ATM Introduction

The Grand Unification

Agenda

- What is it? Who wants it? Who did it?
- Header and Switching
- ATM Layer Hypercube
- Adaptation Layers
- Signaling
- Addresses

What is ATM ?

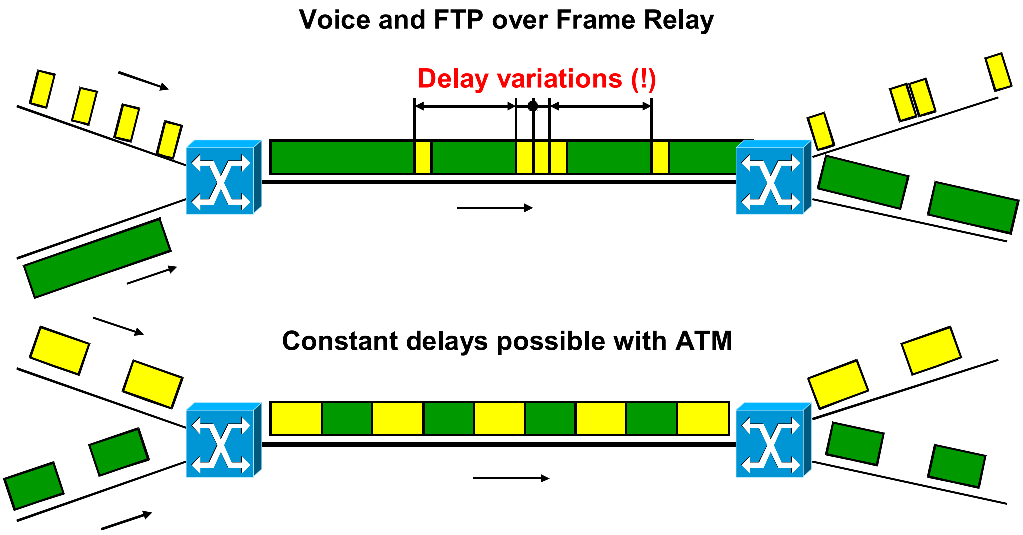
- High-Speed Virtual Circuits
  - PVC and SVC
  - No error recovery
- UNI and NNI defined
- Constant frame sizes → Cells
- Based on B-ISDN specifications
  - Voice, Video, Data

Design Ideas

Asynchronous TDM		ATM
Best trunk utilization	copy →	
Flexible channel assignment through addresses	copy →	

Synchronous TDM		ATM
Fast Switching and short delays through constant timeslots	fake →	Solved through constant frame sizes
Protocol Transparent	fake →	Solved through adaptation layers

Cell Switching and Jitter



Cell Switching

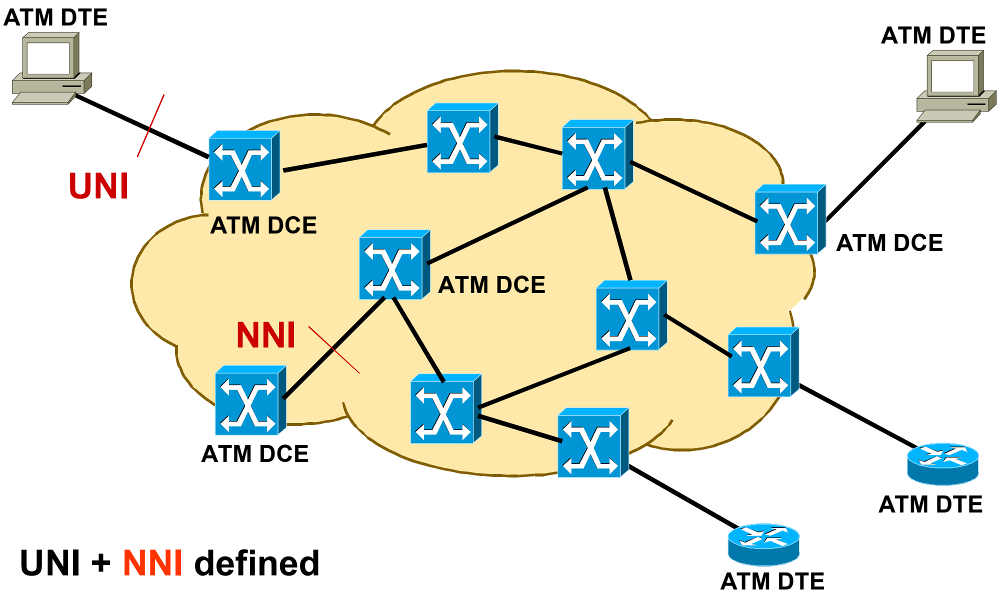
- Forwarding of cells implemented in HW
  - Very fast
- But still packet switching
  - Store and forwarding
  - Asynchronous multiplexing
- Because of constant cell size the queuing algorithms can guarantee
  - Bounded delay
  - Maximum delay variations

For telephony a constant delay is strictly necessary because otherwise echo cancelers would not work.

ATM Usage

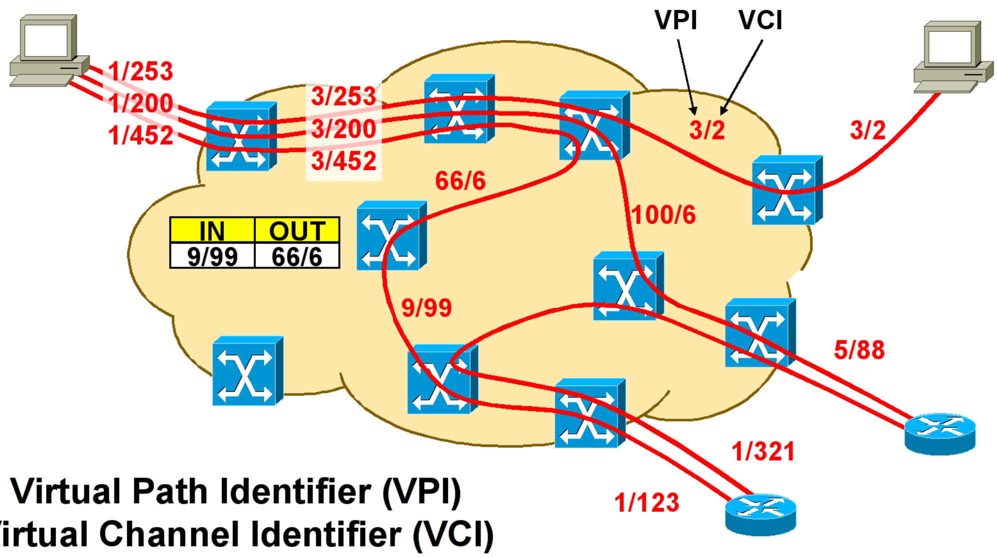
- Public and private networks
  - LAN, MAN, WAN
- Backbone high-speed networks
  - Public (Telcos) or private
- Original goal: World-wide ATM network
  - But Internet technology and state-of-the art Ethernet are more attractive today
- New importance as backbone technology for mobile applications
  - Cellular networks for GSM, GPRS, UMTS, ...

ATM Network



UNI + NNI defined

Virtual Circuits



Virtual Path Identifier (VPI)
Virtual Channel Identifier (VCI)

Who Did It?

- CCITT (now ITU-T) issued first recommendations for B-ISDN in 1988
  - Recommendation I.121
  - Aspects and Terms only
- Switch vendors founded ATM-Forum
  - To accelerate development
  - Majority rule instead of consensus
  - Also pushed ITU-T standardization

The CCITT (ITU-T) standardization process is very time consuming because the final result should meet all demands of all participants such as governments, vendors, users, and other industry representatives. Because of this, the ATM Forum was founded to accelerate the development. Although this efforts also helped the ITU-T standardization efforts, there are important differences between both standards.

