Asynchronous Transfer Mode ATM - Part 1

Dr. Andreas Steffen

©1999-2001 Zürcher Hochschule Winterthur

Introduction
- Public and private ATM networks
- The ATM cell, the cell multiplexing principle
- Virtual path and channel connections
- Virutal path and channel switches

Signalling Protocols and Connection Setup
- Permanent and switched virtual connections
- Public and private user-network interfaces
- Public and private network-network interfaces
- ITU-T and ATM Forum standards
- Point-to-point connection setup
- Point-to-multipoint connection setup

Quality of Service (QoS)
- Service classes
- Traffic parameters
- Quality of service parameters
- Traffic contract
- Connection admission control
- Usage parameter control (policing)
- Generic cell rate algorithm (leaky bucket)

ATM - Themenübersicht

- **Theorie Teil 1** (heute)
  - Auffrischung Grundlagen (ATM Layer, Virtual Connections)
  - ATM Signalisierung (dynamischer Verbindungsaufbau)
  - Traffic Contract, Quality of Service (QoS),
- **Übung**
  - Policing (Leaky Bucket Algorithmus)
- **Theorie Teil 2** (nächste Woche)
  - Congestion Control, ATM Adressierung / Routing
  - LAN Emulation (LANE)
  - Multiprotocol over ATM (MPOA)
  - Multiprotocol Tag Switching (MPLS)
- **Praktikum** (1. / 2. / 8. oder 9.11.2001)
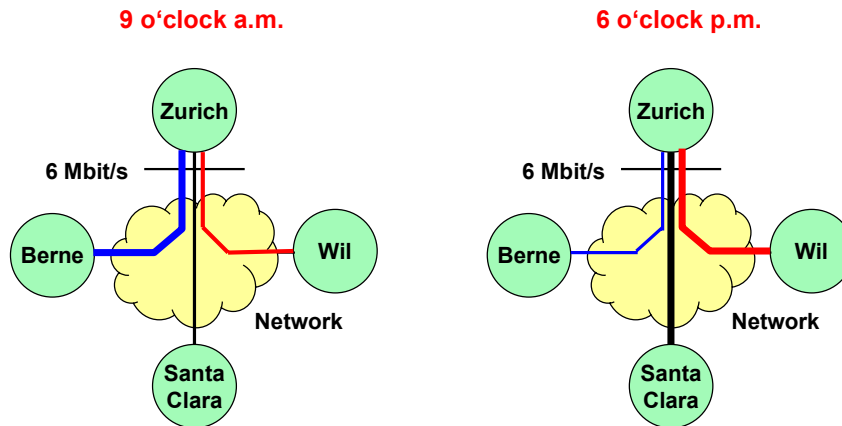 - Konfiguration und Betrieb eines kleinen ATM Netzes

ATM cells ?

Corporate Wide Area Network

 • A company wants to set up a WAN, connecting headquaters in Zurich with the
   production facilities in Wil and with two additional software development groups
   in Berne and Santa Clara (California), respectively.

 • The WAN should carry both phone calls and IP-based data traffic.

 • Total capacity should be limited to 6 Mbit/s.

Traffic situation at 9 o'clock a.m.

 • Many phone calls and heavy IP-traffic between Zurich and Berne.

 • Some IP traffic between Zurich and Santa Clara. No phone calls.

 • Some phone calls and normal IP traffic between Zurich and Wil.

Traffic situation at 6 o'clock p.m.

 • Few phone calls and little IP-traffic between Zurich and Berne.
 • Some phone calls and heavy IP-traffic between Zurich and Santa Clara.
 • Heavy IP-traffic due to production data upload from Zurich to Wil. No phone calls.

PDH / SDH solution

 • Three leased lines from Zurich to Bern, Wil and Santa Clara with a fixed capacity
   of 2 Mbit/s each would not be optimally used during the different hours of the day.

 • Voice and data traffic would have to be assigned (dynamically?) to N x 64 kbit/s
   ISDN B-channels.

ATM solution

 • A single physical line connects Zurich to the WAN.

 • Capacity could be assigned dynamically to the three destinations as long as the
   maximum capacity of 6 Mbit/s is not exceeded.

 • The relative volume of voice and data traffic can also vary dynamically.

ATM - The Network
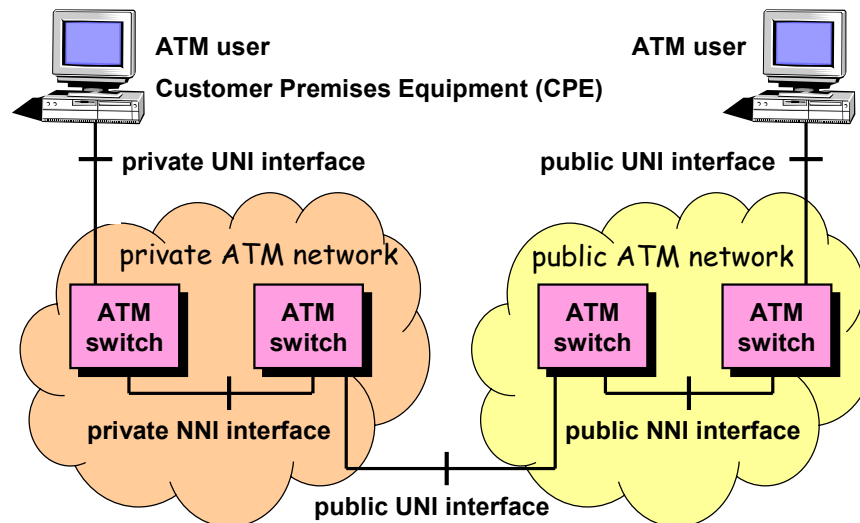
Public ATM networks
- Traditionally operated by the national telecom carriers (national networks)
- The standards are mainly defined by the ITU-T

Private ATM networks
- Large national and international ATM backbone networks operated by private carriers and big companies
- WAN and LAN corporate and campus networks based on ATM (LAN emulation)
- The standards are mainly defined by the ATM forum

