Appendix 6 - ATM Quality of Service (QoS) in Detail

ATM Quality of Service (QoS)

Traffic/Service Classes, Call Admission Control
Usage Parameter Control, ABR

Agenda

- **Introduction**
- **Service Classes and Traffic Attributes**
- **Traffic Control**
- **Flow Control**
- **Special Features for AAL5**

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 2

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Introduction to Traffic Management

- **Remember: ATM is based on statistical TDM**
- **Traffic management**
  - Ability to control the amount of traffic entering the network
    - Maximize efficiency
    - Minimizing data loss
- **Users might limit their traffic into the network**
  - Traffic shaping
- **Nevertheless, traffic control needed during times of heavy utilization**
  - Traffic policing
  - Feedback

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 3

Class of Service

- **Different kinds of traffic**
  - Voice, real-time or streaming
  - Video, real-time or streaming
  - Delay sensitive packet data (SNA, etc.)
  - Delay tolerant packet data (TCP/IP file transfer, etc.)
- **Traffic Management mechanisms must ensure that each kind of traffic experiences**
  - Appropriate bandwidth allocation
  - Bounded cell delay
  - Bounded cell delay variation (Jitter)

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 4

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

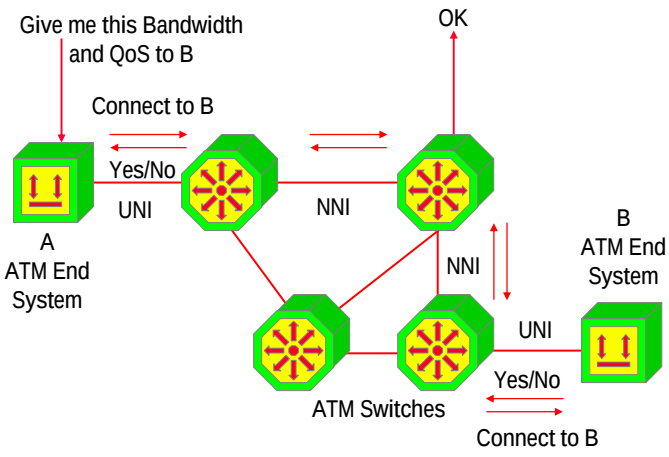
Resource Allocation Objectives

- **In case of network congestion**
  - We need a bandwidth allocation policy
  - Which virtual circuits get what fraction of the usable bandwidth
- **Examples**
  - Voice traffic should always get through
  - Video master frames should always get through
  - Video conferencing detail could be sacrificed
  - User X wants as much bandwidth as possible
    - but will pay a premium to obtain a guaranteed minimum available bandwidth
  - User Y will take as much bandwidth as possible
    - Does not wish to pay for a guaranteed bandwidth reservation and hence be satisfied with best effort

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 5

Goal: Bandwidth on Demand

VC Setup with QoS Parameters



© 2007, D.I. Manfred Lindner ATM QoS, v4.3 6

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Generic Functions

- **Traffic Contract, Traffic Parameters**
- **Connection Admission Control (CAC)**
  - Can requested parameters be fulfilled?
- **Usage Parameter Control (UPC)**
  - Another term for traffic policing
- **Priority Control (scheduling of cells)**
- **Traffic Shaping**
- **Explicit Forward Congestion Indication (EFCI)**
- **Cell/Frame Discard**
- **Feedback Control**
  - ABR Flow Control with RM Cells

© 2007, D.I. Manfred Lindner

Traffic Management

- **Traffic control**
  - Proactive actions
    - Prevents the congestion from happening
    - Well behaved sources (traffic shaping)
    - Well engineered network (connection admission control)
    - ABR control
- **Congestion control**
  - Reactive actions
    - Minimize the impact if it happens
    - Traffic policing
    - Cell/Frame discard