The ATM Forum was founded in 1991.

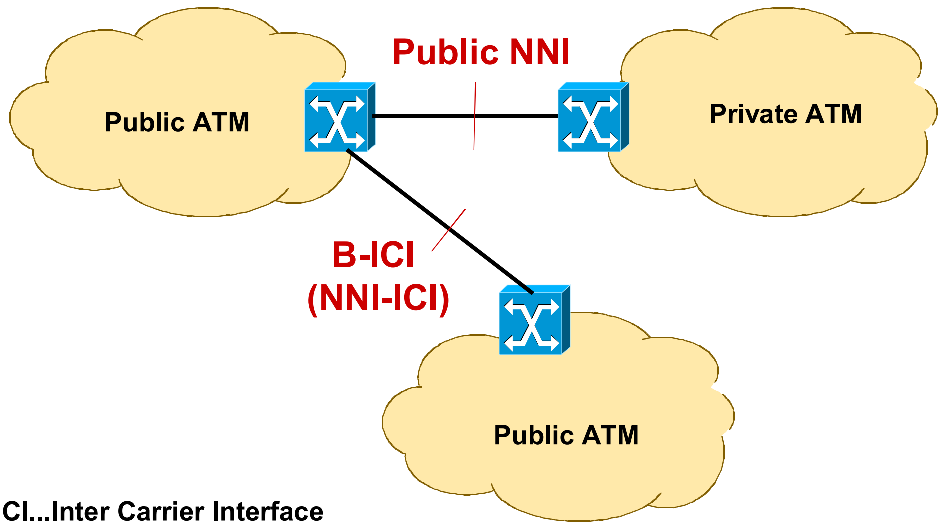
Public and Private Networks

- ITU-T: Public ATM Networks
  - Public UNI: E.164 addressing
  - Public NNI: Static routing
- ATM-Forum: Private ATM Networks
  - Private UNI: OSI NSAP like addressing
  - Private NNI: Dynamic routing (PNNI)

Note that both public and private networks cover SVCs but in order to establish SVCs we need routing tables. The routing tables can be created automatically in private ATM networks using the ATM routing protocol PNNI (Private-NNI). In public networks the routing tables are managed manually.

PNNI is a link-state routing protocol that enables quality of service routing.

NNI Types



ICI...Inter Carrier Interface

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NNI-ISSI (Public NNI)

ISSI = Inter Switch System Interface

Used to connect two switches of one public service provider

NNI-ICI (B - ICI)

ICI - Inter Carrier Interface

Used to connect two ATM networks of two different service providers

Private NNI

Used to connect two switches of different vendors in private ATM networks

What is B-ISDN?

- ITU-T identified several demands
  - Emerging need for broadband services
  - High speed switching
  - Improved data- and image processing capabilites available to the user
  - Support for real-time services
  - Support for interactive services
  - Support for distribution services
  - Circuit and packet mode

Interactive services require a two-way exchange of information.

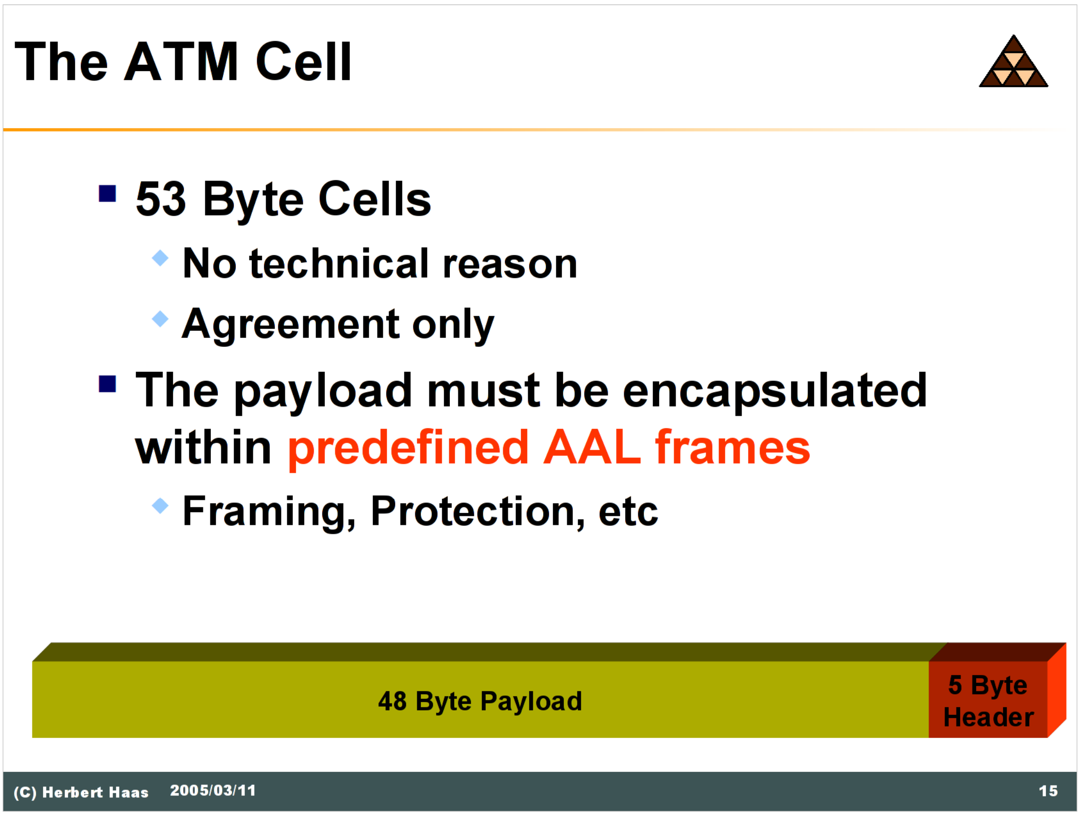
Distribution services are one-to-many and is also called multicast.

ATM and B-ISDN

- B-ISDN are broadband (=highspeed) services for the user
- ATM to transport B-ISDN
- Alternatives to B-ISDN
  - IEEE 802.6 (DQDB) pushed by data communication industry (dying out)
  - Gigabit Ethernet (new)

IEEE 802.6 is a MAN standard and also known as "Distributed Queued Dual Bus". Interestingly, DQDB is very similar to ATM in many aspects (same frame sizes, same idea of adaption layers, etc.), However this alternative, that has been pushed by many proponents of the data communication industry, vanished from market.

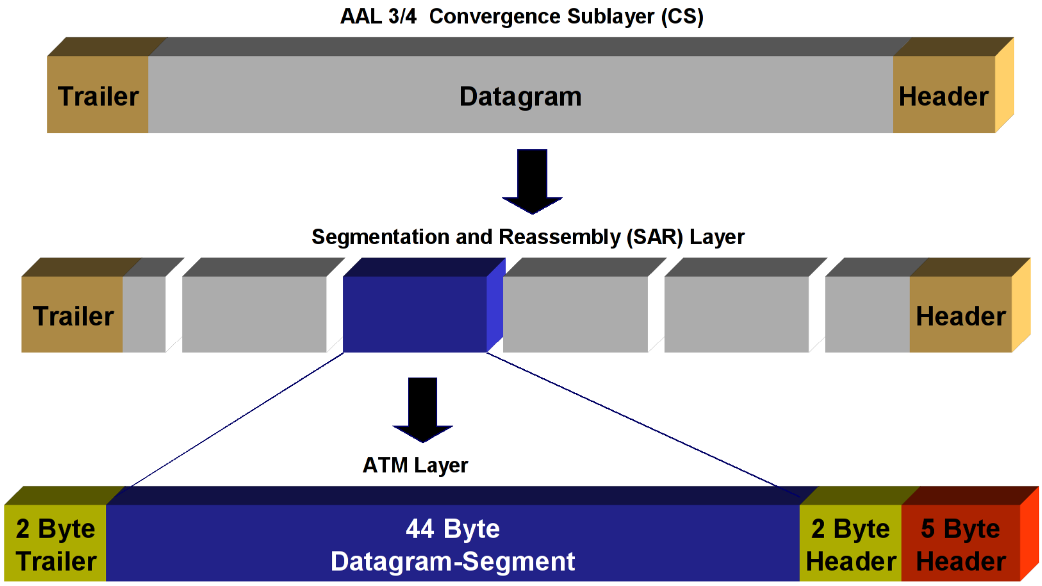
Currently (Gigabit-) Ethernet seems to replace ATM in many areas since it is easier to deploy, easier to manage and less expensive. However, many customers suspects its reliability and quality of service.

