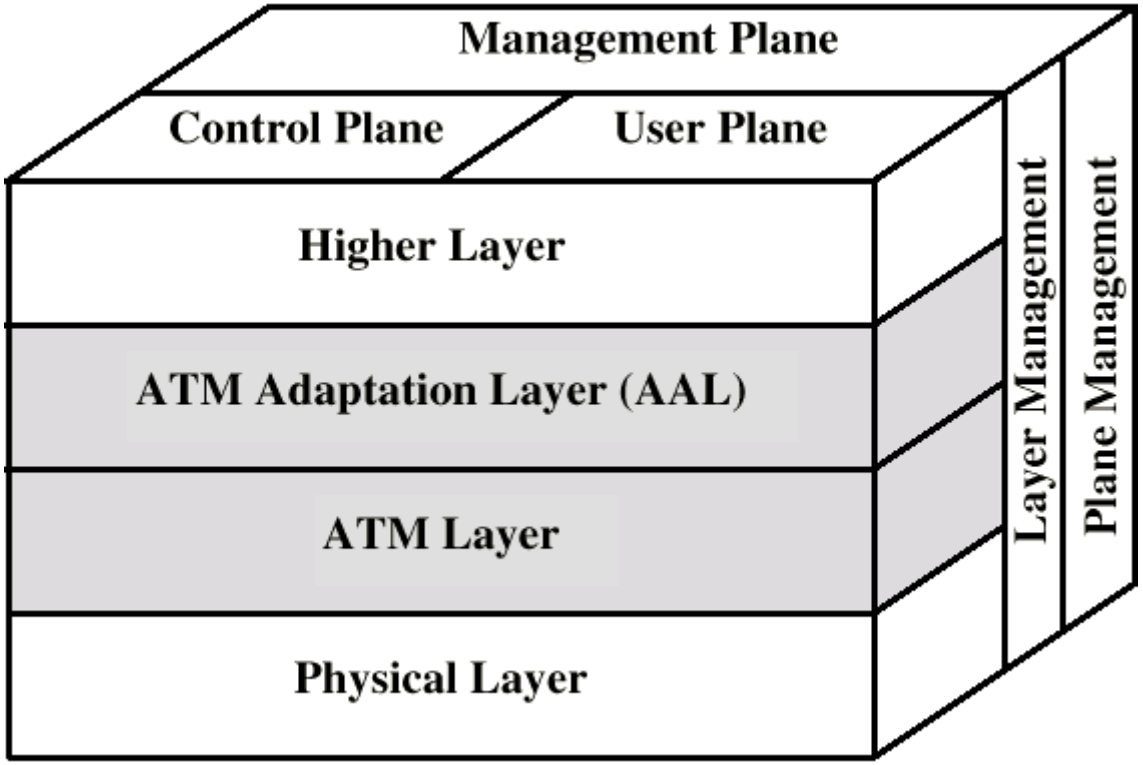
William Stallings
Data and Computer Communications

Chapter 11
Asynchronous Transfer Mode and Frame Relay

Protocol Architecture

- Similarities between ATM and packet switching
  - Transfer of data in discrete chunks
  - Multiple logical connections over single physical interface
- In ATM flow on each logical connection is in fixed sized packets called cells
- Minimal error and flow control
  - Reduced overhead
- Data rates (physical layer) 25.6Mbps to 622.08Mbps

Protocol Architecture (diag)



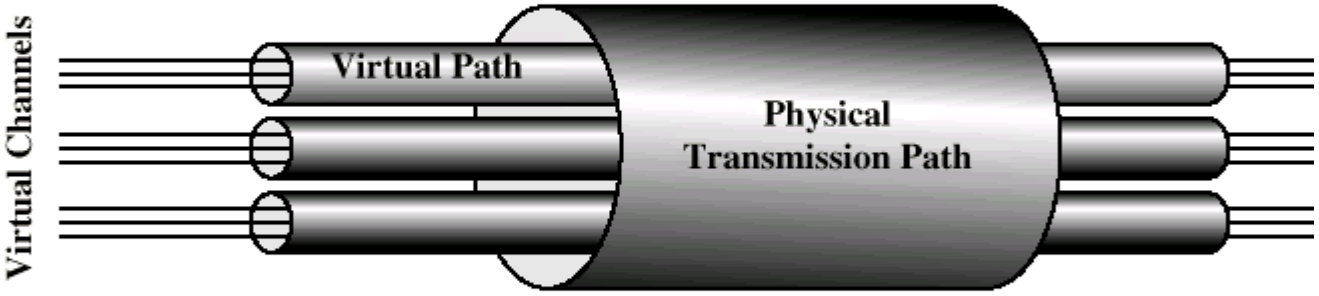
Reference Model Planes

- User plane
  - Provides for user information transfer
- Control plane
  - Call and connection control
- Management plane
  - Plane management
    - whole system functions
  - Layer management
    - Resources and parameters in protocol entities

ATM Logical Connections

- Virtual channel connections (VCC)
- Analogous to virtual circuit in X.25
- Basic unit of switching
- Between two end users
- Full duplex
- Fixed size cells
- Data, user-network exchange (control) and network-network exchange (network management and routing)
- Virtual path connection (VPC)
  - Bundle of VCC with same end points

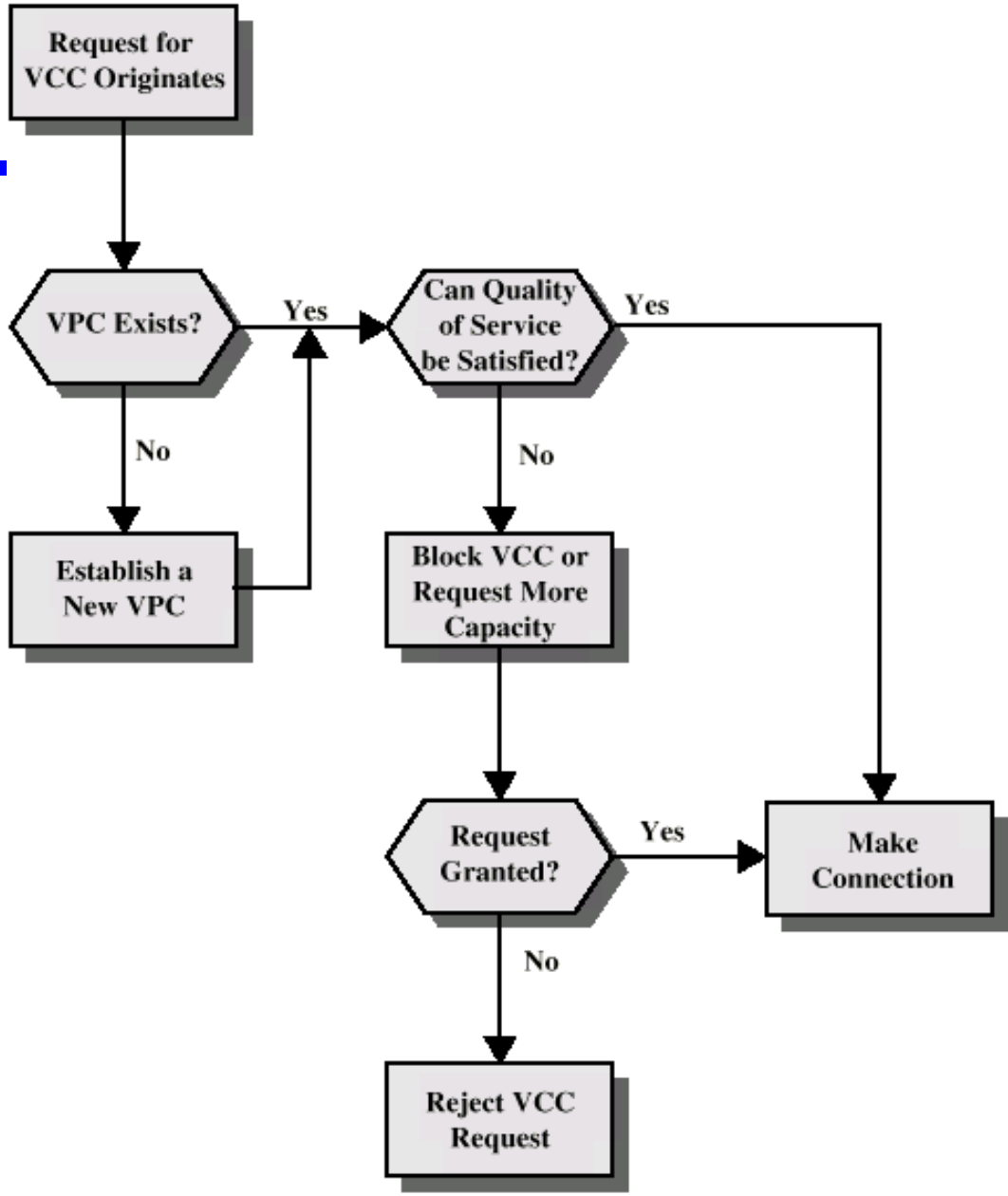
ATM Connection Relationships



Advantages of Virtual Paths

- Simplified network architecture
- Increased network performance and reliability
- Reduced processing
- Short connection setup time
- Enhanced network services

