ATM

Asynchronous Transfer Mode

(and some SDH)

(Synchronous Digital Hierarchy)

Why use ATM ?

Circuit switched connections:

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

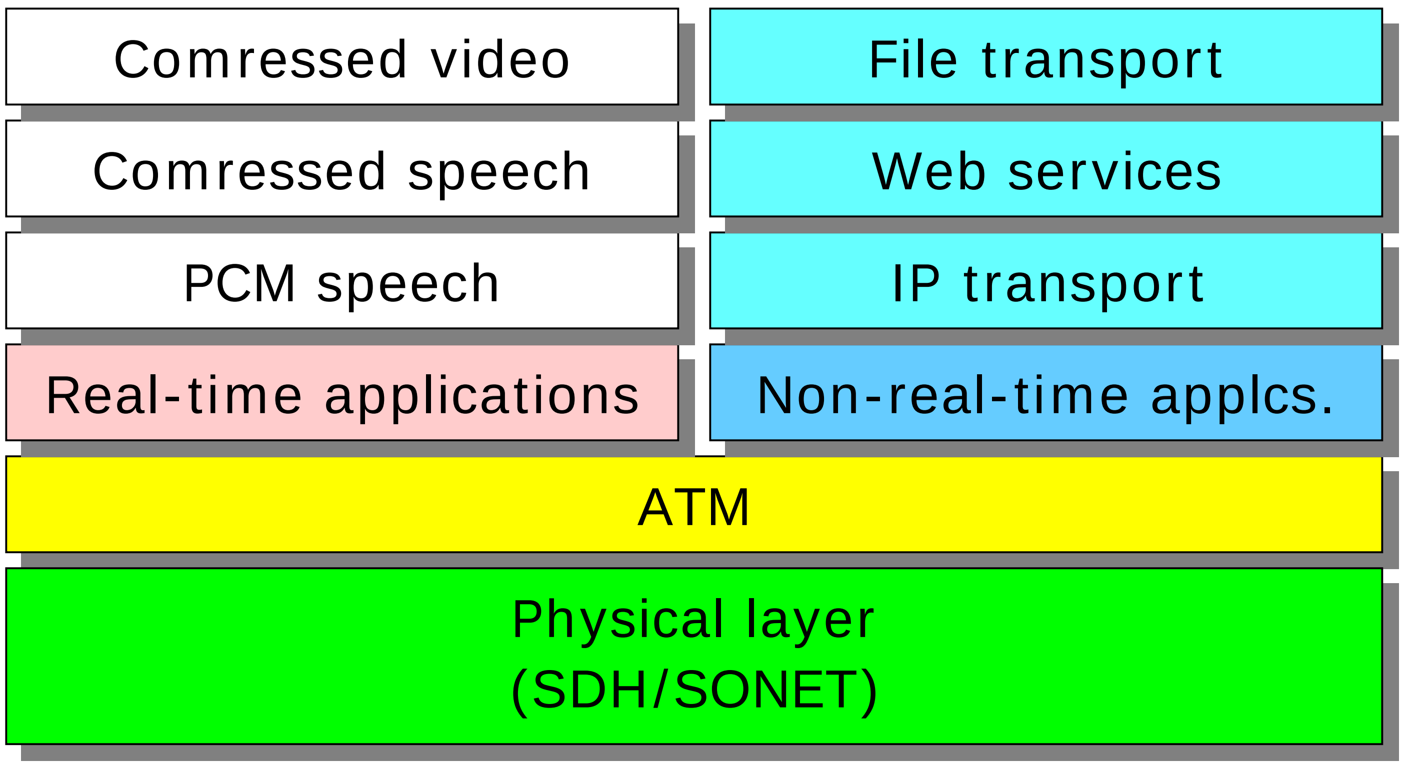
Packet switched connections:

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

ATM is based on virtual connections:

- Minimal node processing, statistical multiplexing

ATM is a core technology



Main characteristics of ATM

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

virtual connections

Statistical multiplexing of cells.

An ATM connection is by definition unidirectional.

ATM supports higher layer service adaptation, and may support different degrees of Quality of Service (QoS) and traffic management (IP term: traffic engineering).

Where/how is ATM used ?

ATM is a transmission technique:

- A company can implement its own ATM network. Network operators provide fixed ATM connections for subscribers on a permanent contract basis (Permanent Virtual Circuits = PVC)
- A network operator can use ATM for internal traffic (so long as QoS conditions of higher layer services are fulfilled). Example: UMTS RAN

In both cases no signalling is required, traffic management is optional!

Two types of virtual connections

Permanent Virtual Circuits (PVC) are set up by the operator on a permanent (or long-term) contract basis

- PVC set-up via network management tools
- No signalling required

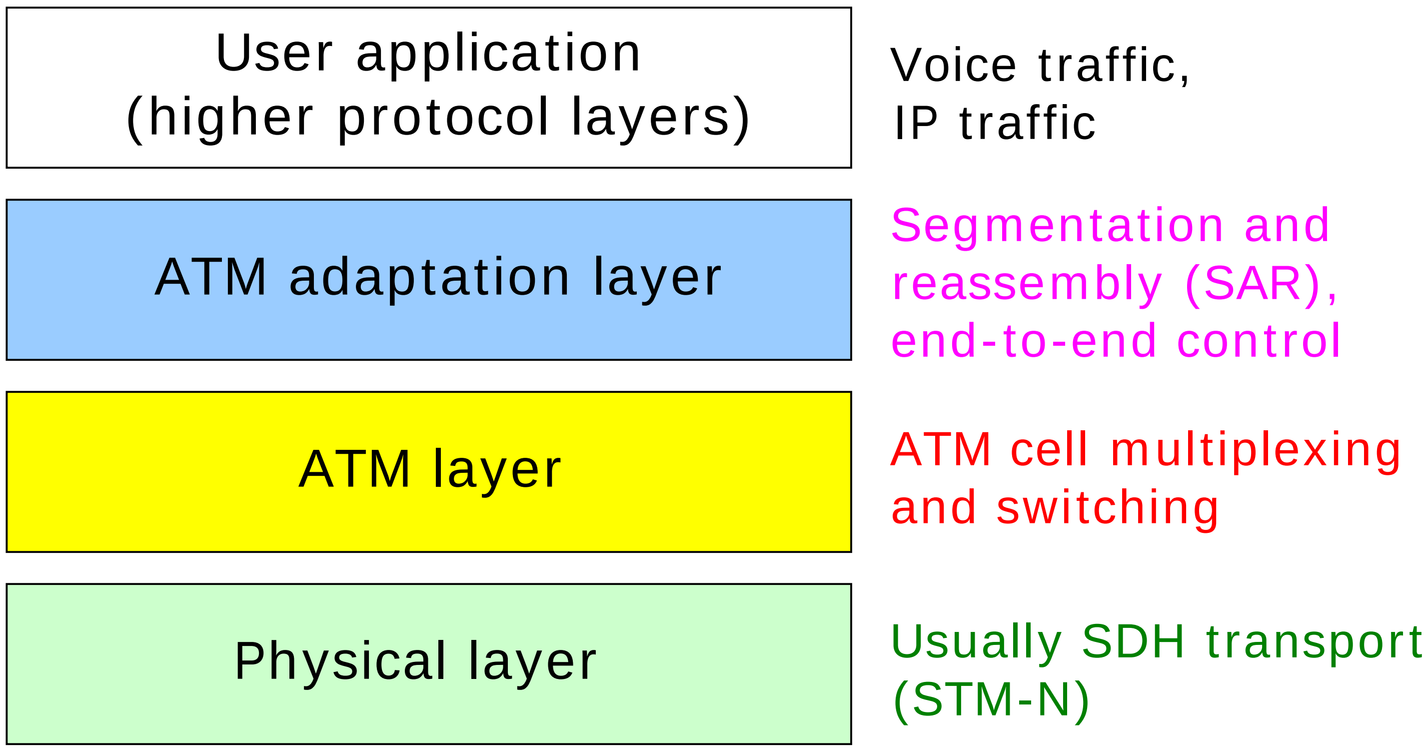
Switched Virtual Circuits (SVC) are controlled by user signaling (ITU-T Q.2931)

- Set-up and release of ATM virtual connections requires signalling (like PSTN/ISDN)
- Signalling channels are set-up on a permanent basis