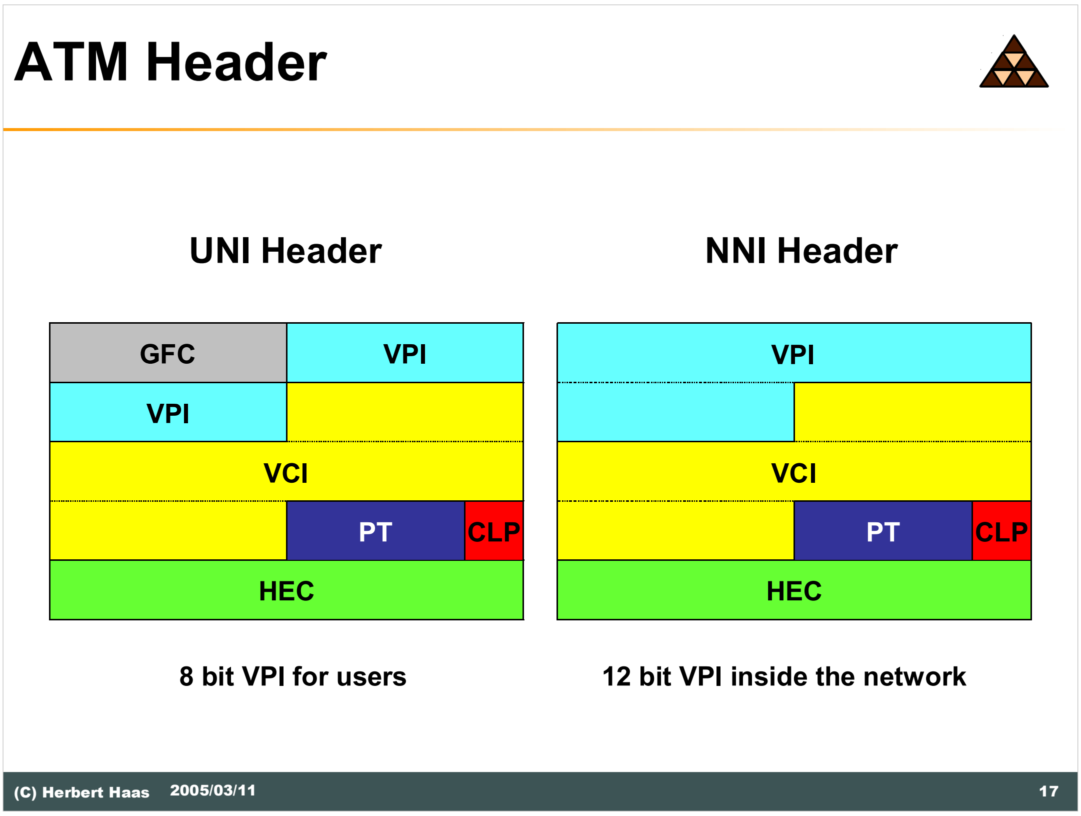


USA proposed a cell size of 64 bytes while the Europeans suggested 32 bytes. At the end they met in the middle at 53 bytes.

Why are ATM cells so small at all? One important reason is to minimize packetization delay (splitting data in cells) so that realtime applications can be easily supported. Another reason – also associated with realtime (voice) applications – is to support the implementation of echo-cancelation devices. Long and variable packet sizes make a echo cancelator run into trouble...

AAL 3/4 Framing Example





The Generic Flow Control (GFC) field is only used on the UNI but not transported into the network. The GFC is not used today as there are better methods available (special flow-control cells).

The Virtual Path Identifier (VPI) is four bits longer inside the network (on NNIs) in order to support better traffic aggregation (Virtual Path Switching).

The Payload Type (PT) is used to identify the cell payload (OAM, Resource Management, ...)

The Cell Loss Priority (CLP) has the same meaning as the DE-bit in Frame Relay. Using the CLP we can distinguish between important and not-so-important cells (CLP=1). Of course we hope that the network would be so kind to drop CLP=1 cells first in case of congestion.

The Header Error Check (HEC) is a CRC-8 to protect the header only – not the payload! You may ask how framing is accomplished? For this purpose a receiver device has to compute the CRC-8 for each 4 bytes and look for a match with the following byte. In case of 6 successive hits the ATM layers are synchronized.

Note: Although ATM is an asynchronous TDM technology it is actually implemented synchronously. There are no gaps between cells but idle cells (VPI/VCI set to zero and payload is 0101010101010101010101...).

Payload Type

User data (0) or OAM (1)	Set to (1) if Congested	User signaling bit

- **100 OAM F5 segment**
- **101 OAM F5 end-to-end**
- **110 Resource Management (RM)**
- **Also used by AAL5 to indicate end of block (EOB)**
- **Other combinations: user data**

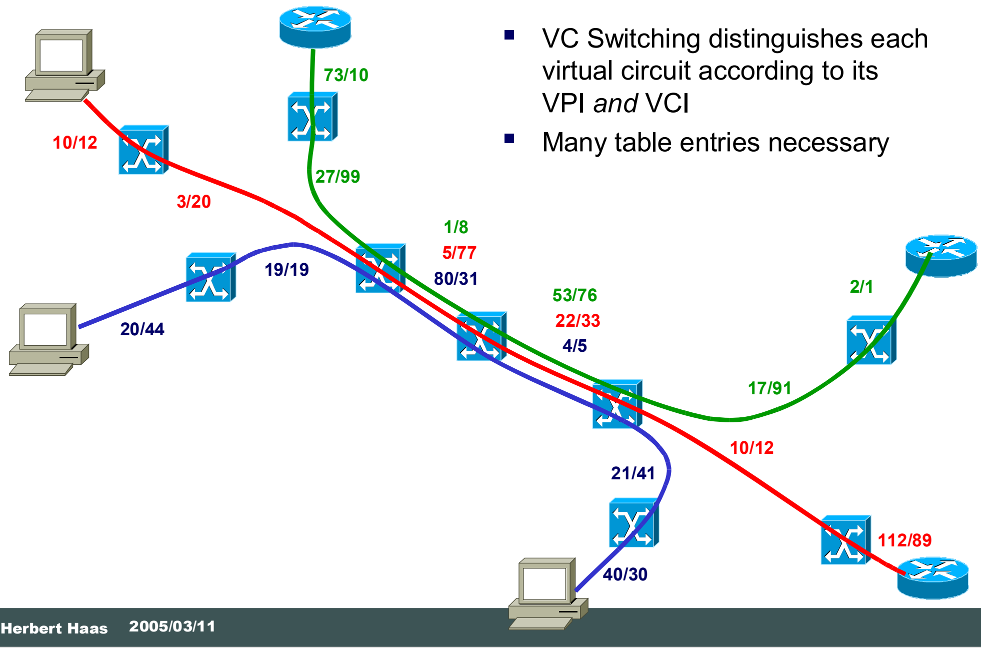
"Flow 5" (F5) is identical to a VC, F4 is the VP flow, F3 is a SONET/SDH Path, F2 is a SONET Line (SDH Mux-section), F1 is a SONET section (SDH regenerator section).

