ATM : ASYNCHRONOUS TRANSFER MODE

Outline

- Introduction
- ATM Architecture
- ATM Connections
- ATM Cell
- Class of Service
- AAL Layer
- Traffic Control
- Congestion Control

Introduction

- Asynchronous Transfer Mode
  - Standardized by the ITU-T in 1987
  - Important technology in the 1980s - 1990s
  - Widely used by the telecommunications industry
- ATM goals
  - A single network for the transport of audio, video and data
  - Mainly used in core networks, ADSL access, and the 3G mobile telephone network
  - With multiple levels of quality of service

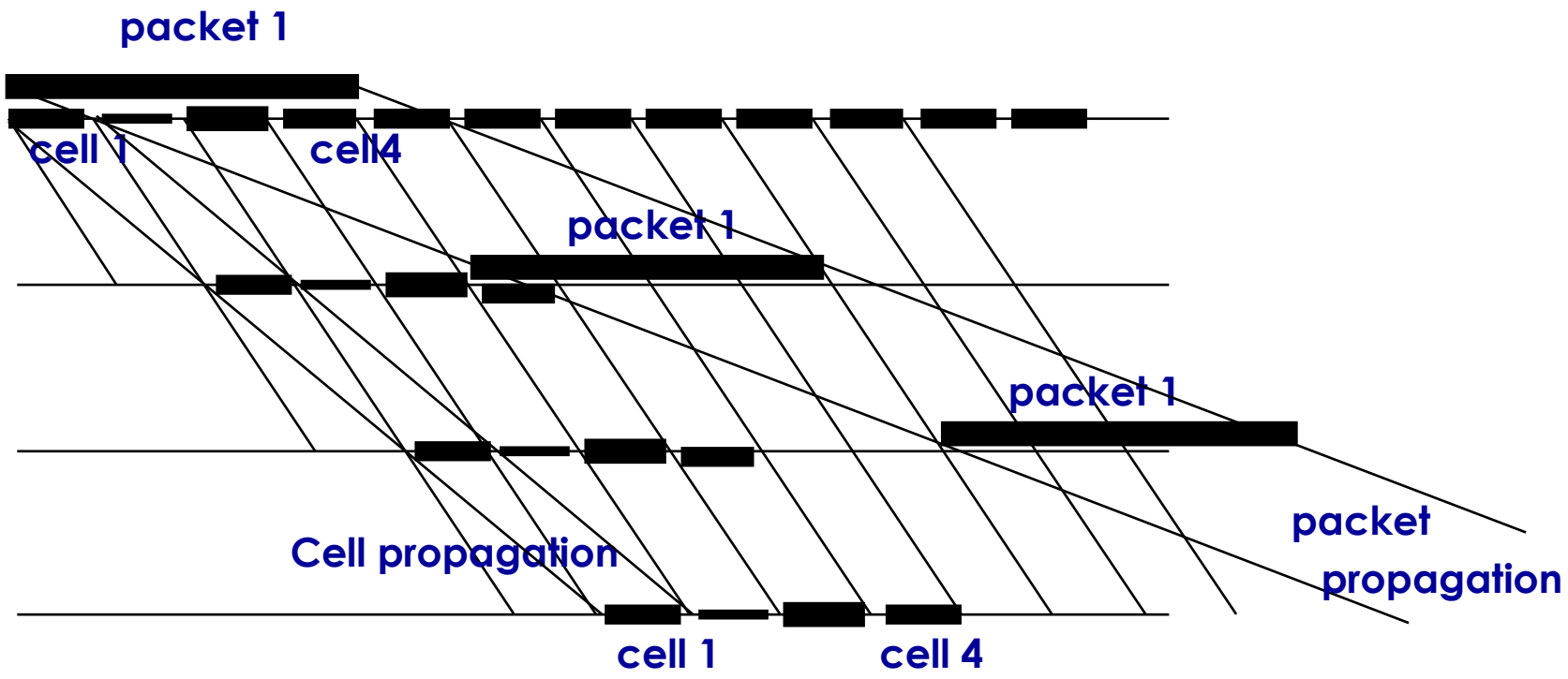
Characteristics

- Abandonment of the circuit switched network → Replace it by cell switching
- Connection oriented
- No error control and flow control between two adjacent nodes
- Error detection only for the cell's header.
- Error detection for user data and data retransmission are realized by the upper layers
- Congestion control mechanisms

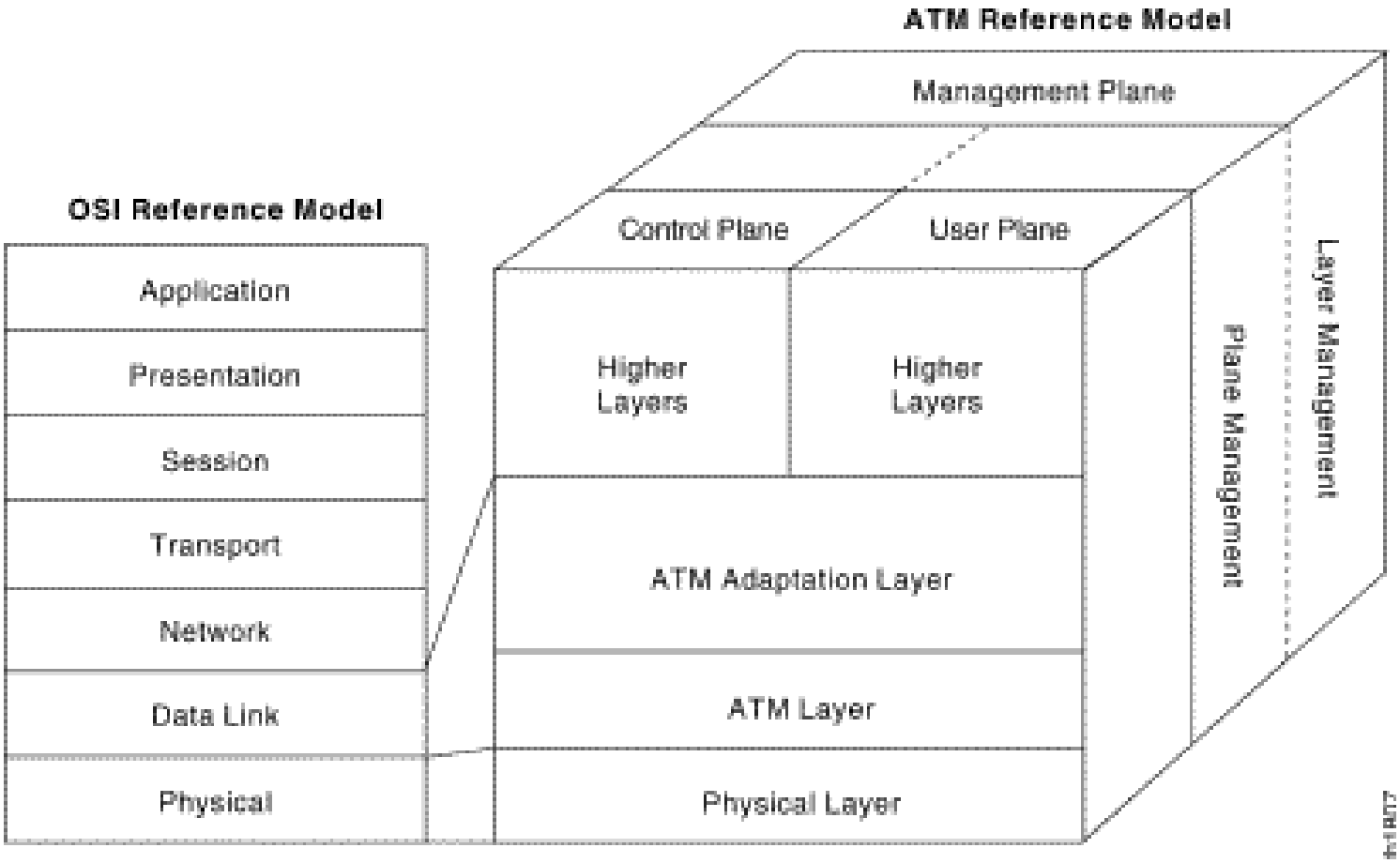
ATM cell size

- If the cell size is too small
  - Header overhead relative to total packet size
  - Processing overhead on devices
- If the cell size is too large
  - Wasted padding when the data is smaller
  - Delay to wait for transmission of previous packet
  - Long packetization time
- ATM cell: 53 bytes (designed by committee!)
  - The U.S. wanted 64 bytes, and Europe wanted 32 bytes
  - Compromise: 5-byte header and 48 bytes of data
- Fixed cell size
  - To optimize the delay in the switch buffer