© 2007, D.I. Manfred Lindner

© 2007, D.I. Manfred Lindner

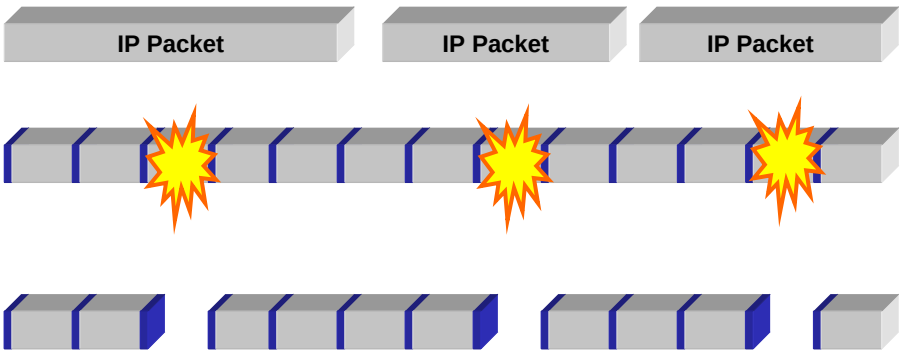
Appendix 6 - ATM Quality of Service (QoS) in Detail

Traffic Management Mechanisms

- **During connection set-up**
  - QoS signaling - UNI
  - Connection admission control (CAC)
  - QoS routing - PNNI
  - Traffic contract
- **During data flow**
  - Traffic policing (Usage Parameter Control)
  - Traffic shaping
  - Priority control
  - Buffer management
  - Cell/Frame discard
  - Flow (congestion) control

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 9

Packets and Cell Loss (1)



Receiver can't recognize any IP packets !

Even a small bit error rate (BER) can lead to retransmission and congestion (!)

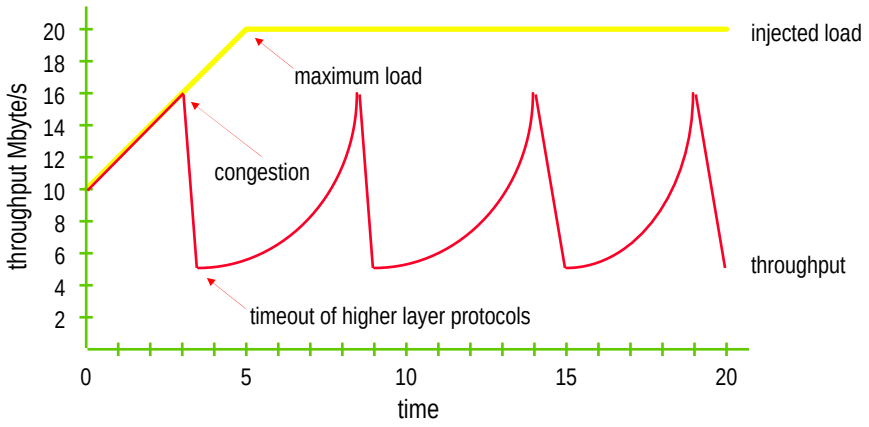
© 2007, D.I. Manfred Lindner ATM QoS, v4.3 10

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Effect of Cell Loss

- **Throughput (congestion) collapse**



congestion - cells are discarded - end user equipment retransmits full block - more load - even more cells are discarded - throughput collapses

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 11

Packets and Cell Loss (2)

- **Cells of damaged packets are still forwarded by ATM switches**
  - Solution: Intelligent Tail Packet Discard or Early Packet Discard
  - will be covered later in this module
- **IP Routers can immediately drop whole packet**
  - And recover queuing resources
  - So BER can be much higher (!)

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 12

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Agenda

- Introduction
- Service Classes and Traffic Attributes
- Traffic Control
- Flow Control
- Special Features for AAL5

© 2007, D.I. Manfred Lindner

Service Classes

Guaranteed Service "Bandwidth on Demand"	CBR	Constant Bit Rate Circuit Emulation, Voice
	rt-VBR nr-VBR	Variable Bit Rate Full Traffic Characterization Real-Time VBR and Non Real-Time VBR
"Best Effort" Service	UBR	Unspecified Bit Rate No Guarantees, "Send and Pray"
	ABR	Available Bit Rate No Full Traffic Characterization (Minimum Guarantee), but Congestion Control Feedback assures low cell loss

© 2007, D.I. Manfred Lindner

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Service Classes

- **CBR Service**
  - Used for very strict bandwidth traffic
  - Minimal delay, minimal delay variation, minimal loss
  - Traffic parameter is peak cell rate (PCR)
  - For example digital leased line emulation
- **VBR Service**
  - Variable bandwidth traffic
  - Useful for video and compressed voice applications
  - Traffic parameters are sustainable (average) cell rate (SCR), PCR, and maximum burst size (MBS)
  - Guaranteed service if source conforms to parameters
  - rtVBR needs minimal delay, minimal delay variation, minimal loss, nrtVBR is less critical

