

# Quality of Service in ATM Networks

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## Components of a QoS Network

	in ATM
1. At network entrance: <b>Policing and Shaping</b> →	UPC: Usage Parameter Control
2. Somewhere in the network: <b>Admission Control</b> →	CAC: Connection Admission Control (not standardized)
3. At switches: <b>Classification, Scheduling</b> →	Not standardized, left to vendors
4. Between hosts and routers: <b>Signaling</b> →	Signaling standards (Q.2931)

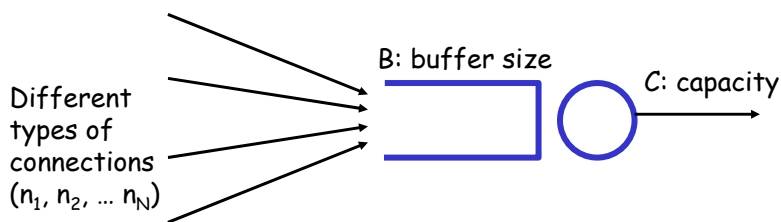
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## Connection Admission Control (CAC)

- **Tasks:**
  - Determine how much system resources are required for a new VC
  - Determine whether these resources are available.
  - Accept or reject the VC request
- **Goals of CAC:**
  - Maximize network utilization
  - Guarantee QoS characteristics for all VCs
- No standards defined in this area
- Most CAC algorithms use an **Equivalent Bandwidth** approach
  - QoS parameters are reduced to a single quantity
  - CAC calculates the Equivalent Bandwidth needed by a VC for given traffic and QoS parameters
  - Network must reserve this bandwidth end-to-end for the VC

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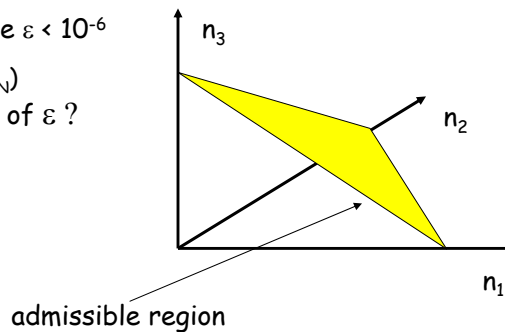
## Connection Admission Control (CAC)



QoS parameters: Loss rate  $\varepsilon < 10^{-6}$

Which values of  $(n_1, n_2, \dots, n_N)$  do not result in a violation of  $\varepsilon$ ?

Find admissible region for set of connections



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## ATM Services at the ATM Layer

The following ATM services have been defined:

Constant Bit Rate (CBR)

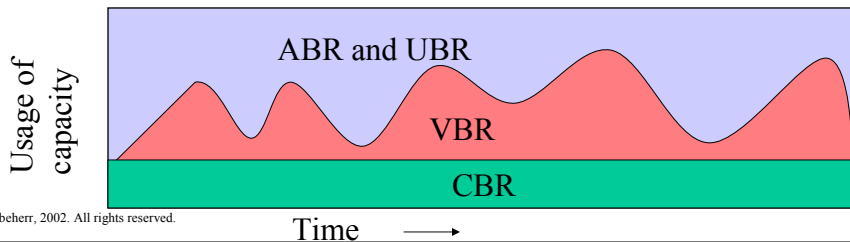
Real-time Variable Bit Rate (rt-VBR)

Non-real-time Variable Bit Rate (nrt-VBR)

Available Bit Rate (ABR)

Unspecified Bit Rate (UBR)

Guaranteed Frame Rate (GFR)



## ATM Layer

The ATM Layer can provide a variety of services for cells from an ATM virtual connection:

- **Constant Bit Rate (CBR)**
  - guarantees a fixed capacity, similar to circuit switching
  - guarantees a maximum delay for cells
- **Variable Bit Rate (VBR)**
  - guarantees an average throughput and maximum delay
- **Available Bit Rate (ABR)**
  - guarantees "fairness" with respect to other traffic
- **Unspecified Bit Rate (UBR)**
  - service is on a "best effort" basis
- **Guarantees Frame Rate (GFR)**
  - Throughput guarantee for multiple cell frames

