Chapter 2 - The TCP/IP and OSI Networking Models

TCP/IP : Transmission Control Protocol/Internet Protocol
OSI : Open System Interconnection

RFC – Request for Comments

TCP/IP Architecture Layers

Application	: HTTP, POP3, SMTP
Transport	: TCP, UDP
Internet	: IP
Network Access	: Ethernet, Frame Relay, PPP (WAN)

Application Layer : Provides interface between application software and the network, Provides network services to the applications.

Transport Layer : (TCP/UDP) Guarantees the delivery of data across the network. TCP uses the mechanism of acknowledgements to guaranty the transmission of data across the network.

Transport Layer header and its encapsulated data is called a **SEGMENT**

Internet Layer : (IP) defines the IP Addressing and Routing.(the process of how a router should forward or route data packets)

Internet Layer header and its encapsulated data, which includes Transport Layer, Application Layer header and any data is called **IP Packet.**

Network Access Layer : defines the protocols and hardwares required to deliver data across some physical network.

Internet Layer (IP) uses the service of the Network Access Layer (Ethernet) to deliver IP Packets over a physical network.

Network Access Layer's encapsulated data are called **FRAMES** which includes network access layer (Ethernet, PPP) header, trailer and their encapsulated data.

IP uses network access layer protocols (Ethernet. PPP) to deliver packets to next router or host, in which IP packets will be encapsulated between Ethernet or PPP header and trailer for transmission over the physical medium as frames.

Ethernet header and trailer may be striped and IP Packet may be encapsulated with PPP header and trailer during transmission depending on the network access protocol between the routers in the network.

Same layer Interaction (different computers) : When a particular layer in one computer wants to communicate with the same layer in another computer, and this is done using headers which are transmitted between the computers.

Adjacent Layer Interaction (same computer) : In a single computer one layer provides services to a higher layer. The software or hardware that implements the higher layer requests the lower layer to perform the task needed.

Five Step Process of TCP/IP host sending data in a network.

Step 1 : application data with application layer header. http ok message returned in a http header followed by content of the web page.

Step 2 : encapsulate application layer data in a transport layer (tcp/udp) header

Step 3 : encapsulate the transport layer data in a internet (IP) layer header

Step 4 : encapsulate the data supplied by the internet layer into network access layer header and trailer.

Step 5 : transmit the bits, physical layer encodes the signal onto a medium to transmit the frames

Encapsulation : is the process of adding headers and trailers around data supplied by a higher level in the network model.

Decapsulation : is the process of stripping (removing) the header and trailer from an encapsulated data.

Networking Model defines a set of network layers and how they interact each other, two most important networking models are TCP/IP and OSI.

OSI Reference Model

OSI Layers	**TCP/IP**	
Application	Application	Layer 7
Presentation		Layer 6
Session		Layer 5
Transport	Transport	Layer 4
Network	Internet	Layer 3
Datalink	Network Access	Layer 2
Physical		Layer 1

All People Seem to Need Data Processing (Layer 7 – Layer 1)

Layer 7 – Layer 5 focuses on application
Layer 4 – Layer 1 focuses on end to end delivery of the data over the network

Application Layer : Interfaces between application software and network also includes authentication services.

Presentation Layer : Defines format and organization of data and includes encryption

Session Layer : Establishes and maintains end-to-end bi-directional flow between end points. Includes managing transaction flows.

Transport Layer : Provides a variety of services between two hosts, connection establishment and termination, flow control, error recovery, and segmentation of large block of data into smaller parts for transmission.

Network Layer : logical addressing, routing (forwarding) and path determination.

Datalink Layer : format the data into frames for transmission onto physical medium, defines the rule for, when the data can be send, defines the means by which to determine transmission errors (FCS : Frame Check Sequence).

Physical Layer : refers to standards for physical characteristics of the transmission medium, including connectors, pins, use of pins, electrical currents, encoding, light modulation, and rules for how to activate and deactivate the use of physical medium.

