The University of Sydney
AUSTRALIA

School of Electrical and Information Engineering

Advanced Communication Networks

Chapter 11

Asynchronous Transfer Mode (ATM) Protocols

Based on chapter 16 of Stallings ISDN-4e book

Abbas Jamalipour

11.1 Introduction

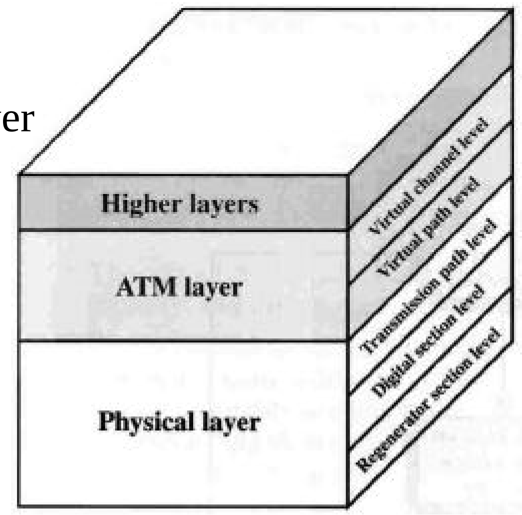
- ATM or *Cell Relay* has a similar concept to frame relay.
- Both ATM and frame relay take advantage of the reliability and fidelity of modern digital facilities for fast packet switching.
- ATM was developed as part of the work on broadband ISDN, but is beginning to find application in non-ISDN environment where very high speed data rates are required.
- ATM still has many similarities with packet-switching networks
  - transferring of data in discrete chunks
  - allowing multiple logical connections to be multiplexed over a single physical interface
- However, ATM has more than X.25 and frame relay
  - organizing the information into fixed-size packets (cells)
  - a streamlined protocol with minimal error and flow control
  - simplified cell processing at each ATM node
  - Thus, less overheads (no. of bits and processing) & higher data rates
- Physical layer of the ATM protocol architecture involves the specification of a transmission medium and a signal encoding scheme.

Data rates specified at the physical layer

155.52 Mbps

622.08 Mbps

Possibility of other data rates (higher and lower)



Overall hierarchy function in ATM network

- Two specific layers for ATM functions
  - **ATM Layer**
    - defines the transmission of data in fixed-sized cells
    - defines the use of logical connections
  - **ATM Adaptation Layer (AAL)**
    - mapping the higher-layer information into ATM cells to be transport over an ATM network
    - collecting information from ATM cells for delivery to higher layers
- Three functional levels of the physical layer
  - Transmission path level
    - Extends between network elements that assemble and disassemble the *payload* of a transmission system.
      - End-to-end communication: payload is the end-user information
      - User-to-network commun.: payload is the signaling information
  - Digital section level
    - Extends between network elements that assemble and disassemble a continuous bit or byte stream.
    - Refers to the exchanges or signal transfer points in a network
  - Regenerator section level
    - A portion of a digital section.
    - For example, a repeater for regeneration (no switching is involved).

11.2 ATM Logical Connections

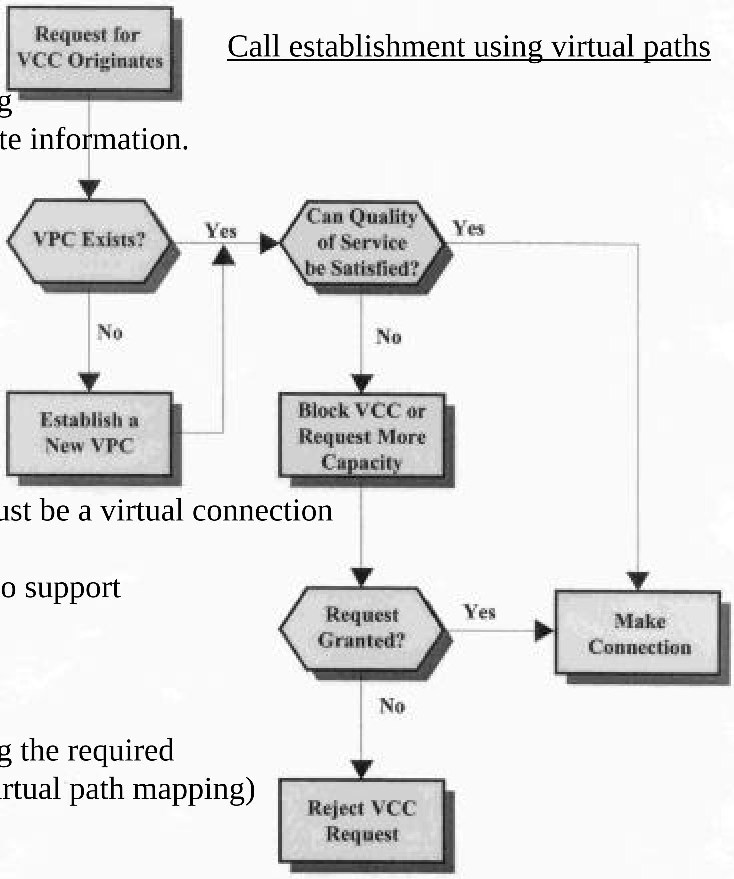
- Logical connections in ATM are referred to as *virtual channel connection* (VCC).
  - Analogous to a virtual circuit in X.25 or a data link connection in frame relay
  - It is the basis unit of switching in an ATM network.
  - A VCC is Set up between two end users through the network and a variable-rate, full-duplex flow of fixed-size cells is exchanged over the connection.
  - Can be also used for user-network and network-network exchange.
- For ATM a second sublayer of processing has been introduced that deals with the concept of virtual path.
  - *Virtual path connection* (VPC) is a bundle of VCCs that have the same endpoints.
  - Thus, all of the cells flowing over all of the VCCs in a single VPC are switched together.

  - Virtual path concept was developed in response to a trend in high-speed networking in which the control cost of the network is becoming an increasingly higher proportion of the overall cost.
  - Controls the cost by grouping connections that share a common path
  - Network management actions can then be applied to a small number of groups of connections instead of to a large number of individual connections.