Call Establishment Using VPs



Virtual Channel Connection Uses

- Between end users
  - End to end user data
  - Control signals
  - VPC provides overall capacity
    - VCC organization done by users
- Between end user and network
  - Control signaling
- Between network entities
  - Network traffic management
  - Routing

VP/VC Characteristics

- Quality of service
- Switched and semi-permanent channel connections
- Call sequence integrity
- Traffic parameter negotiation and usage monitoring

- VPC only
  - Virtual channel identifier restriction within VPC

Control Signaling - VCC

- Done on separate connection
- Semi-permanent VCC
- Meta-signaling channel
  - Used as permanent control signal channel
- User to network signaling virtual channel
  - For control signaling
  - Used to set up VCCs to carry user data
- User to user signaling virtual channel
  - Within pre-established VPC
  - Used by two end users without network intervention to establish and release user to user VCC

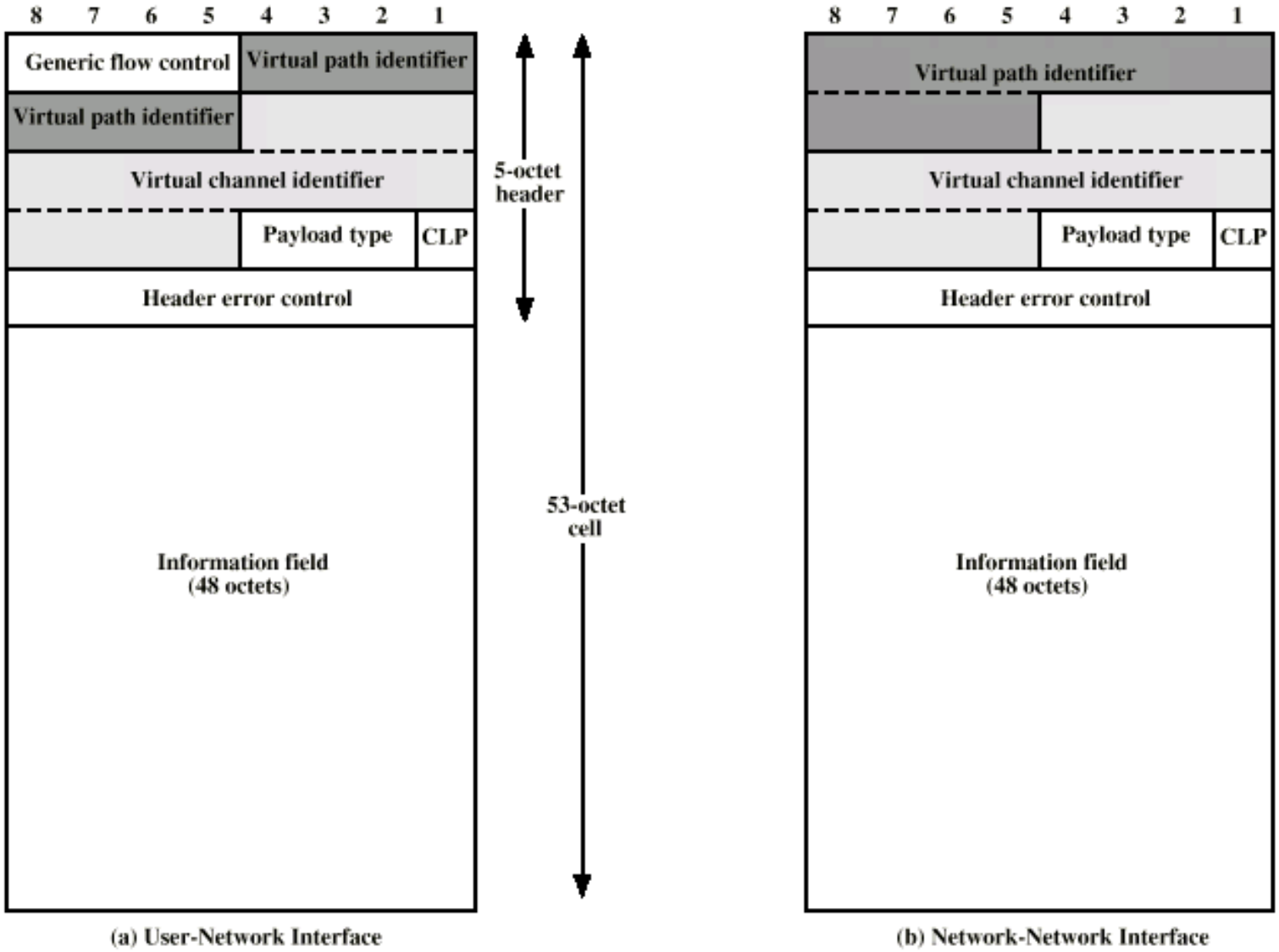
Control Signaling - VPC

- Semi-permanent
- Customer controlled
- Network controlled

ATM Cells

- Fixed size
- 5 octet header
- 48 octet information field
- Small cells reduce queuing delay for high priority cells
- Small cells can be switched more efficiently
- Easier to implement switching of small cells in hardware

ATM Cell Format



Header Format

- Generic flow control
  - Only at user to network interface
  - Controls flow only at this point
- Virtual path identifier
- Virtual channel identifier
- Payload type
  - e.g. user info or network management
- Cell loss priority
- Header error control

Generic Flow Control (GFC)

- Control traffic flow at user to network interface (UNI) to alleviate short term overload
- Two sets of procedures
  - Uncontrolled transmission
  - Controlled transmission
- Every connection either subject to flow control or not
- Subject to flow control
  - May be one group (A) default
  - May be two groups (A and B)
- Flow control is from subscriber to network
  - Controlled by network side

Single Group of Connections (1)

- Terminal equipment (TE) initializes two variables
  - TRANSMIT flag to 1
  - GO_CNTR (credit counter) to 0
- If TRANSMIT=1 cells on uncontrolled connection may be sent any time
- If TRANSMIT=0 no cells may be sent (on controlled or uncontrolled connections)
- If HALT received, TRANSMIT set to 0 and remains until NO_HALT

Single Group of Connections (2)

- If TRANSMIT=1 and no cell to transmit on any uncontrolled connection:
  - If GO_CNTR>0, TE may send cell on controlled connection
    - Cell marked as being on controlled connection
    - GO_CNTR decremented
  - If GO_CNTR=0, TE may not send on controlled connection
- TE sets GO_CNTR to GO_VALUE upon receiving SET signal
  - Null signal has no effect

Use of HALT

- To limit effective data rate on ATM
- Should be cyclic
- To reduce data rate by half, HALT issued to be in effect 50% of time
- Done on regular pattern over lifetime of connection

Two Queue Model

- Two counters
  - GO_CNTR_A, GO_VALUE_A,GO_CNTR_B, GO_VALUE_B

Header Error Control

- 8 bit error control field
- Calculated on remaining 32 bits of header
- Allows some error correction

