Asynchronous Transfer Mode (ATM)

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Goals of ATM

1. ATM, also known as cell relay, involves the transfer of data in discrete chunks called *cells*. Multiple logical connections can be multiplexed over a single path. This is similar to packet switching except that the packets are variable sized and cells are of a fixed size.

2. ATM is used in the WANs and is not constrained to a particular physical medium or data rate (155 Mbps, 622 Mbps, and 2.5 Gbps).

3. ATM has minimal error and flow control capabilities to reduce the overhead of cells the overhead of protocol processing, enabling ATM to operate at high data rates.

ATM Protocol Architecture

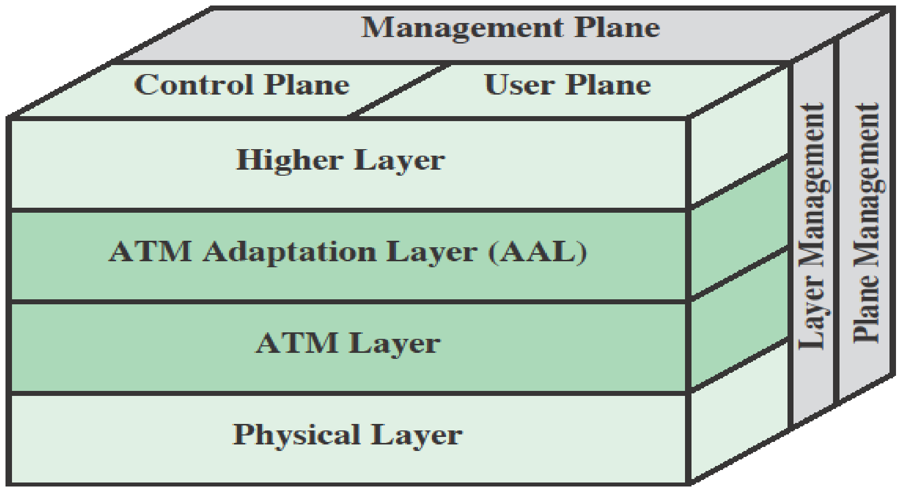

Figure 11.1 ATM Protocol Architecture

ATM Protocol Architecture …

- Physical Layer

  Concerned with specifications of the transmission medium and signal encoding . Data rates specified include 155 and 622 Mbps with other data rates possible.

- ATM Layer

  Defines transmission of data in fixed size cells and also defines the logical connections (Virtual circuits and virtual paths).

- ATM Adaptation Layer (AAL)

  Supports transfer protocols not based on ATM. It maps higher layer information into ATM cells to be transported over an ATM network, then collects information from ATM cells for delivery to higher layers (e.g. a IP packet can be mapped to ATM cells).

(There are 3 planes in the protocol architecture: the *User* plane is for user traffic including flow and error control; the *Control* plane is for connection control; the *Management* plane manages the system as a whole and coordinates the planes and layers).

ATM Protocol Layers …

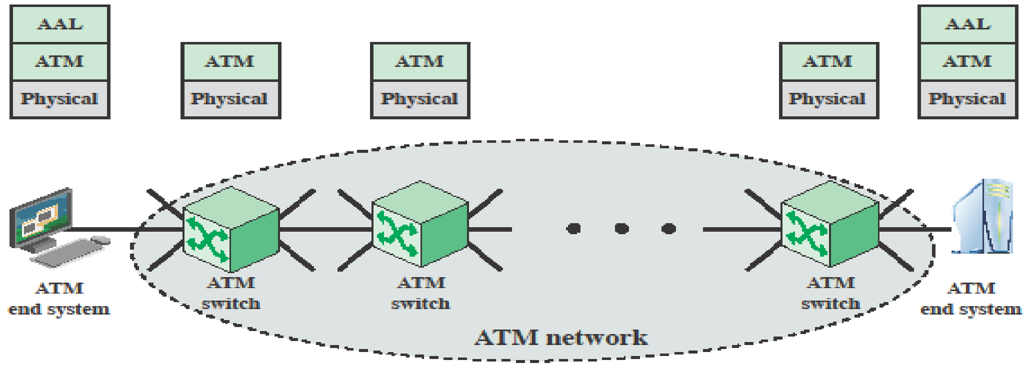

Figure 11.2 ATM Protocol Layers

Virtual Paths (VPs) and Virtual Circuits (VCs)

