# ATM Traffic Management

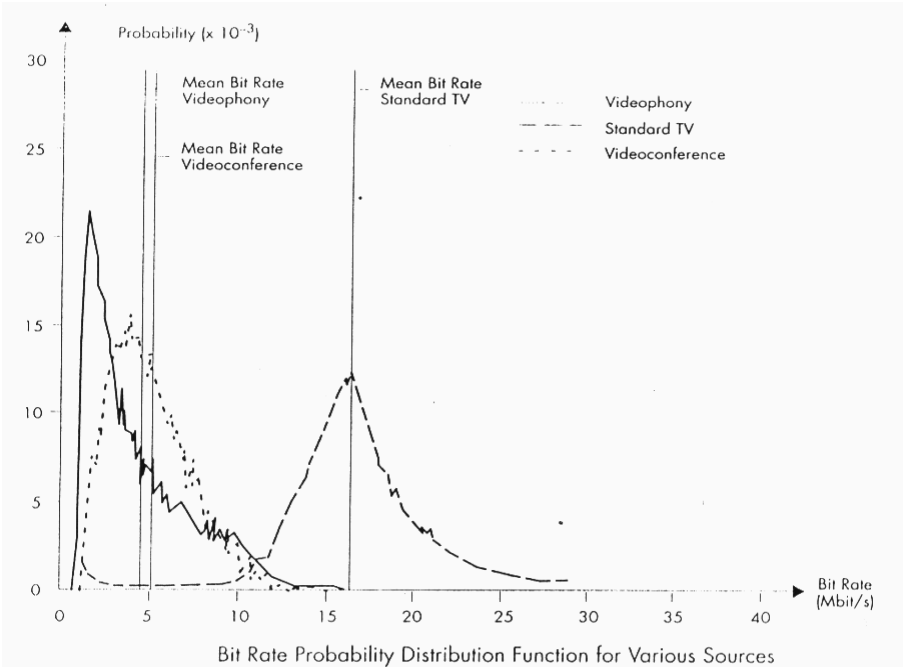


## References

- Traffic Management Specification. Version 4.0. ATM Forum. April 1996. (af-tm-0056-000.pdf)
- ITU-T I.371, I.356, I.150

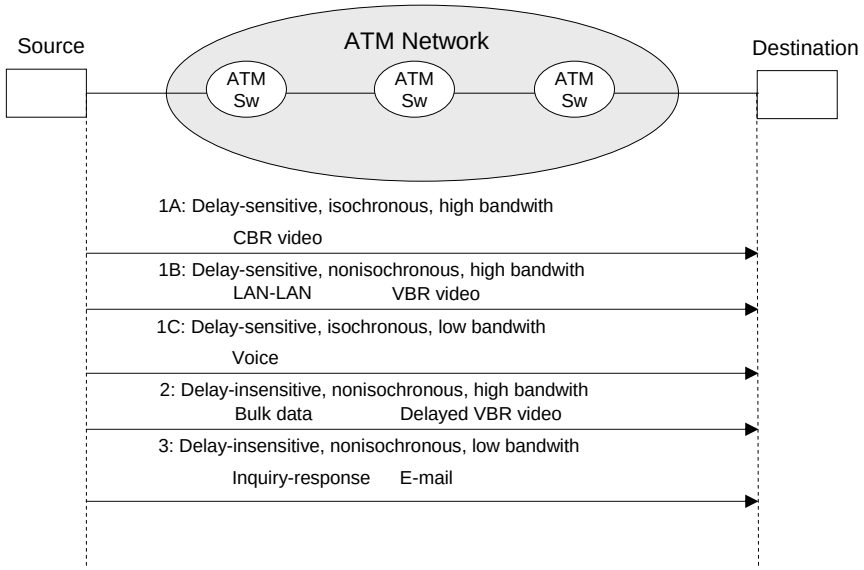
# ATM Traffic Management

- ATM Service Architecture
- ATM Layer Quality of Service
- Traffic Contract
- Generic Functions
- Functions and Procedure for Traffic Management

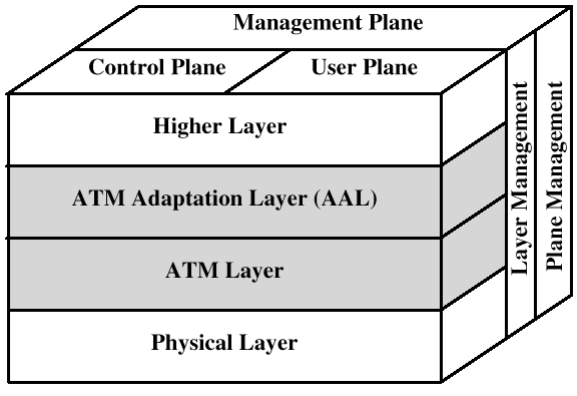


Bit Rate Probability Distribution Function for Various Sources

## Processing the payload at the receiver




## ATM Reference Model



# Service Classification for AAL

| | Class A | Class B | Class C | Class D |
|---|---|---|---|---|
| **Timing relation between source 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** | |



| Item | AAL 1 | AAL 2 | AAL 3/4 | AAL 5 |
|---|---|---|---|---|
| Service class | A | B | C/D | C/D |
| Multiplexing | No | No | Yes | No |
| Message delimiting | None | None | Btag/Etag | Bit in PTI |
| Advance buffer allocation | No | No | Yes | No |
| User bytes available | 0 | 0 | 0 | 1 |
| CS padding | 0 | 0 | 32-Bit word | 0–47 bytes |
| CS protocol overhead (bytes) | 0 | 0 | 8 | 8 |
| CS checksum | None | None | None | 32 Bits |
| SAR payload bytes | 46–47 | 45 | 44 | 48 |
| SAR protocol overhead (bytes) | 1–2 | 3 | 4 | 0 |
| SAR checksum | None | None | 10 Bits | None |

# ATM Classes of Service

- QoS classes (UNI 4.0)
  - Constant Bit Rate (CBR)
  - Variable Bit Rate - Real Time (rt-VBR)
  - Variable Bit Rate - Non Real Time (nrt-VBR)
  - Unspecified Bit Rate (UBR)
  - Guaranteed Frame Rate (GFR)
  - Available Bit Rate (ABR)



# ATM Service Categories

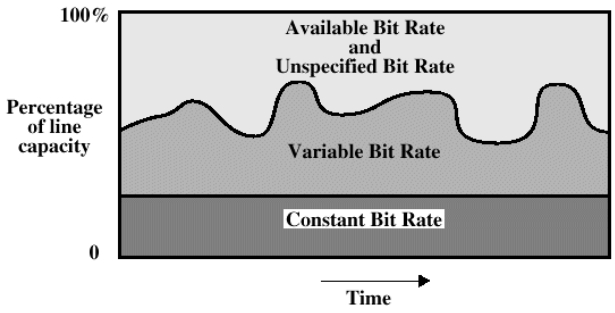
| Class | Description | Example |
|---|---|---|
| CBR | Constant bit rate | T1 circuit |
| RT-VBR | Variable bit-rate:real time | Real-time videoconferencing |
| NRT-VBR | Variable bit-rate:non-real time | Multimedia email |
| ABR | Available bit rate | Browsing the Web |
| UBR | Unspecified bit rate | Background file transfer |
| GFR | Guaranteed Frame Rate | Browsing the Web |

# Characteristics of the ATM service categories

| Service characteristic | CBR | RT-VBR | NRT-VBR | ABR | UBR |
|---|---|---|---|---|---|
| Bandwith guarantee | Yes | Yes | Yes | Optional | No |
| Suitable for real-time traffic | Yes | Yes | No | No | No |
| Suitable for bursty traffic | No | No | Yes | Yes | Yes |
| Feedback about congestion | No | No | No | Yes | No |



# ATM bit-rate services



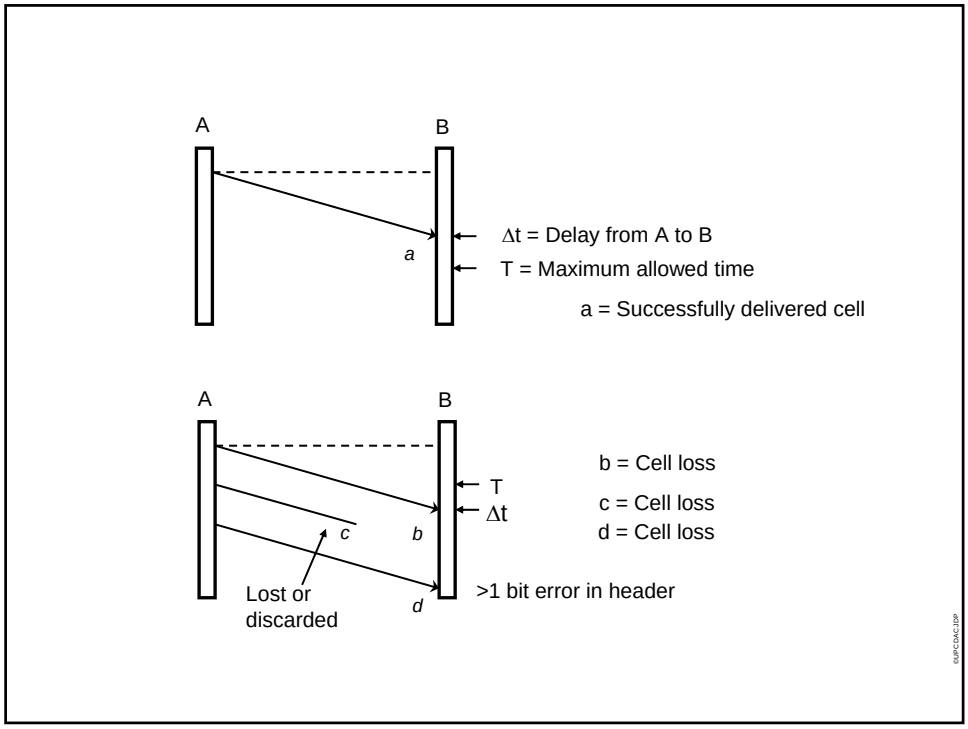
# ATM Traffic Parameters
(user)

