UNIT 3 DATA NETWORKS

Structure

3.0 OBJECTIVES

After reading this unit you will be able to:

- Know various Data Networking technologies such as X.25, ISDN, DSL, FRAME RELAY, and ATM in detail.

3.1 INTRODUCTION

The information or signal that is to be conveyed and reproduced by the communication system can either be continuous (analogue) or discrete (digital). In a digital transmission, only a limited number of discrete or discontinuous signals are transmitted during each discrete interval of time. For more than a century, the primary international communication infrastructure has been the Public Switched Telephone Network (PSTN). Its main component is local loops, trunks and switches. Local loops are analogue, twisted pair circuits, which require modems for transmitting digital data.

Trunks are digital, and can be multiplexed in several ways, including FDM (frequency-division multiplexing), TDM (time division multiplexing).

The switches include crossbars, space division switches, and time division switches.

This telephone system was designed for analogue voice transmission and is proving inadequate for modern communication needs such as data transmission, facsimile and video. Analogue phone lines, which were designed for voice communications, present significant limitations when transmitting data. Line noise, nearly imperceptible to the human ear during phone conversations, frequently wreaks havoc on data transmission, causing distortion, data errors and lost connections. The switching equipment at the phone company's serving office also creates line noise and data corruption.

To transmit data from a PC over an analogue phone line, a modem first converts the PC's digital signal to analogue. The resulting analog signal is then transmitted to the telephone company's central office over a local access line. There, switching equipment converts the analogue signal into 64 kbps data stream using a technique called Pulse Code Modulation (PCM). Next, the digital stream containing the digitised analogue waveform is transmitted onto a long-distance carrier's digital backbone network.

The process is reversed at the other end of the transmission. Switching equipment restores the digitised PCM stream to its original analogue wave form and then transmits it over a local access line to its destination. Finally, another modem restores the analogue wave form back to a digital signal so the PC can process it.

Emerging and evolving communication and computing technologies, coupled with increasing demands for efficient and timely collection, processing and dissemination of information have led to development of integrated systems, i.e., Data Networks. Data Networks provide end-to-end digital connectivity from the local loop all the way across the phone company's backbone network. They also eliminate line noise and the time-consuming conversion from analogue to digital and back. For example X.25, Frame Relay, Narrow Band ISDN (N-ISDN) with no analogue to digital conversion between terminals provide greater reliability, improved performance and increased throughput.

A multiplicity of different data networks have been connected via gateways and bridges so as to allow users of one network to send data to the users of other networks.

3.1.1 Modem

The modem was a big breakthrough in computer communications. It allowed computers to communicate by converting their digital information into an analogue signal to travel through the public phone network. Currently, it is about 56 kb/s bi-directionally. Commonly available modems have a maximum speed of 56 kb/s, but are limited by the quality of the analogue connection and routinely go at about 45-50 kb/s. Some phone lines do not support 56 kb/s connections at all. There were currently two competing incompatible 56 kb/s standards (X2 from U S Robotic (recently bought by 3Com, and K56flex from Rockwell /Lucent). This standards problem was resolved when the ITU released the V.90, and later V.92, standard for 56 kb/s modem communications.

Modems modulate an analogue audio carrier that can pass through the POTS analogue telephone line with digital signals. The modulation technique used by modern modems is a sophisticated combination of phase and amplitude modulation.

Modulation is the process of using one signal (either analogue or digital) to modify another analogue signal, known as the carrier. The three fundamental ways a carrier can be modulated are known as amplitude modulation, frequency modulation, and phase modulation. For AM (amplitude modulation) broadcast radio, an analogue audio signal modulates a carrier in the range between 540KHz and 1640KHz. For FM (frequency modulation) broadcast radio, an analogue audio signal modulates a carrier in the range of 88MHz to 108MHz. Broadcast TV modulates a carrier using AM for the luminance or black and white video, using FM for the sound, and using a form of phase modulation for chrominance or colour information.

3.1.2 Pulse Code Modulation (PCM)

An analogue signal is a signal that varies continuously between a maximum and a minimum value. Analogue speech is represented in digital format through the processes of sampling and analogue-to-digital conversion. The continuous analogue waveform is sampled at regular intervals in time and the analogue values are then converted into binary numbers. This encoding technique is known as Pulse Code Modulation (PCM).

By sampling a signal of limited bandwidth at twice its highest frequency, which for speech is taken as twice 4000Hz (or 8000 times per second), it is possible to reproduce the speech signal perfectly. The standard scale used in North America is an 8-bit nonlinear scale known as u-law 255. The required bit rate, or digital bandwidth, for a PCM-encoded speech signal using u-law 255 is then:

8 bits x 8000 samples / second = 64,000 bits/second = 64 Kbps.

PCM encoding according to u-law is standard throughout the United States European countries use a different encoding algorithm known as A-law.

3.1.3 Getting Data over the Telephone Line: CSUs and DSUs

A modem is designed to transform digital signals into analogue audio signals that fit into a circuit designed for voice transmission. CSU/DSUs adapt one kind of digital signaling to another type that is capable of fitting into the digital telephony system. A channel service unit / digital service unit (CSU/DSU) is a digital-interface device used to connect a router to digital circuits like T1 or E1. The CSU / DSU also provides signal timing for communication between devices.

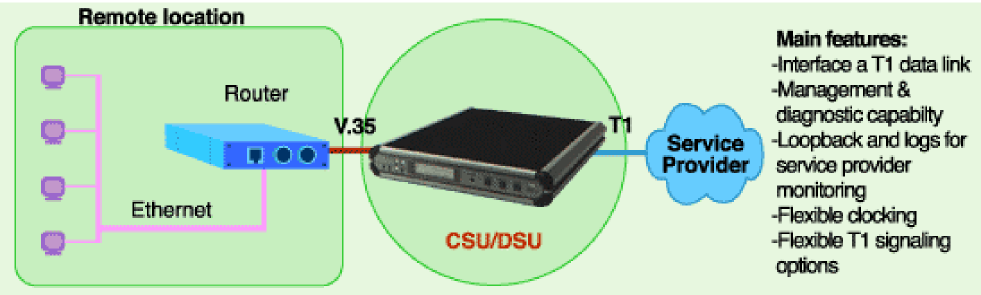

Figure 1: CSU/DSU

3.1.3.1 Channel Service Unit (CSU)

One of the principal functions of a CSU is to protect the carrier and its customers from any weird events your network might introduce onto the carrier's system.

