Data and Computer Communications

Chapter 11 – Asynchronous Transfer Mode

Eighth Edition

by William Stallings

Lecture slides by Lawrie Brown

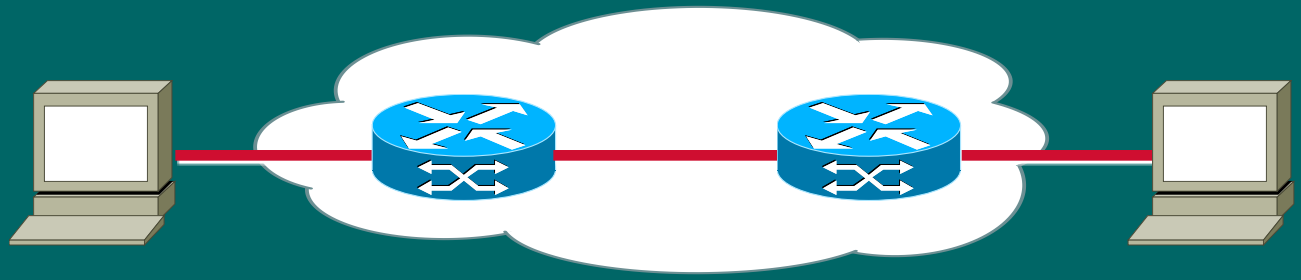
Asynchronous Transfer Mode

One man had a vision of railways that would link all the mainline railroad termini. His name was Charles Pearson and, though born the son of an upholsterer, he became Solicitor to the city of London. There had previously been a plan for gaslit subway streets through which horse-drawn traffic could pass. This was rejected on the grounds that such sinister tunnels would become lurking places for thieves. Twenty years before his system was built, Pearson envisaged a line running through "a spacious archway," well-lit and well-ventilated.

His was a scheme for trains in a drain.

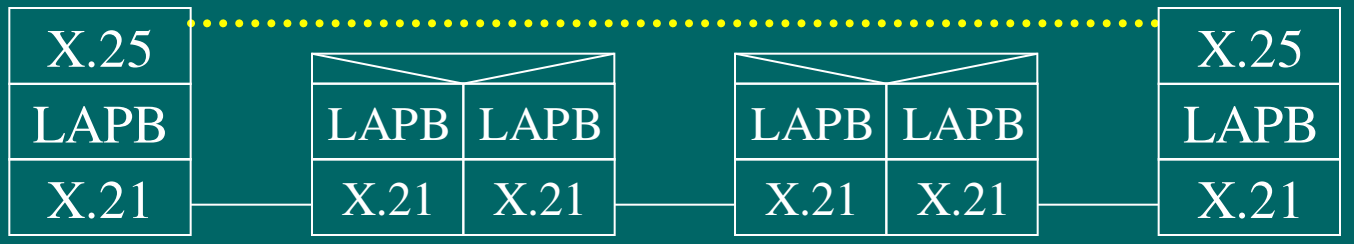
—*King Solomon's Carpet*, Barbara Vine (Ruth Rendell)

WAN Packet Switching Tech.



X.25

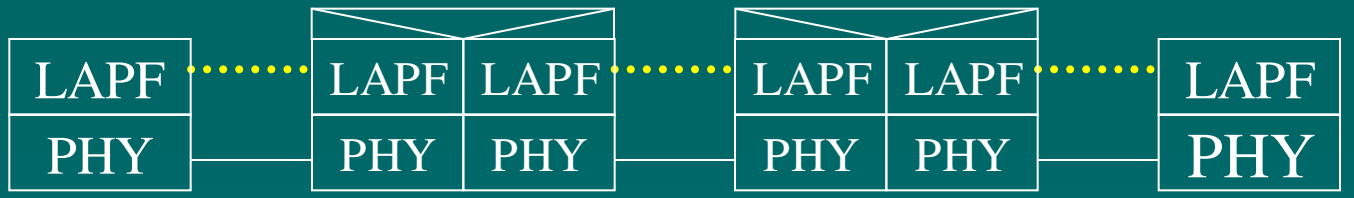
U-plane



FR

U-plane

C-plane

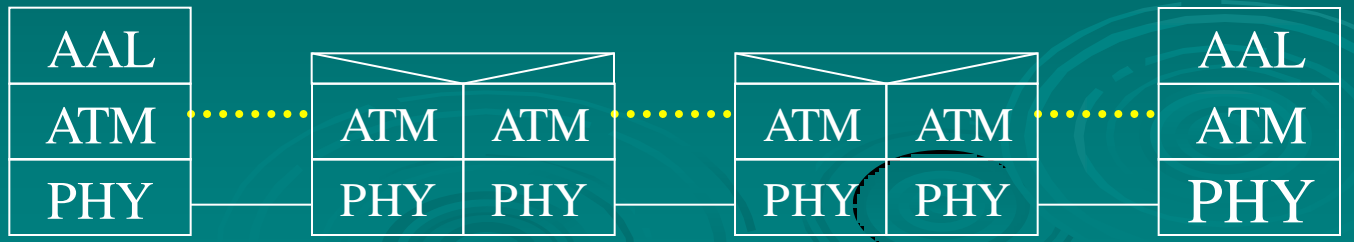


ATM

U-plane

C-plane

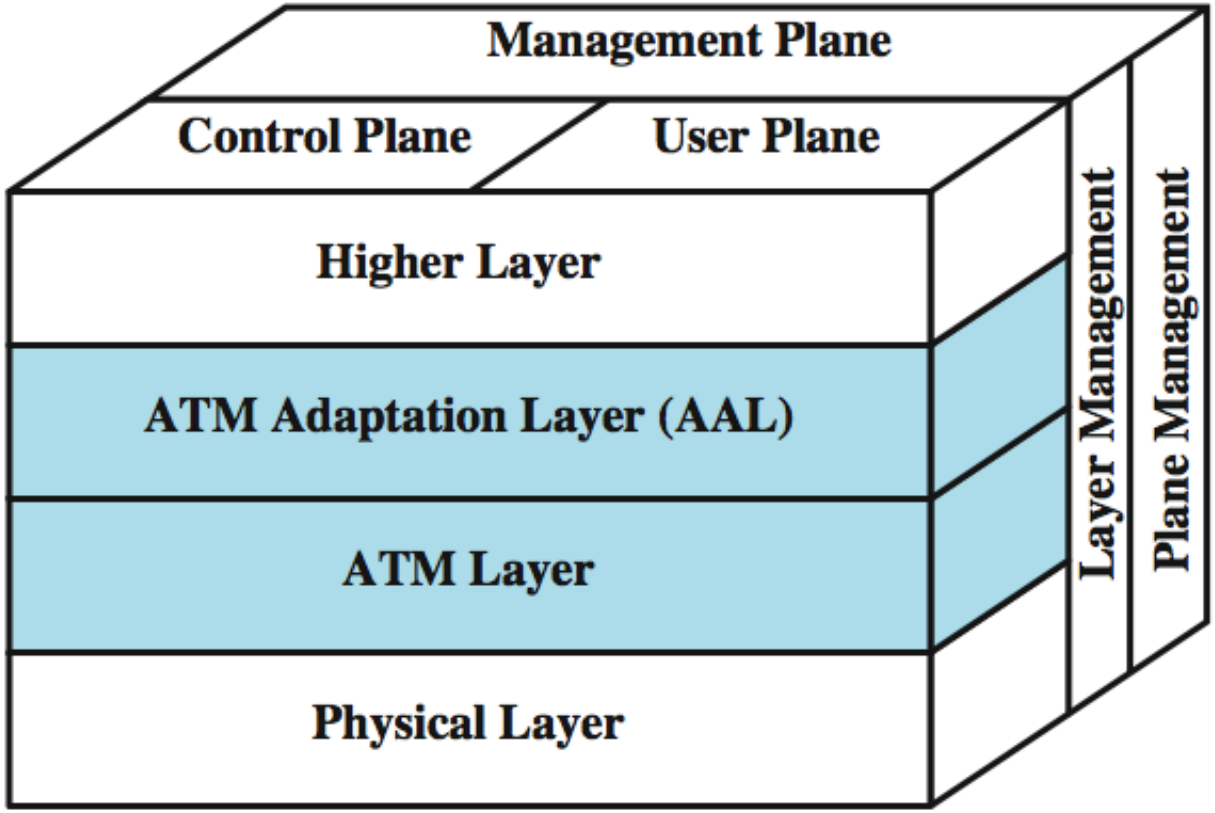
M-plane



ATM

- a streamlined packet transfer interface
- similarities to packet switching
  - transfers data in discrete chunks
  - supports multiple logical connections over a single physical interface
- ATM uses fixed sized packets called cells
- with minimal error and flow control
- data rates of 25.6Mbps to 622.08Mbps