© 2007, D.I. Manfred Lindner

Service Classes

- **ABR Service**
  - Useful for computer applications
  - Variable bandwidth traffic
  - Traffic parameter is minimum cell rate (MCR) and PCR
  - Includes feedback control
- **UBR Service**
  - “Best effort” service
    - No real guarantees
  - Useful for computer applications
  - Variable bandwidth traffic
  - No traffic parameters

© 2007, D.I. Manfred Lindner

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Traffic Management Basics

- **The ATM network establishes**
  - a separate traffic contract with the user for each VC
- **The elements for a traffic contract are**
  - ATM service class
    - framework that defines which of the following parameters are relevant for a certain traffic class
  - ATM traffic parameters
    - specify characteristics of the traffic (cell flow) which is generated by an ATM end system
  - ATM QoS parameter
    - performance parameters expected by an ATM end system from the ATM network when generated traffic is within the contracted parameters; some of these parameters are negotiated (ptp CDV, maxCDT, CLR)

© 2007, D.I. Manfred Lindner

Traffic and QoS Parameters

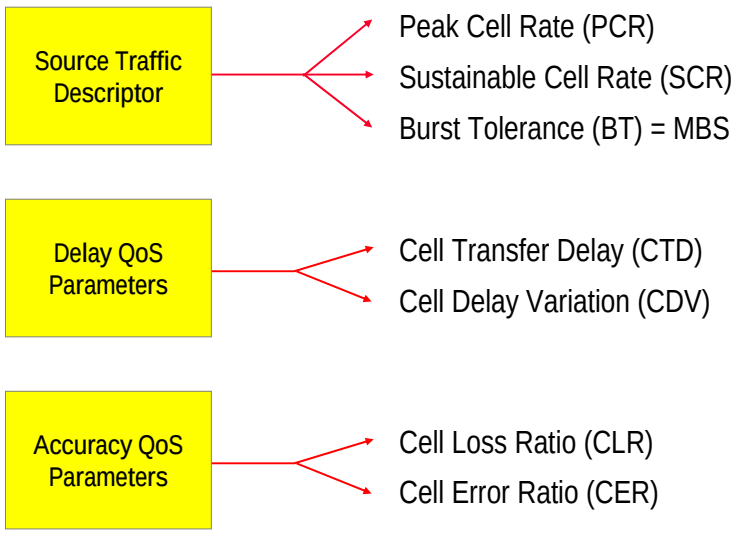
- **ATM traffic parameters**
  - Peak Cell Rate (PCR)
  - Cell Delay Variation Tolerance (CDTV)
  - Sustainable Cell Rate (SCR)
  - Maximum Burst Size (MBS)
  - Minimum Cell Rate (MCR)
- **ATM QoS parameters**
  - Cell Transfer Delay (CTD)
  - Cell Delay Variation (CDV)
  - Cell Loss Ratio (CLR)
  - Cell Error Rate (CER)

© 2007, D.I. Manfred Lindner

© 2007, D.I. Manfred Lindner

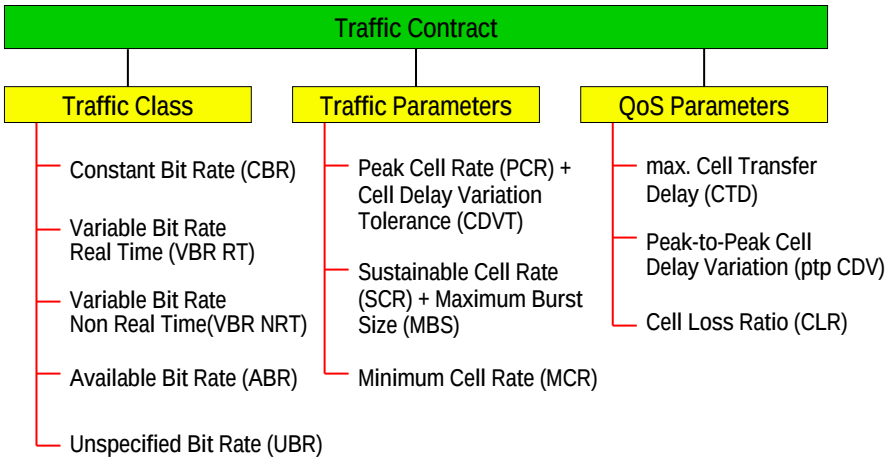
Appendix 6 - ATM Quality of Service (QoS) in Detail