A CSU provides proper electrical termination for the telephone line and performs line conditioning and equalization. It also supports "loopback tests" for the carrier, meaning the CSU can reflect a diagnostic signal to the telephone company without sending it through any CPE, so the carrier can determine if a problem is one it needs to correct itself. CSUs often have indicator lights or LEDs that identify lost local lines, lost telco connections, and loopback operation.

When CSUs were provided only by the telephone company, they were generally powered by the telephone line itself. Nowadays not all telephone lines supply power. So, a CSU may need to have its own power supply, and perhaps a backup power supply, at the user site.

3.1.3.2 Data Service Units (DSUs)

Data service units, sometimes referred to as digital service units-or DSUs, sit between a CSU and customer equipment such as routers, multiplexers, and terminal servers. DSUs are commonly equipped with RS-232 or V.35 interfaces. Their main function is to adapt the digital data stream produced by the customer equipment to the signalling standards of the telephone carrier equipment, and vice versa.

Roughly speaking, a CSU has a similar role to that of an NT1 on ISDN line, while a DSU is comparable to an ISDN terminal adapter. Sometimes CSU/DSUs (and

ISDN terminal adapters) are described as “digital modems”. This terminology is misleading and crude because CSU/DSUs don't modulate or demodulate anything.

3.2 SIGNALLING

Signalling indicates who is calling, what type of call it is (data/voice), and what number was dialled. There are two types of signalling : Channel Associated Signalling and Common Channel Signalling.

3.2.1 Channel Associated Signalling (CAS)

CAS is divided into line signalling and register signalling. Signalling System No 5, R1 and R2, are examples of CAS.

3.2.1.1 Line Signalling

Line signalling handles the exchange of information showing the line state of the trunks between two exchanges, such as seizure, answer, clear forward and clear back. Traffic in time slots 1-15 and 17-31 in a 2 Mbit/s PCM circuit uses time slot 16-for line signalling.

Two voice time slots at a time can send line signals in time slot 16. The use of time slot 16 is shared by the traffic time slot in a 16 frame continuous sequence (one multiframe).

Consequently, every voice channel has 2 kbit/s for the transmission of signalling information. (Each time slot corresponds to 64 kbit/s. One time slot in every 16 frame gives 64/16 = 4 kbit/second. Two channels at a time share the signalling space of a time slot, which gives 4 kbit/s/2 = 2kbit/s for each channel).

3.2.1.2 Register Signalling

Register Signalling handles the exchange of routing information. Register Signalling can be transmitted in different ways, but the most common method is based on multi-frequency signalling, in which two out of, say, six frequencies are combined to form 15 different signals representing digits and categories.

3.2.2 Common Channel Signalling (CCS)

CCS requires a separate signaling network; that is, the signals have a bearer service of their own. Because the signalling network executes this bearer service it can be accessed by users other than PSTN. Other typical users are ISDN and the PLMN. SS7 which belongs to this category is predominant in modern digital network.

3.3 X.25

X.25 is designed to operate effectively regardless of the type of systems connected to the network. It is typically used in the packet-switched networks (PSNs) of common carriers, such as the telephone companies.

3.3.1 X.25 Devices and Protocol Operation

X.25 network devices fall into three general categories:

3.3.1.1 Data Terminal Equipment (DTE)

Data terminal equipment devices are end systems that communicate across the X.25 network. They are usually terminals, personal computers, or network hosts, and are located on the premises of individual subscribers.

Packet Assembler/Disassembler

The packet assembler/disassembler (PAD) is a device commonly found in X.25 networks. PADs are used when a DTE device, such as a character-mode terminal, is too simple to implement the full X.25 functionality. The PAD is located between a DTE device and a DCE device, and it performs three primary functions: buffering (storing data until a device is ready to process it), packet assembly, and packet disassembly. The PAD buffers data sent to or from the DTE device. It also assembles outgoing data into packets and forwards them to the DCE device. (This includes adding an X.25 header.) Finally, the PAD disassembles incoming packets before forwarding the data to the DTE. (This includes removing the X.25 header.)

3.3.1.2 Data Circuit-terminating Equipment (DCE)

DCE devices are communication devices, such as modems and packet switches, that provide the interface between DTE devices and a PSE, and are generally located in the carrier's facilities.

3.3.1.3 Packet-switching exchange (PSE)

PSEs are switches that compose the bulk of the carrier's network. They transfer data from one DTE device to another through the X.25 PSN. Figure 2 illustrates the relationships among the three types of X.25 network devices.

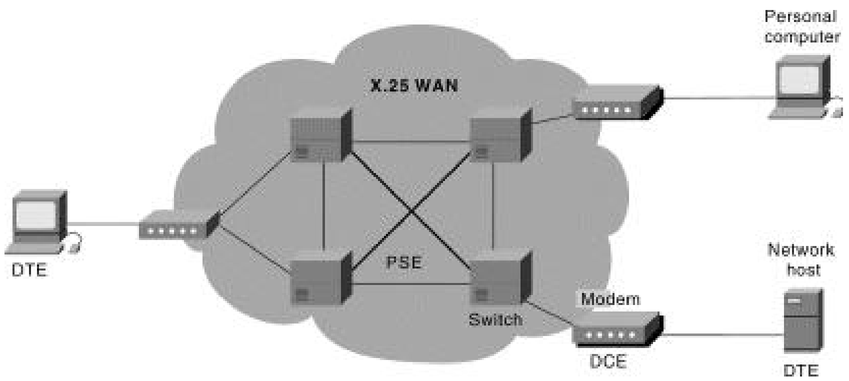

Figure 2 : DTEs, DCEs, and PSEs Make Up an X.25 Network

3.3.2 X.25 Session Establishment

X.25 sessions are established when one DTE device contacts another to request a communication session. The DTE device that receives the request can either accept or refuse the connection. If the request is accepted, the two systems begin full-duplex information transfer. Either DTE device can terminate the connection. After the session is terminated, any further communication requires the establishment of a new session.