- Advantages of using virtual paths
  - ***Simplified network architecture***
    - separation of the network transport functions to those related to an individual logical connection (virtual channel) and those related to a group of logical connections (virtual path)
  - ***Increased network performance and reliability***
    - dealing of the network with fewer, aggregated entities
  - ***Reduced processing and short connection setup time***
    - by reserving capacity on a virtual path connection in anticipation of later call arrivals, new virtual connections can be established by executing simple control functions at the end-points of the virtual path connections
    - no call processing required at transit nodes
  - ***Enhanced network services***
    - virtual path used internal to the network but visible to the end user
    - thus, user may define closed user group or closed networks of virtual-channel bundles

<u>Call establishment using virtual paths</u>

Virtual path control mechanism include calculating routes, allocating capacity, and storing connection state information.



To set up a virtual channel, there must be a virtual connection to the required destination node
- with sufficient available capacity to support the virtual channel,
- with the appropriate QoS

A virtual channel is set up by storing the required state information (virtual channel/virtual path mapping)

- The concepts of virtual path and virtual channel are defined in ITU-T Recommendations with reference to both the user-network and the internal network operation.

Virtual Channel (VC)	A generic term used to describe unidirectional transport of ATM cells associated by a common unique identifier value.
Virtual Channel Link	A means of unidirectional transport of ATM cells between a point where a VCI value is assigned and the point where that value is translated or terminated.
Virtual Channel Identifier (VCI)	Identifies a particular VC link for a given VPC.
Virtual Channel Connection (VCC)	A concatenation of VC links that extends between two points where the adaptation layer is accessed. VCCs are provided for the purpose of user-user, user-network, or network-network information transfer. Cell sequence integrity is preserved for cells belonging to the same VCC.
Virtual Path	A generic term used to describe unidirectional transport of ATM cells belonging to virtual channels that are associated by a common unique identifier value.
Virtual Path Link	A group of VC links, identified by a common value of VPI, between a point where a VPI value is assigned and the point where that value is translated or terminated.
Virtual Path Identifier (VPI)	Identifies a particular VP link.
Virtual Path Connection (VPC)	A concatenation of VP links that extends between the point where the VCI values are assigned and the point where those values are translated or removed, i.e., extending the length of a bundle of VC links that share the same VPI. VPCs are provided for the purpose of user-user, user-network, or network-network information transfer.

Virtual Channel Connection Uses

- **Between end users**
  - to carry end-to-end user data
  - A VPC between end users provides them with an overall capacity
- **Between an end user and a network entity**
  - to carry user-network control signaling
  - A user-to-network VPC can be used to aggregate traffic from an end user to a network exchange or network server
- **Between two network entities**
  - used for network management and routing functions
  - A network-to-network VPC can be used to define a common route for the exchange of network management information

Virtual Path/Virtual Channel Characteristics

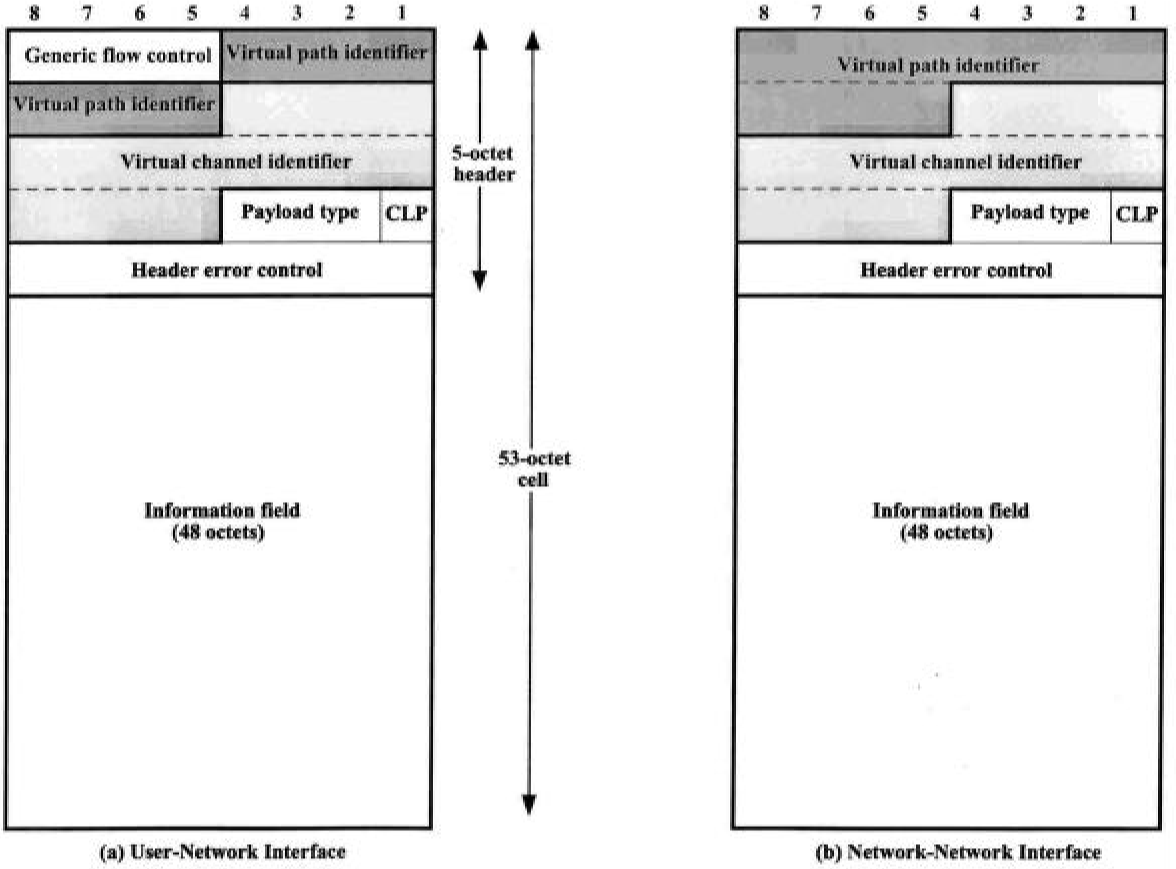
- **Quality of Service**
  - a user of a VCC is provided with a QoS specified by parameters such as cell loss ration and cell delay variation
- **Switched and semi-permanent virtual channel connections**
  - switched connections require call-control signaling
- **Cell sequence integrity**
  - sequence of transmitted cells within a VCC is preserved
- **Traffic parameter negotiation and usage monitoring**
  - traffic parameters can be negotiated between a user and the network for each VCC, monitored by the network
  - parameters: average rate, peak rate, burstiness, peak duration
- **Virtual channel identifier restriction within a VPC**
  - This characteristic is only for VPCs
  - one or more virtual channel identifiers may not be available to the user of the VPC, but may be reserved for network use