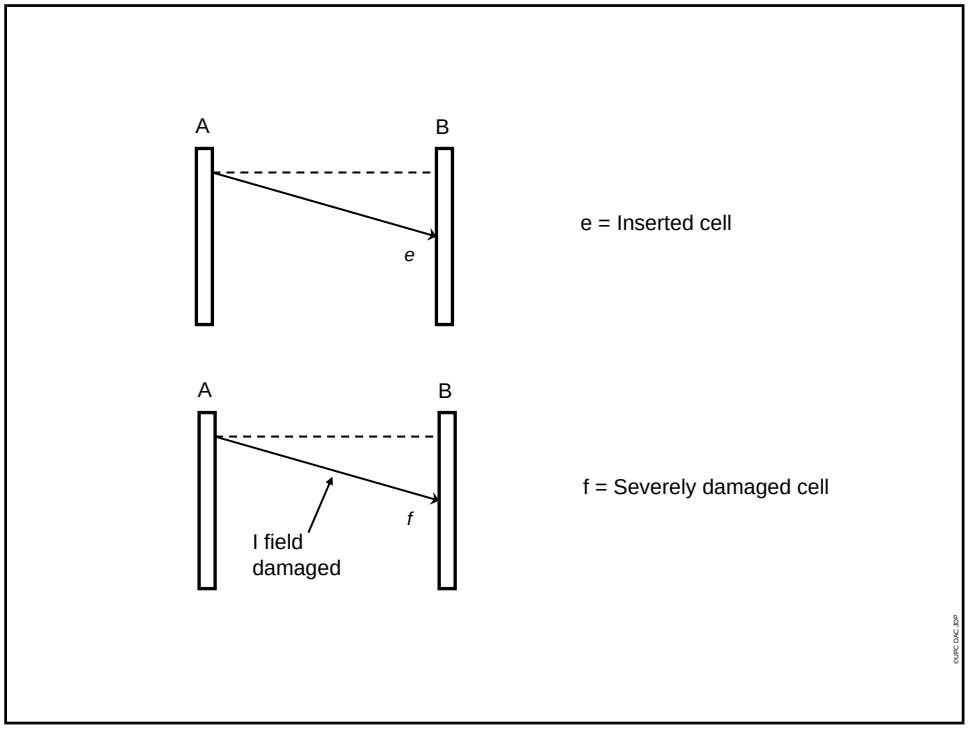
- Peak Cell Rate (PCR)
- Cell Delay Variation Tolerance (CDVT)
- Sustainable Cell Rate (SCR)
- Burst Tolerance (BT)
- Minimum Cell Rate (MCR), for ABR only



# ATM Quality of Service Parameters

| Parameter | Acron. | Meaning |
|---|---|---|
| Peak cell rate | PCR | Maximum rate at which cells will be sent |
| Sustained cell rate | SCR | The long-term average cell rate |
| Minimum cell rate | MCR | The minimum acceptable cell rate |
| Cell delay variation tolerance | CDVT | The maximum acceptable cell jitter |
| Cell loss ratio | CLR | Fraction of cells lost of delivered too late |
| Cell transfer delay | CTD | How long delivery takes (mean and max.) |
| Cell delay variation | CDV | The variance in cell delivery times |
| Cell error rate | CER | Fraction of cells delivered with error |
| Severely-errored c.block ratio | SECBR | Fraction of blocks garbled |
| Cell misinsertion rate | CMR | Fraction of cells delivered to wrong dest. |

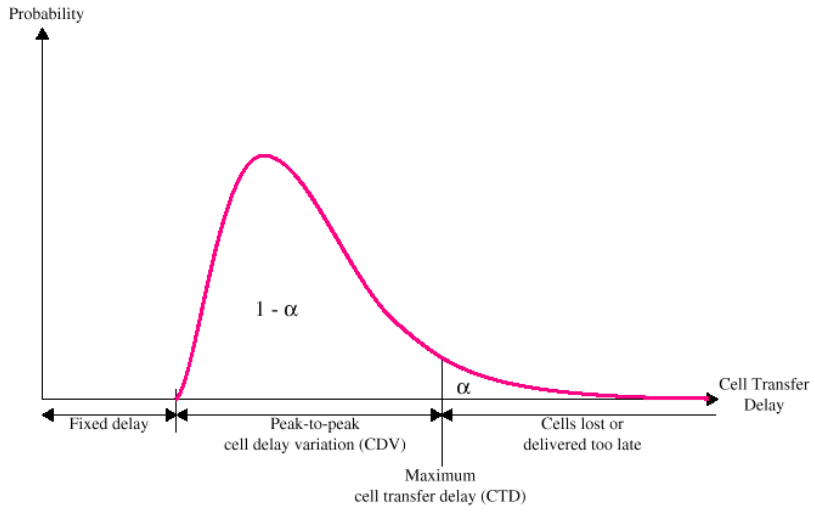

A
B
a
Δt = Delay from A to B
T = Maximum allowed time
a = Successfully delivered cell
A
B
T
Δt
c
b
d
Lost or
discarded
b = Cell loss
c = Cell loss
d = Cell loss
>1 bit error in header


A
B
e
e = Inserted cell
A
B
f
I field
damaged
f = Severely damaged cell

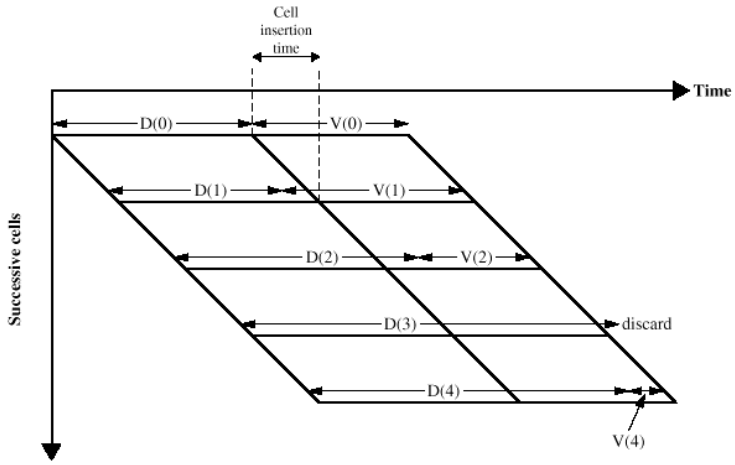
# ATM Quality of Service Parameters (network)

- Peak-to-peak cell delay variation (CDV)
- Maximum cell transfer delay (Max CTD)
- Mean cell transfer delay (Mean CTD)
- Cell loss ratio (CLR)

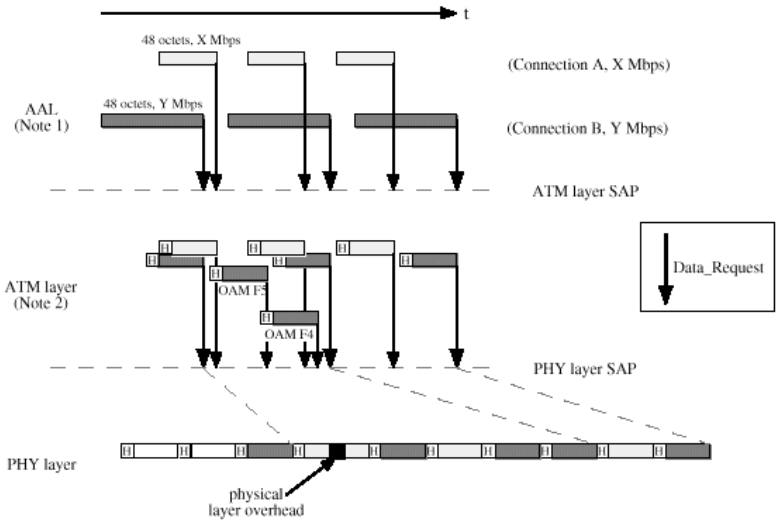
## Cell Transfer Delay probability density function