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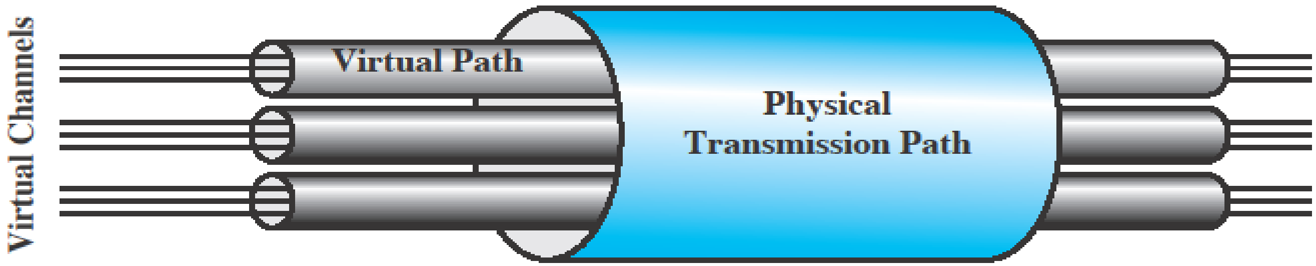

Figure 11.4 ATM Connection Relationships

Virtual Paths (VPs) and Virtual Circuits (VCs) …

- ATM Logical Connections are referred to as Virtual Circuit Connections (VCCs). A VCC is set up between two end users and a variable-rate, full-duplex flow of cells is exchanged over the connection.

- A Virtual Path Connection (VPC) is a bundle of VCCs that have the same endpoint. So all cells flowing within all the VCCs in a VPC are switched together.
  - VPC helps control cost by grouping connections sharing common paths through the network into a single unit. Network management can then be applied to a small number of groups of connections instead of a large number of individual connections.

- Advantages of VPCs:

1. Simplified network architecture (network functions can be separated into those related to a VCC and those related to a group of connections (VPC)).
2. Increased network performance and reliability since the network deals with fewer entities.
3. Reduced processing and short connection set-up time (most of the work is done when a VPC is set-up. By reserving capacity on a VPC in anticipation of later calls, new VCCs can be set-up be executing simple control functions at end-points of the VPC; no call processing is required at transit nodes. So addition of new VCCs to an existing VPC involves minimal processing).
4. Enhanced network services (the VPC is used internal to the network but is also visible to the end user. So user may define closed user groups or closed networks of VCC bundles (lease them)).

Virtual Paths (VPs) and Virtual Circuits (VCs) …

- The VPC mechanisms include calculating routes, allocating capacity and storing connection state information.
- For an individual VCC set-up, control involves checking that a VPC to destination node with sufficient capacity to support a VCC exists and then store state information (VCC/VPC mapping).

- VCC uses

  In a VCC, cell sequence integrity is preserved, i.e. cells are delivered in the order they were sent.

  Examples:
- Between end users to carry end-to-end user data.
- Between an end user and a network entity for user-to-network control signaling.
- Between two network entities for network traffic management and routing functions.

Virtual Paths (VPs) and Virtual Circuits (VCs) …

- VPC/VCC Characteristics

1. QoS: A user of a VCC is provided with QoS specified by parameters such as *cell loss ratio* (ratio of cells lost to cells transmitted) and *cell delay variation*.

2. Cell Sequence Integrity: Sequence of transmitted cells within a VCC is preserved.

3. Traffic parameter and usage monitoring: Traffic parameters such as *average rate, peak rate, burstiness,* and *peak duration,* can be negotiated between a user and the network for each VCC. The input of cells to a VCC is monitored by the network to ensure that the negotiated parameters are not violated.

   - network can deny request for new VCCs if congested or discard cells if negotiated parameters are violated or if congestion becomes severe. In a worst case, a VCC can be terminated.

4. VCC identifier restriction within a VPC: One or more VCC #s may not be available to users of the VPC but may be reserved for network management use.