HEC Operation at Receiver

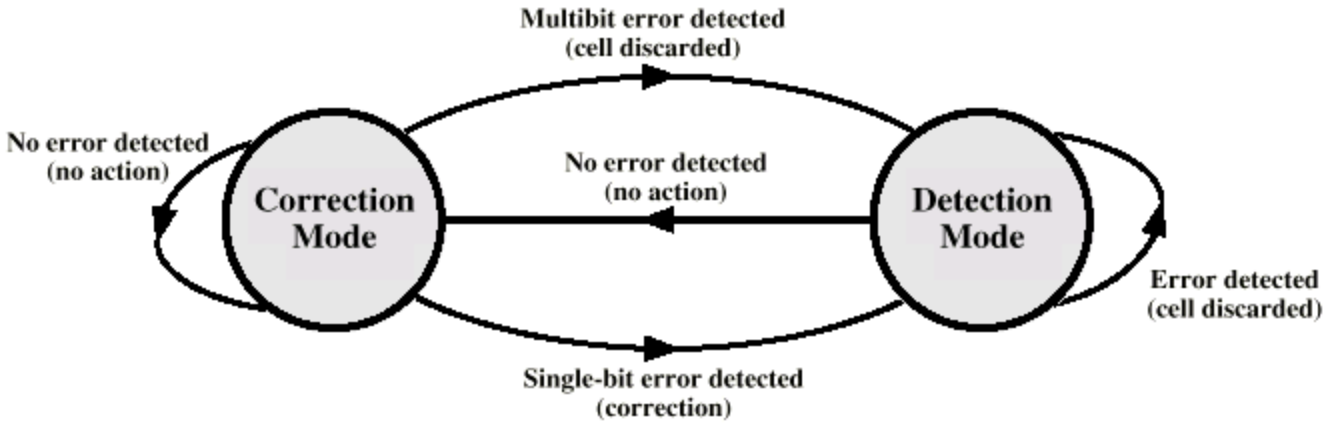
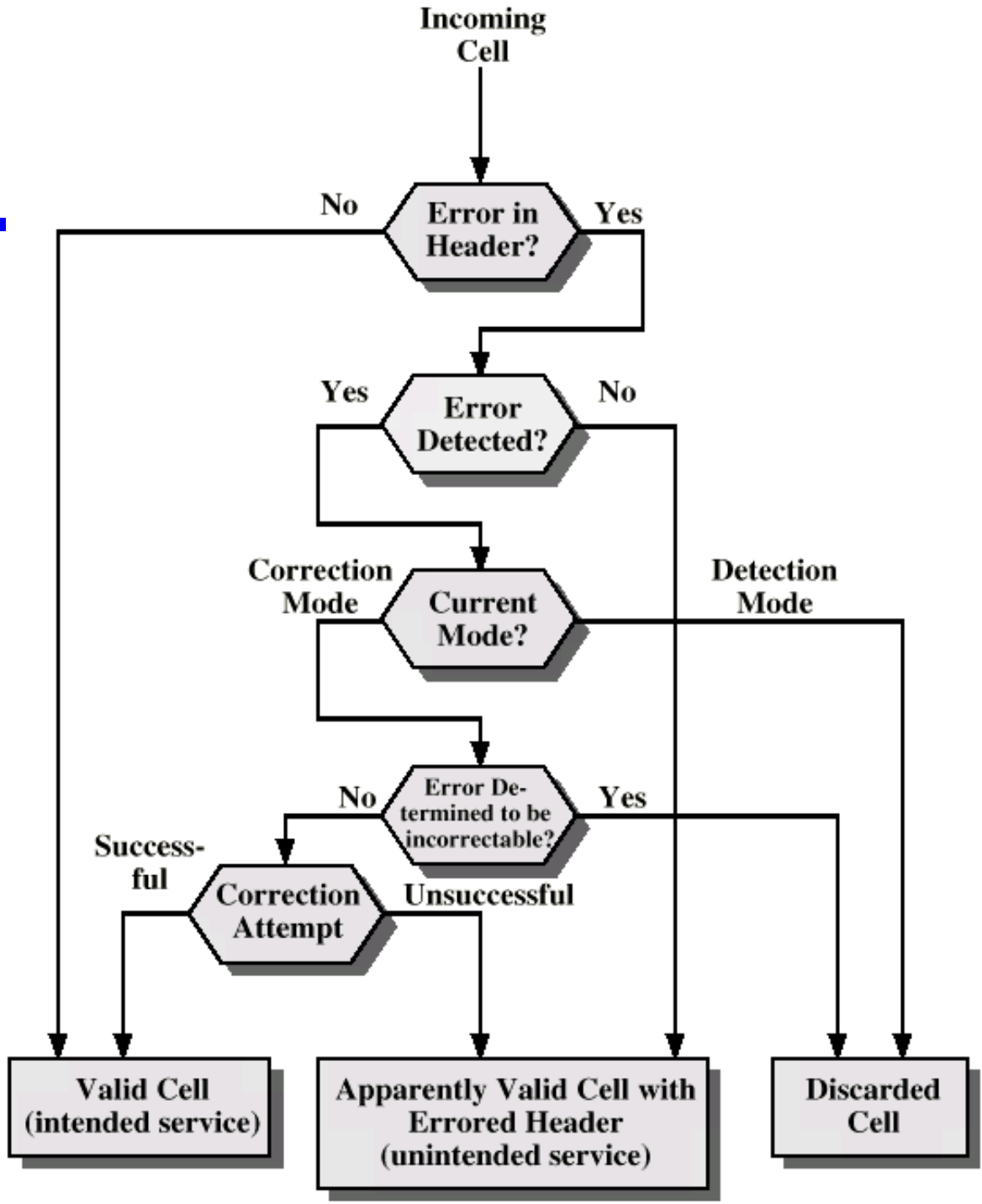
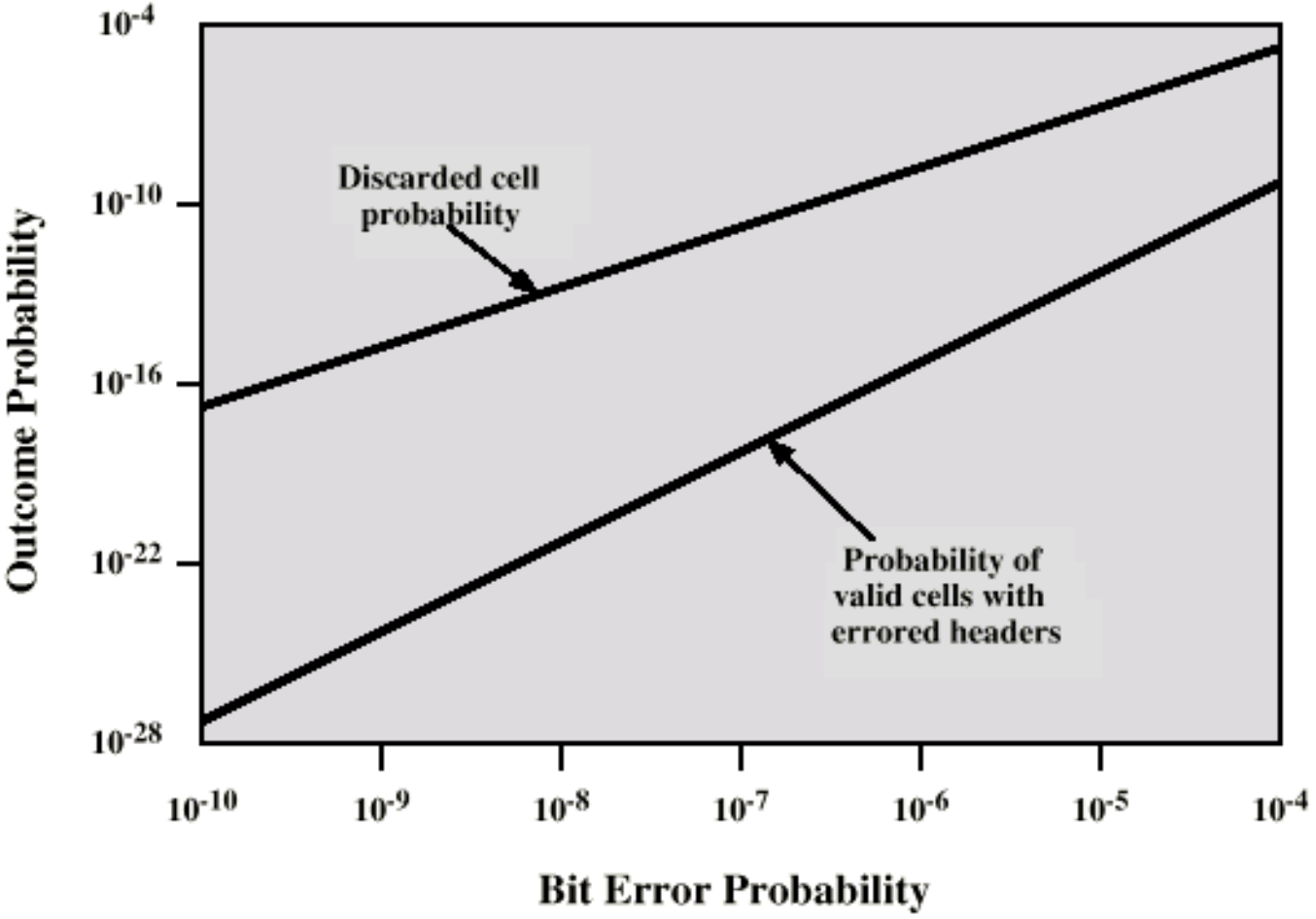