So an OAM F5 segment cell (PT=100) is processed by the next segment, while a OAM F5 end-to-end cell (PT=101) is only processed by an ATM end station (terminating an ATM link). Operation, Administration, and Maintenance (OAM) is discusses in another module (ATM QoS).

Header Fields

- Cell Loss Priority (CLP)
  - Similar to DE bit in Frame Relay
  - Identifies less important cells
- Header Error Check
  - CRC-8 to protect the header only
  - I 4.321: Used for cell delineation (6 successive hits necessary)

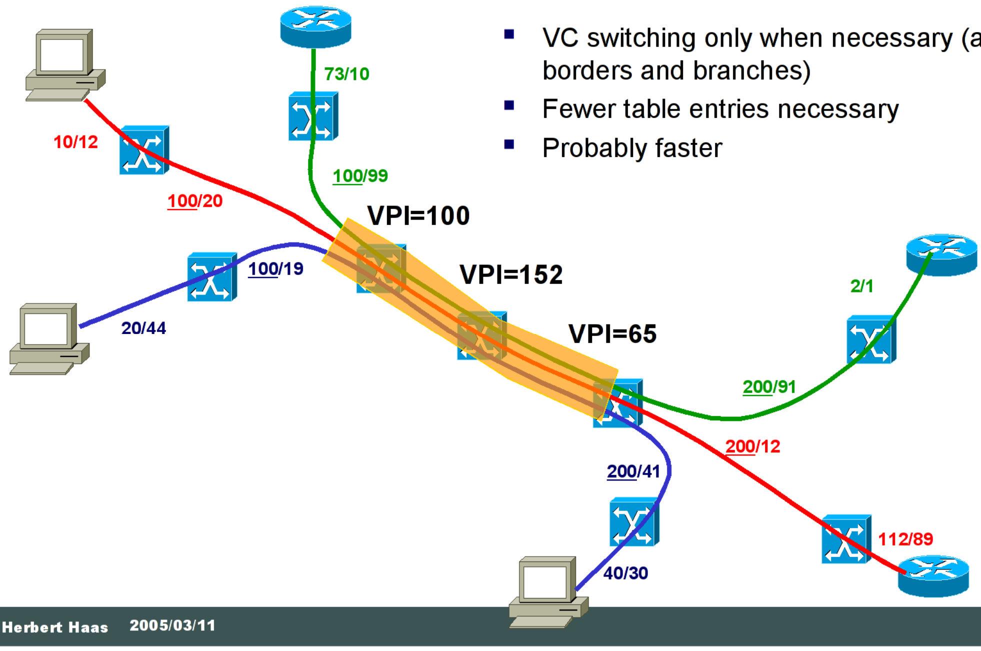
VC Switching



- VC Switching distinguishes each virtual circuit according to its VPI *and* VCI
- Many table entries necessary

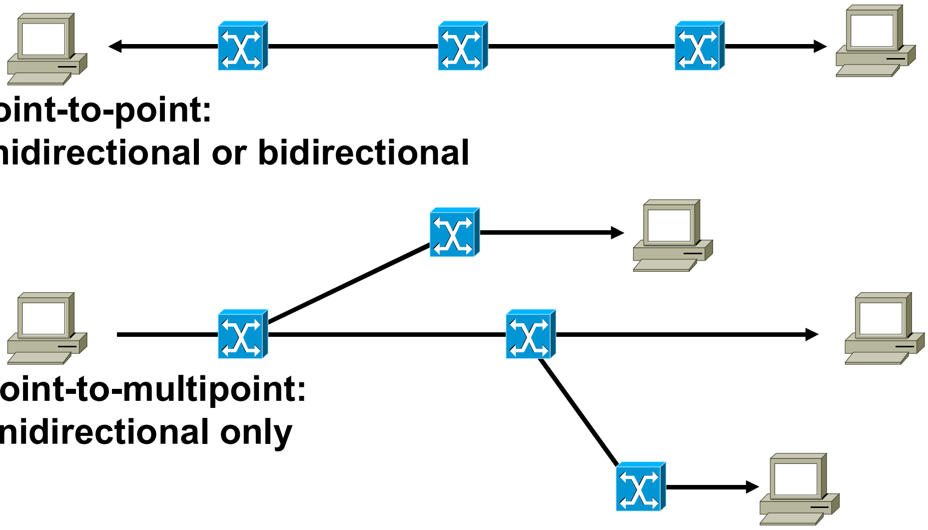
VP and VC Switching

- VC switching only when necessary (at borders and branches)
- Fewer table entries necessary
- Probably faster

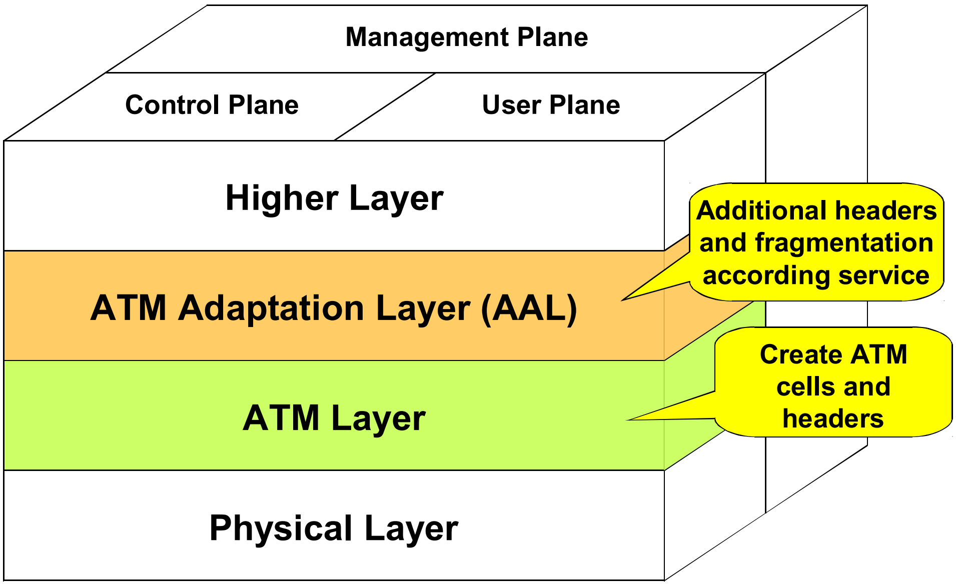


If one customer asks for another 100 virtual circuits, the provider does not need to add 100 additional entries in every switching table—as he must do with Frame Relay for example–- because one VPI represents a number of VCIs and inside the network VPI switching is performed.