Customer Premises Equipment (CPE)
- ATM end systems, e.g. hosts or routers having an ATM physical interface
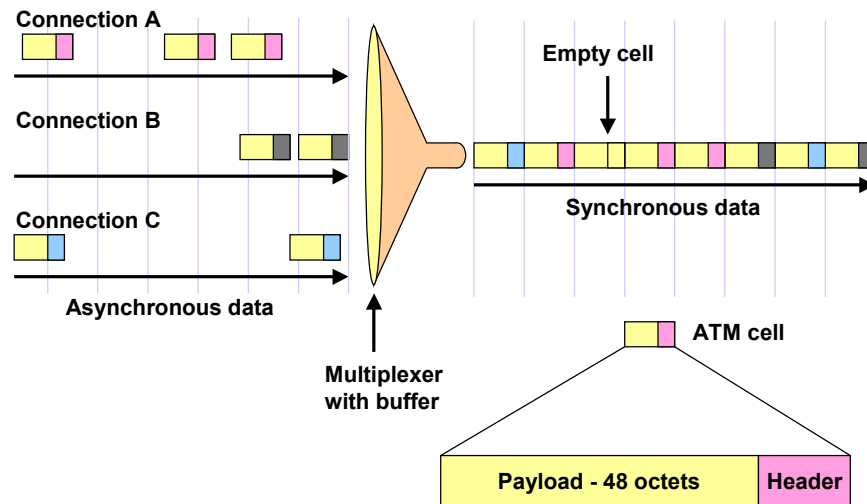- Private ATM networks as seen from the point of view of a public ATM network

User-Network-Interface (UNI)
- Signalling and data interface between the user equipment (CPE) and the network at the network access point
- User Parameter Control (Policing): Measuring and enforcing the parameters of the traffic contract negotiated between user and network
- The interface standards for public and private UNIs have been harmonized

Network-Network-Interface (NNI)
- Signalling and data interface between network elements (ATM switches) within a network
- There are significant differences between the interface standards for public and private NNIs, respectively
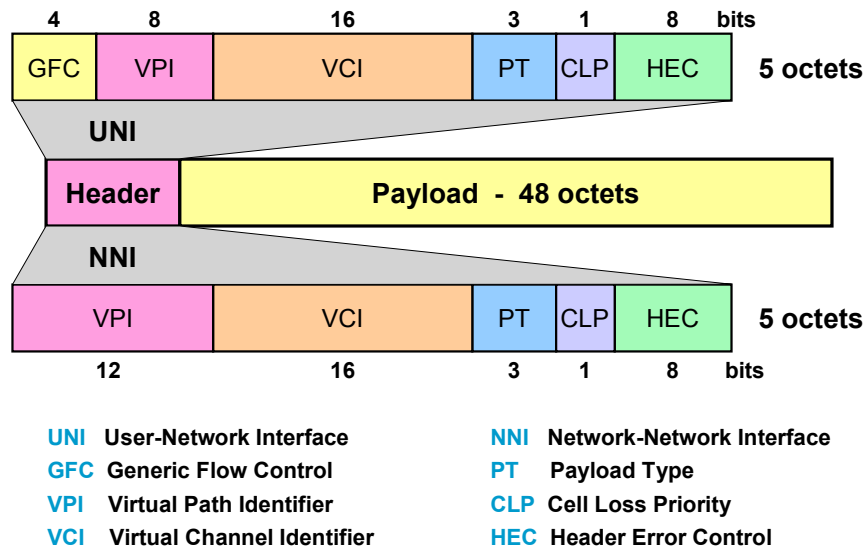
ATM - The Cell Multiplexing Principle

Connection A

Connection B

Connection C

Asynchronous data

Multiplexer with buffer

Empty cell

Synchronous data

ATM cell

Payload - 48 octets   Header

A. Steffen, 26.10.2001, KSy_ATM_1.ppt 6

Asynchronous Inputs

- Several asynchronous data streams (voice, multimedia, data, etc.)arrive from one or several CPEs (customer premises equipment) at the UNI (user-network interface). The data rate of each stream can be time-varying.

- The arriving data octets of the individual streams are packaged into constant size ATM cells, consisting of a 48 octet payload part and a 5 octet header part. Two fields in the header (VPI/VCI) are used to give each individual data stream a unique address.

- All ATM cells formed from the various asynchronous data streams arrive at random intervals at the inputs of an ATM multiplexer where they are temporarily stored in a large buffer.

Synchronous Output

- The ATM multiplexer choses among the incoming ATM cells on a first-come / first-served basis or according to some negotiated priorities and multiplexes the selected cells onto an outgoing synchronous ATM link. Such a link can be carried over 2 Mbit/s or 34 Mbit/s PDH connections or 155 Mbit/s , 622 Mbit/s or 2.5 Gbit/s STM-N connections.

- If the input buffer runs empty then in order to keep up synchronous operation „empty cells" are mapped onto the outgoing ATM stream.

- On the other hand if the input buffer is about to overflow, ATM input cells are discarded according to the parameters settled in the traffic contract for the individual data streams. This operation is called Usage Parameter Control (UPC) or Policing.

ATM - The Cell   53 octets

ZHW — Zürcher Hochschule Winterthur

| 4 | 8 | 16 | 3 | 1 | 8 | bits |

| GFC | VPI | VCI | PT | CLP | HEC | 5 octets |

UNI

| Header | Payload - 48 octets |

NNI

| VPI | VCI | PT | CLP | HEC | 5 octets |

| 12 | 16 | 3 | 1 | 8 | bits |

UNI	User-Network Interface	NNI	Network-Network Interface
GFC	Generic Flow Control	PT	Payload Type
VPI	Virtual Path Identifier	CLP	Cell Loss Priority
VCI	Virtual Channel Identifier	HEC	Header Error Control

A. Steffen, 26.10.2001, KSy_ATM_1.ppt 7

ATM - Layer Specification (ITU-T I.361)

- Defines the ATM-Layer based on a synchronous stream of ATM cells with a constant size of 53 octets each.