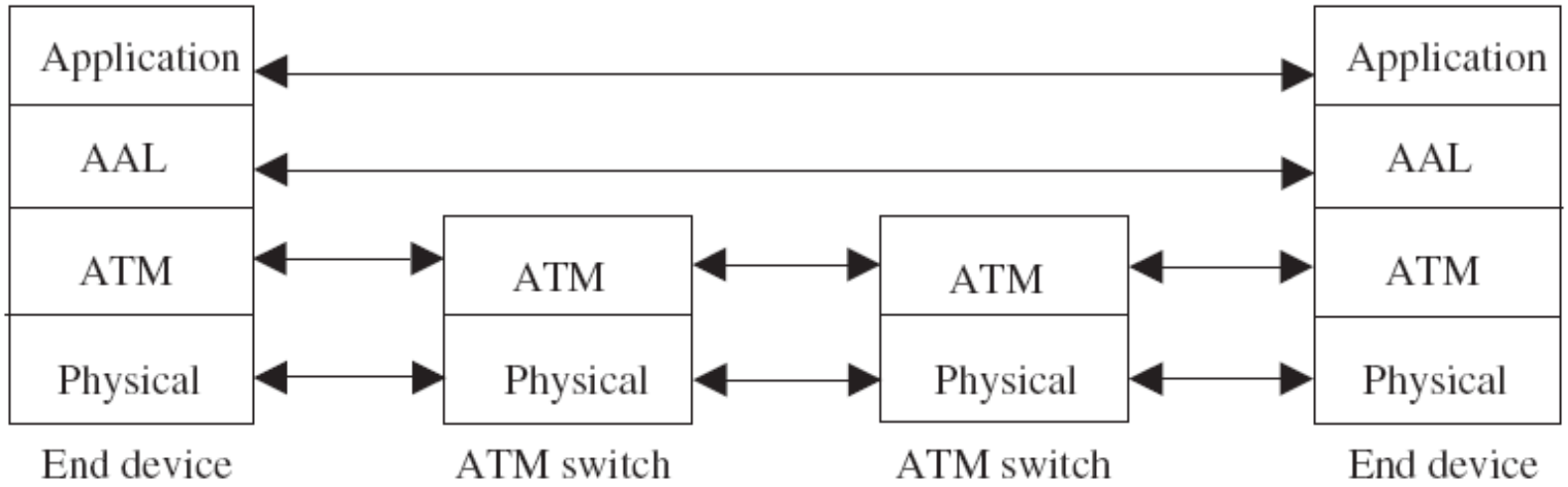
Large packets vs. small cell



Reference Model

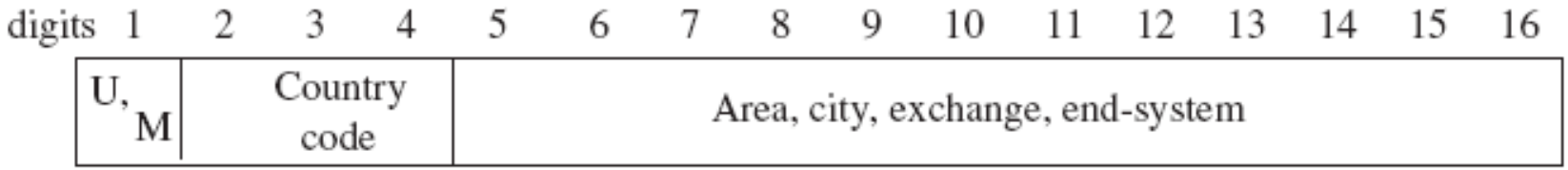


ATM – User plane



ATM address

- Each ATM terminal and ATM switch has a unique address
- Example of an ATM address based on the E.164 addressing



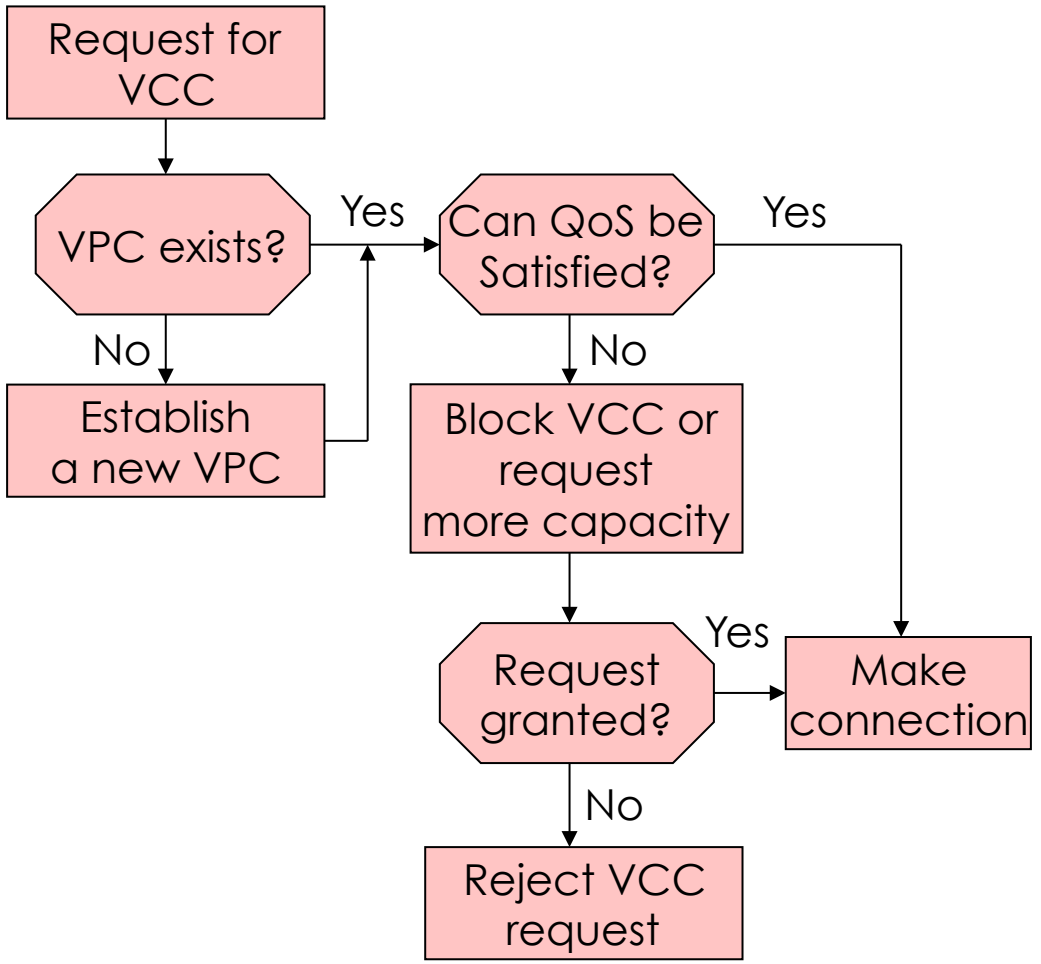
ATM Connections (1)