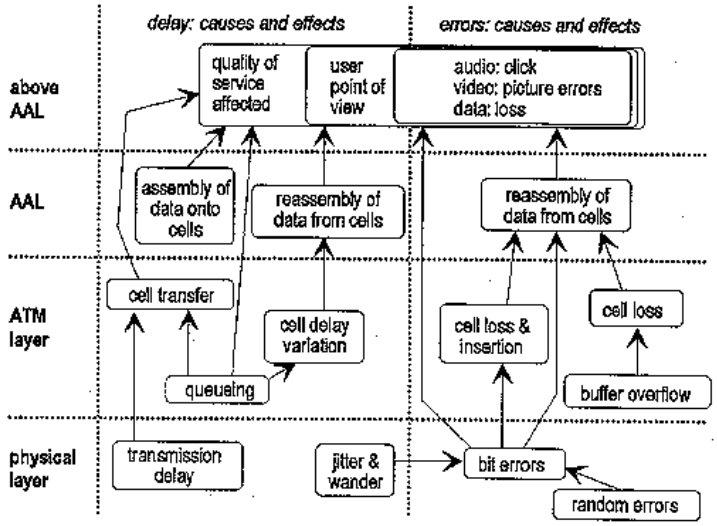
# Time reassembly of CBR cells




# Origins of cell delay variation (I.371)



# QoS in ATM Networks



## ATM Service Category Attributes

| Attribute | ATM Layer Service Category | | | | |
|---|---|---|---|---|---|
| | **CBR** | **RT-VBR** | **NRT-VBR** | **UBR** | **ABR** |
| **Traffic Parameters:** | | | | | |
| PCR and $CDVT_{PCR}(4,5)$ | specified | | | specified (2) | specified (3) |
| SCR, MBS, $CDVT_{PCR}(4,5)$ | n/a | specified | | n/a | |
| MCR (4) | n/a | | | n/a | specified |
| **QoS Parameters:** | | | | | |
| Peak-to-peak CDV | specified | specified | unspecified | | |
| maxCTD | specified | specified | unspecified | | |
| CLR (4) | specified | | | unspecified | (1) |
| **Other Attributes:** | | | | | |
| Feedback | unspecified | | | unspecified | specified (6) |



## ATM Service Category Attributes

1. CLR is low for sources that adjust cell flow in response to control information. Whether a quantitative value for CLR is specified is network specific.
2. May not be subject to CAC and UPC procedures
3. Represents the maximum rate at which the ABR source may ever send. The actual rate is subject to the control information.
4. These parameters are either explicitly or implicitly specified for PVCs or SVCs.
5. CDTV refers to the Cell Delay Variation Tolerance. CDVT is not signaled. Different values of CDVT may be specified for SCR and PCR. In general, CDVT need not have a unique value for a connection. Different values may apply at each interface along the path of a connection.

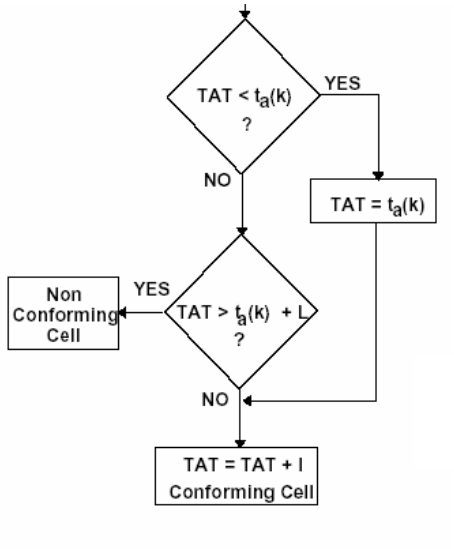
## Traffic management in ATM networks

- Source:
  - Traffic parameters
  - QoS class
  - Generates traffic according to contract
- Network
  - QoS parameters appropriate for QoS class
  - Enforce source traffic (UPC)

## Traffic Contract

- Traffic Parameters and Descriptors
- Traffic Contract Specification
- Cell conformance and Connection Compliance
- Traffic Contract Parameters and Related Algorithms (GCRA)
- Traffic Contract and Conformance Definitions

# Virtual scheduling algorithm

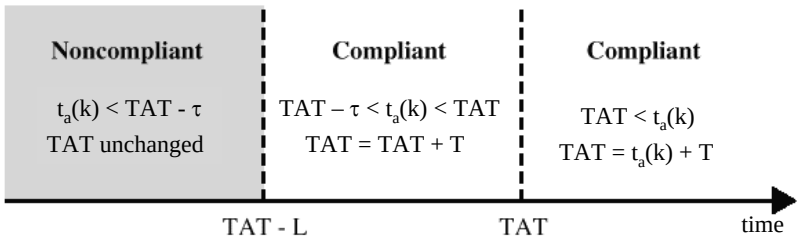



I = Increment
L = Limit
$t_a(k)$ = Time of arrival of a cell

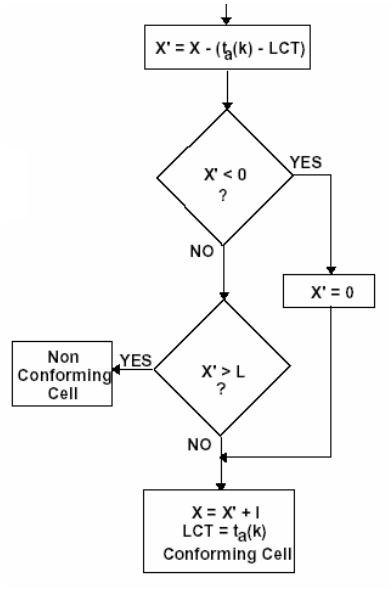
TAT= Theoretical arrival time

At the time of arrival $t_a(1)$ of the first cell of the connection, TAT = $t_a(1)$

# Virtual scheduling algorithm GCRA (T,τ)



# Continuous-state Leaky-Bucket

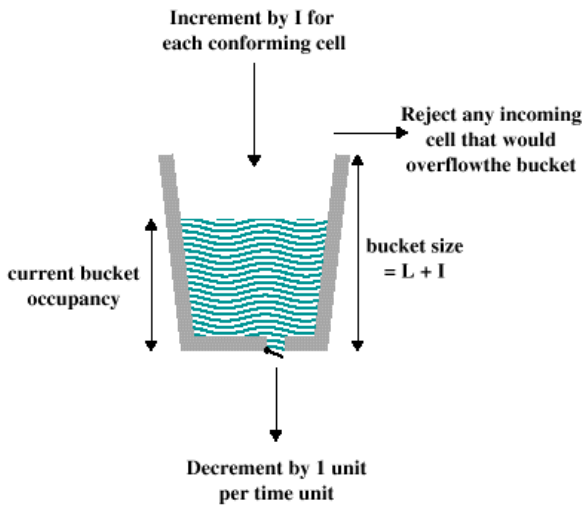



I = Increment
L = Limit
$t_a(k)$ = Time of arrival of a cell

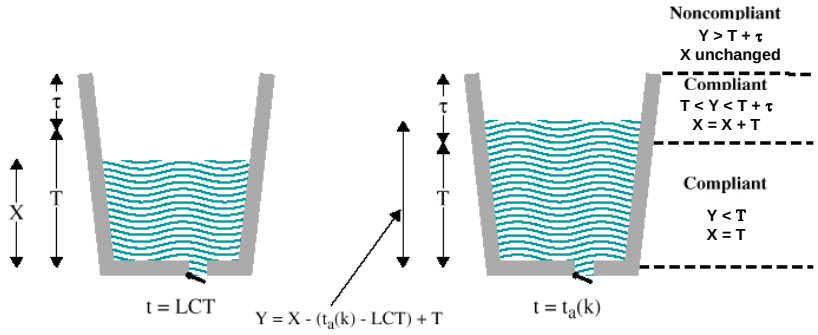
X = Value of the leaky bucket counter
X' = Auxiliary variable
LCT = Last compliance time

At the time of arrival $t_a(1)$ of the first cell of the connection, X = 0 and LCT = $t_a(1)$