GFC - Generic Flow Control (UNI only)

- This field is rarely used, because the GFC protocol hasn't been defined properly
- Uncontrolled equipment: GFC = '0000'
- Controlled equipment: GFC ≠ '0000' (GFC protocol)

VPI - Virtual Path Identifier

- Identifies a virtual path between two ATM nodes

VCI - Virtual Channel Identifier

- Identifies a virtual channel between two ATM nodes or a virtual channel within a virtual path
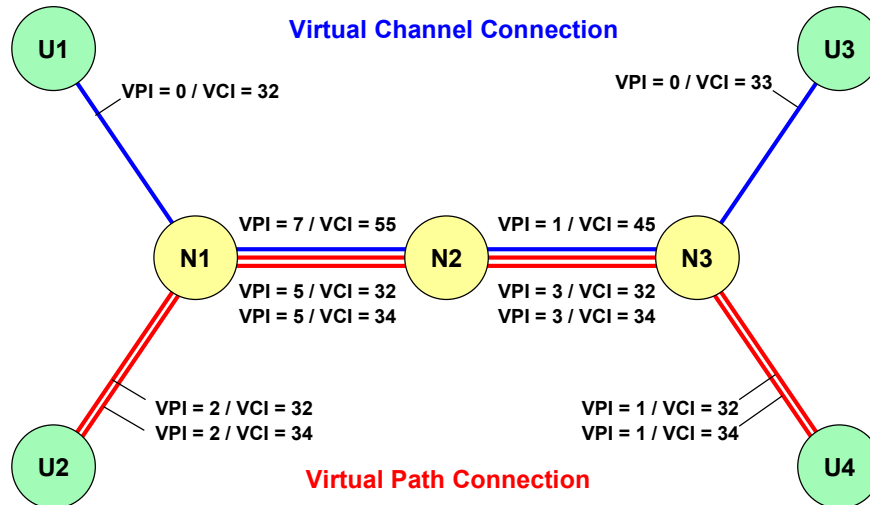
PT - Payload Type

- User data cells experiencing congestion
- User data cells experiencing no congestion
- Operations and Maintenance (OAM) cells
- Resource Management (RM) cells

CLP - Cell Loss Priority

- Higher priority: CLP = '0'   (data)
- Lower priority: CLP = '1'   (loss tolerant voice / video)
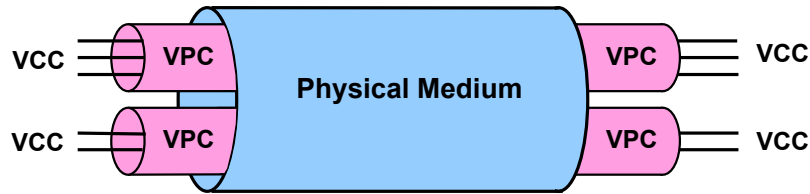
HEC - Header Error Control

- The HEC field is a CRC-8 check sum on the 5 octets of the header information only
- When a single bit error occurs the header information is corrected
- When multiple bit errors occur the cell is discarded
- Is also used for cell alignment and synchronisation

Virtual Channel Connection

VPI = 0 / VCI = 32

VPI = 0 / VCI = 33

U1

U3

VPI = 7 / VCI = 55

VPI = 1 / VCI = 45

N1

N2

N3

VPI = 5 / VCI = 32
VPI = 5 / VCI = 34

VPI = 3 / VCI = 32
VPI = 3 / VCI = 34

VPI = 2 / VCI = 32
VPI = 2 / VCI = 34

VPI = 1 / VCI = 32
VPI = 1 / VCI = 34

U2

U4

Virtual Path Connection

A. Steffen, 26.10.2001, KSy_ATM_1.ppt 8

ATM is a connection-oriented technology !

• In contrast to the popular **connection-less** IP-protocol where each IP-datagram
must find its way through the internet (helped by static or dynamic routing tables),
ATM is inherently a **connection-oriented** technology, where each point-to-point or
point-to-multipoint connection must be **set up** first before it can be used.

• This connection setup can be done either **statically** by manual configuration or
automatically using the signalling protocols described later in this chapter.
Once a connection between two ATM end points has been found and set up,
each ATM cell in this connection takes the same route through the ATM network.
ATM cells also keep their relative order in which they were sent by the transmitting
node.

ATM - Virtual Channels and Virtual Paths

VCC === VPC | **Physical Medium** | VPC === VCC

VCC === VPC | | VPC === VCC

- **VCC - Virtual Channel Connection** (VPI = n, VCI = m)
  - **Single connection between two ATM end systems**
- **VPC - Virtual Path Connection** (VPI = n)
  - **Bundle of several VCCs taking a common path between two ATM end systems**

Virtual Channel Connection (VCC)

- A virtual channel connection is a single point-to-point connection through an ATM network. A physical link between two ATM nodes can be shared by a nearly unlimited numbers of VCCs, as long as the maximum transmission capacity of the link is not exceeded.
- A virtual channel between two ATM nodes is uniquely characterized by its combined VPI / VCI identifiers.

Virtual Path Connection (VPC)

- A virtual path connection is a bundle of several virtual channel connections that have the same endpoints.
- A virtual path between two ATM nodes is uniquely characterized by its VPI identifier.
- Treating several VCCs as a single VPC increases switching efficiency, because an ATM switches must look only at the VPI field of each ATM cell.
- As a service for its customers, an ATM carrier can assign and set up a virtual path between two customer end points. The customer is then free to choose the number and the capacity of the individual virtual connections within this predefined VPC.
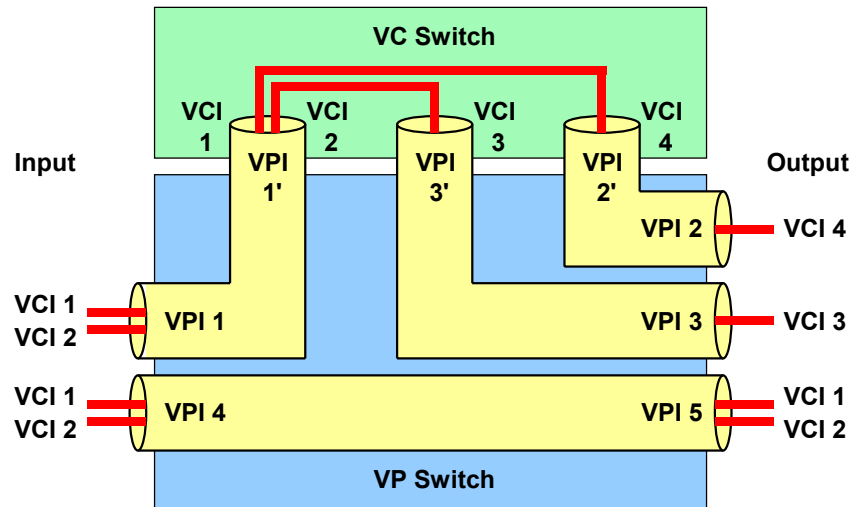
VP-Switch

• A VP-switch, often also called an **ATM cross-connect,** switches ATM cells on a virtual path level by looking at the VPI identifiers only. The VCI field is usually left unchanged. Thus VP switches can be implemented very efficiently.
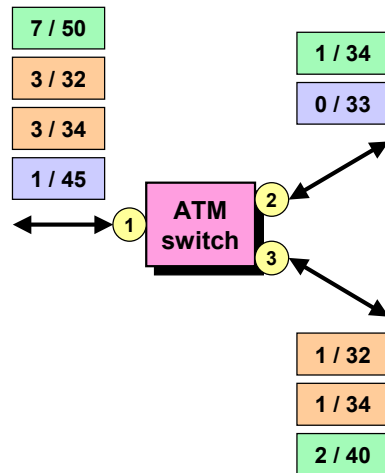
VC-Switch

• A VC-switch handles ATM cells on a virtual channel level by looking at both the VPI and VCI identifiers. Both VPI and VCI values usually change on the outgoing connection.