- Logical connection in ATM
  - Virtual Channel Connections (VCCs) set up between 2 end users
  - Virtual Path connection (VPC), which is a bundle of VCCs that have the same endpoints.
- Advantages to use VPs
  - Simplified network architecture
    - Define on a unique physical network, several logically independent networks (VPCs for each logical network which can not be used for other logical networks)
  - Increased network performance
    - Network deals with fewer aggregated entities

ATM Connections (2)

- Reduced processing and short connection set-up
  - By reserving capacity on a VPC in anticipation of later call arrivals, new VCC can be established by executing simple control functions at the endpoints of the VPC (no call processing is required at transit nodes)
  - Addition of new virtual channels to an existing VP involves minimal processing

ATM Connections (3)



Connection establishment (1)

- Connection managed in the control plane
  - Method 1- permanent virtual connection (PVC): established manually by a network administrator using network management procedures. It remains in place for a long time.
  - Method 2 - switched virtual connection (SVC): established in real-time by the network using signaling procedures. It remains up for an arbitrary amount of time : Need to establish a Signaling VCC first using a meta-signaling VCC (VPI = 0, VCI = 5)
- SVC uses a signaling protocol: Q. 2931
  - The sender sends a SETUP message to the ingress switch
  - The ingress switch chooses the next switch based on the routing algorithm (using the ATM address) and transfers the SETUP message
  - Each switch continues to transfer the SETUP message until the egress switch
  - The egress switch sends the SETUP message to the receiver
  - Receiver sends an ACK message to the sender

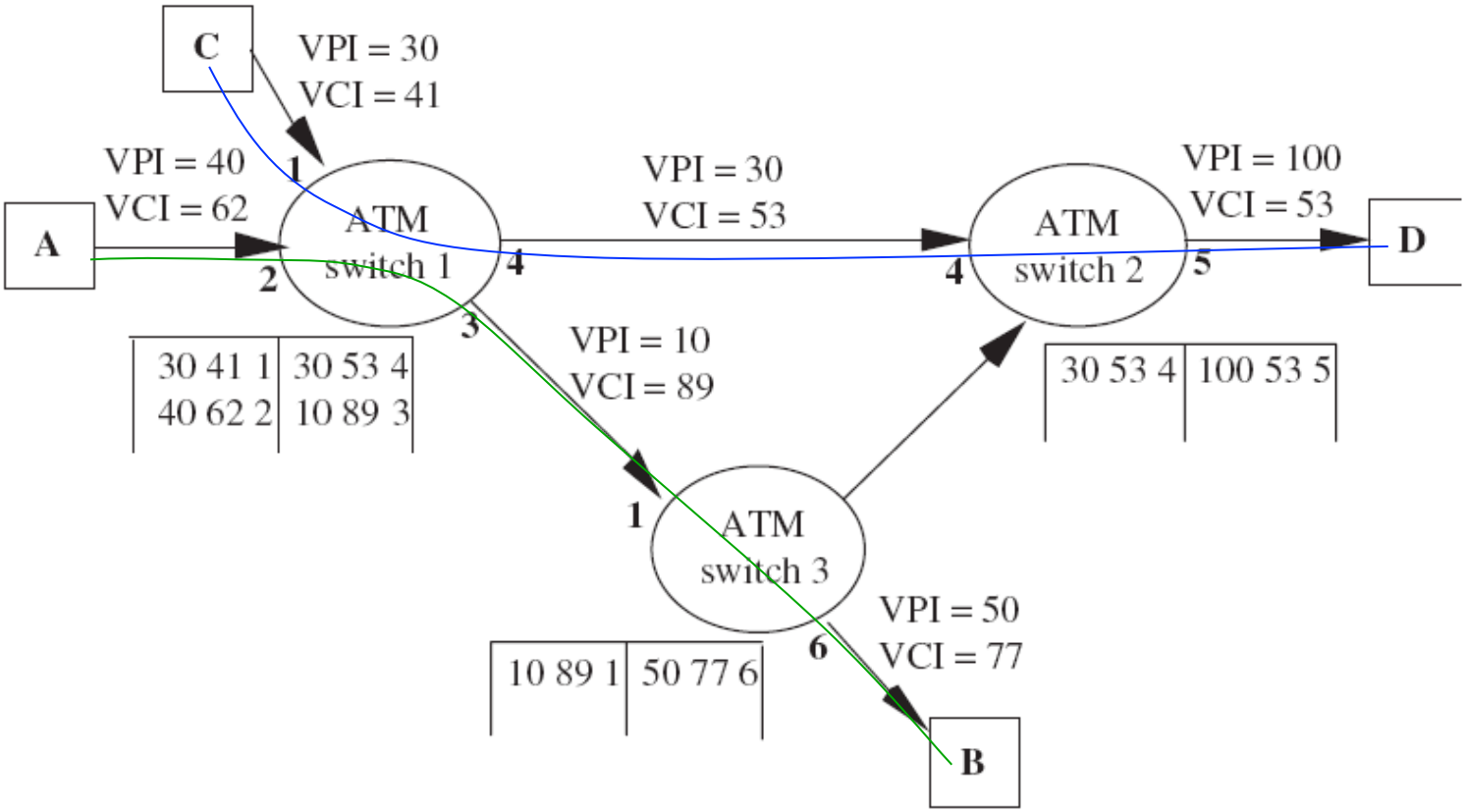
Connection establishment (2)

- Each switch on the way
  - Admission Control
  - Necessary resources allocation
  - Selection of the label value VPI/VCI
  - Update the switching table

Closing Connection

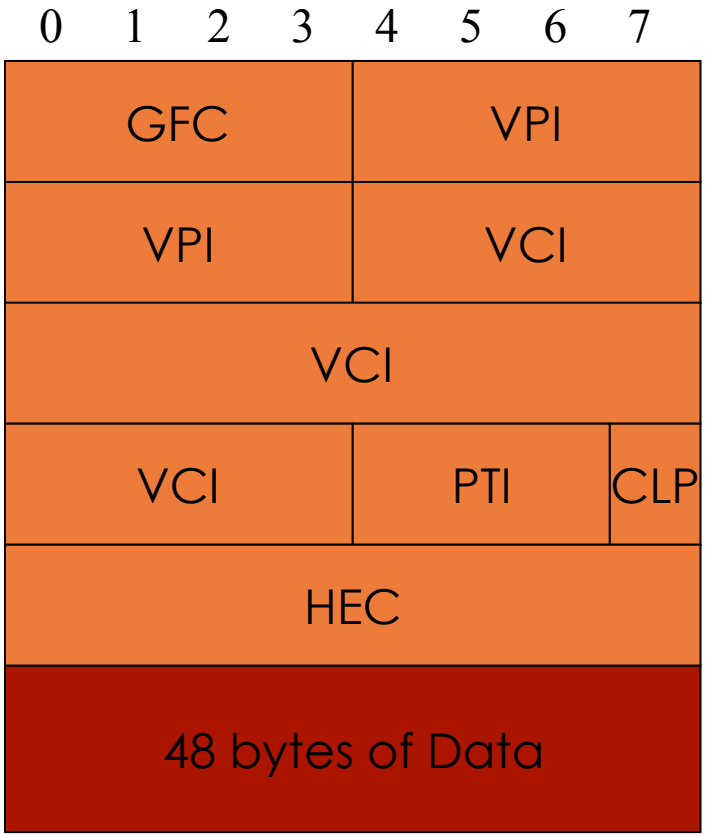
- Each switch on the way
  - Remove the input corresponding to the connection in the switch table
  - Return the label value VPI/VCI
  - Free allocated resources