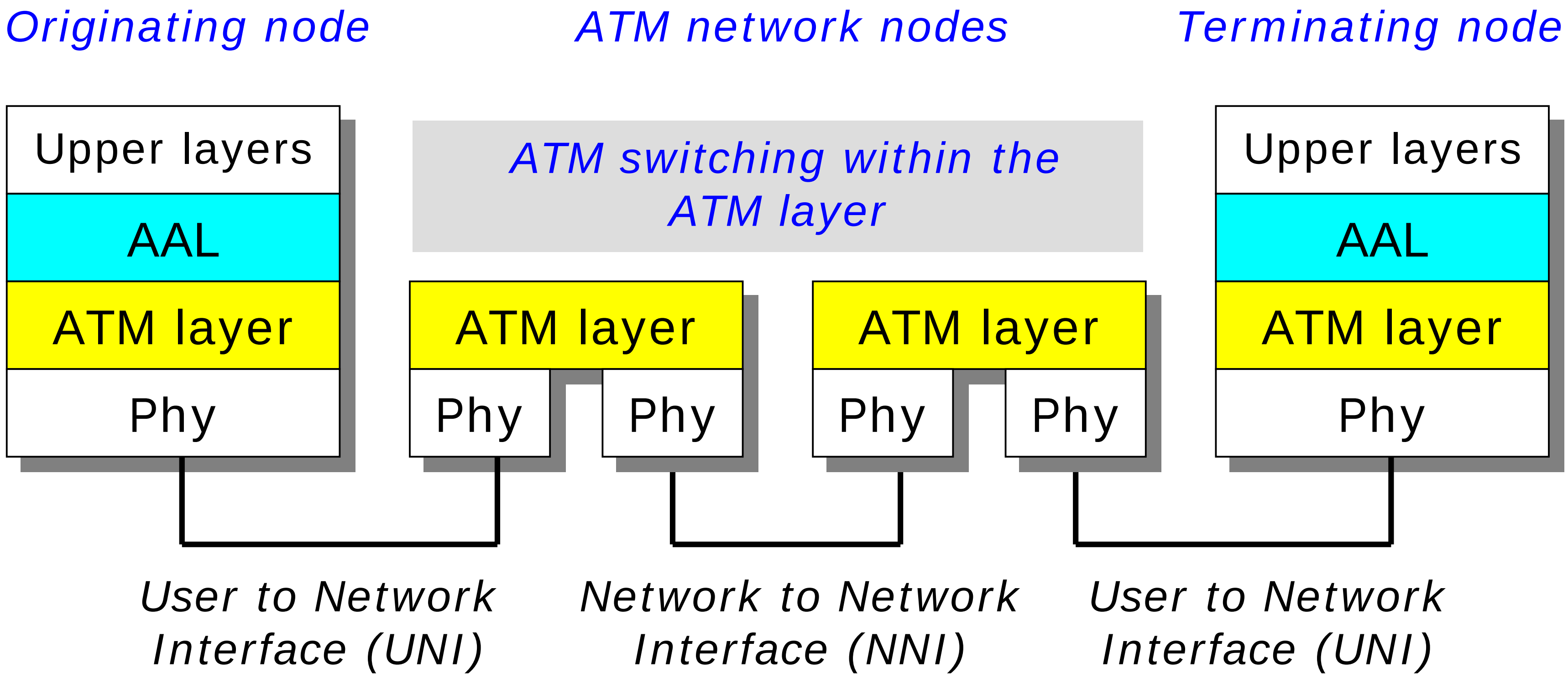
~~Broadband ISDN~~

Not very much used

ATM protocol reference model



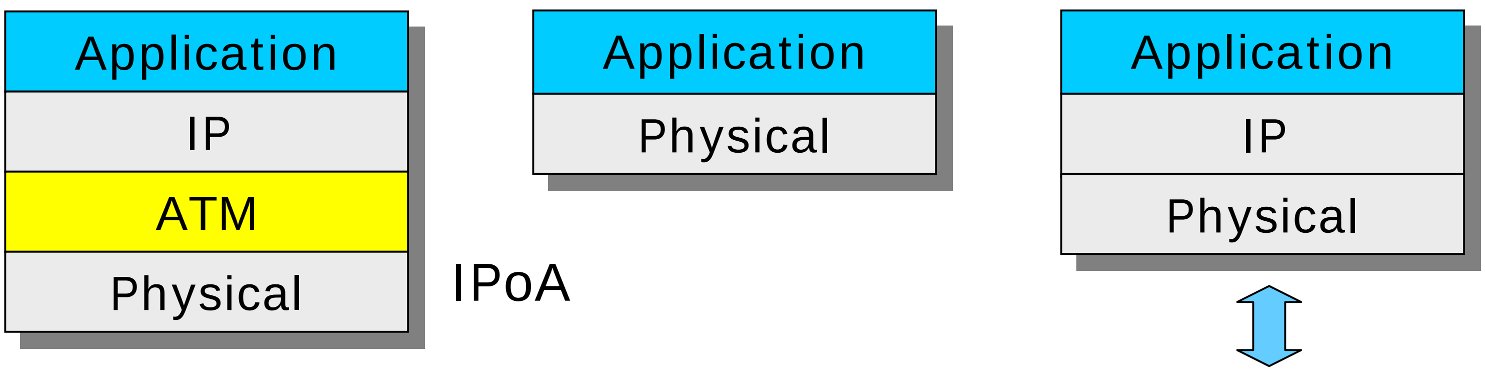
Typical ATM network connection

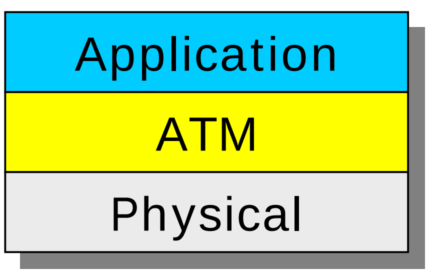


ATM is a transport technique

for implementing network “backbone”

Network backbone based on ATM | *Network backbone based on TDM* | *Network backbone based on IP*





PoS (Packet over SDH/SONET)

Application can be circuit switched or packet switched (possibility of IP-over-IP)

Functions of the Physical layer

The *physical medium sublayer* (lower sublayer) handles and adapts bits as they are fed to the physical medium (e.g., electro-optical conversion)

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 method)
- Mapping of cells into, e.g., SDH VC-4 payload
- Calculation and verification of HEC byte

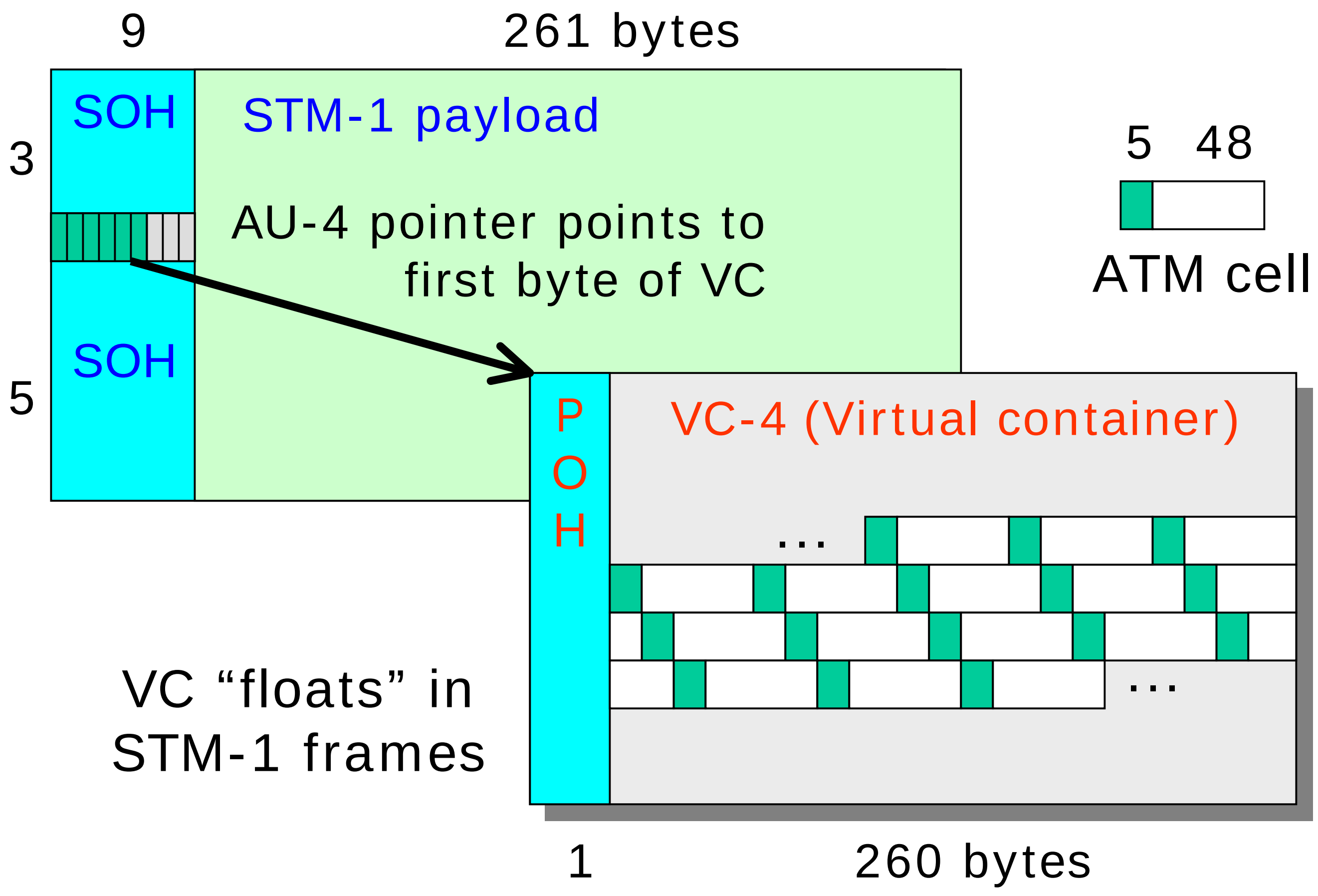
Digital transmission system hierarchy

PDH (Plesiochronous Digital Hierarchy)

