ATM (& B-ISDN)

(ATM = Asynchronous Transfer Mode)

- ATM is a connection-oriented, cell-based technique for the transfer of information
- ATM is not equivalent with B-ISDN
- The concept of QoS is important
- ITU-T (I-series) vs. ATM Forum recs/specs

Why use ATM ?

Conventional circuit switched connection:

- After initial setup no processing in network nodes
- Fixed bit rates, fixed time delay

Conventional packet switched connection:

- Flexible bandwidth allocation due to statistical multiplexing, varying time delay
- Complex processing in network nodes

ATM somewhere inbetween:

- Minimal node processing, statistical multiplexing

Characteristics of ATM

ATM is a connection-oriented technique ⇔ the information in form of cells is routed through the network along a single path. Cells are always received in sequence.

The digital information is packed into ATM cells (5 octets header + 48 octets payload). Cells are transmitted through the network independently. Statistical multiplexing is possible.

An ATM connection is by definition unidirectional.

ATM supports (will support) higher layer service adaptation, different degrees of QoS and traffic management.

ATM is not equivalent with B-ISDN

ATM is a transmission technique which can be employed anywhere, wherever the network conditions permit:

a) A company can implement its own ATM network, leasing physical lines from a network operator.

b) A network operator could use ATM for internal traffic (so long as certain QoS conditions are fulfilled).

c) Network operators may also provide fixed ATM connections for certain subscribers on a permanent contract basis (Permanent Virtual Circuits = PVC)

⇔ no signaling required, traffic management is optional!

B-ISDN is not equivalent with ATM

B-ISDN is (at least in practice) based on ATM.

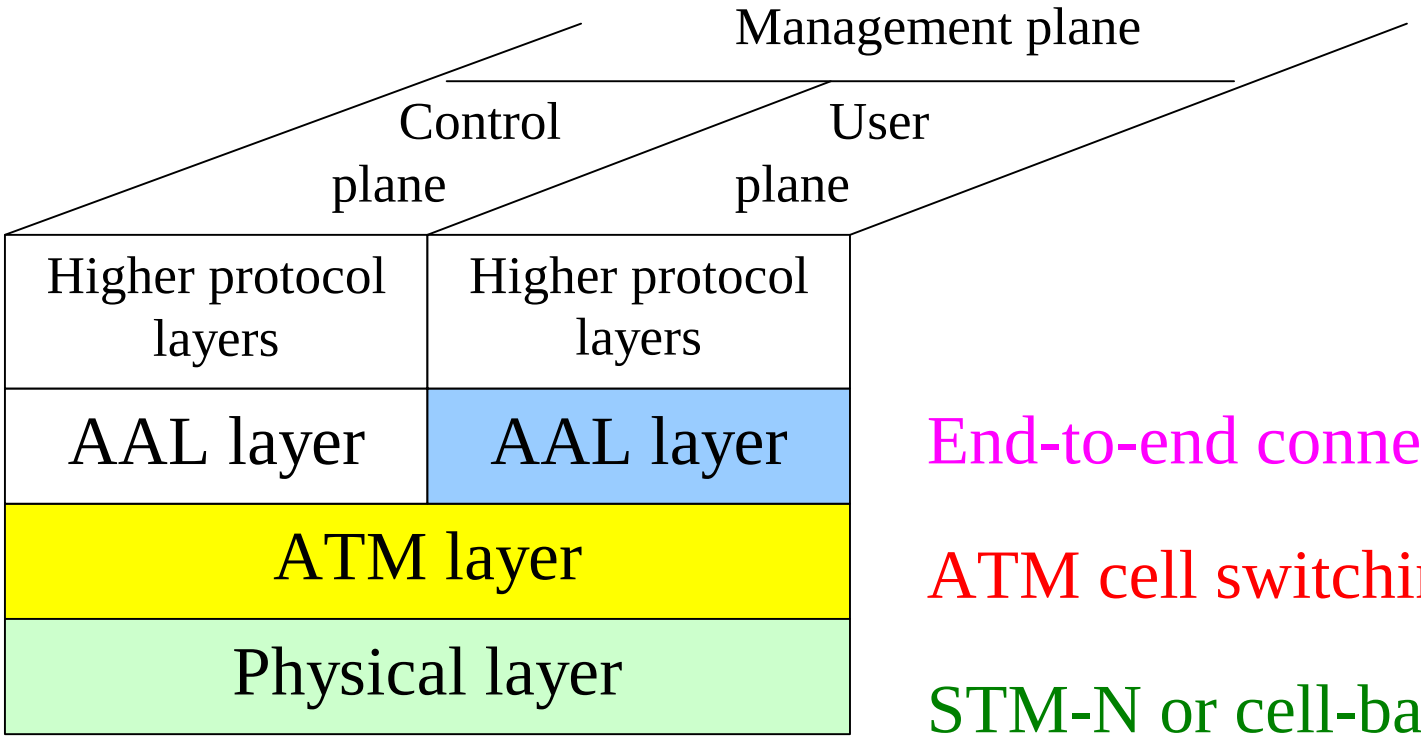
However, B-ISDN is a public network. In B-ISDN, there are the following two options:

a) Permanent Virtual Circuits (PVC), set up by the operator on a long-term contract basis — easy