Label switching

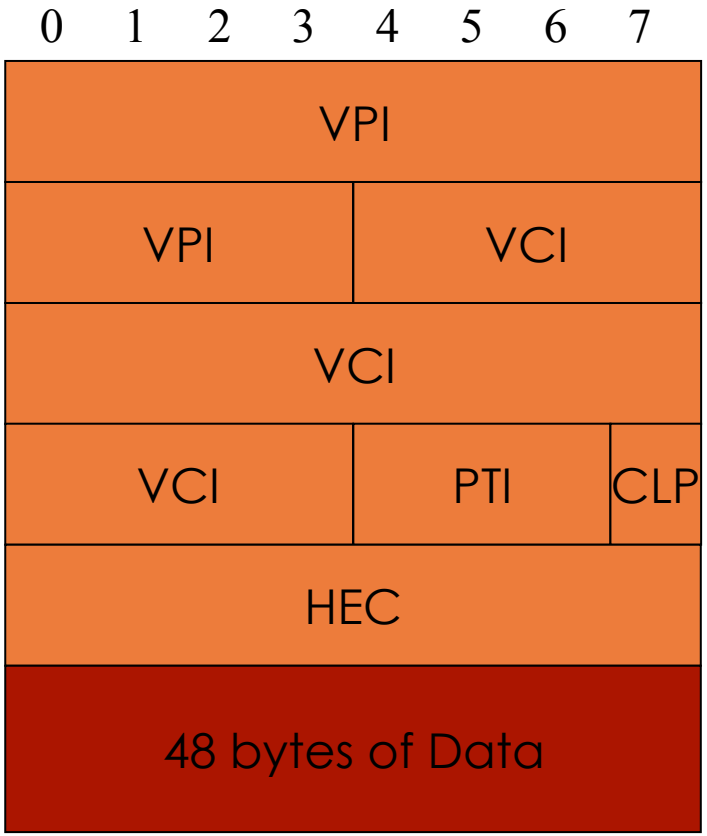


Cell Format

UNI Cell (User-Network Interface)



NNI Cell (Network-Network Interface)

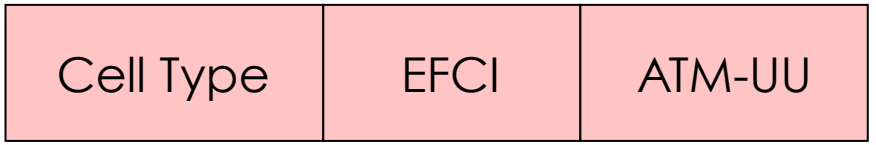


Cell Format

- GFC (Generic Flow Control) allows the multiplexing of several terminals transmissions in the same UNI interface
- An ATM connection is called a VCC (Virtual Channel Connection)
  - VPI (Virtual Path Identifier)
  - VCI (Virtual Channel Identifier)
  - VPI/VCI is called ATM label or connection identifier (CI – Connection Identifier)

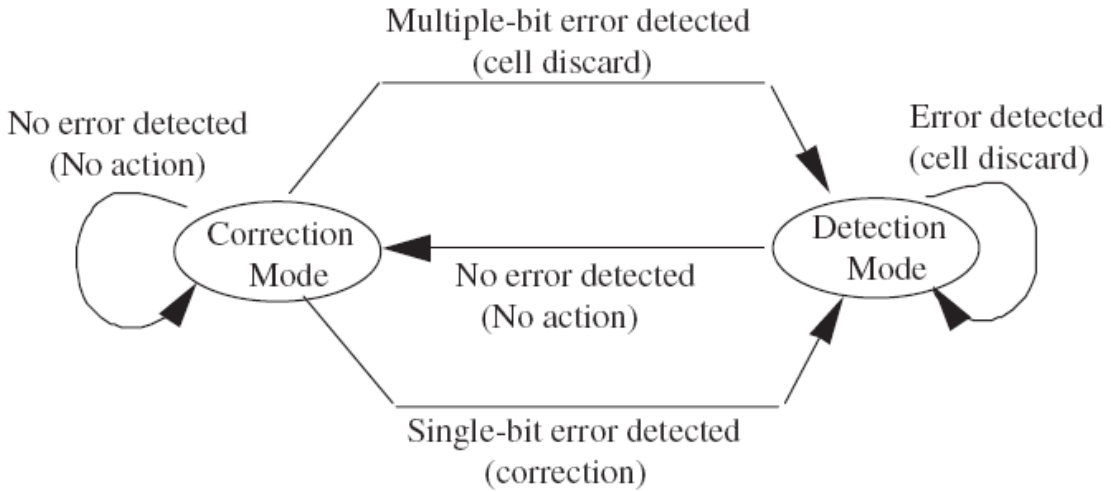
Cell Format

- PTI (Payload Type Indicator)
  - Cell type
    - 1: OAM Cell(Operation, Administration, and Maintenance)
    - 0: User Data Cell
- EFCI (Explicit Forward Congestion Indication)
  - 1: Congestion
  - 0: No congestion
- ATM-UU
  - Can be used by AAL-5
  - 1: Last segment
  - 0: Not the last segment



Cell Format

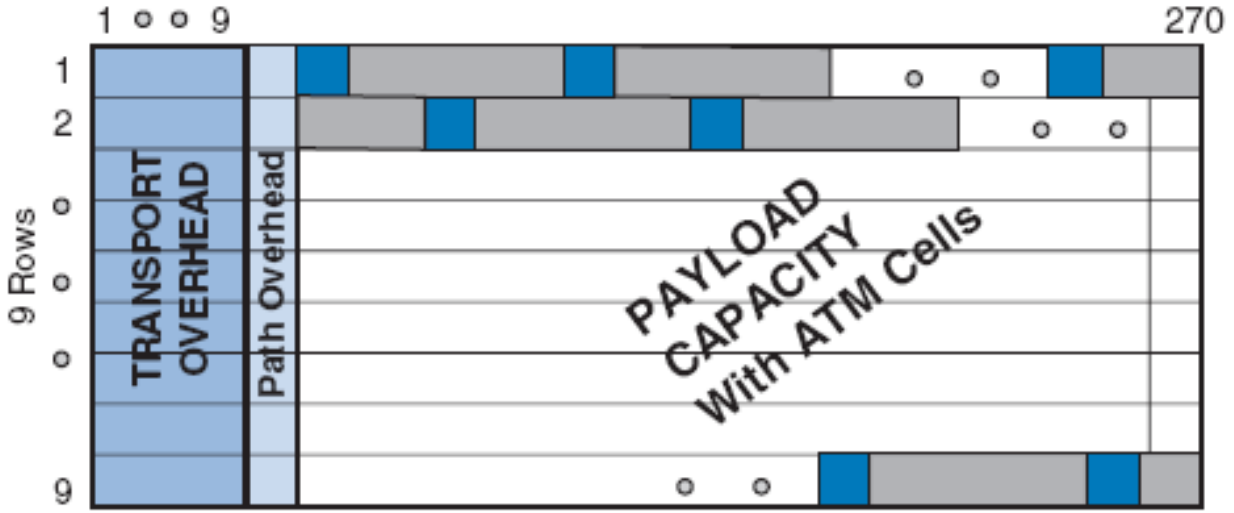
- CLP (Cell Loss Priority)
  - 1 Cell can be lost
  - 0 Important cell
- HEC (Header Error Control)
  - CRC (Cyclic Redundancy Control)
    - Polynomial generator $x^8 + x^2 + x + 1$
  - Detect and correct the binary errors
  - Used for the cell's delimitation