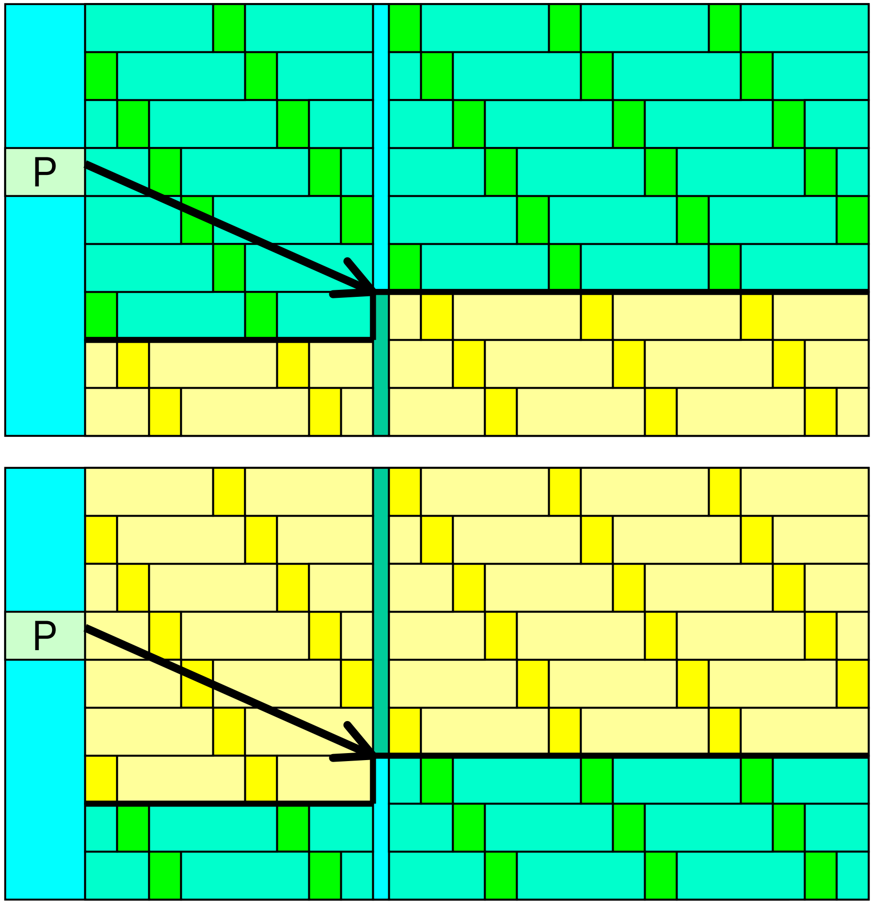
Japan		*USA*		*Europe*	
J1	1.5 Mb/s	T1	1.5 Mb/s	E1	2 Mb/s
J2	6	T2	6	E2	8
J3	32	T3	45	E3	34
J4	98	T4	274	E4	140

SONET (North Am.)		SDH
STS-1	51.84 Mb/s	
STS-3	155.52	STM-1
STS-12	622.08	STM-4
STS-48	2.488 Gb/s	STM-16

Mapping of ATM cells into STM-1 frames



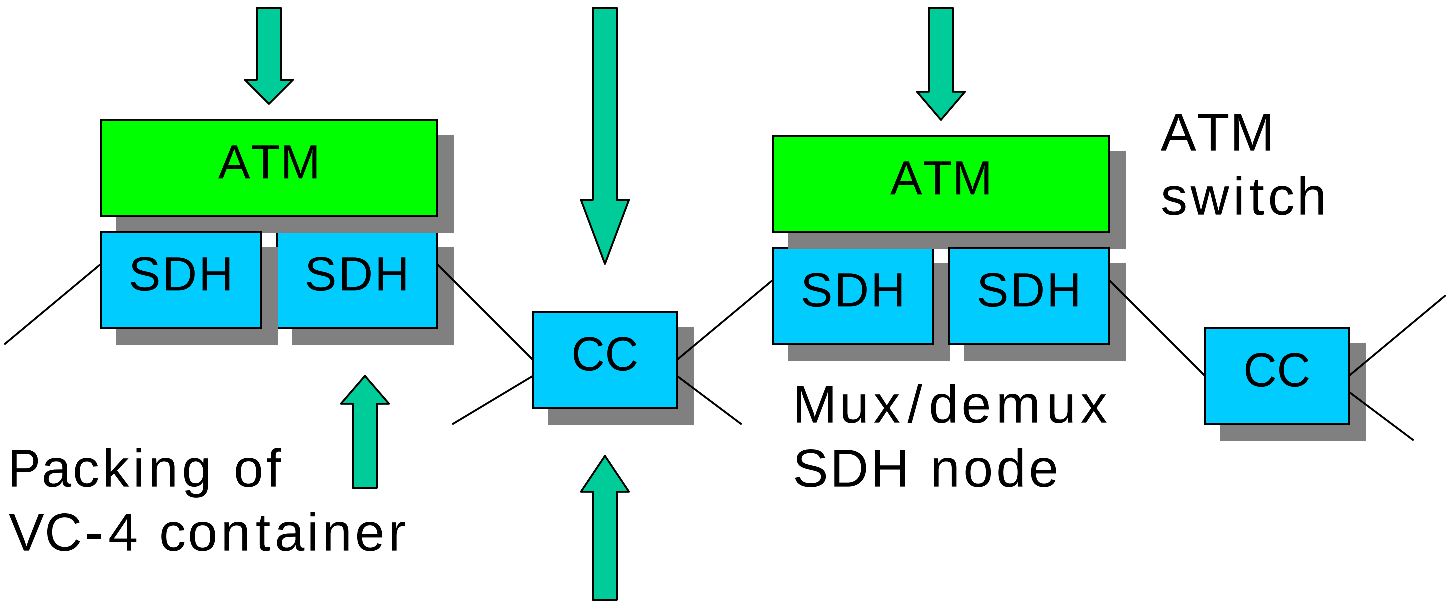
Filling of STM-1 payload in practice



In reality, the STM-1 payload is filled like this

Where is pointer processing needed?

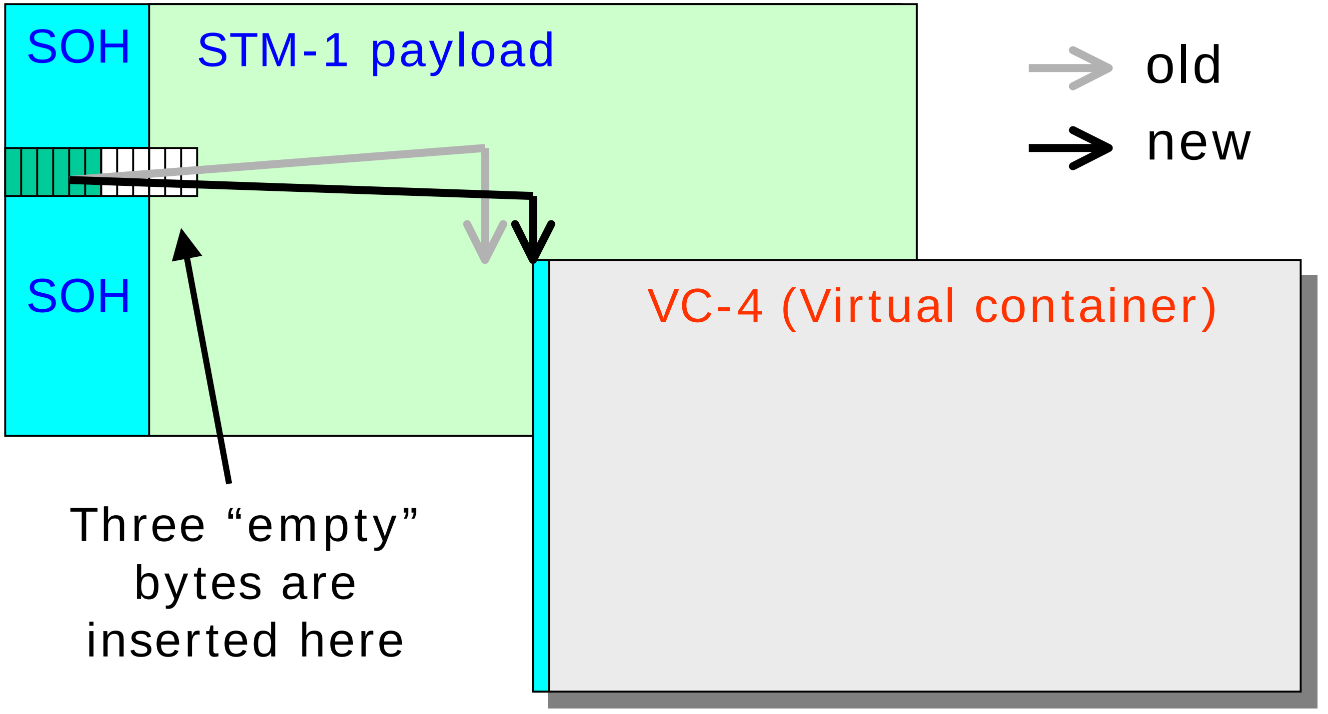
Pointer processing is needed when different SDH network nodes have slightly different clock rates



VC-4 container passes transparently through SDH cross-connect (CC) equipment

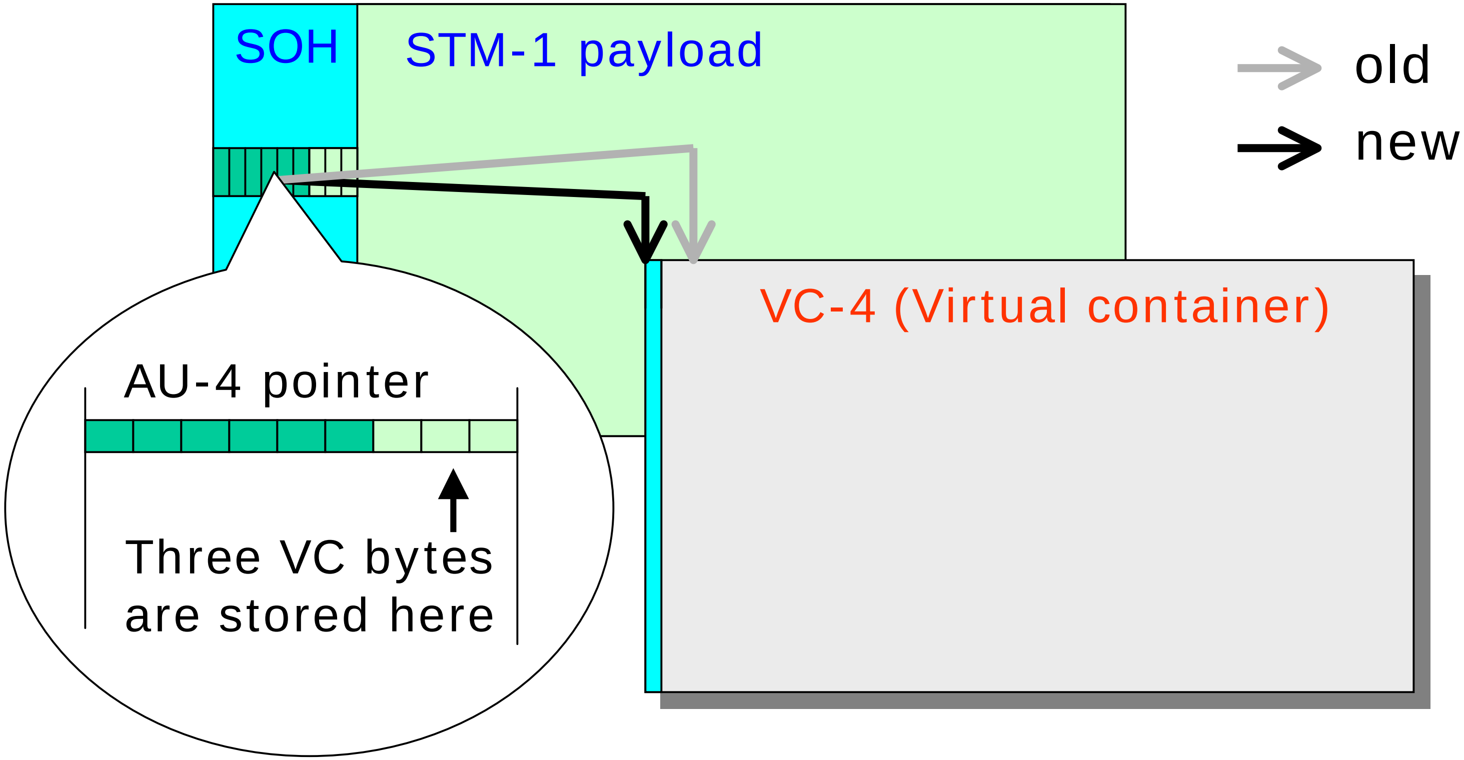
Pointer adjustment (1)