3.3.3 X.25 Virtual Circuits

A virtual circuit is a logical connection created to ensure reliable communication between two network devices. A virtual circuit denotes the existence of a logical, bidirectional path from one DTE device to another across an X.25 network. Physically, the connection can pass through any number of intermediate nodes, such as DCE devices and PSEs. Multiple virtual circuits (logical connections) can be multiplexed onto a single physical circuit (a physical connection). Virtual circuits are demultiplexed at the remote end, and data are sent to the appropriate destinations.

Two types of X.25 virtual circuits exist: switched and permanent. *Switched Virtual Circuits (SVCs)* are temporary connections used for sporadic data transfers. They require that two DTE devices establish, maintain, and terminate a session each time the devices need to communicate. *Permanent Virtual Circuits (PVCs)* are permanently established connections used for frequent and consistent data transfers. PVCs do not require that sessions be established and terminated. Therefore, DTEs can begin transferring data whenever necessary because the session is always active.

The basic operation of an X.25 virtual circuit begins when the source DTE device specifies the virtual circuit to be used (in the packet headers) and then sends the packets to a locally connected DCE device. At this point, the local DCE device examines the packet headers to determine which virtual circuit to use and then sends the packets to the closest PSE in the path of that virtual circuit. PSEs (switches) pass the traffic to the next intermediate node in the path, which may be another switch or the remote DCE device.

When the traffic arrives at the remote DCE device, the packet headers are examined and the destination address is determined. The packets are then sent to the destination DTE device. If communication occurs over an SVC and neither device has additional data to transfer, the virtual circuit is terminated.

3.3.4 X.25 Packet Format

All of the X.25 packets contain 3 bytes of header format along with user data.

3.4 INTEGRATED SERVICES DIGITAL NETWORK (ISDN)

ISDN allows multiple digital channels to be operated simultaneously through the same regular phone wiring used for analogue lines. Therefore, the same physical wiring can be used, but a digital signal, instead of an analogue signal, is transmitted across the line. It provides faster connection. While an analogue modem has to dial, wait for an answer and then make the connection, an ISDN connection makes a call in almost an instant. The call setup time between two ISDN subscribers is extremely short. ISDN allows data to be transmitted simultaneously across the world using end-to-end digital connectivity.

This scheme permits a much higher data transfer rate than analogue lines. In addition, the latency, or the amount of time it takes for a communication to begin, on an ISDN line is typically about half that of an analogue line. This improves response for interactive applications, such as games. It is difficult to set up and rather expensive. Compared to DSL or even cable modem, it is slow and expensive.

The first generation, sometimes referred to as “Narrowband ISDN”, is based on the use of a 64 kbps channel as the basic unit of switching and has a circuit switching orientation. The major contribution of the Narrowband ISDN has been Frame Relay. The second generation, referred to as “Broadband ISDN”, supports very high data rates (100s of Mbps) and has a packet switching orientation. The major technical contribution of the Broadband ISDN has been ATM, also known as cell relay. The most common application on ISDN is videoconferencing.

3.4.1 ISDN Devices

ISDN devices includes

3.4.1.1 Terminals

ISDN terminals come in two types:

- Specialized ISDN terminals are referred to as terminal equipment type 1 (TE1). TE1s connect to the ISDN network through a four-wire, twisted-pair digital link.
- Non-ISDN terminals, such as DTE, that predate the ISDN standards, are referred to as terminal equipment type 2 (TE2). TE2s connect to the ISDN network through a terminal adapter (TA).

3.4.1.2 Terminal Adapters (TAs)

The ISDN TA can either be a standalone device or a board inside the TE2. If the TE2 is implemented as a standalone device, it connects to the TA via a standard physical-layer interface. Examples include EIA/TIA-232-C (formerly RS-232-C), V.24, and V.35.

3.4.1.3 Network-termination devices, Line-termination equipment and Exchange-termination Equipment

Beyond the TE1 and TE2 devices, the next connection point in the ISDN network is the network termination type 1 (NT1) or network termination type 2 (NT2) device. These are network-termination devices that connect the four-wire subscriber wiring to the conventional two-wire local loop. In North America, the NT1 is a customer premises equipment (CPE) device. In most other parts of the world, the NT1 is part of the network provided by the carrier. The NT2 is a more complicated device that typically is found in digital private branch exchanges (PBXs) and that performs Layer 2 and 3 protocol functions and concentration services. An NT1/2 device also exists as a single device that combines the functions of an NT1 and an NT2.

ISDN specifies a number of reference points that define logical interfaces between functional groups, such as TAs and NT1s. ISDN reference points include the following:

R—The reference point between non-ISDN equipment and a TA.

S—The reference point between user terminals and the NT2.

T—The reference point between NT1 and NT2 devices.

U—The reference point between NT1 devices and line-termination equipment in the carrier network. The U reference point is relevant only in North America, where the NT1 function is not provided by the carrier network.

Figure 3 illustrates a sample ISDN configuration and shows three devices attached to an ISDN switch at the central office. Two of these devices are ISDN-compatible, so they can be attached through an S reference point to NT2 devices. The third device (a standard, non-ISDN telephone) attaches through the reference point to a

TA. Any of these devices also could attach to an NT1/2 device, which would replace both the NT1 and the NT2. In addition, although they are not shown, similar user stations are attached to the far-right ISDN switch.