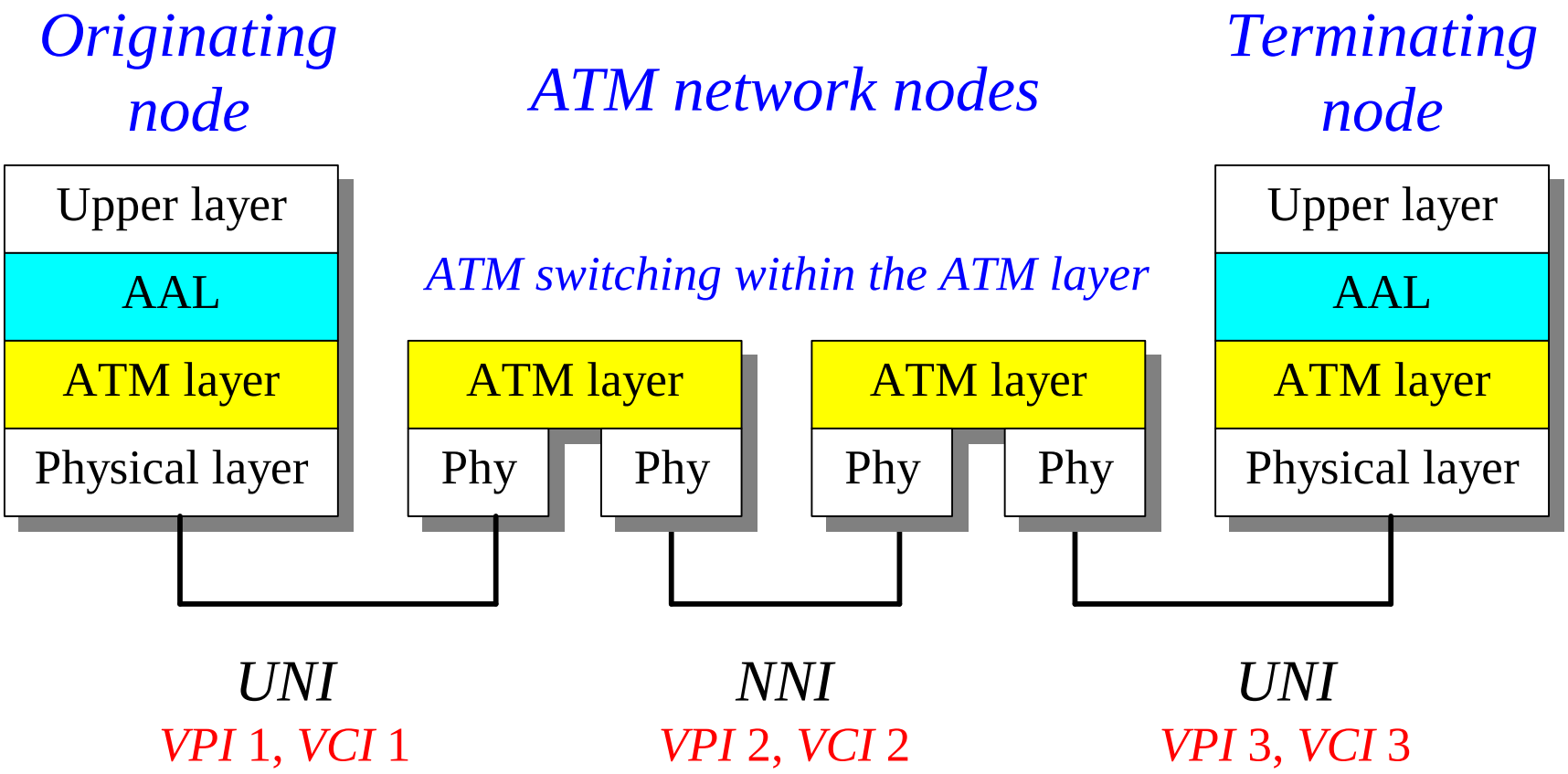
b) Switched Virtual Circuits (SVC), controlled by user signaling (ITU-T Q.2931). — not easy

Before a public switched ATM network can be implemented, a number of complex issues must be standardized (signaling, traffic management).

