Advanced Network Technologies

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ATM Fundamentals

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- **Transfer mode**

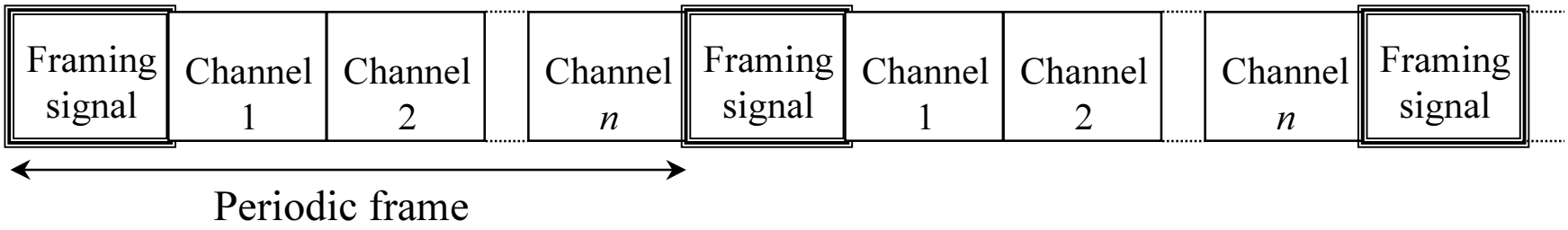
  → a specific way of transmitting and switching information in a network

- **Synchronous transfer mode (STM)**

  → a data unit associated with a given channel is identified by its position (TDM)

  → predefined channel bit rates (n*64kbs, E1: 2.048Mbps)

  → end to end synchronous circuit



- **Asynchronous Transfer Mode (ATM)**

  → a data unit associated with a specific virtual channel may occur in any position

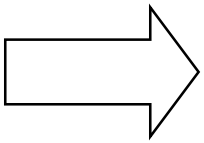
  → flexibility of bit bit rate allocation ! (e.g. bandwidth allocation on demand)

  → some problems:

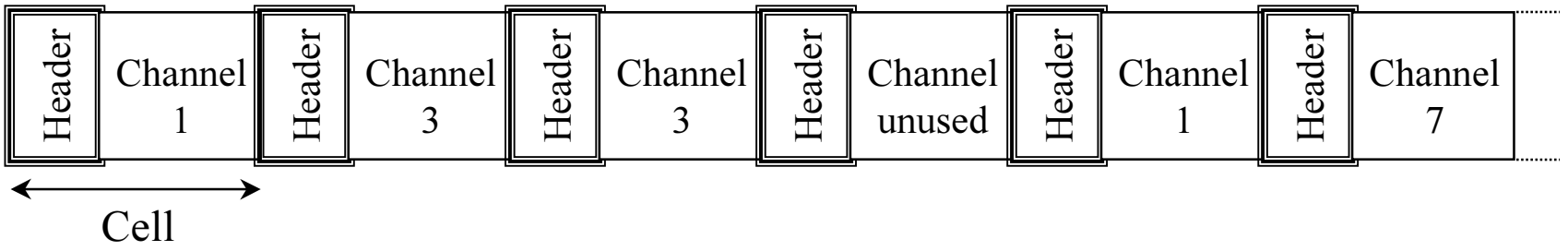
    → impacts of possible cell loss

    → cell transfer delay

    → cell delay variation



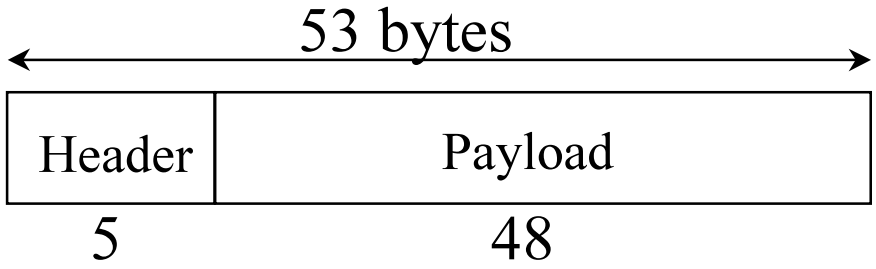
Quality of Service



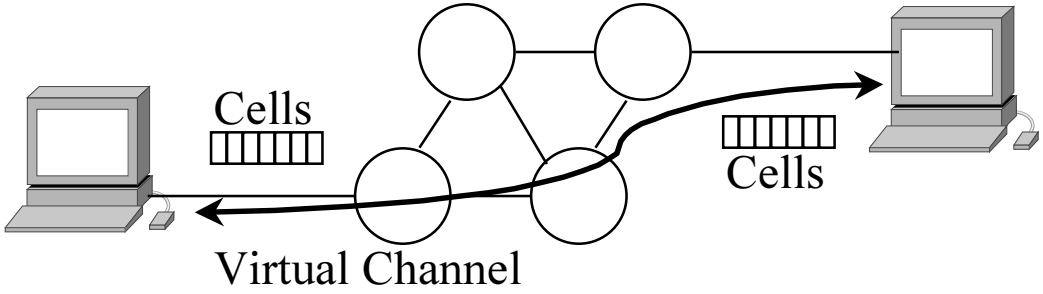
ATM - fundamentals

- Small fixed-size cells (5+48 byte, header+payload)
  - too long → higher delays
  - too short → too many overhead

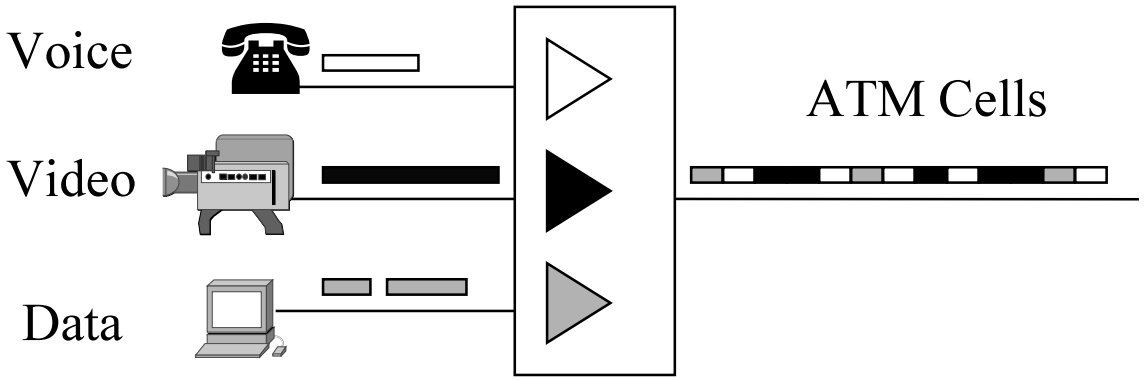
ATM Cell Format :



- Connection oriented - cell switching
  - low overhead → low processing time and delay



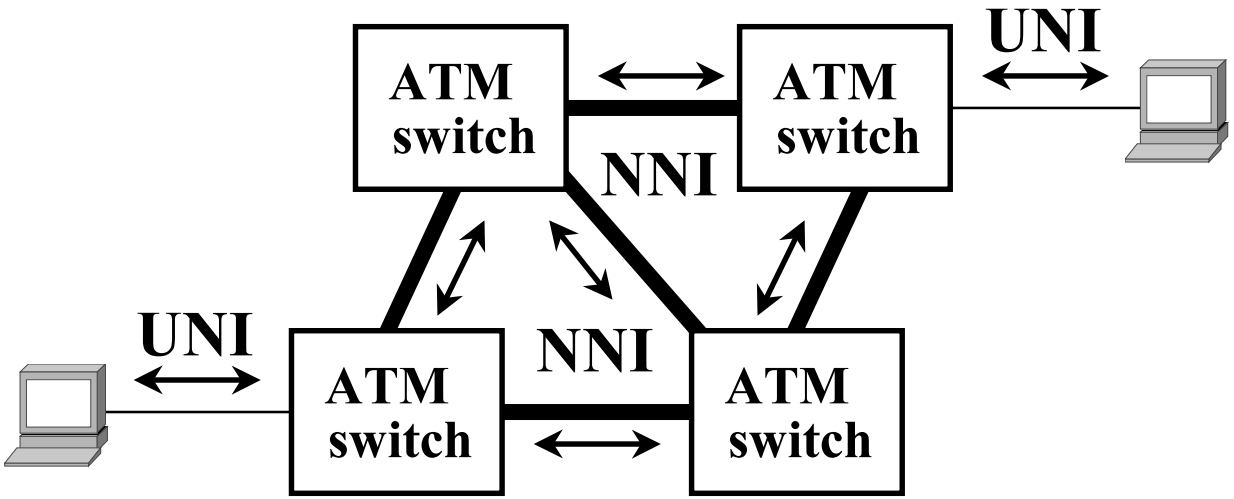
- Flexible, application independent (conversion of application data units to/from cells), it can handle
  - low or high bit rate connection or
  - dynamic bandwidth allocation



- Both LAN and WAN technology
  - 20 bytes structured hierarchical address format

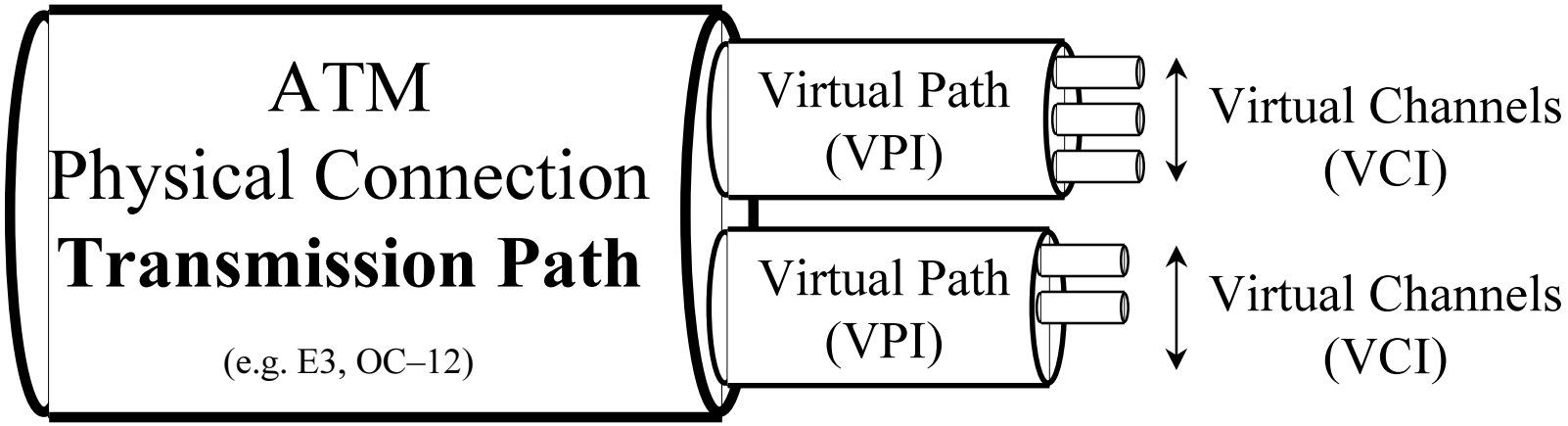
The ATM signaling

- Signaling is used for managing connections
  - user to network signaling
    (UNI User to Network Interface)
  - inter exchange signaling
    (NNI Network to Network Interface)



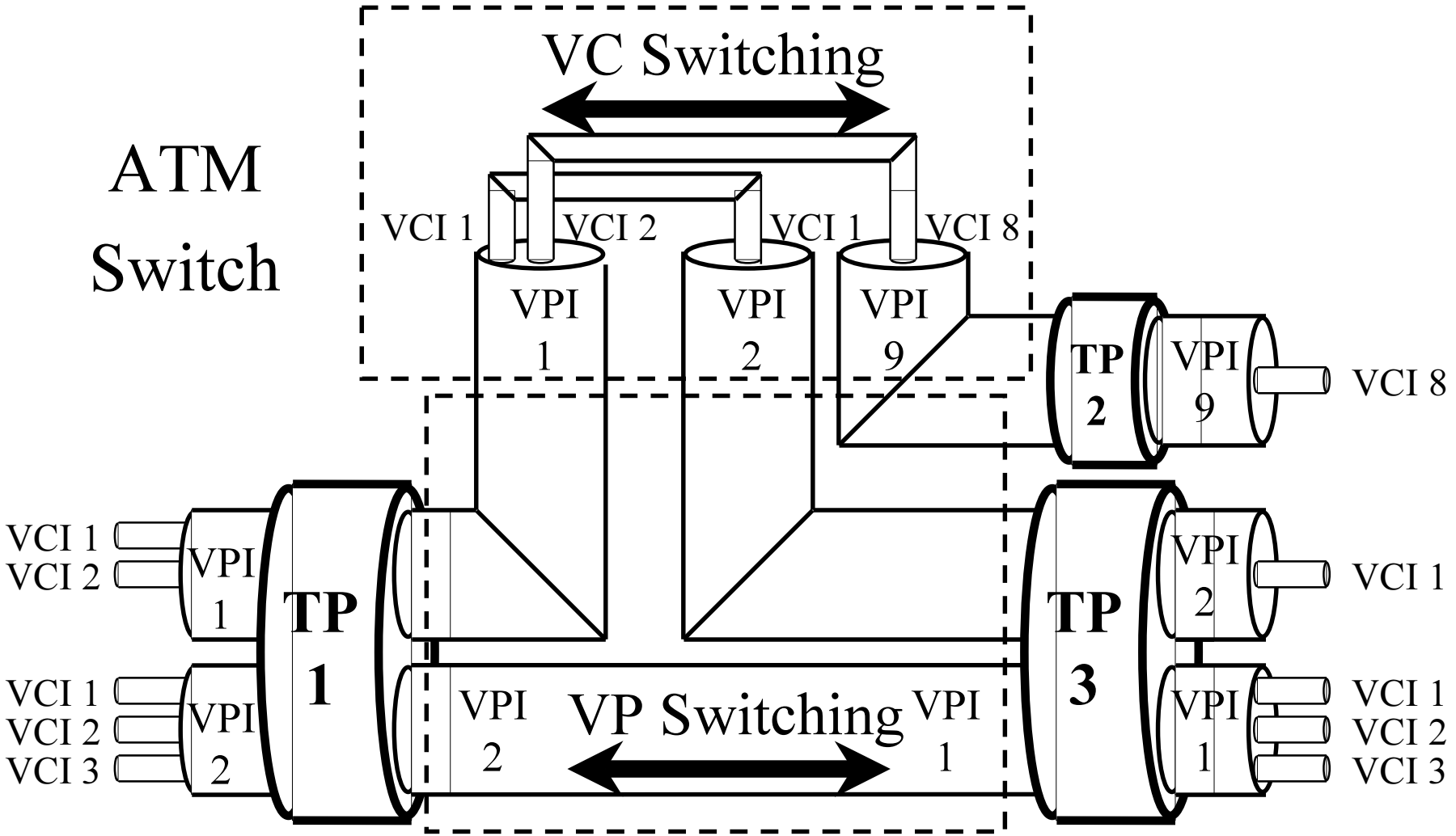
Virtual Path and Virtual Channel

- ATM is connection oriented
- The links (**Transmission Paths TP**) between network elements are carrying a hierarchical structure of connections:
  - **Virtual Channel (VC)** 'A concept used to describe unidirectional transport of ATM cells associated by a common unique identifier' - the **Virtual Channel Identifier (VCI)**
  - **Virtual Path (VP)** 'A concept used to describe unidirectional transport of cells belonging to virtual channels that are associated by a common identifier' - the **Virtual Path Identifier (VPI)**