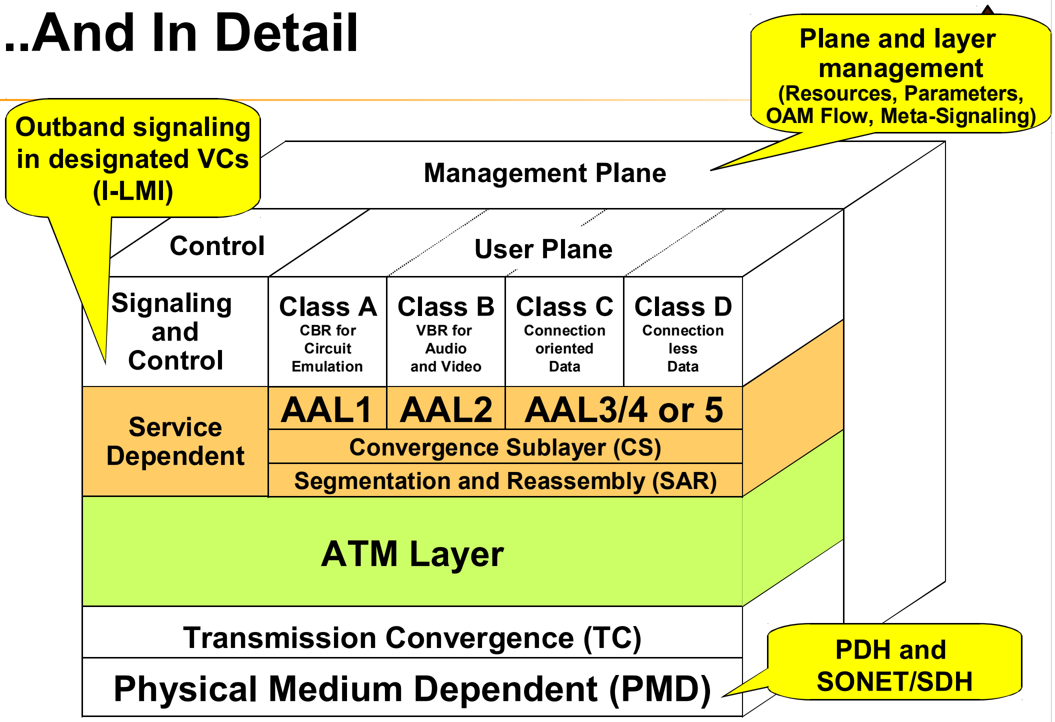
Connection Types



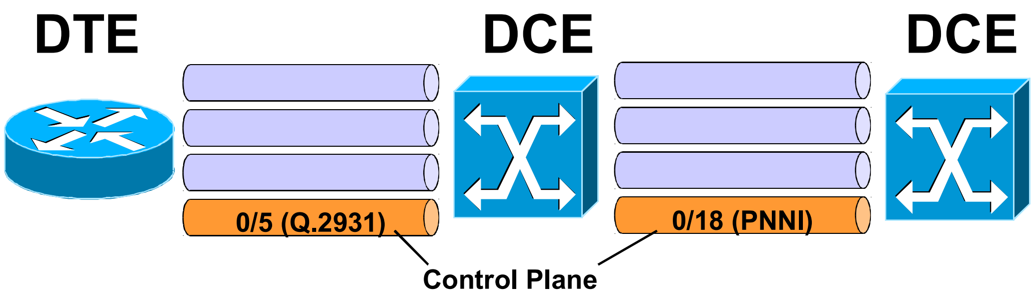
ATM Protocol Architecture



...And In Detail



Control Plane



- Signaling through dedicated virtual ciruit = "Outband Signaling"

Reserved Labels

VPI	VCI	Function
0	0- 15	ITU-T
0	16 - 31	ATM Forum
0	0	Idle Cell
0	3	Segment OAM Cell (F4)
0	4	End-to-End OAM Cell (F4)
0	5	Signaling
0	16	ILMI
0	17	LANE
0	18	PNNI

Physical Layer

- Transmission Convergence (TC) allows simple change of physical media
  - PDH, SDH, SONET
  - HEC and cell delineation
- Physical Medium Dependent (PMD) cares for (e. g.)
  - Line coding
  - Signal conversions

Interface Examples

Standard	Speed	Medium	Comments	Encoding	Connector	Usage
SDH STM-1	155,52	Coax	75 Ohm	CMI	BNC	WAN
PDH E4	139,264	Coax	75 Ohm	CMI	BNC	WAN
PDH DS3	44,736	Coax	75 Ohm	B3ZS	BNC	WAN
PDH E3	34,368	Coax	75 Ohm	HDB3	BNC	WAN
PDH E2	8,448	Coax	75 Ohm	HDB3	BNC	WAN
PDH J2	6,312	TP/Coax	110/75 Ohm	B6ZS/B8ZS	RJ45/BNC	WAN
PDH E1	2,048	TP/Coax	120/75 Ohm	HDB3	9pinD/BNC	WAN
PDH DS1	1,544	TP	100 Ohm	AMI/B8ZS	RJ45/RJ48	WAN
SDH STM-4	622,08	SM fiber		SDH	SC	LAN/WAN
SDH STM-1	155,52	SM fiber		SDH	ST	LAN/WAN
SDH STM-1	155,52	MM fiber	62,5 um	SDH	SC	LAN/WAN
SDH STM-4	622,08	SM fiber		NRZ	SC (ST)	LAN
SDH STM-4	622,08	MM (LED)		NRZ	SC (ST)	LAN
SDH STM-4	622,08	MM (Laser)		NRZ	SC (ST)	LAN
SDH STM-1	155,52	UTP5	100 Ohm	NRZI	RJ45	LAN
SDH STM1	155,52	STP (Type1)	150 Ohm	NRZI	9pinD	LAN
FIber Channel	155,52	MM fiber	62,5 um	8B/10B		LAN
TAXI	100	MM Fiber	62,5 um	4B/5B	MIC	LAN
SONET STS1	51,84	UTP3		NRZI	RJ45	LAN
ATM 25	25,6	UTP3		NRZI	RJ45	LAN

ATM Layer

- Multiplexing and demultiplexing of cells according VPI/VCI
- Switching of cells
  - "Label swapping"
  - Note: origin of MPLS
- Error management: OAM cells
- Flow Control
- Qos negotiation and traffic shaping

Adaptation Layers

- ATM only provides bearer service
- ATM cannot be used directly
- Applications must use adaption layers to access the ATM layer
- Consist of SAR and CS
  - Part of DTEs only
  - Transparent for switches (DCEs)

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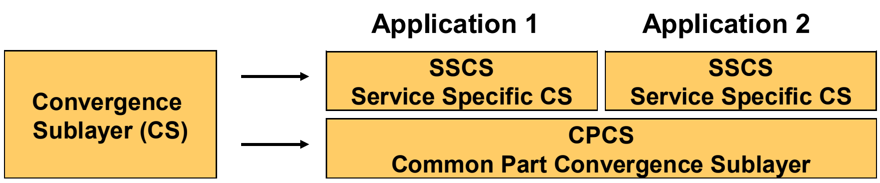
The ATM adaption layers translate between the specific worlds of higher layer protocols such as IP, X.25, or PCM-Voice and the cell-nature of the ATM layer itself. Using specific adaptation layers, nearly every application can be transported over ATM. This capability emphasizes again the B-ISDN idea that has been realized.

Note: "Application" means simply "any higher layer communication protocol". Just consider ATM as a "Transport Layer" (not to confuse with the OSI layer 4!) that provides "Bearer Services".

Adaptation Sub-Layers

- Convergence Sublayer (CS)
  - Service dependent functions
    (clock recovery, message identification)
  - Adds special information
    (e. g. Frame Relay header)
- Segmentation and Reassembly (SAR)
  - You name it...

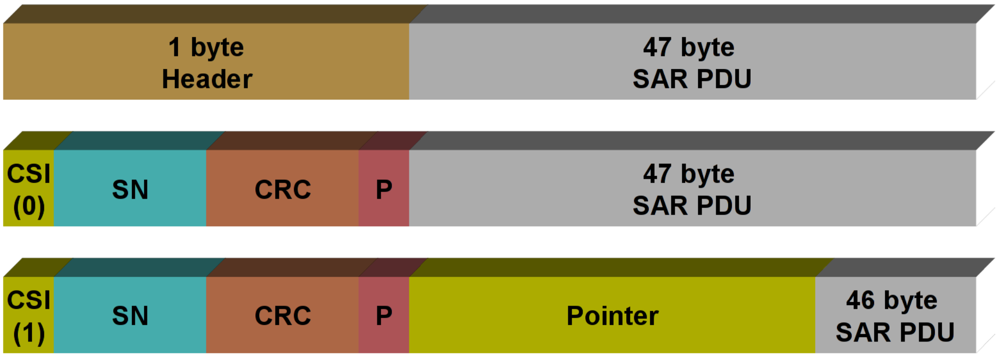


The Convergence Sublayer (CS) is divided in two further sublayers, the Common Part Convergence Sublayer (CPCS) and the Service Specific Convergence Sublayer (SSCS). The CPCS is common to all instances of a specific AAL. Therefore only one CPCS has been defined per AAL while many SSCS can be defined for the same AAL.