Protocol Architecture



Reference Model Planes

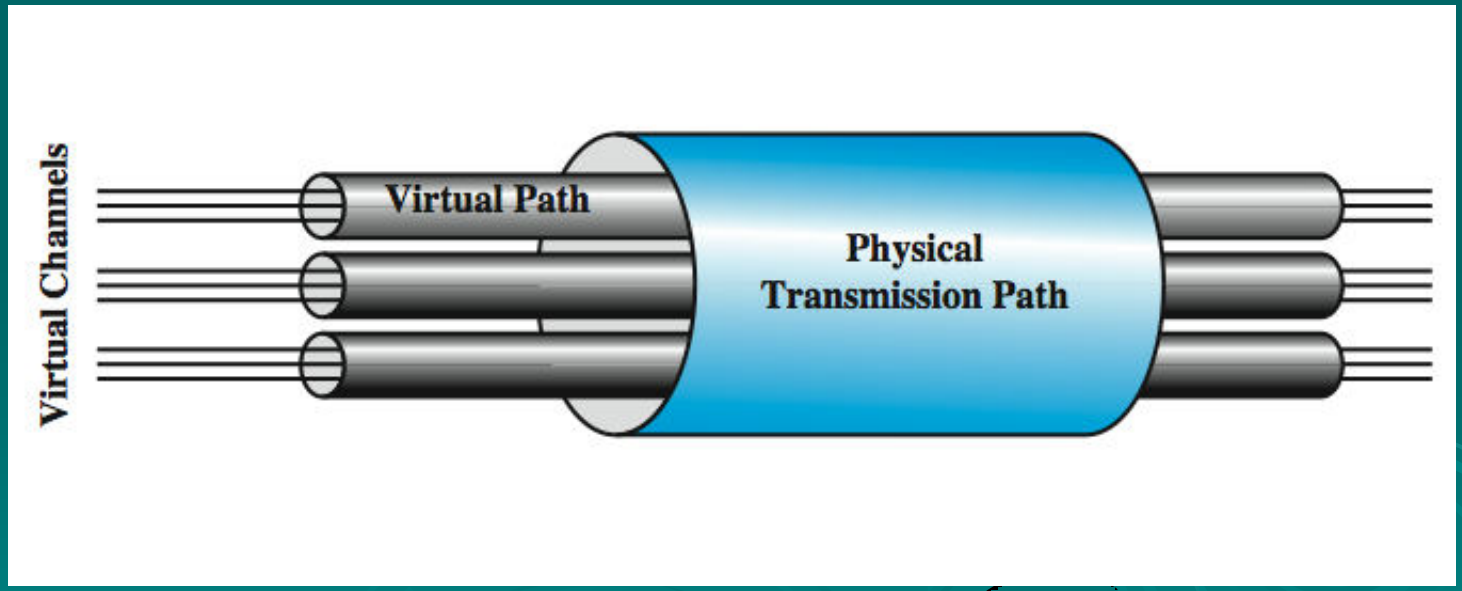
- user plane
  - provides for user information transfer
- control plane
  - call and connection control
- management plane
  - plane management
    - whole system functions
  - layer management
    - Resources and parameters in protocol entities

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
- also for
  - user-network exchange (control)
  - network-network exchange (network mgmt & routing)

ATM Virtual Path Connection

- virtual path connection (VPC)
  - bundle of VCC with same end points

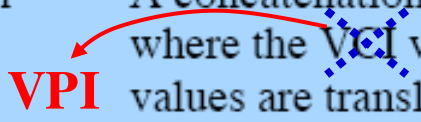


Virtual Channel Terminology

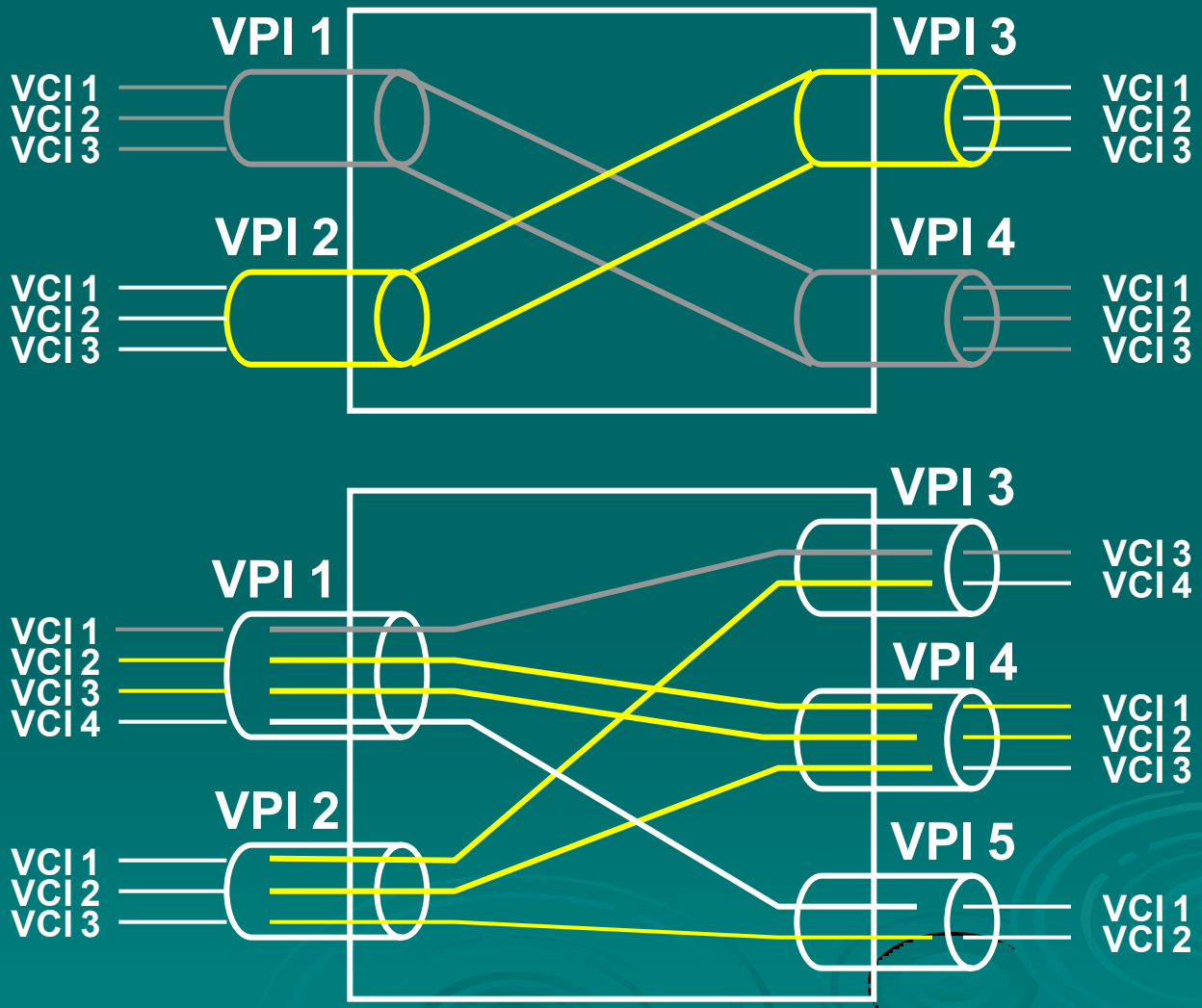
Virtual Channel (VC)	A generic term used to describe unidirectional transport of ATM cells associated by a common unique identifier value.
Virtual Channel Link	A means of unidirectional transport of ATM cells between a point where a VCI value is assigned and the point where that value is translated or terminated.
Virtual Channel Identifier (VCI)	A unique numerical tag that identifies a particular VC link for a given VPC.
Virtual Channel Connection (VCC)	A concatenation of VC links that extends between two points where ATM service users access the ATM layer. 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 Terminology