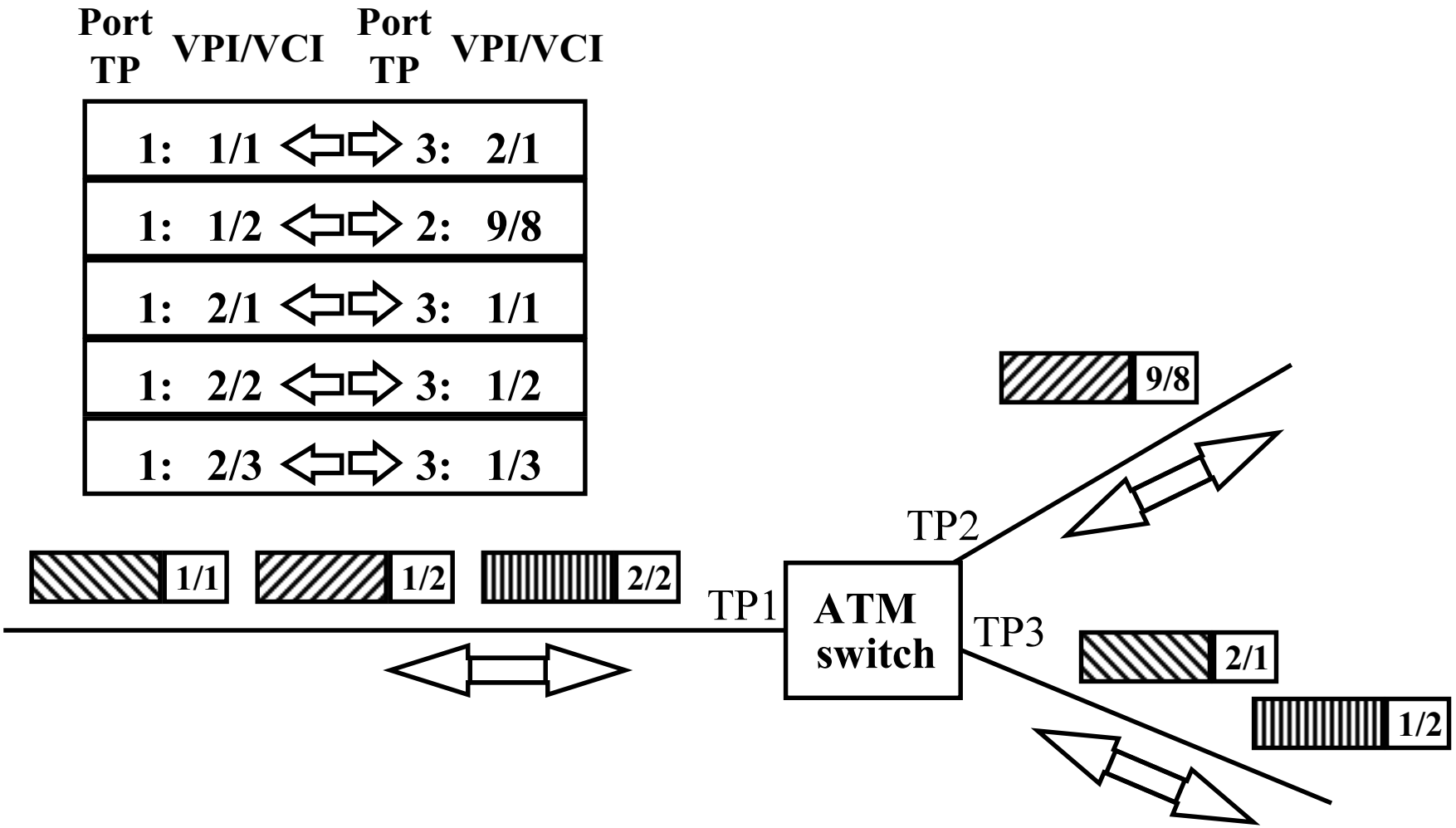


- Connections are identified by the VPI/VCI

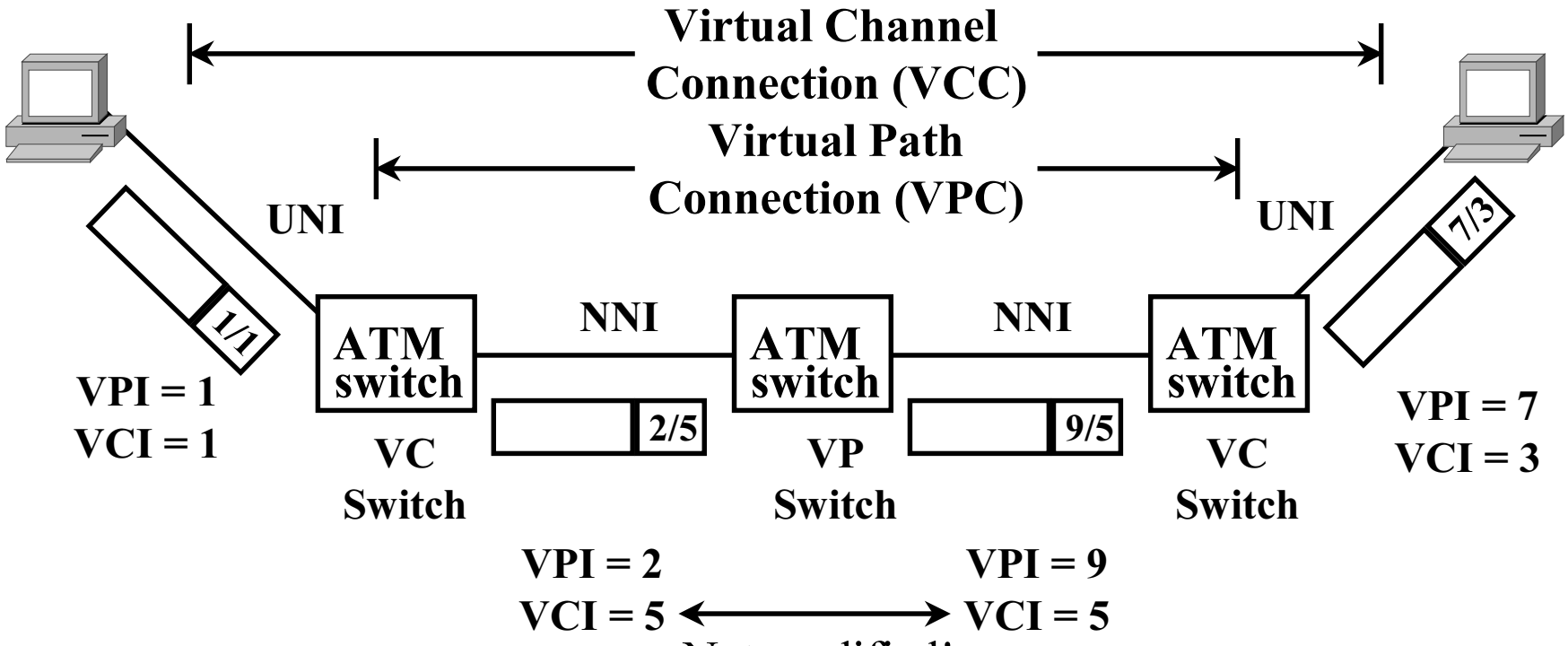
- A connection could have different VPI/VCI identifier on each Transmission Path



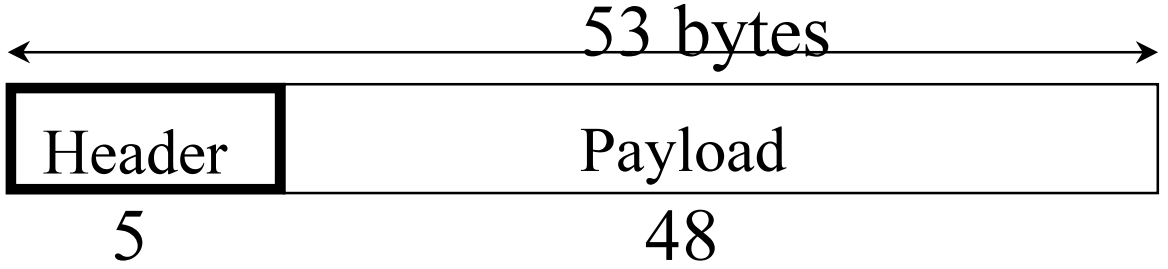
ATM Switching Table



- A concatenation of VC links is called **Virtual Channel Connection (VCC)**
- A concatenation of VP links is called **Virtual Path Connection (VPC)**

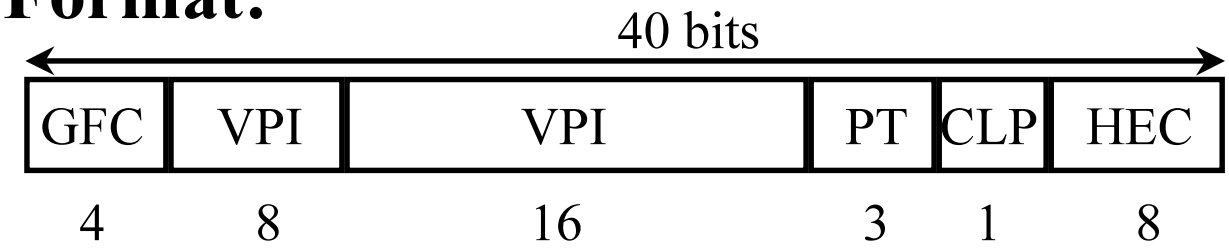


The ATM cell header format

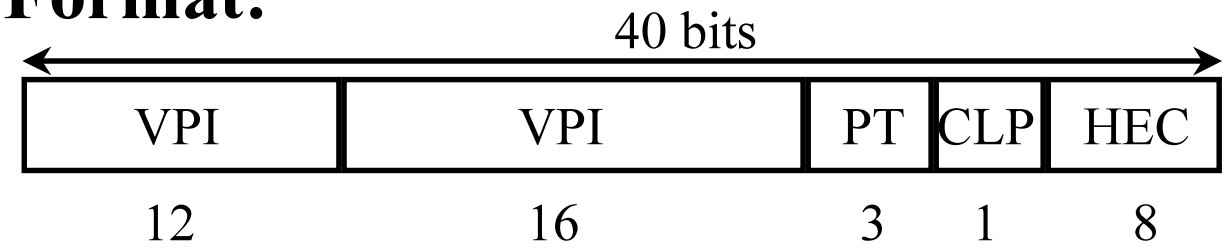


- Depending on the signalling used, there are **two different header format**

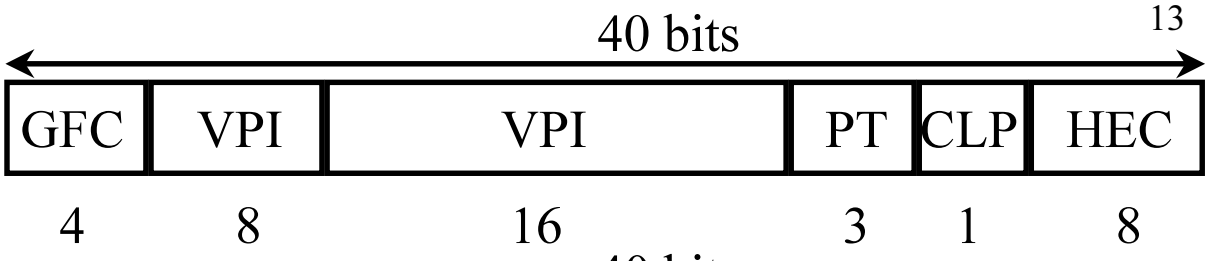
UNI Header Format:



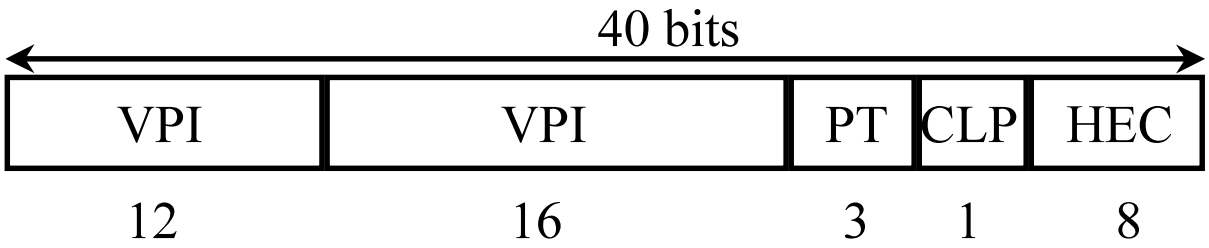
NNI Header Format:



UNI Header Format:

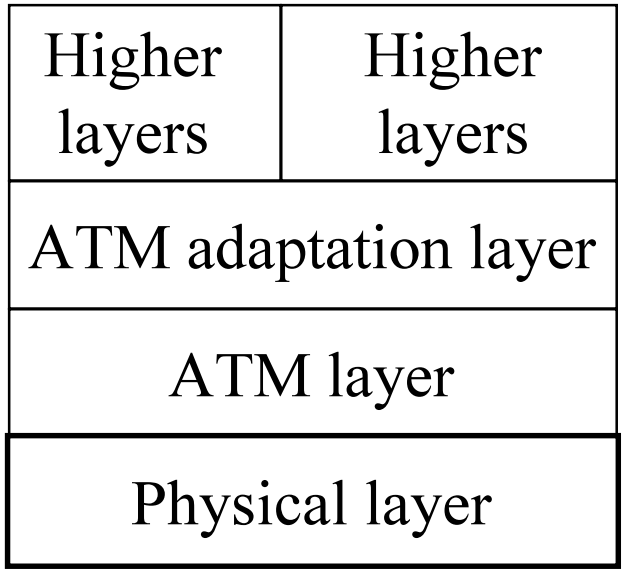


NNI Header Format:



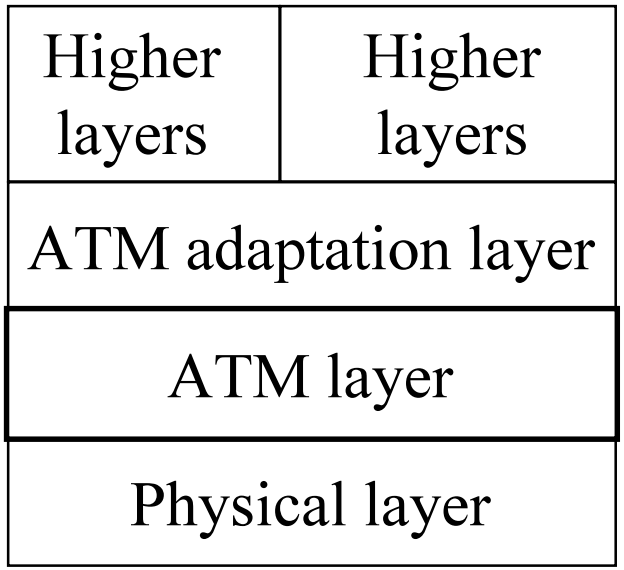
- **GFC -** *generic flow controll*, for identifying multiple stations sharing a single ATM interface (typically not used: GFC=0000)
- **VPI -** *virtual path identifier*, conjunction with the VCI identifies the next destination of the cell passing through the ATM switch
- **VCI -** *virtual channel identifier*
- **PT -** *payload type*, 3 bits indicating: **1. bit**: user data, or control, **2. bit**: congestion, **3. bit**: indicates, whether the cell is the last in a series of cells representing an AAL5 frame
- **CLP -** *congestion loss priority bit*, indicates whether the cell should be discarded in case of congestion (CLP=0, dont discard)
- **HEC -** *header error control*, checksum calculated only on the header

The ATM Reference Model



- Physical layer
  - → transmission and receipt bits
  - → framing
    - → keeping tracks of cell boundaries
    - → packaging cells to frames

The ATM Reference Model



- ATM layer

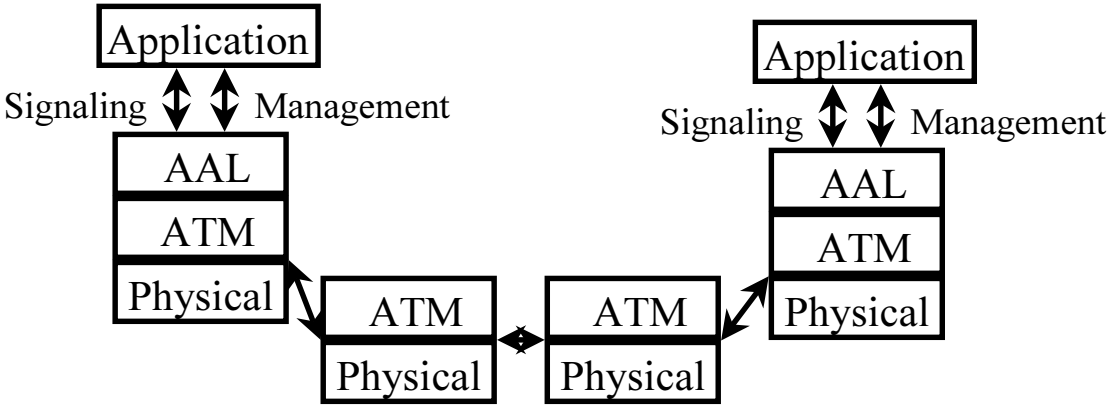
  → establishing connections and passing cells through ATM network

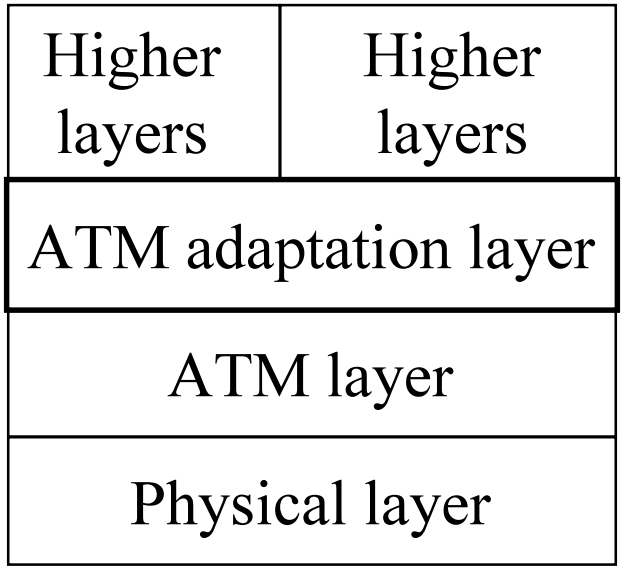
  → cell header handling, inserting and removing

  → cell relay

  → multiplexing and demultiplexing connections

The ATM Reference Model





- ATM adaptation layer (AAL)

  → adaption of services provided by the ATM layer to the requirements of the higher layer

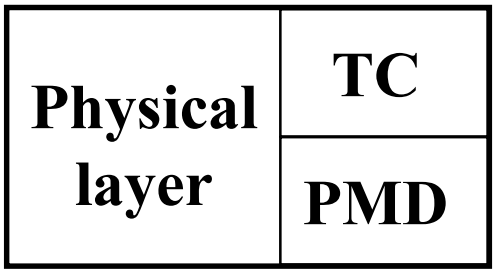
  → set-up/terminate end-end virtual channel

  → segmentation/reassembly of messages to/from cells

  → control Quality of Service delivery

  → flow control

Physical layer - two sublayers:



- **Transmission Convergence sublayer**
  - ***Cell delineation*** - maintains ATM cell boundaries
  - ***Header error control sequence generation and verification*** (8 bit CRC for the header only) - to ensure valid data
  - ***Cell rate decoupling*** - inserts or suppresses idle (unassigned) ATM cells to adapt the rate of valid ATM cells to the payload capacity of the transmission system
  - ***Transmission frame adaptation*** - packages ATM cells to frames acceptable to the particular physical layer implementation
  - ***Transmission frame generation and recovery*** - generates and maintains the appropriate physical layer frame structure
- **Physical Media Dependent sublayer**

- **Physical Media Dependent sublayer**
  - responsible for sending and receiving continuous flows of bits with associated timing information to synchronize transmission and reception
  - physical medium dependent:
    (includes only physical medium dependent functions)

ATM SDH/SONET bit rates

SDH	SONET	Mbps
	STS-1/OC-1	51.84
STM-1	STS-3/OC-3	155.52
STM-4	STS-12/OC-12	622.08
STM-8	STS-24/OC-24	1,244.16
STM-16	STS-48/OC-48	2,488.32

SDH—Synchronous Digital Hierarchy
SONET—Synchronous Optical Network

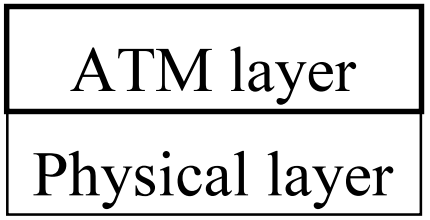
STM—Synchronous Transport Module
STS—Synchronous Transport Signal
OC—Optical Carrier

CCITT (Consultative Committee for International Telephony and Telegraph)
ITU (International Telecommunications Union)