Control Signaling

- Control Signaling: The exchange of information involved in the process of establishment and release of VPCs and VCCs
- Four methods for establishment/release (I.150)
  - *semi-permanent VCCs* may be used for user-to-user exchange
    - no control signaling is required
  - use of a low data rate permanent channel, called *meta-signaling*, to set up VCCs when no pre-established channel exists
  - meta-signaling channel can be used to set up a VCC between the user and the network for call control signaling
    - This *user-to-network signaling virtual channel* can then be used to set up VCCs to carry user data.
  - meta-signaling channel can also be used to set up a *user-to-user signaling virtual channel*
    - It can then be used to allow two end users to establish and release user-to-user VCCs to carry user data.

11.3 ATM Cells

- ATM has fixed-size cells consists of a 5-byte and a 48-byte information field. Advantages are:
  - reducing queuing delay for high-priority cells
  - cells can be switched more efficiently in high data rates of ATM
  - easier implementation of switching mechanism in hardware



(a) User-Network Interface (b) Network-Network Interface

- The *generic flow control field* can be used for control of cell flow only at the local user-network interface (details of applications for further study)
  - This field could be used to assist the customer in controlling the flow of traffic for different qualities of service.
  - One usage would be a multiple-priority level indicator to control the flow of information in a service-dependent manner.

- *Virtual path identifier (VPI)* constitutes a routing field for the network.
  - 8 bits at the user-network interface and 12 bits in network-network interface
  - for more virtual paths to be supported within the network
- *Virtual channel identifier (VCI)* is used for routing to and from the end user; functions much as a service access point.
- *Payload-type (PT)* field indicates the type of information in the information field.

PT coding	Interpretation
0 0 0	User data cell, AAU = 0, congestion not experienced
0 0 1	User data cell, AAU = 1, congestion not experienced
0 1 0	User data cell, AAU = 0, congestion experienced
0 1 1	User data cell, AAU = 1, congestion experienced
1 0 0	OAM F5 segment associated cell
1 0 1	OAM F5 end-to-end associated cell
1 1 0	Resource management cell
1 1 1	Reserved for future function

AAU = ATM user to ATM user indication

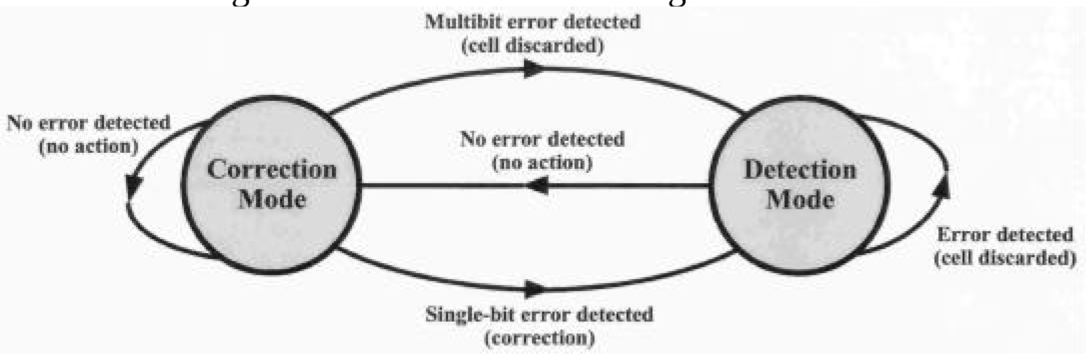
  - First bit of “0” shows user information
    - Then the second bit indicates whether congestion has been experienced
    - The third bit (AAU) is a one-bit field that can be used to convey information between end users
  - First bit of “1” indicates that the cell carries network management information
- *Cell-loss priority (CLP)* is used to provide guidance to the network in the event of congestion.
  - 0: indicates a cell of relatively higher priority (should be discarded only when no other alternative is available
  - 1: indicates that this cell is subject to discard within the network
  - A way for congestion control
  - User can employ this field to insert extra information to the network
  - In the case of congestion, a cell with marked CLP for discard will be in preference to cells fall within agreed traffic limits.