AAL1

- Constant Bit Rate (CBR)
- Circuit Emulation
- Expensive
  - Overprovisioning like leased line necessary
  - Queuing prefers AAL1 cells over all other traffic (in case of congestion)

AAL1



CSI …. Convergence Sublayer Indication (1 bit) – "1" if pointer exists
SN ….. Sequence Number (3 bits)
CRC ... Cyclic Redundancy Check (3 bits)
P ……. Parity (1 bit)

The CSI values in cells 1, 3, 5, and 7 are interpreted as a 4 bit timing value in order to measure timing differences between network's reference clock and transmitter clock. The 3 bit CRC only protects the 4 bit CSI+SN field. The parity bit is set such that the parity of the 8 header bits is even.

The sequence number is basically for cell-loss detection.

AAL2

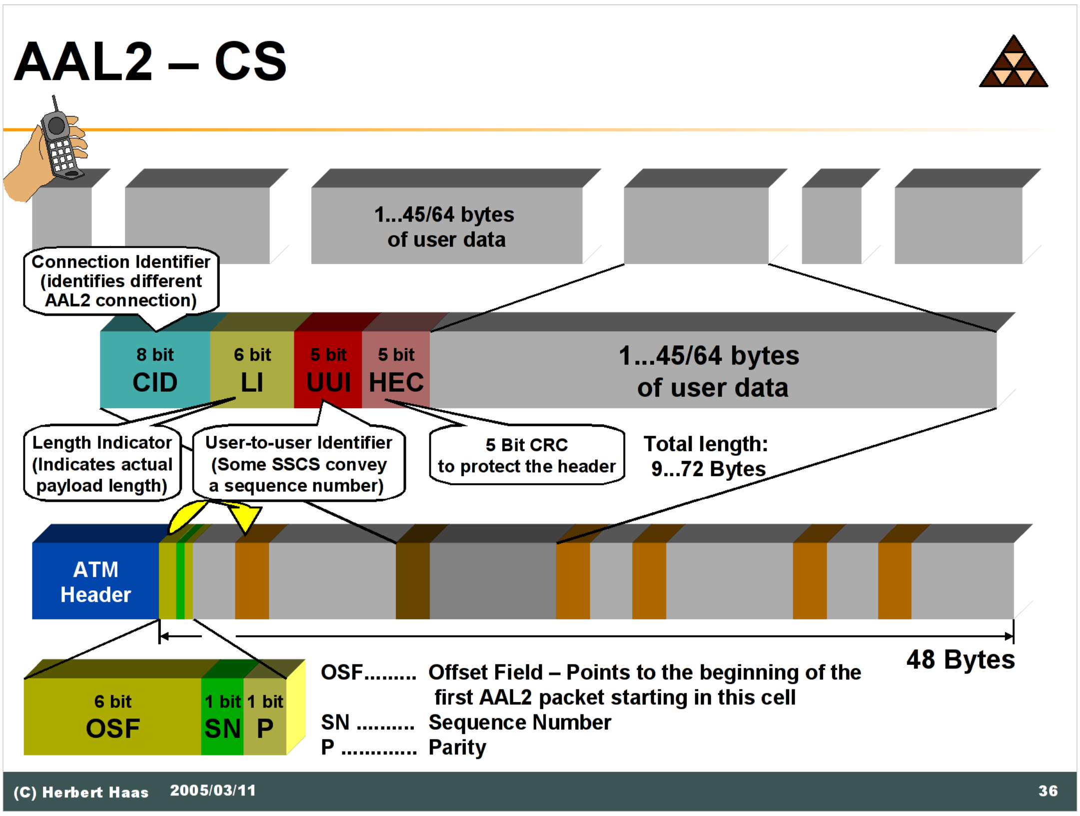
- Analog applications that require timing informations but not CBR
  - Variable Bit Rate (VBR)
  - Compressed audio and video
- Relatively new (1997/98)
  - Original standard withdrawn and later reinvented for mobile systems

AAL2 for Mobile Systems

- Cellular communication issues
  - Packetization delay (→ QoS)
  - Bandwidth efficiency (→ Money)
- Before AAL2 low-bit rate real-time applications were used by "partial filling" of ATM cells
  - Using "AAL0" or AAL1
  - Very inefficient (few bytes per cell only)
- AAL2 is designed to be fast and efficient

AAL0 simply means using ATM without any adaptation layer. The AAL2 CPCS allows variable packet length between 1 byte to 45 bytes, so the packetization delay can be kept very small, if needed. On the other hand, bandwidth efficiency is achieved by multiplexing several AAL2 connections within one ATM (VPI/VCI) pipe.

Note: Instead of having partially filled ATM cells, the CPCS will fill each cell with AAL2 packets from multiple sessions!



The slide above shows the most important tasks of the Common Part Convergence Sublayer (CPCS). Basically, CPCS-packets consist of a one-byte header and up to 45 bytes user data (typically compressed voice or video). Even longer payloads are supported if an appropriate SSCS is used additionally (I.366.1).

Does make a 1-bit sequence number any sense? Yes, together with the Parity (P) it provides a simple mechanism to check for cell loss and errors inside the "Start Field" (SF = OSF + SN + P).

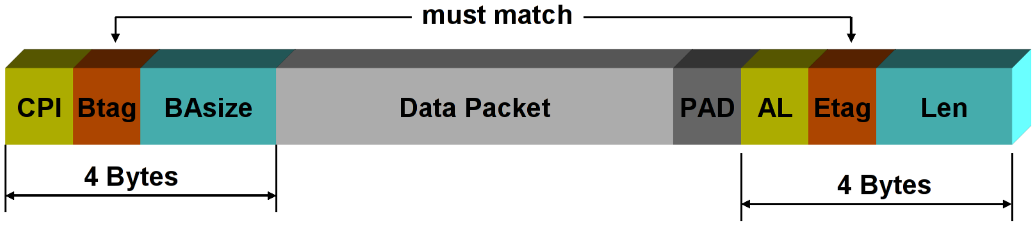
One of the most important applications for AAL2 today is compressed voice as for GSM, which generates 260 bits packet every 20 ms. To each of these packet a AAL2 header is attached, indicating the length and the connection. For GSM there is no need for pre-processing by an SSCS, in fact there is no SSCS implemented.

Although the multiplexing feature of AAL2 dramatically improves bandwidth efficiency, the main disadvantage is a significant increase in overhead. But this overhead is not worth to mention when comparing AAL2 with the older method of partial filling. When users want to send more than a few hundreds of bytes per packet then AAL5 is more efficient.