ATM can use any physical medium capable for carrying ATM cells

Framing	Speed (Mbps)	Standardized physical mediums and max. distances						
		Plastic Fiber	Multi-Mode Fiber	Single-Mode Fiber	Coaxial Cable	UTP–5	UTP–3	STP
DS1	1.544							exists
E1	2.048				exists			
J2	6.23							exists
DS3	45				exists			
E3	34				exists			
E4	139				exists			
ATM25	25.6					100m	100m	100m
STS 1	51.8						100m	
STS3c/STM1	155	50m	2km	15km+		100m	100m	
STS 12c/STM4	622	50m	100m	15km+				
4B/5B (FDDI-TAXI)	100		2km					
8B/10B (Fiberchannel)	155		exists					exists

ATM layer

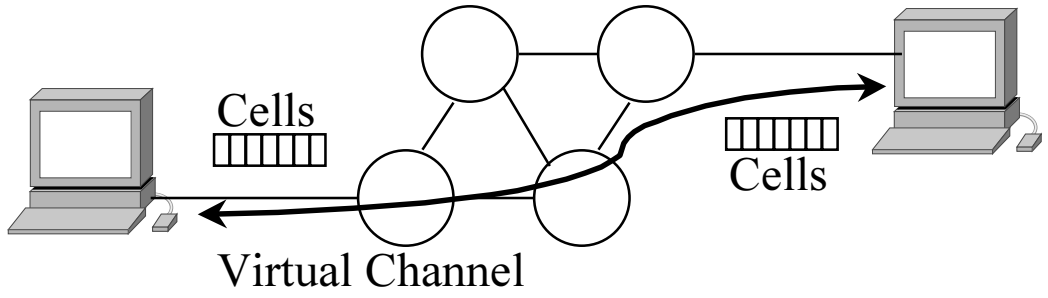


- Establishing connections and passing cells through ATM network - **ATM switching**

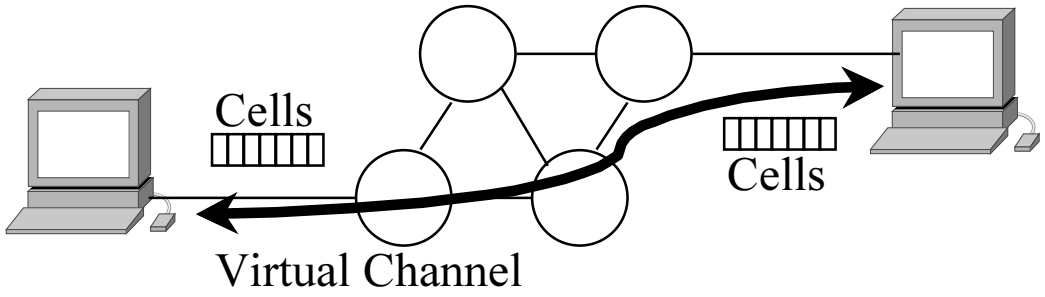
Port	VPI/ VCI	Port	VPI/ VCI
1:	1/1	3:	2/1
1:	1/2	2:	9/8
1:	2/1	3:	1/1
1:	2/2	3:	1/2
1:	2/3	3:	1/3

Connection Types

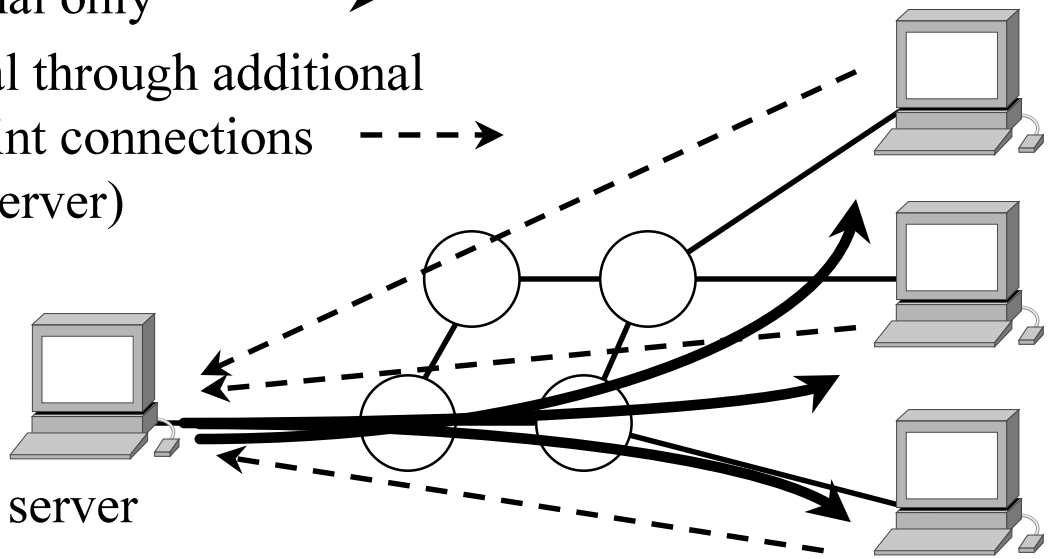
- **Connection oriented** - cell switching
  - all the cells are travelling on the same path (**virtual channel**)
  - it guarantees the **cell sequence integrity** (under normal fault-free conditions)
    (nowhere in the network can a cell belonging to a specific virtual channel connection overtake another cell of the same virtual channel connection that has been sent earlier)
  - **Point-to-point** connection types
- **Point-to-multipoint** connection types



- **Point-to-point** connection types
  - unidirectional or bidirectional



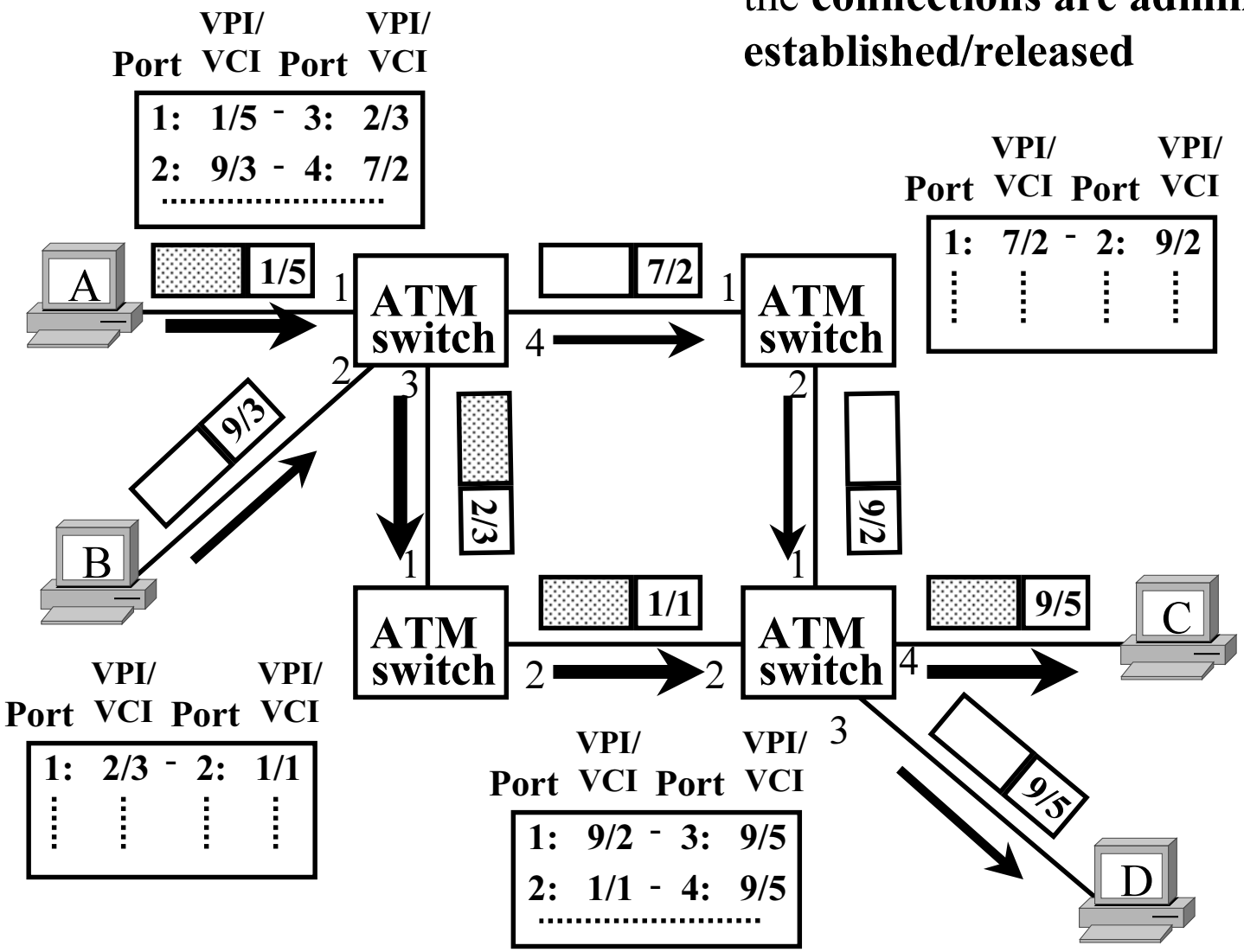
- **Point-to-multipoint** connection types
  - unidirectional only
  - bidirectional through additional point-to-point connections (multicast server)



Connection Services

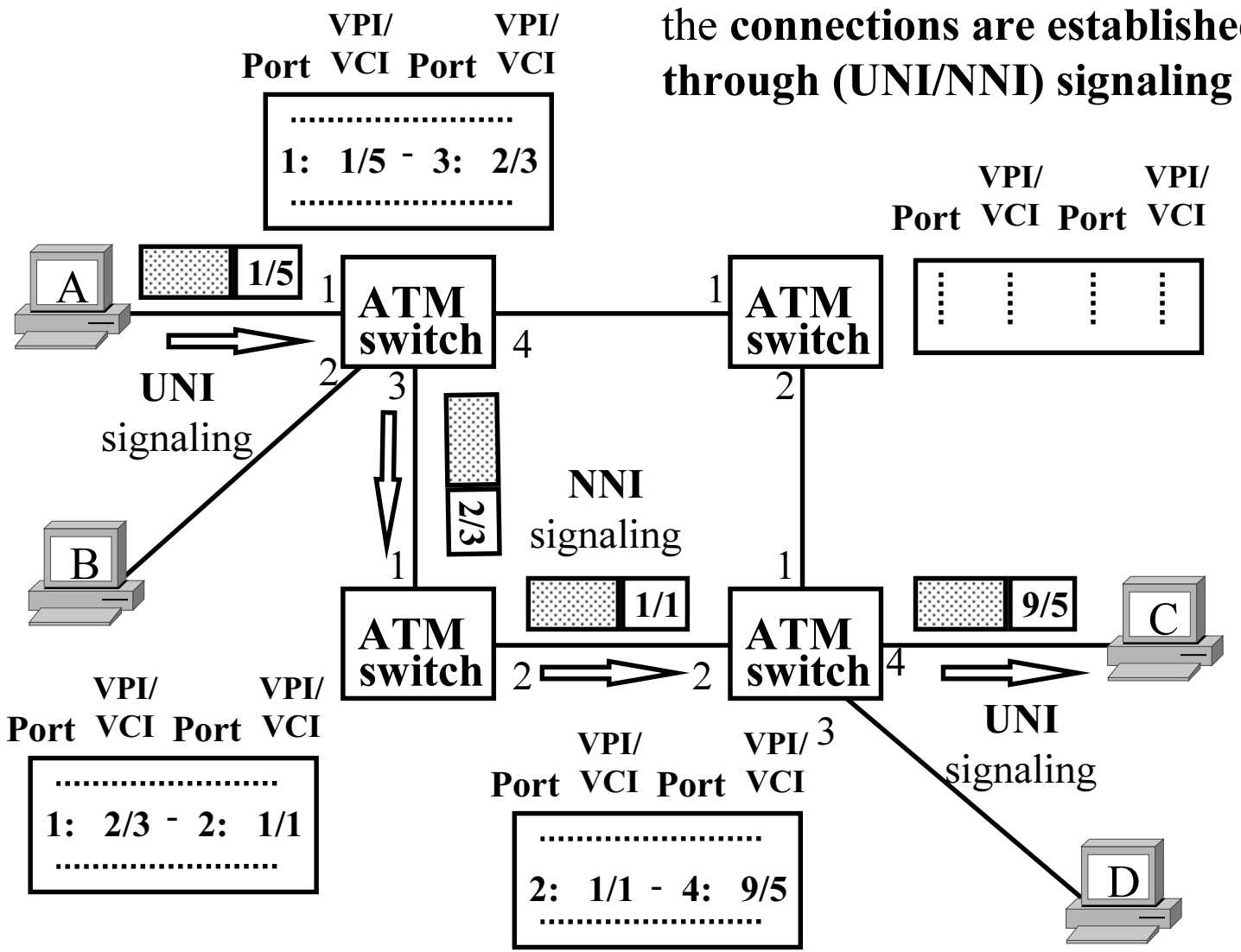
- **Permanent Virtual Circuit (PVC)**

VPI/VCI tables are handled manually, the **connections are administratively established/released**

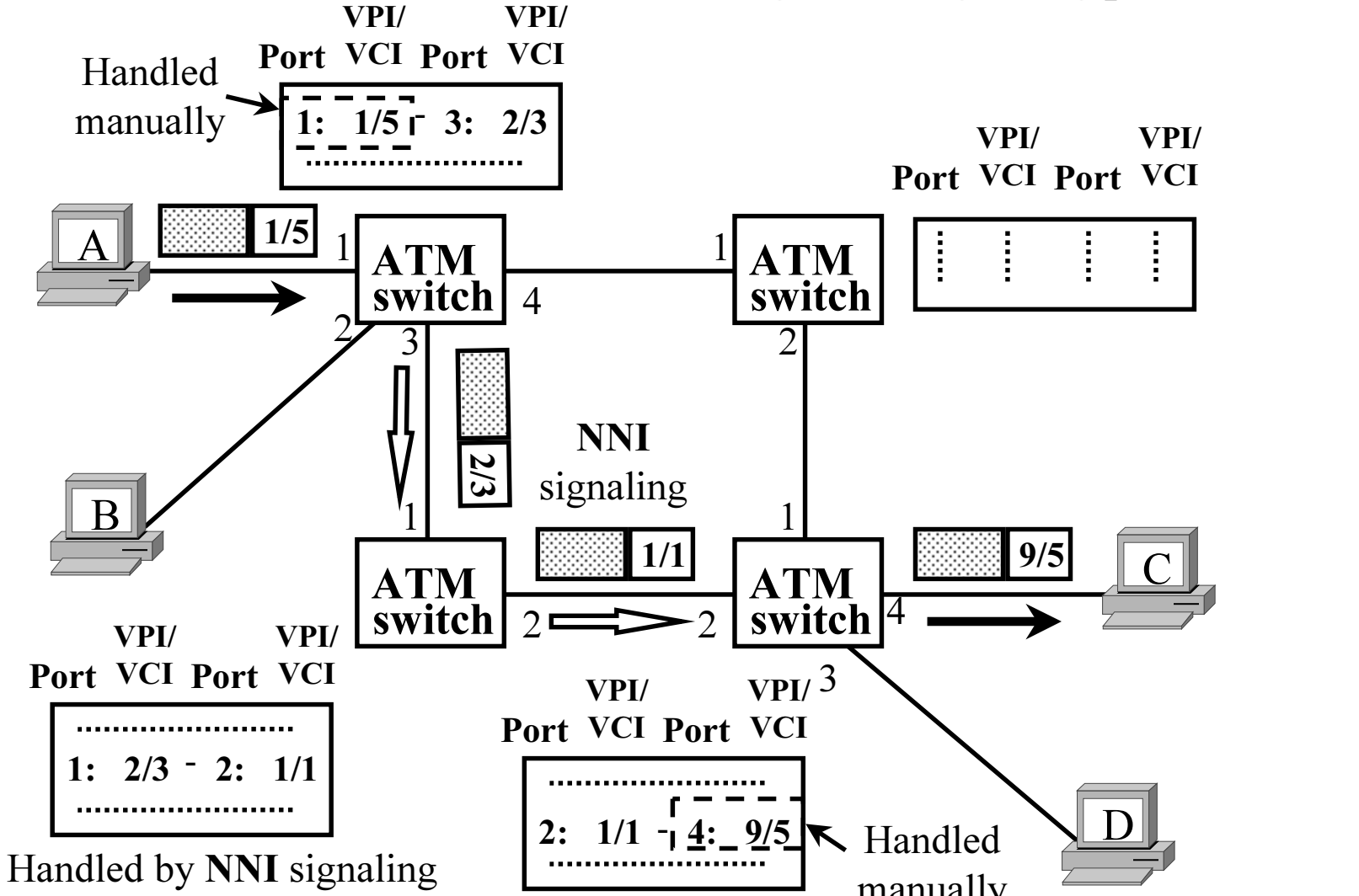


- **Switched Virtual Circuit (SVC)**

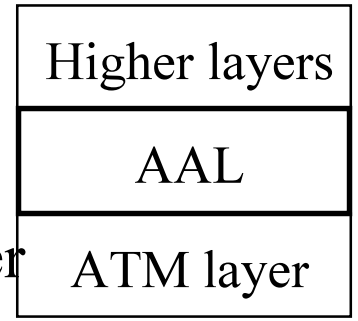
VPI/VCI tables are automatically handled , the **connections are established/released through (UNI/NNI) signaling procedure**



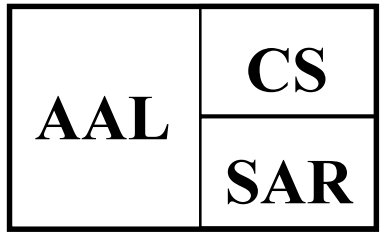
- **Soft Permanent Virtual Circuit (Soft PVC)**
  - **User - network connections are established/released administratively**
  - **Network - network connections through NNI signaling procedure**



ATM adaptation layer (AAL)