ATM Cell Format

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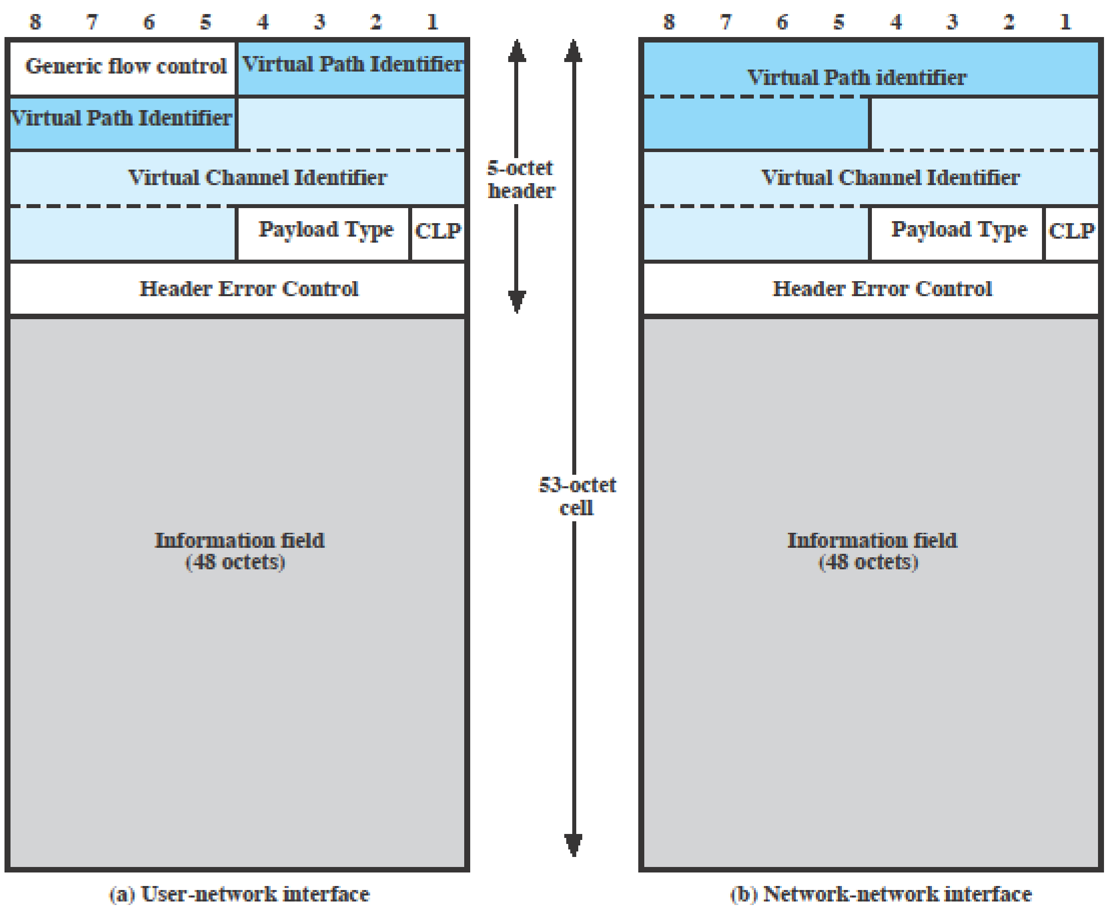


Figure 11.6 ATM Cell Format

ATM Cell Format …

- Fixed size cell has a 5-byte header and 48-byte data field.
  - Use of small cells may reduce queuing delay for a high-priority cell (since it waits less if it arrives slightly behind a lower priority cell that has gained access to the transmitter).
  - Fixed size cells can be switched more efficiently (i.e. easier to implement switching mechanism in hardware and build more scalable switches). This is important for the high data rates of ATM.

- Header format

GFC (4-bits): *Generic Flow Control* to assist the customer in controlling traffic flow based on QoS. This field is only retained at the user-network interface (UNI) and not retained at the network-network interface (NNI) between ATM switches.

VPI (8-bits at the UNI and 12-bits at the NNI allowing more VPCs to be represented within the network): *Virtual Path Identifier* is a routing field for the network.

VCI (16-bits): *Virtual Channel Identifier* is used for routing to and from an end user.

ATM Cell Format …

- Header format (continued)

  PTI (3-bits): *Payload Type* indicates type of information in the information field.

  The MSB indicates the type of ATM cell that follows. This bit set to 0 indicates user data; a bit set to 1 indicates network management data.

  The middle bit indicates whether the cell experienced congestion in its journey from source to destination. This bit is also called the Explicit Forward Congestion Indication (EFCI) bit. This bit is set to 0 by the source; if an interim switch experiences congestion while routing the cell, it sets the bit to 1. After it is set to 1, all other switches in the path leave this bit value at 1.