Physical layer (1)

- Transmission Convergence Sub-layer (TC)
  - Converts the flow of ATM cells into bit stream
  - Decoupling of cell rate
    - Insertion of idle cells (VPI = VCI = PTI = CLP = 0) to maintain the continuous bit stream expected from PM
  - Generation and verification of the HEC field
  - Transmission frame generation in the case of frame-based physical layer (e.g., SONET/SDH frame: payload capacity of 2340 Bytes)

Physical layer (2)



- Physical Medium Sub-layer
  - Transforms the bit stream from the TC sub-layer into signals adapted for the medium transmission

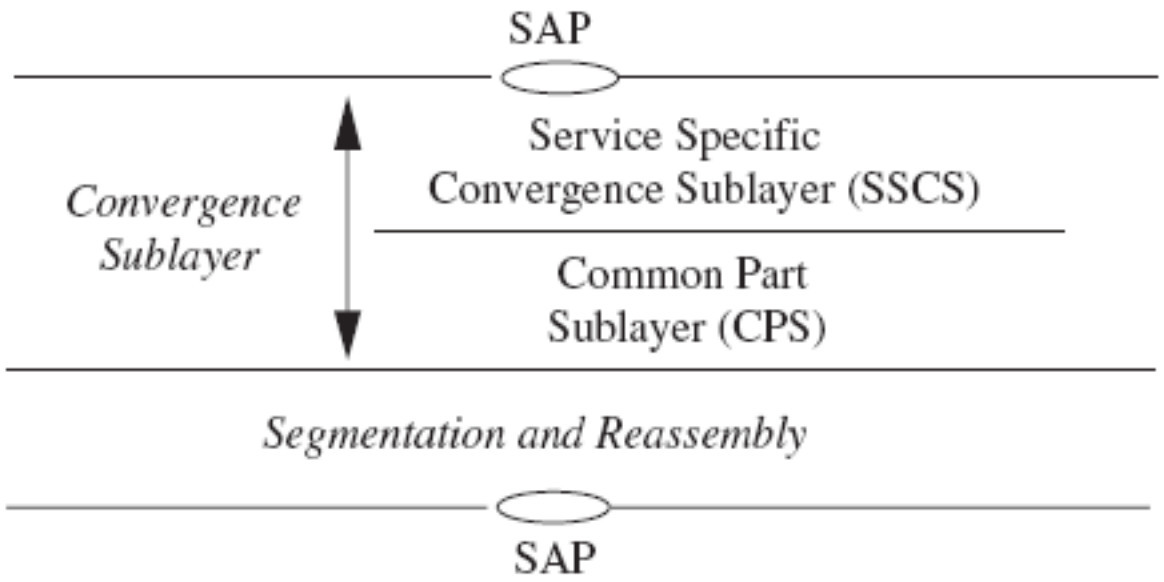
Classes of service

<table>
<tr><td>Class A</td><td>Class B</td><td>Class C</td><td>Class D</td></tr>
<tr><td>CBR</td><td colspan="3">VBR</td></tr>
<tr><td colspan="2">Source/Destination : synchronous</td><td colspan="2">Source/Destination : Non-synchronous</td></tr>
<tr><td colspan="3">Connection oriented</td><td>No connection oriented</td></tr>
<tr><td rowspan="2">AAL1</td><td rowspan="2">AAL2</td><td>AAL3</td><td>AAL4</td></tr>
<tr><td colspan="2">AAL5</td></tr>
</table>

Classes of service

- Constant bit rate (CBR)
  - Real time and constant bit rate applications
- Real-time variable bit rate (RT-VBR)
  - Real time and variable bit rate applications
- Non-real-time variable bit rate (NRT-VBR)
  - Non real time but sensitive to delay applications
- Available bit rate (ABR)
  - Applications able to adapt the bit rate depending on the networks conditions
- Unspecified bit rate (UBR)
  - Applications with no constraints
- Guaranteed frame rate (GFR)
  - Applications needing a minimal guaranteed bit rate.

AAL Layer


SAP
Service Specific
Convergence Sublayer (SSCS)
Convergence
Sublayer
Common Part
Sublayer (CPS)
Segmentation and Reassembly
SAP

AAL Layer

- Convert traffic from higher-level layer to ATM payloads and provide different types of services to the higher-level layer
- Two sub-layers
  - Convergence Sublayer (CS)
    - Provide service specific functions
      - SSCS (Service-Specific Convergence Sub-layer)
      - CPS (Common Part Sub-layer)
  - SAR (Segmentation And Reassembly)
    - During the transmission, upper sub-layer data blocks are segmented into blocks whose sizes are adapted to the transmission in the data field of the ATM cell
    - Those blocs are reassembled at the receiver

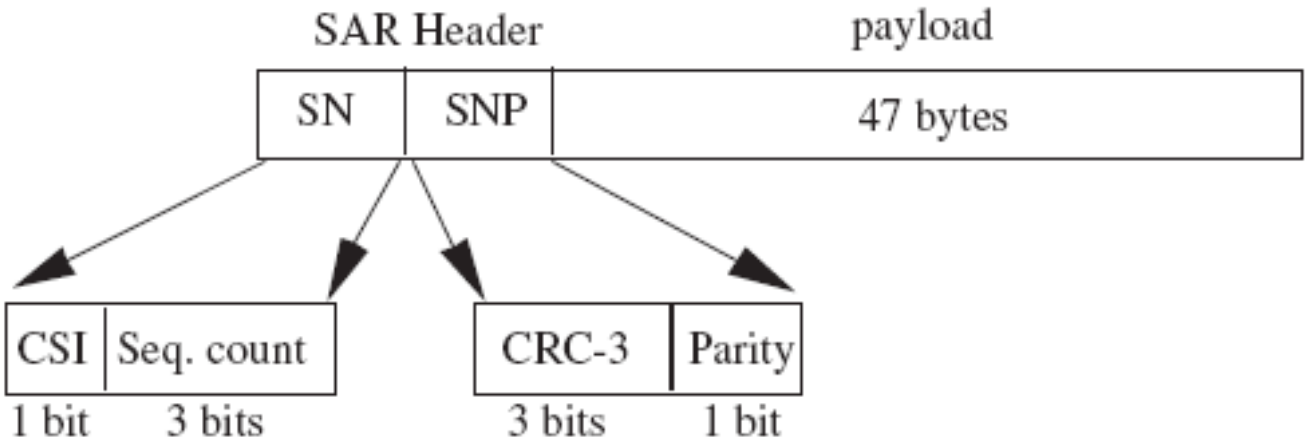
AAL Layer

- AAL-1
  - For the CBR class applications
- AAL-2
  - For the VBR class applications
- AAL-3/4
  - Connectionless mode service. Not used.
- AAL-5
  - For the UBR, ABR et GFR class applications

AAL-1

- Transfer the CBR class traffic (circuit emulation, CBR video, high quality CBR audio)
  - Transfer and delivery at a constant bit rate
    - Delay variation is smoothed by delaying cells in buffers at the reception
  - Transfer of timing information between the sending and receiving application
    - Transfer the source clock frequency to the receiver
  - Detect lost or misrouted cells
- Contains two sub-layers
  - CS
    - Handle cell delay variation and delivery at the same bit rate
    - Transfer of timing information
    - Manage the data sequence
  - SAR
    - Detection and correction of binary errors.