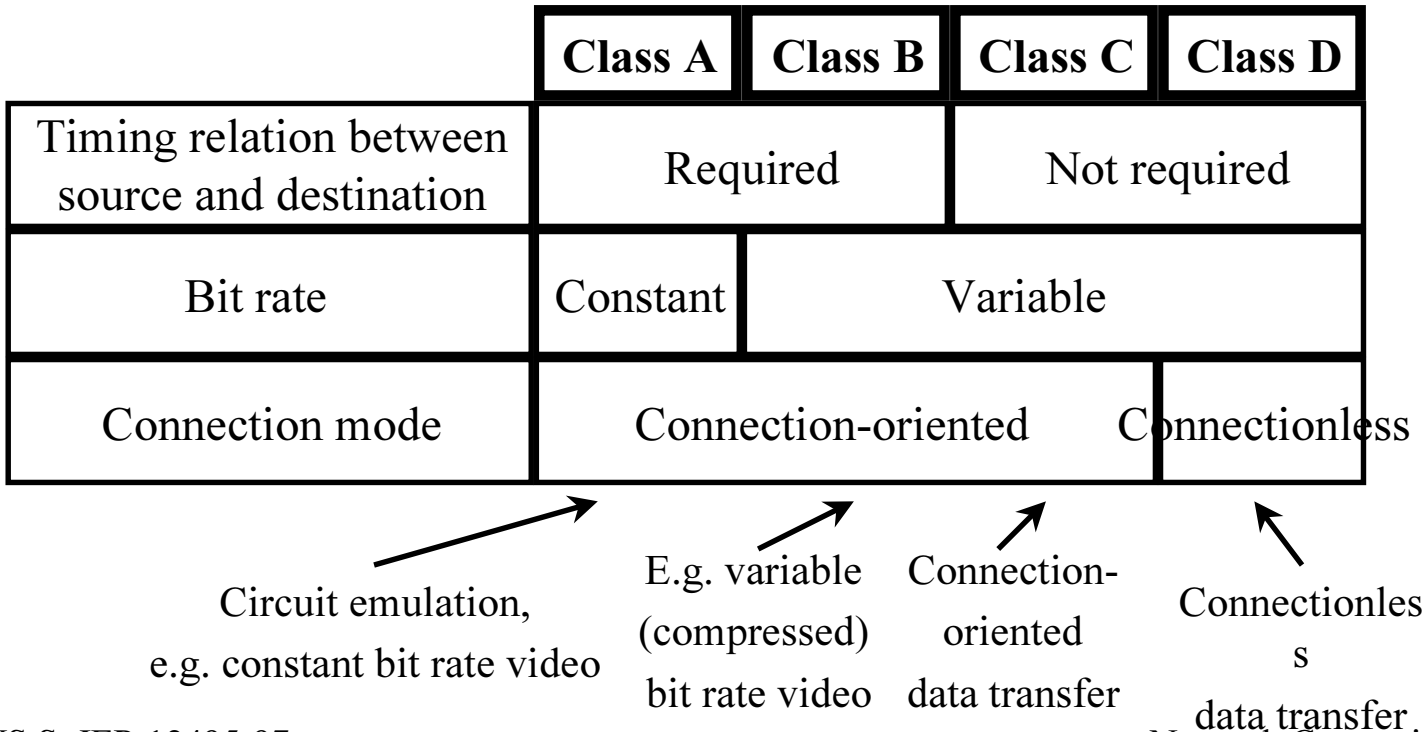


- Adaptation of services provided by the ATM layer to the requirements of the higher layer
- AAL is subdivided into two sublayers
  - **convergence (CS)** sublayer
    - service dependent
    - provides the AAL service at the AAL SAP (Service Access Point) for the higher layers
  - **segmentation and reassemby (SAR)** sublayer
    - segmentation/reassembly of higher level PDUs (Protocol Data Unit) to/from the information field of the ATM cells (48 byte)



Adaptation Layer Service Classes

- To minimize the number of AAL protocols service classes are defined
- Each service class need specific CS and SAR sublayer
- There are different Adaptation Layer Types (AAL protocols) for serving the different service classes

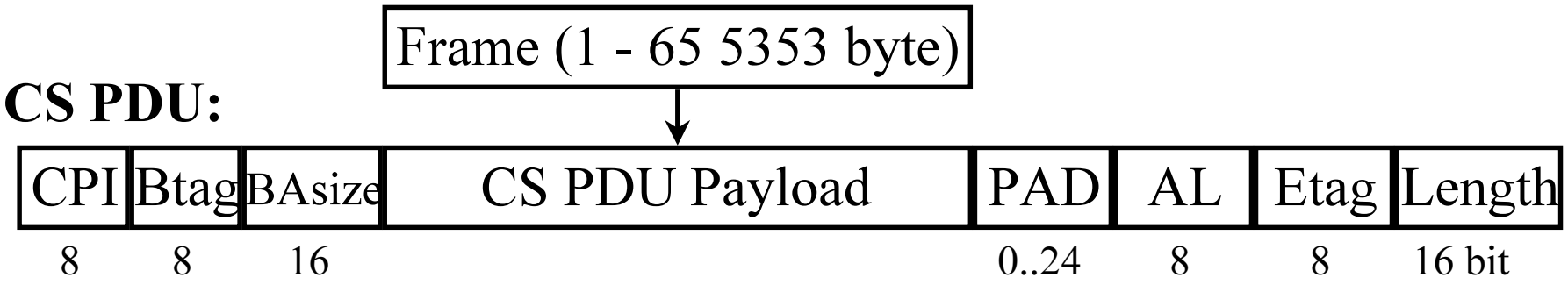


Adaptation Layer Types

- Each AAL type has different service class and specific CS and SAR sublayer
- **AAL type 1 (Class A)**
  - synchronous traffic with constant bit rates
    - e.g. voice, or video
- **AAL type 2 (Class B)**
  - synchronous traffic with variable bit rates
    - e.g. compressed video
- **AAL type 3/4 (Class C/D)**
  - datagram transport
- **AAL type 5 (Class C)**
  - datagram transport (simpler)

AAL type 3/4

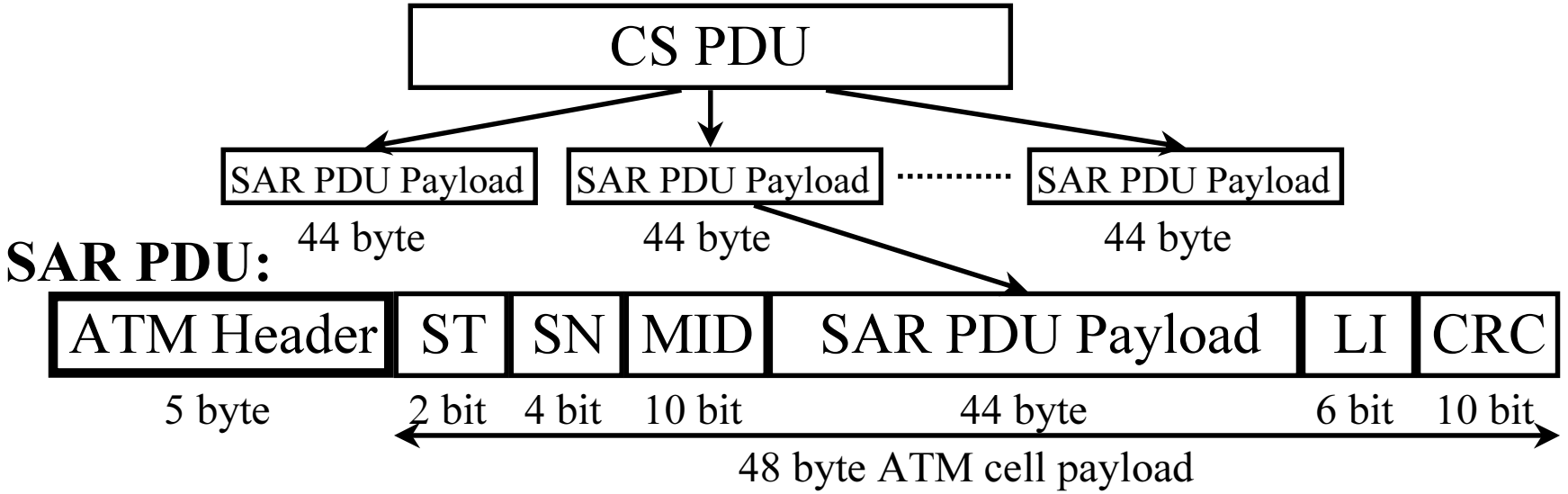
- The AAL 3/4 Convergence Sublayer (CS) creates a **Protocol Data Unit (CS PDU)** from the data Frame



- **CPI** Common Part Indicator, version number
- **Btag/Etag** Beginning/Ending Tag, help proper association of the CS PDU header and trailer (same numeric value is set both fields)
- **BAsize** Buffer Allocation Size, indicates to the receiving peer entity the maximum buffering requirements to receive the CS PDU
- **PAD**, ensures, that the payload must be an integer multiple of four bytes
- **AL** Alignment, is used for 32 bit alignment of the CS PDU trailer
- **Length**, the length of the CS PDU payload field (detects loss or gain)

AAL type 3/4

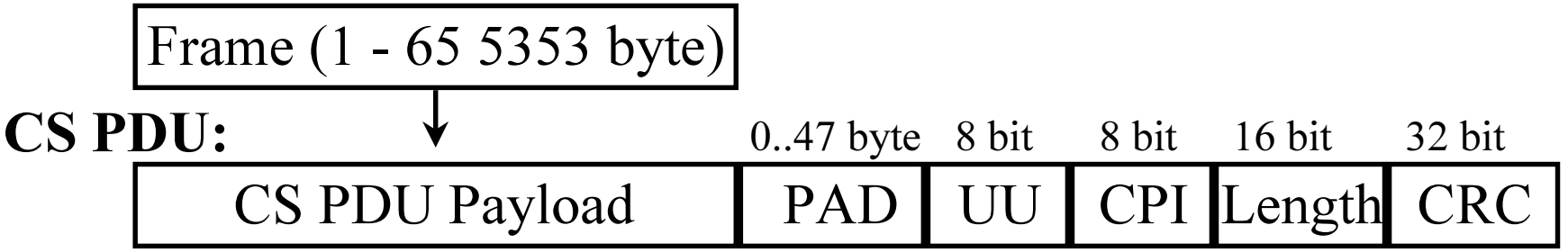
- The AAL 3/4 Segmentation and Reassemby (SAR) sublayer creates ATM cells **(SAR PDU**-s) from the CS PDU



- **ST** Segment Type, first/middle/last cell, or single cell message
- **SN** Sequence Number, mod 16 counter on the cell sequence
- **MID** Multiplexing Identifier, identifying multiple PDU on a single VC
- **LI** Length Indicator, the length of valid data (from the CS PDU) in the payload field in bytes
- **CRC**, 10 bit CRC on SAR PDU header and payload (detects errors)

AAL type 5

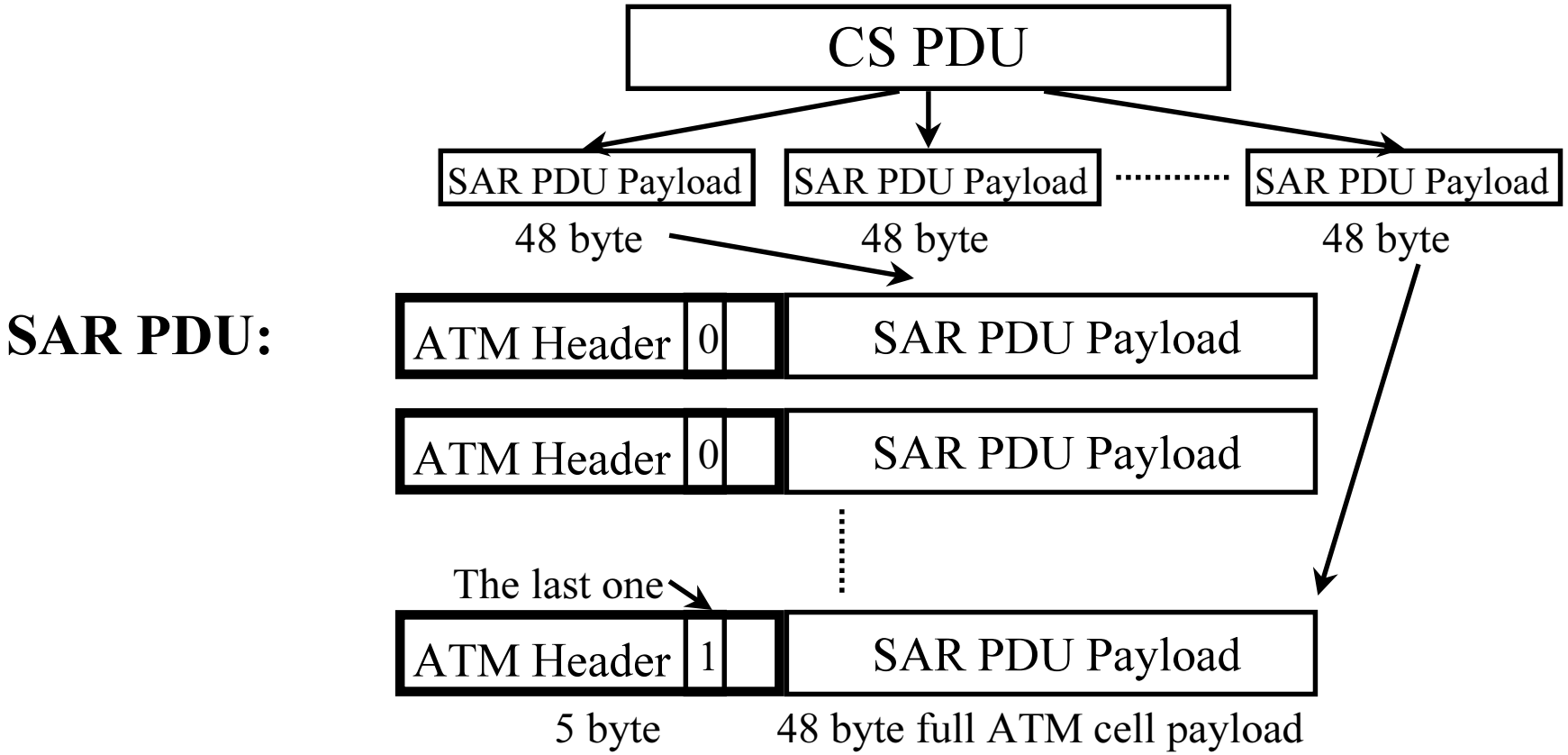
- The goal is to reduce of the overhead of the AAL 3/4
- Variable bit rate without timing relation between the source and the destination
- AAL 5 is not supporting multiplexing (in spite of AAL 3/4)
- The AAL 5 CS creates a **CS PDU** from the data Frame



- **PAD**, 48 byte alignment of the CS PDU (ATM cell payload)
- **UU** User-to-User identification, used for transparent transfer of CS user-to-user information
- **CPI** Common Part Indicator, version number (same as in AAL 3/4)
- **Length**, the length of the CS PDU payload field (detects loss or gain)
- **CRC**, 32 bit CRC on CS PDU (detects errors)

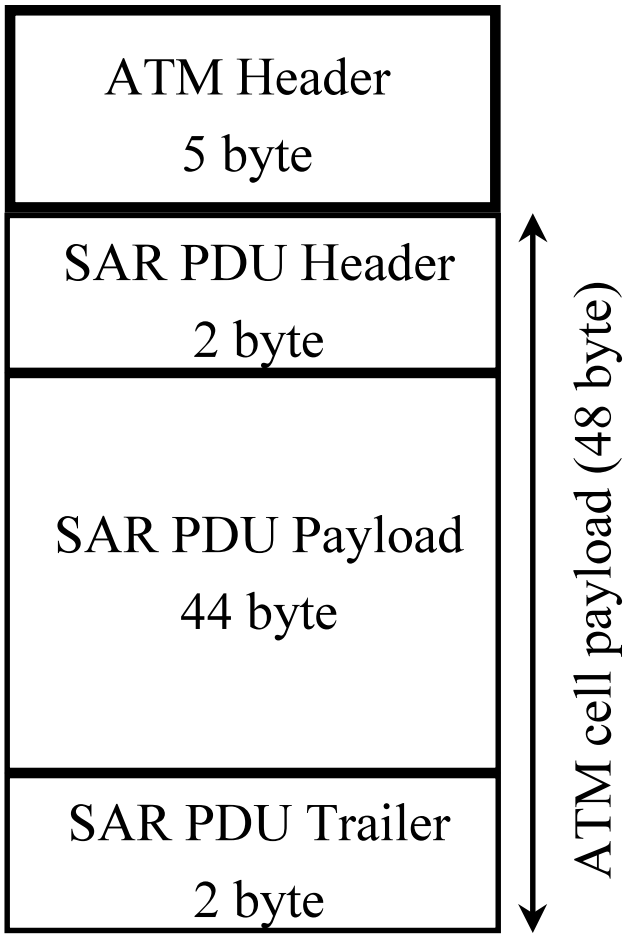
AAL type 5

- The AAL 5 Segmentation and Reassemby (SAR) sublayer creates ATM cells **(SAR PDU-s)** from the CS PDU

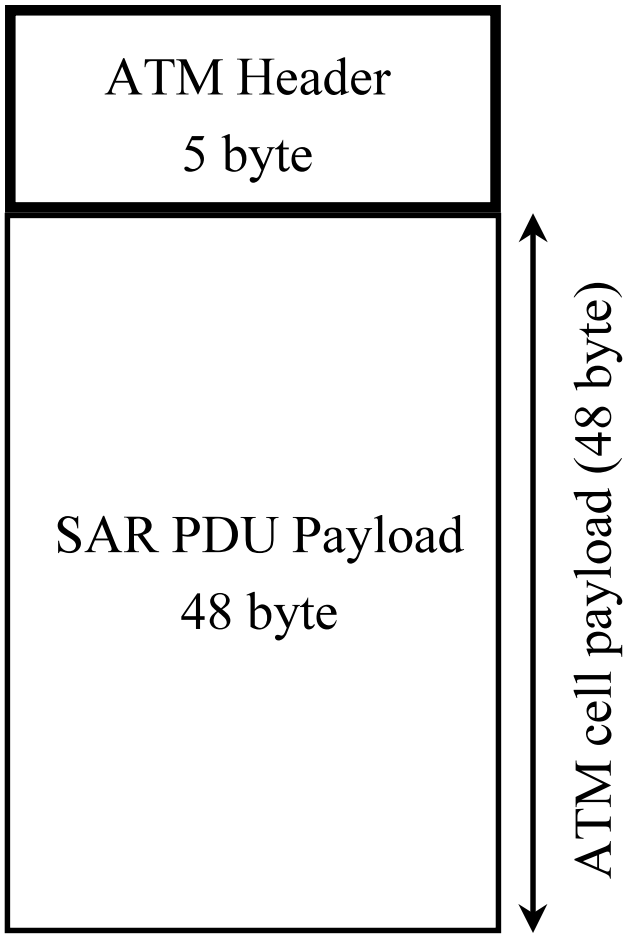


- **ATM Header PT** (Payload Type) **field 3. bit**: indicates, whether the cell is the **last in a series** of cells representing an AAL5 CS PDU