Combined Switches

• In a typical ATM node, path level switching and channel level switching are often combined as it is shown in the above figure. Acting as a first stage, a VP-switch handles the large ATM transit volume, whereas a smaller percentage of cells that must be switched on the individual channel connection level are fed into a separate VC-Switch.

ATM - Switching Tables

Bidirectional Unicasts

Inputs		Outputs	
Port	**VPI/VCI**	**Port**	**VPI/VCI**
1	1 / 45	2	0 / 33
1	3 / ..	3	1 / ..
2	0 / 33	1	1 / 45
3	1 / ..	1	3 / ..

Unidirectional Multicasts

Inputs		Outputs	
Port	**VPI/VCI**	**Port**	**VPI/VCI**
1	7 / 50	2	1 / 34
1	7 / 50	3	2 / 40

A. Steffen, 26.10.2001, KSy_ATM_1.ppt 11

I/O Structure an ATM Switch

• An ATM switch can have a variable number of interface cards (e.g. Ethernet, PDH, SDH cards) and each card has a certain number of bidirectional physical ports (usually 1- 8 ports per card).

• An ATM switch should be able to switch any virtual channel arriving at any of the input ports to any virtual channel leaving through any output port.

• In order to configure the input / output mapping, a switching table with an entry for each virtual channel or path connection is needed.
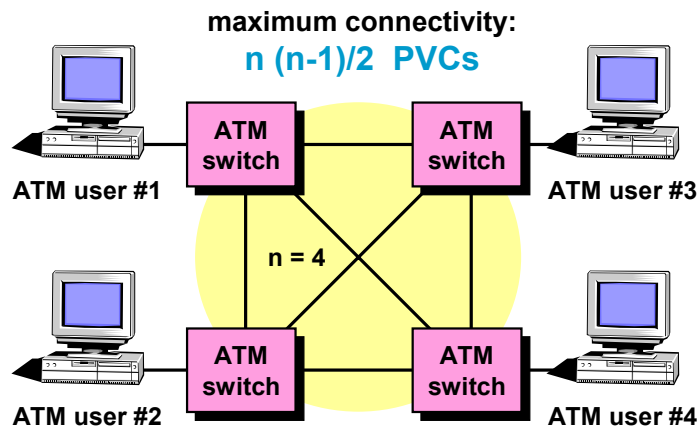
Bidirectional Unicasts

• For bidirectional connections usually only one direction has to be configured explicitly. The required inverse direction entry in the switching table (using the same VPI/VCI values) is automatically generated.

Unidirectional Multicasts

• ATM easily supports unidirectional multicasts. ATM cells can be duplicated and copied onto as many output ports as desired.

• A multicast from an ATM root or server node to several ATM leaf or client nodes will share a single virtual channel per physical line as long as possible and can thereby save valuable bandwidth. Actual duplication of ATM cells will only occur in those intermediate nodes where virtual channel connections to different endpoints must fork.

Asynchronous Transfer Mode (ATM)

Signalling Protocols
and
Connection Setup

maximum connectivity:
n (n-1)/2 PVCs

ATM switch   ATM switch

ATM user #1   ATM user #3

n = 4

ATM switch   ATM switch

ATM user #2   ATM user #4

■ **PVC - Permanent Virtual Connection** (static setup)

■ **SVC - Switched Virtual Connection** (requires signalling)

A. Steffen, 26.10.2001, KSy_ATM_1.ppt 13


How to cope with complexity ?

• Given **n** ATM users the total number **n (n-1)/2** of potential virtual connections increases quadratically with **n**. For 10 users maximum connectivity requires the configuration of 45 virtual channel connections. For 100 users already 4950 VCC setups are necessary.

• In practical applications only a very small percentage of all potential connections will actually ever be used. The enormous effort required to configure all possible end-to-end routes statically, before even a single ATM cell gets transmitted, wouldn't pay off.

• So, similarly to a normal telephone call, it would be desirable to set up an ATM connection just shortly before it is actually used and releasing it when the connection isn't needed any more. In order to implement such a dynamic setup of ATM connections a **signalling protocol** is required.

PVC - Permanent Virtual Connection

• A virtual connection that is configured and set up **statically** is called a Permanent Virtual Connection (PVC).

• PVCs can be used when only a small number of connections must be set up or for connections that are used over a long period of time.

• PVCs are often used for predefined control connections with „well-known" VPI/VCI values.

SVC - Switched Virtual Connection

• A virtual connection that is configured and set up **dynamically** just before use is called a Switched Virtual Connection (SVC).

