Unit 6
Emerging Technologies

Unit Objectives
After completion of this unit you will be able to identify and describe the following concepts:
1. Access Technologies
   a. ISDN—BRI and PRI—Protocol overview, data rates, equipment types
   b. ADSL and HDSL—Protocol overview, data rates, coding schemes
2. Fast Packet Technologies
   a. Frame Relay—Protocol overview, frame structure
   b. ATM—Protocol overview, cell header, adaptation layers, types of service, QoS

Introduction
This unit provides an overview of some modern access and transport technologies. The access technologies, addressed in this unit, carry digital traffic between a customer location and the serving wire center (central office) over ordinary twisted-pair wire without the use of repeaters. The transport technologies we will consider were developed to replace older packet technologies (such as X.25), allowing for faster transport of digital information over wide area networks.

6-1 Access Technologies—Digital Subscriber Lines (DSLs)
The DSL technologies we will consider in this unit are ISDN and xDSL. We will consider narrow-band ISDN, BRI (Basic Rate Interface) and PRI (Primary Rate Interface), access standards and two common types of xDSL: ADSL (Asymmetric Digital Subscriber Line) and HDSL (High data rate Digital Subscriber Line).

6-1.2 ISDN (Integrated Services Digital Network)
ISDN is officially defined by the ITU (International Telecommunications Union) as a network evolving from the existing telephone digital networks, that will provide end-to-end digital connections and support a wide range of services. We will focus on the interface standards for BRI and PRI access.

ISDN provides telecommunications services (teleservices) via **Bearer** channels. A bearer channel is a transmission channel provided for user purposes. Signaling, for call control, is performed by **Data** channels. These two channel types are abbreviated to **B** and **D** channels. The B channel rates are 64 Kbps for BRI and PRI ISDN. The D channel rate is 16 Kbps for a BRI and 64 Kbps for a PRI.

Basic Rate Interface (BRI)
We will first take a look at a simple BRI. It is often considered the first of the family of DSLs. A BRI consists of **2B + 1D** channels. So, the user rate is 2(64 Kbps) + 16 Kbps or **144 Kbps**. The BRI allows for two simultaneous voice calls or one voice call and one 64 Kbps data call.

The 2B channels can be combined to provide a rate of 128 Kbps for data transfer or video conferencing.

Refer to Figure 6.1. Two standard reference points are shown in the illustration: S and U. The **S interface** is the subscriber interface, connecting the user's ISDN Terminal Equipment (TE 1) to the Network Terminating equipment (NT 1) over two wire pairs (TX and RX pairs). The **U interface** uses the standard phone line (2-wire) to connect to the central office Line Terminating equipment (LT) which connects the Exchange Termination (ET) to the subscriber line.

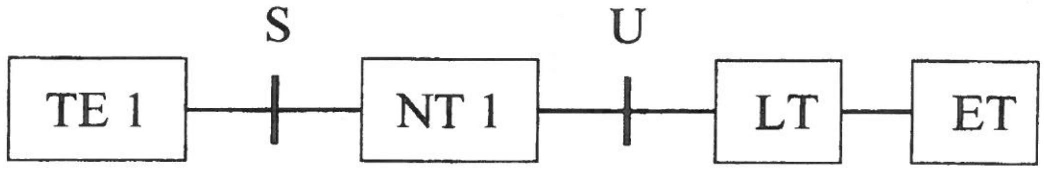

Figure 6.1 A Single Connection over a Basic Rate Interface

The actual transmission speed from the user's equipment (TE 1) is 192 Kbps. This is due to additional overhead for access control and synchronization. The information is re-framed at the U interface to 160 Kbps. The line code on the U interface is 2B1Q, which has 2 bits/baud, so the baud rate to the CO is 80 Kbaud. Figure 6.2 provides a summary of BRI parameters on both sides of the NT unit.

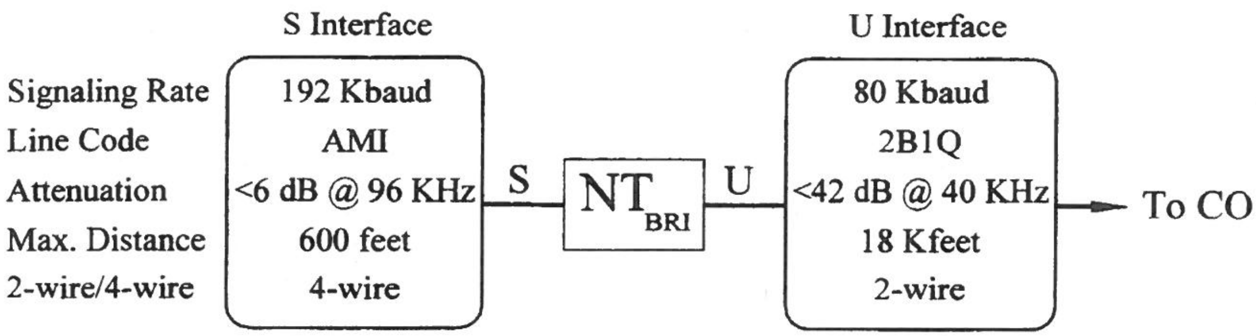

Figure 6.2 S and U Interface Parameters

When implementing an ISDN BRI (or any DSL), care must be taken to remove any **load coils** between the customer and the CO. Load coils are inductors that are typically placed in the loop (customer to CO link) to compensate for capacitive reactance (X_c). The load coils improve the attenuation characteristics of the loop for analog voice (<4 KHz), but act as a low-pass filter for higher frequencies. Since ISDN BRI requires at least 40 KHz of bandwidth, these load coils must be removed for the signal to pass.