AAL type 3/4 ATM cell overhead



AAL type 5 ATM cell overhead



ATM traffic parameters and transfer capabilities

- To be able to optimize the ATM network operation, ATM **traffic is grouped into various categories** of connections with **different traffic characteristics**:
  - **source traffic descriptor** - the source's connection request:
    - e.g. peak cell rate, average cell rate, cell delay variation tolerances, burstiness, peak duration
- Based on the required traffic parameters (**source traffic descriptor**) and the **network transfer capabilities** - a **'traffic contract'** can be established between the user and the network
- The traffic contract is **negotiated** between the user and the network during the connection establishment (signaling)
- Conformance to the negotiated traffic contract can be enforced by the network

ATM Source traffic descriptor

- A set of source traffic parameters
- **Peak Cell Rate (PCR)**
  - the maximum cell rate at which a source may send its cells during the connection's lifetime
- **Sustainable Cell Rate (SCR)**
  - always smaller than the PCR (an average cell rate)
  - parameter used for burst-type traffic
- **Maximum Burst Size (MBS)**
  - the amount of cells which may be sent at the PCR
- **Minimum Cell Rate (SCR)**
  - the minimum cell rate which is guaranteed by the network for the source during the connection's lifetime

ATM performance parameters - the Quality of Service (QoS)

- **Cell Loss Ratio**
  - ratio of lost cells to transmitted cells
- **Mean Cell Transfer Delay (MCTD)**
  - average of the cell delay between the endpoints
- **Cell Delay Variation Tolerance (CDVT)**
  - jitter, the maximal allowed variation of the cell transfer delay on the same connection

ATM transfer capabilities - Service Classes

(According to the ATM Forum)

- **Constant Bit Rate (CBR)**
  - used by connections requesting a fixed amount of bandwidth to be continuously available during the connection's life time (e.g. real time video)
- **Variable Bit Rate (VBR) (real time / non real time)**
  - suitable for applications with varying bit rate requirements where there exists prior knowledge of some traffic characteristic (e.g. compressed real time video)
- **Available Bit Rate (ABR)**
  - supports LAN-like applications, where users accept unreserved bandwidth but want to make optimum use of the bandwidth actually available
- **Unspecified Bit Rate (UBR)**
  - the best effort service, but no guarantee on cell loss and delay (e.g. Internet)

ATM Service Classes and the Quality of Service

(According to the ATM Forum)

	Constant Bit Rate	**Variable Bit Rate Real Time**	**Variable Bit Rate Non RT**	**Available Bit Rate**	**Unspecified Bit Rate**
Cell Loss Ratio	*Specified*	*Specified*	*Specified*	*Specified*	*Unspecified*
Cell Transfer Delay Cell Delay Variation	*Specified*	*Specified*	*Mean CTD only*	*Un-specified*	*Unspecified*
Peak Cell Rate	*Specified*	*Specified*	*Specified*	*Specified*	*Specified*
Sustainable Cell Rate Burst Tolerance	*n/a*	*Specified*	*Specified*	*n/a*	*n/a*
Minimum Cell Rate	*n/a*	*n/a*	*n/a*	*Specified*	*n/a*

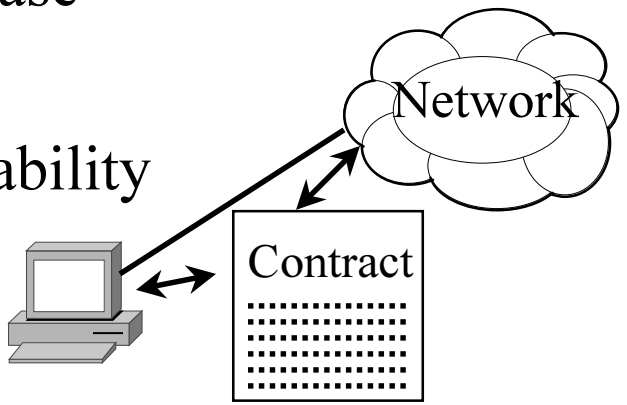
n/a : Not applicable

Mechanisms to achive a specified QoS

- **Connection Admission Control (CAC)**
  - **negotiation** of the **traffic contract** is between the user and the network in the call establishment phase
- **Usage and Network Parameter Control (UPC, NPC)**
  - **'Traffic Policing'** - a set of actions taken by the network to **monitor** and **control** that the **traffic contract is respected** in terms of traffic offered and validity of the ATM connection, at the user access and the network access respectively
- **Traffic Shaping**
  - **altering the tarffic characteristics** on the user side to **ensure conformance to the traffic contract**, e.g. reducing the peak cell rate by buffering

Connection Admission Control (CAC)

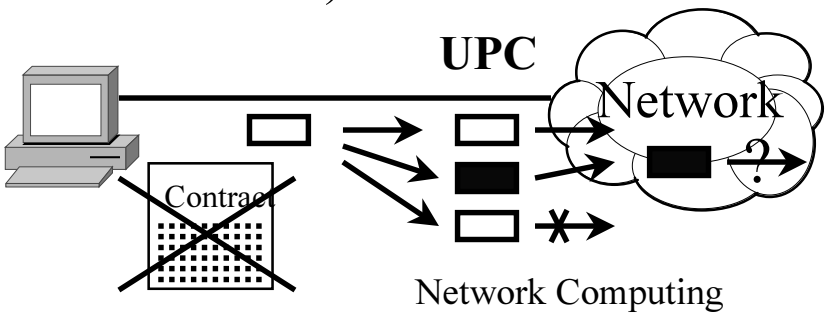
- **negotiation** of the **traffic contract** is between the user and the network in the call establishment phase
- CAC is provided with:
  - the required ATM layer transfer capability
  - the source traffic descriptors
  - the required QoS class



- a connection can only be accepted if sufficient network resources are available to establish the connection end-to-end with is required quality of service
  - e.g. for a required CBR service class the available link capacity needs to be checked; for a required UBR service class the available buffer space could be the primer factor to be considered

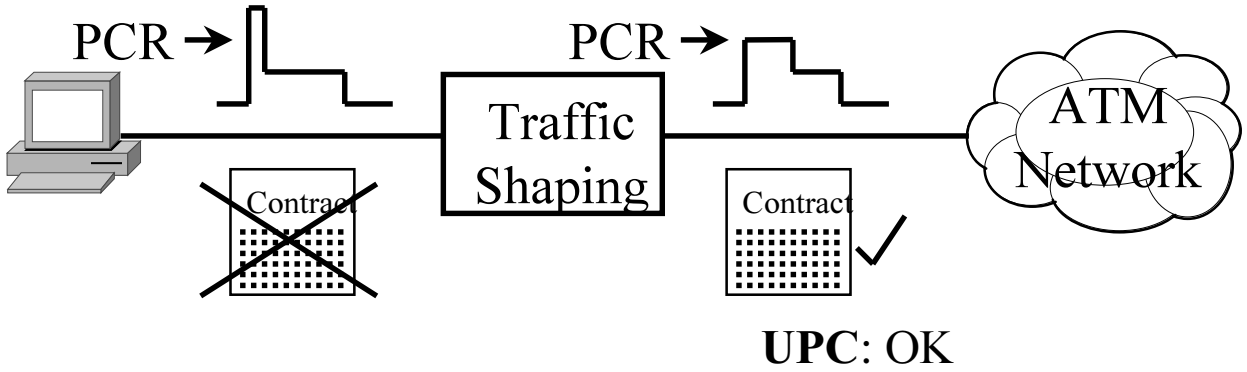
Usage and Network Parameter Control (UPC, NPC)

- **'Traffic Policing'** - a set of actions taken by the network to **monitor** and **control** that the **traffic contract is respected**
- Checking the validity of VPI/VCI values
- Monitoring the traffic volume entering the network from all active VP and VC connections to ensure that the agreed parameters are not violated
- **In case of traffic contract violation** UPC/NPC can
  - **discarding cells** that violate the negotiated parameters
  - the 'guilty' connection may be released
  - **tagging of violating cells** and discard later if necessary (CLP - congestion loss priority bit in ATM header)
  - do nothing (**forwarding**)



Traffic Shaping

- **altering the traffic characteristics on the user side** to **ensure conformance to the traffic contract**, e.g. reducing the peak cell rate by buffering - better network utilisation, but increased cell transfer delay

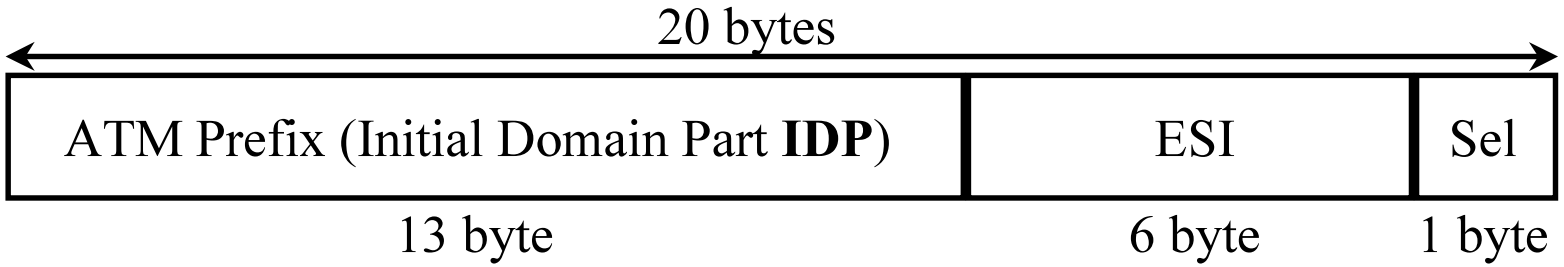


ATM Addressing

- The **ATM address** identifies the **ATM End-System (AES)**
- The **ATM address** may differ depending upon whether the end-system connects to **private or public ATM network**
- Several ATM address formats have been developed, **one for public networks**, and **two for private networks**
- For private networks, *ATM Forum* has defined the use of the **Network Service Access Point (NSAP)** address format (not a true NSAP address, it does not terminate at the Network Layer)
- **Public ATM networks** are using the globally unique **E.164 numbers** (it is also used by the Narrowband Integrated Services Network (**NISDN**)) (8 byte - 16 digit ISDN telephone number) (only the UNIs connected directly to the public network will be assigned E.164 addresses)

The ATM End-System (AES) NSAP format

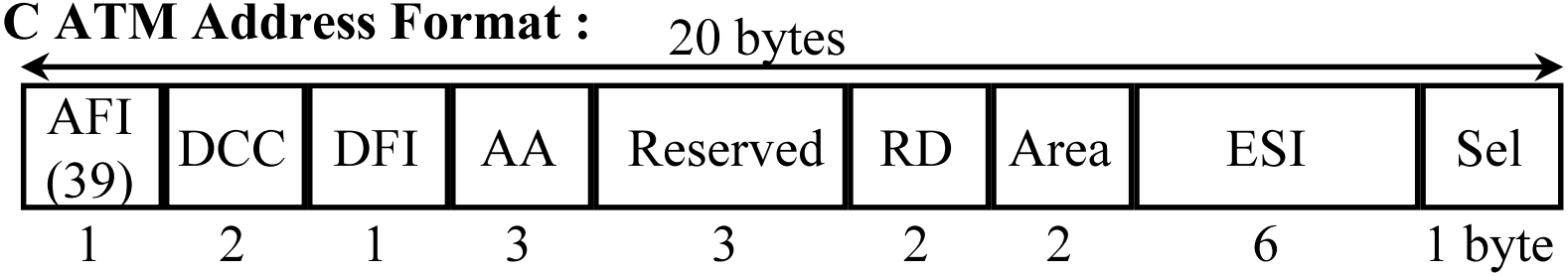
- All ATM NSAP addresses have the following format:



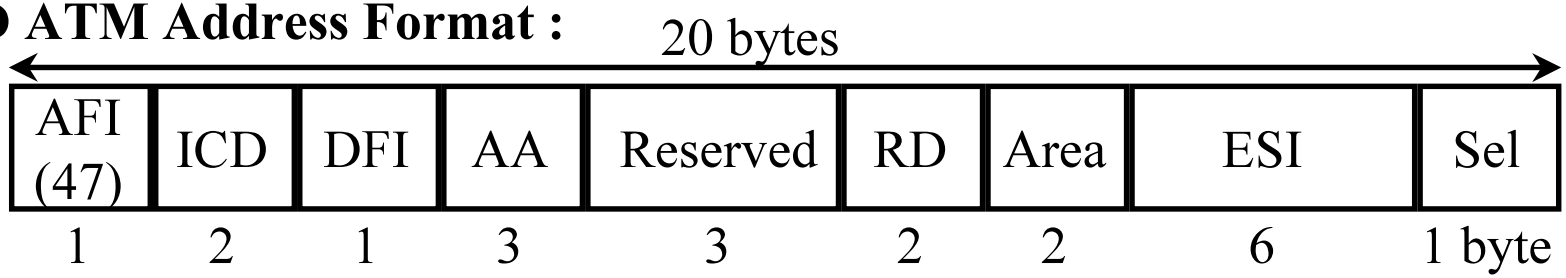
ESI : End-System Identifier, 6 byte, must be **unique within a particular IDP** (in almost all cases it is the globally unique IEEE 802 Media Access Control (**MAC**) Address)

SEL : Network Service Access Point (NSAP) Selector, used by ATM end-systems for multiplexing to identify subinterfaces (not used for routing)

DCC ATM Address Format :



ICD ATM Address Format :



AFI :Authority and Format Identifier
identifies the type of the address

DCC : Data Country Code (ISO 3166)

ICD : International Code Designator (British Standard Institute)

DFI : Domain specific part Format Identifier,
identifies the format used by the body

AA :Administrative Authority
an organisational identifier
(structuring the reminder of the address)

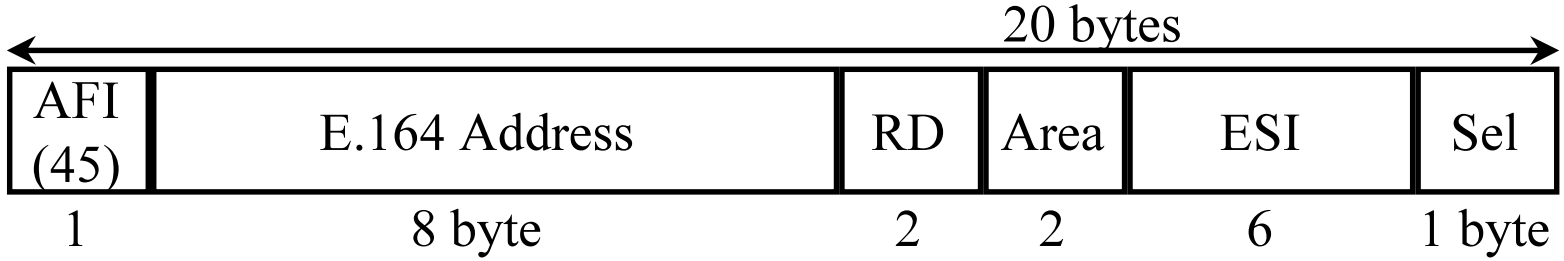
RD : Routing Domain

Area : Area identifier

ESI : End System Identifier (MAC Address)

SEL : NSAP Selector
(to identify subinterfaces)

NSAP encapsulated E.164 Address Format :



- **The E.164 Address Format**
  (Global ISDN numbering plan: 8 byte - 16 digit)

  1.digit: **Unicast**, or **Multicast** address

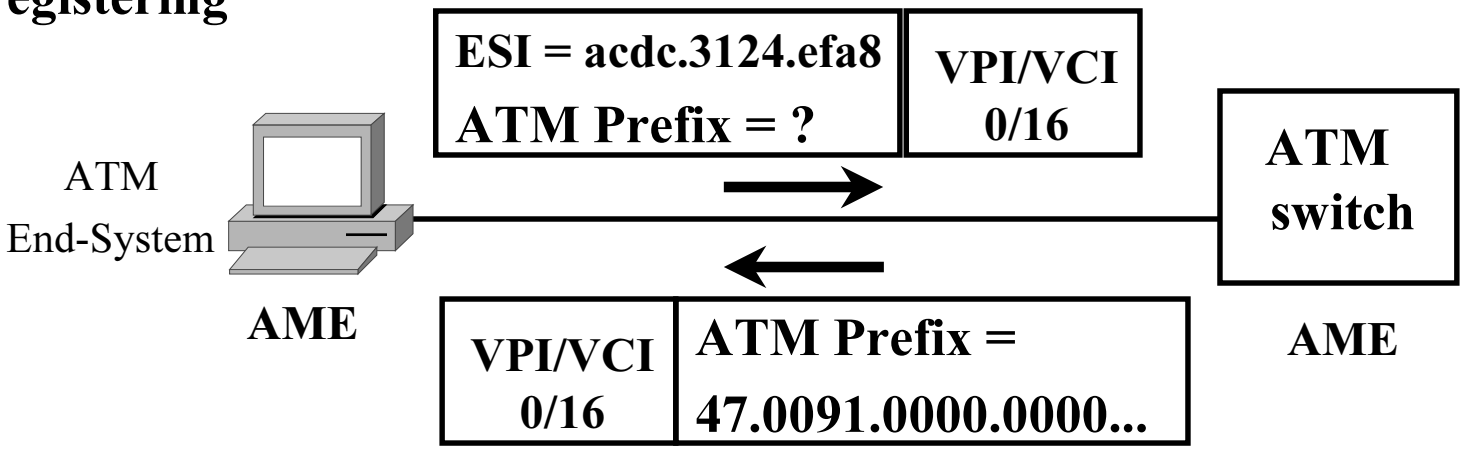
  2-4: **Country code** (1-3 digit)

  3-16: **Area, City, Exchange, End-System** (nationally assigned)

Automatic ATM End-System address prefix configuration

Interim Local Management Interface (ILMI):

- **Peer-to-peer network management protocol (ILMI reserved VCC: VPI=0, VCI=16)**
- Each device participating in the ILMI implements the **ATM Management Entity (AME)**
- **ILMI uses SNMP message syntax** (Simple Network Management Protocol) and **ILMI MIB** (Management Information Base)
- ILMI MIB supports interface configuration, max. number of supported connections, speed, media type, operational status, etc., **address registering**



ATM Trunking and Routing

Interim Interswitch Signaling Protocol (IISP)

- Standardised by the **ATM Forum**
- IISP provides **table based rerouting**, but **no topology discovery** (intended as an interim solution for small ATM networks)
- It is also called **PNNI Phase 0**

Private Network-Network Interface (PNNI)

- Standardised by the **ATM Forum**
- PNNI is both **Signaling** and **Routing Protocol**
- PNNI is supporting **topology discovery** via the distribution of reachability information, **hierarchical routing and addressing** and **QoS** (applied on the majority of ATM networks)
- It is also called **PNNI Phase 1**

IP over ATM

- **IP over ATM Fundamentals**
- **Encapsulation**
- **Addressing and Routing**
- **Address Resolution**
- **Next Hop Resolution Protocol**

IP over ATM

Transmission Control Protocol and **Internet Protocol (TCP/IP)** are one of the most widely used protocol suites in the computer communication area

(The popular Internet and WWW are based on IP)

IP is a **connectionless** protocol. IP datagrams contain the source and destination address.