Traffic Descriptor and QoS Parameters



© 2007, D.I. Manfred Lindner ATM QoS, v4.3 19

Traffic Attributes



© 2007, D.I. Manfred Lindner ATM QoS, v4.3 20

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Traffic Attributes

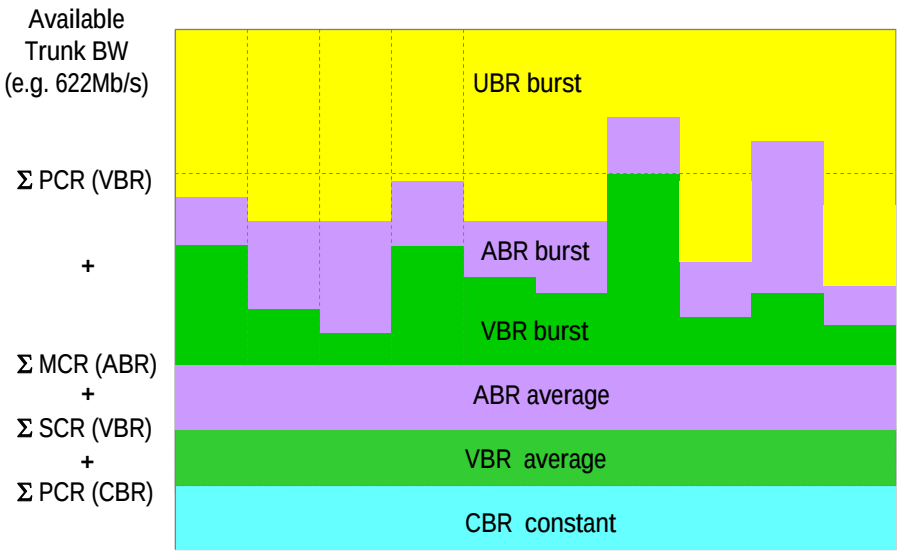
- **Specified for each service class**

ATTRIBUTE	CBR	rt-VBR	nrt-VBR	ABR	UBR
PCR & CDVT	Specified			Specified	
SCR, MBS, CDVT	n/a	Specified		n/a	
MCR	n/a			Specified	n/a
max CTD & ptp CDV	Specified		Unspecified	Unspecified	
CLR	Specified			Optional	Unspecified

CLR = Cell Loss Ratio
CTD = Cell Transfer Delay
CDV = Cell Delay Variation
MBS = Maximum Burst Size
PCR = Peak Cell Rate
CDVT = CDV Tolerance
SCR = Sustainable CR
MCR = Minimum CR

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 21

ATM as an Intelligent Bandwidth Management System



© 2007, D.I. Manfred Lindner ATM QoS, v4.3 22

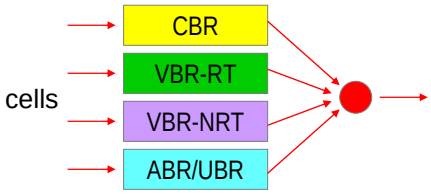
© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Queuing System

- **Buffer structure**
  - Switch must have different priority queues
  - Enforce absolute priority for service classes

ATM Switch Output Queue



© 2007, D.I. Manfred Lindner

Agenda

- **Introduction**
- **Service Classes and Traffic Attributes**
- **Traffic Control**
- **Flow Control**
- **Special Features for AAL5**