Primary Rate Interface (PRI)

The ISDN PRI consists of **23 B + 1 D** in North America (30 B + 1 D in many other countries). An ISDN PRI then, has a total bit rate of 23(64 Kbps) + 64 Kbps or 1.536 Mbps. The added framing overhead of 8000 bps makes the total **line rate of an ISDN PRI equal 1.544 Mbps** (a T-1 rate).

A typical application of an ISDN PRI would be an ISDN PBX (Private Branch Exchange). Refer to Figure 6.3. Notice that an NT 2 (in this case, a PBX) is connected to terminal equipment, acting as an interface between the subscriber's terminals and the NT 1, via the **T interface**.

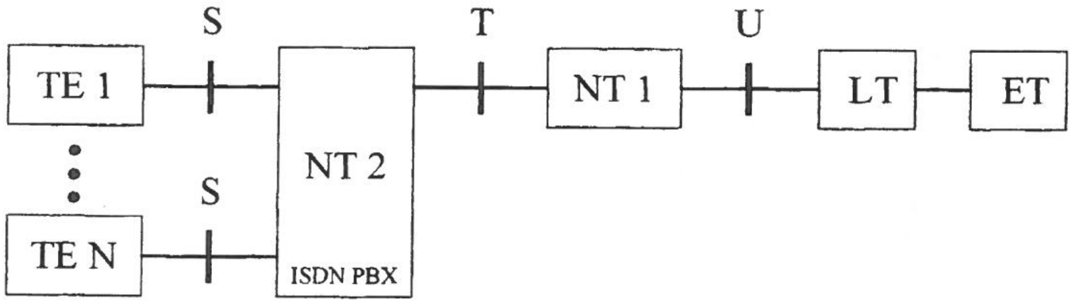

Figure 6.3 Multiple Terminals Connected using Primary Rate Interface

Since an ISDN PRI is carried by a T-1 (in North America), all T-1 parameters and limitations will apply. Refer to Figure 6.4, showing some PRI interface parameters.

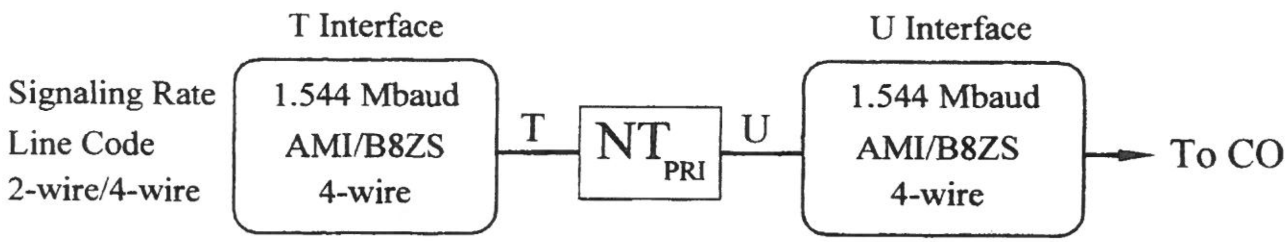

Figure 6.4 Some T and U Interface Parameters

Besides B and D channels, ISDN PRI also has other channel types: **H0** @ 384 Kbps and **H11** @ 1.536 Mbps. H0 is a common channel for video conferencing and, as you can see, H11 uses the entire PRI.

6-1.3 HDSL and ADSL

HDSL and ADSL are two access technologies that provide high-speed service to end users **over existing twisted pair facilities**. Both HDSL and ADSL provide users with higher data rates than ISDN BRI.

HDSL (High data rate Digital Subscriber Line)

HDSL was developed in the late 1980s as an up-scale ISDN BRI. The primary purpose of HDSL is the replacement of T-1 lines between the central office and customers.

The use of a T-1 for connection to an end customer requires placement of repeaters every 3,000 to 5,000 feet. The line code used by a T-1 (AMI or B8ZS) generates high signal levels on the transmission line, requiring lines to be segregated into separate binder groups in order to reduce interference with other services.

The relatively low bandwidth and low signal power of HDSL eliminates the need for repeaters and separate binder groups while providing the same access rate as a T-1 (1.544 Mbps). This makes HDSL a cost-effective alternative to T-1s for customer access.

HDSL has a low bandwidth and low signal power relative to a T-1 due to the line code used and how it is implemented. HDSL uses the same line code as ISDN BRI—2B1Q. You will recall, from unit 2, that the 2B1Q line code provides 2 bits per baud.