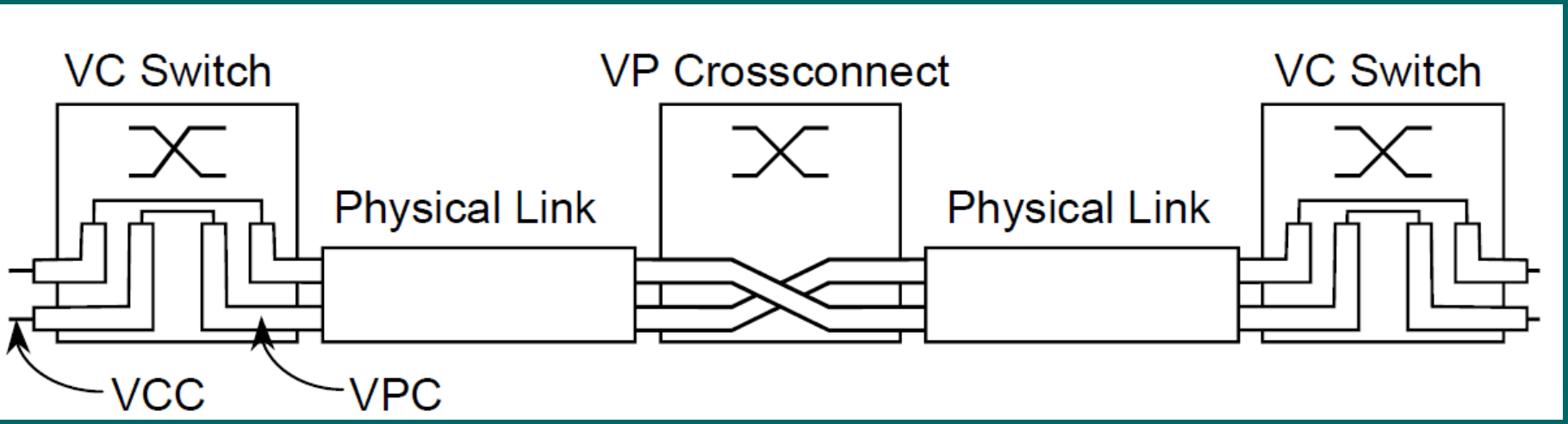
Virtual Path	A generic term used to describe unidirectional transport of ATM cells belonging to virtual channels that are associated by a common unique identifier value.
Virtual Path Link	A group of VC links, identified by a common value of VPI, between a point where a VPI value is assigned and the point 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.



VP/VC Switching -1



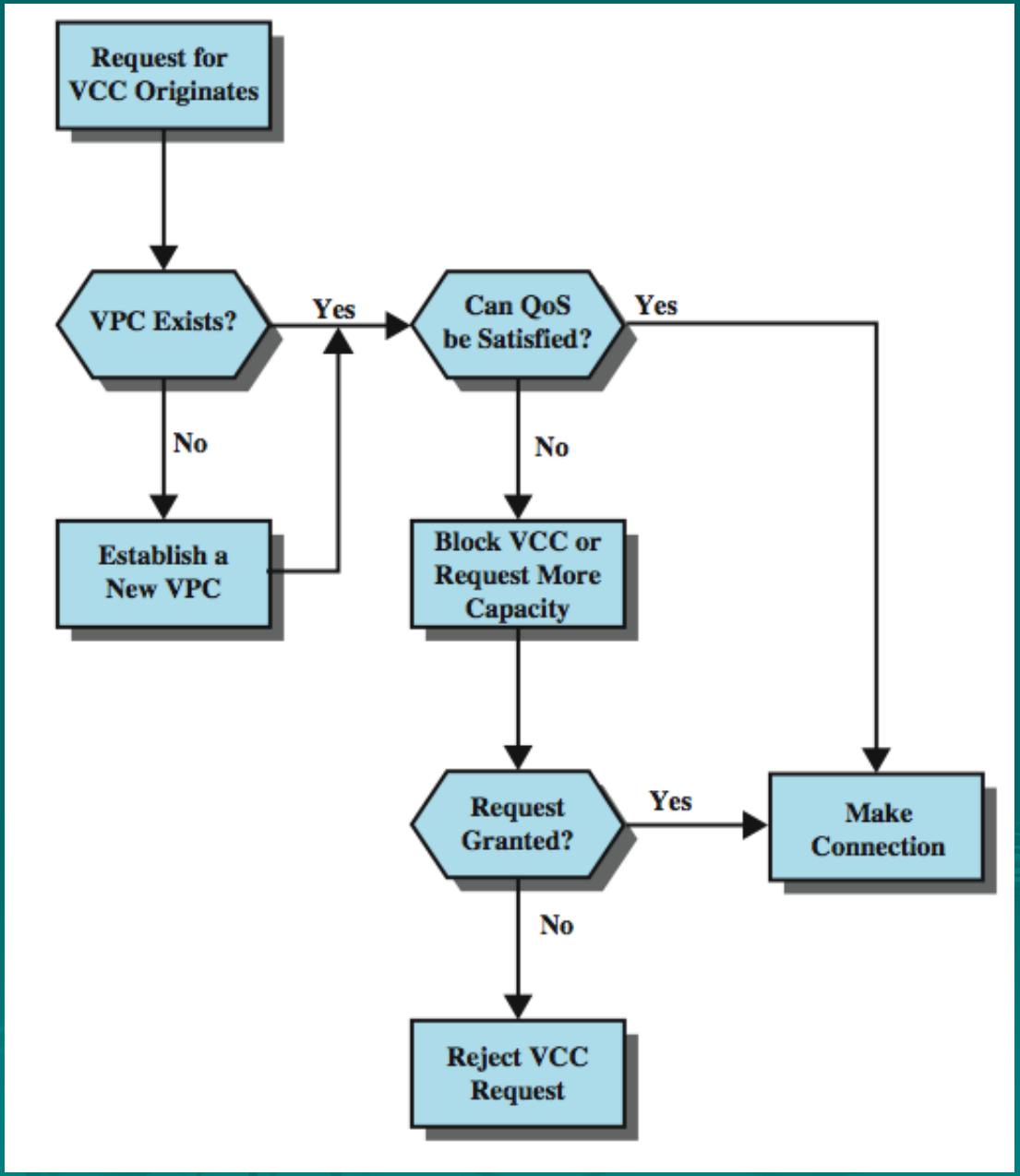
VP/VC Switching -2



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 for the exchange of network management information

VP/VC Characteristics

- quality of service: **cell loss ratio, cell delay variation**
- switched and semi-permanent channel connections
- call sequence integrity
- traffic parameter negotiation and usage monitoring