AAL-1 SAR-PDU

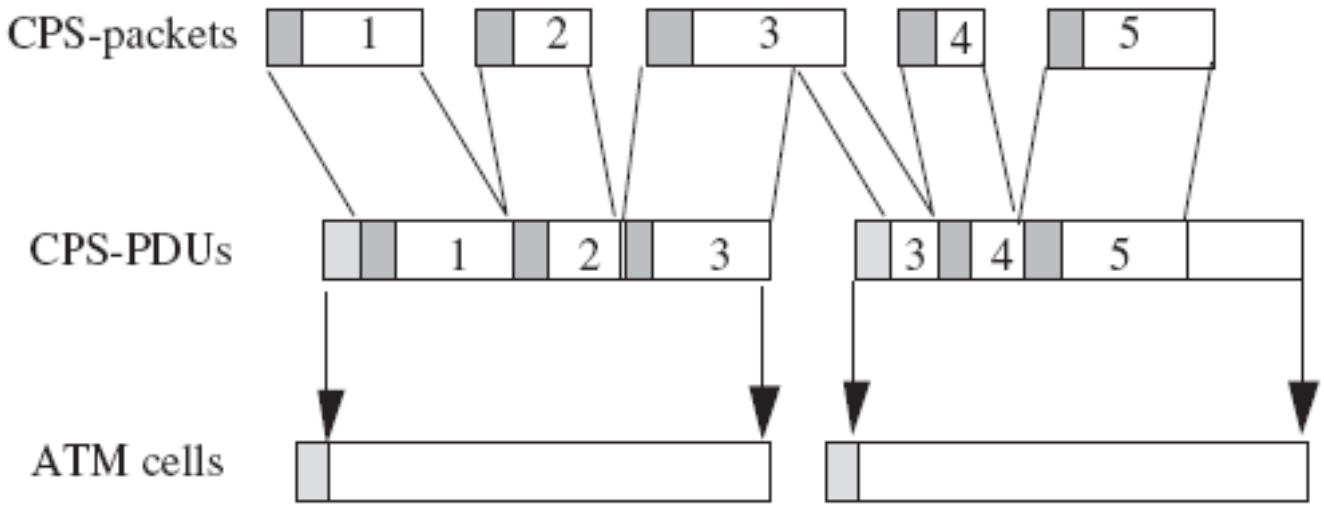


SN : Sequence Number
SNP: Sequence Number Protection
CSI: Convergence Sublayer Indication (0)
Sequence count: Detect lost cells or wrong inserted ones
CRC-3 : Computed for CSI and Sequence count fields
Parity: Even parity bit computed for CSI, Sequence count and CRC-3 fields

AAL-2

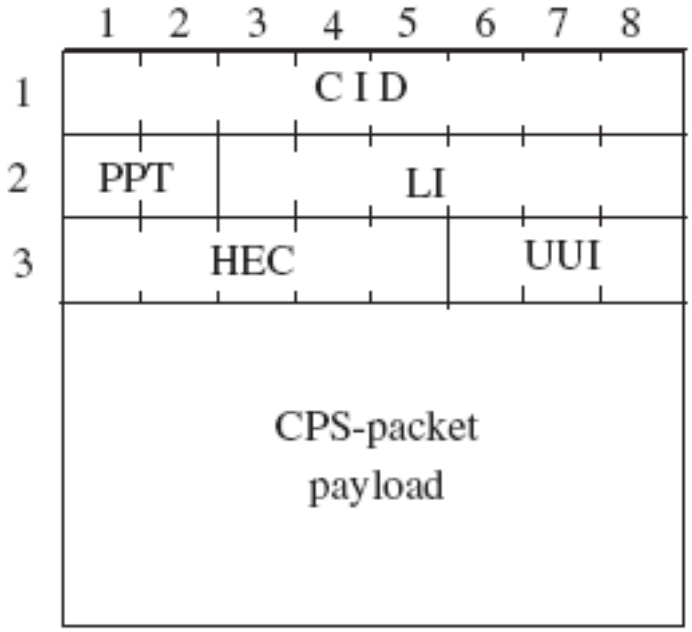
- For low variable bit rate applications that are sensitive to delay (voice, fax)
- Used specially for the cellular telephony (UMTS, for example)
- Allows to multiplex low variable bit rate flows into a single ATM connection and demultiplexes them back to the individual data streams at the receiving side
- Contains one sub layer
  - CS with SSCS (Service Specific Convergence Sublayer) and CPS (Common Part Sublayer)
  - No SAR

Flow Multiplexing in an ATM connection



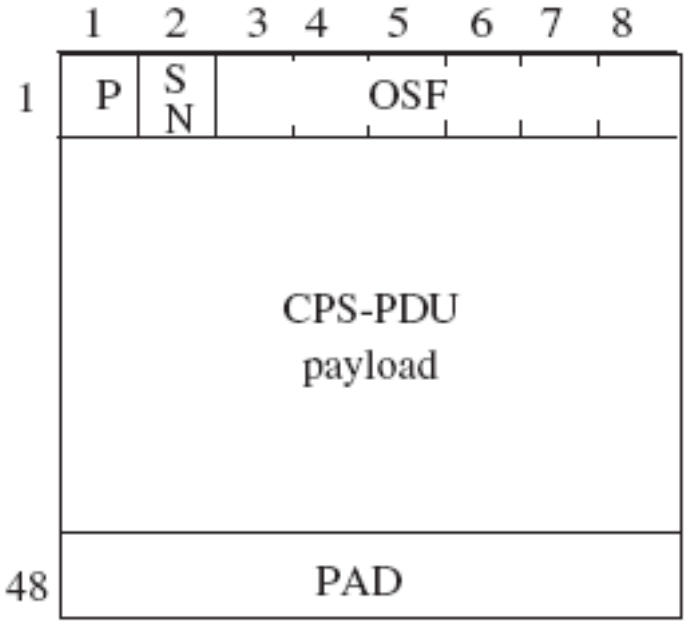
Packing CPS-packets into CPS-PDUs

CPS and CPS-PDU Packets



CPS-packet

CID : Channel Identifier
LI : Length Indicator [byte]
PPT : Packet Payload Type
UUI : User-to-User Indication



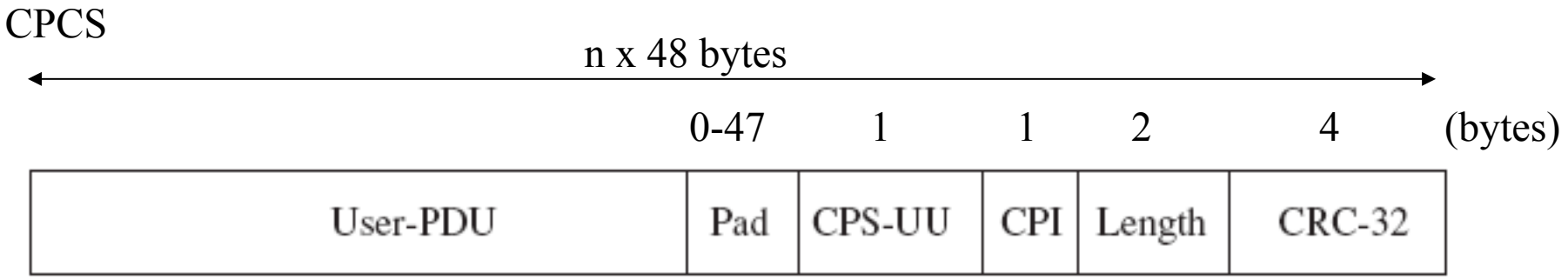
CPS-PDU

HEC : Header Error Control ($x^5 + x^2 + 1$)
P : Parity bit (odd)
SN : Sequence Number
OSF : Offset Field