Figure 6.5 shows a comparison between T-1 transport and HDSL transport. There are several variations of HDSL. For illustrative purposes, we will only consider the type referred to as "Echo-cancelled hybrid dual-duplex".

Notice that the T-1 uses one wire pair for transmit (TX) and another wire pair for receive (RX). Both T-1 pairs are transporting data at the full rate (1.544 Mbps). A T-1 provides full-duplex service by using the two wire pairs—one in each direction.

As illustrated, HDSL also uses two pairs. With HDSL, though, each pair is transporting **half** of the total data rate (plus some overhead) **in both directions**. HDSL provides full-duplex service by an **echo canceling** technique. Echo canceling allows for full-duplex on the same pair by constructing a replica of the transmitted signal and subtracting it from the received signal.

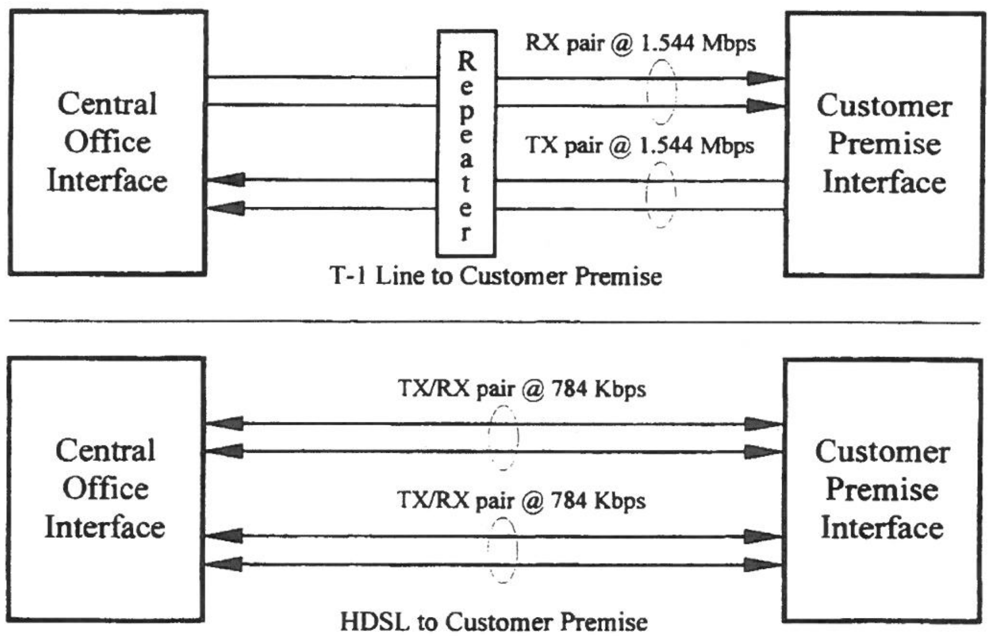

Figure 6.5 T-1 and HDSL Comparison

The following table provides a summary of HDSL and T-1 characteristics.

Digital Carrier	Line Code	Required Bandwidth/pair	Full-duplex Technique	Max. distance w/o repeater	Separate Binder Group
T-1	AMI/B8ZS	768 KHz	TX pair/RX pair	5,000 feet	Yes
HDSL	2B1Q	196 KHz	Echo Canceling	12,000 feet	No

ADSL (Asymmetric Digital Subscriber Line)
ADSL is a local loop access technology that provides asymmetrical transport of data, while also providing plain old telephone service (POTS) **over existing twisted pair cable**. The term *asymmetric* is used because the downstream (towards customer) data rate is greater than the upstream (towards network) data rate. The actual **data rate is dependent on the line condition and distance** to the central office.

The following table is a summary of data rate ranges of ADSL, based on distance to the CO. It is important to note that actual customer data rates are typically much lower than those shown in the table.

Distance to CO	Maximum Data Rate
18,000 feet	1.544 Mbps
16,000 feet	2.048 Mbps
12,000 feet	6.312 Mbps
9,000 feet	8.448 Mbps

Refer to Figure 6.6. The ADSL signal uses a modulation scheme that divides the bandwidth of the local loop, up to 1.104 MHz, into 256 carrier (tone) slots. The interface equipment, referred to as the ADSL Transmission Unit (ATU), dynamically tests each slot for quality. Slots that are noisy or have interference are not used. Each carrier is Quadrature Amplitude Modulated (QAM). This multi-carrier technique is called **Discrete Multitone** (DMT). The POTS is located in the bottom 4 KHz of the available bandwidth. The user bit rate is the sum of all of the carrier bit rates.