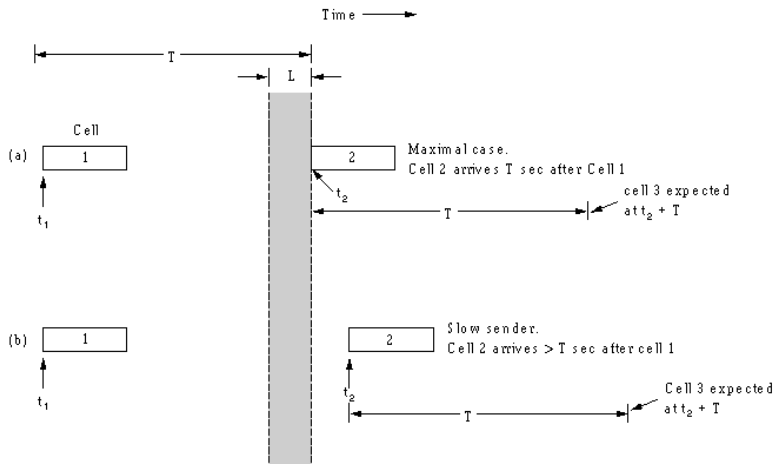
# Leaky Bucket Algorithm



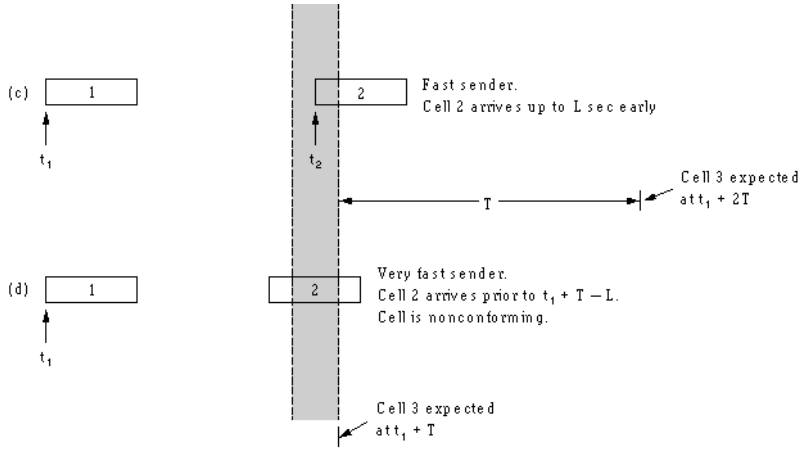
# Continuous-state Leaky-Bucket GCRA (T,τ)



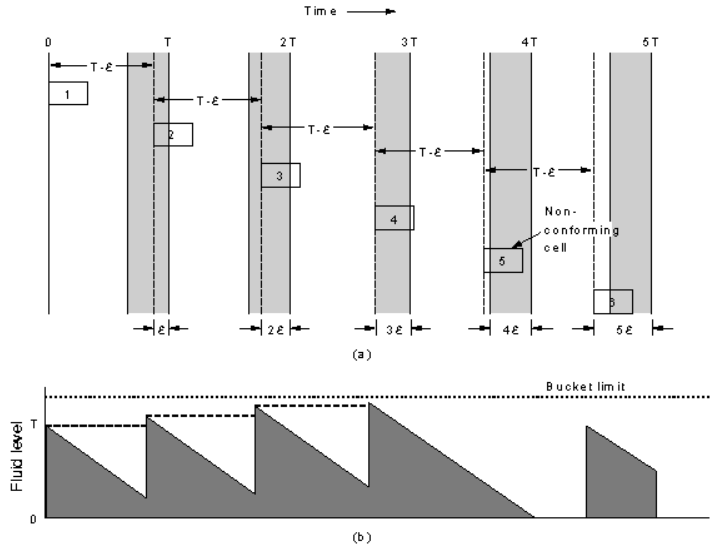

# The Generic Cell Rate Algorithm



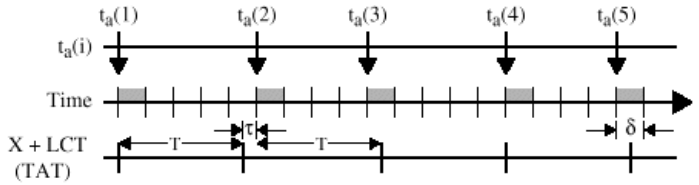
# The Generic Cell Rate Algorithm



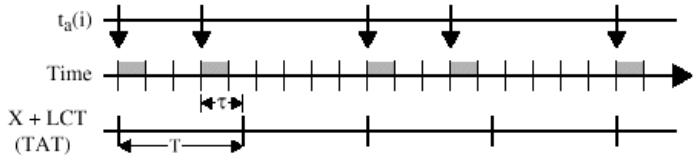

# The Generic Cell Rate Algorithm



# Example GCRA. T = 4.5δ

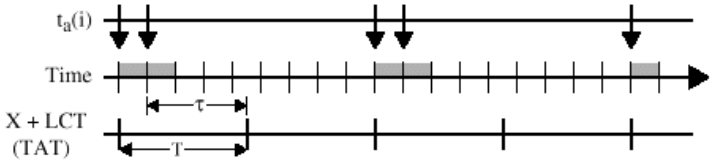



**(a) Ideal cell arrival (τ = 0.5δ)**

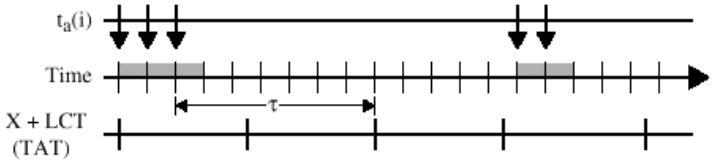



**(b) Possible cell arrival (τ = 1.5δ)**

# Example GCRA. T = 4.5δ




**(c) Possible cell arrival (τ = 3.5δ)**




**(d) Possible cell arrival (τ = 7δ)**

The burst tolerance is represented as $\tau_s$. Thus the sustainable cell rate algorithm is expressed as GCRA($T_s$, $\tau_s$).

Unlike the CDV, the burst tolerance is not selected directly. Rather, it is derived from an understanding of the burstiness of the traffic stream. In particular, let T be the time between cells at the peak rate. If the traffic stream is constrained by both a peak cell rate using GCRA(T, $\tau$) and a sustainable cell rate GCRA($T_s$ , $\tau_s$), then the maximum burst size, MBS, that may be transmitted at the peak rate is given by

$$MBS = \left\lfloor 1 + \frac{\tau_s}{T_s - T} \right\rfloor$$

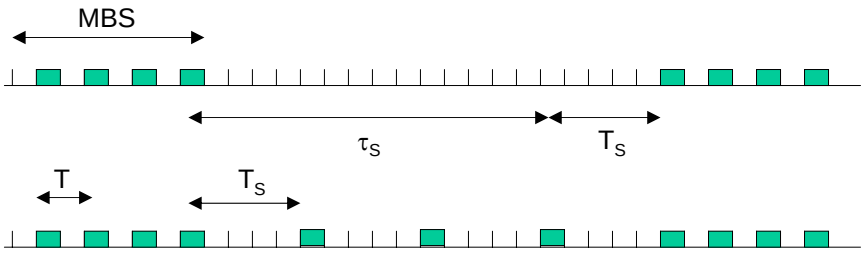
In the signaling message, the burst tolerance is conveyed using MBS, which is coded in number of cells. The MBS is then used to derive $\tau_s$ , which in turn is used in the GRCA algorithm to monitor the sustainable cell rate. Given the MBS, T, and $T_s$, then $\tau_s$ can be any value in the half-closed interval

$$[(MBS-1)(T_S-T), MBS(T_S-T)$$

For uniformity, the minimum value is used:

$$\tau_s=(MBS-1)(T_S-T)$$

# Burst tolerance




Relation between MBS, $\tau_S$, $T_S$ and T.

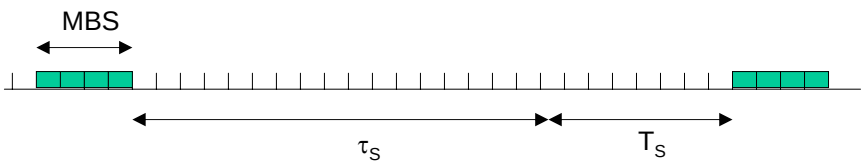
# Example GCRA

- PCR = 2016 Kbps = 4754.7 cells/sec.
- SCR = 201.6 Kbps = 475.47 cells/sec.
- CDVT = 3 msec.
- MBS = 64 cells

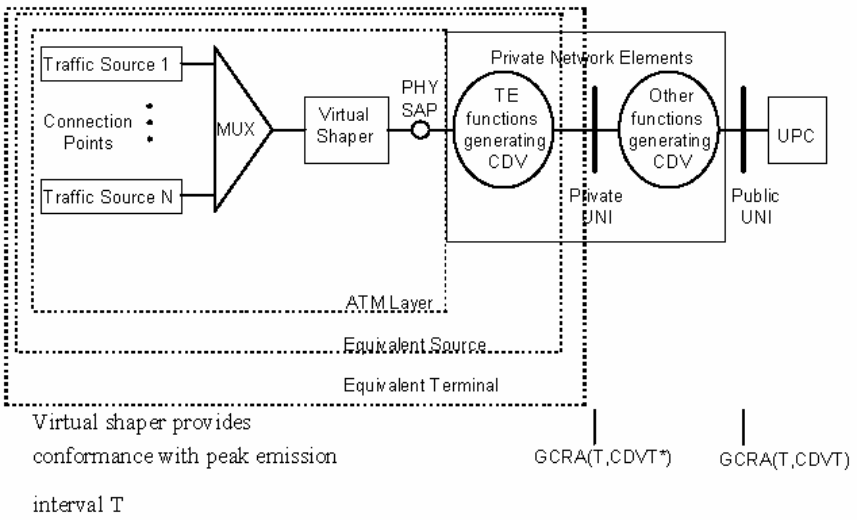
- T = 1/PCR = 0.21 msec. ; T' = 1
- Ts = 1/SCR; T's = 10
- CDVT = 3/0.21 = 14.28 cells at PCR !