• Standardized **signalling protocols** are needed to find, set up and later release an optimal switched virtual connection through an ATM network.
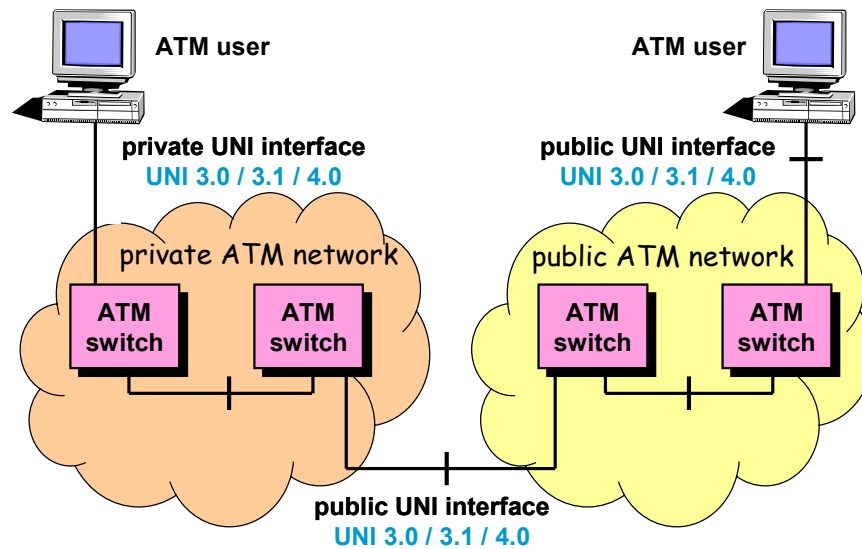
Private User-Network Interface
 • Interface between the customer premises equipment (CPE) and a private ATM network
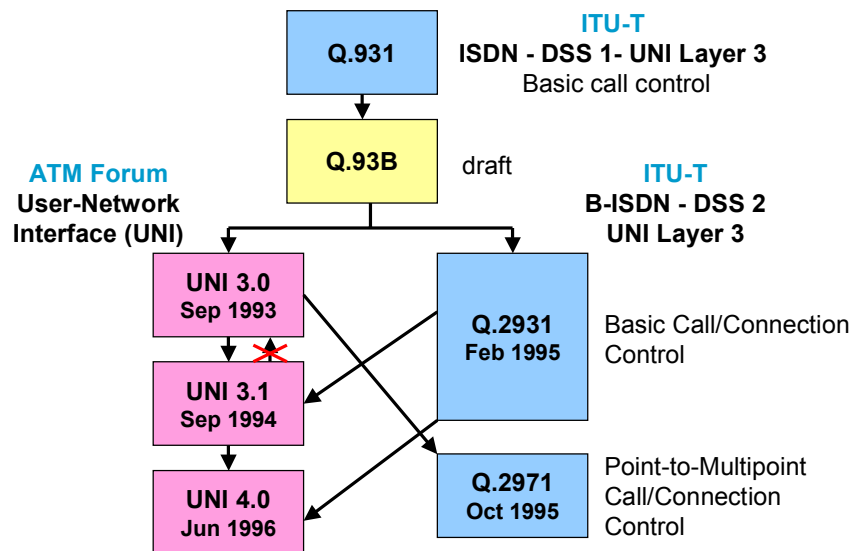
Public User-Network Interface
 • Interface between the customer premises equipment (CPE) and a public ATM network
 • Interface between a private ATM network and a public ATM network

UNI Standards
 • Several, partly incompatible releases of UNI standards are currently in use
 • Most common are the UNI 3.0 / 3.1 and 4.0 standards defined by the ATM Forum

Q.931

ITU-T
ISDN - DSS 1- UNI Layer 3
Basic call control

ATM Forum
User-Network Interface (UNI)

Q.93B   draft

ITU-T
B-ISDN - DSS 2 UNI Layer 3

UNI 3.0 Sep 1993

UNI 3.1 Sep 1994

UNI 4.0 Jun 1996

Q.2931 Feb 1995   Basic Call/Connection Control

Q.2971 Oct 1995   Point-to-Multipoint Call/Connection Control

A. Steffen, 26.10.2001, KSy_ATM_1.ppt 15

UNI Standard Development

• The ATM standardizaton process was extremely tiresome and took many years to complete. It was characterized by a fierce battle between two factions:

• The ITU-T (dominated by the national telco operators) wanted a full-grown broadband communications standard, which as an extension of the existing narrowband ISDN standard, would encompass all conceivable applications like voice, data, multimedia, etc.

• The ATM Forum (an interest group of ATM equipment manufacturers and private network operators) wanted simple standards in order to roll out ATM equipment for private data networks as fast as possible.

Q.931

• N-ISDN UNI layer 3 signalling standard selected as the basis for the B-ISDN UNI

Q.93B

• ITU-T working draft for the B-ISDN UNI, derived from Q.931

Q.2931

• Q.93B developed into Q.2931. Progress by the ITU-T working group was very slow.

UNI 3.0

• ATM Forum released an early subset of Q.93B signalling in the UNI 3.0 specification

UNI 3.1

• ATM Forum released UNI 3.1 to keep abreast with continuing Q.2931 development.
• Due to a different data link protocol, UNI 3.1 is **not** compatible with UNI 3.0 !

UNI 4.0

• Final version by the ATM Forum. Is to a large extent compatible with final Q.2931

Q.2971

• Covers point-to-multipoint connections defined in UNI 3.0 but not contained in Q.2931
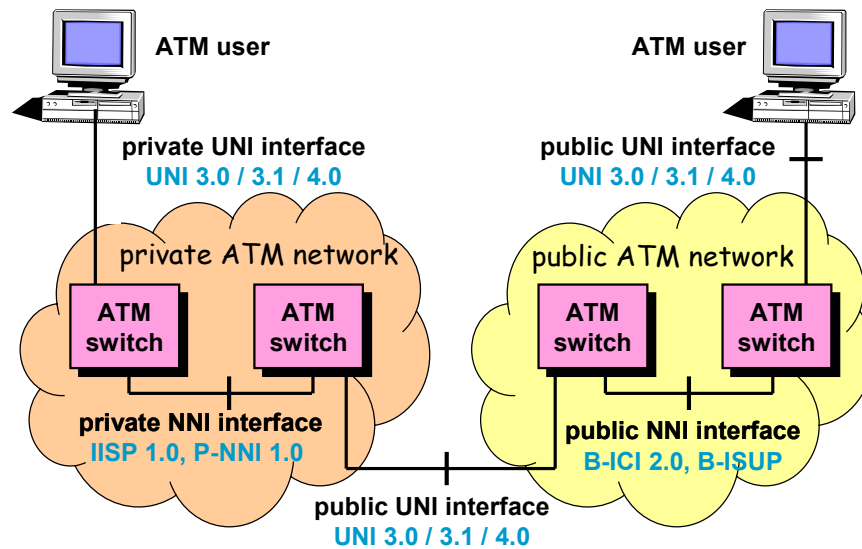
Private Network-Network Interface

• Signalling between nodes of a private ATM network

• Signalling protocols specified by the ATM Forum:

  • Interim Inter-Switch Signalling Protocol (IISP 1.0)
 • Private Network-Network Interface (P-NNI 1.0)

Public Network-Network Interface

• Signalling between nodes of a public ATM network

• Signalling protocols specified by the ITU-T:

  • Broadband ISDN User Part (B-ISUP) based on the Signalling System No 7 (SS7)
  • Broadband Inter-Carrier Interface (B-ICI)

NNI Standards

  • Clear distinction and incompatibility between public and private ATM networks
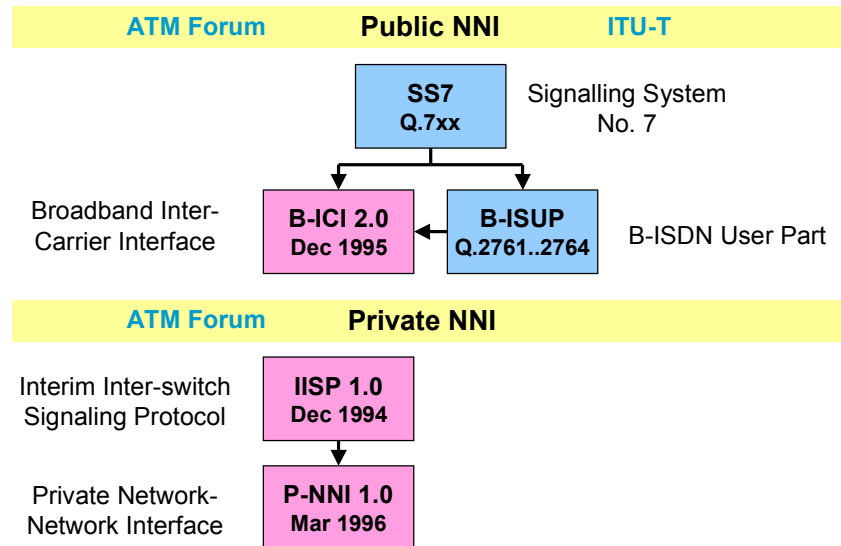
Public NNI

• Specified by the ITU-T. Used exclusively in public ATM networks usually operated by national carriers.

SS7

• The Signalling System No. 7 is used by public carriers to distribute signalling information in the N-ISDN and GSM networks. It is also used for B-ISDN.

B-ISUP

• The broadband ISDN User Part (B-ISUP) has been derived from the narrowband ISDN User Part (ISUP). It is part of the SS7 protocol family.

B-ICI 2.0

• The Broadband Inter-Carrier Interface (B-ICI) defines the signalling at the interface between two public networks operated by different carriers.

Private NNI

• Specified by the ATM Forum. Used exclusively in private ATM networks.
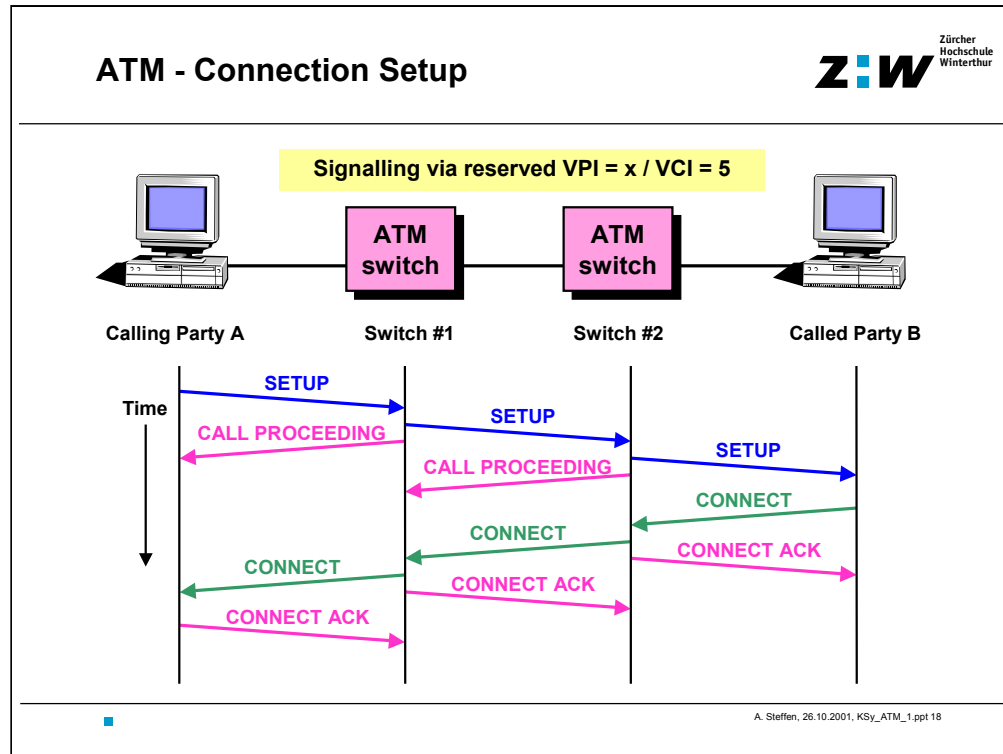
IISP

• The Interim Inter-Switch Protocol (IISP) is very simple. It was introduced in an early development stage to allow the roll-out of first generation ATM switches. The IISP uses static VC address tables and thus allows permanent virtual connections (PVCs) only.

P-NNI

• P-NNI incorporates dynamic VC routing protocols and thus supports the setup of switched virtual connections (SVCs).

Signalling Channels

- An ATM connection setup uses either
  - the default **point-to-point signalling channel** preconfigured with VPI = x / VCI = 5.
  - or a dedicated signalling channel that is created first using the default **meta-signalling channel** with VPI = x / VCI = 1.
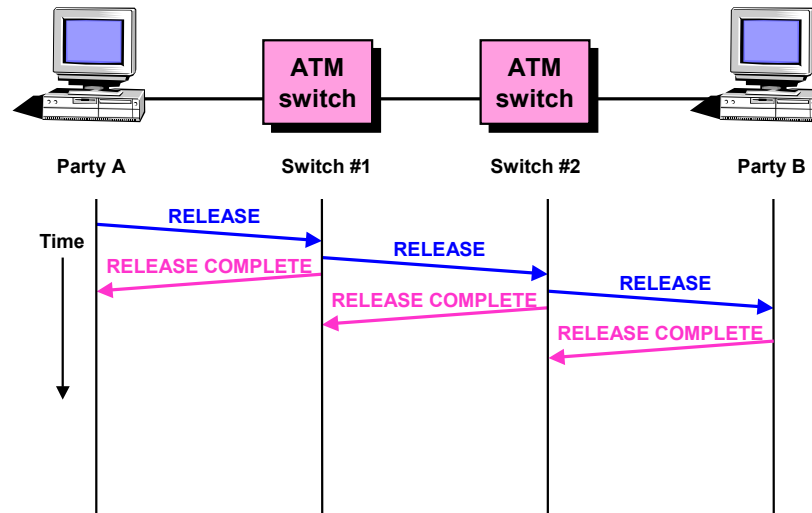- Using VC routing protocols an optimal path can be found through an ATM network.