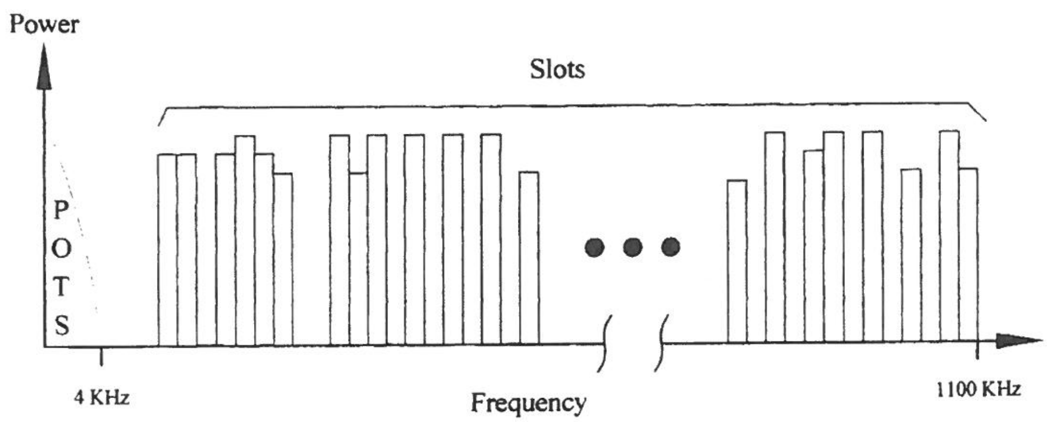

Figure 6.6 Discrete Multitone Modulation Scheme for ADSL

Exercise 6-1 Access Technologies

Fill in the blanks.

1. An ISDN BRI has _____ bearer channel(s) and _____ data channel(s).
2. A BRI requires ______ wire pair(s) and a PRI requires ______ wire pair(s) for transport.
3. The bandwidth requirement of a BRI on the U-interface is _________.
4. ISDN BRI and _________ both use _________ line code.
5. The data rate of ADSL is limited by ___________ and ________ _____________.
6. _________ was designed to replace T-1s in the local loop because it does not ____________ with other services and can go further without the need for ______________.
7. ADSL uses _____________ _____________ modulation of multiple ____________ in dynamically tested slots. This technique is called ___________ ______________.
8. The technique that allows for full duplex with HDSL is called _________ _____________.
9. In order to provide high data rate services over existing phone lines, _________ _________ must be removed to allow the higher ___________ signals to pass.
10. __________ provides high speed data and analog voice over the same wire pair.

6-2 Fast Packet Technologies

The Fast Packet technologies to be considered in this unit are Frame Relay and ATM (Asynchronous Transfer Mode). These technologies are referred to as "Fast Packet" because they were developed to replace the older X.25 packet switching protocol.

X.25 was developed in the mid-1970s for transporting data over wide area networks. At the time, there was a need for a technology that was capable of transporting data in a reliable manner. In the 1970s, most traffic was carried over long distances by microwave repeaters, subject to interference and fading (signal loss). The switching facilities for voice traffic were mostly still mechanical, generating a great amount of electrical and mechanical noise. The terminal equipment for data transfer did not have a high level of capability built into it. Thus the need for a protocol that would provide highly reliable data delivery in an environment that was not friendly to data. X.25 guaranteed delivery by breaking the data down into small packets (short bursts of information) and verifying error-free delivery at each node along the way. The data transfer process with X.25 was reliable, but slow.

By the mid-1980s, times had changed. Traffic was now typically carried over optical fiber, through electronic switching facilities to terminal equipment with a high degree of processing power. The need for a reliable transport protocol was fading, while the need for a faster transport protocol was on the rise.

It was recognized that eliminating some of the error-correcting ability and moving the intelligence from the core network (switching nodes) to the terminal equipment would improve data throughput. This is the origin of Frame Relay and ATM.

Before going further, we will define some terms associated with packet technologies.

Permanent Circuit—A **pre-established, dedicated end-to-end connection** used exclusively by the customer leasing the service. Also called a "leased line".
Circuit switching—A technique for establishing a **temporary dedicated connection** for the transport of user information. Typically used for real-time traffic, such as a phone call.
Packet Switching—A technique for **sharing transport resources** among a group of users, interspersing user traffic over the same facilities. User traffic is in the form of short bursts of information, referred to as "packets".
Virtual Connection—An **end-to-end connection that is packet switched** among many users, with each user **appearing to have a permanent circuit.**
Permanent Virtual Circuit (PVC)—A **virtual connection that is pre-established.**
Switched Virtual Circuit (SVC)—A virtual connection that is established on demand, appearing to the end user as a switched circuit.
User Network Interface (UNI)—End user (subscriber) access to the network.
Network Node Interface (NNI)—The interface between two network nodes.
Frame—A layer 2 PDU (refer to unit 5).
Cell—A frame of fixed length, 53 octets in ATM.

Since X.25 is a packet switching technology capable of providing both PVCs and SVCs, the newer technologies replacing X.25 must also be capable of providing these service types. Frame Relay and ATM both provide PVCs and SVCs. The major change is the level in the 7-layer model at which they operate. You will recall (refer to unit 5) that higher level protocols are smarter (more processing of information) but slower (more processing takes more time).