Layer Name	Protocols and Specification	Devices
Application, Presentation, Session (Layer 7 – 5)	Telent, HTTP, FTP, SMTP, POP3, VoIP, SNMP	Firewall, Intrusion detection systems.
Transport (Layer 4)	TCP, UDP	
Network (Layer 3)	IP	Routers
DataLink (Layer 2)	Ethernet (IEEE 802.3), HDLC, Frame Relay, PPP	Lan Switches, wireless access points, cable modem, dsl modem
Physical (Layer 1)	RJ-45, EIA/TIA -232, V.35, Ethernet (IEEE 802.3)	Lan Hub, repeater

Benefits of Layered Protocol Specifications

Less Complex : Layered protocol network model breaks the functions and tasks of the networking into smaller chunks

Standard Interfaces : standard interfaces definition between the layers enables multiple vendors to develop products on specific layers

Easier to develop : reduced complexity mean easier program changes and faster product development

Easier to learn : easier to learn more details of a protocol specification

Multi-vendor interoperability : creating products meeting same networking standards means, computers and network gears from different vendors can work together

Modular engineering : vendors can concentrate on developing modular products in specific layers

A software or a hardware device in a layer does not have to worry, or can assume that the software and hardware devices in other layers will perform functions defined for that layer.

OSI Encapsulation
OSI model uses PDU – Protocol Data Unit to refer to its encapsulated data in each layers.

L7PDU : Application(L7)H + Data
L6PDU : Presentation(L6)H + Data
L5PDU : Session(L5)H + Data
L4PDU : Transport(L4)H + Data
L3PDU : Network(L3)H + Data
L2PDU : Data Link(L2)H + Data + L2T

L2PDU is transmitted into the physical link.

Please go to ……Do I know this Already –QUIZ. – Chapter 2. :- Page 18.

Chapter 4 - Fundamentals of WAN's

WAN physical and data-link standards and protocols define how to network between devices that are far apart in some cases thousands of miles.

OSI Layer 1 – for Point to Point WANs

Point to Point WAN is a type of WAN for connecting remote sites.

Service Providers (Telcos) provide leased line for companies to have WAN connectivity.

Point to Point WAN connection is also called leases circuit and leased line as the line is exclusively available for the devices at the either end of the connection to send and receive data at any time they want.

Ethernet switches has many different types of interfaces, but all the interfaces are some form of Ethernet. Routers provide capability to connect many different types of layer 1 and layer 2 technologies and is used commonly when a LAN is connected to a WAN.

CO – central office where telco locates devices that creates its own network.

Point to Point Leased line components

R1, R2 – routes
CSU/DSU – external Channel Service Unit / Data Service Unit
WAN switches in the CO
Routers are connected to CSU/DSU using short cables (max 50ft).
A much longer cable connects CSU/DSU to WAN switch in the CO
Routers and CSU/DSU are CPE (customer premises equipments)

Demarcation point (demar) defines the boundaries of responsibilities between telco and company (customer) in a PPP Wan.

WAN Cabling Standards

Point to Point WAN uses synchronous point to point serial link interface on its routers.

Synchronous serial interface in cisco routers uses physical connector types such as 60 – Pin D-shell connector.

CSU/DSU end of the cable uses physical connector standards such as EIA/TIA-232 , EIA/TIA-449, V.35, X.21, EIA-350

Many of the pins in the above connectors are used for control functions, a few are used for transmitting data, and some pins are used for clocking.

The cable between the CSU/DSU and the telco CO typically uses a RJ-48 connector.

When a router has an internally built CSU/DSU, physical line from telco CO is directly connected to a port in the router, typically to a RJ-48 port in the router serial interface card.

Clock Rate, Synchronization, DCE and DTE

Every WAN circuit provided by a service provider runs at one of many possible pre-defined speed. This speed is often referred to as clock rate, bandwidth or link speed.

To make a WAN link work, various devices need to synchronize their clock so that they run exactly at the same speed, this process is called synchronization.

Synchronous circuits imposes time ordering at the link's sending and receiving ends.

Synchronization occurs between two CSU/DSU on a leased line, by having one CSU/DSU (the slave) adjust its clock to match the clock rate of the other CSU/DSU (the master). A networking device synchronizes its clock several times per second.