IP packets are transferred in a best-effort manner:

- no error correction capabilities
- no QoS guarantees
- no information about successful delivery
- the correct order of the datagram fragments is not guaranted

Higher layers over IP

TCP - Transmission Control Protocol and **Internet Protocol**
- connection-oriented reliable transport protocol

UDP - User Datagram Protocol

- connectionless unreliable transport protocol

IP over ATM

Native **ATM ABR (Available Bit Rate)** and **ATM UBR (Unspecified Bit Rate)** transfer capabilities are developed for data connection and able to substitute TCP/IP

- they might be build the Internet of the future -

but at the moment (and in the near future) TCP/IP-based networks are essential in internetworking

Carrying IP traffic over ATM-based network

The most mature mechanism is based on **RFC 1577**
'Classical IP and ARP over ATM'
(Internet Engineering Task Force IETF, 1994, update in 1996):

- This model considers ATM to be a **'wire' for the transport of higher-layer** (similar to LANE, but instead MAC, it uses IP addresses)
- The model describes the **transmission of IP datagrams**, their **encapsulation into ATM** cells and the **ATM address resolution protocol** (ATM-ARP)
- The **IP network** is a **logical association** of network elements (hosts, routers), which is **independent of the underlying ATM networks**

Logical IP Subnetwork (LIS):

- A **group of IP nodes** (hosts or routers) that **connected to a single ATM network** and belonging to the **same IP subnetwork**
- Connections towards an IP node outside the LIS must be conveyed via **IP router** (IP node connected to more LISs)
- An ATM endpoint can belong to several LISs via a single physical interface
- IP routers between LISs, could be easily become a bottleneck - **Next Hop Resolution Protocol** (NHRP) could solve this problem
- Within a LIS all ATM connections are VCCs (permanent (PVC), or switched (SVC))
- The **IP Maximum Transfer Unit (MTU)** sizes within a LIS are the same for all VCs (9180 bytes)

Carrying IP traffic over ATM-based network

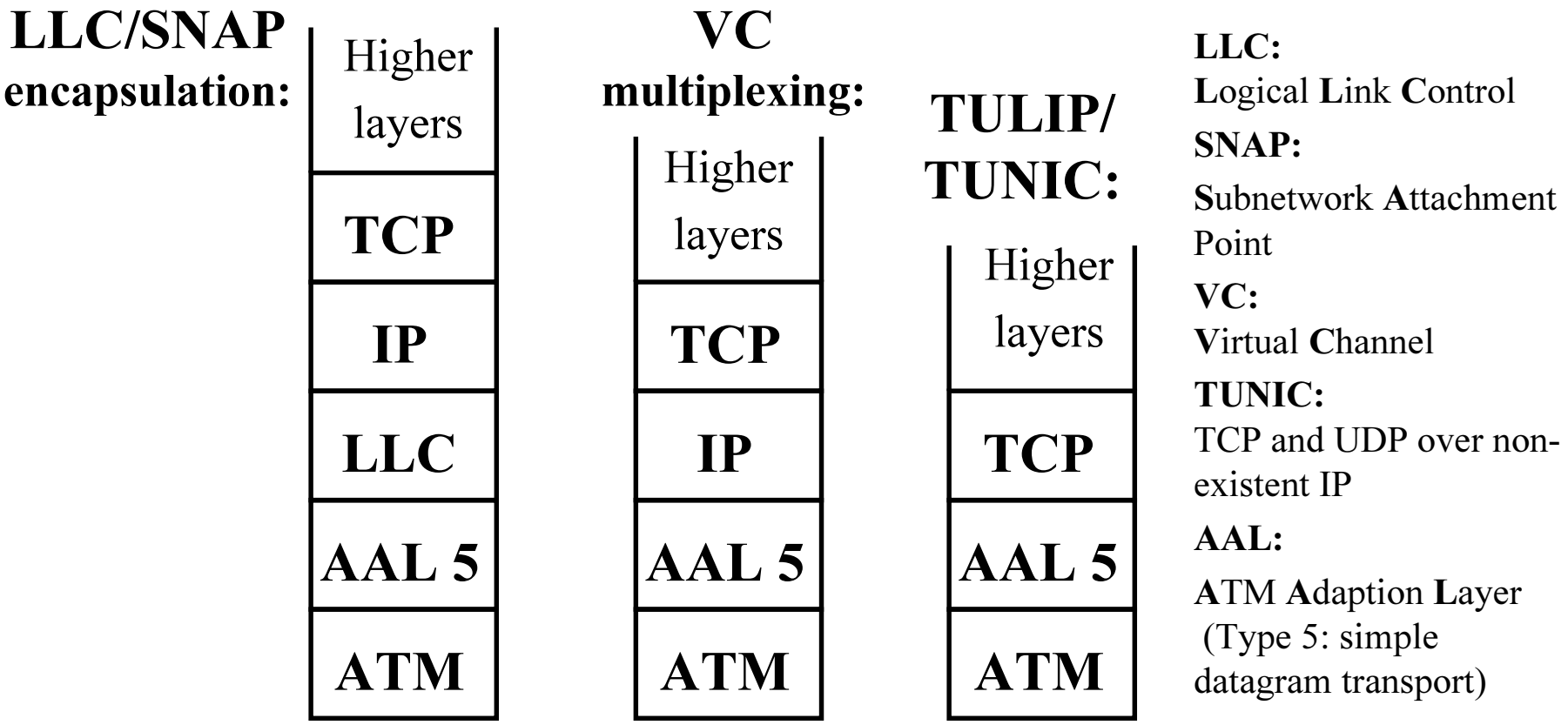
Main questions to solve:

- **Encapsulation**
- **Routing**
- **Addressing/address resolution**

Encapsulation:

- In traditional LAN conventions ‘encapsulation’ denotes the **Logical Link Control (LLC) layer multiplexing and addressing** - higher layer protocols are encapsulated with the LLC information
- This LLC information can be considered as being a **‘in-band’ signaling** message which addresses the higher layer data packets to the destination
- In **ATM networks ‘out-of-band’ signaling** is used (signaling information is conveyed via separate virtual connection and not bounded to the actual user data-transfer)
- IP over ATM - a way of ‘marry’ the two world - many solutions exists

The three main encapsulation schemes:



- **The greater the amount of the multiplexing and addressing function realised in the end-station, the less information needs to be transported via the ATM signaling protocol**

LLC/SNAP encapsulation:

(Logical Link Control / Subnetwork Attachment Point)

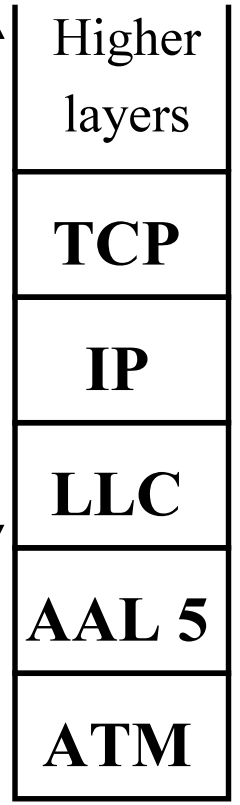
- This scheme identifies the protocol by an **IEEE 802.2 LLC Type 1** (unacknowledged, connectionless mode) **header**, which is followed by a **Subnetwork Attachment Point** (SNAP) **header**

LLC (3 byte) 0xAA-AA-03	**OUI** 0x00-00-00	**Ether type** 0x08-00	**IP PDU** up to 2^{16}-9 byte

LLC indicating the presence of SNAP header

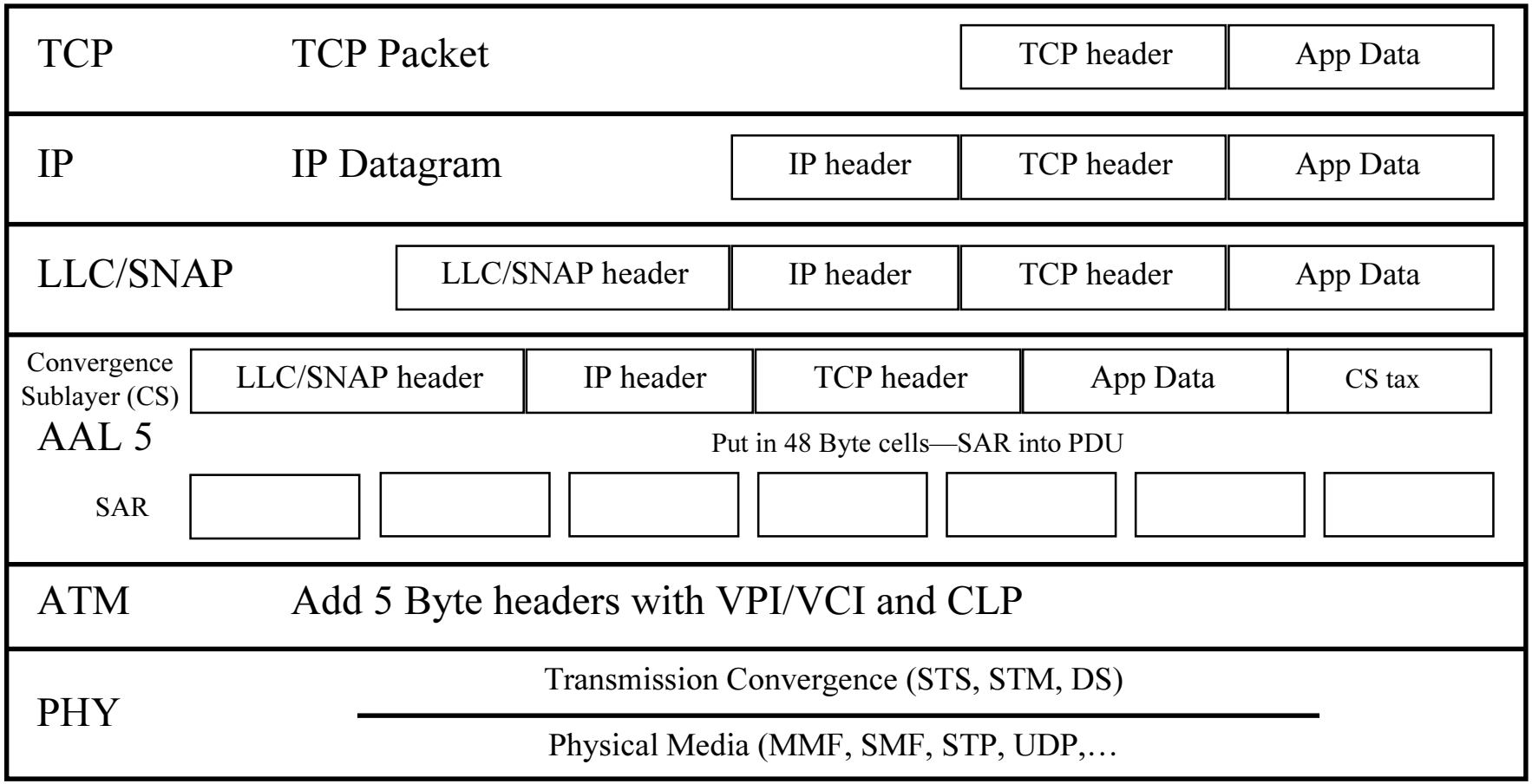
SNAP header, 3+2 byte **O**raganizationally **U**nique **I**dentifier and the indication of Ethertype

IP Protocol **D**ata **U**nit

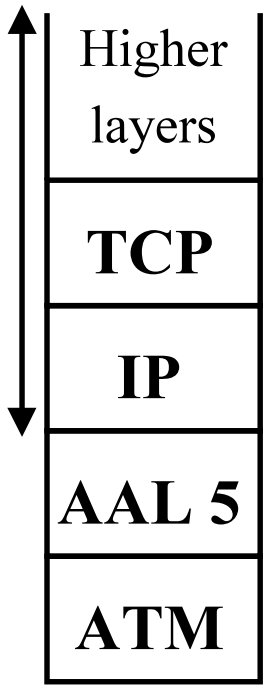


- **Most of the multiplexing function needs to exist in the end-station** (generating, evaluating the LLC/SNAP header), the LLC entity constitutes the endpoint for the ATM/AAL5 connection, no information about the sender's higher layer protocol is transmitted via the ATM signaling channel
- **Best suited for PVC**-based ATM networks, or networks **not capable of carrying many parallel VCs** (however, SVC connection is also defined RFC 1755), several higher-layer protocol can share a single VCC

Example:
TCP over ATM - LLC/SNAP encapsulation



VC multiplexing:



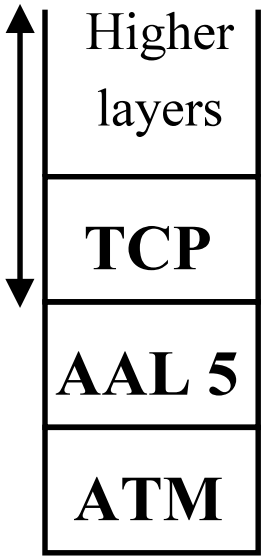
- This scheme is also known as **'null encapsulation'** (the LLC function does not exists)
- Layer 3 packets (such as IP) are **directly mapped onto an ATM/AAL 5**
- The ATM signaling specifies the **Layer 3 entity as the ATM destination** for the connection
- The VC multiplexing incurs **less overhead than LLC/SNAP** encapsulation it requires **many VCCs, separate one for each individual Layer 3 protocol pair** between two ATM endpoints (generating potentially high amounts of signaling traffic)

TULIP / TUNIC :

TULIP: **T**CP and **U**DP over **L**ightweight **IP**

TUNIC: **T**CP and **U**DP over a **N**on-existent **IP** **C**onnection

- Eliminates the entire IP network layer, **ATM AAL 5 connection exists directly between transport layer entities** (such as TCP, UDP)
- Major restriction: it **requires single hop reachability between endpoints** (for lack of IP, there are no intermediate IP routers either)
- Simple end-station multiplexing and addressing functions, high demand for the ATM signaling protocol
- For the future networks at the moment:
  having single hop reachability and
  higher-layer protocols demand support for different QoS levels



Summary :

Encapsulation method:	Demultiplexing in end-sytem:	in signaling message:	Application:
LLC/SNAP	Source address Destination address Protocol family Protocol Port	Nothing	Default method for 'classical IP and ARP over ATM', it provides simple and smooth internetworking with existing procedures; LANEv2, MPOA
VC multiplexing	Source address Destination address Protocol Port	Protocol family	Less overhead; LANEv2
TUNIC	Nothing	Source address Destination address Protocol family Protocol Port	For the future at the moment (QoS)

LLC/SNAP:

TCP (connection oriented) - IP (connectionless) - ATM (connection oriented)

Addressing and routing

Overlay model

- **Most commonly used** addressing model
- **Both IP and ATM addresses** are used
- For **IP ↔ ATM** address mapping the **ARP/RARP mechanism is adopted**

Peer model

- This model assumes, that the **IP addresses** (Network Layer Address)are **algorithmically mapped into** (NSAP-based) **ATM addresses**.
- Routing information can be easily exchanged among IP hosts/routers and ATM network entities - while **each network retains its classical routing mechanisms**
- **No need for separate ARP mechanism**
- A connection set-up request containing an IP address **could be routed directly by the routing mechanism of the ATM** (e.g. PNNI)
- Disadvantage: Using **different routing protocols in the IP and ATM** networks may lead to **less optimal end-to-end routes**

Integrated model

- **Based on PNNI** (Private Network Network Interface)
- Route calculations are taking account the **network topologies and the link states of both the IP and ATM network**
- Optimal route for IP packets in mixed IP/ATM environments