© 2007, D.I. Manfred Lindner

© 2007, D.I. Manfred Lindner

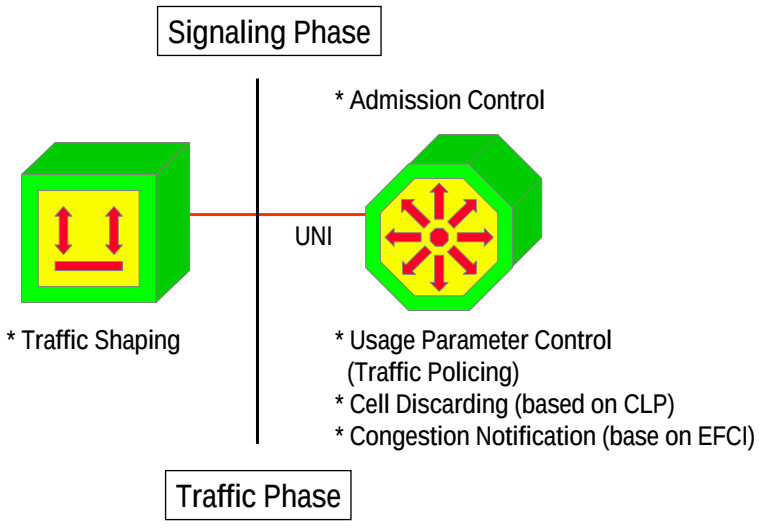
Appendix 6 - ATM Quality of Service (QoS) in Detail

Traffic Control

- **Proactive congestion prevention**
  - Connection Admission Control
    - Allows or refuses a connection based on the available bandwidth and the requested traffic parameters
  - Usage Parameter Control
    - Controls the use of the network based on a traffic contract agreed between the user and the network
- **Priority control**
  - Selective cell discarding based on CLP bit
    - CLP=0 cells are higher priority than CLP=1 cells
    - CLP=1 cells may be discarded during periods of congestion
  - The CLP bit will be set by the ATM network

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 25

Traffic Control

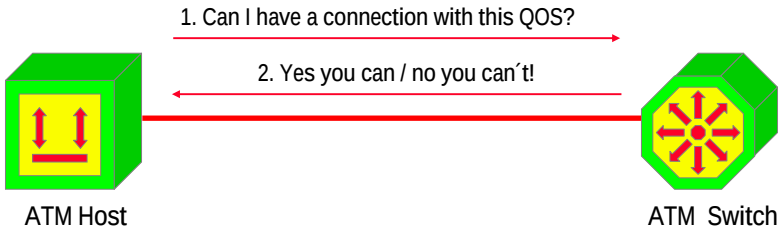


© 2007, D.I. Manfred Lindner ATM QoS, v4.3 26

© 2007, D.I. Manfred Lindner

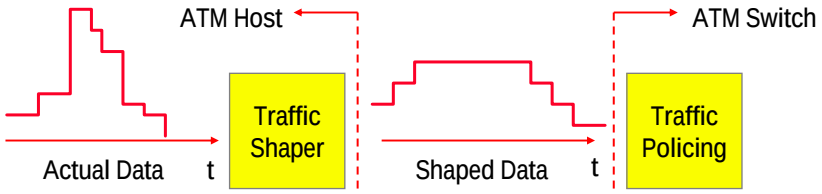
Appendix 6 - ATM Quality of Service (QoS) in Detail

Connection Admission Control



If CAC passes, network and user define a traffic contract.

Traffic Shaping and Policing

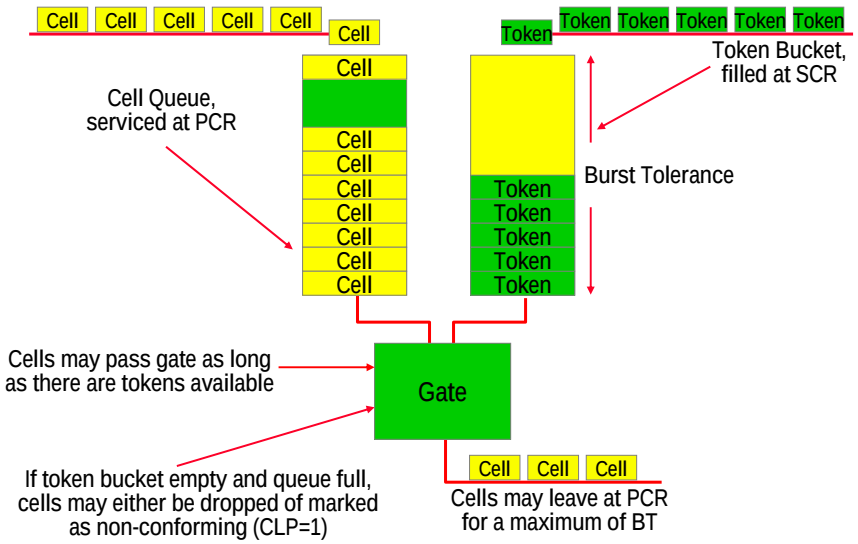


- **Traffic Shaping**
  - Leaky Bucket / Token Bucket
  - Constrain data bursts
  - Limit Peak Rate
  - Constrain Jitter
- **Usage Parameter Control**
  - Does received traffic meet contract ?
  - Set CLP bit
  - Discard cells with CLP = 1 if needed
  - Leaky Bucket / Token Bucket