Refer to Figure 6.7, comparing X.25 to Frame Relay and ATM. Notice that X.25 provides error control at each node in the network. It does this by sending an ACK (acknowledgement) for a good packet, and a NAK (negative acknowledgement) for a bad packet. A NAK requires a retransmission. You can also see that X.25 is a three layer protocol stack.

ATM and Frame Relay both work at layer 2, even though they are called Fast **Packet** (a layer 3 PDU term) technologies. These layer 2 protocols do not perform error control at each node in the network. **A corrupt frame or cell is simply discarded**, allowing for higher layer protocols residing in terminal equipment to provide error control.

The address fields of both ATM and Frame Relay, unlike layer 3 addresses, are **not end-to-end addresses**. These layer 2 protocols only indicate the address of the **next link** in the path. This layer 2 addressing technique is called "label swapping" because the address is remapped to the next switch at each switch in the path.

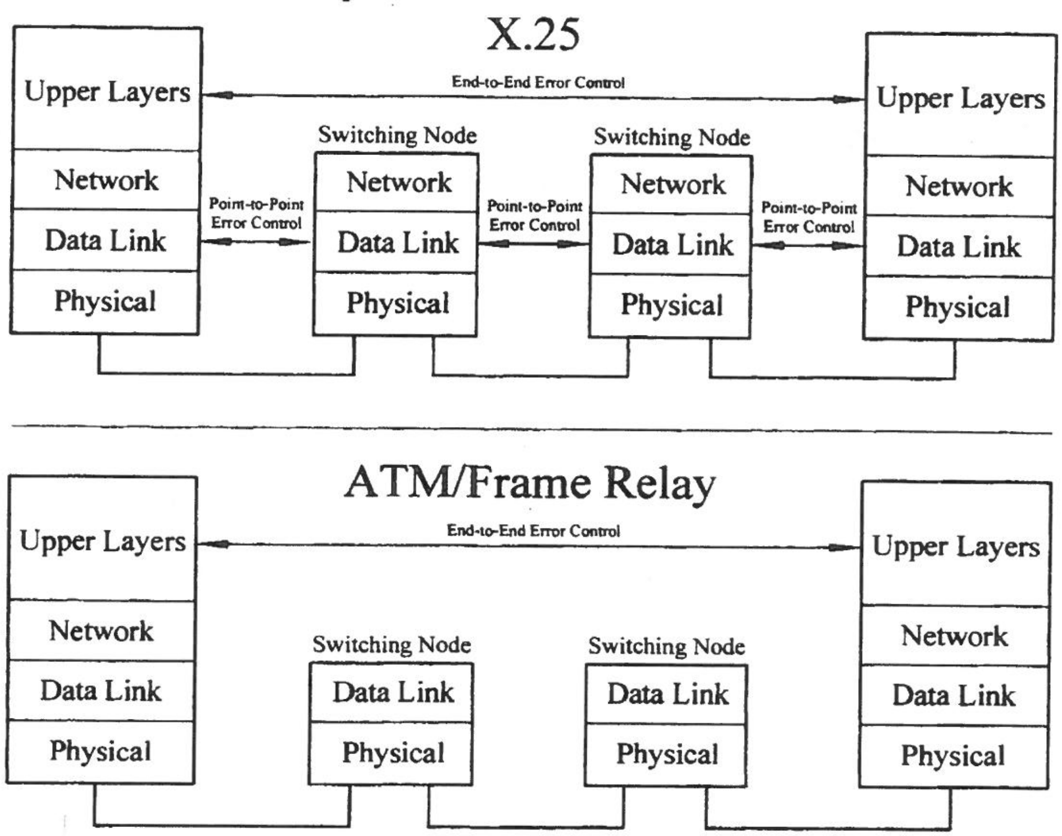

Figure 6.7 Comparison of X.25 protocol layers to Frame Relay and ATM

6-2.2 Frame Relay

Frame Relay is typically used to connect LANs over a wide area network at data rates from 56 Kbps up to 1.544 Mbps (T-1). It is less expensive than a permanent circuit (leased line) and faster than X.25 service. The layer 2 functionality of Frame Relay is reflected in the name of its address field. A Frame Relay address is referred to as a **Data Link Connection Identifier (DLCI)**.

As a tariffed service, Frame Relay is provided to a customer with a service agreement referred to as the Committed Information Rate (CIR). The CIR is an agreed upon transfer rate between the service provider and the customer. One of the benefits of Frame Relay is that a customer can "burst" above the CIR for short periods of time without penalty. Obviously, the service provider should not be responsible for transporting traffic that is constantly exceeding the agreed upon CIR. So, Frame Relay provides a mechanism that allows the service provider to discard frames, during periods of congestion, that do not conform to the agreed upon CIR. This is referred to a "Discard Eligible" frames.

A frame is considered Discard Eligible (DE) when the burst rate exceeds the CIR for a given period of time. The actual DE point varies among providers. When the DE point is reached, a **DE bit** is set in the frame header. This does not mean that the frame will be discarded. It just makes the frame a lower priority than frames that are not Discard Eligible, causing DE frames to be the first frames dropped if there is congestion in the network.

