Asynchronous Transfer Mode (ATM)
ATM Outline

- ATM Introduction
  - Motivation for ATM Architecture
- Design Assumptions
- ATM Adaptation Layers
- Old ATM Design
- Revised ATM Design
- AAL Details
- MPLS
ATM Introduction

- ITU-T lead the standards development.
- ATM Forum ensures interoperability among private and public ATM implementations.
- commonly used to implement WANs.
- DSL uses ATM for multiplexing and switching.
- used as a backbone in IP networks and Internet.
Issues Driving LAN Changes

- Traffic Integration
  - Voice, video and data traffic
  - **Multimedia** became the 'buzz word'
    - One-way batch Web traffic
    - Two-way batch voice messages
    - One-way interactive Mbone broadcasts
    - Two-way interactive video conferencing

- Quality of Service guarantees (e.g. limited jitter, non-blocking streams)

- LAN Interoperability

- Mobile and Wireless nodes
Figure 5.9  Example ATM LAN configuration.
Figure 5.10  ATM LAN hub configuration.
ATM Adaptation Layers

Voice
- Digital voice samples
  - A/D
  - $s_1, s_2 ...$
  - AAL
  - cells

Video
- Picture frames
  - A/D
  - Compression
  - AAL
  - compressed frames
  - cells

Data
- Bursty variable-length packets
  - AAL
  - cells

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Asynchronous Transfer Mode (ATM)

MUX

Voice
Data packets
Images

Wasted bandwidth

TDM

ATM

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ATM

- ATM standard (defined by CCITT) was widely accepted by common carriers as mode of operation for communication (particularly BISDN).
- ATM is a form of **cell switching** using small fixed-sized packets.

![Basic ATM Cell Format](image)

- **Header**: 5 Bytes
- **Payload**: 48 Bytes
ATM Conceptual Model
Four Design Assumptions

1. ATM network will be organized as a hierarchy.
   - User’s equipment connects to networks via a UNI (User-Network Interface).
   - Connections between provided networks are made through NNI (Network-Network Interface).

2. ATM will be connection-oriented.
   - A connection (an ATM channel) must be established before any cells are sent.
ATM Interfaces

Private ATM network
- LAN switch
- Workstation
- Router
- Audio
- Video
- Server

Public ATM network A
- NNI
- UNI

Public ATM network B
- NNI
- B-ICI

UNI = user-network interface
NNI = network node interface
B-ICI = broadband intercarrier interface

Figure 11.3 ATM Interfaces
two levels of ATM connections:
- virtual path connections (VPC)
- virtual channel connections (VCC)

indicated by two fields in the cell header:
- virtual path identifier VPI
- virtual channel identifier VCI
ATM Virtual Connections

- Virtual Path Connection (VPC)
  - bundle of Virtual Channel Connections (VCC) with same end points.
3. Vast majority of ATM networks will run on optical fiber networks with extremely low error rates.

4. ATM must support low cost attachments.
   - This decision lead to a significant decision: to prohibit cell reordering in ATM networks.

→ ATM switch design is more difficult.
ATM Cell Formats

(a) User-network interface

(b) Network-network interface

Information field
(48 octets)

Header Error Control

Virtual Channel Identifier

Virtual Path Identifier

Generic flow control

Payload Type

CLP

Virtual Path Identifier

(DCC 9th Ed. Stallings)
## Payload Type (PT) Field Coding

<table>
<thead>
<tr>
<th>PT Coding</th>
<th>Interpretation</th>
<th>SDU-type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 0</td>
<td>User data cell, congestion not experienced,</td>
<td>0</td>
</tr>
<tr>
<td>0 0 1</td>
<td>User data cell, congestion not experienced,</td>
<td>1</td>
</tr>
<tr>
<td>0 1 0</td>
<td>User data cell, congestion experienced,</td>
<td>0</td>
</tr>
<tr>
<td>0 1 1</td>
<td>User data cell, congestion experienced,</td>
<td>1</td>
</tr>
<tr>
<td>1 0 0</td>
<td>OAM segment associated cell</td>
<td></td>
</tr>
<tr>
<td>1 0 1</td>
<td>OAM end-to-end associated cell</td>
<td></td>
</tr>
<tr>
<td>1 1 0</td>
<td>Resource management cell</td>
<td></td>
</tr>
<tr>
<td>1 1 1</td>
<td>Reserved for future function</td>
<td></td>
</tr>
</tbody>
</table>

SDU = Service Data Unit  
OAM = Operations, Administration, and Maintenance
### ATM Cell Switching