Figure 11.5 HEC Operation at Receiver

Effect of Error in Cell Header



Impact of Random Bit Errors



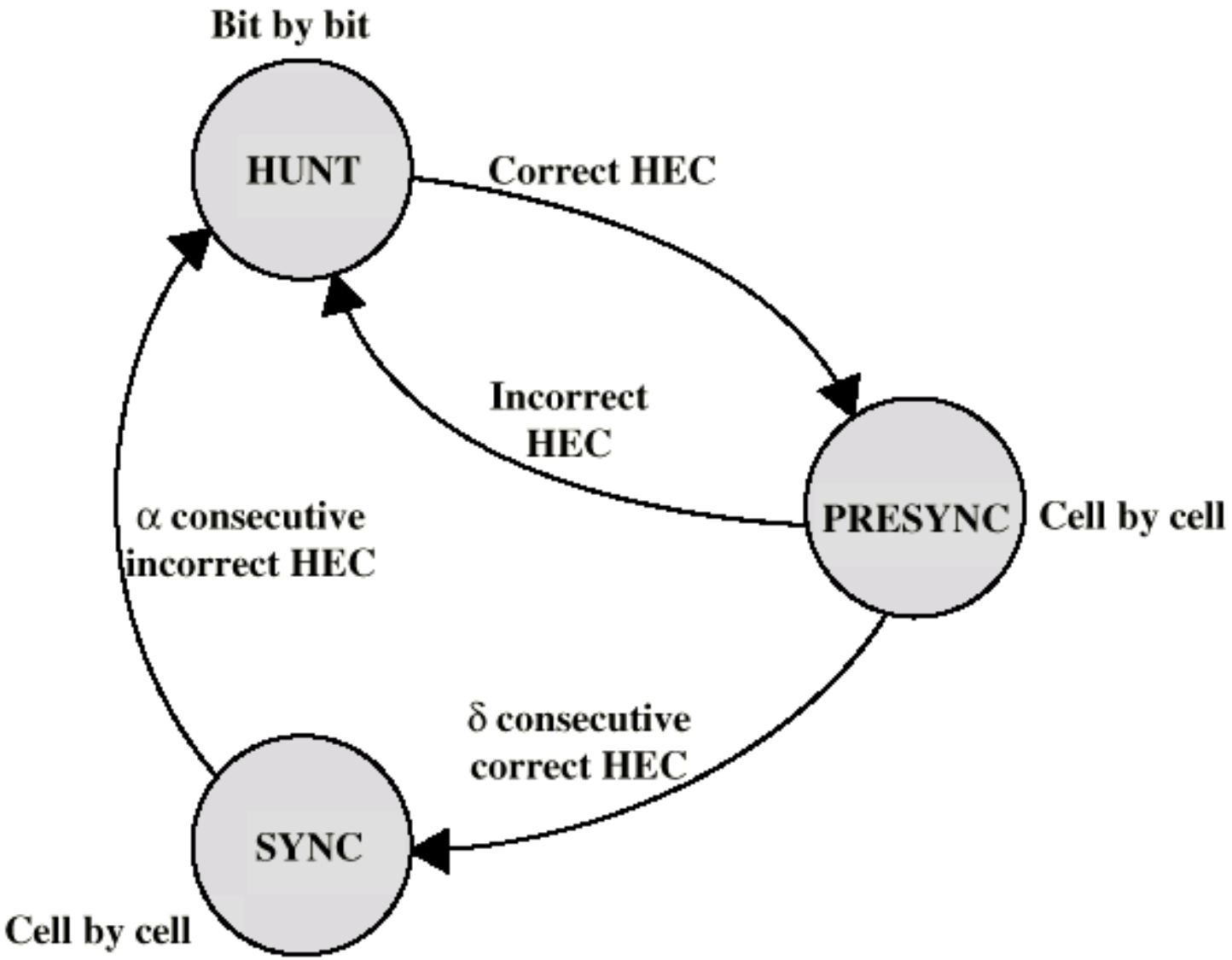
Transmission of ATM Cells

- 622.08Mbps
- 155.52Mbps
- 51.84Mbps
- 25.6Mbps
- Cell Based physical layer
- SDH based physical layer

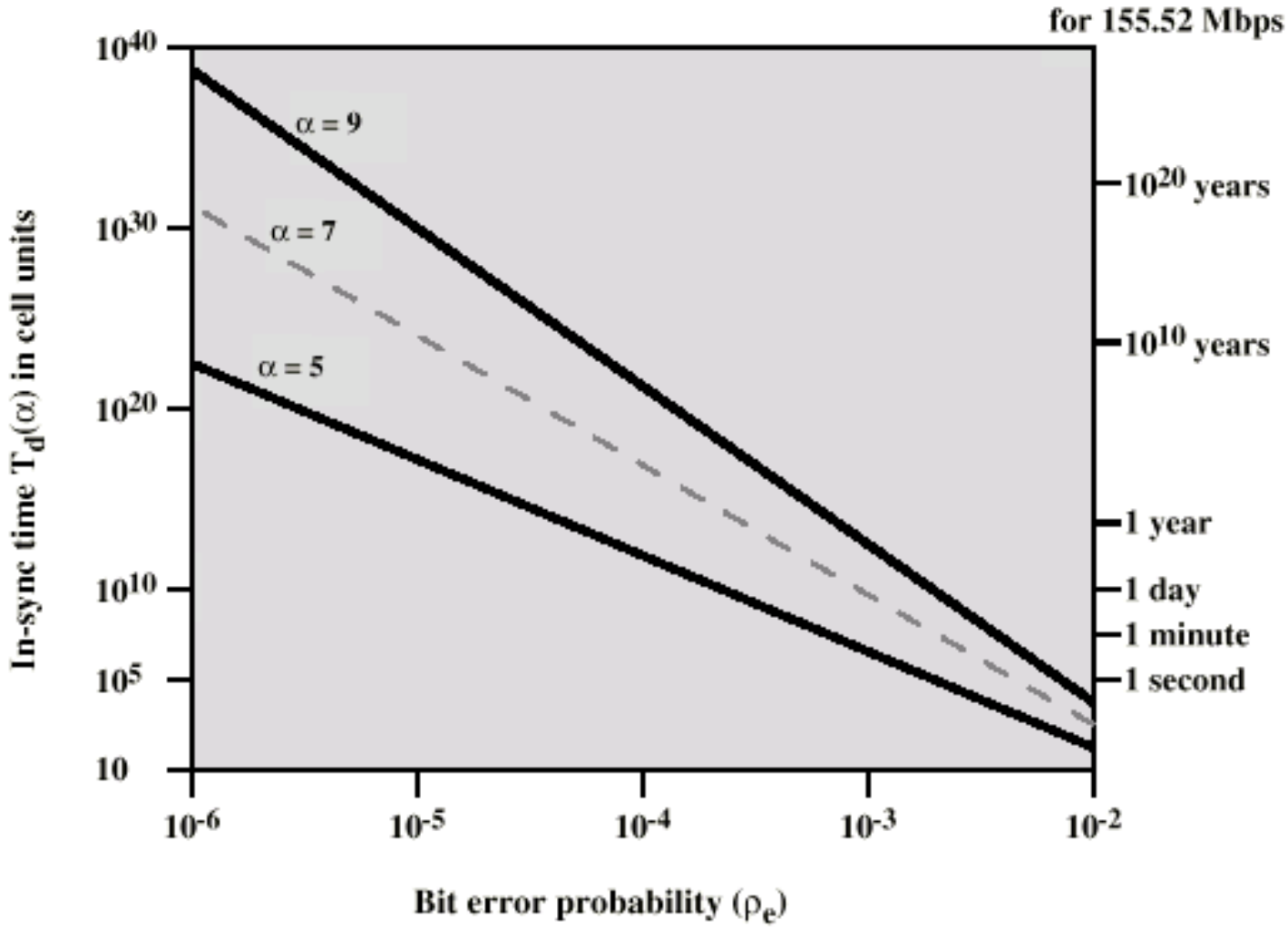
Cell Based Physical Layer

- No framing imposed
- Continuous stream of 53 octet cells
- Cell delineation based on header error control field