# Traffic Specification in ATM

## ATM Terminology

Peak Cell Rate (PCR)  
Sustained Cell Rate (SCR)  
Maximum Burst Size (MBS)

Cell Delay Variation Tolerance (CDVT)  
Minimum Cell Rate (MCR)  
Maximum Frame Size (MFS)

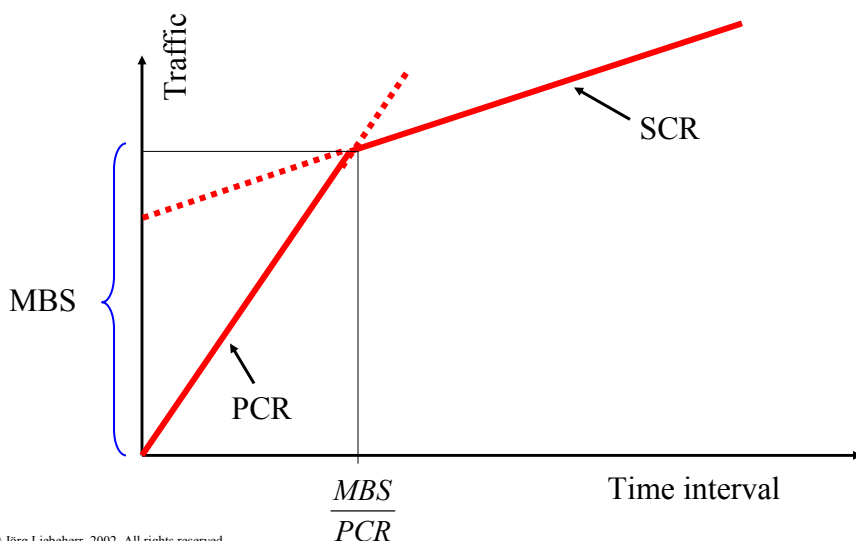
## Interpretation

Maximum rate  
Maximum average rate  
Max. number of cells that can be sent at peak rate

Delays variation introduced when sending cells  
Minimum rate  
Maximum number of cells in a frame

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# Traffic Conditioning



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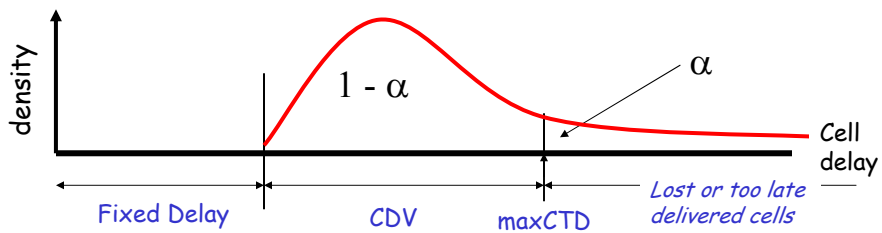
# QoS Parameters in ATM

## ATM Terminology

Cell Loss Rate (CLR)  
 Max. Cell Transfer Delay (maxCTD)  
 Peak-to-peak Cell Delay Variation (peak-to-peak CDV)

## Interpretation

↔ Lost cells/transmitted cells  
 ↔ Worst-case end-to-end delay  
 ↔ Range of delays



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# ATM Network Services

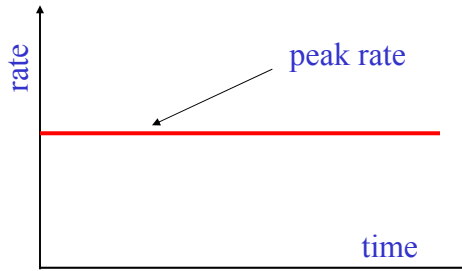
Service	Traffic Parameters		QoS Parameters		
	Bandwidth	Burst Size	Loss	Delay	Jitter
CBR	PCR		CLR	maxCTD	CDV
rt-VBR	PCR, SCR	MBS	CLR	maxCTD	CDV
nrt-VBR	PCR, SCR	MBS	CLR		
ABR	PCR, MCR		low		
UBR	PCR*				
GFR	PCR, MCR, MBS, MFS		low		