- VPC only
  - virtual channel identifier restriction within VPC

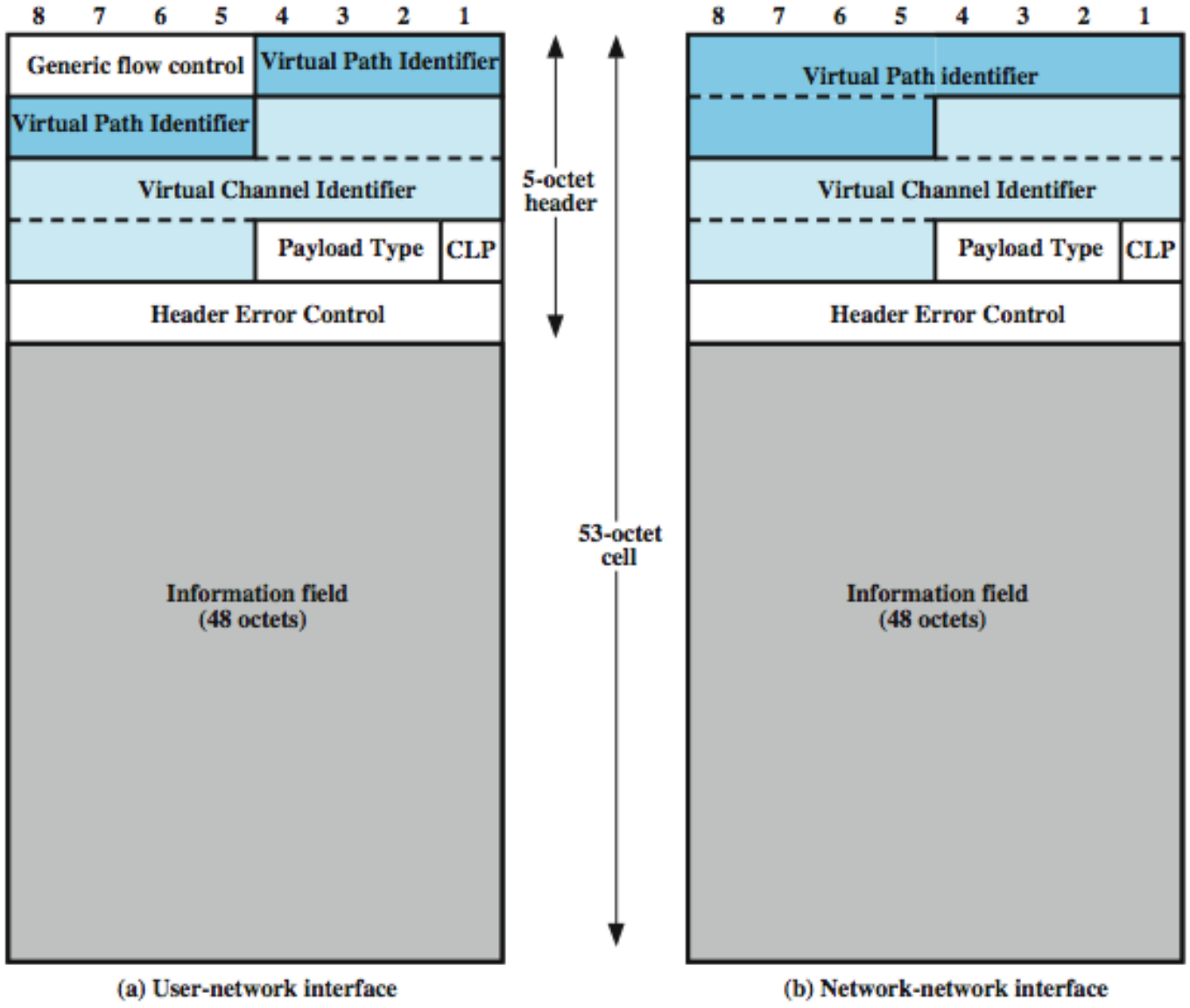
Control Signaling - VCC

- to establish or release VCCs & VPCs
- uses a separate connection
- methods are:
  1. semi-permanent VCC
  2. meta-signaling channel
  3. user to network signaling virtual channel
  4. user to user signaling virtual channel

Control Signaling - VPC

- methods for control signalling for VPCs:
  1. Semi-permanent
  2. Customer controlled
  3. Network controlled

ATM Cells


8 7 6 5 4 3 2 1
Generic flow control
Virtual Path Identifier
Virtual Path Identifier
Virtual Channel Identifier
Payload Type
CLP
Header Error Control
Information field
(48 octets)
5-octet
header
53-octet
cell
8 7 6 5 4 3 2 1
Virtual Path identifier
Virtual Channel Identifier
Payload Type
CLP
Header Error Control
Information field
(48 octets)
(a) User-network interface
(b) Network-network interface

ATM Header Fields

- generic flow control
- Virtual path identifier
- Virtual channel identifier
- payload type
- 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 subject to flow control or not
- if subject to flow control
  - may be one group (A) default
  - may be two groups (A and B)
- flow control is from subscriber to network

GFC - Single Group of Connections

1. If TRANSMIT=1 send uncontrolled cells any time. If TRANSMIT=0 no cells may be sent
2. If HALT received, TRANSMIT=0 until NO_HALT
3. If TRANSMIT=1 & no uncontrolled cell to send:
    1. If GO_CNTR>0, TE may send controlled cell and decrement GO_CNTR
    2. If GO_CNTR=0, TE may not send controlled cells
4. TE sets GO_CNTR to GO_VALUE upon receiving SET signal

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

- uses two counters each with current & initial values:
  - GO_CNTR_A
  - GO_VALUE_A
  - GO_CNTR_B
  - GO_VALUE_B

GFC Field Coding

Two directions

	Uncontrolled	Controlling → Controlled		Controlled → Controlling	
		1-Queue Model	2-Queue Model	1-Queue Model	2-Queue Model
First bit	0	HALT(0)/NO_HALT(1)	HALT(0)/NO_HALT(1)	0	0
Second bit	0	SET(1)/NULL(0)	SET(1)/NULL(0) for Group A	cell belongs to controlled(1) /uncontrolled(0)	cell belongs to Group A(1)/ or not (0)
Third bit	0	0	SET(1)/NULL(0) for Group B	0	cell belongs to Group B(1)/ or not (0)
Fourth bit	0	0	0	equipment is uncontrolled(0)/ controlled(1)	equipment is uncontrolled(0)/ controlled(1)