ITU-T Protocol reference model

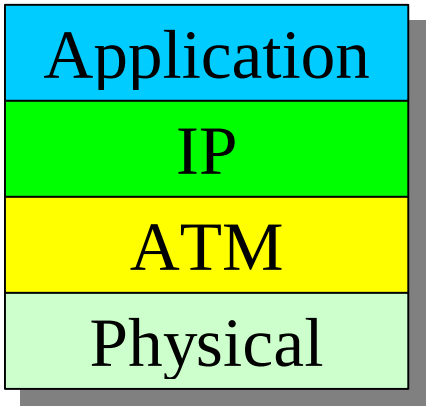


ATM network connection



Generic use of ATM within networks

1. ATM may complement IP based technology

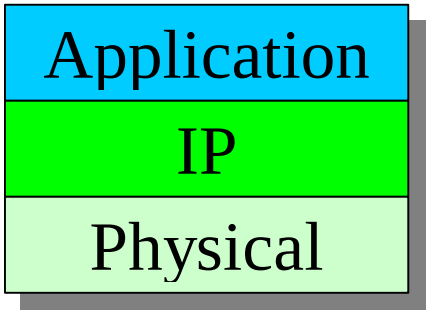


IP ubiquitous in future

voice over ATM
IP over ATM

network backbone based on ATM

2. ATM may be replaced by IP based technology



voice over IP

network backbone based on IP

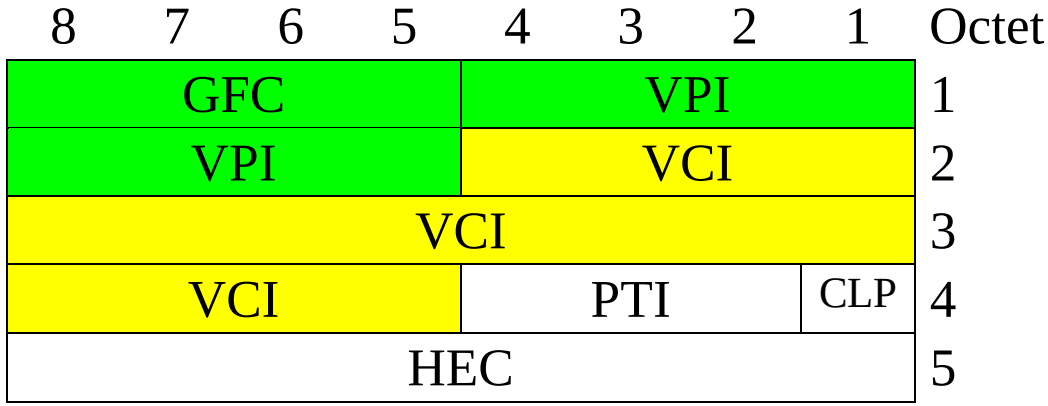
Functions of the Physical layer

1. The *physical medium sublayer* (lower sublayer) handles and adapts bits as they are fed to the physical medium (e.g., electro-optical conversion)
2. The *transmission convergence sublayer* (upper sublayer) converts the flow of cells from the ATM layer into a continuous bit stream (and vice versa), involving:
   - Cell rate decoupling (bit rate adaptation)
   - Cell delineation (generally using HEC)
   - Mapping of cells into, e.g., the VC-4 payload
   - Calculation and verification of HEC

Functions of the ATM layer

1. To create the ATM cell by generating / adding a header to the information field received from the AAL (and performing the reverse operation at the receiving end)
2. To multiplex and demultiplex the ATM cell flows from different connections using appropriate identifiers (VCI and VPI) located in the cell headers
3. To perform cell switching, routing, and/or relaying within the ATM network (also using VCI and VPI)
4. To provide mechanisms for flow control and other traffic management functions.

ATM cell header structure (UNI)

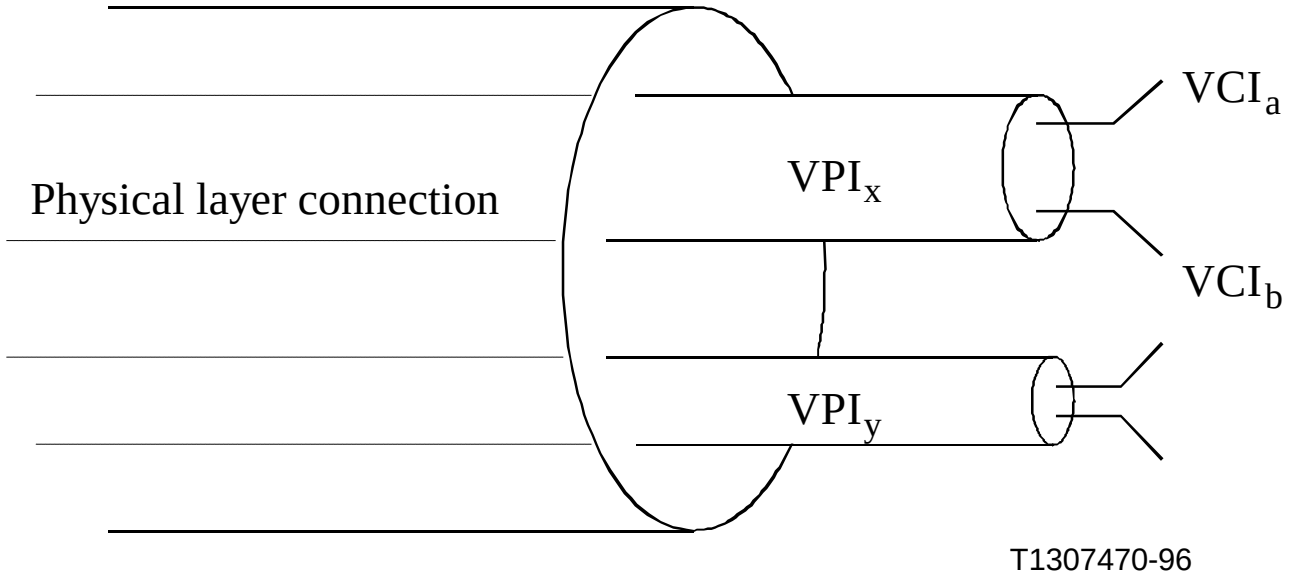


GFC	Generic Flow Control	HEC	Header Error Control
VPI	Virtual Path Identifier	PTI	Payload Type Indicator
VCI	Virtual Chanel Identifier	CLP	Cell Loss Priority

NNI (between ATM network nodes): GFC => VPI

Virtual Path/Channel Connection

See Figure G.3.3 in ”Understanding Telecommunications”



NOTE – VCI$_a$ and VCI$_b$ represent two of the possible values of VCI within the VP link with the value VPI$_x$. Similarly, VPI$_x$ and VPI$_y$ refer to two of the possible values of VPI within the physical layer connection.