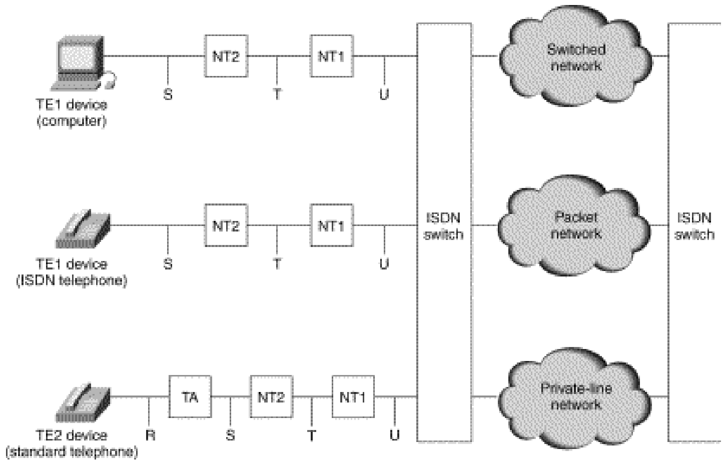

Figure 3 : Sample ISDN Configuration Illustrates Relationships Between Devices and Reference Points

3.4.2 Basic types of ISDN

There are two basic types of ISDN services, i.e., Basic Rate Interface (BRI) and Primary Rate Interface (PRI).

3.4.2.1 Basic Rate Interface (BRI)

The most common type of ISDN is at 144 Kbps. This is split up as 2B+D : 2 base voice/video channels of 64 Kbps each, and 1 data channel of 16 Kbps. The base channels are used to send information, which can accommodate up to eight devices. Therefore a small office or teleworker at home can have a PC, fax machine and phone connected to a single ISDN Line while the data channel is used for handshaking. The ISDN Basic Rate Interface (BRI) service offers two B channels and one D channel (2B+D). BRI B-channel service operates at 64 kbps and is meant to carry user data; BRI D-channel service operates at 16 kbps and is meant to carry control and signalling information, although it can support user data transmission under certain circumstances. The D channel signalling protocol comprises Layers 1 through 3 of the OSI reference model. BRI also provides for framing control and other overhead, bringing its total bit rate to 192 kbps. A data channel (D channel) handles signalling at 16 kb/s or 64 kb/s, depending on the service type. The 'D' Channel carries dialling, ringing, and caller ID information for the other two channels. In some areas, the D channel can also be used for low-speed, full-time data communication using service called Always On/ Dynamic ISDN (AO/DI). Always On ISDN exploits the use of the 'D' channel for X.25, packet-based communication between the user and the packet handler of X.25 network. For Internet communication, the multilink protocol and TCP/IP protocols are encapsulated in the X.25 logic circuit. Due to these protocol conversions, effectively a 9.6 k bit/sec leased line service is available to the user.

3.4.2.2 Primary Rate Interface (PRI)

PRI is intended for users with greater capacity requirements. Typically the channel structure is 23 B channels plus one 64 kb/s D channel for a total of 1536 kb/s. In Europe, PRI consists of 30 B channels plus one 64 kb/s D channel for a total of

1984 kb/s. It is also possible to support multiple PRI lines with one 64 kb/s D channel using Non-Facility Associated Signaling (NFAS).

It is designed for application that needs to transmit larger amount of data, such as in LAN interconnections, Private Branch Exchange (PBX) Connections, and video conferencing applications. Unlike BRI, PRI uses 23 B channels and a D channel with a data transfer rate of about 1.5 million bits per second when all channels are used at once. In short, PRI consists of an aggregate of multiple B channels.

ISDN Primary Rate Interface (PRI) service offers 23 B channels and 1 D channel in North America and Japan, yielding a total bit rate of 1.544 Mbps (the PRI D channel runs at 64 kbps). ISDN PRI in Europe, Australia, and other parts of the world provides 30 B channels plus one 64-kbps D channel and a total interface rate of 2.048 Mbps. The PRI physical layer specification is ITU-T I.431.

3.5 DIGITAL SUBSCRIBER LINE (DSL)

DSL is a technology that works on the presumption that digital data does not require changes into the analogue form and back. Digital data is transmitted to your Computer directly as digital data and this allows the phone company to use a much wider bandwidth for transmitting them for you. DSL is a technology for bringing high-bandwidth information to homes and small business is over ordinary copper telephone lines. Telephone companies use the 300 Hz to 3200 Hz frequency band to transmit voice. If data have to be transmitted on these lines, they must be disguised and made to look like audio frequencies, and that's what modem do. Despite its name, DSL does not refer to a physical line but to a modem or rather a pair of modems.

Now, DSL makes use of a wider band of frequencies; it preserves the lower frequencies for voice transmission and uses high frequencies to transmit data, due to which more data can be transferred per unit time. As a consequence, the maximum transfer rate shoots up from the current 56 kbps to up to 52 Mbps. A DSL line can carry both data and voice signals and the data part of the line is continuously connected. xDSL refers to different variations of DSL such as ADSL, HDSL and RADSL, etc.

3.5.1 Asymmetric Digital Subscriber Line (ADSL)

ADSL is called “asymmetric” because most of its two-way or duplex bandwidth is devoted to the downstream direction, sending data to the user. Only a small portion of the bandwidth is available for upstream or user-interaction messages. However, most Internet, and especially graphics or multi-media web data need a lot of downstream bandwidth, but user requests and response are small.

3.5.2 HDSL

HDSL most commonly operates with two pairs to deliver symmetric T1 or E1 rates (1.544 Mbps or 2.048 Mbps) which it does by sending half the data on one pair, and half on the other, both operating as full duplex echo-cancelled links (with either 768 Kbps for T1 and either 1168 or1024 Kbps for E1). HDSL is a lot simpler and more robust than the old T1 service, which required repeaters every few hundred yards and was consequently difficult to install and maintain. As a result, it has essentially replaced T1 lines and the odds are good that if you have recently got a “T1 line”, it is actually HDSL. (To be strictly accurate, you should refer to DS1 - Digital

Subscriber 1 - for rates of service, while "T1" refers to the older physical implementation using AMI - Alternate Mark Inversion - line code on two simplex connections).