<table>
<thead>
<tr>
<th>Frame</th>
<th>Video</th>
<th>Voice</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>32</td>
<td>N</td>
<td>75</td>
</tr>
<tr>
<td>32</td>
<td>3</td>
<td>2</td>
<td>39</td>
</tr>
</tbody>
</table>

**Switching Rules:**
- Frame 1: Video 25, Voice 32
- Frame 5: Video 25, Voice 32
- Frame 6: Data 32, Video 61
- Frame N: Video 75

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Two Levels of ATM Switches

Digital Cross Connect

Only switches virtual paths

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ATM Adaptation Layers (AAL) - the protocol for packaging data into cells is collectively referred to as AAL.

- Must efficiently package higher level data such as voice samples, video frames and datagram packets into a series of cells.

**Design Issue:** How many adaptation layers should there be?
ATM in the Protocol Stack

End system  Network  End system

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CCITT envisioned four classes of applications (A–D) requiring four distinct adaptation layers (1–4) which would be *optimized* for an application class:

A. Constant bit-rate applications  **CBR**
B. Variable bit-rate applications  **VBR**
C. Connection-oriented data applications
D. Connectionless data application
An AAL was further divided into:

**Convergence Sublayer (CS)**
manages the flow of data to and from **SAR** sublayer.

**Segmentation and Reassembly Sublayer (SAR)**
breaks data into cells at the sender and reassembles cells into larger data units at the receiver.
Original ATM Architecture

Upper Layers

AAL SAPs

CS
- handling lost / misdelivered cells
- timing recovery (class A, B)
- interleaving

SAR
- split frames / bit stream into cells
- re-assemble frames / bit stream

ATH
- cell routing
- multiplexing / demultiplexing
- generic flow control

TC
- cell header verification and cell delineation
- rate decoupling
- transmission frame adaptation

PL
- bit timing
- physical medium

Abbreviations
- AAL = ATH Adaptation Layer
- SAR = Segmentation And Reassembly
- CS = Convergence Sub-layer
- PL = Physical Layer
- TC = Transmission Convergence
- PH = Physical Medium

SERVICE CLASSES for AAL

<table>
<thead>
<tr>
<th>class</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Constant Bit Rate</td>
</tr>
<tr>
<td>B</td>
<td>Variable Bit Rate</td>
</tr>
<tr>
<td>C</td>
<td>Connection Oriented Data</td>
</tr>
<tr>
<td>D</td>
<td>Connectionless Data</td>
</tr>
</tbody>
</table>

1. Protocol Reference Model in the User Plane. See Section 4.1 for AAL SAP classes (A to D) and values (1 to 4).
Physical Layer ATM Adjustments

- Physical layer
  - Transmission convergence sublayer
  - Physical medium dependent sublayer
  - Physical medium
  - ATM layer
The AAL interface was initially defined as classes **A-D** with SAP (Service Access Points) for **AAL1-4**.

**AAL3** and **AAL4** were so similar that they were merged into **AAL3/4**.

The data communications community concluded that **AAL3/4 was not suitable** for data communications applications. They pushed for standardization of **AAL5** (also referred to as SEAL – the Simple and Efficient Adaptation Layer).

**AAL2 was not initially deployed**.
Revised ATM Architecture

(a) Service type

<table>
<thead>
<tr>
<th>Service type</th>
<th>AAL 1</th>
<th>AAL 2</th>
<th>AAL 3/4</th>
<th>AAL 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing relation</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bit rate</td>
<td>Constant</td>
<td>Variable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td>Connection-oriented</td>
<td>Connectionless</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(b) ATM

- CS protocols
- SAR sublayer protocols
- Timing and cell loss recovery (AAL 1/2)
  - Cell loss detection (AAL 3/4/5)
- Segmentation and reassembly
- Satisfies interface requirements
- Processes cell pay
- Processes cell header
- Transports cells

CS = Convergence sublayer
SAR = Segmentation and reassembly
Revised ATM Service Categories

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CBR</strong></td>
<td>Constant Bit Rate</td>
<td>T1 circuit</td>
</tr>
<tr>
<td><strong>RT-VBR</strong></td>
<td>Real Time Variable Bit Rate</td>
<td>Real-time videoconferencing</td>
</tr>
<tr>
<td><strong>NRT-VBR</strong></td>
<td>Non-real-time Variable Bit Rate</td>
<td>Multimedia email</td>
</tr>
<tr>
<td><strong>ABR</strong></td>
<td>Available Bit Rate</td>
<td>Browsing the Web</td>
</tr>
<tr>
<td><strong>UBR</strong></td>
<td>Unspecified Bit Rate</td>
<td>Background file transfer</td>
</tr>
</tbody>
</table>
Quality of Service (QoS) requirements are handled at connection time and viewed as part of signaling (e.g., RSVP).