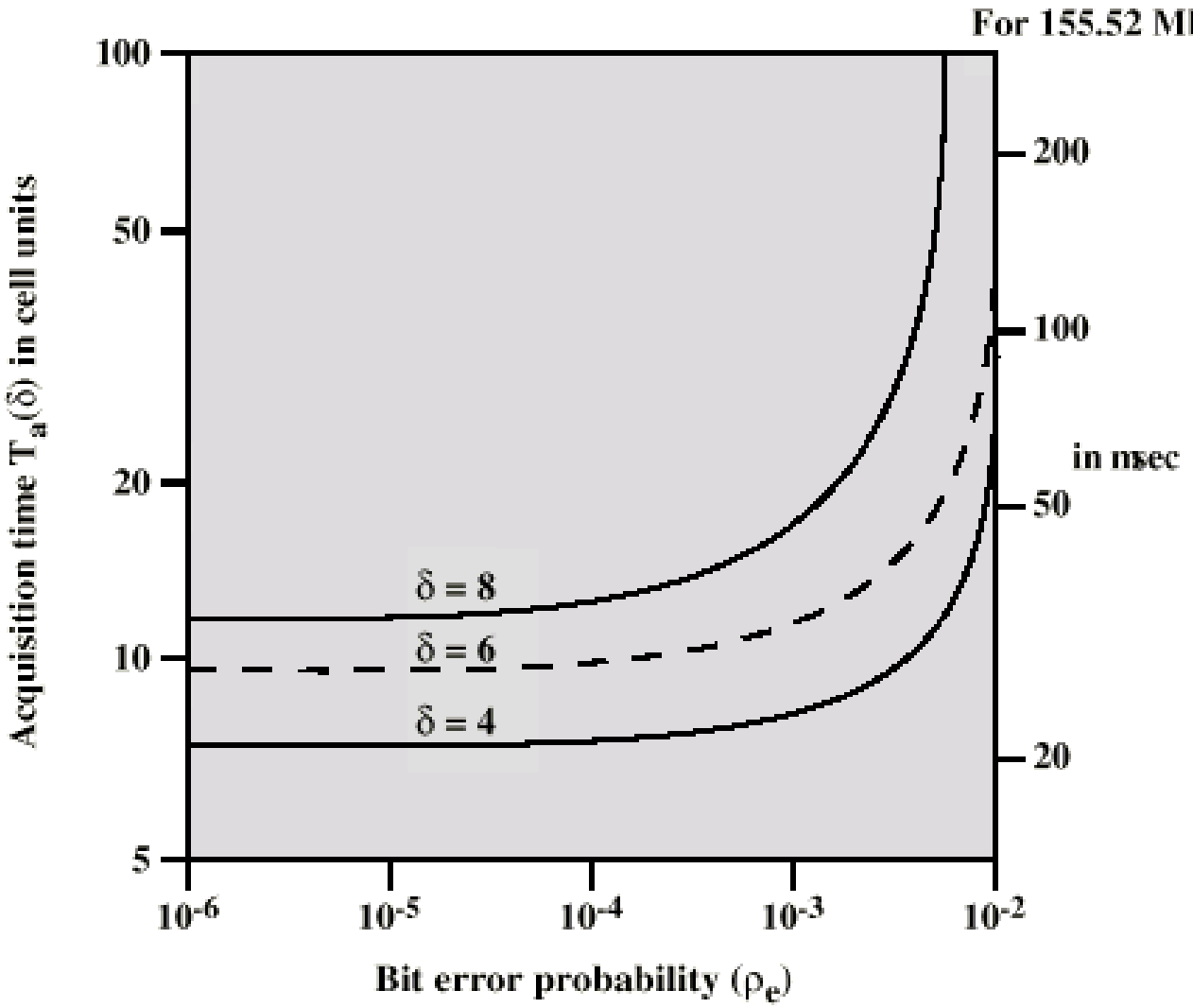
Cell Delineation State Diagram



Impact of Random Bit Errors on Cell Delineation Performance



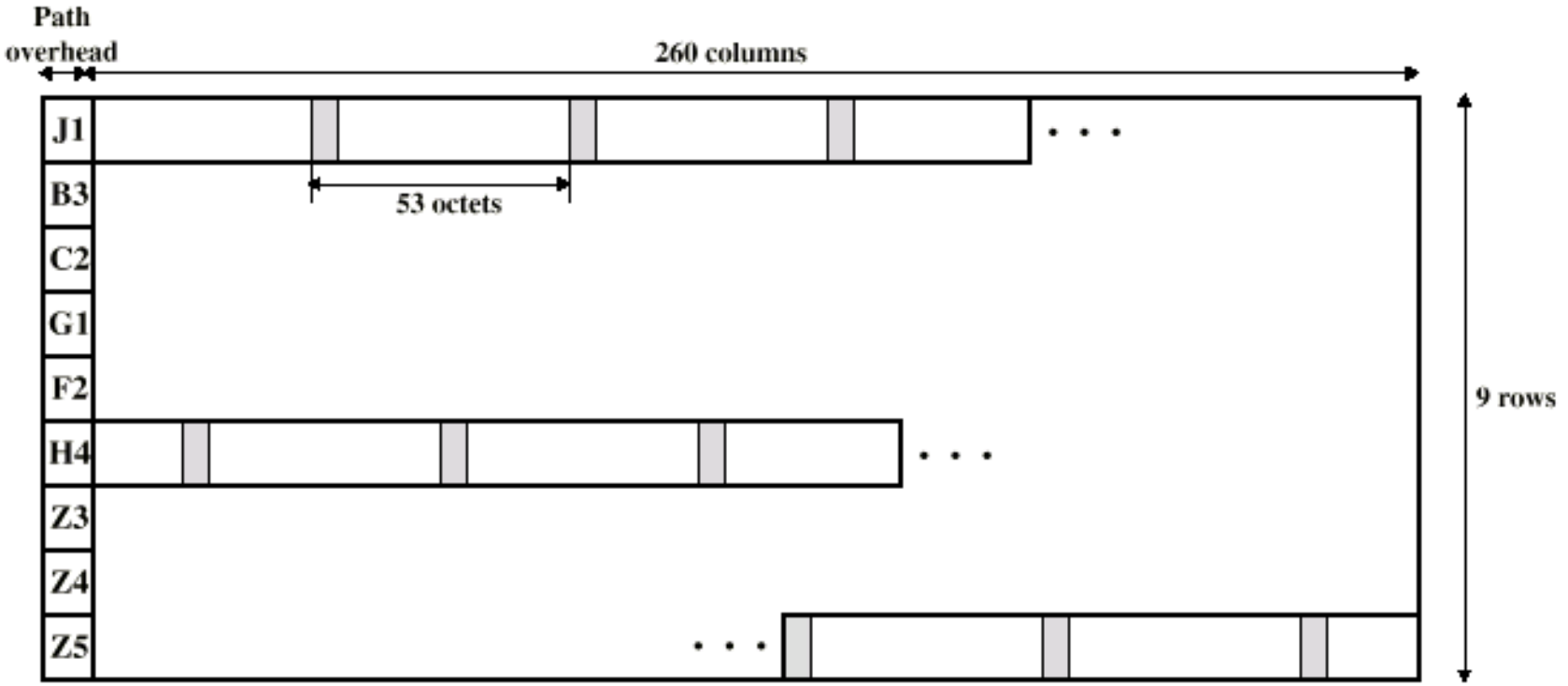
Acquisition Time v Bit Error Rate



SDH Based Physical Layer

- Imposes structure on ATM stream
- e.g. for 155.52Mbps
- Use STM-1 (STS-3) frame
- Can carry ATM and STM payloads
- Specific connections can be circuit switched using SDH channel
- SDH multiplexing techniques can combine several ATM streams

STM-1 Payload for SDH-Based ATM Cell Transmission



ATM Service Categories

- Real time
  - Constant bit rate (CBR)
  - Real time variable bit rate (rt-VBR)
- Non-real time
  - Non-real time variable bit rate (nrt-VBR)
  - Available bit rate (ABR)
  - Unspecified bit rate (UBR)

Real Time Services

- Amount of delay
- Variation of delay (jitter)

CBR

- Fixed data rate continuously available
- Tight upper bound on delay
- Uncompressed audio and video
  - Video conferencing
  - Interactive audio
  - A/V distribution and retrieval

rt-VBR

- Time sensitive application
  - Tightly constrained delay and delay variation
- rt-VBR applications transmit at a rate that varies with time
- e.g. compressed video
  - Produces varying sized image frames
  - Original (uncompressed) frame rate constant
  - So compressed data rate varies
- Can statistically multiplex connections

nrt-VBR

- May be able to characterize expected traffic flow
- Improve QoS in loss and delay
- End system specifies:
  - Peak cell rate
  - Sustainable or average rate
  - Measure of how bursty traffic is
- e.g. Airline reservations, banking transactions

UBR

- May be additional capacity over and above that used by CBR and VBR traffic
  - Not all resources dedicated
  - Bursty nature of VBR
- For application that can tolerate some cell loss or variable delays
  - e.g. TCP based traffic
- Cells forwarded on FIFO basis
- Best efforts service