In practice clocking concept includes a hierarchy of different clock sources. The telco provides clocking information to the CSU/DSUs based on the transitions in the electrical signal on the circuit. The two CSU/DSUs then adjust their speeds to match the clocking signals from telco.The CSU/DSUs each supply clocking signals to the routers so that the routers simply react, sending and receiving data at the correct rate. So from the routers perspective, the CSU/DSU is considered to be clocking the link.

The device that provides clocking, typically CSU/DSU is considered to be Data Communication Equipment (DCE) and the device receiving clocking typically the router is considered to be Data Terminal Equipment (DTE).

DTE serial cables (for routers) and DCE serial cable (for CSU/DSU) exists.

WAN in the lab, Point to Point serial link, **back to back** serial connection can be built using two routers one acting as DTE and one as DCE and connected together using interconnected DTE and DCE serial cables and with a clock rate configuration command in the DCE router.

DTE cable, the cable that typically connects a router (dte) to a csu/dsu does not swap the transmit and receive pins, however a DCE cable does the swaping of the Transmit and receive pins.

```
      DTE Cable                  DCE Cable                    DTE Cable
R1 ------------------  CSU/DSU ----------------------------CSU/DSU--------------------R2
```

Link Speed offered by telco

PCM – Pulse code modulation – converts analogue signal to digital signal
and according to this, 64,000 bits required to represent 1 sec voice and is the baseline transmission speed (64Kbps). Digital Signal Level 0 (DS0).

According to PCM voice analog signals are sampled 8000 times per sec, each sample requiring 8 bits, so 8000 * 8 = 64000 bits required to represent 1 sec voice.

The combination of multiple slower speed lines and channels into a faster speed lines or channel – for instance combining 24DS0 channels into a single DS1 (T1) line is called Time division multiplexing (TDM).

T1 and T3 are standards used in United States
E1 and E3 are Japanese and European standards

WAN Speed summary

DS0	64kbps
DS1 (T1)	1.544 Mbps (24 DS0s plus 8kbps overhead)
DS3 (T3)	44.736 Mbps (28 DS1s plus management overhead)
E1	2.048 Mbps (32 DS0s)
E3	34.064 Mbps (16 E1s plus management overhead)
J1 (Y1)	2.048 Mbps (32 DS0s : Japanese standard)

Type of signalling (DS1, DS3 etc) and signalling specification define the electrical signals that encode binary 1 and 0 on the line.

OSI Layer 2 – for Point to Point WANs

Two most popular data link layer protocols used in Point to point links are High level data link control (HDLC), and Point to Point Protocol (PPP).

Main objective of HDLC data link layer is the delivery of the data across the link, error checking, and identification of data packet type in the frame.

Standard HDLC Frame

1	1	1	variable	4	(bytes)
Flag	Address	Control	Data	FCS	

Cisco proprietary HDLC Frame

1	1	1	2	variable	4	(bytes)
Flag	Address	Control	Type	Data	FCS	

International Telecommunications Union (ITU) defined HDLC
Internet Engineering Task Force (IETF) defined PPP

PPP works same as HDLC, framing is identical. PPP including the protocol type field, is used in a multi vendor router point to point serial link environment.

Pont to Point WAN:

Synchronous : the imposition of time ordering on a bit stream, practically a device tries to use the same speed as the other device on other end of the serial link, however by examining the transition between the voltage states on the link, a device can notice slight variation in the speed on each end and can adjust its speed accordingly.

Clock source : the device to which the other device on the link adjust their speed when using a synchronous link.

CSU/DSU: Channel service unit/ data service unit, connects the routher to the teleco network in a point to point serial link.

T1 : A line from telco that allows transmission of data at 1.544 Mbps
E1 : Similar to T1, but used in Europe, at the rate of 2.048 Mbps and 32 64Kbps (DS0) channels

Point to Point Leased line (PPP) is also called : leased line, leased circuit, serial link, serial line, point-to-point link, and circuit.

Frame Relay and Packet Switching

In packet switching a physical WAN connectivity exists and a company can connect a large number of routers to the packet switching service, using a single serial link from each router to the packet switching service.

Two most commonly used Packet Switching services are Frame Relay and Asynchronous Transfer Mode (ATM).

For frame relay a leased line is installed from the router to nearby Frame Relay switch and is called **access links** and runs the same speed and same signalling standards as a point to point leased line.