- CDVT characterizes an interface and is not connection specific
- PCR in UBR is not subject to CAC or UPC

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## Constant Bit Rate (CBR)

- For applications with constant rate requirements: video and audio
- Very sensitive to delay and delay variations
- Adaptation Layer: AAL1



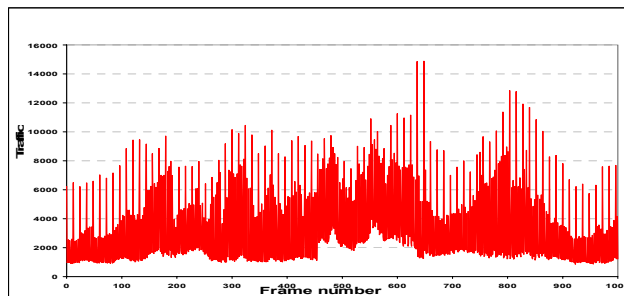
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## Variable Bit Rate (rt-VBR, nrt-VBR)

- For applications with variable rate requirements: compressed audio and video (rt-VBR) data applications (nrt-VBR), such as transactions
- Adaptation Layer: AAL2, AAL 3 / 4, AAL5

Example: 30 sec  
MPEG-1 trace (from  
Terminator)

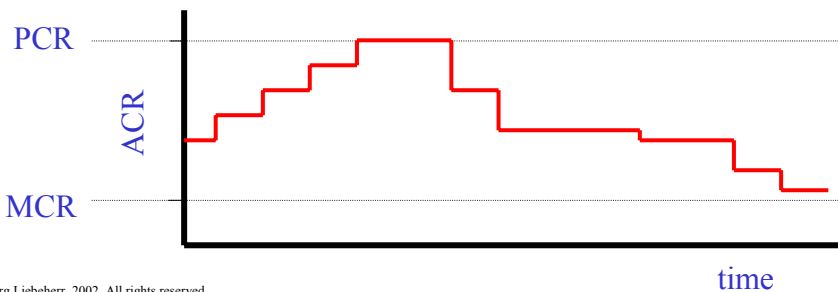
- Peak rate: 1.9 Mbps
- Avg. rate: 0.261 Mbps



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## Available Bit Rate (ABR)

- For applications that can tolerate changes to rate  
Interconnection of LANs
- Transmission rate (ACR) changes between MCR and PCR
- ACR is set by a feedback algorithm (to be discussed)
- Adaptation Layer: AAL 5



## Unspecified Bit Rate (UBR)

- "Best effort service"
  - No bandwidth, loss, or delay guarantees
  - UBR gets the bandwidth that is not used by CBR, VBR, ABR
- No UPC and no feedback
- Applications: Non-critical data applications (file transfer, web access, etc.)
- Adaptation Layer: AAL5

## Usage Parameter Control (UPC)

- UPC = Traffic Conditioning in ATM
  - It is usually done at the User-Network Interface (UNI), but can be done at any switch
  - Can be done at both VP and VC levels
- UPC is performed by the **Generic Cell Rate Algorithm (GCRA)**
- GCRA is based on the concept of a **leaky bucket**

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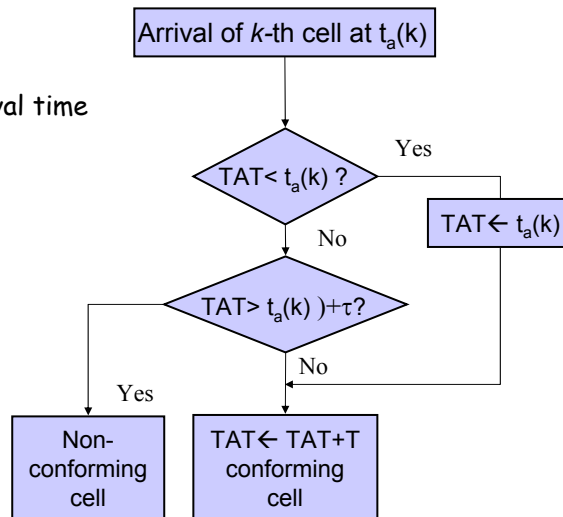
## GCRA: Generic Cell Rate Algorithm