Refer to Figure 6.8. Let's take a look at a Frame Relay frame and consider the header information.

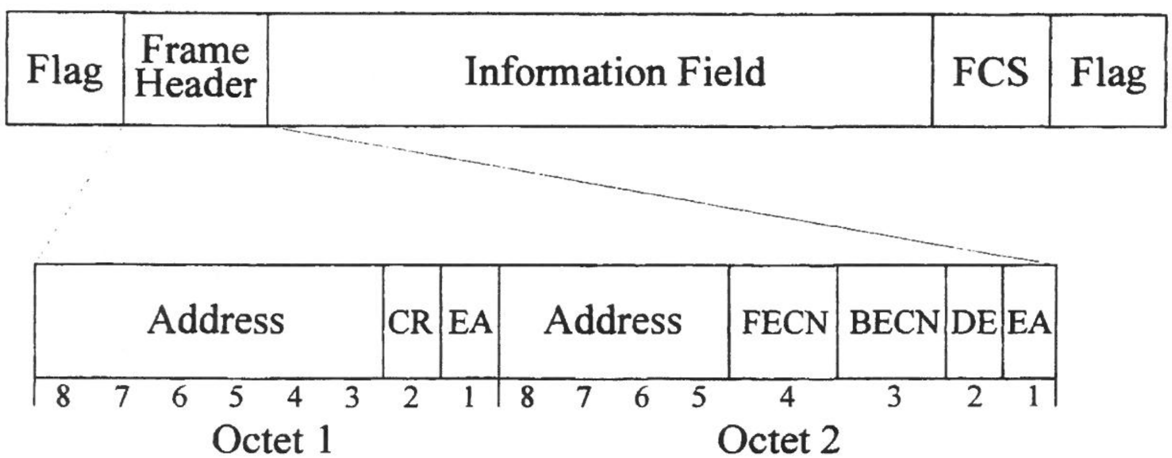

Figure 6.8 Frame Relay Frame Structure

- ✓ **Flag**—An 8-bit sequence that signals the start and end of the frame.
- ✓ **Frame Header**—Part of the frame providing address and control information.
  - ✓ **Address**—The **DLCI** in two parts, totaling 10 bits (1024 possible virtual circuits per interface).
  - ✓ **CR** (Command/Response)—Not used by Frame Relay, but can be used by attached users.
  - ✓ **EA** (Extended Address)—Indicates if the current octet is the **last octet** of the header field. This allows for more than 1024 virtual circuits per interface by extending the number of address octets.

  - ✓ **FECN** (Forward Explicit Congestion Notification)—Set by the network to notify the receiver that there was congestion experienced in the receiver's direction.
  - ✓ **BECN** (Backward Explicit Congestion Notification)—Set by the network to notify the sender that there was congestion experienced in the receiver's direction.
  - ✓ **DE** (Discard Eligible)—Indicates that the frame should be discarded (due to congestion) in preference to other frames that do not have the DE bit set.
- ✓ **Information Field**—Contains upper layer protocol (such as IP) and/or user information. The recommended maximum information field size is 1600 octets.
- ✓ **FCS** (Frame Check Sequence)—A 2-octet field used to determine if the frame has errors. If a frame has errors, it is dropped.

6-2.3 Asynchronous Transfer Mode (ATM)

Frame Relay was developed for transfer of data at speeds up to T-1. ATM was developed to transport all types of traffic over high-speed SONET networks. The concept of transporting and switching all types of traffic over the same facilities is called convergence. ATM is a convergence technology. It can efficiently transport and switch voice, video and data.

Different traffic types have different requirements. Real-time traffic, such as voice or other interactive traffic, is more tolerant of errors and loss than delay. During a conversation, if voice information is lost there may be a discernable "click" or noise burst, but the conversation can continue. A delay in response during a conversation can be distracting. Data transfers, on the other hand, can take longer delays, but are less tolerant of errors or lost information.

In order to accommodate both real time and non-real time traffic over the same facilities, a prioritization scheme must be implemented. Real time interactive traffic must be allowed to go before non-real time traffic. In cases of network congestion, real time traffic must be discarded and non-real time traffic must be buffered (stored) until congestion is reduced.

ATM provides a prioritization scheme referred to as Quality of Service (QoS). **QoS considers three main parameters for traffic: bit rate, loss tolerance and delay tolerance.** Various traffic types have different requirements for the three parameters. Traffic is broken down into categories, reflecting priorities.

- ✓ **Constant Bit Rate (CBR)**—highest priority with bandwidth reserved for its transport. Typically used for streaming video and voice calls.
- ✓ **Variable Bit Rate-real time (VBR-rt)**—assigned to "bursty" real time traffic, such as video conferencing and compressed voice.
- ✓ **Variable Bit Rate-non-real time (VBR-nrt)**—assigned to data traffic, this priority is buffered behind real time traffic.
- ✓ **Unspecified Bit Rate (UBR)**—lowest priority, waits for all other traffic before being transported.