Function of PTI bits (UNI)

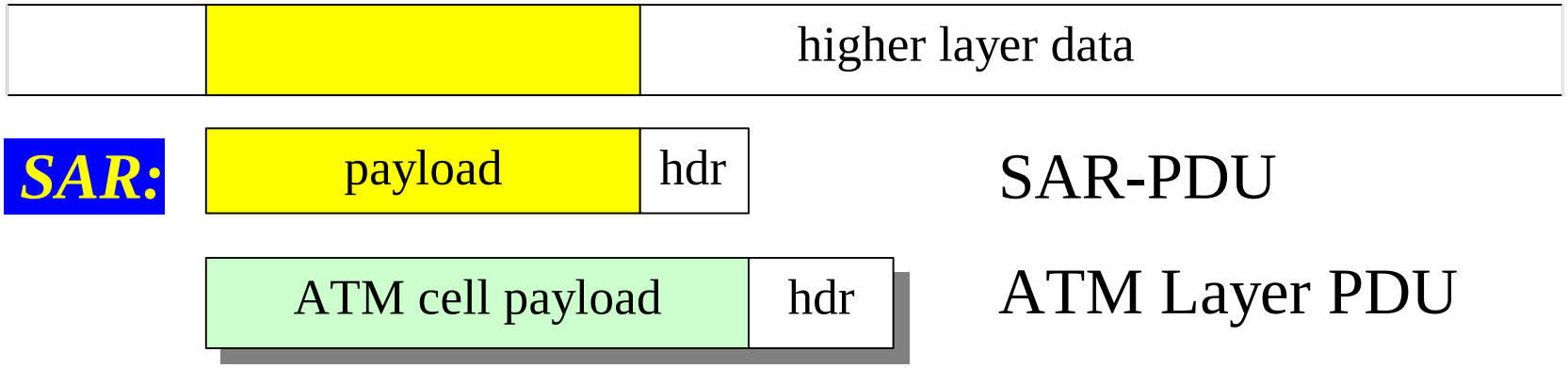
4 3 2	
0 0 0	User data cell, no congestion. ATM user-to-ATM-user indication = 0
0 0 1	User data cell, no congestion. ATM-user-to-ATM-user indication = 1
0 1 0	User data cell, congestion experienced. ATM-user-to-ATM-user indication = 0
0 1 1	User data cell, congestion experienced. ATM-user-to-ATM-user indication = 1
1 0 0	OAM F5 segment associated cell
1 0 1	OAM F5 end-to-end associated cell
1 1 0	Resource management cell
1 1 1	Reserved for future VC functions

is used for AAL functions (not really part of ATM layer)

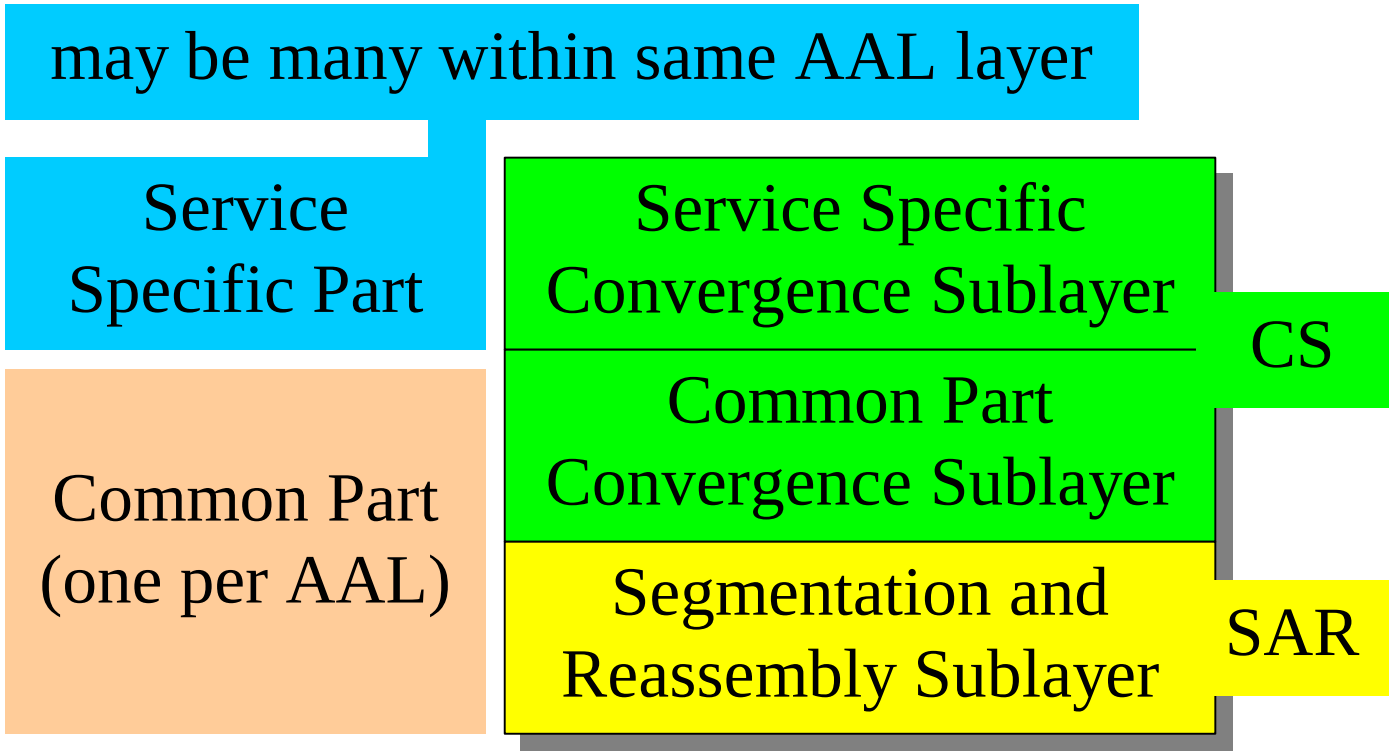
ATM Adaptation Layer (AAL)