Frame relay switch in the telco network examines the data frame sent by the router. Frame relay defines its own data link header and trailer, the header holds a field called Data Link Connection Identifier (DLCI), WAN switches forwards the frame based on the DLCI until it reaches the destination router.

Frame Relay header and trailer are defined by a protocol called Link Access Procedure Frame (LAPF).

Frame relay uses Frame Switching (Layer 2)as it switches (forwards) incoming frames to devices one by one based on the DLCI.

Packet Switching (Layer 3) is a more common term.

In Layer 2 Frame Relay,
DCE – device providing service (Frame Relay Switch)
DTE – device needing frame switching service (Router at customer site)

But from a Layer 1 perspective CSU/DSU provides clocking to the Router,
CSU/DSU is still the DCE and
Router is still the DTE

The logical path a frame travels between each pair of routers is called a frame relay virtual circuit (VC). Typically a service provided pre-configure all the required details of a VC, and these VCs are called (permanent) PVC.

VCs share the access link, and frame relay network. Frame relay enable you to expand the WAN with only one access link, multiple VCs and less hard wares. (Eg. One central office router connecting to many branch office routers, CO Router will have just one access link and many VCs to all the branch routers in the Frame relay network).

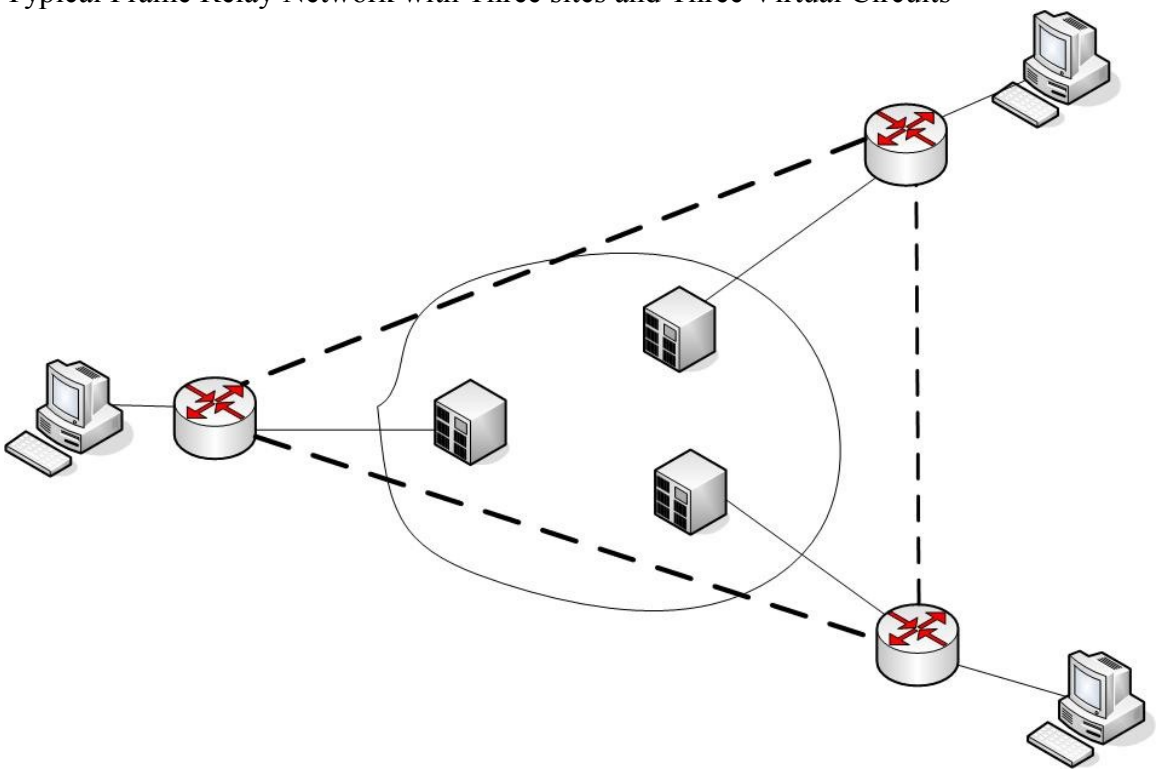
CIR – committed information rate for a VC and it is like a minimum bandwidth, clock rate of a point-to-point circuit. CIR is offered by Service Providers as its customers will be competing each other for capacity in the providers network.