# Example GCRA

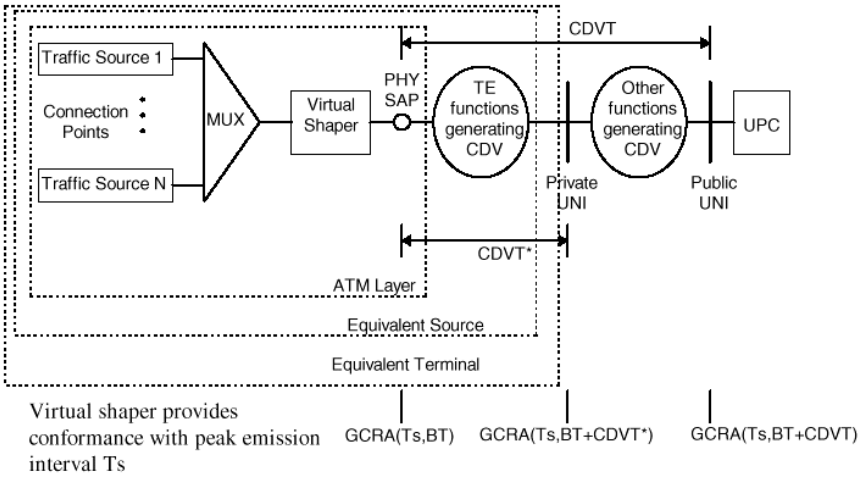
- $\tau_s=(MBS-1)(T_S-T)$
- $\tau_s = 63 * (10 – 1) = 567$ cells



## PCR Reference Model




## SCR and BT Reference Model



# Burst tolerance

The burst tolerance $\tau_s$ is a source traffic parameter and reflects the *time scale* during which cell rate fluctuations are tolerated.It is defined in relation to the sustainable cell rate according to the algoritm GCRA($T_s$, $\tau_s$) and determines an upper bound on the length of a burst transmitted in compliance with the connection's peak cell rate.

The maximum nomber of cells which may pass the GCRA transparently at peak cell rate is given by the following formula:

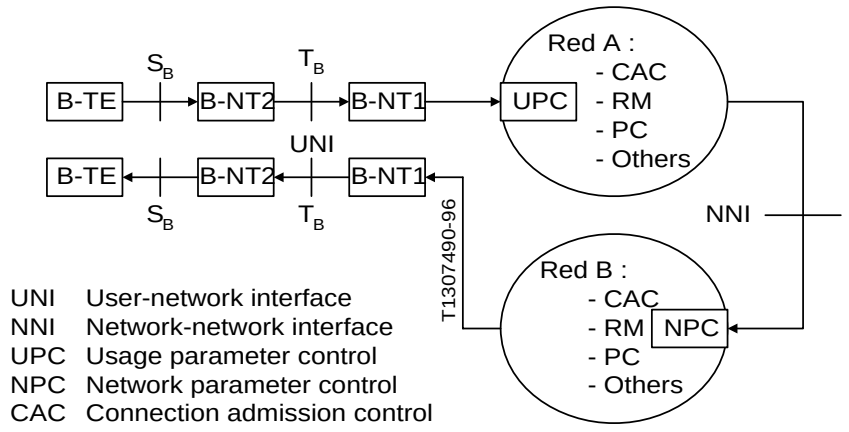
$$MBS = \left\lfloor 1 + \frac{\tau_s}{T_s - T} \right\rfloor$$

Where $\lfloor x \rfloor$ is the gratest integer less than or equal to x and MBS stands for Maximum Burst Size

# Generic Functions

- Connection Admission Control (CAC)
- Usage Parameter Control (UPC)
- Cell Loss Priority control (CLP)
- Traffic Shaping (TS)
- Network Resource Management (NRM)
- Frame Discard
- ABR Flow Control

# Generic Functions

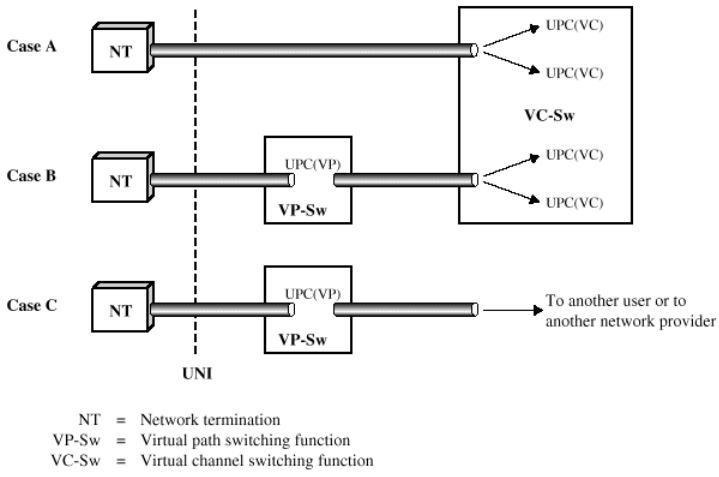



| | |
|---|---|
| UNI | User-network interface |
| NNI | Network-network interface |
| UPC | Usage parameter control |
| NPC | Network parameter control |
| CAC | Connection admission control |
| RM | Resource management |
| PC | Priority control |

# Generic Functions

- Connection Admission Control (CAC)
- Usage Parameter Control (UPC)
- Cell Loss Priority control (CLP)
- Traffic Shaping (TS)
- Network Resource Management (NRM)
- Frame Discard
- ABR Flow Control

# Location of Usage Parameter Control



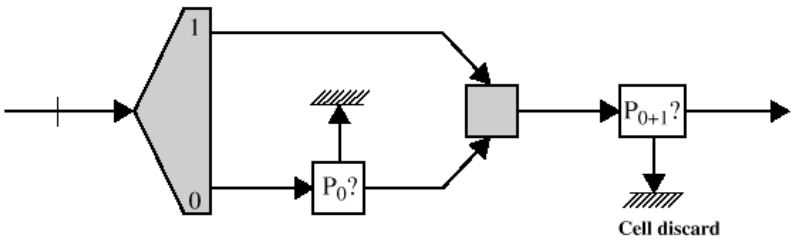

NT = Network termination
VP-Sw = Virtual path switching function
VC-Sw = Virtual channel switching function

# Traffic Traffic Conformance Definitions

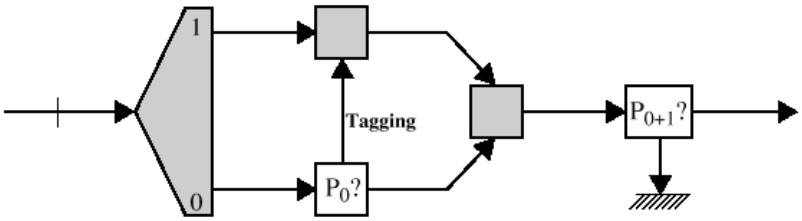
| Conformance Definition | PCR flow | SCR flow | Tagging option active | CLR on |
|---|---|---|---|---|
| CBR.1 | 0 + 1 | ns | na | 0 + 1 |
| VBR.1 | 0 + 1 | 0 + 1 | na | 0 + 1 |
| VBR.2 | 0 + 1 | 0 | No | 0 |
| VBR.3 | 0 + 1 | 0 | Yes | 0 |
| UBR.1 | 0 + 1 | ns | na | U |
| UBR.2 | 0+1 | ns | Yes[4] | U |

# UPC Function

## No cell tagging



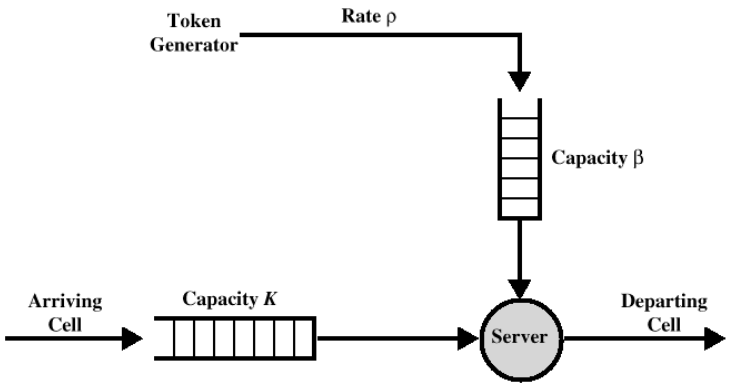
# UPC Function
## Cell tagging




# Generic Functions

- Connection Admission Control (CAC)
- Usage Parameter Control (UPC)
- Cell Loss Priority control (CLP)
- Traffic Shaping (TS)
- Network Resource Management (NRM)
- Frame Discard
- ABR Flow Control