Header Error Control

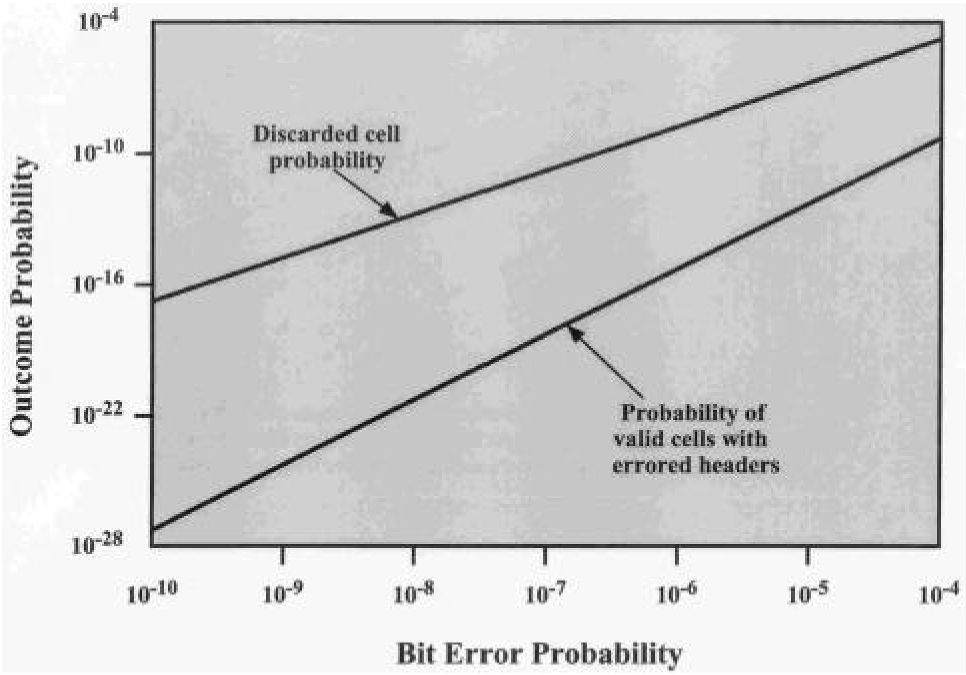
- ATM cells include an 8-bit header error control (HEC) field.
  - Calculated based on the remaining 32 bits using polynomial

$$X^8 + X^2 + X + 1$$

  - Since 8 bits codes used for 32 bits, the code can not only be used for detecting errors but also for correcting errors

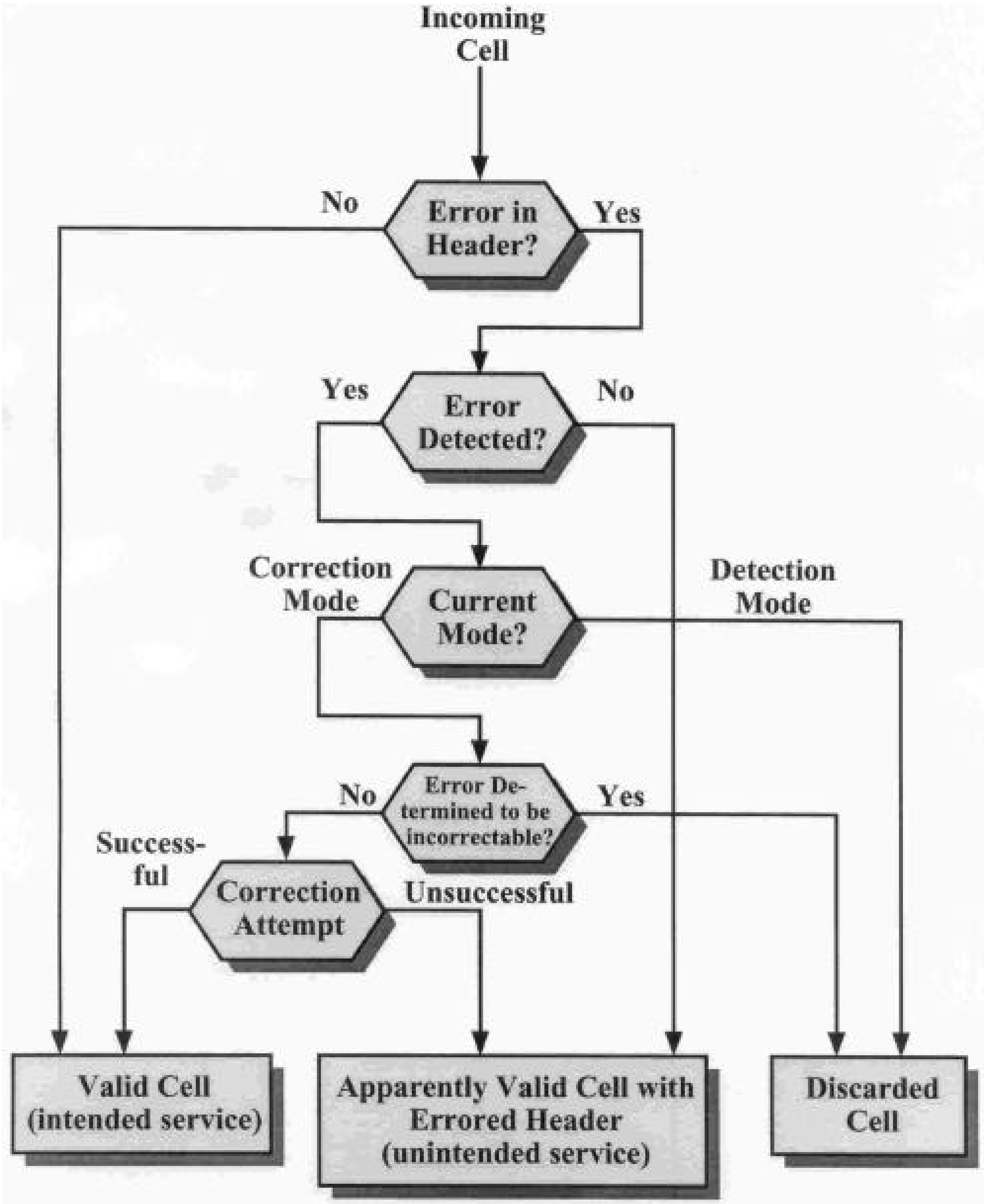


  - The error-protection function provides
    - recovery from single-bit header errors
    - a low probability of the delivery of cells with bursty errored headers
    - Error characteristics of fiber-based transmission systems are a mixture of single-bit errors and relatively large burst errors



Impact of random bit errors on HEC performance (I.432)

- HEC operation at the receiver
  - initially in the default mode for single bit error correction
  - remains in error-correction mode as long as no errors are detected
  - in the case of detected errors, correct the error if it is a single-bit error
  - or detecting the error as a multi-bit error
  - then moves to detection mode (no error correction is performing)
  - this is because the error would be in burst

