

## L15 - ATM Quality of Service (QoS)

### ATM Quality of Service (QoS)

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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**

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### Introduction to Traffic Management

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- **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

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### 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)

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### 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

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### 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

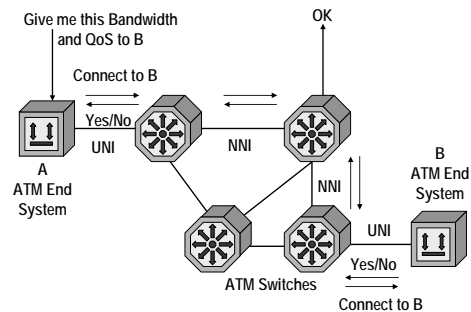
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### Goal: Bandwidth on Demand

VC Setup with QoS Parameters



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### 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

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### Traffic Management Mechanisms

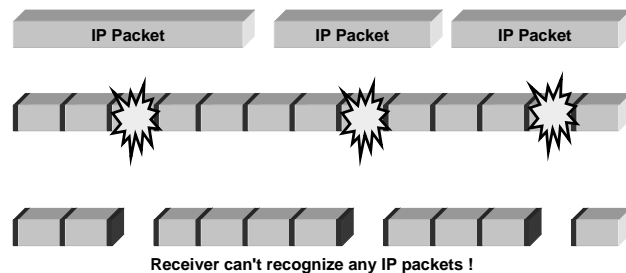
- **During connection set-up**
  - QoS signaling - UNI
  - Connection admission control (CAC)
  - QoS routing - PNNI
  - Traffic contract
- **During data flow**
  - Traffic policing (Usage Parameter Control)
  - Traffic shaping
  - Priority control
  - Buffer management
  - Cell/Frame discard
  - Flow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

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### Packets and Cell Loss (1)



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

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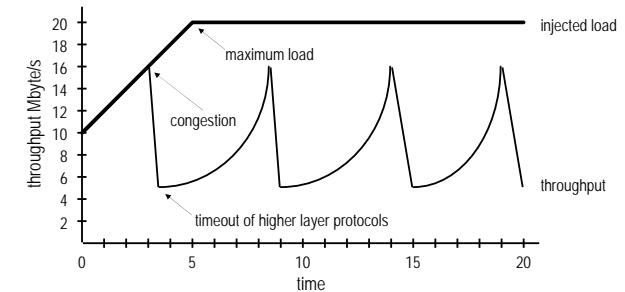
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### Effect of Cell Loss

- **Throughput (congestion) collapse**



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

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### 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 (!)

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### Agenda

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

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### Service Classes

<b>Guaranteed Service</b> "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
<b>"Best Effort" Service</b>	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

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### 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

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### 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

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#### 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)

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#### 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)

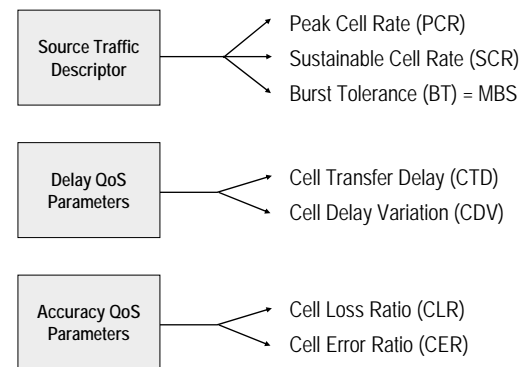
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#### Traffic Descriptor and QoS Parameters

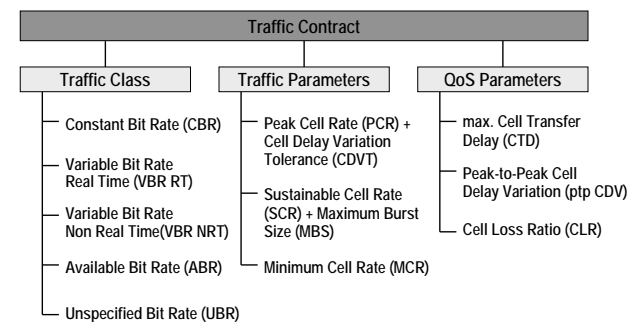


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#### Traffic Attributes



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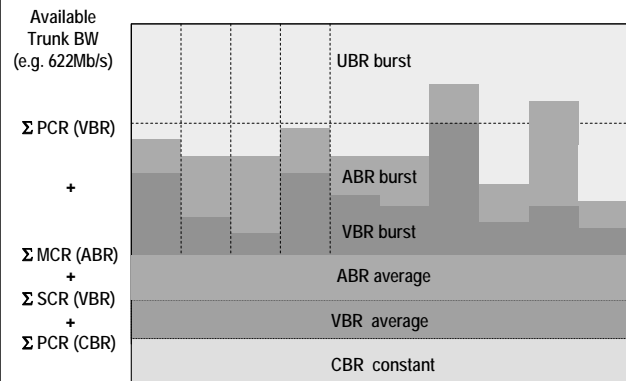
#### Traffic Attributes