HDSL is also popular for connecting wireless base stations into the PSTN (muliple connections, a lot cheaper than fibre) and for ' pairgain' applications - squeezing many voice channels into one piece of copper.

DSL Type	Down rate Downstream; Upstream	Distance Limit	Application
ISDN Digital Subscriber Line (ISDNL)	128 Kbps	18,000 feet on 24 guage wire	Similar to the ISDN, BRI service but data only (no voice on the same line).
High bit-rate Digital Subscriber Line (HDSL)	1.544 Mbps to 6 Mbps depending on the subscribed service.	18,000 feet on 24 guage wire	T1/E1 service between server and phone company or within a company. WAN, LAN Server access.
Sinle-lines DSL (SDSL)	1.544 Mbps duplex (US and Canada); 2.048 Mbps (Europe) on a single duplex line downstream and upstream.	12,000 feet on 24 guage wire	Same as for HDSL but requiring only one line of twisted pair.
Asymmetric Digital Subscriber Line (ADSL)	1.544 to 6.1 Mbps downstream; 16 to 640 kbps upstream	1.544 Mbps at 18,000 feet; 6.312 Mbps at 12,000 feet; 8.44 Mbps at 9000 feet.	Used for Internet and Web access, motion video, video on demand, remote LAN access.
Very high Digital Subscriber Line (VDSL)	2.9 to 52.8 Mbps downstream; 1.5 to 2.3 Mbps upstream; 1.6 Mbps to 2.3 Mbps downstream.	4,500 feet at 12.96 Mbps; 3,000 feet at 25.82 Mbps; 1,000 feet at 51.84 Mbps	ATM networks, Fibre to the neighbour hood.

3.6 FRAME RELAY

Frame Relay is a simplified form of packet switching, similar in principle to X.25, in which synchronous frames of data are routed to different destinations depending on header information. Frame Relay combines the statistical multiplexing and port sharing features of X.25 with the high speed and low delay characteristics of TDM circuit switching. Defined as a "Packet mode" service, frame relay organizes data into individually addressed units known as frames rather than placing into fixed time slots. This gives frame relay statistical multiplexing and port sharing characteristics. Frame Relay often is described as a streamlined version of X.25, offering fewer of the robust capabilities, such as windowing and retransmission of last data that are offered in X.25. Frame Relay originally was designed for use across Integrated Services Digital Network (ISDN) interfaces. Today, it is used over a variety of other network interfaces as well.

The difference between Frame Relay and X.25 is that Frame Relay is strictly a Layer 2 protocol suite, whereas X.25 provides services at Layer 3 (the network layer) as well.. X.25 guarantees data integrity and network-managed flow control at the cost of some network delays. Frame Relay switches packets end to end much faster, but there is no guarantee of data integrity at all. This enables Frame Relay to offer higher performance and greater transmission efficiency than X.25, and makes Frame Relay suitable for current WAN applications, such as LAN interconnection.

Frame relay offers distinct advantages for the Wide Area Network. First, it was a more efficient WAN protocol than IP, using only 5 bytes of overhead versus 20 of IP. In addition, frame relay was easily switched. IP switching was not widely available in the WAN, and IP routing added unnecessary delays and consumed more bandwidth in the network.

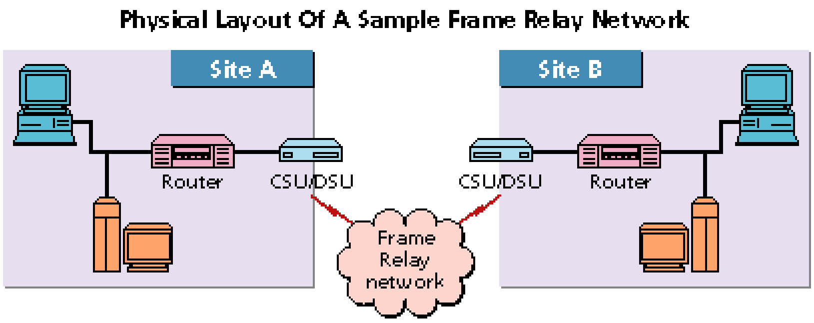

Figure 4: Frame Relay Network

3.6.1 Frame Relay Devices

Devices attached to a Frame Relay WAN fall into the following two general categories:

Data terminal equipment (DTE) and Data circuit-terminating equipment (DCE).

DTEs generally are considered to be terminating equipment for a specific network and typically are located on the premises of a customer. In fact, they may be owned by the customer. Examples of DTE devices are terminals, personal computers, routers, and bridges.

DCEs are carrier-owned Internet-working devices. The purpose of DCE equipment is to provide clocking and switching services in a network, which are the devices that actually transmit data through the WAN. In most cases, these are packet switches. Figure 22 shows the relationship between the two categories of devices.

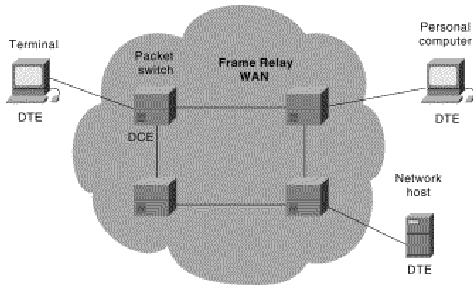

Figure 5 : DCEs Generally Reside Within Carrier-Operated WANs

The connection between a DTE device and a DCE device consists of both a physical layer component and a link layer component. The physical component defines the mechanical, electrical, functional, and procedural specifications for the connection between the devices. One of the most commonly used physical layer interface specifications is the recommended standard (RS)-232 specification. The link layer component defines the protocol that establishes the connection between the DTE device, such as a router, and the DCE device, such as a switch.