Implemented in the terminal nodes only (network aspects are not addressed, these are covered by the ATM layer)

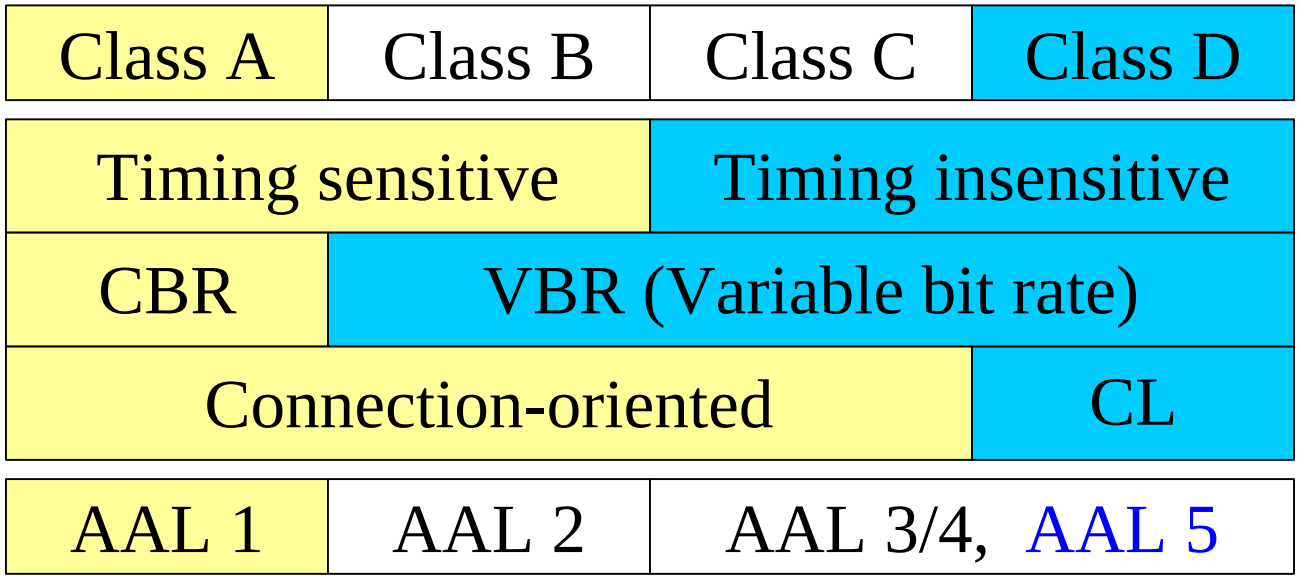
CS: flow and timing control, error correction, handling of lost and misinserted cells, (also SAR functionality)



AAL layer structure



Service classes vs. AAL protocols



Speech
Circuit emulation

LAN emulation
Frame relay

AAL protocols

AAL 1: constant bit rate, small delay (variation)
(voice & video transport)

AAL 2: variable bit rate, small delay (variation)
(used in UMTS radio access network)

AAL 3/4: variable bit rate, not time sensitive, complex

AAL 5: variable bit rate, not time sensitive
no retransmission mechanisms
(UMTS RAN, LAN emulation, signaling)

