identifying the encapsulated data—**Determines the type of header that follows the datalink header

OSI Layer 2 of WANs (3)

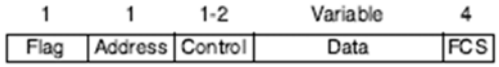
1. Arbitration

- HDLC is very simple as compared with Ethernet
- Ethernet uses CSMA/CD algorithm arbitrates
- point-to-point serial link, each router can send over the four-wire (two-pair) circuit at any time, so there is no need for any kind of a arbitration.

OSI Layer 2 of WANs (4)

- HDLC defines framing that includes an
  1. address field, a
  2. frame check sequence (FCS) field,
  3. And a protocol type field.
- These three fields in the HDLC frame help provide the other three functions of the data link layer.

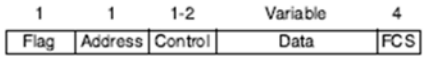
HDLC Framing



OSI Layer 2 of WANs (5)

2. Addressing

HDLC Framing



- HDLC defines a 1-byte address field, although on point-to-point links, it is not really needed.
- In the past HDLC was used for a multidrop circuit. With a multidrop circuit, one central site device could send and receive frames with multiple remote sites.
- HDLC defined the address field to identify the different remote sites on a multidrop link.
- Now HDLC used for point to point links so address is not used, routers insert decimal 3 into address field.

OSI Layer 2 of WANs (6)

3. Error Detection

- HDLC performs error detection just like Ethernet—it uses an FCS field in the HDLC trailer. And just like Ethernet, if a received frame has errors in it, the frame is discarded, with no error recovery performed by HDLC.

4. Identifying the encapsulated data

- Only CISCO routers uses this function.
- HDLC performs the function of identifying the encapsulated data just like Ethernet as well.
- When a router receives an HDLC frame, it wants to know what type of packet is held inside the frame.

OSI Layer 2 of WANs (7)

2. Point-to-Point Protocol

Comparing the basics, PPP behaves exactly like HDLC

1. There is an address field, but the addressing does not matter.
2. PPP does discard errored frames that do not pass the FCS check.
3. And PPP uses a 2-byte Protocol Type field—although PPP's Protocol Type field is defined by the protocol

OSI Layer 2 of WANs (8)

- PPP-unique features fall into two main categories:

1. Those needed regardless of the Layer 3 protocol sent across the link
2. Those specific to each Layer 3 protocol

- Each link that uses PPP has one LCP (generic control) per link and one CP for each Layer 3 protocol defined on the link.

OSI Layer 2 of WANs (9)

Link Control Protocol (LCP),

- focuses on the features that apply regardless of the Layer 3 protocol used.
- LCP performs most of its work when the line comes up, so it has a lot more work to do with dialed links, which come up and down a lot, versus leased lines, which hopefully seldom fail.

OSI Layer 2 of WANs (10)

PPP LCP Features

Function	LCP Feature	Description
Error detection	Link quality monitoring (LQM)	PPP can take down a link based on the percentage of errors on the link using LQM.
Looped link detection	Magic number	The telco might reflect the data that a router sends it back to the router, to test a circuit. PPP uses a feature called magic numbers to detect a looped link and takes down the link.
Multilink support	Multilink PPP	This allows multiple parallel serial links to be connected between the same two routers, balancing traffic across the links.
Authentication	PAP and CHAP	Particularly useful for dial-up links, PPP initiates an authentication process to verify the identity of the device on the other end of the serial link.

OSI Layer 2 of WANs (11)

IP Control Protocol (IPCP) (type of LC)

- provides for IP address assignment over a PPP link.
- When a user dials a new connection to an ISP using a modem, PPP typically is used, with IPCP assigning an IP address to the remote PC.

- If a router is configured for IPX, AppleTalk, and IP on a PPP serial link, the router configured for PPP encapsulation automatically tries to bring up the appropriate controlprotocols for each Layer 3 protocol.

OSI Layer 2 of WANs (12)

3. Other Point-to-Point WAN Data-Link Protocols

- WAN data-link protocols can be compared relative to two main attributes.

1. First, some protocols do support multiprotocol traffic by virtue of having a defined protocol type field.
2. Also, some protocols actually perform error recovery—so when the receiving end notices that the received frame did not pass the FCS check, it causes the frame to be resent.