AAL-5

- Due to its simplicity, it is the most popular AAL used for data transfer
- Two sub-layers
  - CS with CPCS (Common Part Convergence Sub-layer): CPCS-PDU length a multiple of 48 octets
  - SAR
    - SAR-PDU is a segment of 48 octets without header/trailer added
    - ATM-UU bit of the PTI field is used to start the reassembly procedure of the CPCS-PDU (i.e., each ATM cell that carries a segment of a CPCS-PDU has its ATM-UU = 0, except the ATM cell that carries the last segment of the CPCS-PDU whose PTI field contains the indication ATM-UU = 1)

AAL-5



- Data size: 1 to 65535 bytes
- Padding for the total length is a multiple of 48 bytes.
- UU (User to User) used to transfer transparently CPS user-to-user information
- CPI initialized to 0 (to support future AAL5 functions)
- Length in bytes of the CPS-PDU payload (i.e., User-PDU)
- CRC for error control calculated over the entire contents of the CPS-PDU (i.e., User-PDU, Pad, CPS-UU, CPI and Length)

Traffic Control

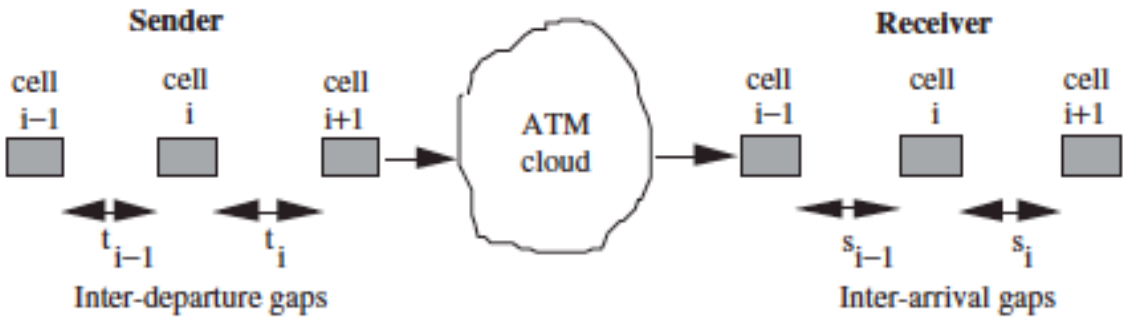
- *Traffic contract* is negotiated between the user and the network
  - Definition of the traffic parameters
- Two necessary functions for the traffic control
  - Connection Admission Control (CAC)
  - Usage Parameter Control (UPC)
    - Surveillance of the contract parameters during the data transfer phase

Traffic Parameters

- Peak Cell Rate (PCR)
  - The peak rate of the connection
- Sustained cell rate (SCR)
  - The upper limit of the connection average rate
  - Average bit rate <= SCR <= Peak Rate
- Minimum Cell Rate (MCR)
  - Minimal bit rate
- Initial Cell Rate (ICR)
  - Data rate at the beginning or after an idle period
- Maximum burst size (MBS)
  - The maximum number of consecutive cells that can be sent at peak rate
- Cell Delay Variation Tolerance (CDVT)
  - Tolerance to delay variations

QoS Parameters

- Cell Loss Ratio (CLR)
  - Rate of lost cells
- Cell Transfer delay (CTD)
  - Average transfer delay between UNIs
- Cell delay variation (CDV)
  - The variability of cell transfer delay
  - Impact on the jitter
- Example
  - CLR = 10^{-6}
  - CDV = 3 ms
  - Max CTD = 20 ms



Traffic and QoS parameters for the ATM classes of service

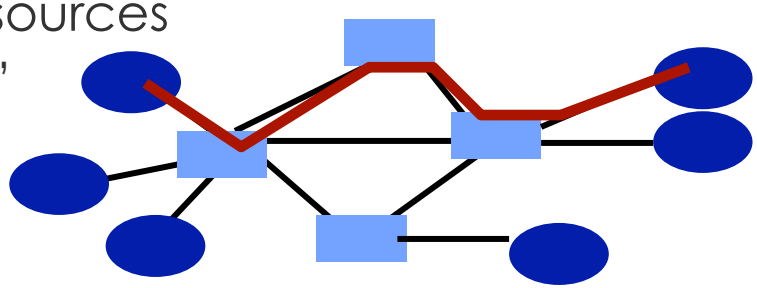
- Service CBR : constant bit rate
  - Traffic: PCR, CDVT
  - QoS: CLR, CDV, CTD
  - Example: telephone – video traffic
- Service RT-VBR : sporadic flow with controlled delay variation
  - Traffic: PCR, SCR, MBS, CDVT
  - QoS: CLR, CDV, CTD
  - Example: compressed video traffic
- Service NT-VBR: sporadic flow with delay variation control
  - Traffic: PCR, CDVT, SCR, MBS
  - QoS: CLR
  - Examples: airline reservations, banking transactions

Traffic and QoS parameters for the ATM classes of service

- Service UBR : Best effort
  - No required parameters
  - Example: Internet IP traffic
- Service ABR : Minimum guaranteed bit rate and peak rate not guaranteed
  - Traffic: PCR, MCR, ICR
  - QoS: CLR
  - Example: sporadic traffic with minimal bandwidth directly available
  - Only class that uses congestion control

Connection Admission Control

- Takes place at circuit set-up
- Source sends a reservation message
  - Example: "this virtual circuit needs 5 Mbps"
- Each switch along the path
  - Keeps track of the reserved resources
    - Example: "the link has 6 Mbps left"
  - Checks if enough resources remain
    - Example: "6 Mbps > 5 Mbps, so circuit can be accepted"
- Creates state for circuit and reserves resources
  - Example: "now only 1 Mbps is available"



Connection Admission Control

- Deterministic Multiplexing
  - Peak rate characterization
  - Set the capacity of the VPC equal to the total of the peak data rates of all the VCCs within the VPC

$$\sum_{i=1}^{r} n_i d_i < C$$

- Statistical Multiplexing
  - Characterization by the effective bandwidth (Intermediate value between the maximum rate and the average rate)
  - Group VCCs into VPCs on the basis of similar traffic characteristics and similar QoS requirements.

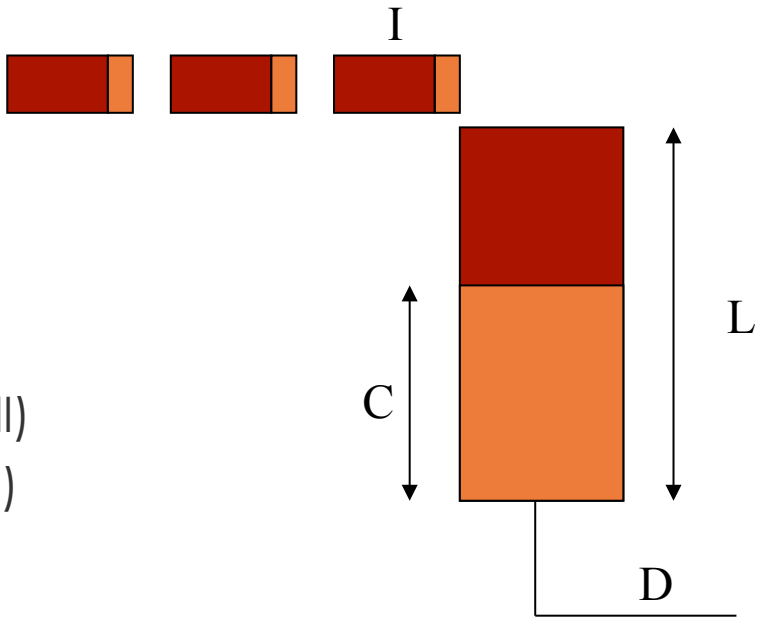
$$\sum_{i=1} n_i d_i^e < C$$

User Parameter Control

- Detect every traffic contract violation and take the required actions
- Only the peak rate has to be controlled
- For the other traffic descriptor parameters, CAC decides which ones have to be controlled
- UPC implementation mechanisms
  - Leaky Bucket
  - GCRA (T, τ) Generic Cell Rate Algorithm
    - 1/T : controlled cell rate (T = 1/PCR)
    - τ : cell propagation time tolerance