SETUP Message

- The **calling party** (host A) sends a SETUP message to switch #1 it is attached to.
- Switch #1 forwards the SETUP message to switch #2, the next hop on the way to host B. Switch #1 then sends back to host A a CALL PROCEEDING message.
- Switch #2 forwards the SETUP message to host B and sends back to switch #1 a CALL PROCEEDING message.

CONNECT Message

- The **called party** (host B) receives the SETUP message and is willing to accept a connection with host A. It answers with a CONNECT message that it sends to switch #2, its next hop on the way back to host A.
- Switch #2 forwards the CONNECT message to switch #1 and sends back to host B a CONNECT ACK message. A bidirectional SVC is established between host B and switch #2.
- Switch #1 forwards the CONNECT message to host A and sends back to switch #2 a CONNECT ACK message. A bidirectional SVC is established between switch #2 and switch #1.
- Host A sends back to switch #1 a CONNECT ACK message. A bidirectional SVC is established between switch #1 and host A. A bidirectional virtual connection between host A and host B has been created.

ATM - Connection Release

Party A   Switch #1   Switch #2   Party B

Time

RELEASE
RELEASE COMPLETE
RELEASE
RELEASE COMPLETE
RELEASE
RELEASE COMPLETE

Connection Release

• The release of a bidirectional virtual connection can be initiated either party.
  We will examine the case when party A wants to terminate a connection.

RELEASE Message

• Party A send a RELEASE message over the signalling channel to switch #1.

• Switch #1 forwards the RELEASE message to switch #2 and sends back
  a RELEASE COMPLETE message to party A. The bidirectional virtual connection
  between host A and switch #1 is now released.

• Switch #2 forwards the RELEASE message to party B and sends back
  a RELEASE COMPLETE message to switch #1. The bidirectional virtual connection
  between switch #1 and switch #2 is now released.

• Party B receives the RELEASE message and sends back a RELEASE COMPLETE
  message to switch #2. The bidirectional virtual connection between switch #2 and
  party B is now released. With this last step the whole virtual connection between
  the two parties has been released.

ATM - Point-to-Multipoint Connections

Z:W Zürcher Hochschule Winterthur

Leaf B

Root A

ATM Network N

Leaf C

Leaf D
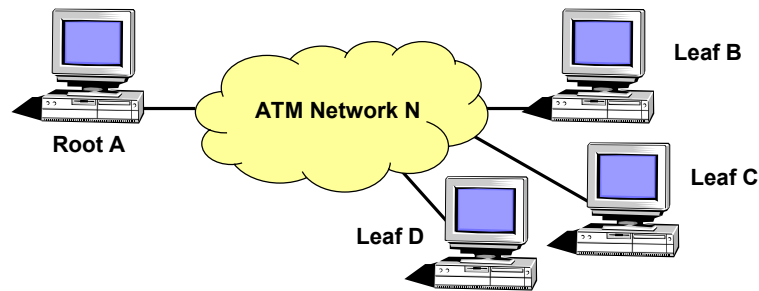
■ **Root Initiated Connection Setup**
  ■ A ⇒ B: **SETUP**   B ⇒ A: **CONNECT**
  ■ A ⇒ C: **ADD PARTY**   C ⇒ A: **ADD PARTY ACK**
■ **Leaf Initiated Join (LIJ) - UNI 4.0 Feature !**
  ■ D ⇒ N: **LEAF SETUP REQUEST**
  ■ A/N ⇒ D: **ADD PARTY**   D ⇒ A/N: **ADD PARTY ACK**

Root Initiated Connection Setup

• Root A wants to set up a point-to-multipoint connection to the leaves B and C.

• The first connection between root A and leaf B is set up as a normal point-to-point connection using the SETUP and CONNECT messages.

• In order to add the second leaf C, root A sends an ADD PARTY message out to the network in the direction of leaf C. As long as the route to leaf C follows the already established route to leaf B, the ADD PARTY message is forwarded through the network.

• At the node where the routes between leaf B and leaf C branch, the ADD PARTY message is converted into a SETUP message. Leaf C answers the SETUP message with a CONNECT message that is send back through the network in the direction of root A.

• When the CONNECT message reaches the node where the routes from leaves B and C join, the CONNECT message is converted into a ADD PARTY ACK message that is sent further down the network until it reaches root A.

Leaf Initiated Join (LIJ)

• With UNI 3.0 / 3.1, a root had to know in advance all the leaves taking part in a multicast. After the establishment of the required point-to-multipoint connections no additional leaves were able to join.

• Starting with UNI 4.0 a new leaf D wanting to joint an already running point-to-multipoint connection can send a LEAF SETUP REQUEST message to the network

Root LIJ Call

• The LEAF SETUP REQUEST is forwarded by the network to the root which adds leaf D using the normal ADD PARTY / ADD PARTY ACK mechanism.

Network LIJ Call

• When the LEAF SETUP REQUEST reaches a node in the already established point-to-multipoint tree, this node joins leaf D to the multicast tree using the SETUP / CONNECT mechanism without notifying the root.

Quality of Service (QoS)

ATM - Service Classes

- ## CBR - Constant Bit Rate
  - Circuit emulation, e.g. T1 (1.5 Mbit/s) or E1 (2 Mbit/s)
  - Real-time audio / video coded at a constant bit rate

- ## rt-VBR - real time Variable Bit Rate
  - Compressed video (MPEG-2) coded at a variable bit rate with stringent real- time requirements (video conference)

- ## nrt-VBR - non real time Variable Bit Rate
  - Frame Relay, data transfers for transaction-processing applications (airline reservations, banking transactions, etc.)

- ## UBR - Unspecified Bit Rate
  - „Best effort" without any guarantees (e-mail, file transfer, etc.)