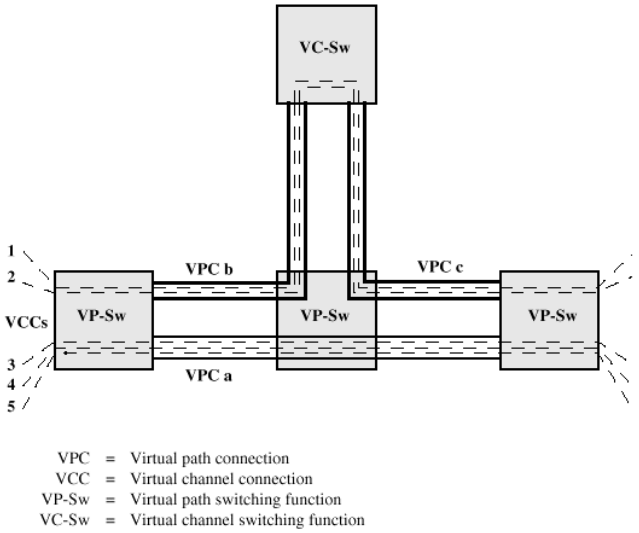
# Traffic Shaping
## Token Bucket Algorithm




# Generic Functions

- Connection Admission Control (CAC)
- Usage Parameter Control (UPC)
- Cell Loss Priority control (CLP)
- Traffic Shaping (TS)
- Network Resource Management (NRM)
- Frame Discard
- ABR Flow Control

## Resource Management using VPs




VPC = Virtual path connection
VCC = Virtual channel connection
VP-Sw = Virtual path switching function
VC-Sw = Virtual channel switching function

## Generic Functions

- Connection Admission Control (CAC)
- Usage Parameter Control (UPC)
- Cell Loss Priority control (CLP)
- Traffic Shaping (TS)
- Network Resource Management (NRM)
- Frame Discard / Cell Discard
- ABR Flow Control

## Traffic management in ATM networks

- Source:
  - Traffic parameters
  - QoS class
  - Generates traffic according to contract
- Network
  - QoS parameters appropriate for QoS class
  - Enforce source traffic (UPC)

## Congestion Control

- Cell discarding mechanisms
  - Partial Packet Discard (PPD)
  - Early Packet Discard (EDP)

## Cell discarding

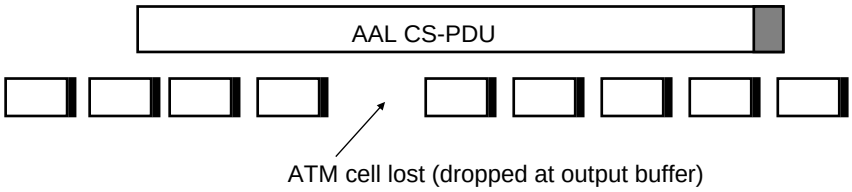
- Basically for UBR traffic
- Best-Effort environment
- Typically packet data traffic
- Mixes of heterogeneous traffic (LAN interconnection over ATM and TCP/IP over ATM)

## Packet oriented communications

| | |
|---|---|
| LAN interconnection | (IEEE 802.2 frames) |
| WAN interconnection | (X.25 packets) |
| HS LAN interconnection | (FDDI, IEEE 802.2 frames) |
| FRAME-Relay over ATM | (LAP-E frames) |
| Data traffic | (TCP/IP segments) |
| SMDS traffic | (SMDS messages) |
| LAN Emulation over ATM | (IEEE 802.2 frames) |

# QoS for packet oriented communications

- The Packet Loss Ratio is the QoS parameter




when one cell is lost the remaining cells of the PDU are useless
it implies the re-transmission of the PDU for data services
it implies degradation of QoS for interactive services



# QoS for packet oriented communications

***Packet loss ratio depends on***

- cell loss rate (CLR)
- packet length (number of cells per PDU)
- bit-rate at which the PDU is transmitted (PCR)
- capacity of the VC, VP or link (PCR / C)
- traffic control mechanisms applied (shaping)
- overall traffic load of the VC, VP, link
- traffic characteristics of other cell streams

## Selective cell discarding

- Partial Packet Discard (PPD)
  - if buffer is full then drop cell
  - once a cell is dropped, all the subsequent cells of the AAL-CS PDU are discarded
  - reduces congestion without degrading the packet loss ratio
  - improves packet loss ratio for other flows
  - truncated packets are transmitted

©UPC/DAC/JDP

## Selective cell discarding

- It is a traffic control function that is performed at AAL level
- It is applied on a connection basis (VCI in the cell header)
- When a cell is dropped because of buffer overflow a discard signal is associated with the corresponding VCI
- While the discard signal is active all cells with that VCI are discarded as they arrive at the input port
- The last cell (AAL5 End-of-SDU-Type cell) is not discarded and resets the discard signal for that connection
- This mechanism can be implemented in hardware

©UPC/DAC_JDP

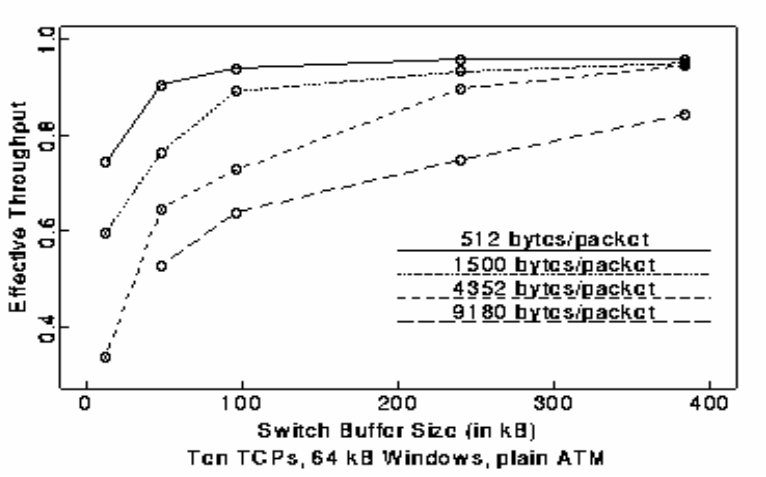
## Selective cell discarding

- Early Packet Discard (EPD)
  - discard only entire packets (AAL-CS PDU)
  - if first cell arrives and buffer occupancy is above a pre-defined threshold, discard it
  - discard all the subsequent cells of the PDU
  - it is useful for long buffers
  - behaves as a bridge or router discarding entire PDUs

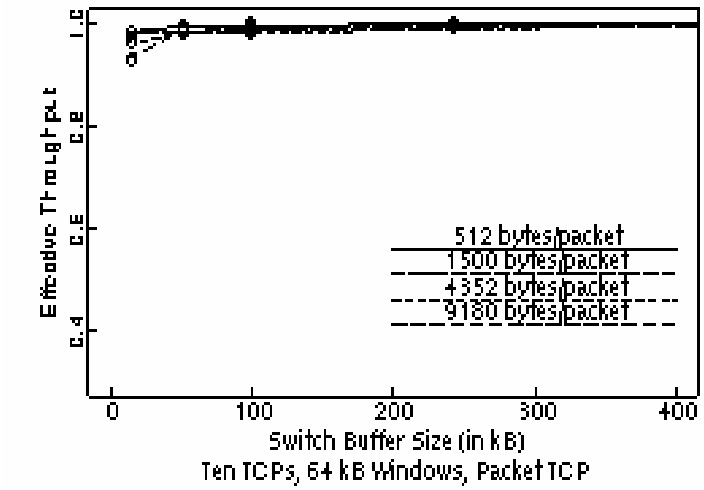
## Dynamics of TCP over ATM

- Performance study by simulation
- 10 simultaneous TCP connections are contending for the same output buffer
- Packet sizes: 20 - 200 cells
- Buffer size: 256 - 8000 cells
- TCP window: 8KB, 16KB, 32KB, 64KB
- TCP slow-start and fast retransmit