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

#### ATM as an Intelligent Bandwidth Management System

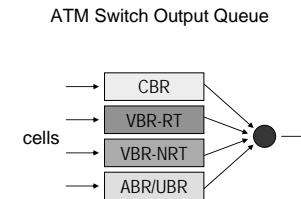


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#### Queuing System

- Buffer structure

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



#### Agenda

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

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#### 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

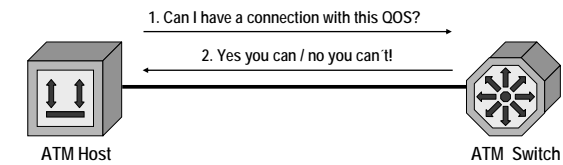
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#### Connection Admission Control



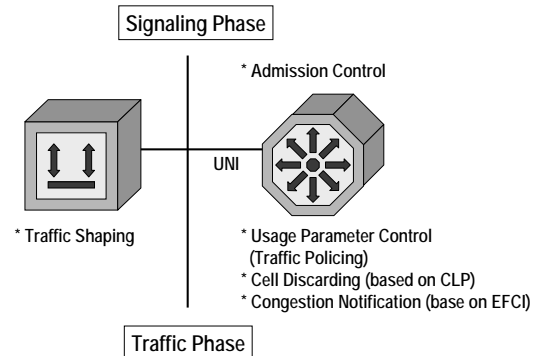
If CAC passes, network and user define a traffic contract.

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#### Traffic Control

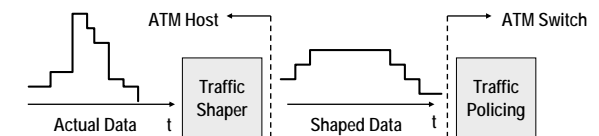


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#### Traffic Shaping and Policing



- **Traffic Shaping**

- Leaky Bucket / Token Bucket
  - Constrain data bursts
  - Limit Peak Rate
  - Constrain Jitter

- **Usage Parameter Control**

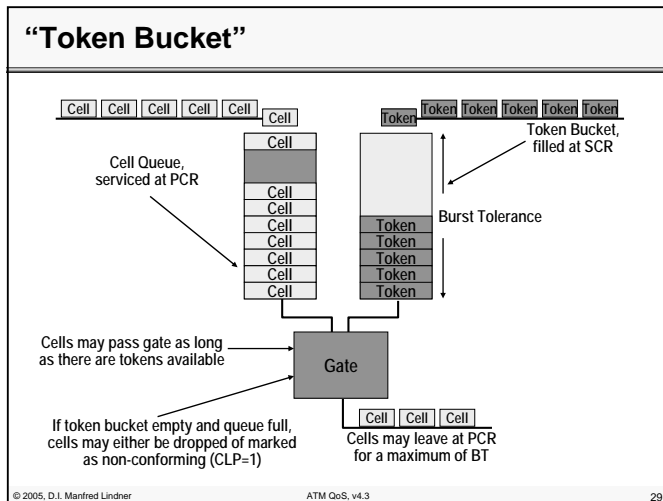
- Does received traffic meet contract ?
  - Set CLP bit
  - Discard cells with CLP = 1 if needed
  - Leaky Bucket / Token Bucket

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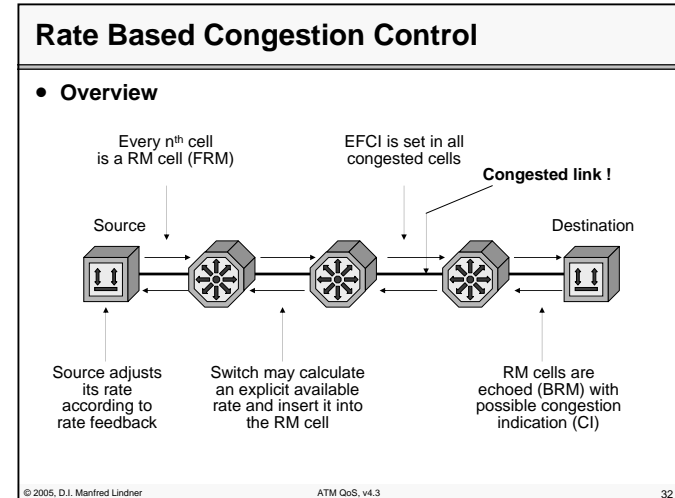
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- #### Available Bit Rate Service
- **Allows efficient, dynamic use of extra bandwidth available from higher priority ATM connections**
    - Each user gets its fair share of the available bandwidth
  - **The network controls the amount of data each 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
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### 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

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### 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

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### 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

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### 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

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#### 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

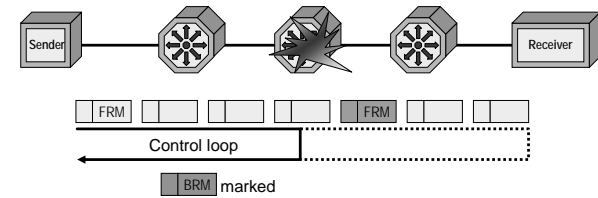
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#### Relative Rate Mode