The QoS is pre-assigned to each PVC (Permanent Virtual Circuit) based on an agreement with the service provider. A higher QoS will cost more than a lower QoS. SVC (Switched Virtual Service) QoS is established during call setup.

In order to keep delay to a minimum, ATM uses a **fixed length frame** called a **cell**. The length of the cell is **53 octets**. Keeping the cell short reduces the amount of time that a cell must wait for processing. Making it a fixed length eliminates the need for overhead and processing to determine how long it is.

Another unique aspect of the ATM cell is that there is **no error check performed on the information**. Typically, at the data link layer, an error check of the entire frame is performed at the end of the frame (refer to Frame Relay FCS). This requires that the entire frame must first be loaded into the switching node before it can be evaluated. ATM eliminates this process and only performs an error check on the header information. This technique makes ATM a very fast switching protocol.

ATM has two basic types of equipment functions: Access functions and switching functions. The access function takes different types of information from different types of equipment (router, PBXs, etc.) and **formats it into cells** for transport over the ATM network. The switching function takes in 53 octet cells and switches them to the next node. ATM equipment types can be dedicated to one function or capable of both functions.

When formatting different types of information into cells, it is necessary to segment the information into small pieces that fit into an ATM payload and reassemble them back into their original format at the other end. This process is called Segmentation and Reassembly (SAR). It is a function performed by the ATM Adaptation Layer (AAL).

ATM has five Adaptation Layers associated with different **classes** of traffic. The class of traffic is based on QoS requirements and other parameters. The following is a summary table of classes of traffic and associated Adaptation Layers.

	Service Class			
	Class A	**Class B**	**Class C**	**Class D**
Timing Relation between Source and Destination	Required		Not Required	
Bit Rate	**Constant**	**Variable**		
Connection mode	**Connection-Oriented**			Connectionless
Adaptation Layer	AAL type 1	AAL type 2	AAL type 3/5	AAL type 4
Application Example	Voice, StreamingVideo, Circuit Emulation	Compressed voice, video conferencing	Connecting LANs, X.25 and Frame Relay transport	Datagram service

Notice that each AAL is associated with a specific type of traffic. The most common AAL for the transport of data is AAL 5. It is preferred to AALs 3 and 4 because of all of the AALs, **AALs 3 and 4 have the highest amount of overhead** and **AAL 5 has the lowest overhead**.

Refer to Figure 6.9. Now that we have seen the classes of service and associated Adaptation Layers, let's take a look at the ATM cell format.

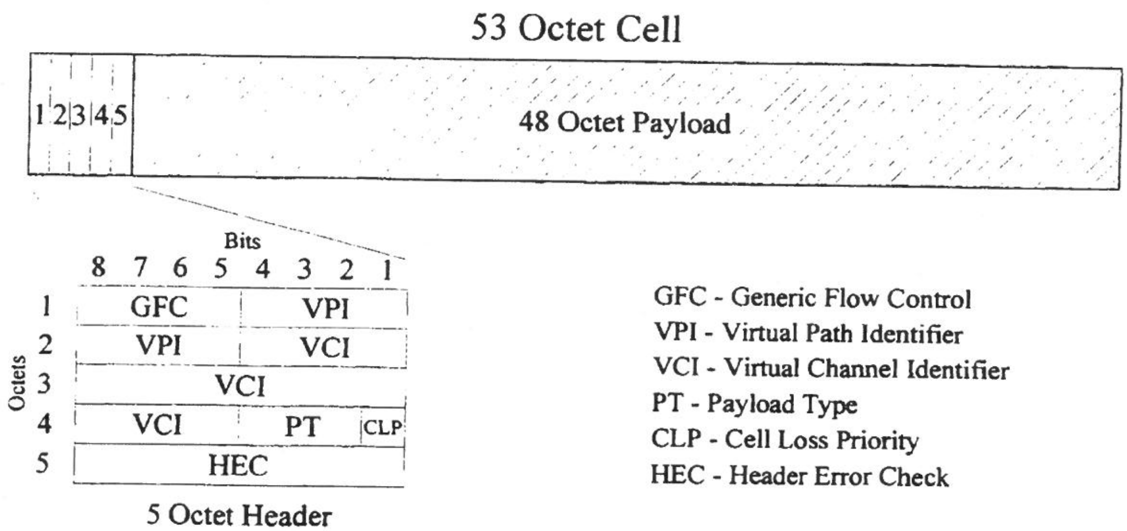

Figure 6.9 ATM Cell: Header and Payload

GFC (Generic Flow Control)—Not currently used. In UNI equipment this field is set to 0000. In NNI equipment this field is replaced by an extended VPI field.
Virtual Path Identifier (VPI)—a group address identifier using 8 bits in a UNI, allowing for up to 256 virtual paths. As with Frame Relay, the address only has local significance.
Virtual Channel Identifier (VCI)—an element address identifier contained within a Virtual Path. The VCI length is 16 bits, allowing for up to 65,536 VCIs per VPI. An ATM address is a combination of the VPI and VCI.
Payload Type (PT)—used for identifying the payload as either user information or network management messages. The PT is also used for congestion notification.
Cell Loss Priority (CLP)—As with Frame Relay, ATM customers establish a service agreement with the service provider. The CLP bit performs the same function as the Frame Relay Discard Eligible bit when a customer exceeds the agreed upon rate for an extended period of time.
Header Error Check (HEC)—used for error detection of the previous four octets. Upon detection of an error, the cell is discarded.
Payload—user information plus some extra overhead.