OSI Layer 2 of WANs (13)

List of WAN Data-Link Protocols

Protocol	Error Correction?	Type Field?	Other Attributes
Synchronous Data Link Control (SDLC)	Yes	No	SDLC supports multipoint links. It assumes that an SNA header occurs after the SDLC header.
Link Access Procedure Balanced (LAPB)	Yes	No*	LAPB is used mainly with X.25.
Link Access Procedure on the D Channel (LAPD)	No	No	LAPD is used by ISDN lines for signaling to set up and bring down circuits.
Link Access Procedure for Frame Mode Bearer Services(LAPF)	No	Yes	This is a data-link protocol used over Frame Relay links.
High-Level Data Link Control (HDLC)	No	No*	HDLC serves as Cisco's default on serial links.
Point-to-Point Protocol (PPP)	Supported but not enabled by default	Yes	PPP was meant for multiprotocol interoperability from its inception, unlike all the others.

OSI Layer 2 of WANs (14)

- **Synchronization**
- Both of HDLC and PPP are synchronous.
- Synchronous means sending and receiving ends uses the same clock.
- it is expensive to build devices that truly can operate at exactly the same speed.
- So, the devices operate at close to the same speed and listen to the speed of the other device on the other side of the link.
- One side makes small adjustments in its rate to match the other side.

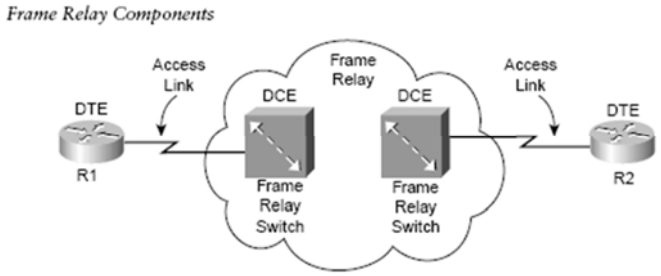
WAN Terminology

Term	Definition
Synchronous	The imposition of time ordering on a bit stream. Practically, a device tries to use the same speed as another device on the other end of a serial link. However, by examining transitions between voltage states on the link, the device can notice slight variations in the speed on each end and can adjust its speed accordingly.
Asynchronous	The lack of an imposed time ordering on a bit stream. Practically, both sides agree to the same speed, but there is no check or adjustment of the rates if they are slightly different. However, because only 1 byte per transfer is sent, slight differences in clock speed are not an issue. A start bit is used to signal the beginning of a byte.
Clock source	The device to which the other devices on the link adjust their speed when using synchronous links.
DSU/CSU	Data service unit/channel service unit. Used on digital links as an interface to the telephone company in the United States. Routers typically use a short cable from a serial interface to a DSU/CSU, which is attached to the line from the telco with a similar configuration at the other router on the other end of the link.
Telco	Telephone company.
Four-wire circuit	A line from the telco with four wires, comprised of two twisted-pair wires. Each pair is used to send in one direction, so a four-wire circuit allows full-duplex communication.
T1	A line from the telco that allows transmission of data at 1.544 Mbps.
E1	Similar to a T1, but used in Europe. It uses a rate of 2.048 Mbps and 32 64-kbps channels.

OSI Layer 2 of WANs (16)

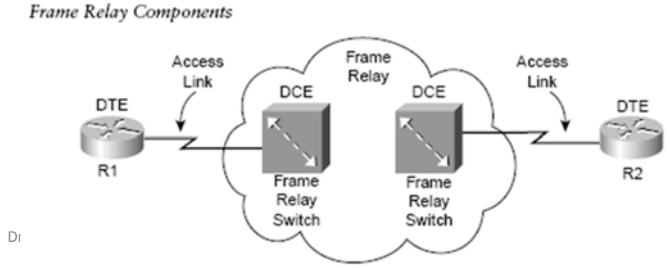
Frame Relay

- Frame Relay networks are multi-access networks, which means that more than two devices can attach to the network, similar to LANs.
- To support more than two devices, the protocols must be a little more detailed.



OSI Layer 2 of WANs (17)

- Frame Relay uses the same Layer 1 features as a point-to-point leased line.
- For a Frame Relay services, a leased line is installed between each router and a nearby Frame Relay switch; these links are called *access links.*
- The access links run the same speeds and use the same signaling standards as do point-to-point leased lines.

