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.
- ATM commonly used to implement WANs.
- DSL uses ATM for multiplexing and switching.
- ATM still used as a backbone in some IP networks.
Issues Driving LAN Changes

- **Traffic integration**
  - Voice, video and data traffic
  - **Multimedia** became the 'buzz word' in the 1990s
    - 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

A/D → AAL

$s_1, s_2 \ldots$

Digital voice samples

Video

A/D → Compression → AAL

picture frames

compressed frames

cells

Data

AAL → cells

Bursty variable-length packets

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Asynchronous Transfer Mode (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

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

Figure 11.3 ATM Interfaces
ATM Connections

- 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

8 7 6 5 4 3 2 1
Generic flow control Virtual Path Identifier
Virtual Path Identifier
Virtual Channel Identifier
Payload Type CLP
Header Error Control

5-octet header

53-octet cell

Information field (48 octets)

Virtual Path identifier
Virtual Channel Identifier
Payload Type CLP
Header Error Control

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

#### Switching Example

<table>
<thead>
<tr>
<th>Input</th>
<th>Switching</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video 25</td>
<td>25</td>
<td>Voice 67</td>
</tr>
<tr>
<td>Voice 32</td>
<td>32</td>
<td>Video 67</td>
</tr>
<tr>
<td>Data 32</td>
<td>32</td>
<td>Data 39</td>
</tr>
<tr>
<td>Video 61</td>
<td>61</td>
<td>Video 75</td>
</tr>
</tbody>
</table>

The switch processes different types of traffic (video, voice, data) and routes them through the network. The switch matrix is shown as a diagram with inputs and outputs, demonstrating how cells are transferred through the network.
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 Protocol Architecture

- **Management plane**
  - **Control plane**
    - Higher layers
  - **User plane**
    - Higher layers

- **ATM Adaptation Layer**

- **ATM layer**

- **Physical layer**

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ATM in the Protocol Stack

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End system → Network ← End system

AAL
ATM
PHY

User information

...
CCITT envisioned four classes of applications (A-D) requiring four distinct adaptation layers (1-4) which would be optimized for an individual 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

![Diagram of ATM Architecture with explanations of various layers and functionalities](image)

### Abbreviations
- AAL - ATH Adaptation Layer
- SAR - Segmentation And Reassembly
- CS - Convergence Sub-layer
- PL - Physical Layer
- TC - Transmission Convergence
- PM - 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 relationship</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) AAL

CS protocols

SAR sublayer protocols

Timing and cell loss recovery (AAL 1/2)

Cell loss detection (AAL 3/4/5)

Segmentation and reassembly

SAP 1

SAP 2

SAP 3/4

SAP 5

SAP 1

SAP 2

SAP 3/4

SAP 5

ATM

Physical

CS = Convergence sublayer

SAR = Segmentation and reassembly

Satisfies interface requirements

Processes cell pay

Processes cell he

Transports cells
Revised ATM Service Categories

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR</td>
<td>Constant Bit Rate</td>
<td>T1 circuit</td>
</tr>
<tr>
<td>RT-VBR</td>
<td>Real Time Variable Bit Rate</td>
<td>Real-time videoconferencing</td>
</tr>
<tr>
<td>NRT-VBR</td>
<td>Non-real-time Variable Bit Rate</td>
<td>Multimedia email</td>
</tr>
<tr>
<td>ABR</td>
<td>Available Bit Rate</td>
<td>Browsing the Web</td>
</tr>
<tr>
<td>UBR</td>
<td>Unspecified Bit Rate</td>
<td>Background file transfer</td>
</tr>
</tbody>
</table>
QoS, PVC, and SVC

- 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

User data stream

Convergence sublayer

SAR sublayer

ATM layer

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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>
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</td>
<td>0-47</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

(48 bytes of Data)

### 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

Assume null

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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
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.
- 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