Leaky Bucket

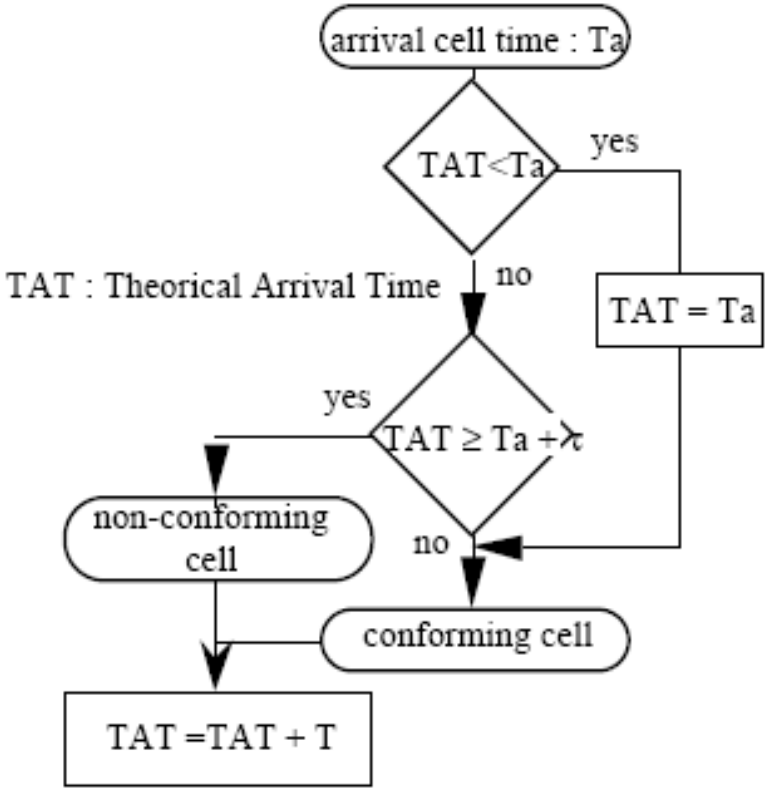
- Leaky bucket
  - variable C: Size of the bucket at time t
  - constant L : Maximal bucket capacity
  - constant D : leaking rate
  - constant I : burst size
- Algorithm
  - initialization : C=0
  - Cell arrival :
    if C+I < L ***then*** C = C+I (conforming cell)
    else overflowing (non-conforming cell)
  - Periodically (T) : C= C-D (if C ≠ 0)



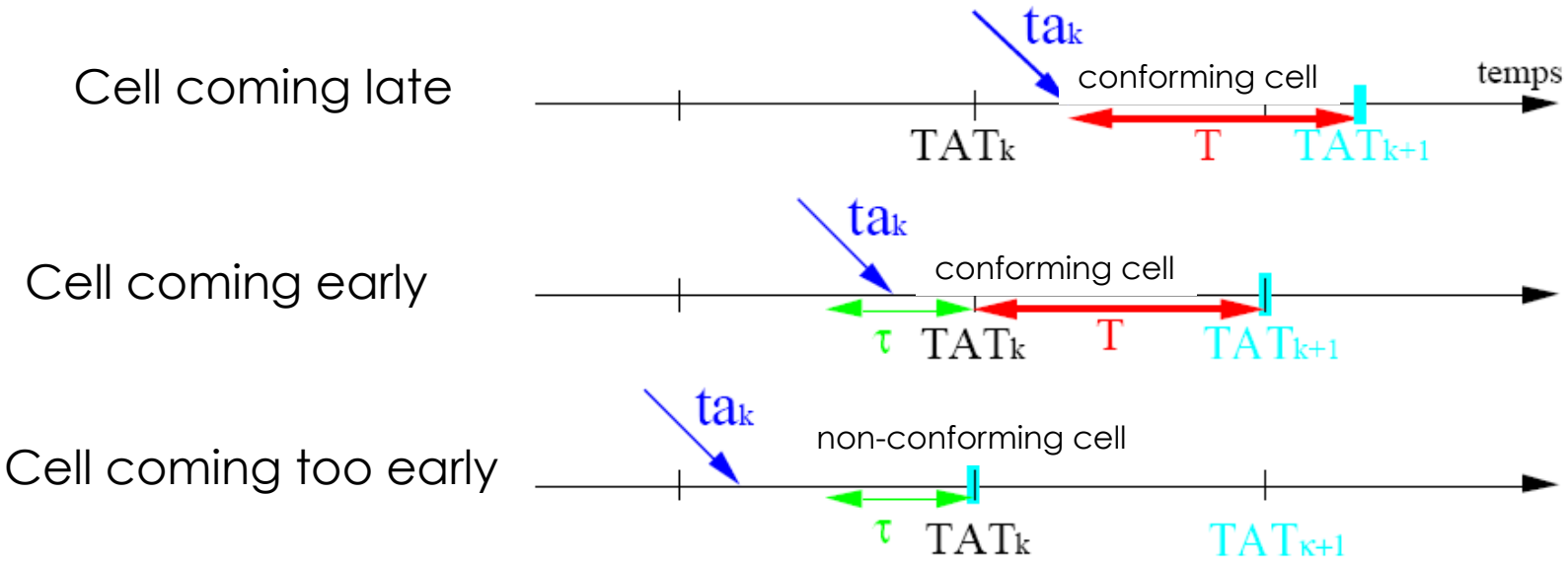
GCRA

- Used to verify the conformity of the user' transmissions with the contract
- It operates on the basis of the peak cell rate PCR and a CDVT tolerance limit of τ
- Monitor the rate at which cells arrive and to assure that the inter-arrival time is not too short to cause the flow to exceed the PCR by an amount greater than the tolerance limit
- Consider 2 consecutive cells c1 and c2 received at time t1 and t2
  - If (t2 – t1) >= 1/PCR : c2 accepted
  - Else if (t2 – t1) > 1/PCR – CDVT : c2 accepted
  - Else : c2 rejected

GCRA


arrival cell time : Ta
TAT<Ta
yes
TAT : Theorical Arrival Time
no
TAT = Ta
yes
TAT ≥ Ta +τ
non-conforming cell
no
conforming cell
TAT =TAT + T

GCRA (T, τ) : example



Ta : Cell arrival time
TAT : Theoretical cell arrival time
1/T : controlled data rate
τ : cell delay tolerance

Other mechanisms of Traffic control: Selective Reject

- QoS different for CLP = 0 and CLP = 1
  - Partial Buffer Sharing
    - CLP0 can always enter
    - CLP1 can enter if number < S
- Push Out
  - CLP0 and CLP1 can enter in the buffer
  - If the buffer is full
    - CLP1 rejected
    - CLP0 replace CLP1 if possible

Congestion Control

- Goal: Minimize the congestion consequences by reducing its duration …
- Available for ABR flow
  - RM Cells (Resource Management) with PTI = 110 sent by the source to the destination
  - Transmitted every 32 cells
  - Make a round trip between the sender and the receiver
    - Intermediate switch along the path can insert feedback control info
    - The source uses this information for managing (i.e. increasing or decreasing) its transmission rate
  - Congestion
    - PTI EFCI = 1 for data packets

Congestion Control

- During an effective congestion, cells to be destroyed have to be chosen (Selective Reject)
  - Cells with low priorities (CLP = 1)
  - Cells marked by the UPC that do not respect the traffic contract (CLP = 1)
- Less important connection cells
  - Traffic connection UBR
  - Connection having the highest CLR