ATM provides permanent virtual connections and switched virtual connections.

- **Permanent Virtual Connections (PVC)**
  - Permanent connections set up *manually* by network manager.

- **Switched Virtual Connections (SVC)**
  - Set up and released *on demand* by the end user via signaling procedures.
(b) CS PDU with pointer in structured data transfer

(a) SAR PDU header

<table>
<thead>
<tr>
<th>CSI</th>
<th>Seq. Count</th>
<th>SNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 bit</td>
<td>3 bits</td>
<td>4 bits</td>
</tr>
</tbody>
</table>
AAL 1

Higher layer

Convergence sublayer

SAR sublayer

ATM layer

b₁  b₂  b₃  ...

User data stream

CS PDUs

SAR PDUs

ATM Cells

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### (a) CPCS-PDU format

<table>
<thead>
<tr>
<th>CPI</th>
<th>Btag</th>
<th>BASize</th>
<th>CPCS - PDU Payload</th>
<th>Pad</th>
<th>AL</th>
<th>Etag</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1 - 65,535</td>
<td>0-3</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

(b) SAR PDU format

<table>
<thead>
<tr>
<th>ST</th>
<th>SN</th>
<th>MID</th>
<th>SAR - PDU Payload</th>
<th>LI</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
<td>10</td>
<td>44</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

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Assume null

Pad message to multiple of 4 bytes. Add header and trailer.

Each SAR-PDU consists of 2-byte header, 2-byte trailer, and 44-byte payload.
Convergent Sublayer Format

<table>
<thead>
<tr>
<th>Information</th>
<th>Pad</th>
<th>UU</th>
<th>CPI</th>
<th>Length</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 65,535 (bytes)</td>
<td>0-47</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

SAR Format

48 bytes of Data

1-bit end-of-datagram field (PTI)
AAL 5

Higher layer

Service specific convergence sublayer

Common part convergence sublayer

SAR sublayer

ATM layer

Information

Assume null

PTI = 0

48 (0)

48 (0)

48 (1)

PTI = 0

PTI = 0

PTI = 1

Information

PAD

T

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STM-1 (STS-3) Payload for SDH-Based ATM Cell Transmission
**MPLS (Multi Protocol Label Switching)**

Figure 6-1  *MPLS Network Elements*

- ATM LSR
- Packet-based LSR
- Edge LSR
- LC-ATM interfaces
- Customer sites running ordinary IP

*WPI*  
*Computer Networks*  
ATM
The Nortel Networks Passport 8600 Routing Switch

- designed for high-performance Enterprise, carrier, and service provider networks.
- As a chassis based Ethernet switching platform, the **Passport 8600** series provides wire speed L2-L7 traffic classification, filtering, forwarding and routing. Hardware based wire speed performance enables fast and efficient traffic classification, policy enforcement and filtering.
- Provides wire speed L2- L7 traffic classification.
The Nortel Networks Passport 8600 Routing Switch

- Multi-layer redundancy with five 9’s reliability
- Integrated intelligent bandwidth connectivity for 10/100/1000 Ethernet, ATM, PoS, 10 Gig and WDM
- Seamless LAN/MAN/WAN connectivity
- Eight policy enabled hardware queues per port
- 512 Gigabits per second backplane switch capacity.
Nortel Ethernet Routing Switch 8600

- Avaya Switch ERS 8600
- Configurable as a 1.440 Terabit Switch cluster using SMLT
- 10 Gigabit Ethernet
- Packet Over SONET
  6 OC-3 or 3 OC-12 ports
- ATM
- 4 firewall or IDS
ATM Summary

- Motivation for ATM Architecture
- Four Design Assumptions
- ATM Hierarchy
  - UNI, NNI, VPI, VCI, two switch levels
- Old ATM Design
  - Convergence Sublayer (CS), Segmentation and Reassembly Sublayer (SAR)
- ATM Adaptation Layers
  - AAL1-4
ATM Summary

- New ATM Design
  - PVC, SVC
- AAL Details
  - AAL1, AAL3-4, AAL5
- Multi-Protocol Layer Switching (MPLS)
  - Passport Switch