000	User data cell, congestion not experienced, AAU* =0
001	User data cell, congestion not experienced, AAU=1
010	User data cell, congestion experienced, AAU=0
011	User data cell, congestion experienced, AAU=1
100	Network management segment cell
101	Network management end-to-end cell
110	Resource management cell
111	Reserved for future function

(*AAU represents ATM-user to ATM-user and is represented by the LSB of the *Payload Type* field. When AAU = 1, it indicates that the cell carries network management information. This allows for the insertion of network management cells into a user's VCC without affecting the user's data. So it provides in-band control information. This bit indicates the last cell in a block for AAL5 in user ATM cells.)

ATM Cell Format …

- Header format (continued)

CLP (1-bit): *Cell Loss Priority* provides guidance to the network in the event of congestion. CLP = 0 indicates a cell of high priority which should not be discarded. CLP = 1 indicates a cell that is subject to discard.

- When the CLP bit is set to 1, the interim switches sometimes discard the cell in congestion situations.

- An ATM user sets the CLP bit to 1 when a cell is created to indicate a lower priority cell. The ATM switch can set the CLP to 1 if the cell exceeds the negotiated traffic parameters of a VCC. Later if congestion is experienced, the cell that has been marked with CLP = 1 is subject to discard in preference to cells that fall within agreed traffic limits.

HEC (8-bits): *Header Error Code* is calculated based on the remaining 32-bits of the header. Polynomial used for the checksum is $x^8 + x^2 + x + 1$. In the case of ATM, the input to calculate the checksum is only 32-bits compared to the 8-bits for the code.

- The HEC only checks the ATM header and not the ATM payload. Checking the payload for errors is the responsibility of upper layer protocols.

Cell Framing (Delineation)

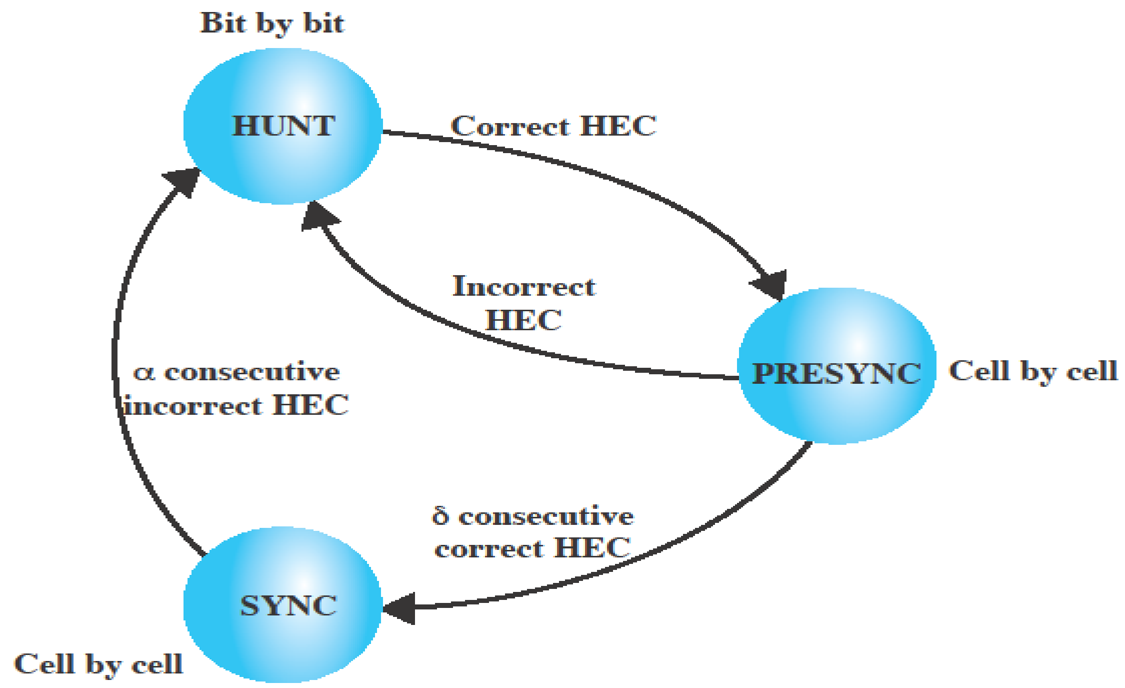


Figure 11.10 Cell Delineation State Diagram

To recognize a cell boundary. This is done by the Transmission Convergence Sub-layer which is part of the Physical Layer. It uses the HEC since no flags are available to signal end of a cell. A finite state machine is used as shown above.