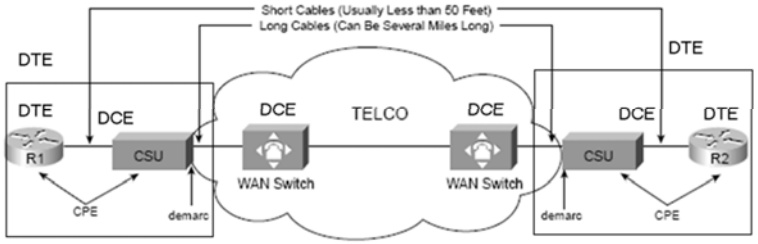


OSI Layer 2 of WANs (18)

- Each frame header holds an address field called a data-link connection identifier (DLCI).
- The WAN switch forwards the frame, based on the DLCI, through the provider's network until it gets to the router on the other side of the network.
- so that it's called packet switching service, and that's the main difference between point2point and frame relay.

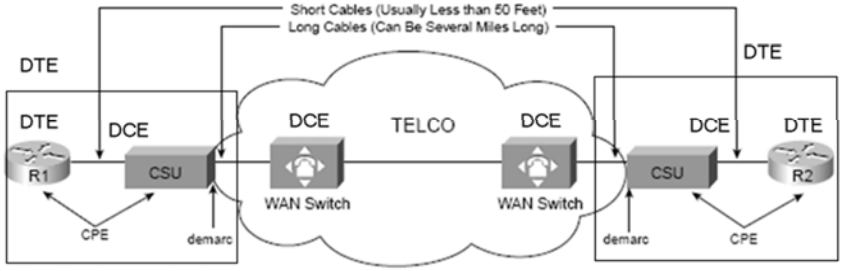
OSI Layer 2 of WANs (19)

- Frame Relay protocols resemble OSI Layer 2 protocols; the term usually used for the bits sent by a Layer 2 device is *frame*
- the Frame Relay switches are called DCE, and the customer equipment—routers, in this case—are called DTE
- *DCE refers to the device providing the service, and the term DTE refers to the device* needing the frame-switching service.



OSI Layer 2 of WANs (20)

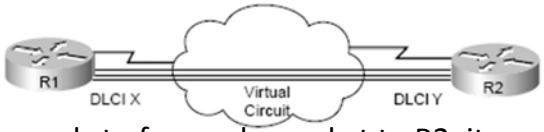
- At the same time, the CSU/DSU provides clocking to the
- router, so from a Layer 1 perspective, the CSU/DSU is still the DCE and the router is still the DTE.
- It's just two different uses of the same terms.



OSI Layer 2 of WANs (21)

- The logical path between each pair of routers is called a Frame Relay *permanent virtual circuits (PVCs).*

Frame Relay PVC Concepts

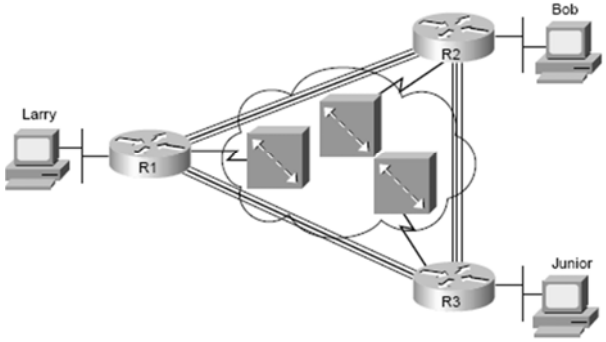


- When R1 needs to forward a packet to R2, it encapsulates the Layer 3 packet into a Frame Relay header and trailer and then sends the frame.
- R1 uses a Frame Relay address called a DLCI in the Frame Relay header.

OSI Layer 2 of WANs (22)

- Permanent virtual circuit (PVC) is the main feature of frame relay over p2p
- Figure shows connecting 3 sites using 3 leased lines and 3 frame relay switches

Typical Frame Relay Network with Three Sites



OSI Layer 2 of WANs (23)

- In the example, both VCs terminating at R1 use the same access link.
- So, with large networks with many WAN sites that need to connect to a central location, only one physical access link is required from the main site router to the Frame Relay network.
- If point-to-point links were used, a physical circuit, a separate CSU/DSU, and a separate physical interface on the router would be required for each point-to-point link.
- So, Frame Relay enables you to expand the WAN but add less hardware to do so.

OSI Layer 2 of WANs (24)

- Frame Relay is designed with the concept of a *committed information rate (CIR).*
- *Each VC has a CIR, which is a guarantee by the provider* that a particular VC gets at least that much bandwidth.
- You can think of CIR of a VC like the bandwidth or clock rate of a point-to-point circuit, except that it's the minimum value—you can actually send more, in most cases.

Thanks,

C U Next Week isA,…..