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

"Token Bucket"



© 2007, D.I. Manfred Lindner

Agenda

- Introduction
- Service Classes and Traffic Attributes
- Traffic Control
- Flow Control
- Special Features for AAL5

© 2007, D.I. Manfred Lindner

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

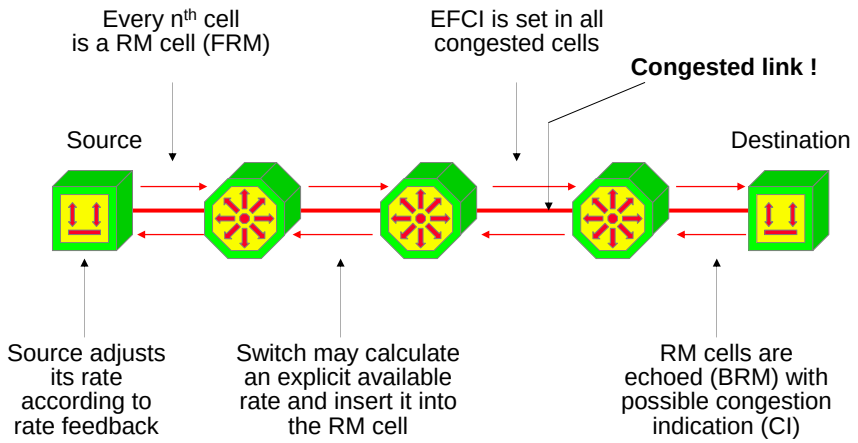
Available Bit Rate Service

- **Allows efficient, dynamic use of extra bandwidth available from higher priority ATM connections**
  - Each user gets its fair share of the available bandwidth
- **The network controls the amount of data each user can send at any particular time**
  - No data is lost if the user conforms to the feedback
- **Rate based feedback (congestion control)**
  - Uses special Resource Management (RM) cells
- **Requires end stations to participate**
- **Most useful for computer applications**
  - e.g. File Transfer

© 2007, D.I. Manfred Lindner

Rate Based Congestion Control

- **Overview**



© 2007, D.I. Manfred Lindner

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Rate Based Congestion Control

- **Important parameters**
  - PCR Peak Cell Rate
    will be policed by the network
  - MCR Minimum Cell Rate
    will be guaranteed
  - ICR Initial Cell Rate
    startup rate after the source being idle
  - ACR Allowed Cell Rate
    current rate at which a source is allowed to send
  - RIF Rate Increase Factor
    controls the rate at which the cell transmission rate increases

Rate Based Congestion Control

- **Important parameters**
  - RDF Rate Decrease Factor
    controls the rate at which the cell transmission rate decreases
  - Nrm Number of cells between Forward Resource Management Cells
  - Trm Provides an upper bound on the time between forward RM-cells for an active source

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Source Behavior

- **A new source begins to transmit at initial cell rate ICR** (determined at Call Setup)
- **Source must send at least one (F)RM cell every Nrm cells transmitted**
  - At least every Trm a (F)RM cell must be sent
- **If (B)RM cell is not received back or received (B)RM cell has CI flag set**
  - The source decreases its allowed cell rate ACR by the factor RDF until MCR is reached
- **If RM cell gets received and CI Flag is not set**
  - The source increases cell rate ACR by the factor RIF except NI (No Increase) flag is set

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 35

Destination Behavior

- **Destination returns all (F)RM cells back**
  - Reverses direction bit
- **Monitors EFCI bits in data cells**
  - If data cell has EFCI set, than CI in (B)RM cell is set or new ER (Explicit Rate) is calculated