3.6.2 Frame Relay Virtual Circuits

A frame relay network will often be depicted as a network cloud, because the frame relay network is not a single physical connection between one end point and the other. Instead a logical path is defined within the network. This logical path is called a virtual circuit. Bandwidth is allocated to the path until actual data need to be transmitted.

Frame Relay provides connection-oriented data link layer communication. This means that a defined communication exists between each pair of devices and that these connections are associated with a connection identifier. This service is implemented by using a Frame Relay virtual circuit, which is a logical connection created between two data terminal equipment (DTE) devices across a Frame Relay packet-switched network (PSN).

Virtual circuits provide a bidirectional communication path from one DTE device to another and are uniquely identified by a data-link connection identifier (DLCI). A number of virtual circuits can be multiplexed into a single physical circuit for transmission across the network. This capability often can reduce the equipment and network complexity required to connect multiple DTE devices.

A virtual circuit can pass through any number of intermediate DCE devices (switches) located within the Frame Relay PSN.

Frame Relay virtual circuits fall into two categories: switched virtual circuits (SVCs) and permanent virtual circuits (PVCs)

- Switched Virtual Circuits: Switched virtual circuits (SVCs) are temporary connections used in situations requiring only sporadic data transfer between DTE devices across the Frame Relay network. A communication session across an SVC consists of the following four operational states:

Call setup—The virtual circuit between two Frame Relay DTE devices is established.

Data transfer—Data are transmitted between the DTE devices over the virtual circuit.

Idle—The connection between DTE devices is still active, but no data are transferred. If an SVC remains in an idle state for a defined period of time, the call can be terminated.

Call termination—The virtual circuit between DTE devices is terminated.

After the virtual circuit is terminated, the DTE devices must establish a new SVC if there is additional data to be exchanged. It is expected that SVCs will be established, maintained, and terminated using the same signalling protocols used in ISDN.

Only a few manufacturers of Frame Relay DCE equipment support switched virtual circuit connections. Therefore, their actual deployment is minimal in today's Frame Relay networks.

Previously not widely supported by Frame Relay equipment, SVCs are now the norm. Companies have found that SVCs save money in the end because the circuit is not open all the time.

- Permanent Virtual Circuits: Permanent virtual circuits (PVCs) are permanently established connections that are used for frequent and consistent data transfers between DTE devices across the Frame Relay network. Communication across a PVC does not require the call setup and termination states that are used with SVCs. PVCs always operate in one of the following two operational states:

Data transfer—Data are transmitted between the DTE devices over the virtual circuit.

Idle—The connection between DTE devices is active, but no data are transferred. Unlike SVCs, PVCs will not be terminated under any circumstances when in an idle state.

DTE devices can begin transferring data whenever they are ready because the circuit is permanently established.

3.6.2.1 Data-Link Connection Identifier

Frame Relay virtual circuits are identified by data-link connection identifiers (DLCIs). DLCI values typically are assigned by the Frame Relay service provider (for example, the telephone company).

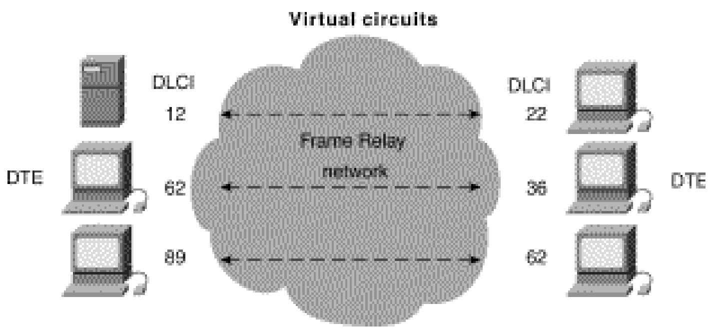

Figure 6 : A Single Frame Relay Virtual Circuit Can Be Assigned Different DLCIs on Each End of a VC

Frame Relay DLCIs have local significance, which means that their values are unique in the LAN, but not necessarily in the Frame Relay WAN.

Figure 6 illustrates how two different DTE devices can be assigned the same DLCI value within one Frame Relay WAN.

3.7 ASYNCHRONOUS TRANSFER MODE (ATM)

ATM, sometimes referred to as cell relay, is a culmination of all the developments in circuit switching and packet switching over the last two decades. ATM can be viewed as an evolution from Frame Relay. The difference is that Frame relay uses variable length packets called frames whereas ATM uses fixed length packets called cells. Like Frame Relay, ATM has little overheads for error control. By using fixed packet lengths, the processing overheads are further reduced as compared to Frame Relay. The result is that ATM can work in the range of 10s and 100s of Mbps compared to 2 Mbps in the case of Frame Relay. ATM can be used equally well for LAN, MAN and WAN. ATM allows full, guaranteed bandwidth to every user unlike shared-bus networking technologies such as Ethernet, Token Ring or FDDI. The switching architecture of ATM gives it the capability for parallel transmission. In fact, each node can have a dedicated connection to any other node. ATM is not restricted to one speed or physical media. It supports scalable speeds of 45 Mbps to 2.4 Gbps and beyond. It can employ several media from Category 3 unshielded twisted pair to a single and multimode fibre.

ATM is a technology based on cell relay. It uses packets, called cells, which are of fixed length of 53 bytes. ATM is the first technology that can be used equally well for the LAN, MAN and WAN. FDDI (Fibre Distributed Data Interface) is a good architecture for LANs, and frame relay has possibilities for WANs, but neither of these architectures is suitable for both LANs and WANs.

3.7.1 ATM Structure

The ATM architecture is organized into layers like any other network architectures, and into planes, which specify domains of activity.

3.7.1.1 Physical Layer

The ATM physical layer corresponds to the OSI Reference Model physical layer, concerned with the physical medium and interfaces, and with the framing protocols (if any) for the network. The physical layer has two sublayers. The lower sublayer, physical medium (PM), includes the definition for the medium (like optical fiber) and the bit-timing capabilities. The upper is responsible for making sure that valid cells are breaking off individual cells from the data stream of the higher layer (the ATM layer), checking the cell's header, and encoding the bit values.