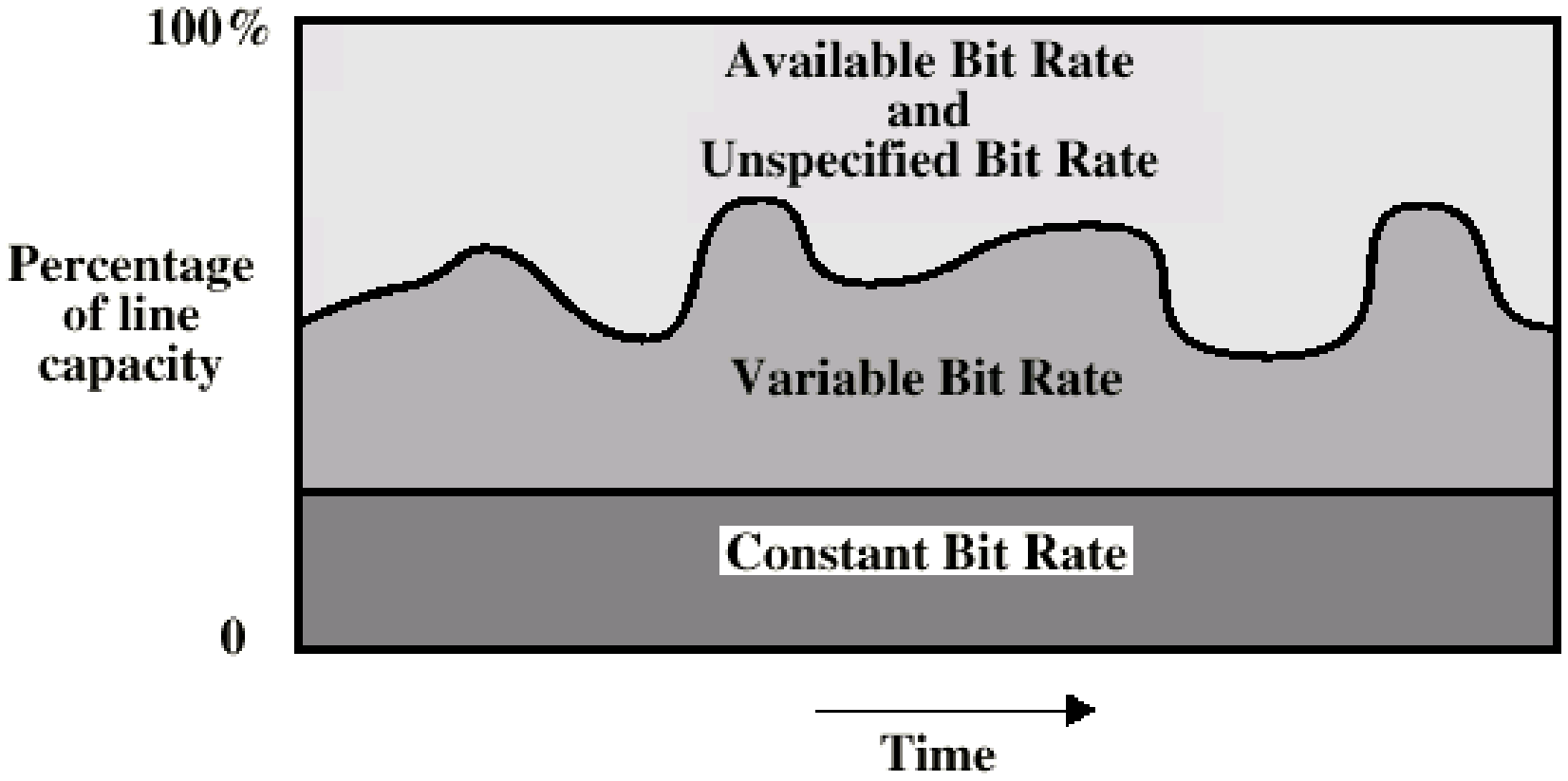
ABR

- Application specifies peak cell rate (PCR) and minimum cell rate (MCR)
- Resources allocated to give at least MCR
- Spare capacity shared among all ARB sources
- e.g. LAN interconnection

ATM Adaptation Layer

- Support for information transfer protocol not based on ATM
- PCM (voice)
  - Assemble bits into cells
  - Re-assemble into constant flow
- IP
  - Map IP packets onto ATM cells
  - Fragment IP packets
  - Use LAPF over ATM to retain all IP infrastructure

ATM Bit Rate Services



Adaptation Layer Services

- Handle transmission errors
- Segmentation and re-assembly
- Handle lost and misinserted cells
- Flow control and timing

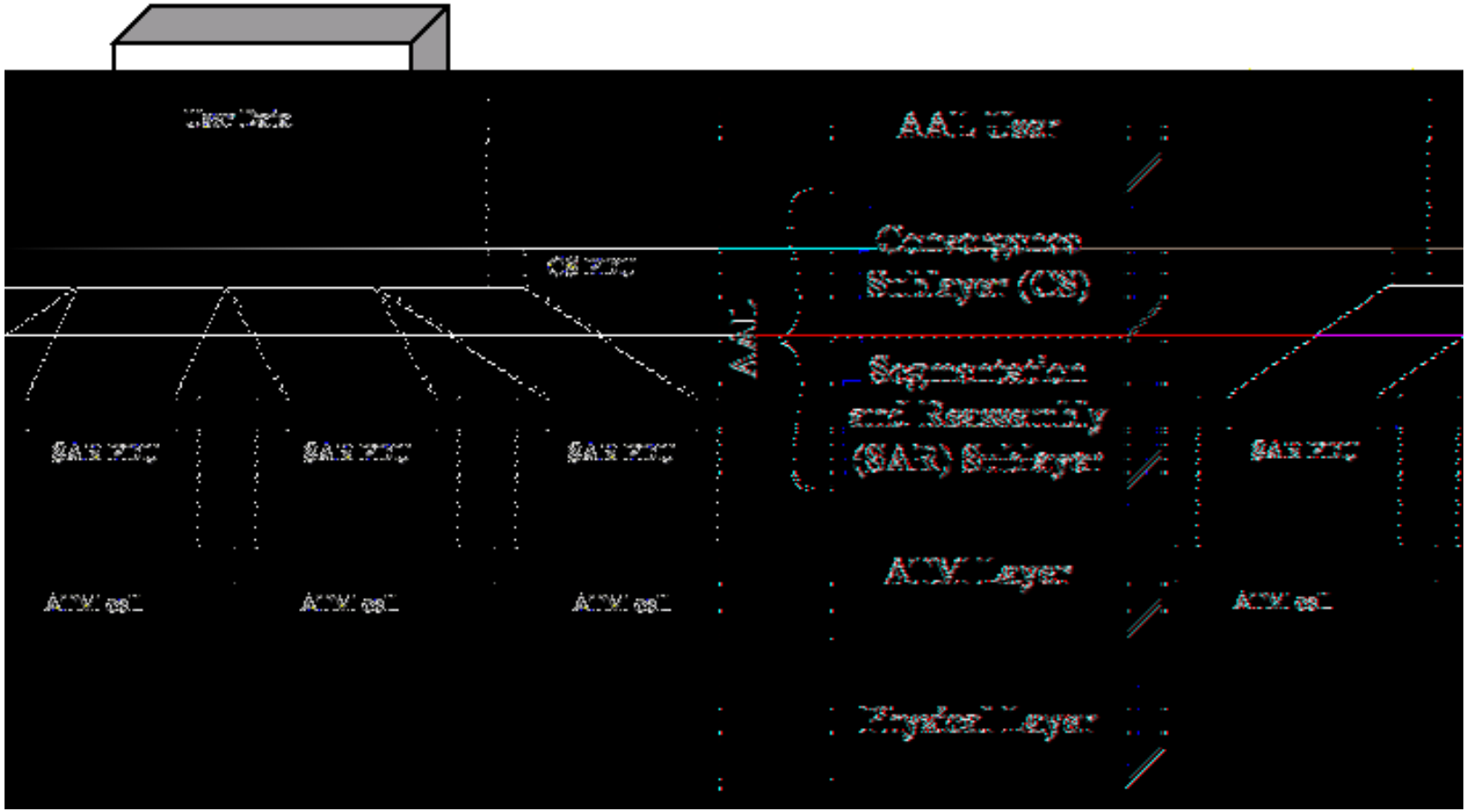
Supported Application types

- Circuit emulation
- VBR voice and video
- General data service
- IP over ATM
- Multiprotocol encapsulation over ATM (MPOA)
  - IPX, AppleTalk, DECNET)
- LAN emulation