- ## ABR - Available Bit Rate
  - Adaptive „best effort" service with guaranteed minimum cell rate (LAN emulation)

ATM - Traffic Parameters

- **PCR - Peak Cell Rate**
  - **Maximum rate at which cells will be sent**

- **SCR - Sustainable Cell Rate**
  - **Long-term average cell rate**

- **MCR - Minimum Cell Rate**
  - **Minimum acceptable cell rate**

- **MBS - Maximum Burst Size**
  - **Maximum number of consecutive cells in a burst**

- **CDVT - Cell Delay Variation Tolerance**
  - **Maximum acceptable cell jitter**

The traffic parameters make up a traffic descriptor, describing the characteristics of the source.

ATM - Quality of Service (QoS) Parameters

Zürcher Hochschule Winterthur

- **CTD - Cell Transfer Delay**
  - Elapsed time between cell exit event at the source and corresponding cell entry event at the destination.
  - maxCTD - maximum Cell Transfer Delay
- **CDV - Cell Delay Variation**
  - Time difference between minimum and maximum cell transfer delay, i.e peak-to-peak cell delay variation.
- **CLR - Cell Loss Ratio**
  - Ratio of lost cells to total transmitted cells

The QoS parameters describe the desired performance at the destination of the virtual channel.

ATM - Applicable Service Class Parameters

Parameter	CBR	rt-VBR	nrt-VBR	ABR	UBR
CLR	✓	✓	✓	✓	—
CTD	max	max	mean	—	—
CDV	✓	✓	—	—	—
PCR & CDVT	✓	✓	✓	✓	✓
SCR & MBS	—	✓	✓	—	—
MCR	—	—	—	✓	—
Congestion Control	—	—	—	✓	—

Traffic Parameters

- Peak Cell Rate (PCR) & Cell Delay Variation Tolerance (CDVT) are mandatory parameters for all service classes. They limit the maximum number of cells per time unit a user can feed into an ATM network and thus allows the ATM operator to plan and manage the actual network capacity.

- In order to control the burstiness of typical Variable Bit Rate (VBR) traffic, the additional parameters Sustainable Cell Rate (SCR) and Maximum Burst Size (MBS) are required.

QoS Parameters

- Bidirectional real-time Constant Bit Rate (CBR) and Variable Bit Rate (VBR) applications like phone calls or video conferences are very sensitive to the delays, therefore a maximum Cell Transfer Delay (CTD) must be specified.

- The guaranteed Cell Delay Variation (CDV) has an effect on the maximum size of the input buffer that is required at the receiving end. Both buffer underflows and buffer overflows should be avoided.

- All service classes with the exception of UBR guarantee a specified upper limit on the Cell Loss Ratio (CLR), i.e. the percentage of cells that can get lost.

ABR versus UBR

- The Available Bit Rate (ABR) and Unspecified Bit Rate (UBR) service classes deliver both a best effort service only, with ABR having the advantage that a Minimum Cell Rate (MBR) which the network must provide, can be specified.

- Using a congestion control mechanism described in part II of the ATM lecture, ABR always tries to offer to the user the maximum cell rate possible at a given moment

ATM - The Traffic Contract

■ **Traffic Contract**
  - **Traffic descriptors (PCR, SCR, MCR, MBS, CDVT)**
  - **QoS parameters (CTD, CDV, CLR)**

■ **CAC - Connection Admission Control**
  - **Can the ATM network establish the new link, so that the required QoS parameters for all connections including the new one can be guaranteed?**
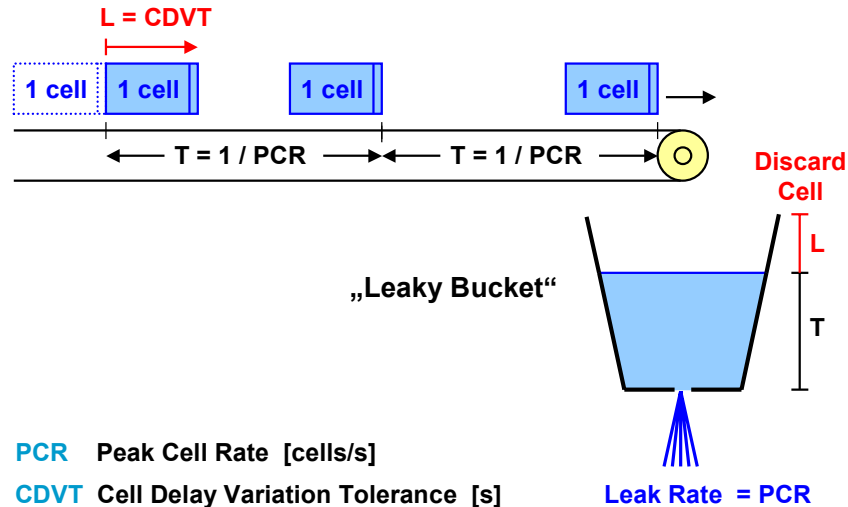
■ **UPC - Usage Parameter Control (Policing)**
  - **Does the link conform to the agreed parameters of the traffic contract?**
  - **Measured and enforced at the input to the ATM network.**

The Traffic Contract

• For each virtual path or channel connection a traffic contract is negotiated, from which both the ATM user and the ATM operator profit:

  • By specifing the characteristics of the ATM source using traffic descriptors the ATM operator gets a stable basis for planning and managing his network.

  • By specifying the desired performance on the basis of QoS parameters the ATM user can expect a guaranteed quality from the network.

The Generic Cell Rate Algorithm (GCRA)

- The algorithm used in ATM access multiplexers for usage parameter control is the generic cell rate algorithm often also called the „leaky bucket" algorithm.

- The negotiated peak cell rate (PCR) limits the maximum number of cells per second an ATM source can feed into the network. The inverse of the peak cell rate T = 1/PCR can be interpreted as the minimum time that must pass between the transmission of two subsequent cells.

- We imagine now that each cell is transporting an equal amount of water that is emptied into a bucket. The size of the bucket is designed to contain exactly the contents of one cell. In the bottom of the bucket a hole is drilled, leaking water at a rate that will empty the bucket in exactly T seconds. If the next cell arrives earlier than T seconds, the contents of the this cell cannot be received by the bucket since there is still water left in it and the whole cell is discarded.

- If the cell arrivals do not occur at constant intervals of exactly T seconds but are allowed to vary by L seconds, the time L being equal to the Cell Delay Variation Tolerance (CDVT) parameter negotiated by the traffic contract then the volume of the bucket must be increased to store L seconds more water.