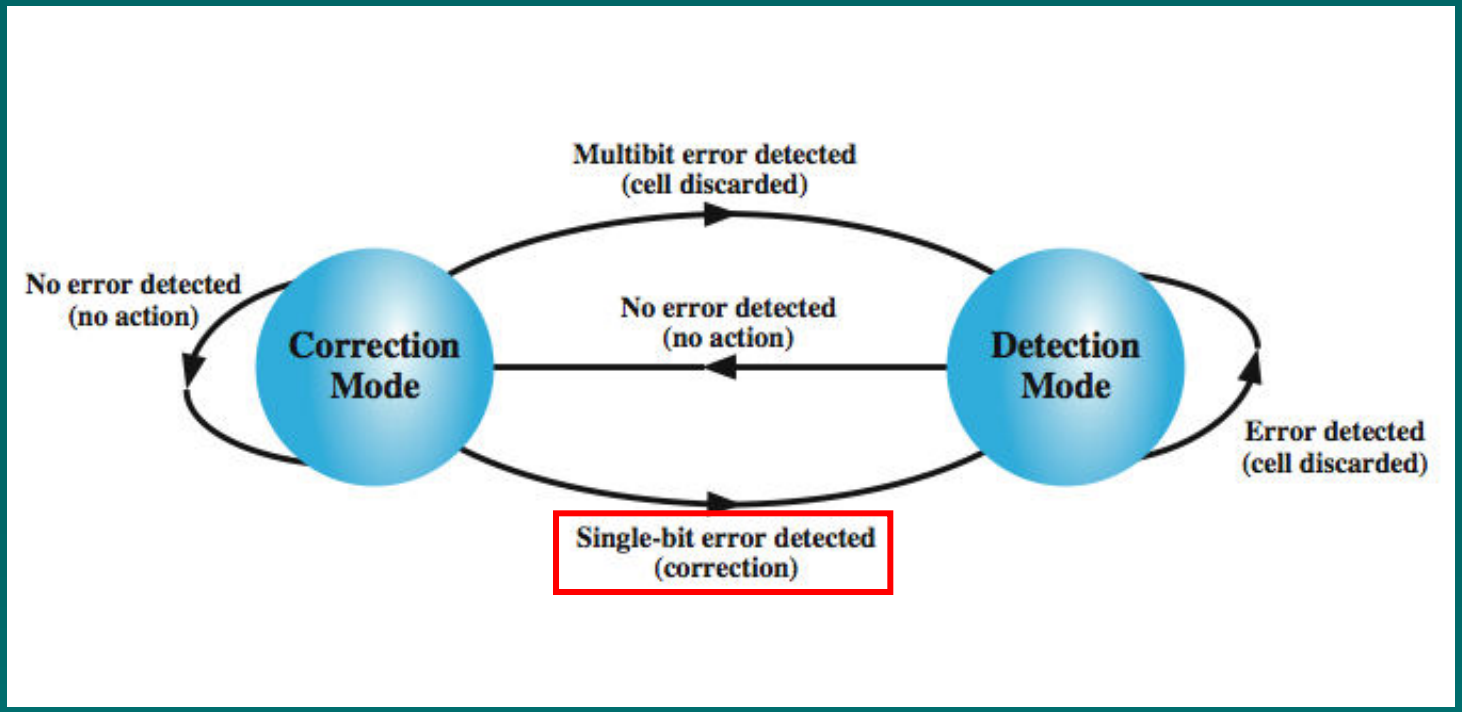
Flow control is exercised in the direction from the subscriber to the network by the network side

Payload Type (PT) Coding

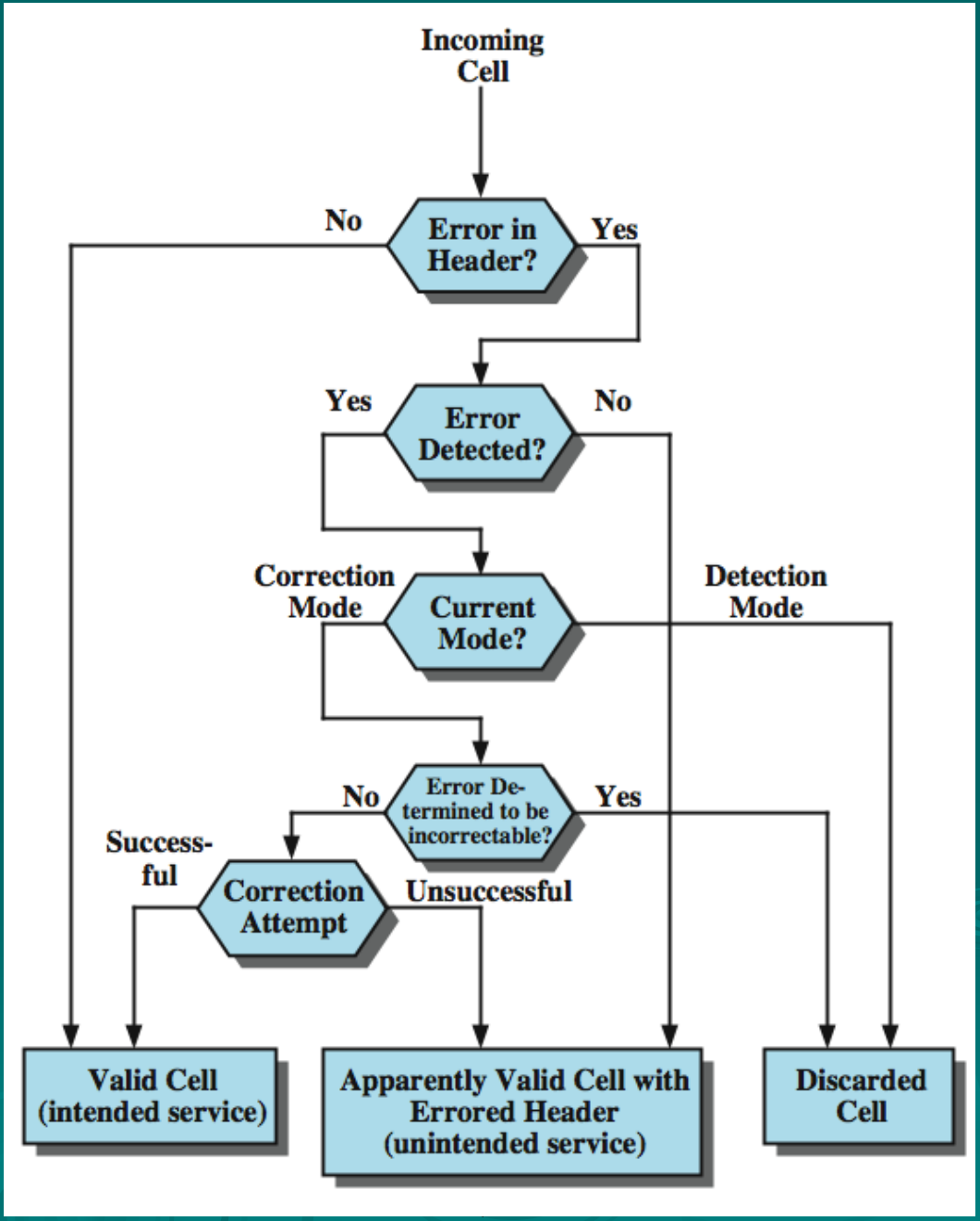
PT Coding	Interpretation		
0 0 0	User data cell,	congestion not experienced,	SDU-type = 0
0 0 1	User data cell,	congestion not experienced,	SDU-type = 1
0 1 0	User data cell,	congestion experienced,	SDU-type = 0
0 1 1	User data cell,	congestion experienced,	SDU-type = 1
1 0 0	OAM segment associated cell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