AAL3 + AAL4

- AAL3 designed to carry **connection-oriented** packets
  - Such as X.25 or Frame Relay
- AAL4 designed to carry **connection-less** datagrams
  - Such as IP or IPX
- Because of similarity both adaptation layers were **combined** to **AAL3/4**

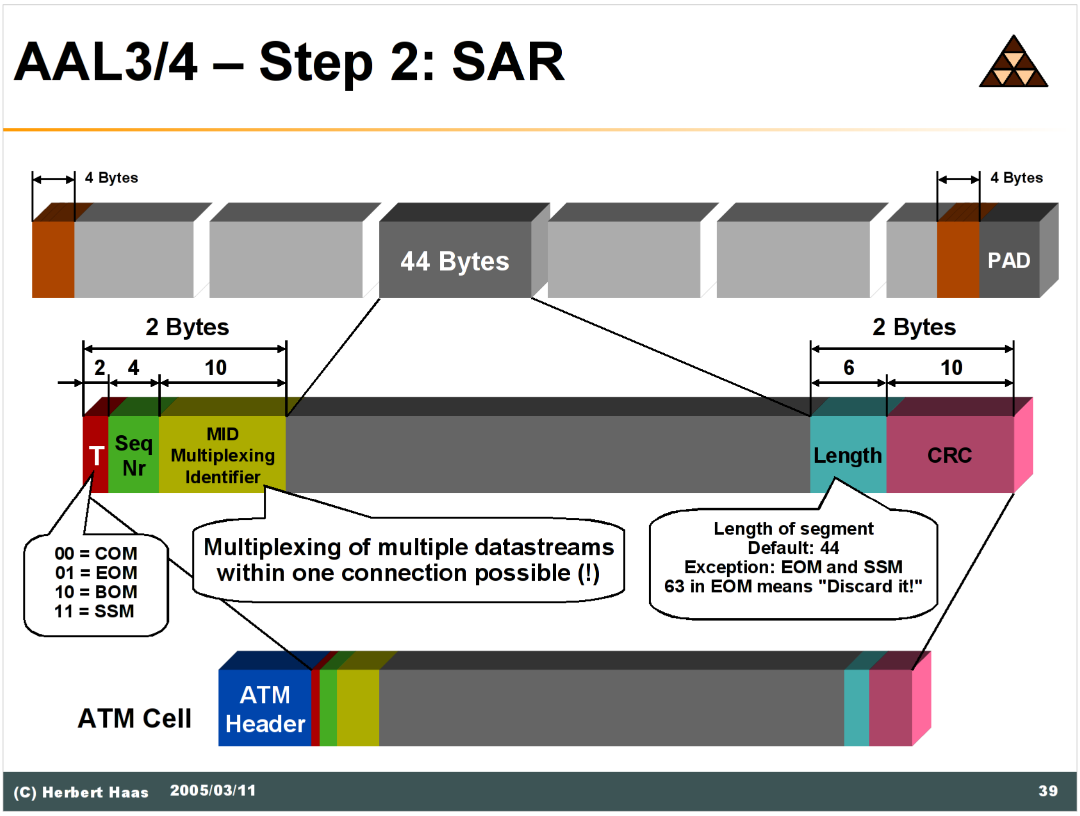
AAL3/4 – Step 1: CS



CPI .... Common Part Indicator (1Byte)
Btag....... Beginning tag (1 Byte)
BAsize... Buffer allocation size (2 Bytes)

PAD........ for 32 bit alignment
AL........... Alignment (1 Byte)
Etag........ Ending tag (1 Byte) – must match Btag
Len .... Length of SAR PDU

CPI indicates the interpretation of the remaining fields. Currently only value zero is defined which indicates that the values in BAsize and Length should be interpreted as amount of bytes.



The sequence number enumeratess each 44 byte segment of the CS frame (modulo 16). The Multiplexing Identifier (MID) allows to multiplex up to 210 different connection-oriented AAL 3/4 connections. For connectionless packets, the MID field can be used as unique identifier associated with each user, in order to multiplex many users over one ATM pipe.

AAL3/4

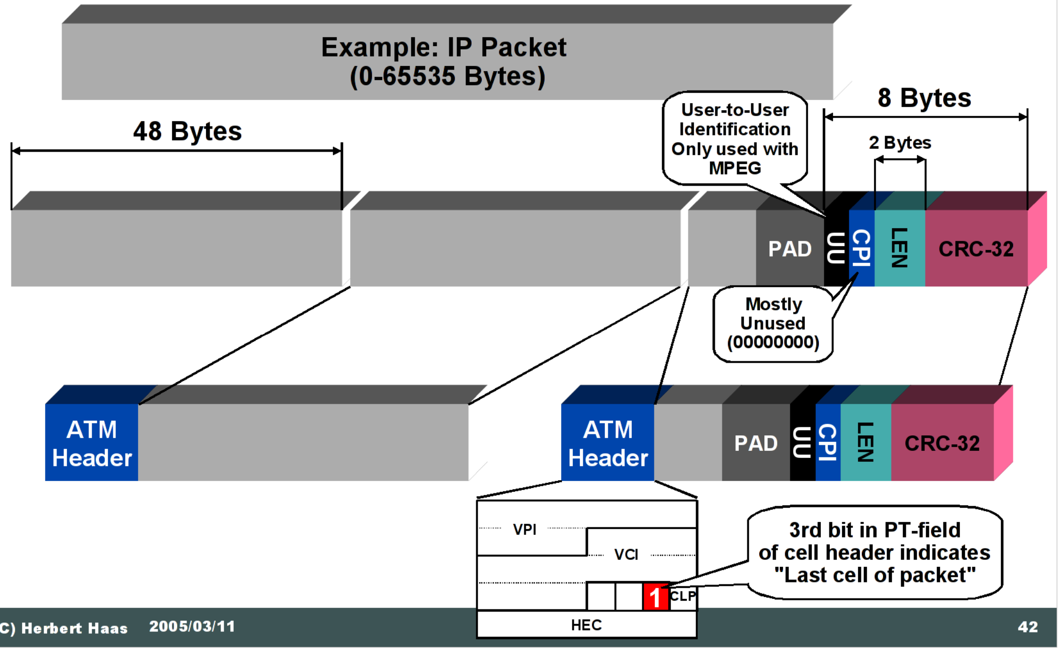
- Can multiplex different streams of data on the same ATM connection
  - Up to 210 streams using the same VPI/VCI
- But too much overhead
  - Sequence numbers unnecessary when not interleaving
  - One CRC for whole packet would be sufficient
  - Length unnecessary
  - Nearly totally replaced by AAL5

AAL5

- Favorite for data communication
  - AAL 5 simulates connectionless data interface
  - Allows simple migration to ATM
- Smallest overhead
  - Convergence Layer:
    8 byte trailer in last cell
  - SAR Layer:
    just marks EOM in ATM header (PT)

AAL5 is the most widely used AAL today. Also UNI signaling, ILMI and PNNI signaling is done upon AAL5.

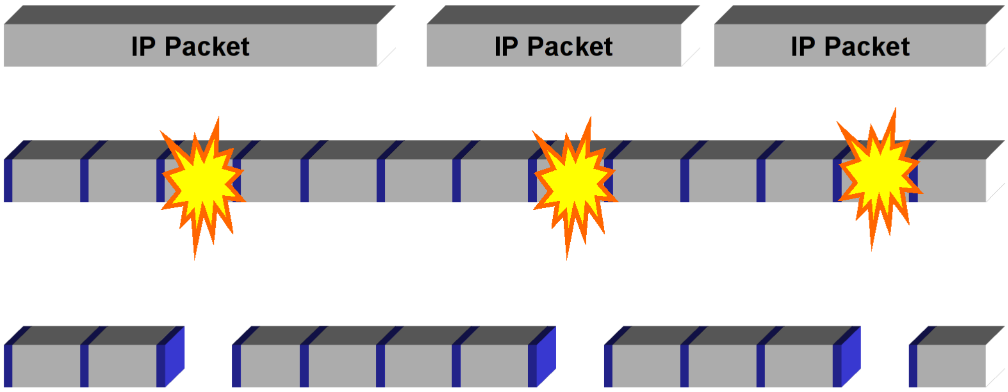
AAL5 Segmentation



The Common Part Indicator (CPI) is not really used until today, so all 8 bits are set to zero.

Most interestingly, the length field is 16 bits that is 64 KByte packets are supported. So, ATM is one of the few technologies that support maximum IP packet sizes (IP also supports up to 65535 Bytes per packet).

Packets and Cell Loss (1)



Receiver can't recognize any IP packets !