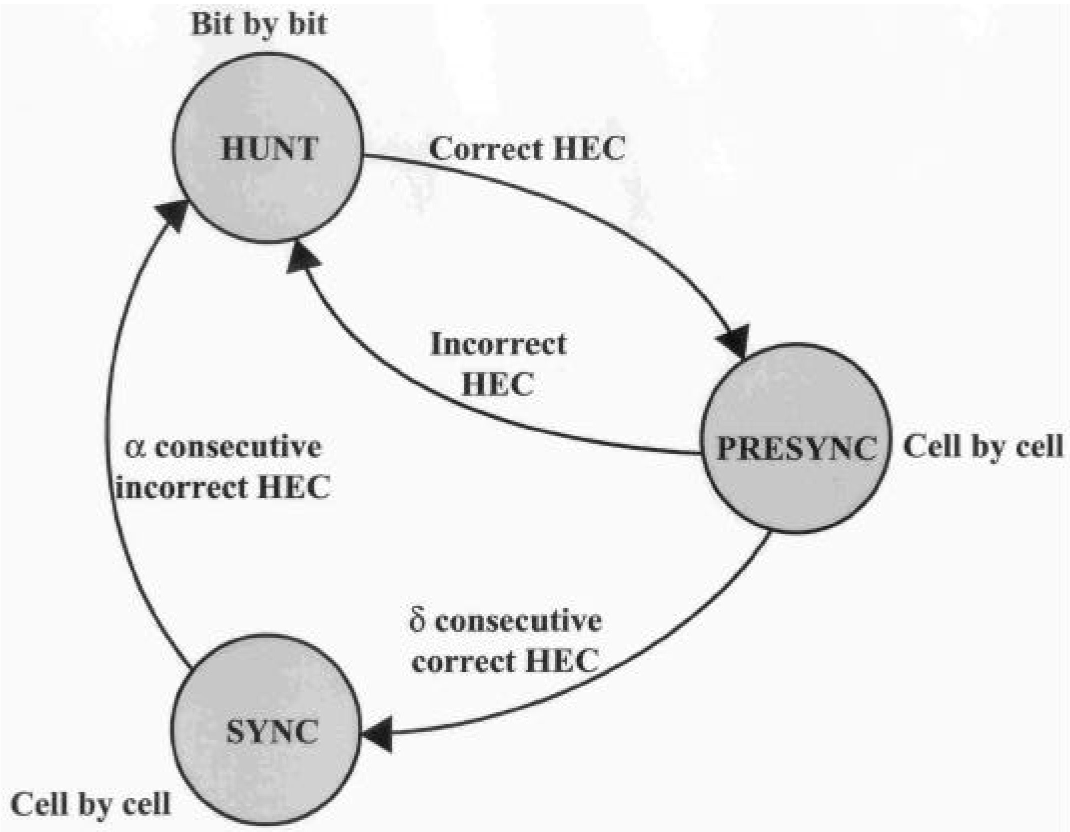


11.4 Transmission of ATM Cells

- I.413, defines two approaches for transmission of ATM cells at 155 Mbps
  - *a cell-based physical layer*
  - *an SDH-based physical layer*

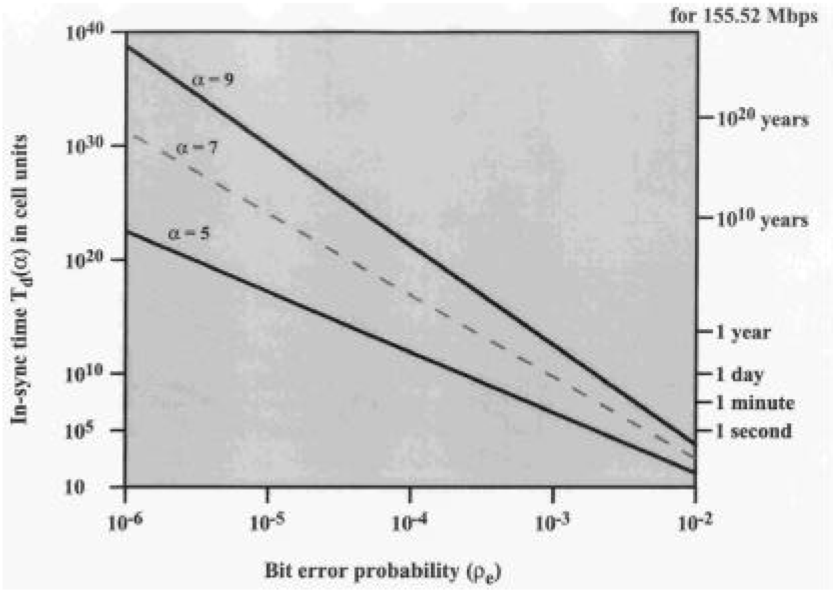
Cell-Based Physical Layer

- continuous steam of 53-byte cells interface structure with no external frame, thus synchronization is required using the HEC field
  - HUNT state: a cell delineation algorithm is performed bit-by-bit for determining the match between received HEC and calculated HEC
  - Then moves to the PRESYNC state
  - PRESYNC state: a call structure is assumed. Cell delineation algorithm is performed cell-by-cell for consecutively ***d*** times
  - SYNC state: the HEC is used for error detection and correction. If HEC coding is incorrect for ***a*** times, then delineation is lost