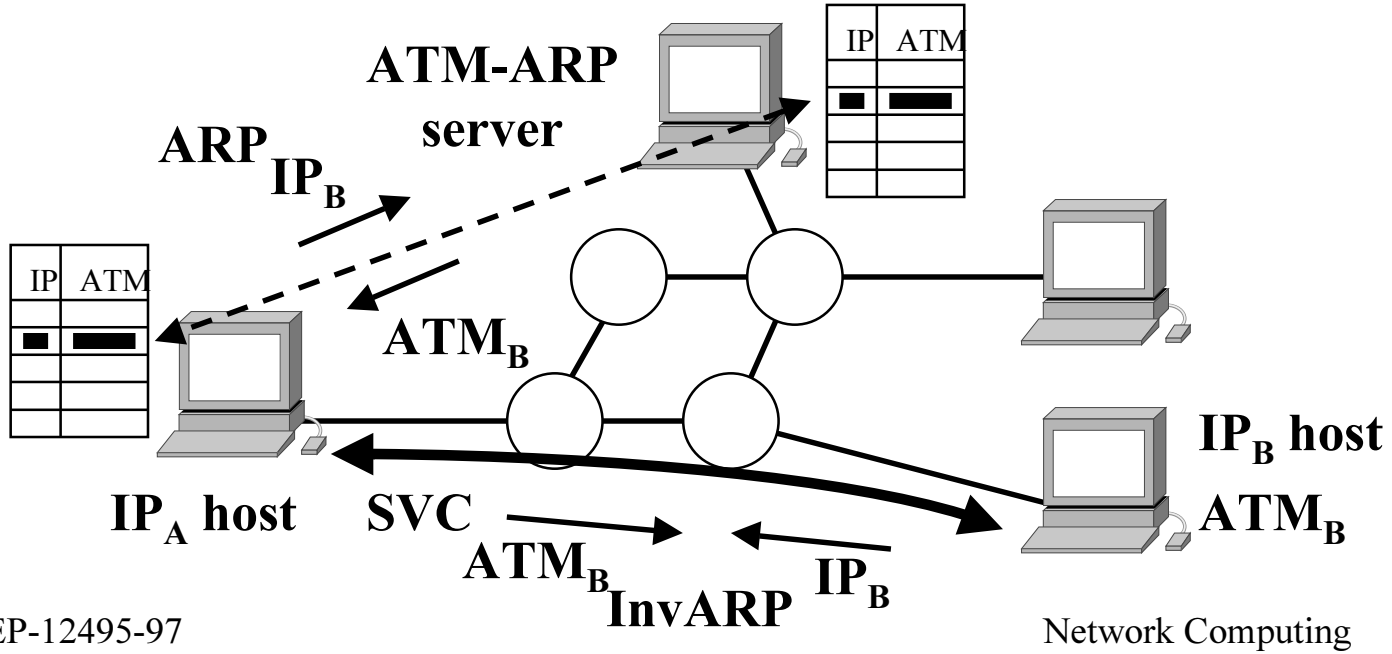
Integrated routing model

- Further **extension of the integrated model**
- It **uses the PNNI protocol** for routing in ATM switches and router based IP networks (it is also called integrated PNNI)
- Because of the PNNI it may lead to optimal end-to-end routes through switched and routed networks as well
- It **supports QoS routing -** suites well for the integrated services Internet

Address resolution (in Overlay model)

- **Classical IP over ATM** mechanism is required to **resolve target IP address to target ATM address and vice versa**
- **ATM-ARP** is based on the 'normal' **ARP and inverse ARP**
- No direct broadcast capabilities of the ATM network **- specific ATM-ARP server** needs to be deployed
- Each **LIS** needs at least one **ATM-ARP server** (all ATM-ARP stay within a LIS)
- The **ATM-ARP servers** are found via **configured unique ATM addresses**
- Host stations are **periodically registering** their **IP and ATM-SNAP or E.164 addresses** to their **ATM-ARP server** (belonging to the same LIS)
- The registered addresses are **stored in the server's database** (ageing)
- **ATM-ARP packets** are **LLC/SNAP encapsulated** and transported via an **ATM/AAL5 VCC**

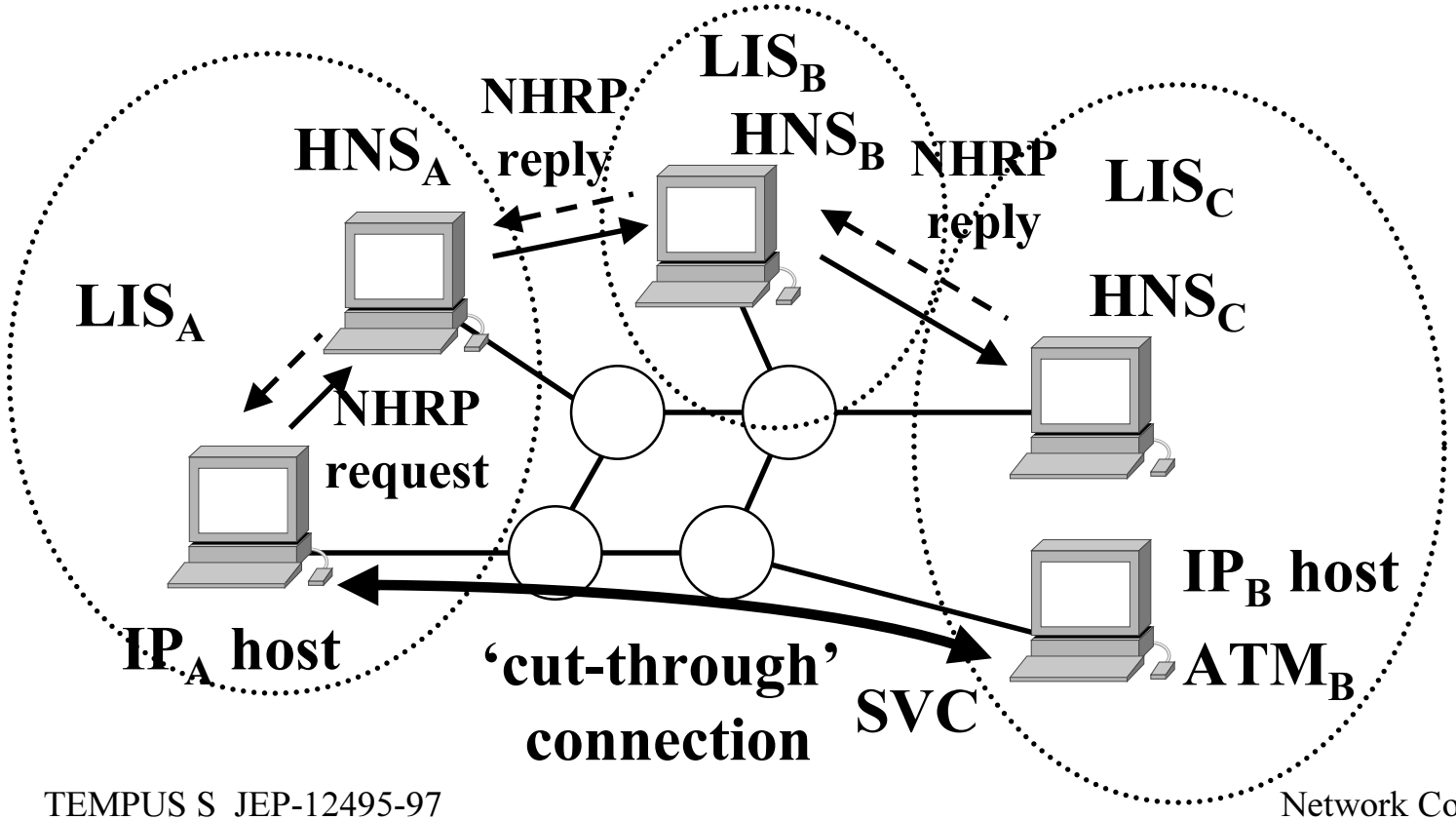
- Clients are sending **ATM-ARP requests** (IP→ATM) to the **ATM-ARP server** of the LIS, **based on the ATM address** returned, they can **establish a VCC** (SVC) to the desired destination
- The **SVCs** established are **not immediately released** after communication, but prior to any subsequent data transmission the **clients must revalidate their own address mapping** (ATM-ARP request to the ATM-ARP server) **-** in case of **no respond** from the **ATM-ARP server**, an **InvARP request** can be sent **directly to the destination client** (via the still existing SVC). Having **no replay** either, the destination **can no longer be reached** via the existing connection and the **SVC is released**.



Next Hop Resolution Protocol (NHRP)

- **Classical IP and ARP over ATM:** connections between hosts in **different LISs** are established **via** (several) **router hops** - every **router constitutes a potential bottleneck**
- The **Next Hop Resolution Protocol (NHRP)** allows a **cut-through connection through several LISs** to be established (direct end-to-end transparent ATM connection - it allows e.g. the ATM's QoS capabilities to be exploited)
- The **Next Hop Server (NHS) performs the NHRP** and realises the **inter-LIS ARP** mechanism (mapping ATM addresses to IP addresses outside the LIS)
- If the destination host is **not part of the ATM network**, **NHS** provides the address of the **egress router** through which this destination can best be reached
- **NHRP is used for MPOA** (Multiple Protocol Over ATM) also (it could be adopted for classical IP networks on broadcast or multiple acces channel too)
- **NHRP** is a specific **ARP** (not routing) mechanism that avoids extra IP hops, **its resolution is based on existing routing tables**

- **NHRP resolution request** is passed along **NHSs** until the request can be answered
- Receiving the NHRP reply, the host knows the destination's ATM address and can thus establish a direct ('cut-through') ATM connection
- Even within a networks with NHRP capabilities the hosts or routers still have the freedom to decide if the 'cut-through' or the routed hop-by-hop connection is used (local decision based on expenses, latency, QoS, etc. requirements)



ATM Local Area Networks

- **Introduction**
- **LAN Emulation**
- **Multiprotocol over ATM**

ATM Local Area Networks

Next generation LAN requirements:

- **Real-time information transfer** (ATM-short cells, ok)
- **Scalable throughput** (ATM cells rate, ok)
- **High transfer capability** (ATM up to 620Mbps, ok)
- **Easily internetworking between LAN and WAN** (ATM is a public network standard too, ok)
- **Standard based solution** (ATM is standardised, ok)

ATM LAN solutions:

- **LAN emulation (LANE)**
  LANE allows ATM to be gradually introduced into existing traditional LANs (it allows coexistence and interoperability among LAN and ATM stations)
- **Multiprotocol over ATM (MPOA)**
  Based on LANE, MPOA provides end-to-end ‘cut-through’ connections at the network layer (OSI Layer 3)

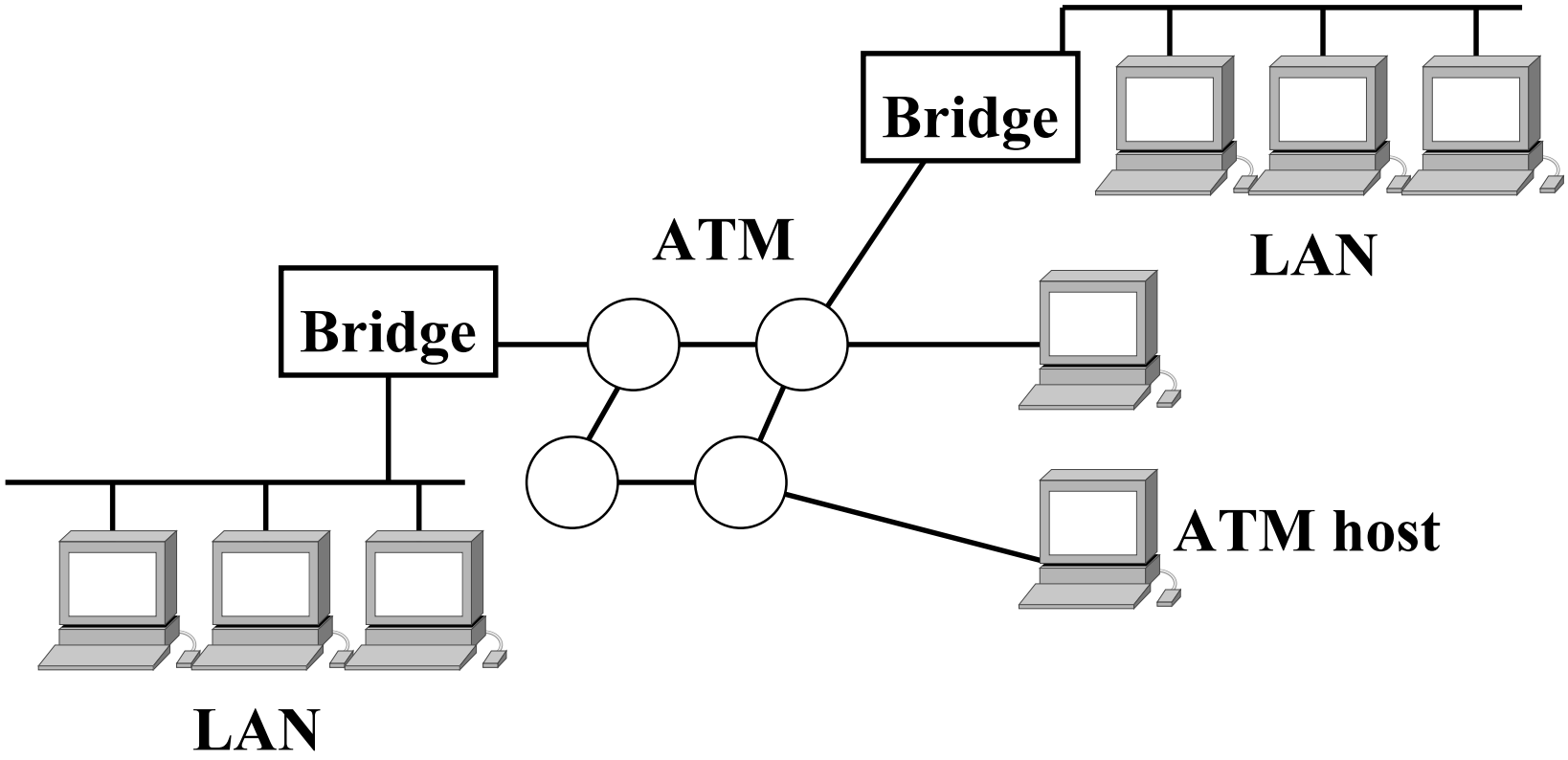
ATM Local Area Network Emulation (LANE)

- Specified by the **ATM Forum** (1995, LANEv2: 1997)
- It gives a migration path from traditional to pure ATM-based LANs
- Several LANs maybe emulated on a single physical ATM network

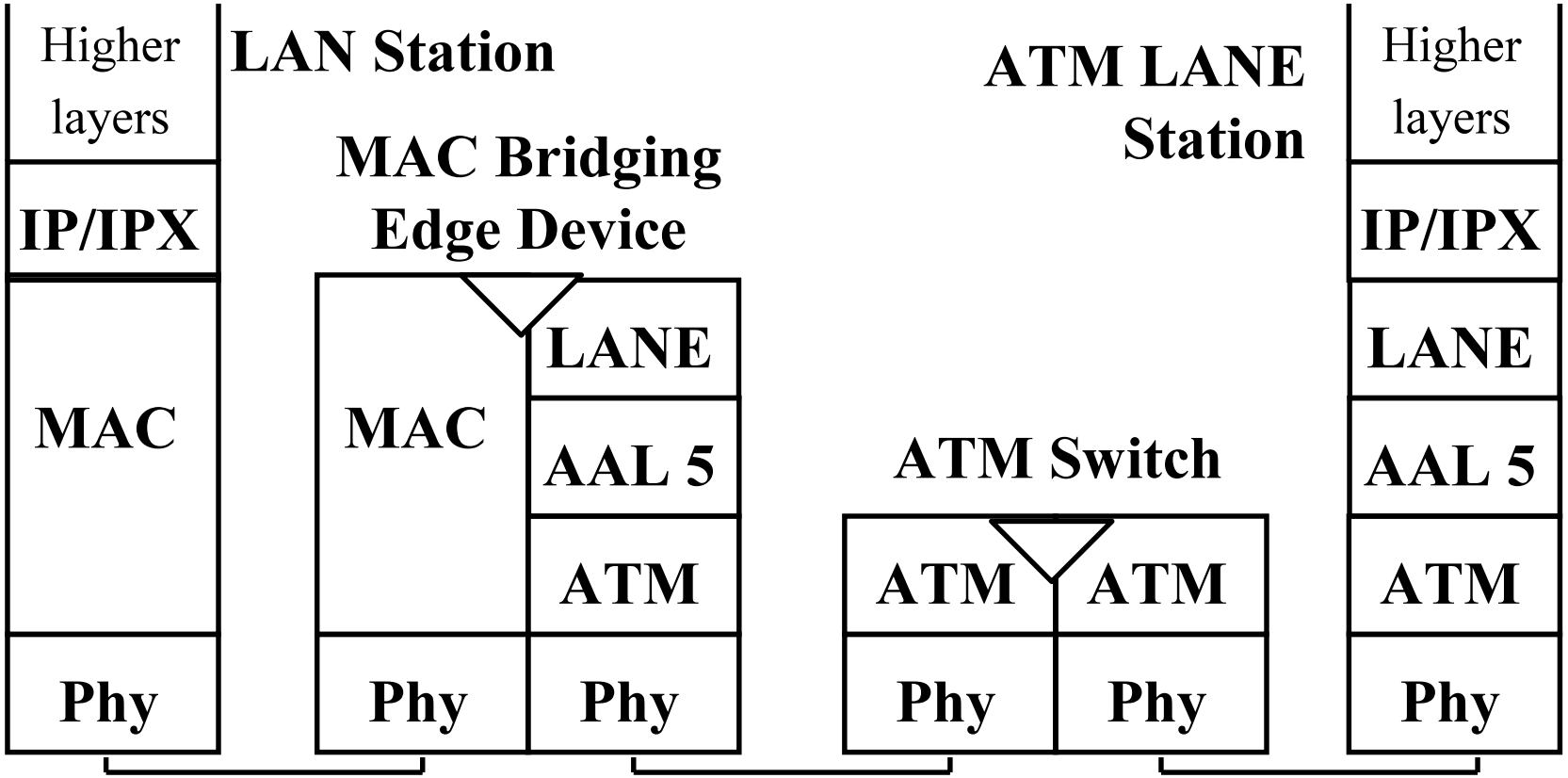
The **main differences** needed to be handled by LANE for interoperability of ATM and legacy LAN are:

- **ATM:** connection-oriented communication with local connection identifiers (VPI/VCI)
- **Legacy LAN:** connectionless communication with global addressing (MAC)

LANE functions can resides in **edge devices** such as LAN switches, bridges, routers, in legacy **LAN to ATM conversion equipment** or in **native ATM hosts**



- **LANE is used instead of the MAC** (Media Access Control) **layer** (instead of shared medium 'broadcast end filter' transfer technique the point-to-point ATM connections are established between endpoints)
- **LANE provides the same service primitives to the higher layer as the 'standardised' MAC device drivers** like the **network driver interface specification (NDIS), or open data link interface (ODI)**
  - achieving transparency for all higher layer LAN protocols (e.g. IP, IPX)



ATM LANE basic building blocks

LAN Emulation Clients (LEC)

- **End-systems** of a **single emulated LAN (ELAN)**
- Communicating each other via **LUNI** (LAN emulation user network interface)
- **LEC** handles the **data forwarding/reception**, **address resolution** (ATM/MAC) and **control functions**
- **Several LEC may exist** in those devices simultaneously **if they are connected to several ELANs**
- **LEC** is a legacy **LAN to ATM conversion equipment**
- Legacy **LANs may contain more than one devices**, so its **LEC represents more MAC addresses** (all the MAC addresses of the LAN) **and a single ATM address - it is also called Proxi LEC**