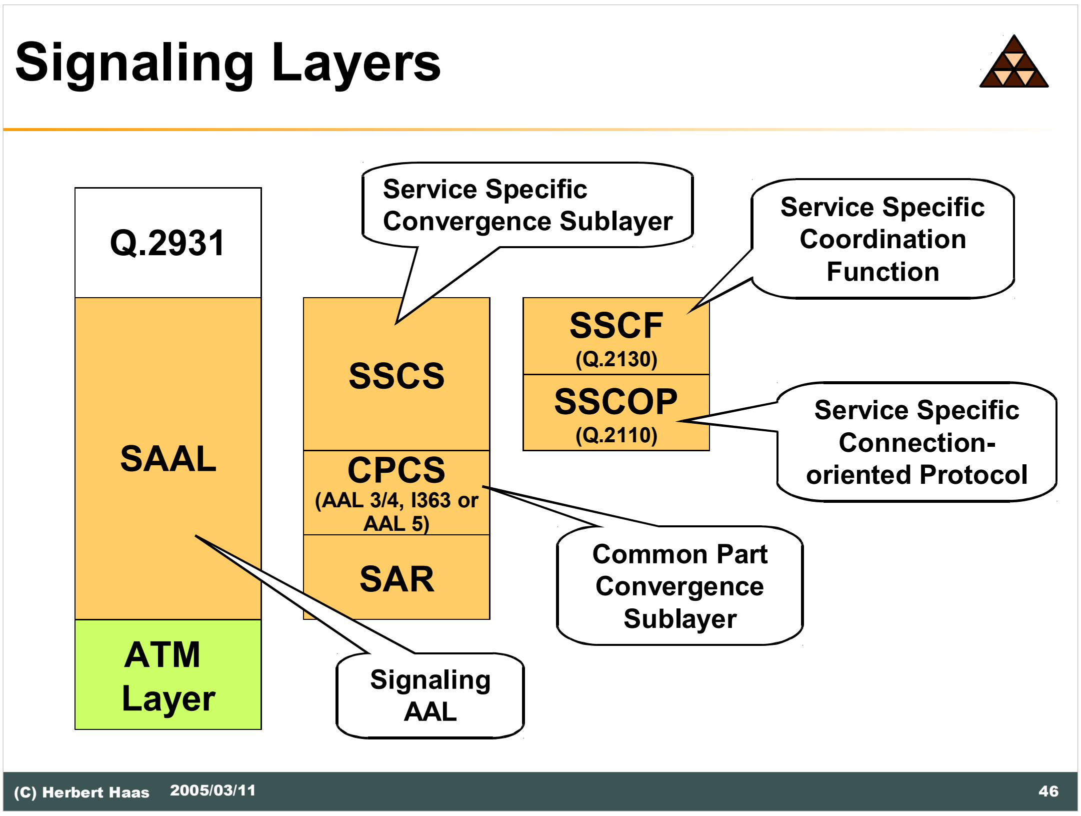
Even a small bit error rate (BER) can lead to retransmission and congestion (!)

Packets and Cell Loss (2)

- Cells of damaged packets are still forwarded by ATM switches
  - Solution: Intelligent Tail Packet Discard or Early Packet Discard
- IP Routers can immediately drop whole packet
  - And recover queuing resources
  - So BER can be much higher (!)

Signaling

- ATM Forum UNI signaling specification
  - UNI 3.0, 3.1 and 4.0 standardized
    - UNI 2.0 PVC
    - UNI 3.0 PVC+SVC, CBR+VBR+UBR
    - UNI 4.0 +ABR, QoS Negotiation
- Based on ITU-T Q.2931 (B-ISDN)



SSCOP is very similar to X.25.

ITU-T recommends AAL 3/4 for CPCS,
while ATM Forum recommends AAL 5.

The Q.2931 protocol has its origins in Q.931 (N-ISDN, D channel) and Q.933 (UNI signaling for Frame Relay). Q.2931 is responsible for:

- Connection establishment
- Negotiation of performance parameters
- VPI/VCI use instead of a D-channel (N-ISDN)
- Uses meta signaling to establish signaling paths and channels (ITU-T)

ITU-T reserved VPI/VCI 0/1 for Meta-Signaling (seldom used) and 0/2 for broadcast signaling (both for UNI headers).

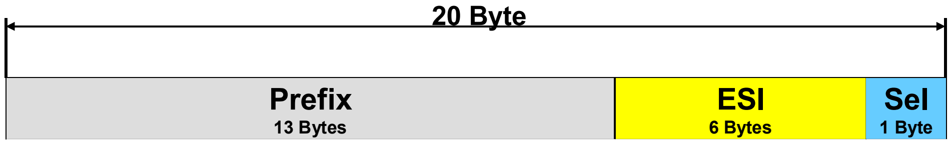
Additionally, the ATM Forum reserved 0/15 for point-to-point signaling, 0/16 for I-LMI, and 0/18 for PNNI.

ATM Addresses

- ATM Forum defined three address-formats
  - ISO DCC NSAP format
  - ISO ICD NSAP format
  - E.164 Address format
- Only public networks may use E.164 address format
  - May also choose other formats

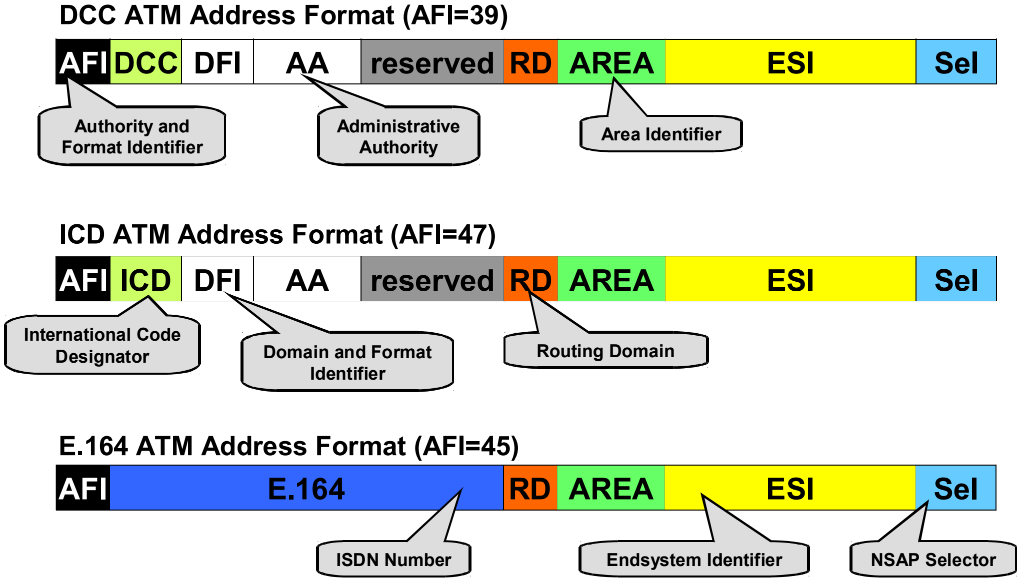
ATM Addresses

- Different types of ATM addresses
- All have 20 byte length
- All consist of three main parts
  - Prefix (Basically topology information)
  - End System Identifier (ESI)
  - NSAP Selector (Selects application)



The NSAP Selector field is basically the same as the port number in TCP.

Address Flavours



Summary

- ATM is the solution for B-ISDN
  - Different broadband services upon common cell relay technology
- Remember: 53 bytes, 5 bytes Header
- Services via Adaptation Layers
  - AAL1, AAL2, AAL3/4, AAL5 (IP)
- Quality of Service
  - Details in other module
- VP and VC switching

Quiz

- Which framing is used with XDSL?
- What are the 4 ATM basic service types regarding QoS?
- ATM flow control is similar to...?
- Which concepts of ATM have been copied for IP networks?

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Q1: ATM cells

Q2: CBR, VBR, ABR, UBR

Q3: Frame Relay ECN

Q4: Label Swapping (MPLS), QoS-Signaling (RSVP) and QoS-Marking (DSCP)