Exercise 6-2 Fast Packet Technologies

Fill in the blanks

1. A __________ is a frame of fixed length.
2. ATM is a _________ switching technology that works at layer ______ of the OSI model.
3. A Frame Relay ________ consists of ten bits.
4. The ______ bit in Frame Relay performs the same function as the ______ bit in ATM.
5. _______ is the highest priority for ATM QoS.
6. __________________ checks its ______________ for errors, but ____________ does not.
7. Class _____ service is a variable bit rate, real time service associated with AAL _____.
8. AAL _____ has the highest overhead of all connection oriented AALs.
9. An ATM cell is _______ octets long with a _______octet payload.
10. In Frame Relay, the _________bit alerts the receiver that congestion was experienced in the receiver's direction.
11. A VPI can contain up to __________ VCIs.
12. Class D ATM service is the only ______________ ATM service.

Unit 6 Summary

- ✓ An ISDN BRI consists of 2 B + 1 D channels.
- ✓ ISDN BRIs and HDSL use the same line code—2B1Q.
- ✓ When implementing DSLs, the load coils must be removed.
- ✓ An ISDN PRI consists of 23 B + 1 D channels, carried by a T-1.
- ✓ HDSL was developed to replace T-1s in the local loop.
- ✓ HDSL can transport data further than a T-1 without a repeater.
- ✓ ADSL uses a Multi-carrier QAM technique to provide asymmetrical high-speed access.
- ✓ The ADSL data rate to a customer is limited by the distance to the CO and the line conditions.
- ✓ Frame Relay and ATM are "Fast Packet" technologies, developed to replace X.25.
- ✓ Frame Relay and ATM discard corrupted Frames/Cells instead of requesting a retransmission.
- ✓ Frame Relay services are based on a Committed Information Rate.
- ✓ Frames that exceed the CIR can be discarded due to congestion.
- ✓ ATM provides a discard process similar to Frame Relay.
- ✓ ATM does not check information (payload) for errors.
- ✓ ATM is a convergence technology, capable of efficient transport of all types of information.
- ✓ ATM provides prioritization of traffic. This is called Quality of Service (QoS).
- ✓ QoS is based on bit rate, loss tolerance and delay tolerance.
- ✓ ATM has several adaptation layers (AALs) for formatting user information.
- ✓ There are several Classes of service, associated with AALs.
- ✓ Some AALs have more overhead than others.

> The purpose of this unit is to provide a general understanding of the subject areas addressed. For more information on the topics covered in this unit, refer to the Web sites and reference books listed in the **Study Guide for the Digital Communications and Computer Literacy Test.**

Answers to Exercises

Exercise 6-1 Access Technologies

1. An ISDN BRI has _2_ bearer channel(s) and _1_ data channel(s).
2. A BRI requires _1_ wire pair(s) and a PRI requires _2_ wire pair(s) for transport.
3. The bandwidth requirement of a BRI on the U-interface is _40 KHz_ .
4. ISDN BRI and _HDSL_ both use _2B1Q_ line code.
5. The data rate of ADSL is limited by _distance_ and _line_ _condition_ .
6. _HDSL_ was designed to replace T-1s in the local loop because it does not _interfere_ with other services and can go further without the need for _repeaters_ .
7. ADSL uses _Quadrature_ _Amplitude_ modulation of multiple _carriers_ in dynamically tested slots. This technique is called _Discrete_ _Multitone_ .
8. The technique that allows for full duplex with HDSL is called _echo_ _canceling_ .
9. In order to provide high data rate services over existing phone lines, _load_ _coils_ must be removed to allow the higher _bandwidth_ signals to pass.
10. _ADSL_ provides high speed data and analog voice over the same wire pair.

Exercise 6-2 Fast Packet Technologies

1. A _cell_ is a frame of fixed length.
2. ATM is a _cell_ switching technology that works at layer _2_ of the OSI model.
3. A Frame Relay _DLCI_ consists of ten bits.
4. The _DE_ bit in Frame Relay performs the same function as the _CLP_ bit in ATM.
5. _CBR_ is the highest priority for ATM QoS.
6. _Frame Relay_ checks its _payload_ for errors, but _ATM_ does not.
7. Class _B_ service is a variable bit rate, real time service associated with AAL _2_ .
8. AAL _3_ has the highest overhead of all connection oriented AALs.
9. An ATM cell is _53_ octets long with a _48_ octet payload.
10. In Frame Relay, the _FECN_ bit alerts the receiver that congestion was experienced in the receiver's direction.
11. A VPI can contain up to _65,536_ VCIs.
12. Class D ATM service is the only _connectionless_ ATM service.