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 36

© 2007, D.I. Manfred Lindner

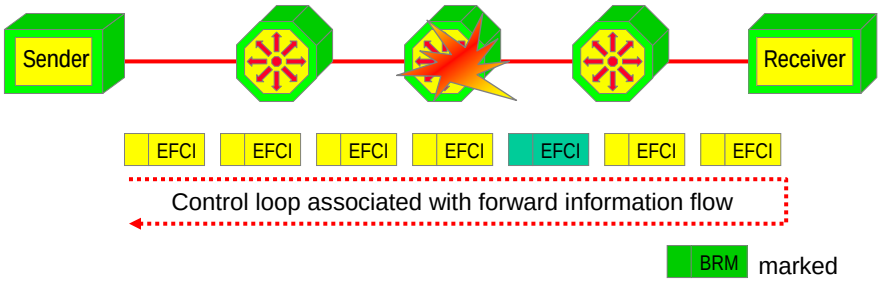
Appendix 6 - ATM Quality of Service (QoS) in Detail

Switch Behavior

- **A switch shall implement at least one of the following methods**
  - EFCI marking
    - Set the EFCI flag in the data cell header
  - Relative Rate marking
    - Set CI (Congestion Indication) or NI (No Increase) flags in forward and/or backward RM cells
  - Explicit Rate marking
    - Reduce the ER (Explicit Rate) field in forward and/or backward RM cells

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 37

EFCI Mode (Binary Mode)



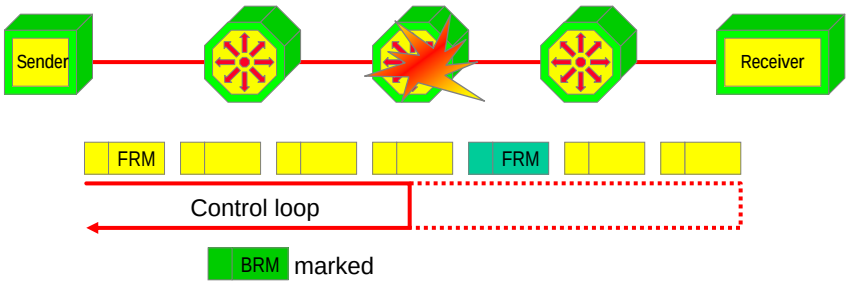
- **Switch sets EFCI flag when congested**
- **Receiver must notify the sender (backward RM cell)**
- **Sender must slow down**
  - Reduces rate by a fixed amount
- **Latency depends on round trip time, works only locally at low utilization**

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 38

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

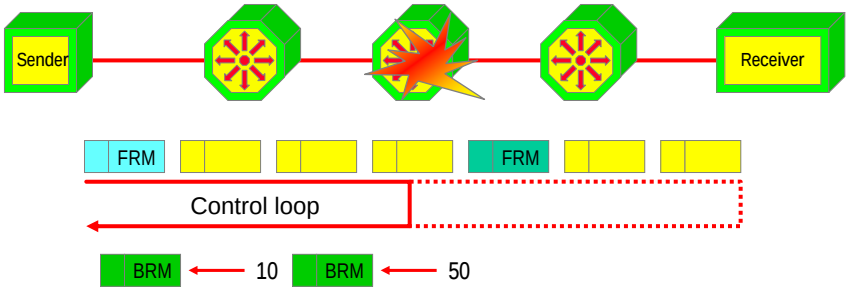
Relative Rate Mode



- **When congested**
  - Mark backward and/or forward Resource Management (RM) cells
  - Source reduces rate by a rate factor
  - Much faster than EFCI mode