LAN Emulation Server (LES)

- **For each ELAN one LES exists**
- LES provides the necessary **control function**, it **registers and resolves the MAC and ATM addresses**

LAN Emulation Configuration Server (LECS)

- Several LANs maybe emulated on a single physical ATM network
- **LECS** has the responsibility of **assigning LEC to a particular ELAN**
- This is done **during the initial configuration** by **transmitting the ATM address of the LES to the LEC**
- Furthermore, it exchanges information on the **own ATM addresses of the LEC**, **LAN type** and **maximum allowed frame size** (MTU) with the LECs (LECS must contain all these information for all LEC of all ELANs - usually LECS needs to be manually configured by the network operator)
- **LEC**s are locating their **LECS** by:
  - **well-known permanent pre-configured VCC** (VPI=0, VCI=17) (used only for finding LECS)
  - obtaining LECS address from its ATM switch **via the ILMI management procedure**
  - using **well-known LECS ATM address** (different addressing can cause problems)
- After finding its LECS, the **LEC establishes a Configuration Direct VCC to the LECS**

Broadcast and Unknown Server (BUS)

- Used for **'flooding' unknown destination address traffic** and **multicast/broadcast traffic to all LECs within an ELAN**
- **Each LEC is associated with a single BUS**, whose unique ATM address can be obtained from the LES
- In additional, **BUS can be used for data transfer between LECs as long as no direct point-to-point VCC could be established** (for reducing delays of LE-ARP and connection establishment)

Location of the servers

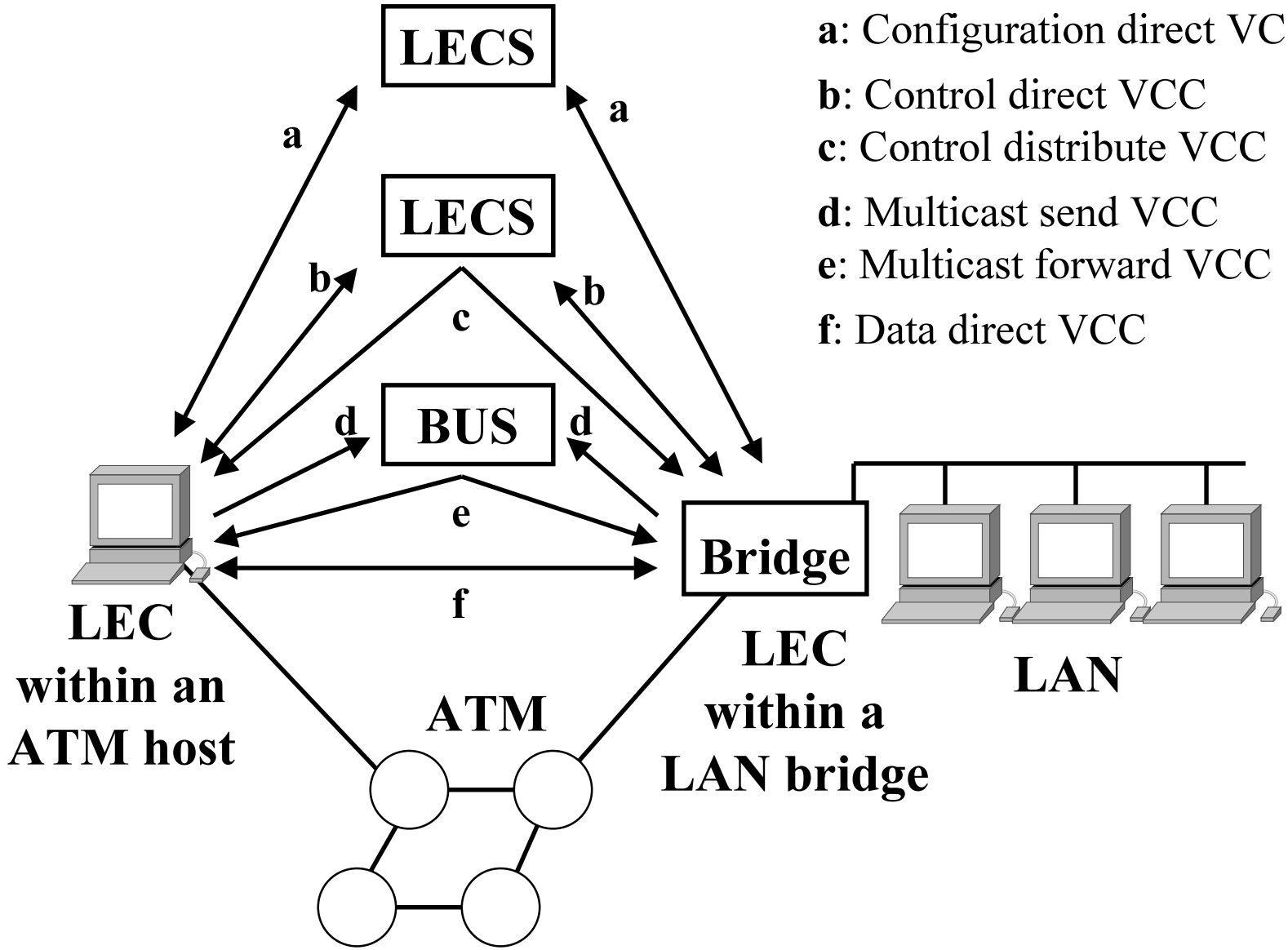
- All the **server functions can be physically distributed or co-located**
- e.g. BUS and LES are ideally co-located for sharing a common database, possibly resulting an optimised BUS forwarding policy

Joining an ELAN and registration

- Getting all the configuration information from the LECS, **LEC is able to establish a connection to its LES (Control Direct VCC)**
- **LEC registers its addresses** (one or more MAC and one ATM address) **at the LES**
- **LEC issuing LAN Emulation Address Resolution Protocol (LE-ARP) messages** to **LES** for obtaining any **unknown ATM addresses**
- **If the LES does not find the requested address** in its cached address table, **it forwards the LE-ARP request to all attached LECs,** through the **point-to-multipoint Control Distribute VCC**
- The first ATM address the LEC try to obtain is the **ATM address of the BUS** (this is done by issuing a **LE-ARP for the all-1s MAC broadcast address**)
- Having the ATM address of the BUS, **LEC establishes a point-to-point Multicast Send VCC to the BUS** and the **BUS in turn adds the LEC** as a leaf to the **point-to-multipoint Multicast Forward VCC**
- LES normally knows all the addresses of its ATM hosts, but it may not know all the MAC addresses associated to the ATM addresses (e.g. a LAN bridge with many MAC hosts on the LAN side)

The data transfer phase

- **Data is transferred in two possible way:**
  - for **broadcast or multicast traffic the LEC transmits the packets to the BUS** for further distribution
  - for **unicast traffic** the **LEC uses a Data Direct VCC** (SVC)
- In case of unicast traffic the LEC may find an **already existing Data Direct VCC** or at least it **knows the destination ATM address -** this case it can directly establish a VCC
- If the **destination ATM address is not known**, the **LEC is issuing a LE-ARP request message to the LES** for obtaining the unknown ATM address. The LES may either **know the requested address** or **forward the LE-ARP request to all attached LECs via the Control Distribute VCC**. The **LEC that knows the correct address mapping will answer via the Control Direct VCC back to the LES**. Now the **LES may forward this answer** either **to the requesting LEC only, or all the LECs**.
- During the waiting period until the LE-ARP answer is received the sending LEC could store (or discard) the packets or send them to the BUS which will flood all the LES. As soon the destination ATM address arrives, (after flushing the broadcasting) the LEC could establish a Data Direct connection.



a: Configuration direct VCC

b: Control direct VCC

c: Control distribute VCC

d: Multicast send VCC

e: Multicast forward VCC

f: Data direct VCC

Advantages and disadvantages of LANE

- LANE allows network administrator to build **Virtual LANs** (**VLAN**). VLAN **allows end-systems to be assigned a logical group** (logical LAN). Having the same physical ATM network VLANs are built by allocating a LEC to a specific ELAN (LES).
  Interconnecting ELANs (VLANs) **routers needed to be used**.
- **Interconnecting different type of ELANs** (e.g. Ethernet - Token Ring) **needs router** (a LEC can belong only to one type of ELAN and a direct connection between different e.g. 'Ethernet LEC' and 'Token Ring LEC' is not possible)
- Since LANE is a bridging technique, it is susceptible to large amounts of broadcast traffic, which might easily flood the entire network. This may cause congestion even on a high-speed ATM network. The LANE servers, LES and BUS constitute potential bottlenecks as well.
- **LANE is limited for 'small' networks**

ATM Multiprotocol over ATM (MPOA)

- Specified by the **ATM Forum** (1997)
- The main goal of the MPOA is giving a service which provides **end-to-end 'cut-through' connections at the network layer** (OSI Layer 3)
- Communication over several subnetworks requires routers which are potential bottlenecks. MPOA allows **optimal, direct end-to-end communication over several subnetworks** (having the same physical ATM network) **without crossing any router**.
- Although **MPOA allows any existing network layer protocol to be used, such as IP, IPX, AppleTalk, DECnet**, the ATM Forum focused its initial work on supporting TCP/IP networks.

MPOA basic principles

- **MPOA uses LLC/SNAP encapsulation** and the **'overlay' model**, where **layer 3 addresses are assigned independently of ATM addresses** and where **layer 3 routing protocols** such as OSPF **run separately from ATM routing** such as PNNI
- For **resolving layer 3 to ATM addresses** MPOA makes use of the **NHRP** and its **NHS**
- MPOA **reduces overhead and broadcast traffic** while **supporting larger MTU sizes** and making full **use of ATM's QoS capabilities** (direct end-to-end ATM connection)
- MPOA builds upon a **distributed router** or **virtual router model**
- The two main tasks of a traditional router are the **route processing** and the **data forwarding**. MPOA makes an attempt to distribute these functions on discrete devices: **MPOA Clients (MPCs)** for **switching and forwarding**, and **MPOA Servers (MPSs)** for building routing tables (**route processing**)
- MPCs connecting legacy LANs to ATM network are also called **edge devices**

MPOA Client (MPC)

- MPC communicates with its MPS via definde protocols
- **MPCs builds the endpoints** of a communication association
- They may reside in **MPOA capable ATM hosts** or in **edge devices** (devices connecting legacy LAN equipment with an ATM network)
- MPC can be considered to be an **intelligent multilayer switch**, since it evaluates either the **destination MAC address** (in case of staying in the same ELAN) or the **destination network layer address** to forward data frames.

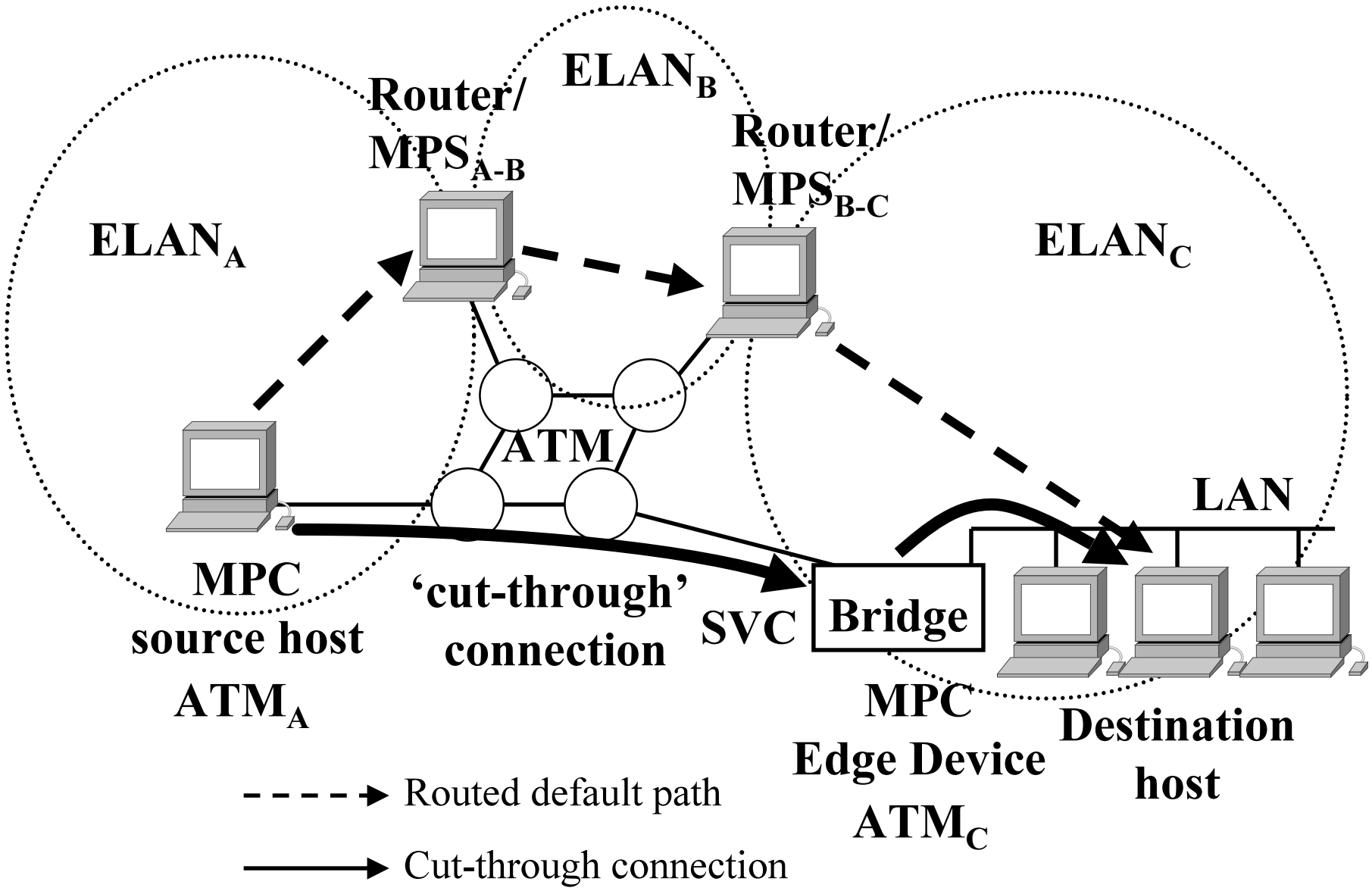
MPOA Server (MPS)

- **MPS is a route server** comprising the set of functions to **build routing tables** and to be able to **answer address queries**
- MPS maintains **MAC layer**, **network layer**, and **ATM layer address mappings** and **runs a routing protocol** such as OSPF (Open Shortest Path First) or RIP (Routing Information Protocol) to communicate with traditional routers
- MPS can be considered to be an enhanced NHS
- MPS can be realised in a dedicated device or be integrated into existing router

Principles of data flow

- As long as a **data flow stays within a single ELAN**, **communication is based on LANE** principles
- In case of **inter-ELAN communication** two possibilities exists to forward data: either on hop-by-hop basis **form router to router**, or using a **short-cut connection** which directly connects two MPCs
- In inter-LAN communication **by default MPCs sending data packets to the default MPS** (via LANE), which **acts as a 'traditional' router**
- As soon as **MPS detects a 'flow' of packets** (several subsequent packets with the same layer 3 address within a given time interval) **it attempts to establish a cut-through connection**
- If the **destination ATM address** for this layer 3 address **is not known**, an **MPOA resolution request needs to be issued** first (it resolved according to the principles of the **NHRP**)
- Having the **destination ATM address** for this layer 3 address, the **source MPC establishes a cut-through VCC connection to the destination MPC**
- **MPCs and MPSs automatically discover each other** using a modified **LANE ARP** protocol

MPOA data flow

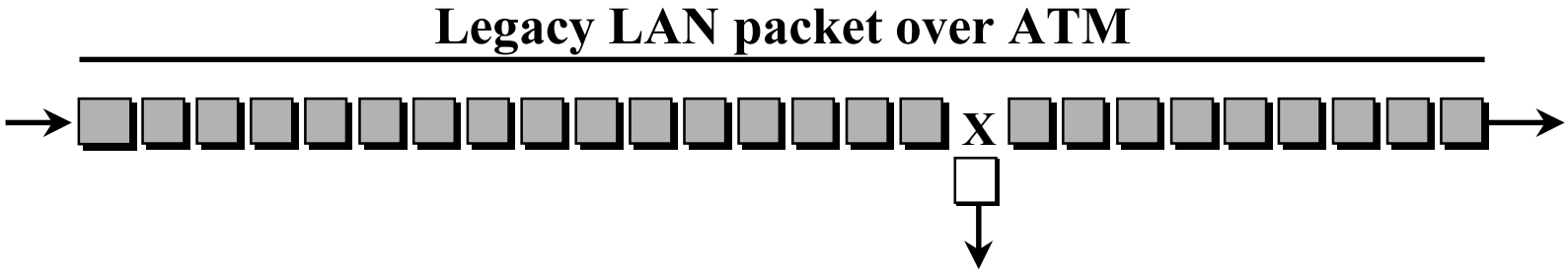


Sensitivity for cell losses in Legacy LAN packet over ATM techniques

Ethernet (MTU: 1500 Byte) = 32 cells

FDDI (MTU: 4470 Byte) = 96 cells

IP over ATM (MTU: 9180 Byte) = 192 cells



- **Loosing even a single cell may destroy the whole packet**
- **A single bit failure causes 32 cells loss (Ethernet)**
- **This may cause congestion even on a high-speed ATM network**

ATM Forum:

- **ATM Forum** was founded in 1991
- **Founders:**
  Cisco Systems, NET, Nortel, Sprint
- Nowadays ATMF has more than 700 members
- **ATMF Working Groups:**
  Signaling, UNI, PNNI, LANE, MPOA
- **http://www.atmforum.com**

ATM References:

Books:

- R. Händel, M.N.Hube, S. Schröder:
  ATM Networks (Addison-Wesley, 1998)
- D. Ginsburg:
  ATM solutions for enterprise internetworking
  (Addison-Wesley, 1996)

WWW sites:

- **http://www.cisco.com**
- **http://www.atmforum.com**
- **e-mail info@atmforum.com**
- **http://cella-relay.indiana.edu**
- **http://www.atmreport.com**
- **http://www.atm-user.com**