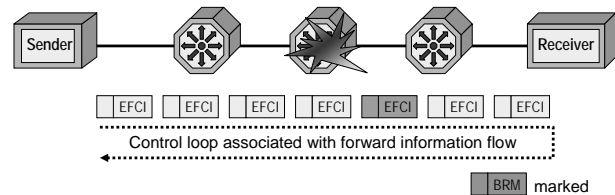
- **When congested**
  - Mark backward and/or forward Resource Management (RM) cells
  - Source reduces rate by a rate factor
  - Much faster than EFCI mode

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#### EFCI Mode (Binary Mode)



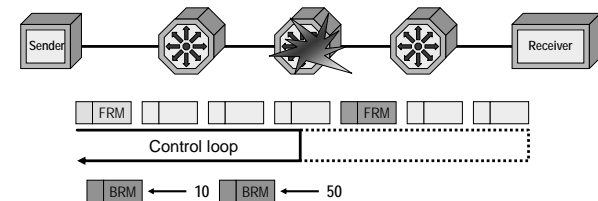
- **Switch sets EFCI flag when congested**
- **Receiver must notify the sender (backward RM cell)**
- **Sender must slow down**
  - Reduces rate by a fixed amount
- **Latency depends on round trip time, works only locally at low utilization**

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#### Explicit Rate Mode



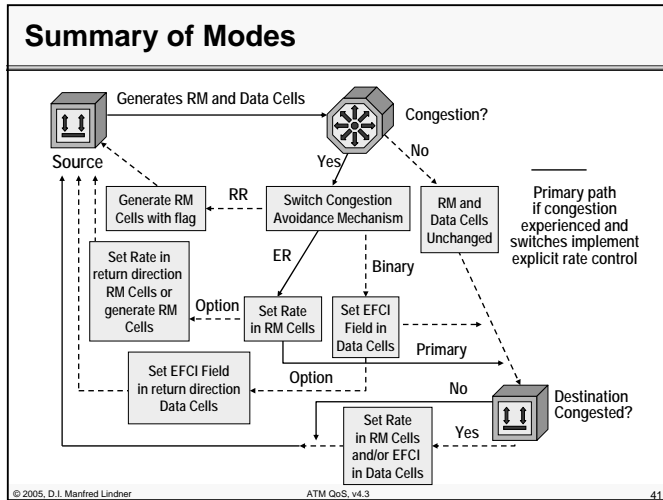
- **RM cells marked with current BW available**
- **Switch rewrites this with new available BW**
- **Only required for long WAN links**

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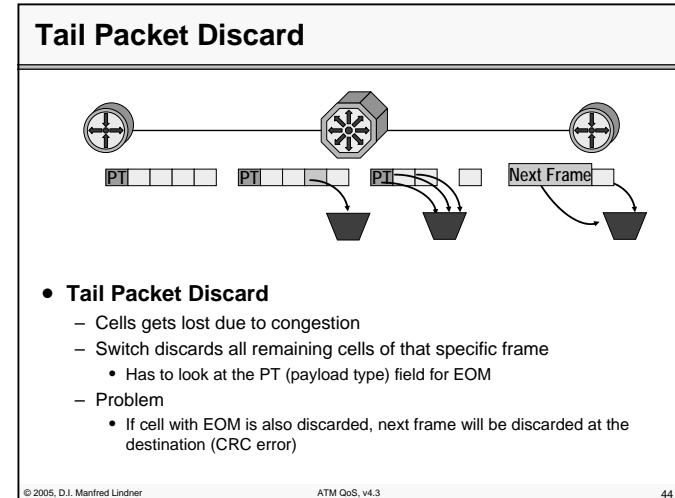
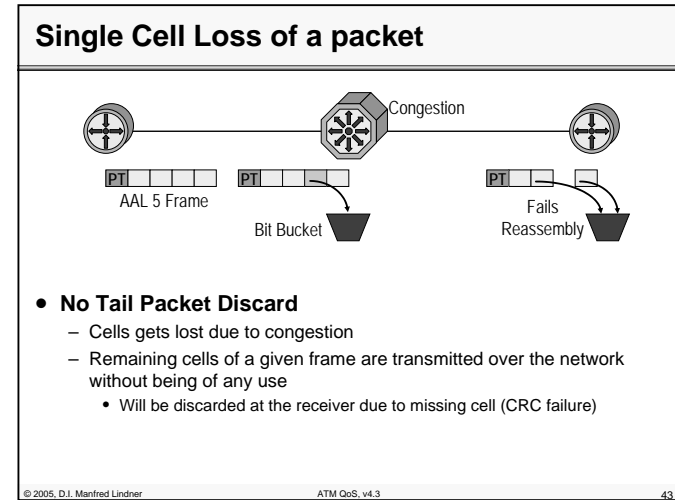
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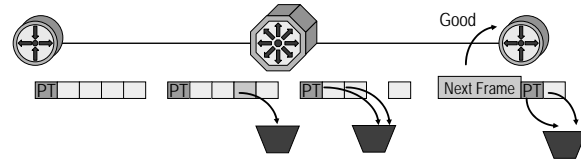
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### Tail Packet Discard



#### • 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.