When VC-4 clock rate is larger than STM-1 clock rate
=> pointer value is shifted forward three bytes



Pointer adjustment (2)

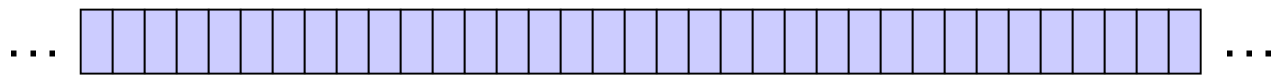
When VC-4 clock rate is smaller than STM-1 clock rate
=> pointer value is shifted back three bytes



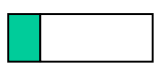
Cell delineation (1)

Cell delineation = finding the borders between cells at the receiving end of an ATM link

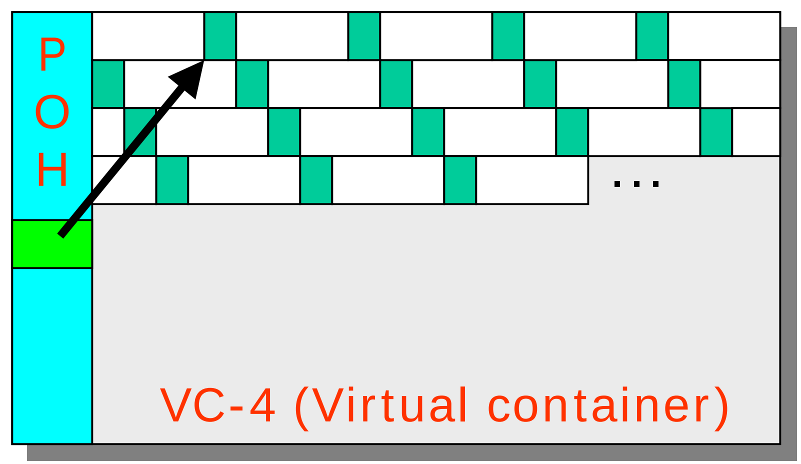
received bit stream ... where does a cell begin?



Method 1:
using VC-4
POH pointer



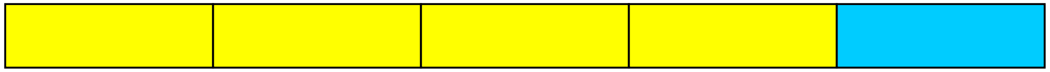
ATM cell



Cell delineation (2)

Method 2: using the HEC byte

We take 4 x 8 consecutive bits from the received bit stream and calculate the checksum



Checksum = HEC byte ?

If the checksum = the next byte (= HEC byte), we have found the header of an ATM cell. If not, we shift one bit position and repeat the calculation ...

Method 2 is usually preferred over Method 1 (better performance)

Functions of the ATM layer

1. ATM cell creation => generating and adding a 5 byte cell header to the 48 byte payload received from the AAL (and giving the payload to the AAL at the receiving end)
2. Multiplexing (and demultiplexing) of the ATM cell flows from different sources using appropriate identifiers (VCI and VPI) located in the cell headers
3. Cell routing (switching and/or relaying) within the ATM network (also using VCI and VPI)
4. The ATM layer may also provide mechanisms for traffic management.

ATM cell header structure

<table>
<tr><td>Bits</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td rowspan="5">Byte in header</td><td colspan="4">GFC* / VPI</td><td colspan="4">VPI</td></tr>
<tr><td colspan="4">VPI</td><td colspan="4">VCI</td></tr>
<tr><td colspan="8">VCI</td></tr>
<tr><td colspan="4">VCI</td><td colspan="3">PTI</td><td>CLP</td></tr>
<tr><td colspan="8">HEC</td></tr>
</table>

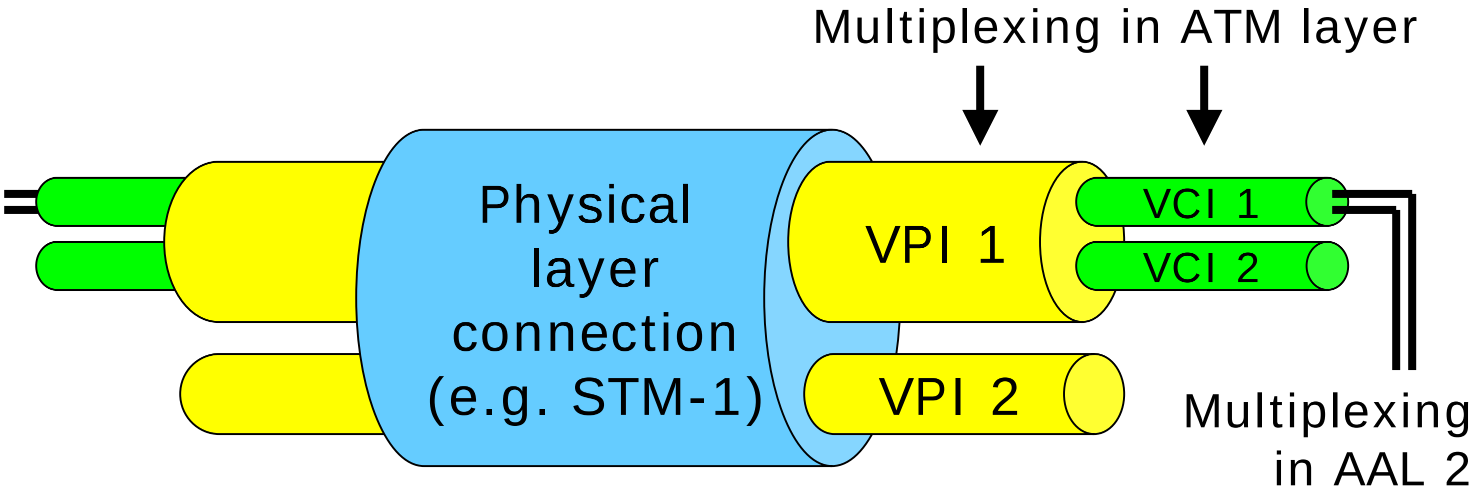
GFC Generic Flow Control
VPI Virtual Path Identifier
VCI Virtual Channel Identifier
HEC Header Error Control
PTI Payload Type Indicator
CLP Cell Loss Priority

* GFC at User to Network Interface (UNI)

VPI and VCI

8	7	6	5	4	3	2	1
GFC* / VPI				VPI			
VPI				VCI			
VCI							
VCI				PTI			CLP
HEC							

VPI and VCI are virtual connection identifiers (used for switching or relaying the cells to the correct destination)



Cell Loss Priority (CLP)

8	7	6	5	4	3	2	1
GFC* / VPI				VPI			
VPI				VCI			
VCI							
VCI				PTI			CLP
HEC							

Cell Loss Priority bit is used to indicate the priority of the cell

In case of network congestion cells with lower priority will be discarded first.

Payload Type Indicator (PTI)

8	7	6	5	4	3	2	1
GFC* / VPI				VPI			
VPI				VCI			
VCI							
VCI				PTI			CLP
HEC							

One PTI bit is used in AAL 5

User data / control data

Traffic management

0 0 0	User data cell, no congestion. ATM-user indication = 0
0 0 1	User data cell, no congestion. ATM-user indication = 1
0 1 0	User data cell, congestion. ATM-user indication = 0
0 1 1	User data cell, congestion. 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

Header Error Control (HEC)

8	7	6	5	4	3	2	1
GFC* / VPI				VPI			
VPI				VCI			
VCI							
VCI				PTI			CLP
HEC							

Only bit errors in ATM cell header are checked, <u>not</u> bit errors in cell payload

At the transmitting side, the checksum is calculated over the four first header bytes. The result is inserted into the HEC field.