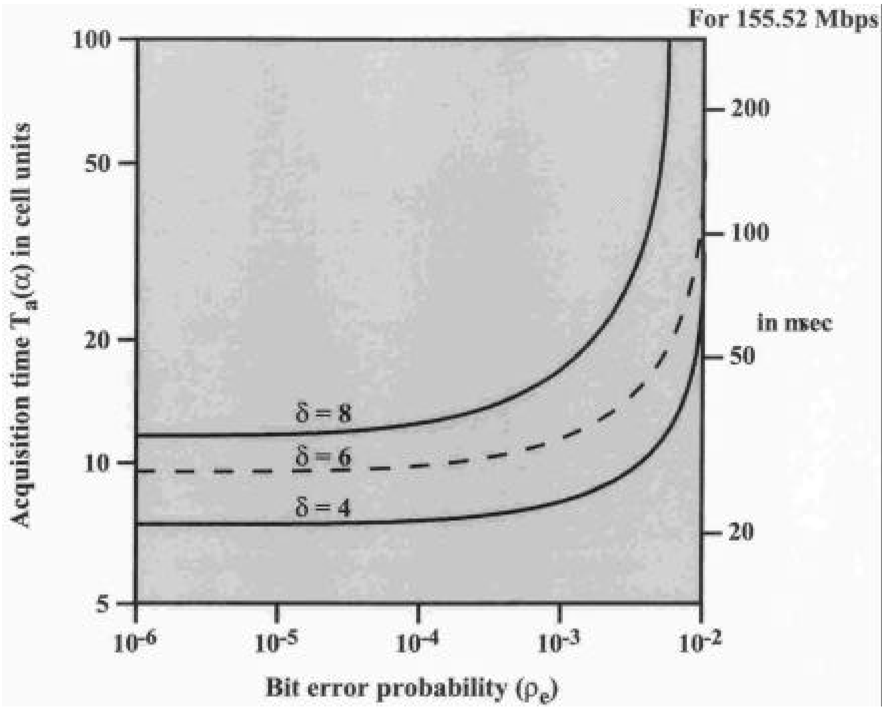


a and *d* are design parameters

- larger *d* results in longer delays in establishing synchronization
- larger *a* results in longer delay in recognizing a misalignment but in greater robustness against false misalignment



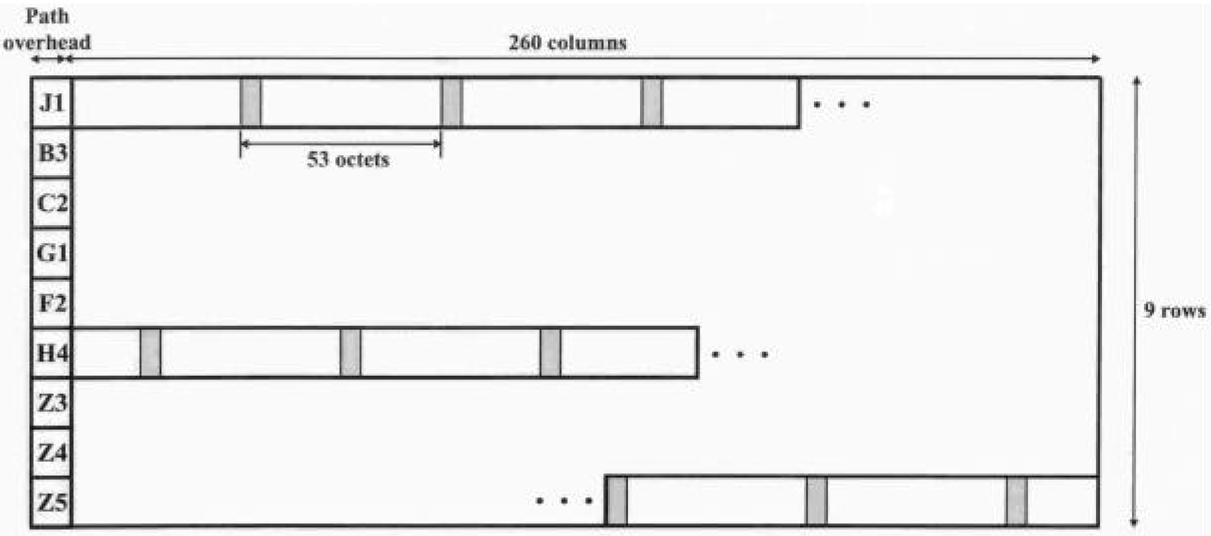
Impact of random bit error on cell-delineation performance (effect of *a*)



Acquisition time versus bit-error probability (effect of *d*)

SDH-Based Physical Layer

- cells can be carried over SONET/SDH with STM-1 frame imposed



- STM-1 payload consists of a 9-byte path overhead portion and ATM cells
- H4 octet is set at the sending side to indicate the next occurrence of a cell boundary (number of bytes in the first cell boundary following H4, 0-52)
- **Advantages of the SDL-based approach**
  - can carry either ATM-based or STM-based payload (using fiber-based transmission infrastructure for a variety of circuit-switched dedicated applications)
  - more efficient for circuit-switched applications such as CBR video traffic than ATM switching
  - combining several ATM streams to build interfaces with higher bit rates than those supported by the ATM layer at a particular site
    - e.g., combination of four separate 155 Mbps ATM streams (STM-1) into a 622 Mbps (STM-4) interface (maybe more cost effective than a single 622-Mbps ATM stream)

11.5 ATM Adaptation Layer

- An adaptation layer in needed to support information transfer protocols not based on ATM such as
  - **PCM**: it is necessary to assemble PCM bits into cells for transmission and to read them out on reception
  - **LAPF**: to map LAPF frames of a frame relay network connected to an ATM network into ATM cells

AAL Services (ITU-T I.362)