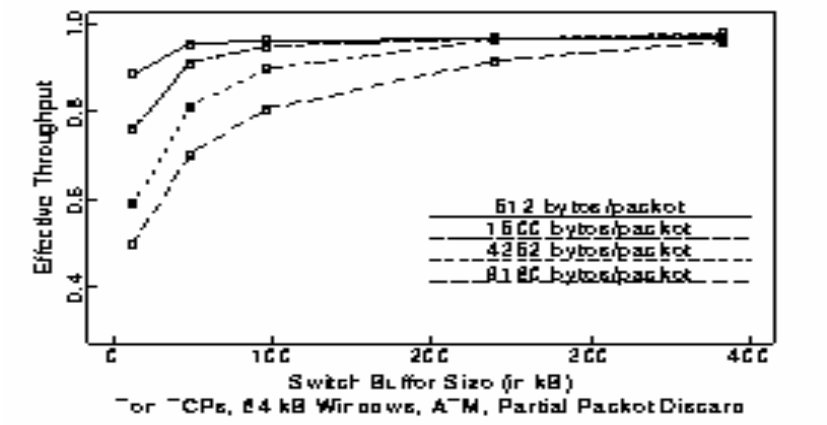
# Dynamics of TCP over ATM




# Dynamics of TCP over ATM



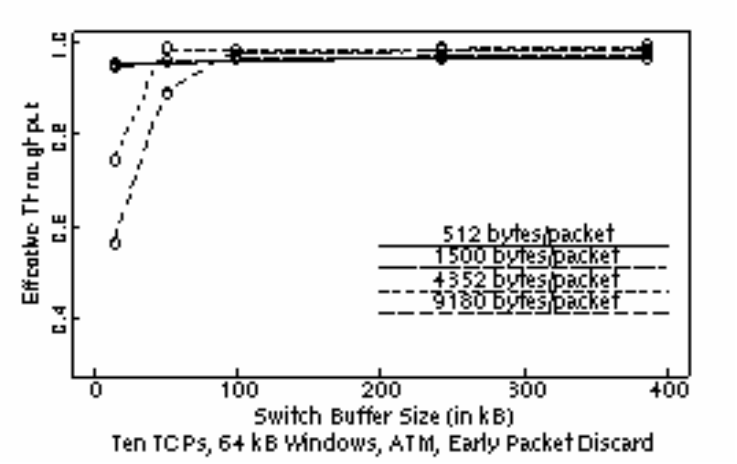
# Dynamics of TCP over ATM




# Dynamics of TCP over ATM

- PPD
  - minor improvement on the effective throughput
  - effective throughput < 60% for long packets and short buffers
  - significant amount of useless cells cause link congestion

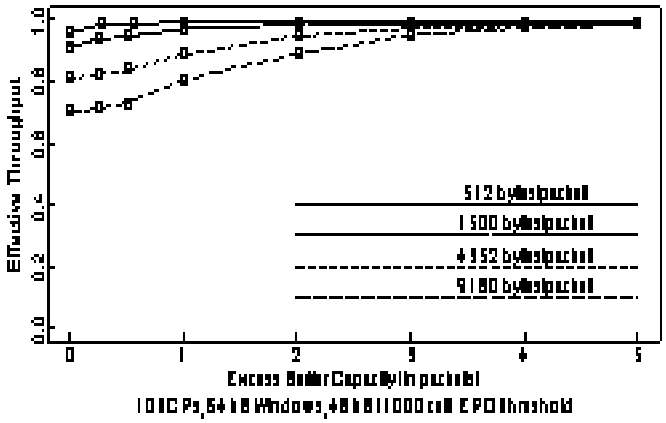
# Dynamics of TCP over ATM




# Dynamics of TCP over ATM

- EPD
  - Threshold = half of the buffer size
  - It is an efficient reactive congestion control mechanism
  - Significant improvement on effective throughput (only < 90% for long packets and short buffers)
  - Emulates packet-based switch

# Dynamics of TCP over ATM




Effective throughput vs. EXCESS buffer capacity in packets for different packet length

# Dynamics of TCP over ATM

- EPD
  - Excess buffer capacity

    EB = k * P cells

    P cells per packet

    k depends on the number of active TCP connections (for 10 connections, k > 3)
  - Bias against connections with shorter packets

## Dynamics of TCP over ATM

- EPD
  - Effective buffer size (threshold) depends on the network context, the tradeoffs between throughput and delay, the mixes of non-best-effort traffic, etc.
  - Can be used with rate-based feedback control schemes
  - Long buffers and best-effort (high CLR)



## TCP performance over ABR and UBR Services in ATM

- Simulation results
  - UBR service with EPD schemes
  - ABR service (rate-based)
  - ABR credit-based scheme
- TCP performs poorly on plain UBR service

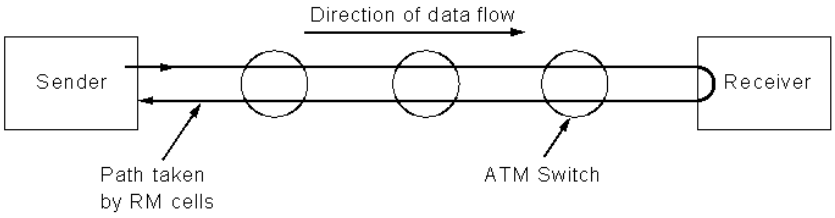
## Generic Functions

- Connection Admission Control (CAC)
- Usage Parameter Control (UPC)
- Cell Loss Priority control (CLP)
- Traffic Shaping (TS)
- Network Resource Management (NRM)
- Frame Discard / Cell Discard
- ABR Flow Control

## Available Bit Rate (ABR)

- ABR is an ATM layer service category for which the limiting ATM layer transfer characteristics provided by the network may change subsequent to connection establishment. A flow control mechanism is specified which supports several types of feedback to control the source rate in response to changing ATM layer transfer characteristics. This feedback is conveyed to the source through specific control cells called Resource Management Cells, or RM-cells. It is expected that an end-system that adapts its traffic in accordance with the feedback will experience a low cell loss ratio and obtain a fair share of the available bandwidth according to a network specific allocation policy. The ABR service does not require bounding the delay or the delay variation experienced by a given connection. ABR service is not intended to support real-time applications. On the establishment of an ABR connection, the end-system shall specify to the network both a maximum required bandwidth and a minimum usable bandwidth. These shall be designated as peak cell rate (PCR), and the minimum cell rate (MCR), respectively. The MCR may be specified as zero. The bandwidth available from the network may vary, but shall not become less than MCR.

# Available Bit Rate
# ABR Flow Control




# ABR Parameters

| Label | Description | Units and range |
|---|---|---|
| PCR | The Peak Cell Rate, PCR, is the cell rate which the source may never exceed. | In Cells/Sec, See Note 1 for range |
| MCR | The Minimum Cell Rate, MCR, is the rate at which the source is always allowed to send. | In Cells/Sec, See Note 1 for range |
| ICR | The Initial Cell Rate, ICR, is the rate at which a source should send initially and after an idle period. | In Cells/Sec, See Note 1 for range |
| RIF | Rate Increase Factor, RIF, controls the amount by which the cell transmission rate may increase upon receipt of an RM-cell. | RIF is a power of two, ranging from 1/32768 to 1. |
| Nrm | Nrm is the maximum number of cells a source may send for each forward RM-cell. | Power of 2<br>Range: 2 to 256 |
| Mrm | Mrm controls allocation of bandwidth between forward RM-cells, backward RM-cells, and data cells. | Constant fixed at 2 |
| RDF | The Rate Decrease Factor, RDF, controls the decrease in the cell transmission rate. | RDF is a power of 2 from 1/32,768 to 1 |
| ACR | The Allowed Cell Rate, ACR, is the current rate at which a source is allowed to send. | Units: Cells/Sec |

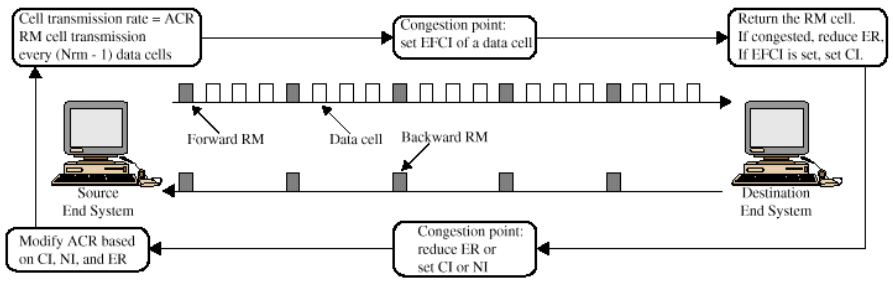
# ABR Parameters

| | | |
|---|---|---|
| CRM | Missing RM-cell count. CRM limits the number of forward RM-cells which may be sent in the absence of received backward RM-cells. | CRM is an integer. Its size is implementation specific. |
| ADTF | The ACR Decrease Time Factor is the time permitted between sending RM-cells before the rate is decreased to ICR. | Units: seconds<br>ADTF range: .01 to 10.23 sec:<br>with granularity of 10 ms. |
| Trm | Trm provides an upper bound on the time between forward RM-cells for an active source. | Units: milliseconds<br>Trm is 100 times a power of two<br>Range: $100*2^{-7}$ to $100*2^{0}$ |
| FRTT | The Fixed Round-Trip Time, FRTT, is the sum of the fixed and propagation delays from the source to a destination and back. | Units : 1 microseconds<br>Range: 0 to 16.7 seconds |
| TBE | Transient Buffer Exposure, TBE, is the negotiated number of cells that the network would like to limit the source to sending during startup periods, before the first RM-cell returns. | Units: Cells<br>Range: 0 to 16,777,215 |
| CDF | The Cutoff Decrease Factor, CDF, controls the decrease in ACR associated with CRM. | CDF is zero, or a power of two in the range 1/64 to 1. |
| TCR | The Tagged Cell Rate, TCR, limits the rate at which a source may send out-of-rate forward RM-cells. | TCR is a constant fixed at 10 cells/second |