### GCRA( $T, \tau$ )

- $t_a(k)$ : arrival of  $k$ -th cell
- TAT: Theoretical arrival time

So:

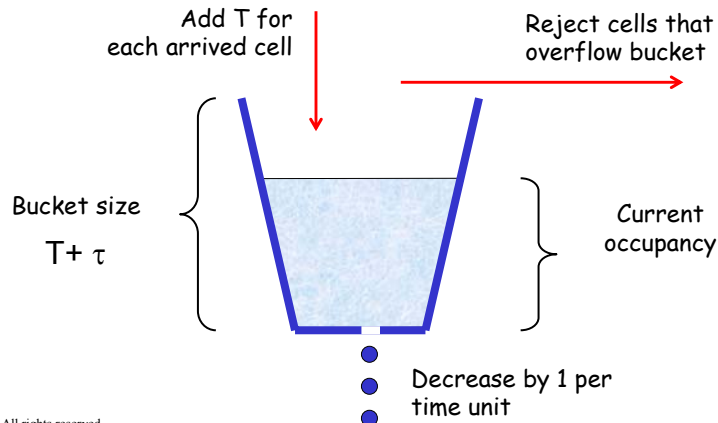
If next cell arrives  
before  $TAT - \tau$   
then  
Cell is conforming  
otherwise  
Cell is non-conforming



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## Leaky Bucket

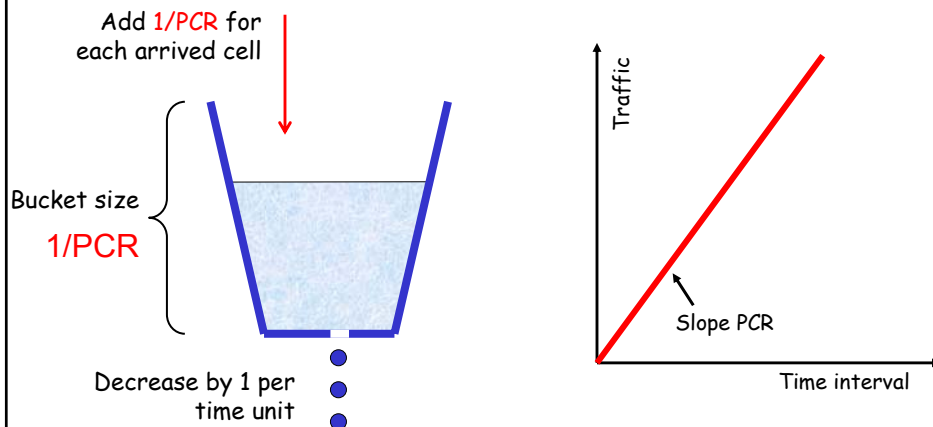
- GCRA ( $T, \tau$ ) can be represented by a Leaky bucket
- Initially, the bucket is empty



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## Enforcing Peak Cell Rate

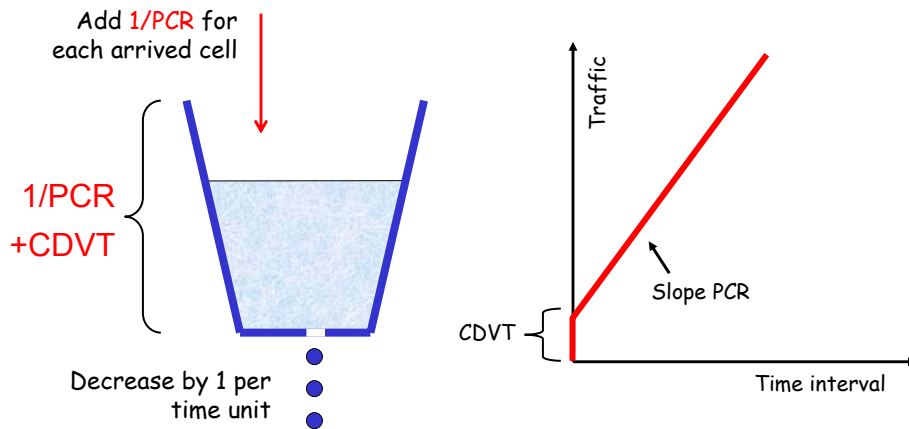
- PCR is enforced with **GCRA ( $1/PCR, 0$ )**