SDU = Service Data Unit
OAM = Operations, Administration, and Maintenance

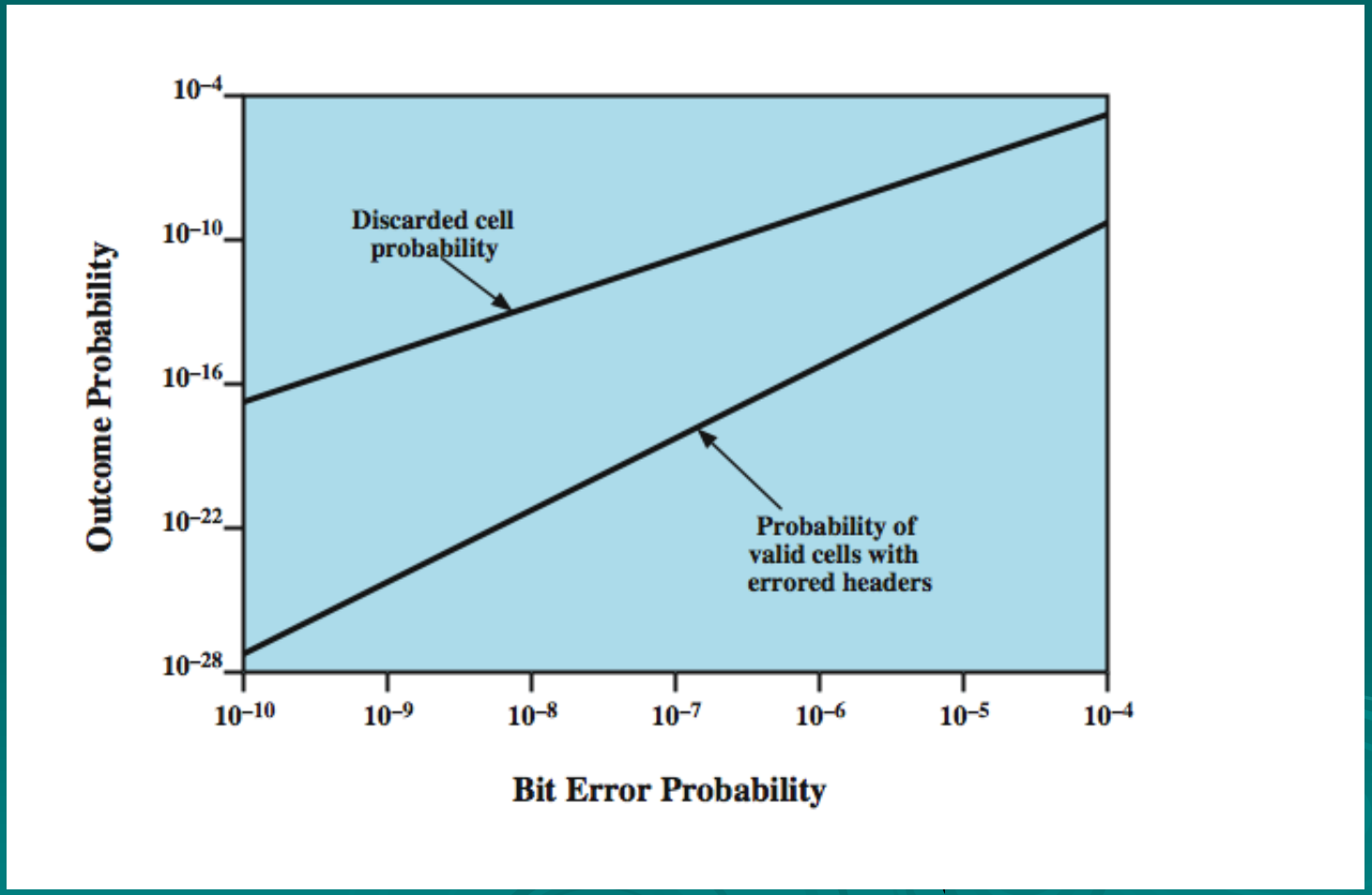
Header Error Control



Effect of Error in Cell Header



Impact of Random Bit Errors on HEC Performance



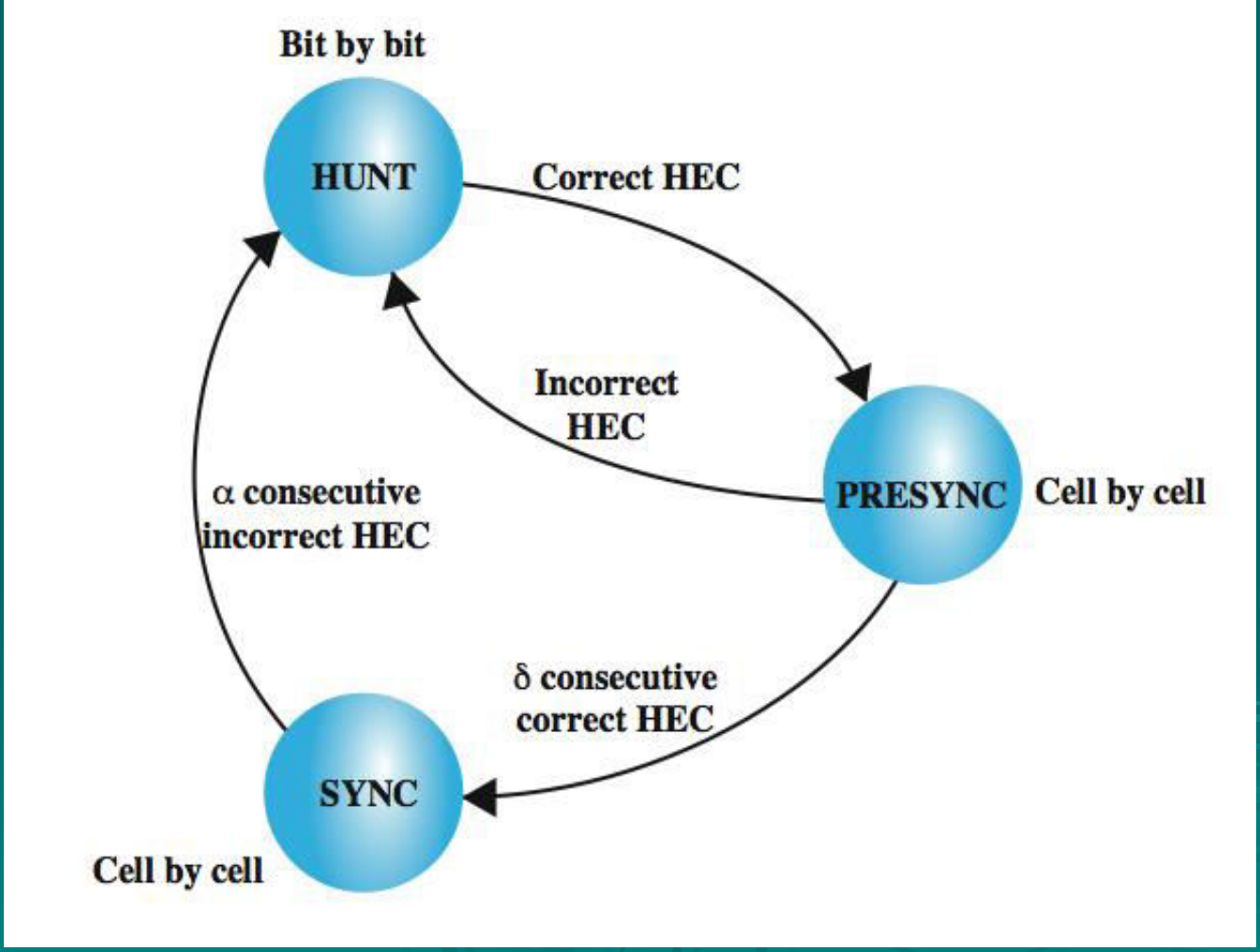
Transmission of ATM Cells

- I.432 specifies several data rates:
  - 622.08Mbps
  - 155.52Mbps
  - 51.84Mbps
  - 25.6Mbps
- two choices of transmission structure:
  - Cell based physical layer
  - SDH based physical layer