AAL 2

When transmitting low bit rate signals, AAL 2 provides

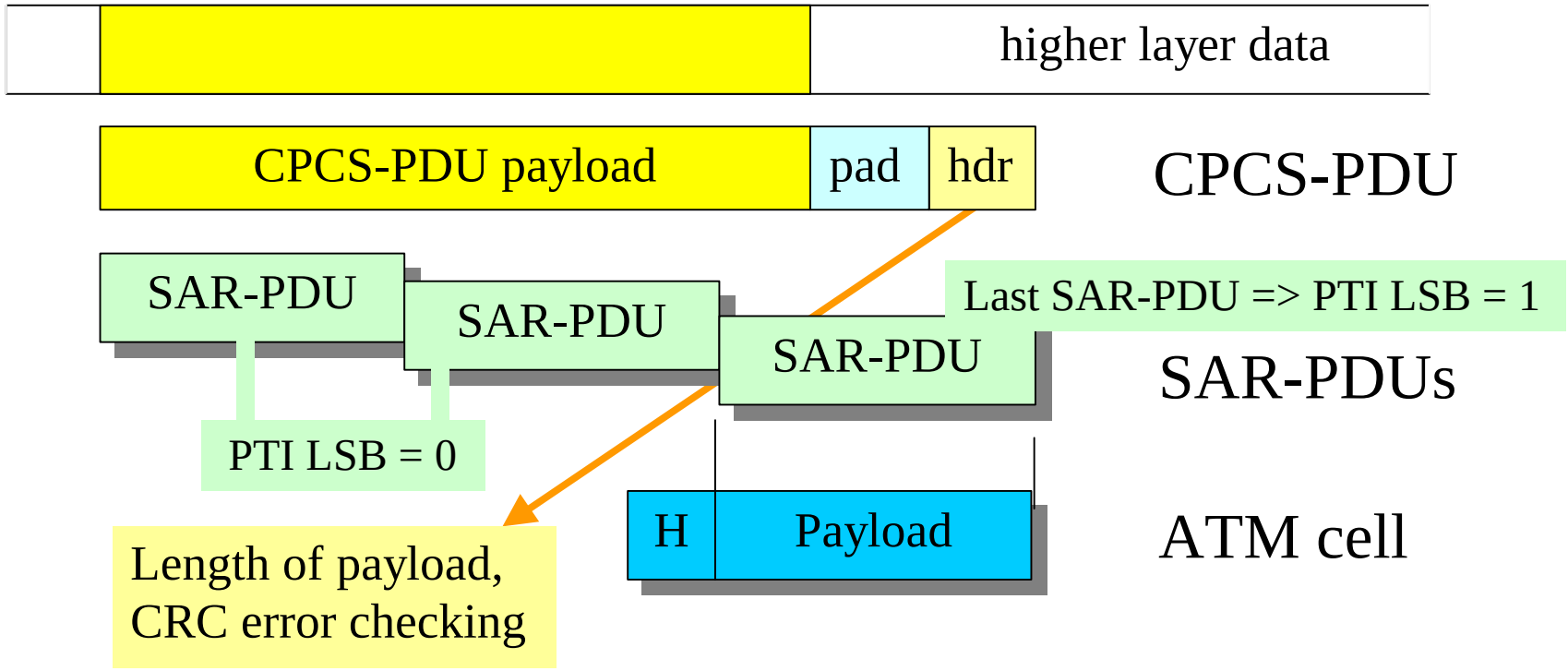
low packetization delay and high bandwidth efficiency

AAL 2 not used => low delay but also low efficiency

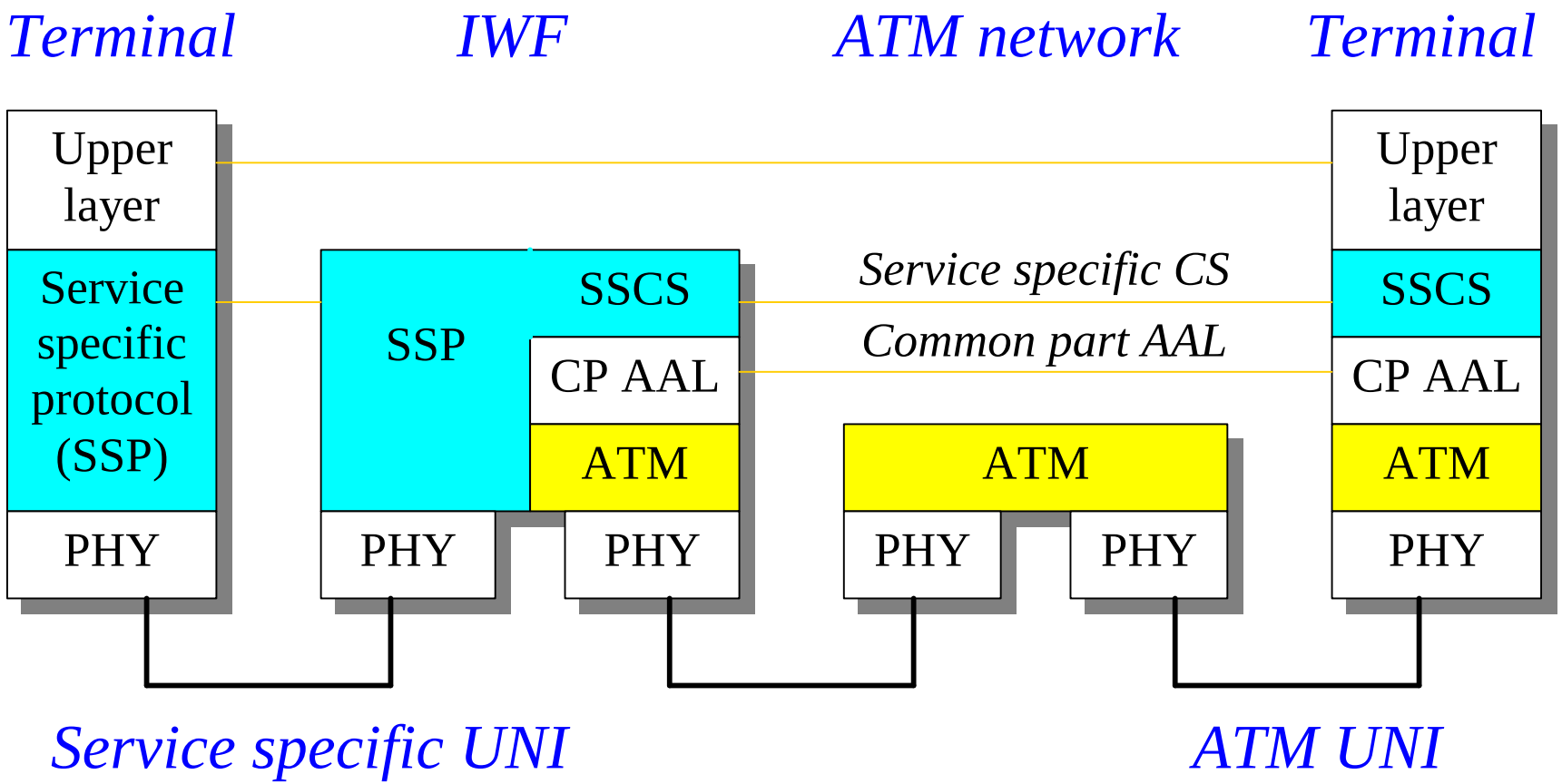
AAL 2 used => multiplexing different signals into a single ATM cell payload in a flexible manner