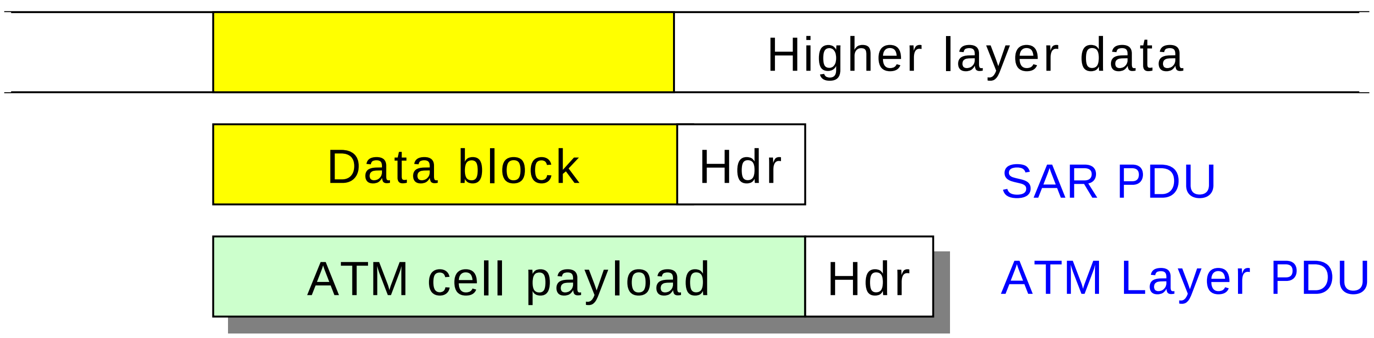
At the receiving side, the HEC byte may be used for error control and cell delineation purposes.

ATM Adaptation Layer (AAL)

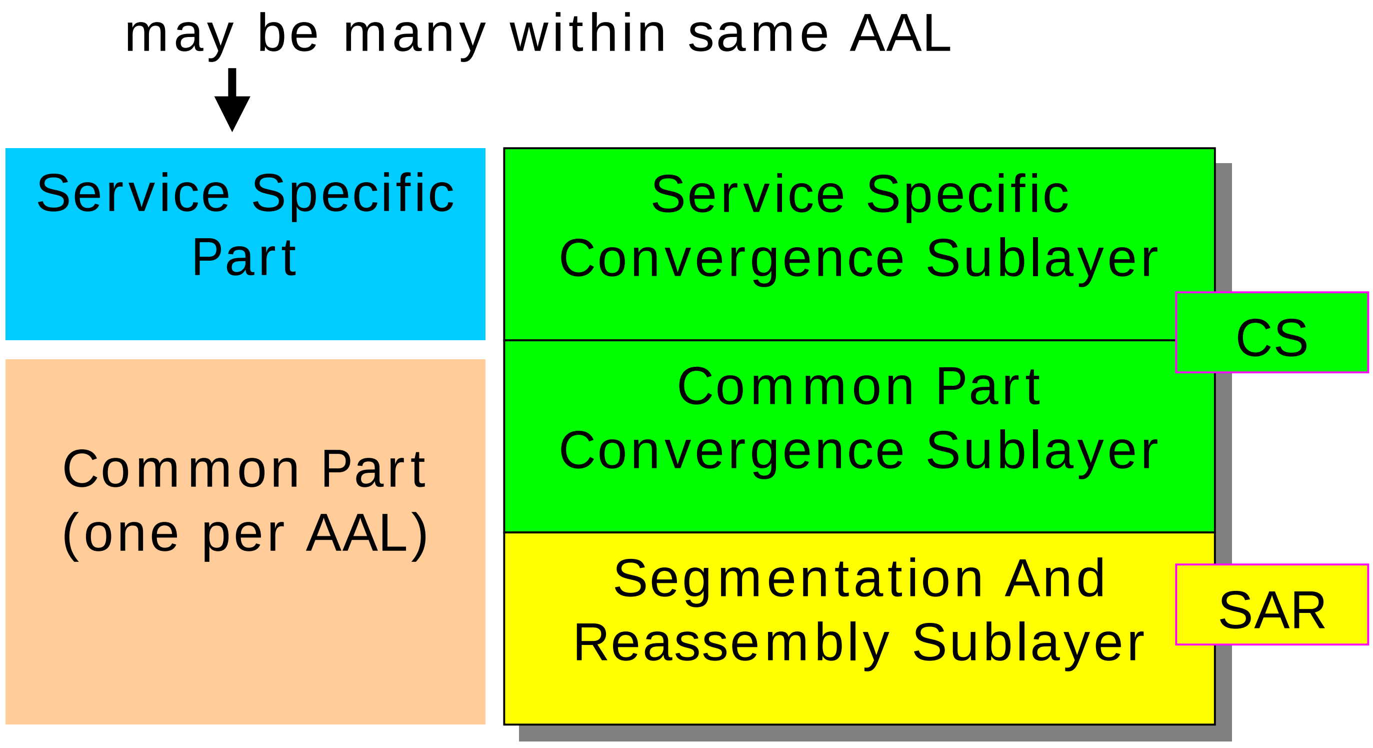
Implemented in the end-point nodes only (routing is not addressed, this is covered by the ATM layer)

CS — Flow and timing control, error correction, handling of lost and misinserted cells

SAR — Segmentation and reassembly of data to fit into ATM cells (as cell payload)



AAL layer structure



Service class vs. AAL protocol

<table>
<tr><td>Class A</td><td>Class B</td><td>Class C</td><td>Class D</td></tr>
<tr><td colspan="2">Timing sensitive</td><td colspan="2">Timing insensitive</td></tr>
<tr><td>CBR</td><td colspan="3">VBR (Variable bit rate)</td></tr>
<tr><td colspan="3">Connection-oriented</td><td>CL</td></tr>
<tr><td>AAL 1</td><td>AAL 2</td><td colspan="2">AAL 5</td></tr>
</table>

Voice over ATM	IP over ATM
Circuit emulation	LAN emulation

AAL protocols

AAL 1	Constant bit rate, small delay, small delay variation (PCM speech transport, PDH circuit emulation)
AAL 2	Variable bit rate, small delay, small delay variation (compressed speech & video transport)
AAL 5	Variable bit rate, not time sensitive, no retransmission mechanisms (LAN emulation, IP transport, signalling transport)

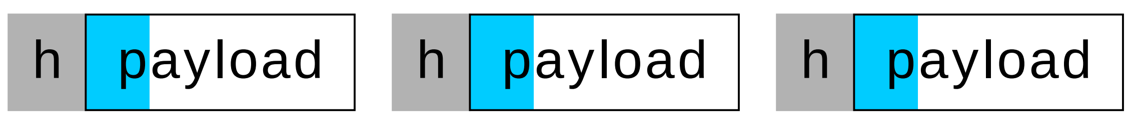
AAL 1

When transmitting low bit rate signals, AAL 1 has a problem:

Either packing delay is large ...

(64 kb/s TDM channel: 47/8000 = 5.9 ms)

... or transmission efficiency is low (cell is nearly empty)



AAL 1 (cont.)

When transmitting low & variable bit rate signals, the problem with AAL 1 is even worse:

Packing delay may be even larger ...

(8 kb/s speech encoding: 47/1000 = 47 ms)

... or transmission efficiency even lower

=> use AAL 2 which offers multiplexing of different signals into the same ATM cell

AAL 2

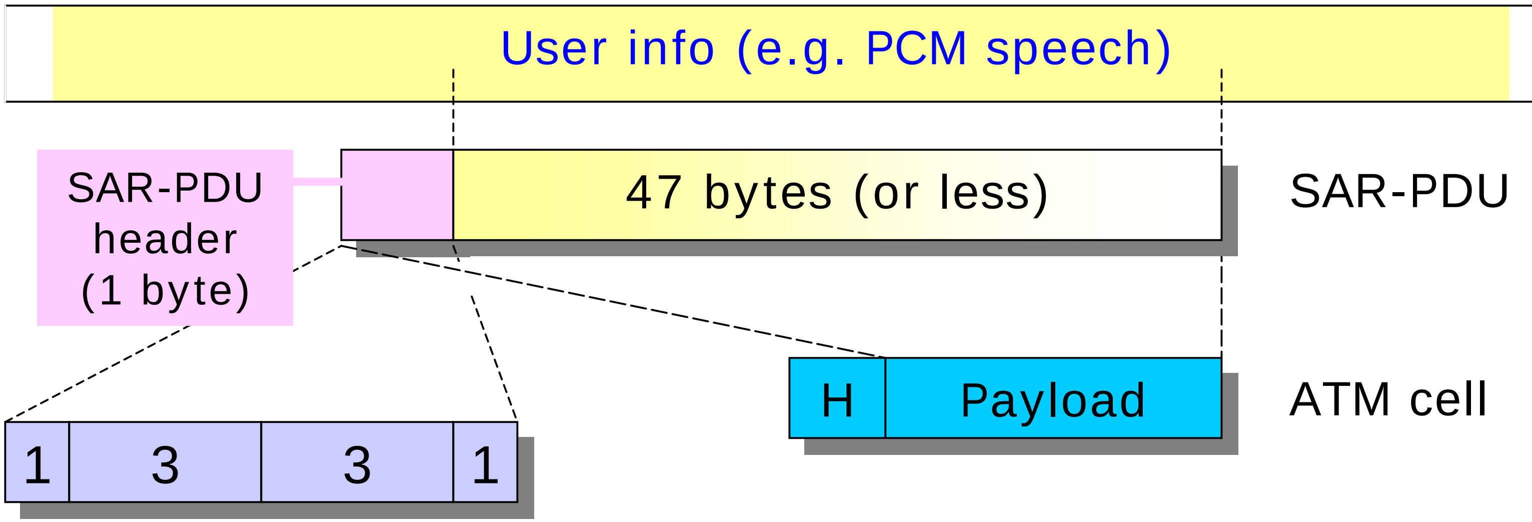
When transmitting many low/variable bit rate signals between two end-points using ATM, AAL 2 provides

low packetization delay and high bandwidth efficiency at the same time

AAL 1 used => low delay means low efficiency:

AAL 2 used => multiplexing of different signals into ATM cell payloads in a flexible manner