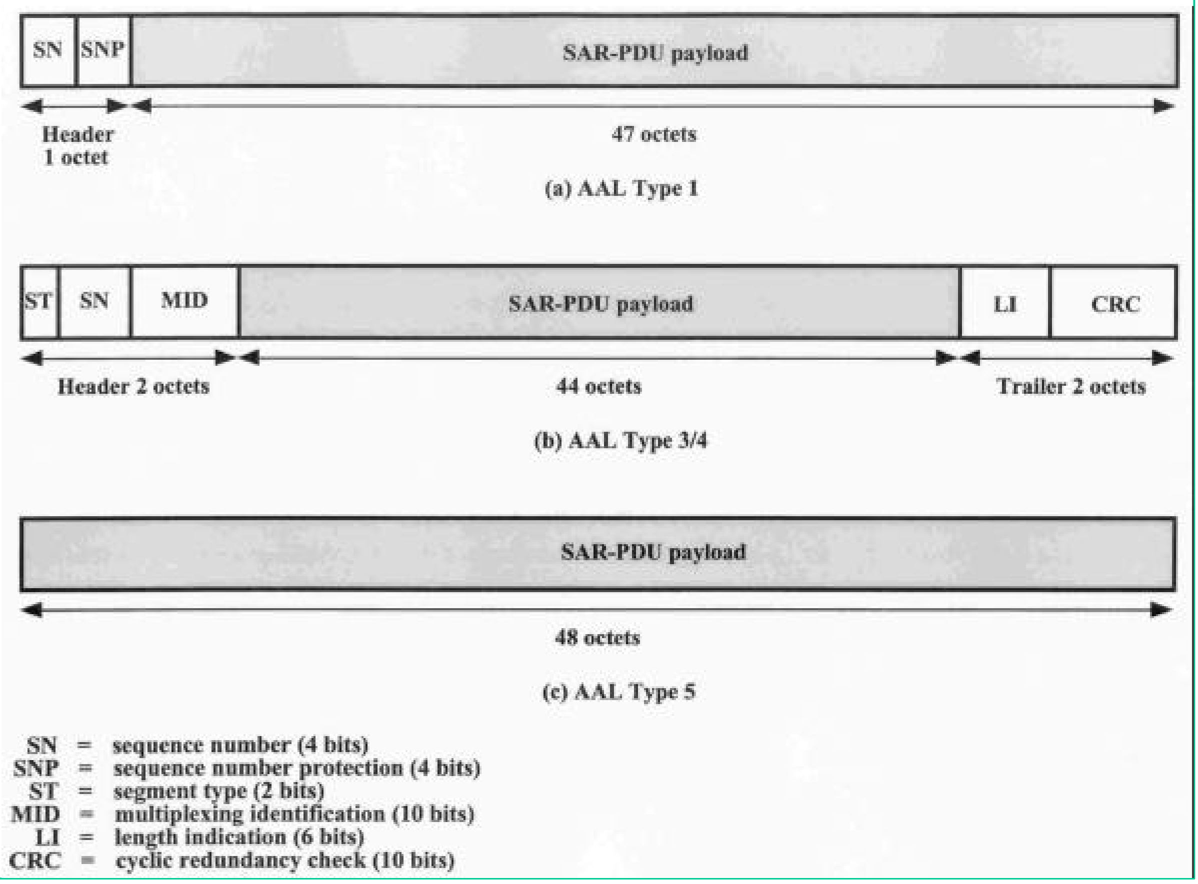
- handling of transmission errors
- segmentation and reassembly, to enable larger blocks of data to be carried in the information field of ATM cells
- handling of lost and misinserted cells conditions
- flow control and timing control

	Class A	Class B	Class C	Class D
Timing relation between souce and destination	Required		Not required	
Bit rate	Constant	Variable		
Connection mode	Connection-oriented			Connectionless
AAL Protocol	Type 1	Type 2	Type 3/4,Type 5	Type 3/4

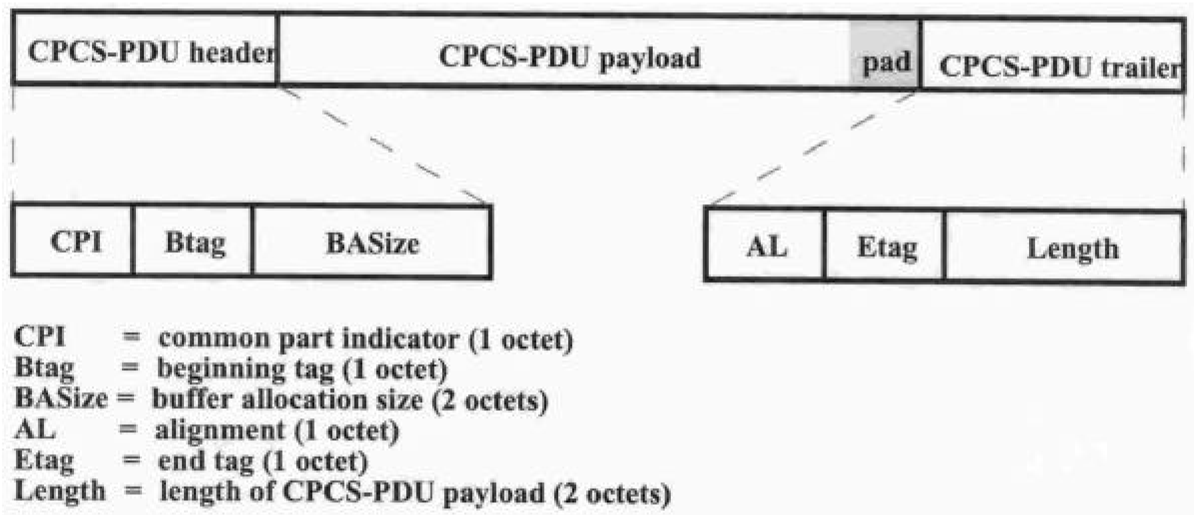
- classification of services is based on
  - whether timing relationship must be maintained between source and destination
  - whether application requires a constant bit rate
  - whether the transfer is connection-oriented or connectionless

AAL Protocols

- organizing the AAL into two logical sublayers
  - **Convergence Sublayer (CS)**
    - provides functions needed to support specific applications using AAL
    - each AAL user attaches to AAL at a service access point (SAP)
    - SAP is simply the address of the application
    - CS is service dependent
  - **Segmentation and Reassembly Sublayer (SAR)**
    - responsible for packaging information received from CS into cells, and
    - unpacking the information at the receiving end
    - total SAR headers and trailersplus CS information is 48 bytes
- Originally ITU-T had one protocol type for each class
  - recently types 3 and 4 merged into a Type 3/4, and a new type 5
  - see below for PDU formats at SAR level except for Type 2 (to be defined)