AAL 5

Simple and efficient => popular, has replaced AAL 3/4



ATM internetworking



ATM layer service performance

ITU-T I.371 ”Transfer Capability”	ATM Forum TM4.0 ”Service Category”	Typical use
Deterministic Bit Rate (DBR)	Constant Bit Rate (CBR)	Voice transmission
(for further study)	Real-Time Variable Bit Rate (RT-VBR)	Compressed video signal transmission
Statistical Bit Rate (SBR)	Non-Real-Time Var. Bit Rate (NRT-VBR)	Statistical multiplexing (data services)
Available Bit Rate (ABR)	Available Bit Rate (ABR)	Resource efficient transmission mode
(no equivalent)	Unspecified Bit Rate (UBR)	Best effort, no guarantees
ATM Block Transfer (ABT)	(no equivalent)	Burst level feedback control

DBR / CBR: Specified for connections that require a certain amount of bandwidth, characterized by a Peak Cell Rate (PCR) value that is continuously available during the entire connection lifetime. The source may emit cells at or below the PCR at any time and for any duration (or may be silent).

Typical applications:

1. Voice (standard 64 kbit/s PCM)
2. Video (uncompressed)
3. Circuit Emulation Services (CES), e.g. carrying PDH signals over ATM connections

This category is mainly intended for (but not restricted to) tightly constrained CTD and CDV services (see next slides).

DBR: The ITU-T recommends that this *Transfer Capability* be used for *QoS Class 1* with stringent QoS requirements and the following performance objectives (see next three slides):

Cell Transfer Delay (CTD): mean CTD < 400 ms

Cell Delay Variation (CDV): difference between upper and lower 10^{-8} quantiles of CTD < 3 ms

Cell Loss Ratio (CLR): $< 3 \times 10^{-7}$

(the following also for QOS *Class 2* and *Class 3*)

Cell Error Ratio (CER): $< 4 \times 10^{-6}$ ($< 4 \times 10^{-7}$ proposed)

Cell Misinsertion Rate (CMR): < 1 / day

Severely Errored Cell Block Ratio (SECBR): $< 10^{-4}$

QoS classes (ITU-T)

Whereas the ATM Forum utilizes individual QoS parameters, the corresponding ITU-T network performance parameters are associated with four QoS classes (see ITU-T I.356):

ATM transfer capabilities	**Applicable QoS class**
DBR, SBR1, ABT/DT, ABT/IT	Class 1 (stringent class)
DBR, SBR1, ABT/DT, ABT/IT	Class 2 (tolerant class)
SBR2, SBR3, ABR	Class 3 (bi-level class)
Any transfer capability	U class (no QoS parameters)

QoS class should not be confused with *Service class (A…D)*.

NPO:s of QoS classes (ITU-T)

ITU-T I.356 p.24

Netw. perf. parameter	*QOS Class 1*	*QOS Class 2*	*QOS Class 3*	*QOS U Class*
CTD	400 ms	U	U	U
CDV	3 ms	U	U	U
CLR	3 E-7	E-5	E-5	U
CER	4 E-6	4 E-6	4 E-6	U
CMR	1 / day	1 / day	1 / day	U
SECBR	E-4	E-4	E-4	U

U - unspecified

RT-VBR: Specified by the ATM Forum for services with stringent time requirements (”real-time applications”), like CBR / DBR above, but with variable bit rate.