3.7.1.2 ATM Layer

The ATM layer is a service-independent layer at which cell headers and trailers are created, virtual channels and paths are defined and given unique identifiers, and cells are multiplexed or demultiplexed. The ATM layer creates the cells and uses the physical layer to transmit them.

Asynchronous transfer mode (ATM) is a high-performance, cell-oriented switching and multiplexing technology that utilizes fixed-length packet to carry different types of traffic.ATM is considered a packet-oriented transfer mode based on: Asynchronous time division multiplexing and the use of fixed length cells. Each cell formats at the Network Node Interface (NNI) and the User Network Interface (UNI) are illustrated below.

The detailed description of the Cell Header Format is as follows:

3.7.1.2.1 Cell Size

An ATM cell is always 48 bytes of data with a 5-byte header. This cell size was determined by the CCITT (now called the ITU-T) as a compromise between voice and data requirements. Figure 7 shows the structure of an ATM cell. The most important fields in the cell header are the Virtual Path Identifier (VPI) and the Virtual Channel Identifier (VCI). Together these identify the connection (called a virtual connection) that this cell belongs to. There is no "destination network address" because this would be too much of an overhead for a 48-byte cell to carry. The VPI/VCI together are similar in function to the Logical Channel Identifier in X.25 or the DLCI of frame relay in that they do not identify the destination address of the

Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1

Generic Flow Control	Virtual Path Identifier (VPI)	
Generic Flow Control	Virtual Path Identifier (VPI)	
Virtual Channel Identifier (VCI)		
Virtual Channel Identifier (VCI)	Payload Type	C L P
Header Error Control (HEC)		
Payload		
…….		
Payload		
Payload		

Figure 7: Structure of an ATM cell

Cell explicitly, but rather they identify a connection, which leads to the desired destination. There is a difference between the number of VPI's at UNI and at NNI. The UNI cell uses only eight bits and the NNI uses twelve bits for the VPI. At UNI the four-bit difference makes up the GFC field.

3.7.1.2.2 Virtual Channels and Virtual Routes

ATM standards defined two types of ATM connections: Virtual Path connections (VPCs), which contain virtual channel connections (VCCs). A virtual channel connection (or virtual circuit) is the basic unit, which carries a single stream of cells, in order, from user to user. A collection of virtual circuits can be bundled together in a virtual path connection. A virtual path connection can be created from end-to-end across an ATM network. In this case, the ATM network does not route cells belonging to a particular virtual circuit. All cells belonging to a particular virtual path are routed the same way through the ATM networks, thus resulting in faster recovery in case of major failures.

Virtual circuits can statically be configured as Permanent Virtual Circuits (PVCs) or dynamically controlled via signalling as Switched Virtual Circuits (SVCs). They can also be point-to-point or point-to-multipoint, thus providing a rich set of service capabilities. SVCs are the preferred mode of operation because they can be dynamically established, thus minimizing configuration complexity.

3.7.1.3 ATM Adaptation Layer (AAL)

The topmost layer, AAL is service-dependent. It provides the necessary protocol translation between ATM and the other communication services (such as voice, video, or data) involved in a transmission. For example, the AAL translates between elements from a pulse-code modulation (PCM) transmission (which encodes voice data in digital form) and ATM cells. The AAL has two sublayers:

3.7.1.3.1 CS (Convergence Sublayer) is the upper sublayer, which provides the interface for the various services. Users connect to the CS through service access points (SAPs).

No protocol data units (PDUs) are defined for this level, because the data passing through is application - and service-dependent. The CS assures the necessary error control and

sequencing as well as the sizing of information.

3.7.1.3.2 SAR (segmentation and reassemble) is the sublayer that packages variable-size packets into fixed-size cells at the transmitting end, and repackages the cells at the receiving end. The SAR sublayer is also responsible for finding and dealing with cells that are out of order or lost. The SAR then chops the CS message into the 48-byte payload packets and attaches them to the five-byte header. A separate PDU is defined for each class of service. Each PDU contains 48 octets, which are allocated for the header, trailer, and data (known as payload in ATM terminology). These PDUs become the data (payload) for the ATM cells that are transmitted. There are five types of adaptation layer services, designated AAL1, AAL2, etc. Of these, the AAL 1 PDU can carry the most data at a time: a 47-octet payload. At the transit node AAL1 prepares voice traffic, AAL2 prepares video traffic ,AAL 3 and AAL 4 each has a 44-octet payload. AA3 and AAL 5 prepare connection-oriented (TCP-like data) and AAL 4 prepares connectionless data (SMDS on LAN like) for cell relay switching. After the preparation stage, the message is delivered to the segmentation layer, where the cells are created and sent. AAL5 is much simpler and relies mostly on the fact that the network is error-free most of the time. AAL5 is also known as SEAL (Simple and Efficient Adaptation Layer) and is the creation of the ATM forum, an organization of users, manufacturers and carriers that try to steer ATM services.

At the receive side the cells go through the reassembly layer and are posted to AAL1,2,3,4, or 5 for the recreation of the original message. This message is then delivered to the video monitor, the voice receiver or the data process expecting it.