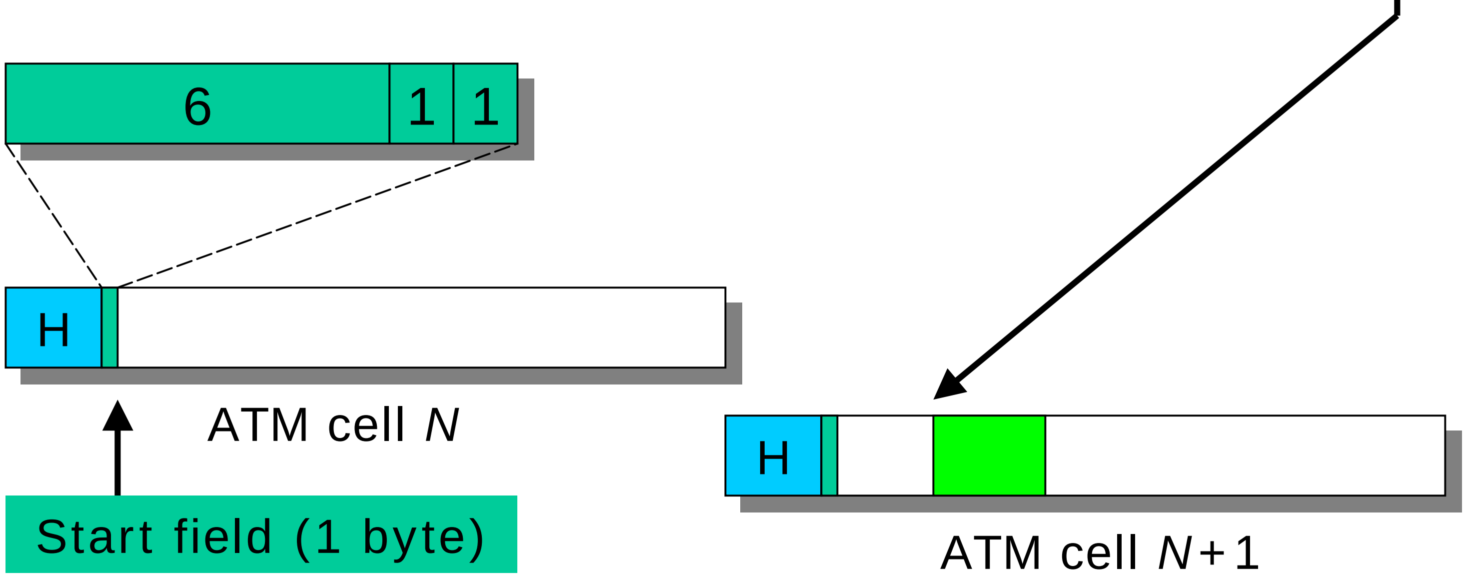
AAL 1 operation



- CSI bit (can be used for transmitting timing information)
- Sequence number (modulo 8)
- CRC field (CRC check for first seven bits)
- Parity bit (parity check for SAR-PDU header only)

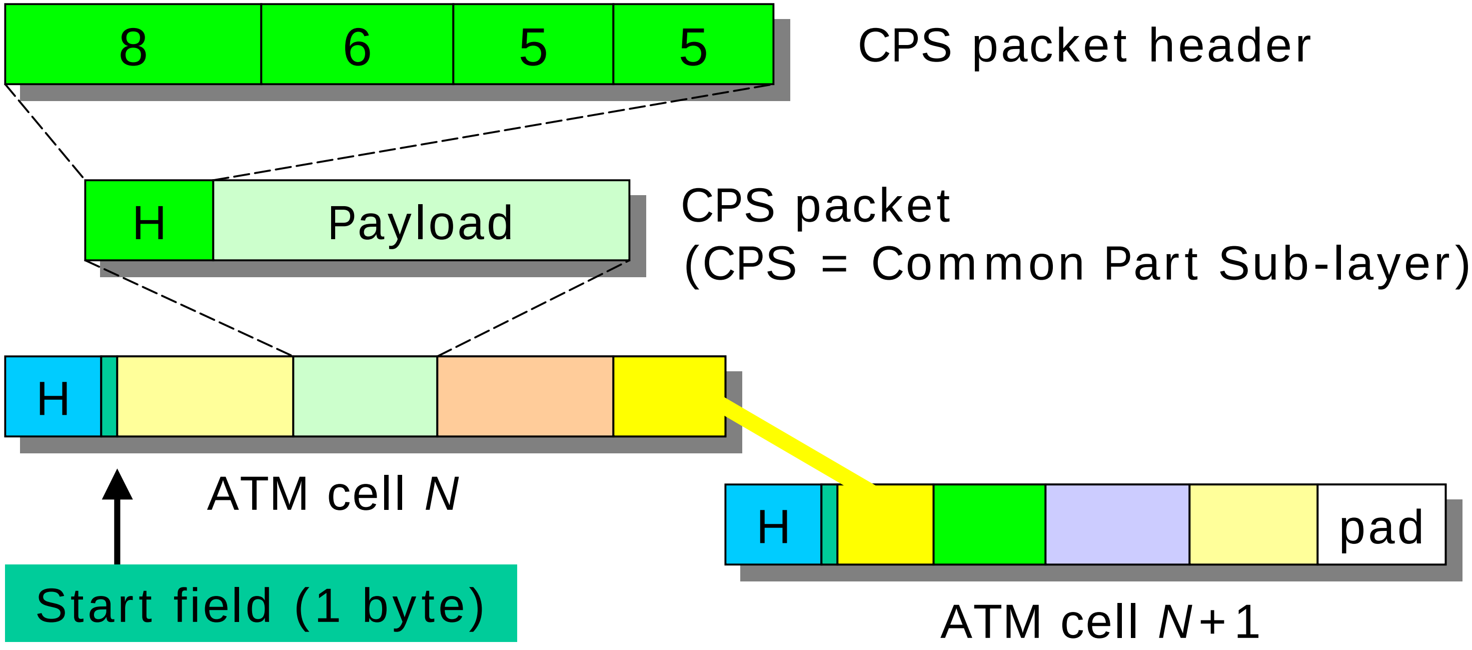
AAL 2 operation

- Offset field (points to first byte of first CPS packet in cell)
- Sequence number (modulo 2)
- Parity bit (parity check for start field only)

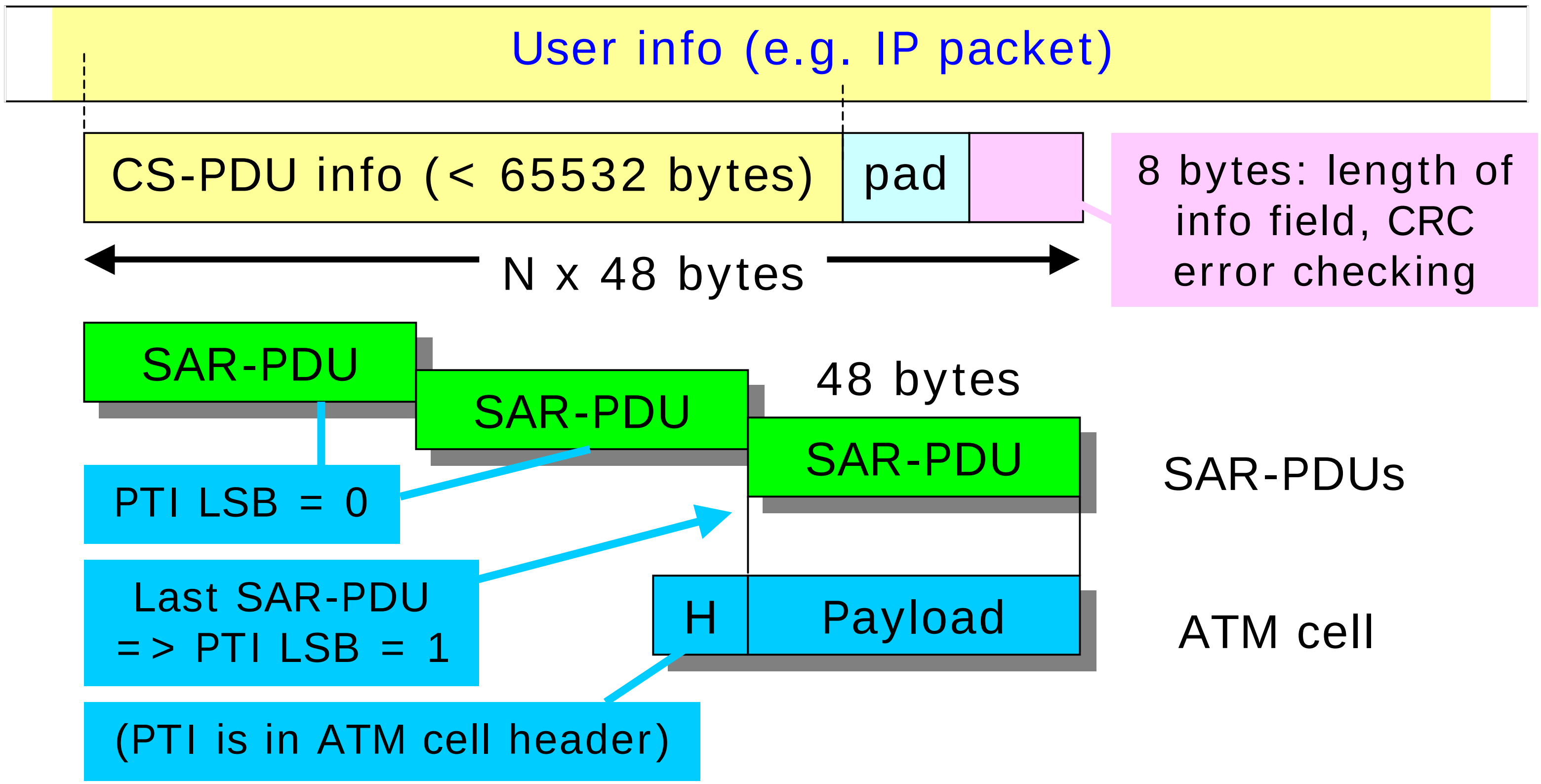


AAL 2 operation (cont.)