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## Enforcing Peak Cell Rate and CDVT

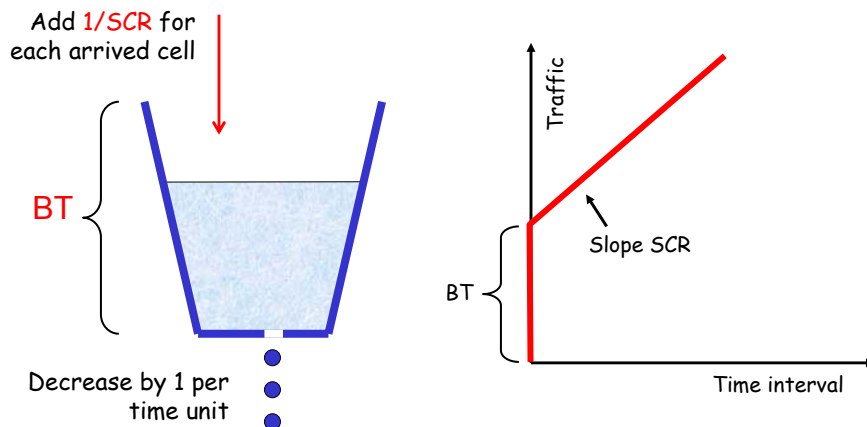
- PCR is enforced with **GCRA** ( $1/PCR$ ,  $CDVT$ )



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## Enforcing SCR and MBS

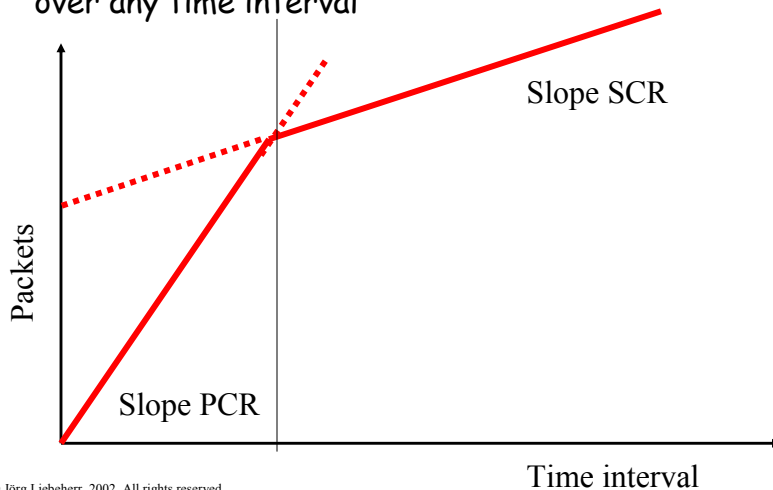
- PCR is enforced with **GCRA** ( $1/SCR$ ,  $BT$ )
- With  $BT = (MBS - 1) (1/SCR - 1/PCR)$



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## Enforcing PCR, SCR and BT

- Maximum traffic that is admitted by dual leaky bucket over any time interval



## UPC Policing

- A Connection can have two traffic profiles:
  - **CLP=0 profile**: traffic sent with CLP = 0
  - **CLP=0+1**: traffic sent with CLP=0 or 1
- Separate GCRA for CLP=1 and CLP=0+1:
  - CLP = 0 and cell conforms to CLP = 0 profile  
→ **cell is transmitted**
  - CLP = 0 and cell does not conform to CLP = 0 profile,  
but conform to CLP=0+1:  
→ **CLP is set and cell transmitted**
  - CLP = 1 and cell conforms to CLP = 0+1 profile:  
→ **cell is transmitted**
  - Cell does not conform to CLP=0+1 profile:  
→ **cell is dropped**

# UPC Policing

- CLP 0 cell:
  - Non-conforming cell: set CLP = 1 and test for CLP0+1 profile
- CLP 1 cell:
  - Non-conforming cells are discarded