# Available Bit Rate

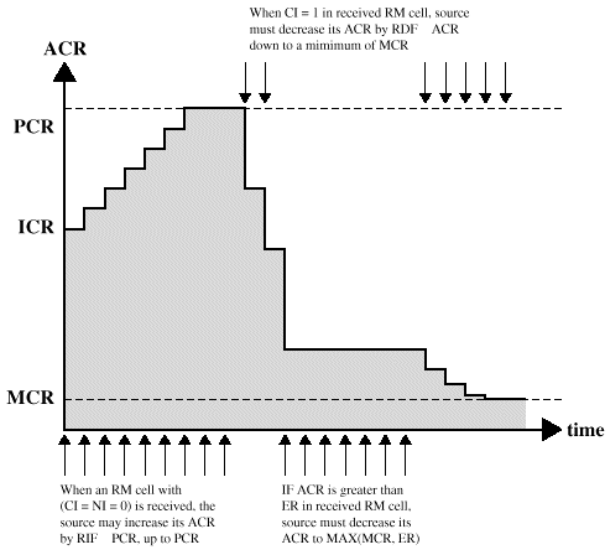
Flow of Data and RM cells on an ABR connection



# ABR Feedback Mechanism

| NI | CI | Action |
|---|---|---|
| 0 | 0 | ACR = max[MCR, min[ER, PCR, ACR+(RIFxPCR)] ] |
| 0 | 1 | ACR = max[MCR, min[ER, ACRx(1-RDF)] ] |
| 1 | 0 | ACR = max[MCR, min[ER, ACR] ] |
| 1 | 1 | ACR = max[MCR, min[ER, ACRx(1-RDF)] ] |

# Allowed Cell Rate



# ABR RM Cells

| FIELD | OCTET | BIT(s) | DESCRIPTION | Initial Value | |
|---|---|---|---|---|---|
| | | | | if source-generated | if switch-generated or destination-generated |
| Header | 1-5 | all | ATM Header | RM-VPC: VCI=6 and PTI=110<br>RM-VCC: PTI=110 | |
| ID | 6 | all | Protocol Identifier | 1 | |
| DIR | 7 | 8 | Direction | 0 | 1 |
| BN | 7 | 7 | BECN Cell | 0 | 1 |
| CI | 7 | 6 | Congestion Indication | 0 | either CI=1 or NI=1 or both |
| NI | 7 | 5 | No Increase | 0 or 1 | |
| RA | 7 | 4 | Request/ Acknowledge | 0 or set in accordance with I.371-draft | |
| Reserved | 7 | 3-1 | Reserved | 0 | |



# ABR RM Cells

| FIELD | OCTET | BIT(s) | DESCRIPTION | Initial Value | |
|---|---|---|---|---|---|
| | | | | if source-generated | if switch-generated or destination-generated |
| ER | 8-9 | all | Explicit Cell Rate | a rate not greater than PCR parameter | any rate value |
| CCR | 10-11 | all | Current Cell Rate | ACR Parameter | 0 |
| MCR | 12-13 | all | Minimum Cell Rate | MCR Parameter | 0 |
| QL | 14-17 | all | Queue Length | 0 or set in accordance with I.371-draft | |
| SN | 18-21 | all | Sequence Number | 0 or set in accordance with I.371-draft | |
| Reserved | 22-51 | all | Reserved | 6A (hex) for each octet | |
| Reserved | 52 | 8-3 | Reserved | 0 | |
| CRC-10 | 52 | 2-1 | CRC-10 | See Section 5.10.3.1 | |
| | 53 | all | | | |

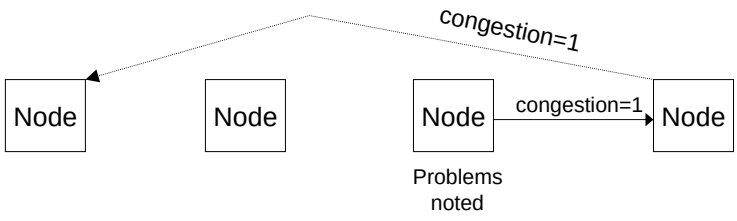
# ABR RM Cells

| 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|
| DIR | BN | CI | NI | RA | Res. | Res. | Res. |

DIR = 0 for forward RM cells
= 1 for backward RM cells
BN = 1 for Non-Source Generated (BECN) RM cells
= 0 for Source Generated RM cells
CI = 1 to indicate congestion
= 0 otherwise
NI = 1 to indicate no additive increase allowed
= 0 otherwise
RA - Not used for ABR. See description below

# Available Bit Rate (ABR)

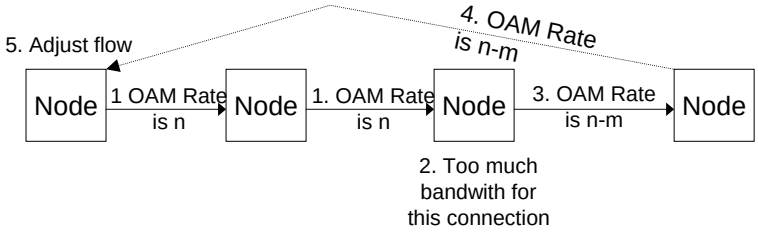
- Binary Rate Feedback
  - Amount of flow not specified
  - A bit is on or off



# Available Bit Rate (ABR)

•Explicit Rate Feedback

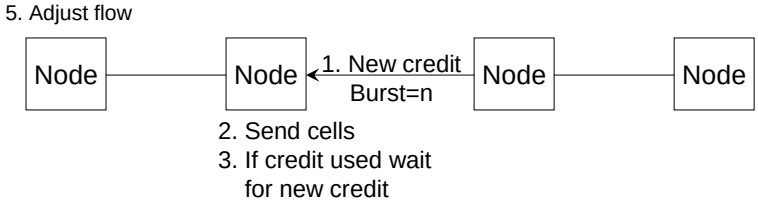
Each node determines each connection's fair share of resources. Periodically source device sends an OAM cell containing its current rate. Any node can reduce or expand this value, which is returned to the source. The source must adjust accordingly.




# Available Bit Rate (ABR)

•Explicit Burst Feedback

Number of cells a transmitter can send is limited by a burst size. Downstream node sends upstream node a credit. If upstream node uses up the credit, it must wait for a new credit.



# Guaranteed Frame Rate

- The GFR service category is intended to support non-real-time applications. It is designed for applications that may require a minimum rate guarantee and can benefit from accessing additional bandwidth dynamically available in the network. It does not require adherence to a flow control protocol. The service guarantee is based on AAL-5 PDUs (frames) and, under congestion conditions, the network attempts to discard complete PDUs instead of discarding cells without reference to frame boundaries. On the establishment of a GFR connection, the end-system specifies a PCR, and a Minimum Cell Rate (MCR) that is defined along with a Maximum Burst Size (MBS) and a Maximum Frame Size (MFS). The GFR traffic contract can be specified with an MCR of zero. The user may always send cells at a rate up to PCR, but the network only commits to carry cells in complete frames at MCR. Traffic beyond MCR will be delivered within the limits of available resources. There are no delay bounds associated with this service category.



# Guaranteed Frame Rate

| | ATM Layer Service Category | | | | | |
|---|---|---|---|---|---|---|
| Attribute | CBR | rt-VBR | nrt-VBR | UBR | ABR | GFR |
| **Traffic Parameters[4]:** | | | | | | |
| PCR and CDVT[5] | Specified | | | Specified [2] | Specified [3] | Specified |
| SCR, MBS, CDVT[5] | n/a | Specified | | n/a | | |
| MCR | n/a | | | | Specified | n/a |
| MCR, MBS, MFS, CDVT[5] | n/a | | | | | Specified |
| **QoS Parameters[4]:** | | | | | | |
| Peak-to-peak CDV | Specified | | Unspecified | | | |
| MaxCTD | Specified | | Unspecified | | | |
| CLR | Specified | | | Unspecified | See Note 1 | See Note 7 |
| **Other Attributes:** | | | | | | |
| Feedback | Unspecified | | | | Specified [6] | Unspecified |

# Guaranteed Frame Rate

| Conformance Definition | PCR flow | SCR flow | Tagging option active | MCR | CLR on |
|---|---|---|---|---|---|
| CBR.1 | 0 + 1 | ns[1] | n/a[2] | ns | 0 + 1 |
| VBR.1 | 0 + 1 | 0 + 1 | n/a | ns | 0 + 1 |
| VBR.2 | 0 + 1 | 0 | No | ns | 0 |
| VBR.3 | 0 + 1 | 0 | Yes | ns | 0 |
| ABR | 0 | ns | n/a | Yes | 0[6] |
| GFR.1 | 0 + 1 | ns | No | Yes | 0[7] |
| GFR.2 | 0 + 1 | ns | Yes[5] | Yes | 0[7] |
| UBR.1 | 0 + 1 | ns | No | ns | U[3] |
| UBR.2 | 0 + 1 | ns | Yes[4] | ns | U |