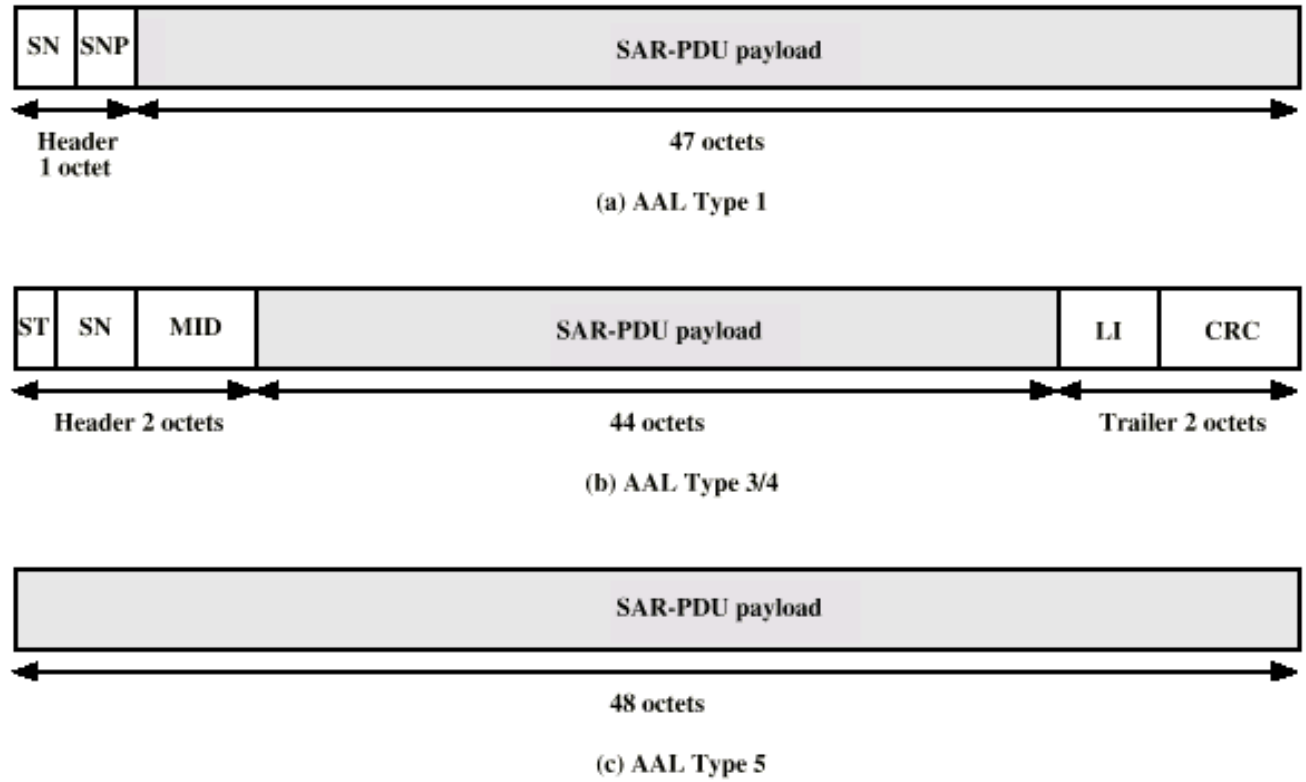
AAL Protocols

- Convergence sublayer (CS)
  - Support for specific applications
  - AAL user attaches at SAP
- Segmentation and re-assembly sublayer (SAR)
  - Packages and unpacks info received from CS into cells
- Four types
  - Type 1
  - Type 2
  - Type 3/4
  - Type 5

AAL Protocols



Segmentation and Reassembly PDU



SN = sequence number (4 bits)
SNP = sequence number protection (4 bits)
ST = segment type (2 bits)
MID = multiplexing identification (10 bits)
LI = length indication (6 bits)
CRC = cyclic redundancy check (10 bits)

AAL Type 1

- CBR source
- SAR packs and unpacks bits
- Block accompanied by sequence number

AAL Type 2

- VBR
- Analog applications

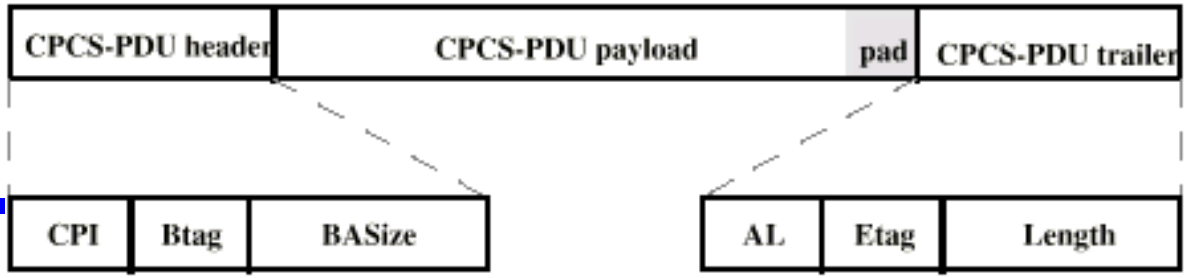
AAL Type 3/4

- Connectionless or connected
- Message mode or stream mode

AAL Type 5

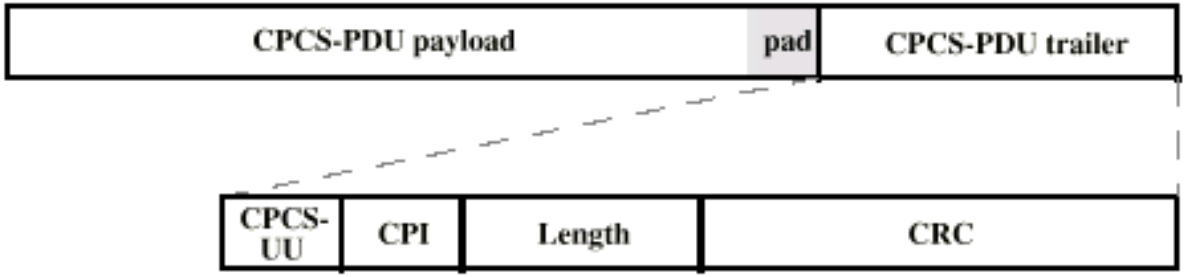
- Streamlined transport for connection oriented higher layer protocols

CPCS PDUs



CPI = common part indicator (1 octet)
Btag = beginning tag (1 octet)
BASize = buffer allocation size (2 octets)
AL = alignment (1 octet)
Etag = end tag (1 octet)
Length = length of CPCS-PDU payload (2 octets)

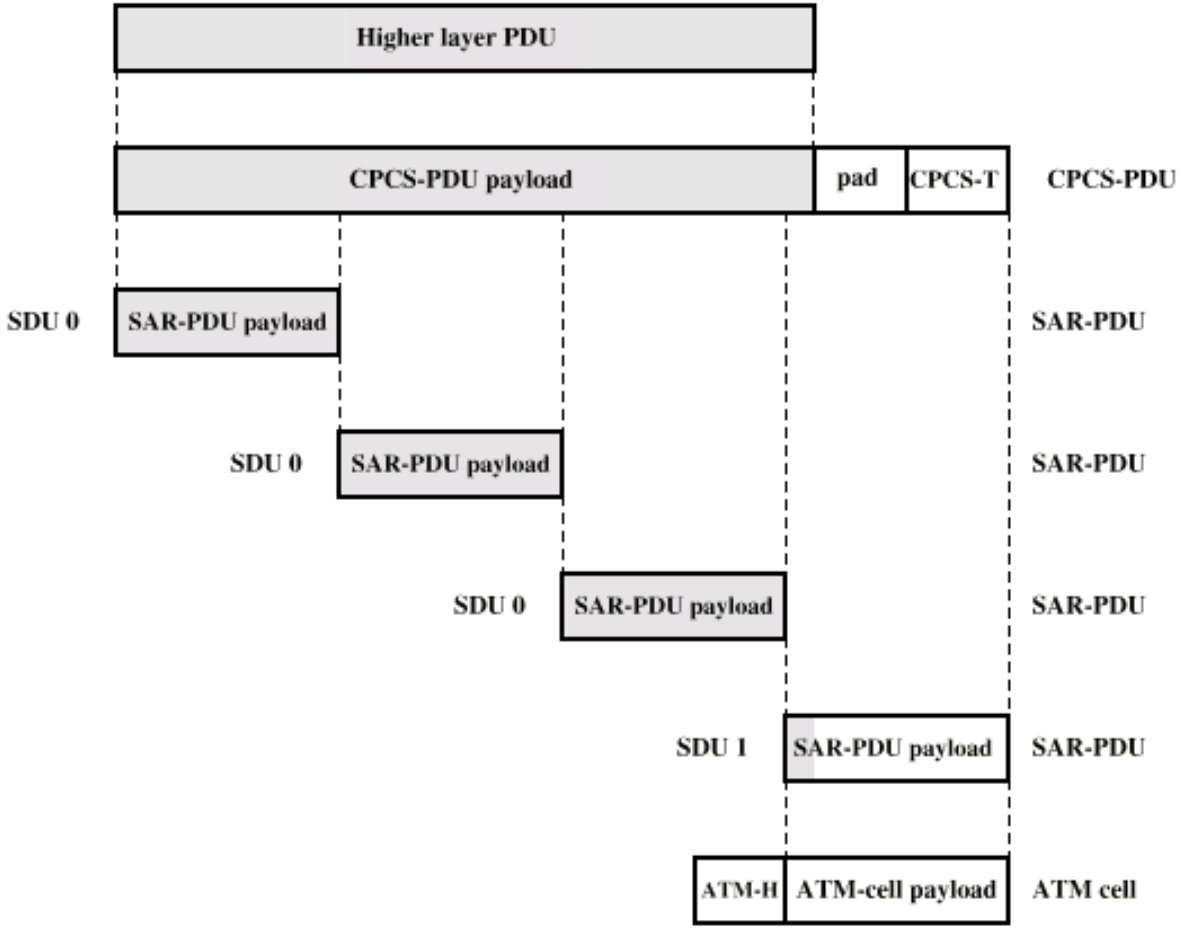
(a) AAL Type 3/4



CPCS-UU = CPCS user-to-user indication (1 octet)
CPI = common part indicator (1 octet)
Length = length of CPCS-PDU payload (2 octets)
CRC = cyclic redundancy check (4 octets)