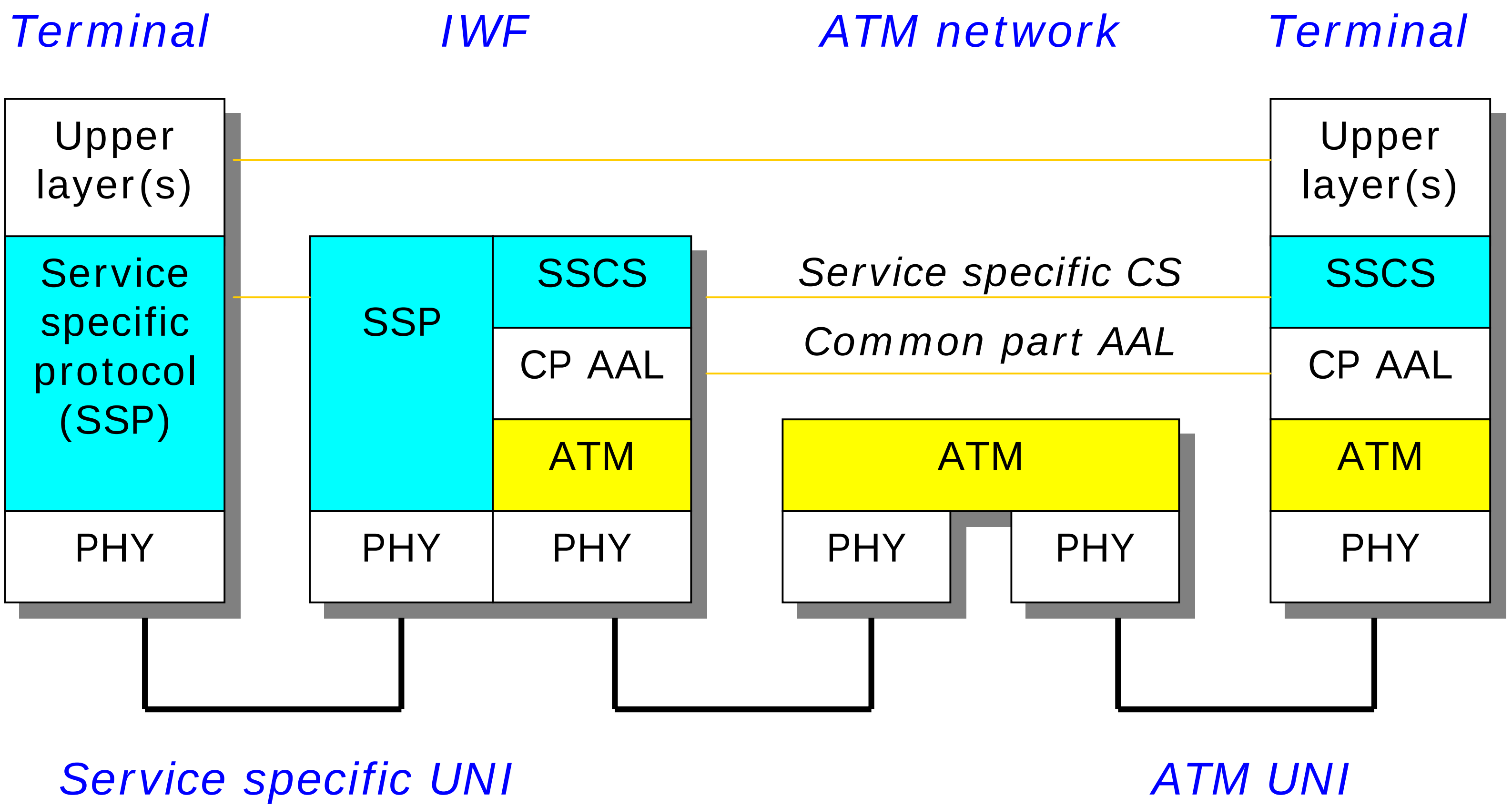
- CID field (uniquely identifies user source)
- Length indicator (length of CPS packet)
- UUI field (service specific information)
- HEC (error check of CPS packet header only)



AAL 5 operation

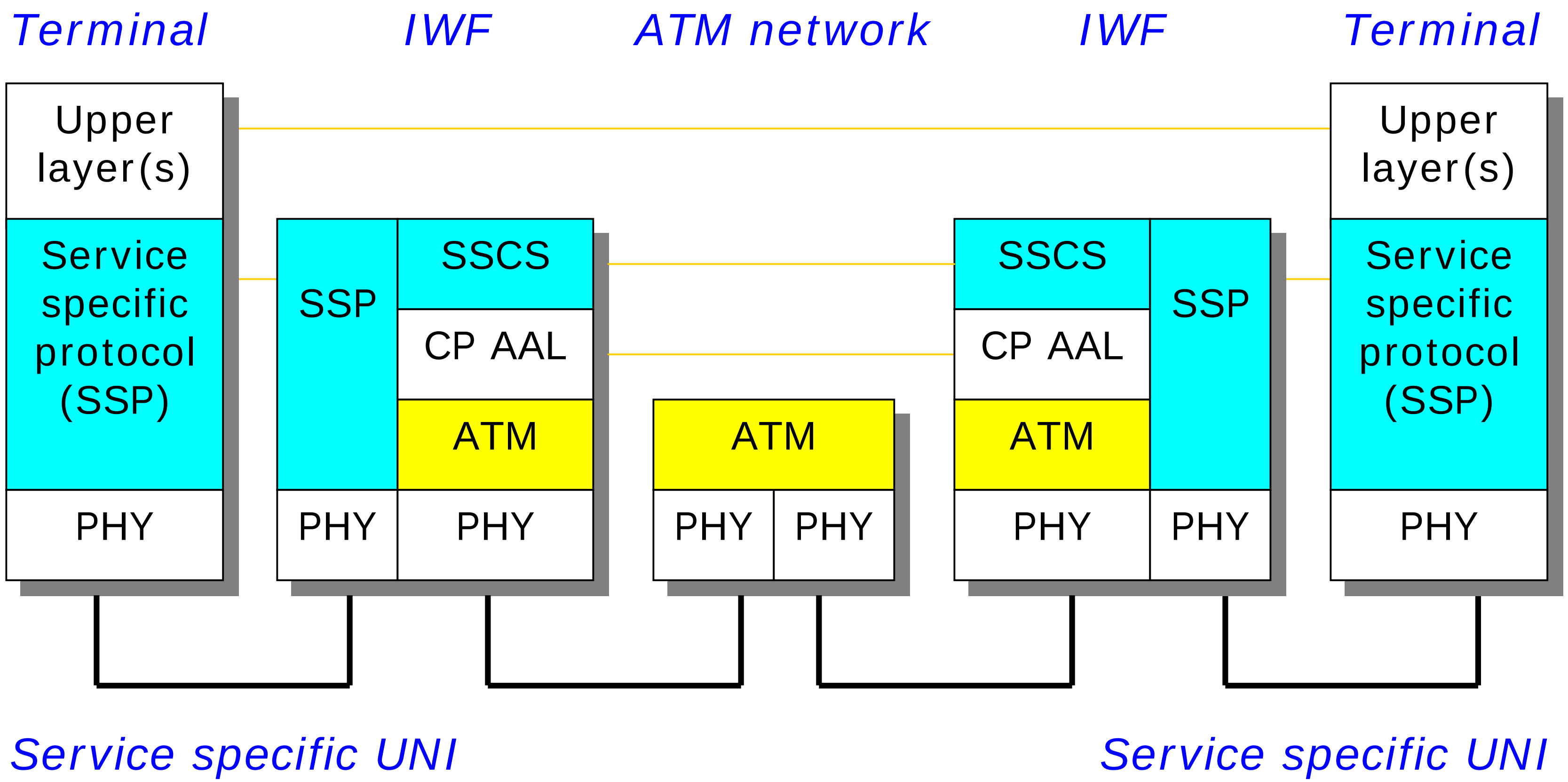


Network interworking with ATM system



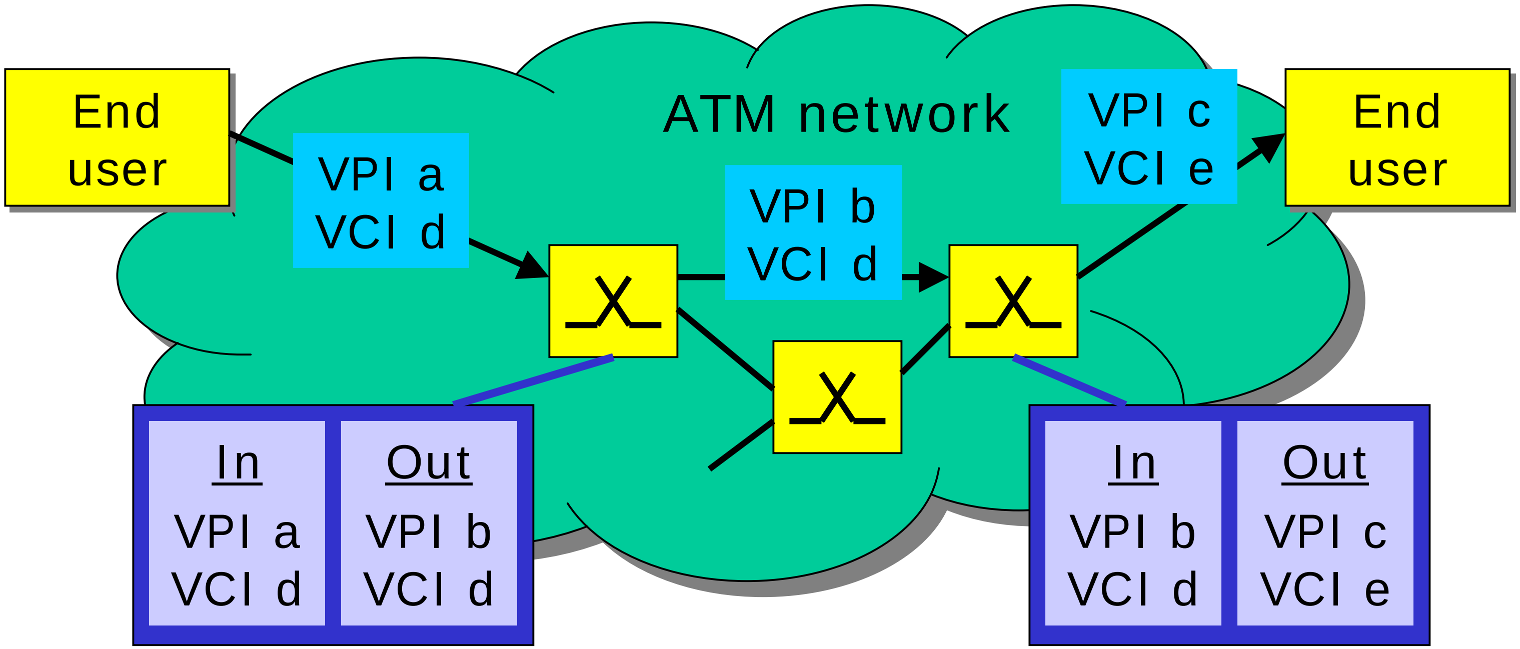
Network interworking over ATM network

(transparent to user, “tunneling”)



ATM routing/switching

Cell switching is based on routing tables with VPI and VCI entries.



switching at virtual path level ... virtual channel level

ATM traffic management

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

In the ATM layer!