3.7.2 ATM Class of Services

There are a number of ATM classes of service. These classes are all outlined in Table 1

Service Categories	Quality of Service Parameter
Constant bit rate (CBR)	This class is used for emulating circuit switching. The cell rate is constant with time. CBR applications are quite sensitive to cell-delay variation. Examples of applications that can use CBR are telephone traffic (i.e., nx64 kbps), videoconferencing, and television
Variable bit rate-non real time (VBR-NRT)	This class allows users to send traffic at a rate that varies with time depending on the availability of user information. Statistical multiplexing is provided to make optimum use of network resources. Multimedia e-mail is an example of VBR-NRT.
Variable bit rate- real time (VBR-NRT)	This class is similar to VBR-NRT but is designed for applications that are sensitive to cell-delay variation. Examples of real-time VBR are voice with speech activity detection (SAD) and interactive compressed video.
Available bit rate (ABR)	This class of ATM services provides rate-based flow control and is aimed at data traffic such as file transfer and e-mail. Although the standard does not require the cell transfer delay and cell-loss ratio to be guaranteed or minimized, it is desirable for switches to minimize delay and loss as much as possible. Depending upon the state of congestion in the network, the source is required to control its rate. The users are allowed to declare a minimum cell rate, which is guaranteed to the connection by the network
Unspecified bit rate (UBR)	This class is the catch-all other class and is widely used today for TCP/IP.

The ATM forum has identified the following technical parameters to be associated with connection. These terms are outlined in Table 2.

Technical Parameter	Definition
Cell Loss Ratio (CLR)	CLR is the percentage of cells not delivered at their destination because they were lost in the network due to congestion and buffer overflow.
Cell transfer delay (CTD)	The delay experienced by a cell between network entry and exit points is called the CTD. It includes propogation delays, queuing delays at various intermediate switches, and service times at queuing points.
Cell delay variation (CDV)	CDV is a measure of the variance of the cell transfer delay. High variation implies large buffering for delay-sensitive traffic such as voice and video.
Peak cell rate (PCR)	The maximum cell rate at which the user will transmit. PCR is the inverse of the minimum cell inter-arrival time.
Sustained cell rate (SCR)	This is the average rate, as measured over a long interval, in the order of the connection lifetime.
Burst tolerance (BT)	This parameter determines the maximum burst that can be sent at the peak rate. This is the bucket-size parameter for the enforcement algorithm that is used to control the traffic entering the network.

Self-Check Exercise

1) What is the difference between “k” and “K” ?
2) Name the two kinds of packet-switching techniques discussed in this chapter, and briefly describe each.
3) Describe the difference between SVCs and PVCs.
4) What is the data-link connection identifier (DLCI)?

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3.8 SUMMARY

Packet switching was developed when long-distance transmission facilities had relatively high error rates compared to today's facilities. So, considerable overheads were built into packet switched schemes to compensate for errors. These reduced the data speeds. Modern high-speed telecommunication systems have much lower error rates and so these error-correcting overheads are unnecessary. Frame relay was developed to take advantage of these high data rates and low error rates.

Frame Relay is a networking protocol that works at the bottom two levels of the OSI reference model: the physical and data link layers. It is an example of packet-switching technology, which enables end stations to dynamically share network resources. Frame Relay networks are designed to operate efficiently at user data rates of up to 2 Mbps as they do not employ most of the overheads involved in error correction. ISDN comprises digital telephony and data-transport services offered by regional telephone carriers.

ISDN involves the digitization of the telephone network to transmit voice, data, text, graphics, music, video, and other source material over existing telephone wires. ISDN uses the following two types of services: Basic Rate Interface (BRI, which offers two B channels and one D channel (2B+D), and an Primary Rate Interface (PRI), which offers 23 B channels and 1 D channel in North America and Japan, and 30 B channels and 1 D channel in Europe and Australia

ISDN runs on the bottom three layers of the OSI reference model, and each layer uses a different specification to transmit data.

3.9 ANSWERS TO SELF CHECK EXERCISES

1) Note that, in ISDN terminology, "k" means 1000 (10^3), not 1024 (2^{10}) as in many computer applications (the designator "K" is sometimes used to represent this value); therefore, a 64 kb/s channel carries data at a rate of 64000 b/s.

2) In variable-length switching, variable-length packets are switched between various network segments to best use network resources until the final destination is reached. Statistical multiplexing techniques essentially use network resources in a more efficient way,

3) A SVC, switched virtual circuit, is created for each data transfer and is terminated when the data transfer is complete. PVC, permanent virtual circuit, is a permanent network connection that does not terminate when the transfer of data is complete. Previously not widely supported by Frame Relay equipment, SVCs are now used in many of today's networks.

4) The DLCI is a value assigned to each virtual circuit and DTE device connection point in the Frame Relay WAN.

3.10 KEYWORDS

Attenuation : Reduction of signal magnitude or signal loss, usually expressed in decibels.

Bandwidth : Information carrying capacity of communication channel. Analogue bandwidth is the range of signal frequencies that can be transmitted by a communication channel or network.

Bits per second (bit/s) : The number of bits passing a point every second. The transmission rate for digital transmission.

Broadband : Service requiring over 2 Mb / s transport capacity.

Channel : The smallest subdivision of a circuit that provides a type of communication service; usually a path with only one direction.

Circuit : A communications path or network; usually a pair of channels providing bi-directional communications.

Circuit Switching : Basic switching process whereby a circuit between two users is opened on demand and maintained for their exclusive use for the duration of the transmission.

Framing : Method of distinguishing digital channels that have been multiplexed together.

E1 : The European standard for high-speed data transmission at 2.048Mb/s - 32 64Kb/s channels are provided.

T1 : A US and Japanese standard for high-speed data transmission at 1.544Mb/s - 24 64Kb/s channels plus 8Kb/s control information are provided. Also called a DS1.

FDM (Frequency Division Multiplexing) : A multiplexing scheme in which the available transmission frequency range is divided into narrower bands. Each of these bands is used to carry a separate channel.

Narrowband : Service requiring up to 2 Mb/s transport capacity.

TDM (Time Division Multiplexer/Multiplexing) The method divides up digital channels to make maximum use of their bandwidth, by taking input from each source in turn. TDMs use one of two methods to achieve this, bit interleaving for synchronous protocols and character interleaving for asynchronous protocols.

Multiplexer : A device for combining several channels to be carried by a single physical channel.

Synchronous : A network where transmission system payloads are synchronised to a master (network) clock and traced to a reference clock. A network where all clocks have the same long term accuracy under normal operating conditions.

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