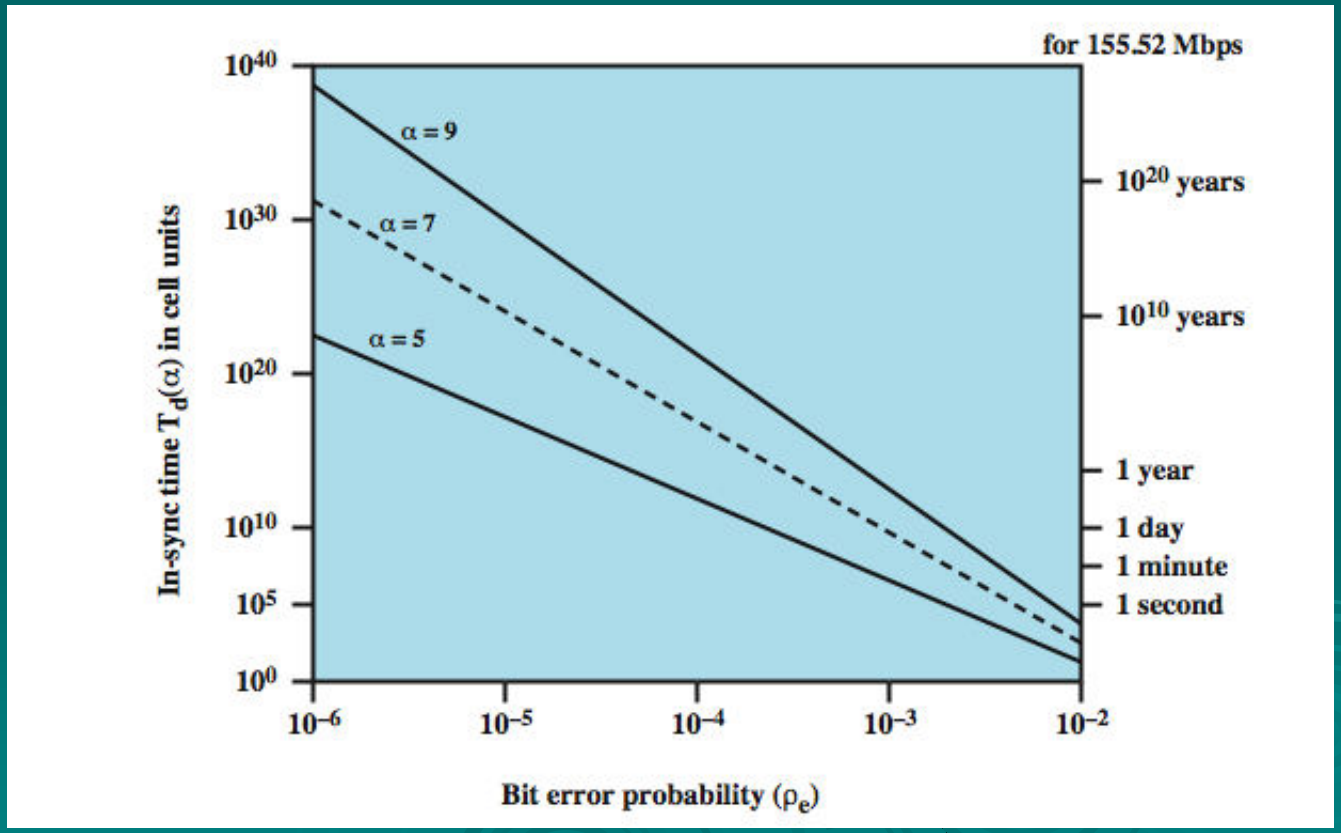
Cell Based Physical Layer

- no framing imposed
- continuous stream of 53 octet cells
- cell delineation based on header error control field