5 service categories (ATM Forum)
or 4 transfer capabilities (ITU-T)

traffic parameters (e.g. PCR, MCR)

individual QoS parameters (e.g. CTD)

ATM traffic management (cont.)

1. Negotiation of traffic contract before transmission

Traffic contract involves traffic parameters and QoS parameters

2. Traffic control mechanisms (enforcement of contract)

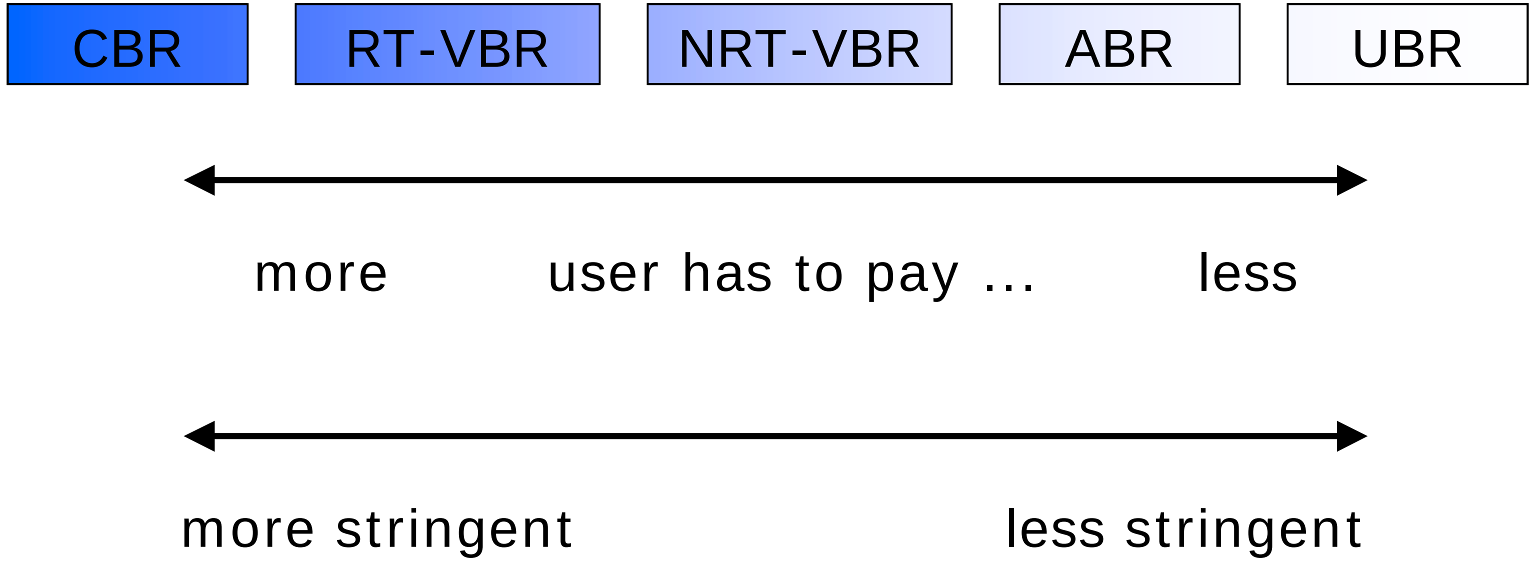
Connection Admission Control (CAC): the network decides if a connection request can be accepted

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

Feedback control (flow control of ABR service)

Service categories (ATM Forum)

ATM Layer Service Category



Service category attributes (ATM Forum)

Attribute	ATM Layer Service Category				
	CBR	RT-VBR	NRT-VBR	ABR	UBR
Traffic parameters					
Peak Cell Rate	specified				
SCR, MBS	n/a	specified		n/a	
MCR	n/a			specified	n/a
QoS parameters					
Max CTD	specified		unspecified		
Max pp CDV	specified		unspecified		
CLR	specified				unspec.
Other attributes					
Feedback	unspecified			specified	unspec.

Constant bit rate (CBR)

(ITU-T: Deterministic bit rate = DBR)

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:

- Voice (standard 64 kbit/s PCM)
- Circuit Emulation Services (CES)

This category is mainly intended for (but not restricted to) real-time (RT) services.

Variable bit rate (VBR)

RT-VBR: Specified by the ATM Forum for services with stringent timing requirements (”real-time applications”), like CBR but for variable bit rate services, e.g. compressed speech.

NRT-VBR: Specified by the ATM Forum for variable bit rate services without stringent timing 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)

Available bit 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:

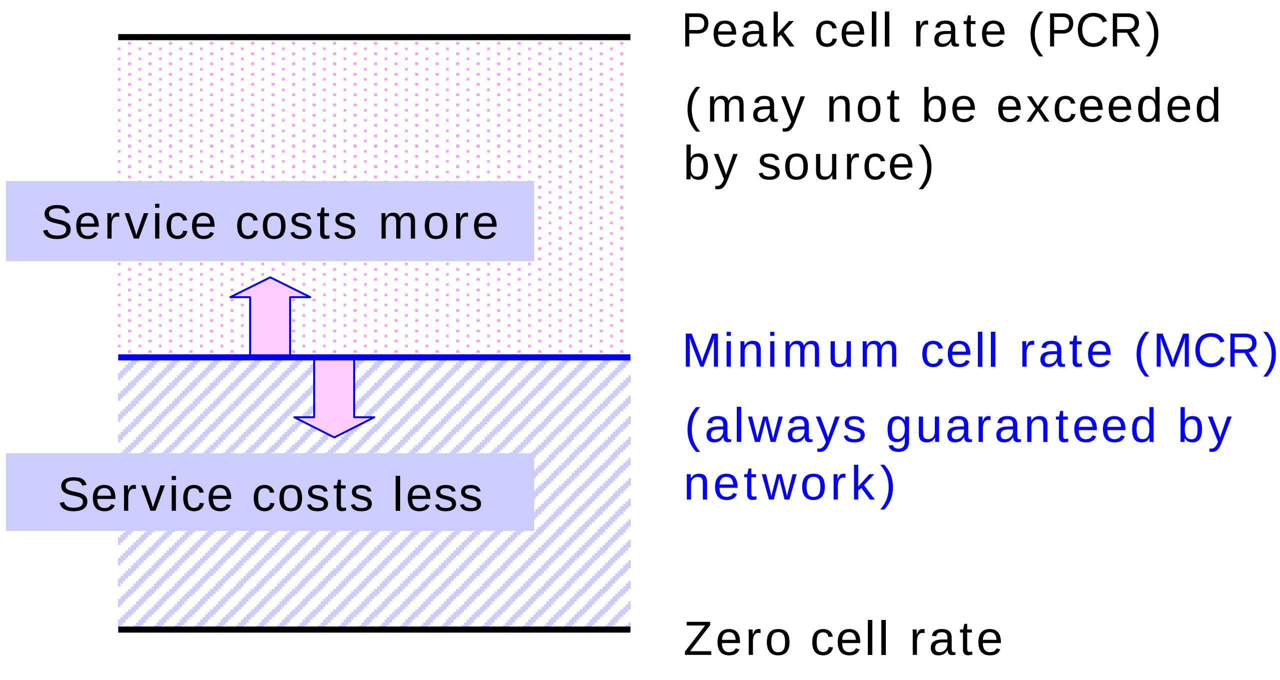
- Peak Cell Rate (PCR)
- Minimum Cell Rate (MCR)

MCR is a bound ($0 < MCR < PCR$) on the cell rate that the network should support. However, the cell rate of the source is allowed to vary between 0 ... PCR.

Typical applications:

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

Interpretation of MCR



Unspecified bit rate (UBR)

No QoS requirements (i.e. ”best effort” service). The only traffic parameter of interest is the PCR which the user is not allowed to exceed. UBR supports a high degree of statistical multiplexing.

Typical applications:

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

(Guaranteed Frame Rate = GFR)

(This is a new service category defined in the ATM Forum Traffic Management Specification Version 4.1)

Quality of Service (QoS) parameters

(and their interpretation)

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

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

Cell Loss Ratio (CLR): < N x 10^{-7}

(less often specified)

Cell Error Ratio (CER): < N x 10^{-6}

Cell Misinsertion Rate (CMR): < N / day

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

Further information on ATM

Links:

www.atmforum.org (note: ATM specifications can be accessed without charge)

www.ericsson.com/support/telecom (the course book)

Books:

there are several books on ATM, Broadband ISDN and SDH/SONET; some may contain errors (so be careful ...)

Web material (important for understanding AAL2):

www.gdc.com/inotes/pdf/aal2tut.pdf

www.gdc.com/inotes/pdf/aal1vs2.pdf