NRT-VBR: Specified by the ATM Forum for variable bit rate services without stringent time requirements (”non-real-time applications”).

In both VBR service categories, we need to specify the following traffic parameters:

- Peak Cell Rate (PCR)
- Sustainable Cell Rate (SCR)
- Maximum Burst Size (MBS)

ITU-T utilizes the traffic parameter *IBT* instead of *MBS*.

SBR: The ITU-T version of NRT-VBR. Consequently, this *Transfer Capability* is used for variable bit rate services with no stringent time requirements. Available as SBR1…SBR3.

Again, we need to specify the following traffic parameters:

- Peak Cell Rate (PCR)
- Sustainable Cell Rate (SCR)
- Intrinsic Burst Tolerance (IBT), a function of PCR, SCR and MBS (ITU-T I.371, p.20)

SCR is an upper bound on the *average cell rate* of an ATM connection, defined over a ”long” time interval.

MBS is the maximum number of consecutive cells allowed at the peak cell rate.

ABR: A relatively new concept. Based on flow control from the network (employing *Resource Management = RM cells*).

In ABR, we need to specify the following traffic parameters:

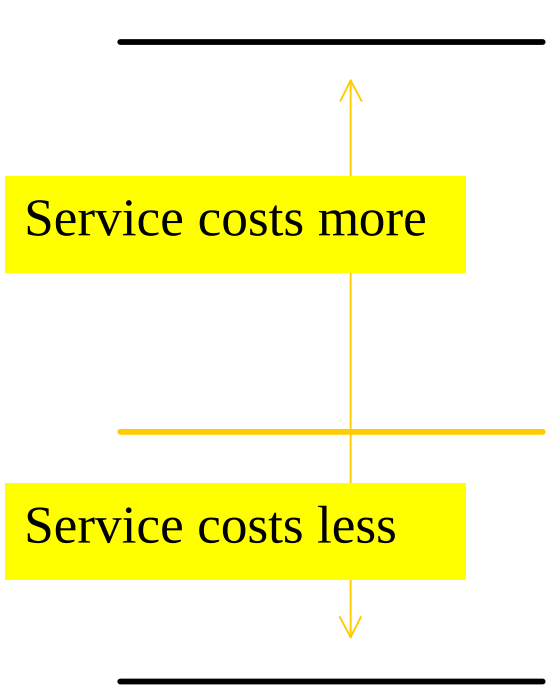
- Peak Cell Rate (PCR)
- Minimum Cell Rate (MCR)

MCR is a bound (0 < MCR < PCR) on the cell rate that the network supports under all conditions. The cell rate of the source may be 0 … MCR at worst, 0 … PCR at best.

Typical applications:

- LAN emulation / LAN interconnection
- File transfer (critical applications)

Available Bit Rate (ABR)



Peak cell rate (PCR)
(may not be exceeded by source)

Minimum cell rate (MCR)
(always guaranteed by network)

Zero cell rate

UBR: No QoS requirements. The only traffic parameter of interest is the PCR.

UBR supports a high degree of statistical multiplexing.

Typical applications:

- File transfer (non-critical applications)
- E-mail

ABT: An *ATM block* is defined as a group of cells located between two RM cells.

ABT with delayed transmission (ABT/DT): the Block Cell Rate (BCR) of each ATM block is negotiated separately.

ABT with immediate transmission (ABT/IT): no feedback from the network ⇔ cells can be discarded.

Service Category attributes (ATM Forum)

Attribute	ATM Layer Service Category				
	CBR	rt-VBR	nrt-VBR	UBR	ABR
Traffic Parameters					
PCR	specified				
SCR, MBS	n/a	specified		n/a	
MCR	n/a				specified
QoS Parameters					
Max CTD	specified		unspecified		
Max pp CDV	specified		unspecified		
CLR	specified			unspec.	Netw.sp.
Other attributes					
Feedback	Unspecified				specified

No simple one-to-one mapping always possible between:

Service classes A … D (upper layers)

AAL 1, AAL 2, AAL 3/4, AAL 5 (AAL)

4 Transfer capabilities / 5 Service categories
(ATM layer)

4 QoS classes / QoS parameters (network)

Traffic management in ATM

The role of traffic management is to protect the network and terminals from congestion in order to achieve certain network performance objectives (NPO:s).

An additional role is to promote the efficient use of network resources (efficient bandwidth resource allocation).

Recs/Specs: *ITU-T:* I.371 *ATM Forum:* TM 4.0

Terminology: 4 transfer capabilities / 5 service categories
traffic parameters (PCR, SCR, MCR, MBS)
network performance parameters ⇔
4 QoS classes / individual QoS parameters

Traffic management (cont.)

1. ***Negotiation of traffic contract before transmission***

   Traffic contract involves traffic descriptors and network performance / QoS parameters or QoS classes

2. ***Traffic control mechanisms (enforcement of contract)***

   Connection Admission Control (CAC): the network decides if a connection request can be accepted

   Usage Parameter Control (UPC): the network detects violations of negotiated parameters and takes appropriate action (e.g., cell discarding or cell tagging)

   Feedback control (e.g., flow control of ABR service)