ATM Adaptation Layer 5 (AAL 5)

- AAL5 is used to carry computer data such as TCP/IP. AAL5 adapts multi-cell higher layer PDUs into ATM cells with minimal error checking and no error detection.
- Unlike most network frames, which place control information in the header, AAL5 places control information in an 8-byte trailer at the end of the packet.
- Each AAL5 packet is divided into an integral number of ATM cells and reassembled into a packet before delivery to the receiving host. This process is known as Segmentation and Reassembly.
- AAL 5 is the most relevant and widely implemented.

AAL5 …

- The AAL layer has two sub-layers: *CS* and *SAR*.

Convergence Sublayer (CS)
Segmentation and Reassembly (SAR)

- CS: provides functionality to support specific applications using AAL. Each AAL user attaches to AAL at a series of service access points (SAP) which is the address of the application (e.g. like a TCP port # to uniquely identify the application).
- SAR: packages information received from the CS into cells for transmission and for unpacking at the other end.

- The AAL5 SAR-PDU is 48 bytes payload as shown:

48 bytes

SAR-PDU payload

A block of data from a higher layer is encapsulated into a PDU at the CS sub-layer. This is then passed to the SAR sub-layer where it is broken up into payload blocks (total length = 48 bytes).

AAL5 …

- The Common Part Convergence Sub-layer (CPCS-PDU) is shown below:

	0-47	8 bytes
CPCS-PDU Payload	**Pad**	**CPCS-PDU trailer**

The 8-bytes trailer is shown next:

1	1	2	4
CPCS-UU	**CPI**	**LEN**	**CRC**

- CPCS-UU (*User-to-user indication*, 1-byte): used to transfer user-to-user information transparently. This is undefined.
- CPI (1-byte): *Common part indicator* is a filling byte (of value 0). This field is to be used in the future for layer management message indication.
- LEN (2-bytes): Length of the CPCS-PDU payload (maximum size is 64KB, not including padding and trailer).
- CRC (4-bytes): To detect errors in the CPCS-PDU.

- Pad within the CPCS-PDU: The payload from the next higher layer is padded out to make the entire CPCS-PDU (including trailer) is a multiple of 48-bytes.

AAL5 …

- The AAL5 SAR-PDU is 48 bytes payload as shown:

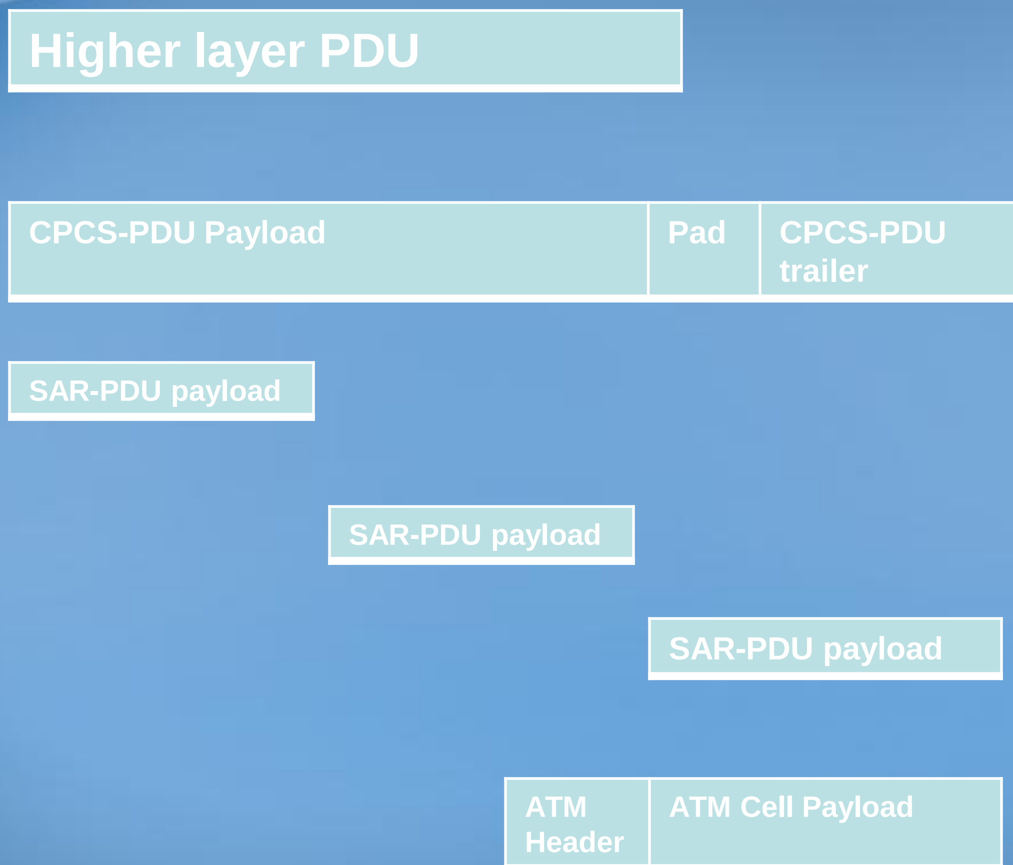
48 bytes

SAR-PDU payload

A block of data from a higher layer is encapsulated into a PDU at the CS sub-layer. This is then passed to the SAR sub-layer where it is broken up into payload blocks (total length = 48 bytes).

- The SAR-PDU has no header and trailer (i.e. no protocol overhead). The implications of a lack of protocol are:
  - No sequence # and so receiver must assume that all SAR-PDUs arrive in sequence for reassembly (CRC field in CPCS-PDU verifies this).
  - To tell when a CPCS-PDU ends, the AAU bit (the LSB bit of the PTI field in the ATM cell header) is used. A CPCS-PDU consists of 0 or more consecutive SAR-PDUs with AAU bit set to 0 followed immediately by a SAR-PDU with AAU bit set to 1.
  - The last cell contains padding to ensure that the entire packet is a multiple of 48 bytes. The final cell contains up to 40 bytes of data, followed by 0 or more padding bytes and the 8-byte trailer. In other words, AAL5 places the trailer in the last 8 bytes of the final cell where it can be found without knowing the length of the packet; the final cell is identified by a bit in the ATM header (the LSB of the PTI field), and the trailer is always in the last 8 bytes of that cell.

AAL 5 Transmission



AAL5 Utilization

- Example: If a 1010 byte message is to be sent via AAL5, what is the utilization, U?

- Add 8 bytes for the CPCS-PDU trailer: 1010 + 8 = 1018 bytes.
- 1018 / 48 = 21.2 cells (this indicates a pad will be necessary to make it a multiple of 48 bytes)

- So 22 cells will need to be sent via AAL5.

- Hence U = 1010 / (22 * 53) = 1010 / 1166 = 0.866 or 86.6%

ATM Bit Rate Services

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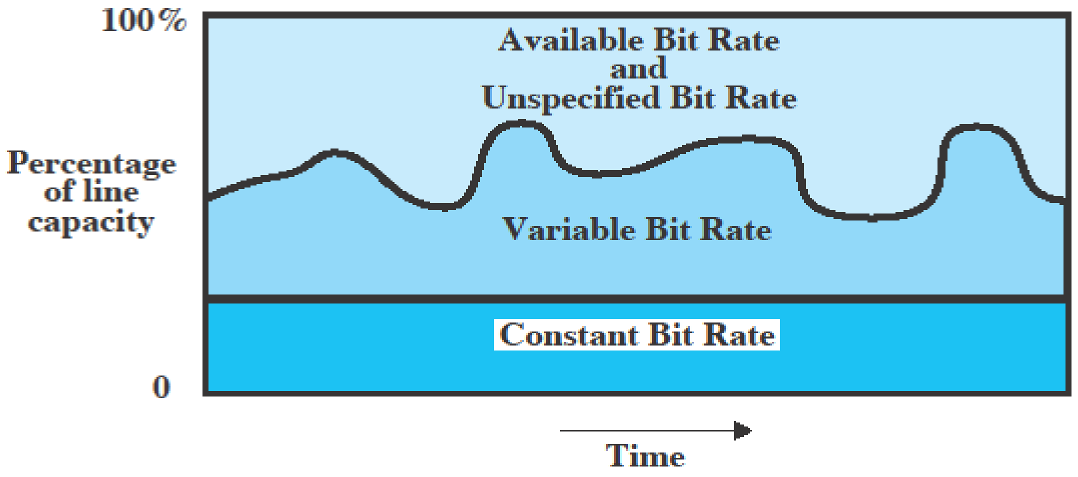

Figure 11.14 ATM Bit Rate Services