(b) AAL Type 5

Example AAL 5 Transmission



CPCS = common part convergence sublayer
SAR = segmentation and reassembly
PDU = protocol data unit
CPCS-T = CPCS trailer
ATM-H = ATM header
SDU = Service Data Unit type bit

Frame Relay

- Designed to be more efficient than X.25
- Developed before ATM
- Larger installed base than ATM
- ATM now of more interest on high speed networks

Frame Relay Background - X.25

- Call control packets, in band signaling
- Multiplexing of virtual circuits at layer 3
- Layer 2 and 3 include flow and error control
- Considerable overhead
- Not appropriate for modern digital systems with high reliability

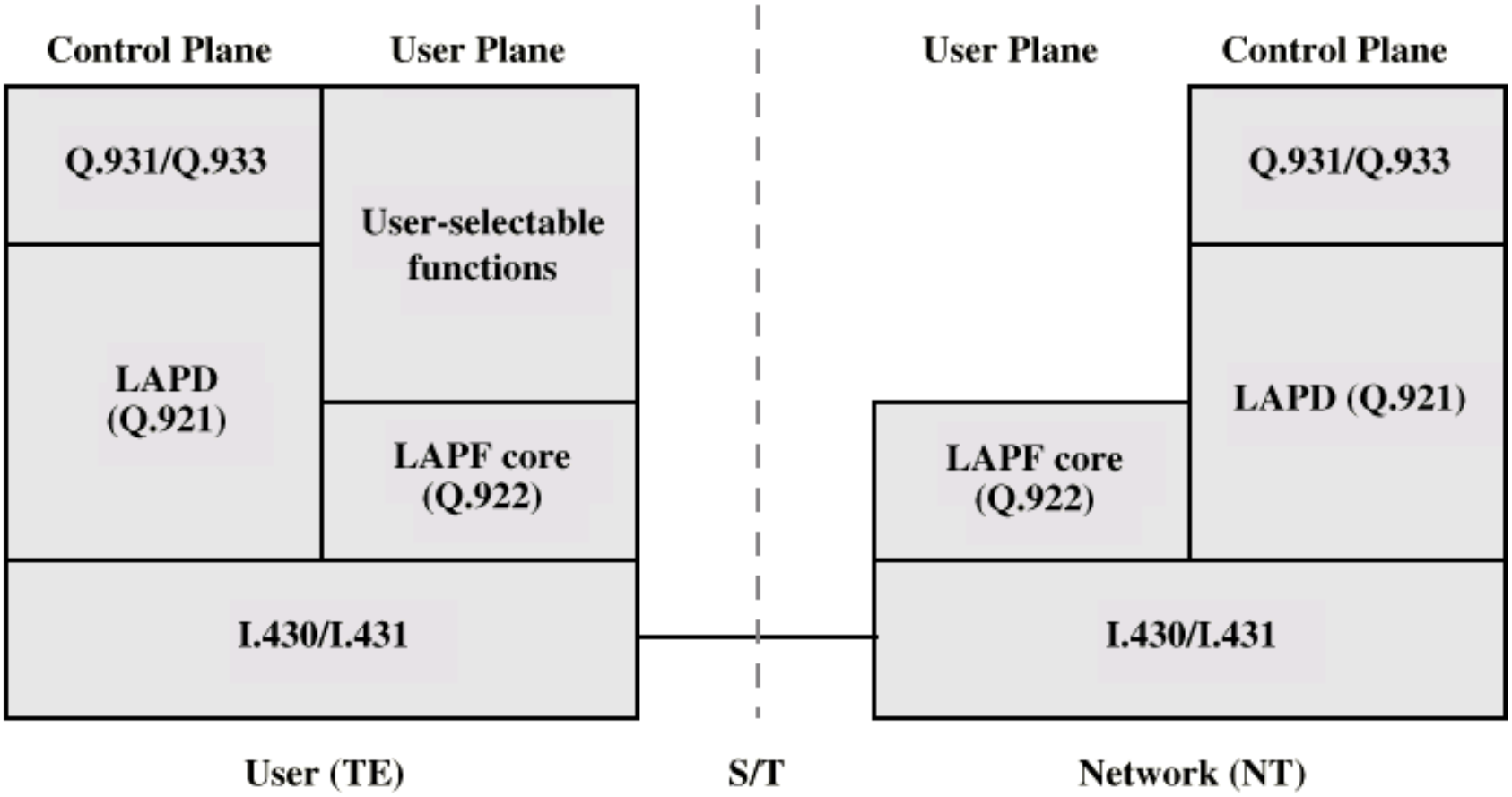
Frame Relay - Differences

- Call control carried in separate logical connection
- Multiplexing and switching at layer 2
  - Eliminates one layer of processing
- No hop by hop error or flow control
- End to end flow and error control (if used) are done by higher layer
- Single user data frame sent from source to destination and ACK (from higher layer) sent back

Advantages and Disadvantages

- Lost link by link error and flow control
  - Increased reliability makes this less of a problem
- Streamlined communications process
  - Lower delay
  - Higher throughput
- ITU-T recommend frame relay above 2Mbps

Protocol Architecture



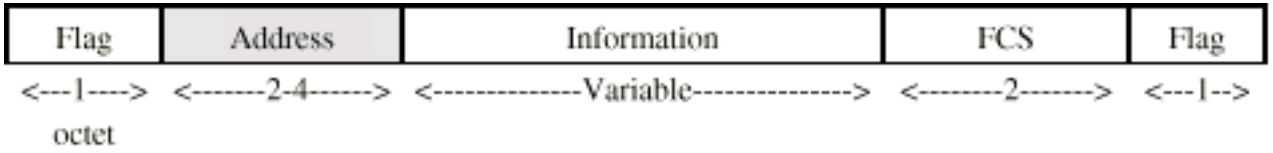
Control Plane

- Between subscriber and network
- Separate logical channel used
  - Similar to common channel signaling for circuit switching services
- Data link layer
  - LAPD (Q.921)
  - Reliable data link control
  - Error and flow control
  - Between user (TE) and network (NT)
  - Used for exchange of Q.933 control signal messages

User Plane

- End to end functionality
- Transfer of info between ends
- LAPF (Link Access Procedure for Frame Mode Bearer Services) Q.922
  - Frame delimiting, alignment and transparency
  - Frame mux and demux using addressing field
  - Ensure frame is integral number of octets (zero bit insertion/extraction)
  - Ensure frame is neither too long nor short
  - Detection of transmission errors
  - Congestion control functions

LAPF Core Formats



(a) Frame format

8	7	6	5	4	3	2	1
Upper DLCI						C/R	EA 0
Lower DLCI				FECN	BECN	DE	EA 1

(b) Address field - 2 octets (default)

8	7	6	5	4	3	2	1
Upper DLCI						C/R	EA 0
DLCI				FECN	BECN	DE	EA 0
Lower DLCI or DL-CORE control						D/C	EA 1

(c) Address field - 3 octets

8	7	6	5	4	3	2	1
Upper DLCI						C/R	EA 0
DLCI				FECN	BECN	DE	EA 0
DLCI							EA 0
Lower DLCI or DL-CORE control						D/C	EA 1

(d) Address field - 4 octets

EA	Address field extension bit
C/R	Command/response bit
FECN	Forward explicit congestion notification
BECN	Backward explicit congestion notification
DLCI	Data link connection identifier
D/C	DLCI or DL-CORE control indicator
DE	Discard eligibility

User Data Transfer

- One frame type
  - User data
  - No control frame
- No inband signaling
- No sequence numbers
  - No flow nor error control

Required Reading

- Stallings Chapter 11
- ATM Forum Web site
- Frame Relay forum