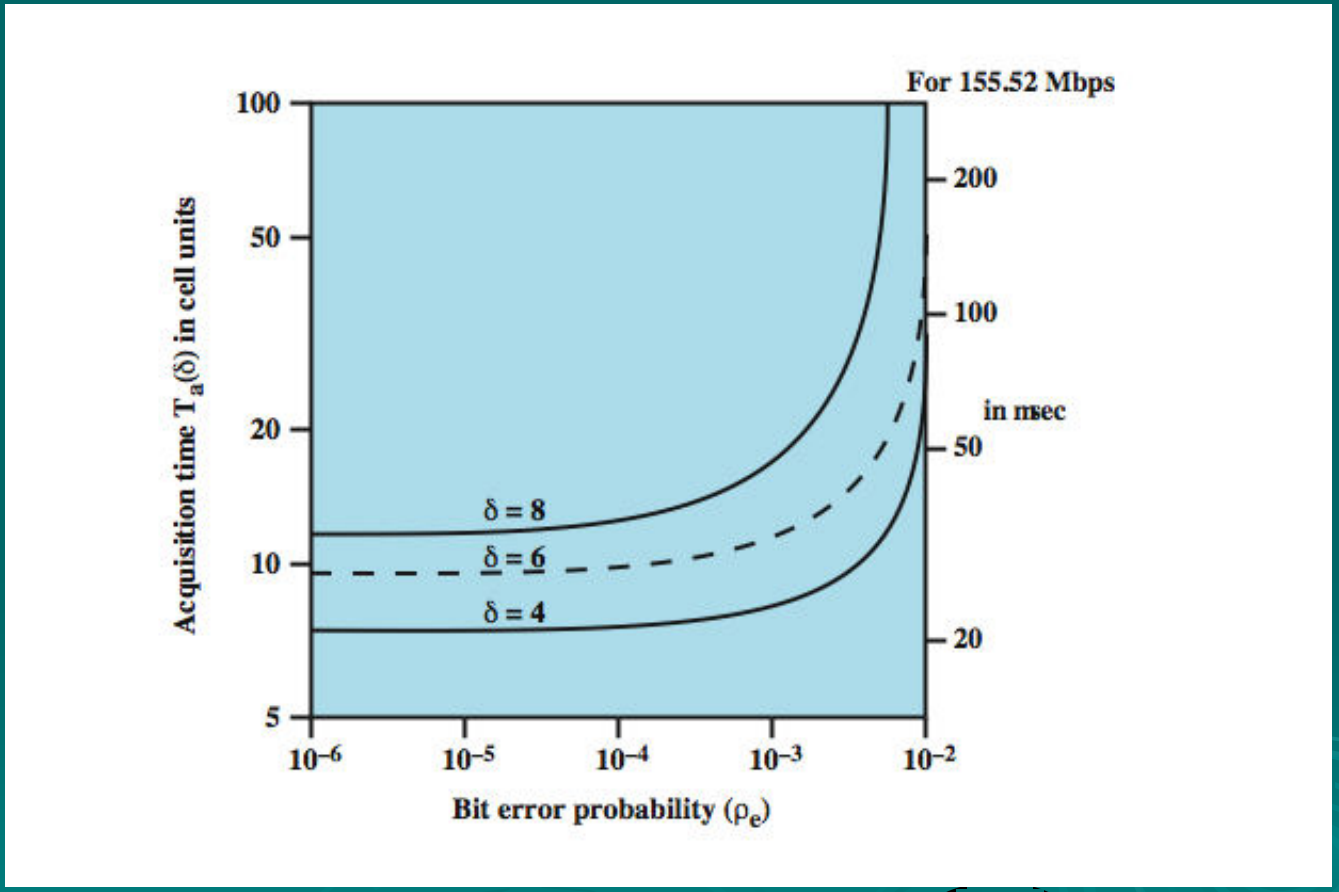
Cell Delineation State Diagram



Impact of Random Bit Errors on Cell Delineation Performance



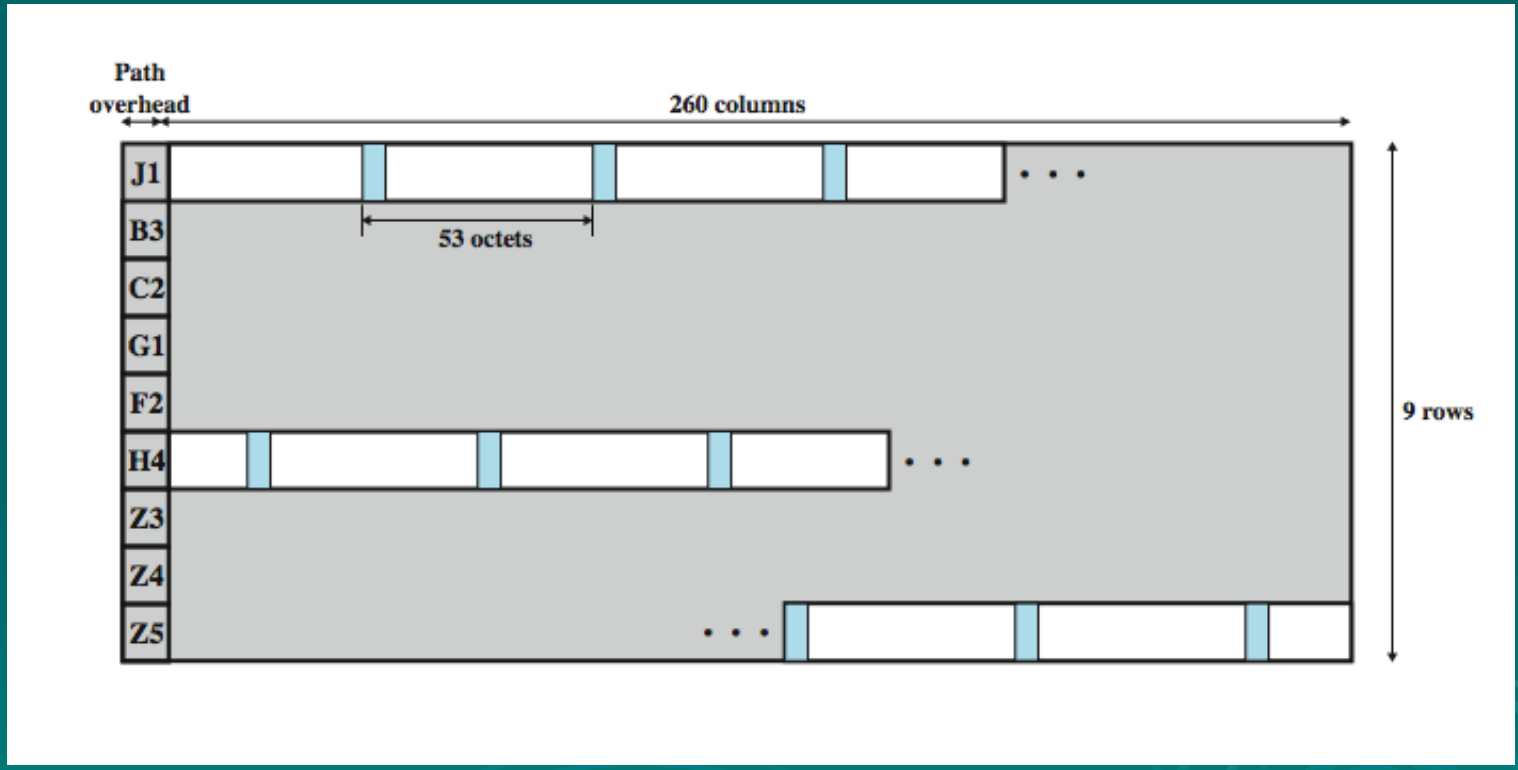
Acquisition Time v Bit Error Rate



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 - limit amount/variation of delay
  - Constant bit rate (CBR)
  - Real time variable bit rate (rt-VBR)
- Non-real time - for bursty traffic
  - Non-real time variable bit rate (nrt-VBR)
  - Available bit rate (ABR)
  - Unspecified bit rate (UBR)
  - Guaranteed frame rate (GFR)

Constant Bit Rate (CBR)

- fixed data rate continuously available
- tight upper bound on delay
- uncompressed audio and video
  - video conferencing
  - interactive audio
  - A/V distribution and retrieval

Real-Time Variable Bit Rate (rt-VBR)

- for time sensitive applications
  - tightly constrained delay and delay variation
- rt-VBR applications transmit data 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
- hence can statistically multiplex connections

Non-Real-Time Variable Bit Rate (nrt-VBR)

- if can characterize expected bursty traffic flow
  - e.g. airline reservations, banking transactions
- ATM net allocates resources based on this
  - to meet critical response-time requirements
- giving improved QoS in loss and delay
- end system specifies:
  - peak cell rate
  - sustainable or average rate
  - measure of how bursty traffic is

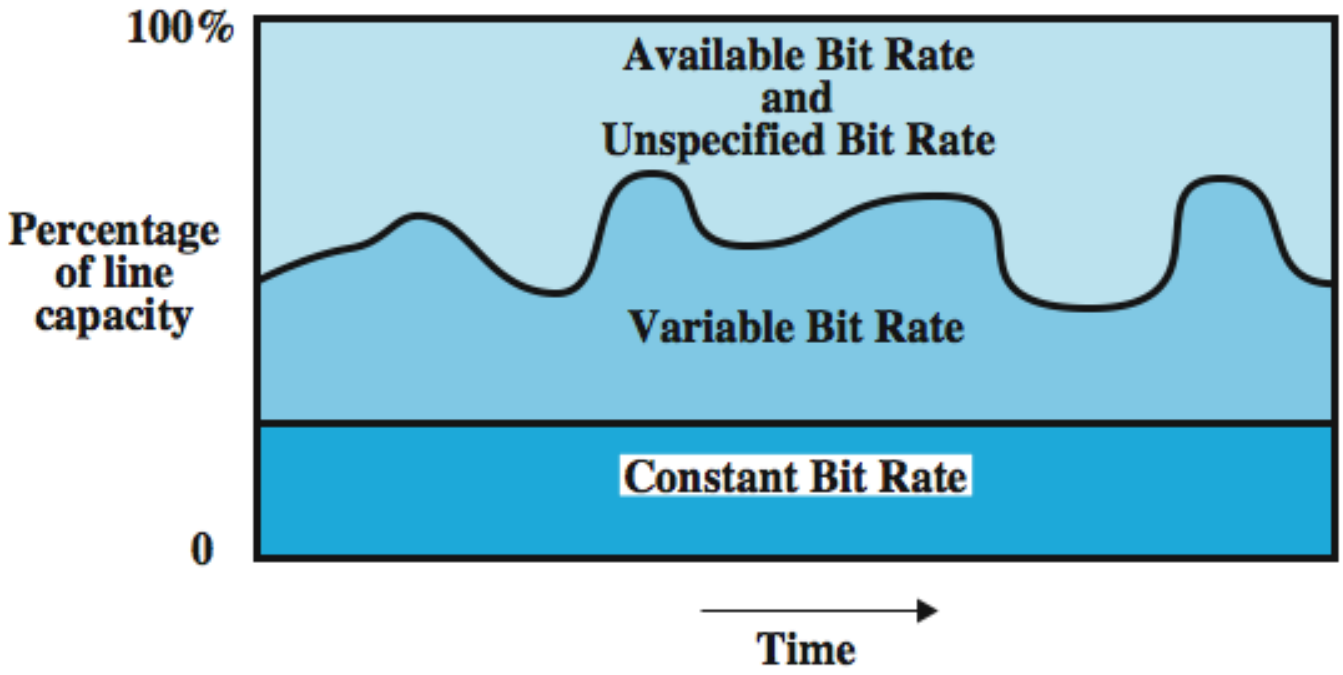
Available Bit Rate (ABR)

- application specifies peak cell rate (PCR) and minimum cell rate (MCR)
- resources allocated to give at least MCR
- spare capacity shared among all ABR sources
  - e.g. LAN interconnection

Unspecified Bit Rate (UBR)

- may be additional capacity over and above that used by CBR and VBR traffic
  - not all resources dedicated to CBR/VBR traffic
  - unused cells due to 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 effort service

ATM Bit Rate Services



Summary of ATM

- 3-plane high-speed cell switching
- Virtual Circuit in ATM layer
  - 2-layered VC: VPI + VCI
- Controls left in ATM
  - Generic Flow Control (User-Network Interface)
  - Congestion Control
- Concept of Quality-of-Service (QoS)
  - QoS parameters + Traffic parameters

Summary of ATM Services

	QoS part	Traffic part
CBR	Tight delay bound	Fixed data rate
rt-VBR	Tightly constrained delay & delay variation	Peak/Avg. cell rate, traffic burstiness
nrt-VBR	Improved QoS in loss and delay	Peak/Avg. cell rate, traffic burstiness
ABR	Spare capacity shared among all ABR sources	Peak/Min. cell rate
UBR	Tolerate some cell loss or variable delays, BE	Unspecified

Summary

- Asynchronous Transfer Mode (ATM)
- architecture & logical connections
- ATM Cell format
- transmission of ATM cells
- ATM services