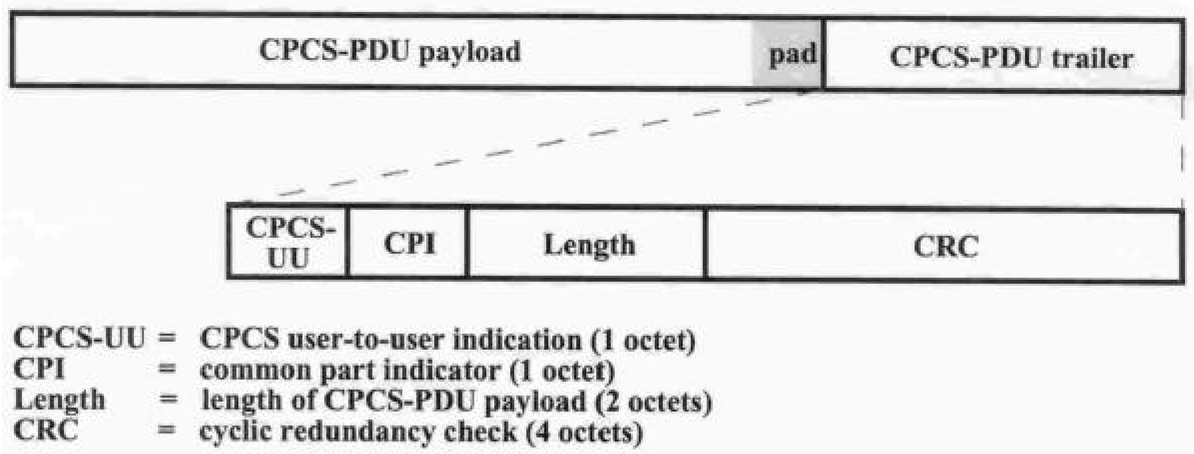


- AAL Type 5 is more popular especially in ATM LAN applications
  - to reduce protocol-processing overhead
  - to reduce transmission overhead
  - to ensure adaptability to existing transport protocols
- A block of data from a higher layer is encapsulated into a protocol data unit (PDU) at the CS sublayer (referred to as the *common-part convergence sublayer*-CPCS)

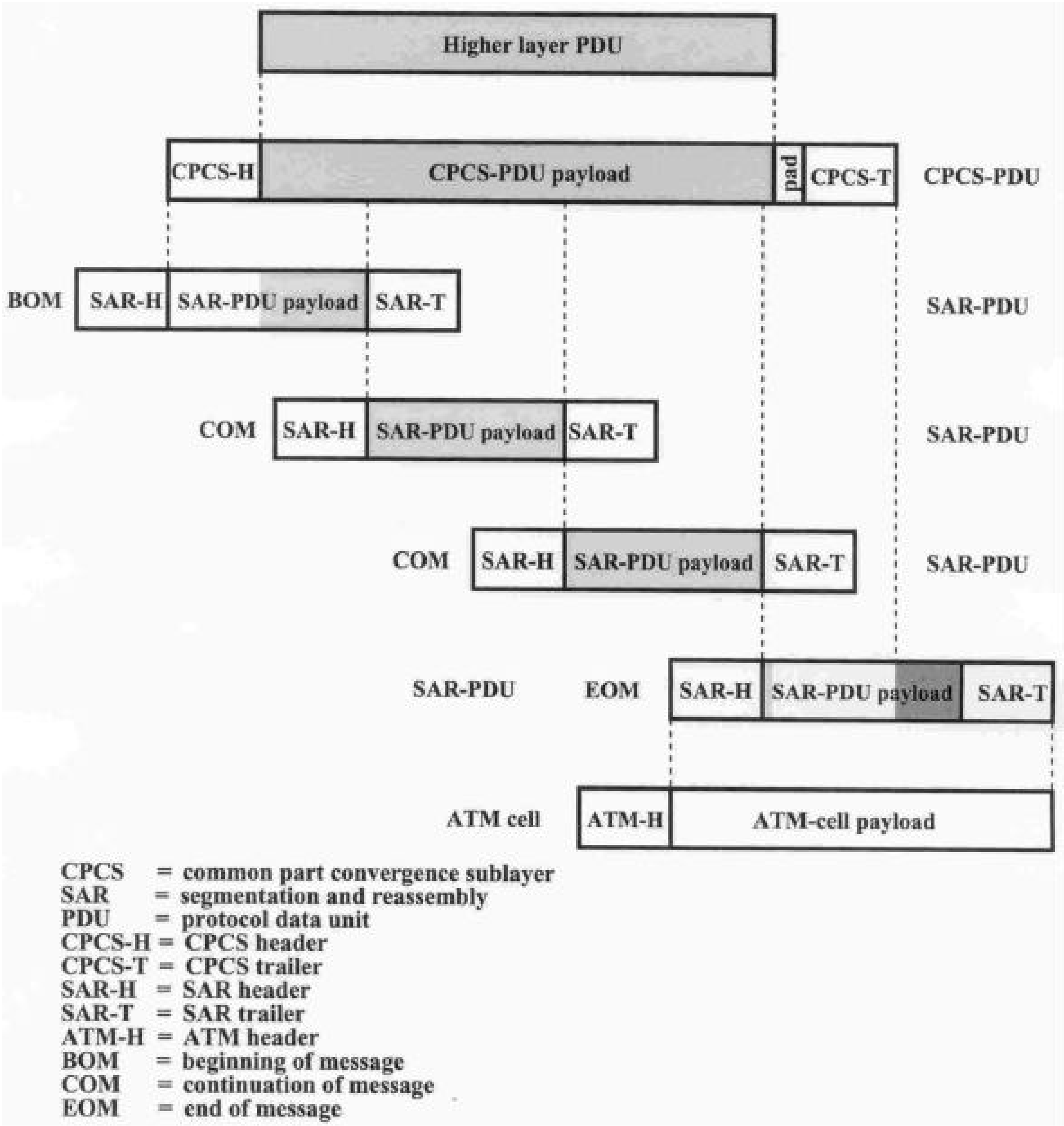


(a) AAL Type 3/4

(b) AAL Type 5



<u>AAL Type 3/4 and Type 5 CSPS PDU</u>



Example of AAL Type 3/4 transmission