In frame relay The main Central Office Router can have one access link and multiple VCs connecting to more than one branch office DTEs.

Frame Relay Topology is…
easier for the SP to implement, costs the provider less, and makes better use of the core of the service providers network.

Clocking: is the process of supplying a signal over a cable, either on a separate pin on a serial cable or as part of the signal transitions in the transmitted signal, so that the receiving device can keep synchronization with the sending device.

Typical Frame Relay Network with Three sites and Three Virtual Circuits



Define:
Access links, back-to-back linking, clocking, DTE (layer 1), CSU/DSU, DCE (layer 1), DS0, DS1, Frame Relay, HDLC, leased line, packet switching, PPP, serial cable, synchronous, T1, virtual circuit.

Access Link : In Frame Relay the physical serial link that connects Frame Relay DTE device, usually a Router to a Frame Relay switch. The access link uses the same physical layer standard as do point-to-point leased lines.

Back-to-Back link : a serial link between two routers, created without CSU/DSUs, by connecting a DTE cable to one router and a DCE cable to another and connecting the two cables together. Typically used in Labs to create serial links without the expenses of an actual leased line from a telco.

Clocking : The process of supplying a signal over a cable, either on a separate pin on a serial cable, or as part of the signal transmission in the transmitted signal, so that the receiving device can keep synchronization with the sending device.

DTE Layer 1 : Data terminal equipment, From a layer 1 perspective DTE synchronizes its clock based on the clocking send by the DCE, from a packet (frame) switching perspective DTE is a device outside the Service Providers network, typically a router.

CSU/DSU : Channel Service Unit / Digital Service Unit. A device that understands the Layer 1 details of the serial link installed by a telco, and how to use a serial cable to communicate with networking equipments such as routers.

DCE Layer 1 : Data communications equipment, From a physical layer (1) perspective, the device providing clocking on a WAN link, typically a CSU/DSU, is the DCE. From a packet (frame) switching perspective the service providers switch (frame relay switch) to which the router might connect is considered the DCE.

DS0 : Digital signal level 0, a 64 Kbps line or channel, of a faster line, inside a telco whose origins are to support a single voice call using original voice PCM codec.

DS1 :Digital signal level 1, a 1.544 Mbps line from telco, with 24 DS0 channels or 64 Kbps each, plus an 8 kbps management and framing channel. Also called a T1.

Frame Relay : An international standard data link protocol, that defines the capabilities to create a frame (packet) switched, service allowing a DTE device typically a router to send data to many other devices using a single physical connection to the Frame relay service.

HDLC : High Level Data Link Control. A bit oriented synchronous data link layer protocol developed by the International Organization for Standards

Leased Line : A serial communication circuit between two end points, provided by some service provider, typically a telephone company or a telco.

Packet (Frame) Switching : A generic reference to network service, typically WAN services, in which the service examines the contents of the transmitted data, to make some type of forwarding decision. This term is mainly used in contrast with the WAN term circuit switching, in which the provider sets up a Layer 1 circuit between two devices, and the provider makes no attempt to interpret the meaning of the bits.

PPP : Point to Point protocol, a protocol that provides connectivity between router to router and host to network connection, over synchronous point to point and asynchronous point to point circuits.

Serial cable : A type of cable with many different styles of connectors used to connect a router to an external CSU/DSU on a leased line installation.

Synchronous : The imposition of time ordering on a bit stream. Particularly a device will try to use the same speed as the 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 adjust the speed accordingly.

T1 : A line from the telco that allows transmission of data at 1.544 Mbps, with the ability to treat the lines as 24 different 64 Kbps DS0 channels (plus 8kbps overhead).

Virtual Circuit : In packet (frame) switched services like Frame Relay, VC refers to the ability for two DTE device typically routers to send and receive data directly to each other, which supplies the same functions as a physical leased line, but doing so without a physical circuit. This term is meant as a contract with a leased line or leased circuit.

Please go to ……Do I know this Already –QUIZ. – Chapter 4. :- Page 71.