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 39

Explicit Rate Mode



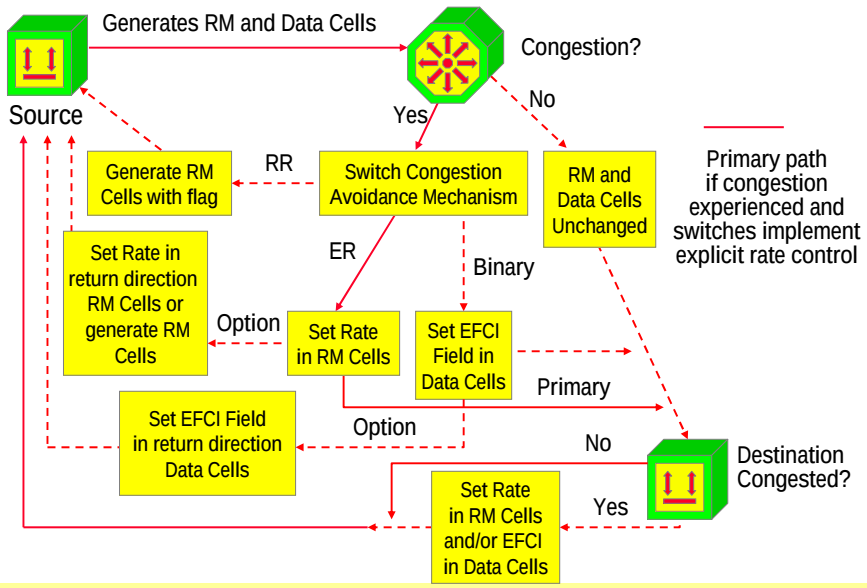
- **RM cells marked with current BW available**
- **Switch rewrites this with new available BW**
- **Only required for long WAN links**

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 40

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Summary of Modes



© 2007, D.I. Manfred Lindner

ATM QoS and Traffic Management

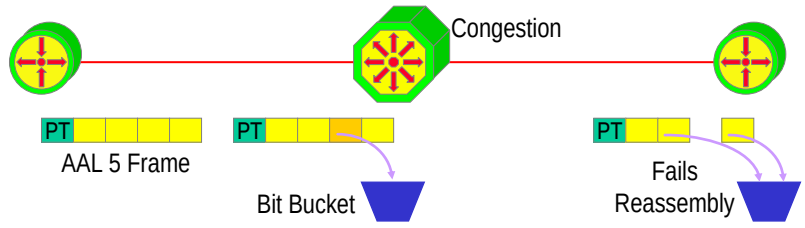
- Introduction
- Service Classes and Traffic Attributes
- Traffic Control
- Flow Control
- Special Features for AAL5

© 2007, D.I. Manfred Lindner

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

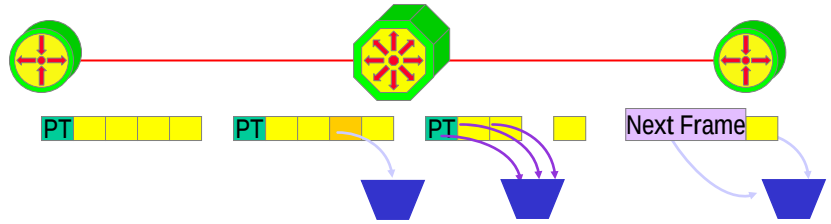
Single Cell Loss of a packet



- **No Tail Packet Discard**
  - Cells gets lost due to congestion
  - Remaining cells of a given frame are transmitted over the network without being of any use
    - Will be discarded at the receiver due to missing cell (CRC failure)

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 43

Tail Packet Discard



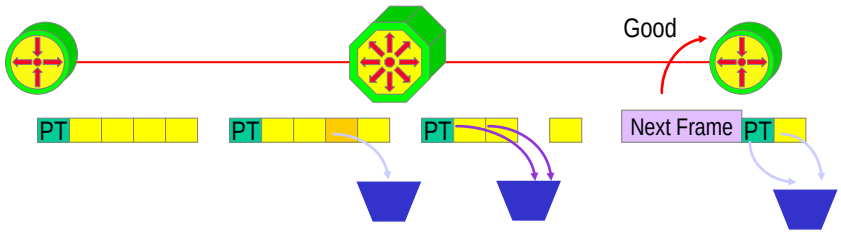
- **Tail Packet Discard**
  - Cells gets lost due to congestion
  - Switch discards all remaining cells of that specific frame
    - Has to look at the PT (payload type) field for EOM
  - Problem
    - If cell with EOM is also discarded, next frame will be discarded at the destination (CRC error)

© 2007, D.I. Manfred Lindner ATM QoS, v4.3 44

© 2007, D.I. Manfred Lindner

Appendix 6 - ATM Quality of Service (QoS) in Detail

Tail Packet Discard



- **Intelligent Tail Packet Discard**
  - Cell gets lost due to congestion
  - Switch discards all remaining cells of that specific frame
    - However, not the last cell containing EOM
    - CLP for this cell is set to “0” to make sure it gets through
  - Destination discards frame fragment, next frame o.k.

© 2007, D.I. Manfred Lindner

© 2007, D.I. Manfred Lindner