Asynchronous Transfer Mode (ATM)
ATM Outline

- Motivation for ATM Architecture
- Design Assumptions
- ATM Adaptation Layers
- Old ATM Design
- Revised ATM Design
- AAL Details
- MPLS
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
Stallings’ “High-Speed Networks”

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 ➔ cells

picture frames ➔ compressed frames

Data

AAL ➔ cells

Bursty variable-length packets
Asynchronous Transfer Mode (ATM)

Voice
Data packets
Images

MUX

Wasted bandwidth

TDM

ATM

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• 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.

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**Basic ATM Cell Format**

- **Header**: 5 Bytes
- **Payload**: 48 Bytes
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 Hierarchy

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ATM Connections

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

Physical Link

Virtual Paths

Virtual Channels
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.
### UNI Cell Format

ATM cell header:

<table>
<thead>
<tr>
<th>GFC (4 bits)</th>
<th>VPI (4 bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VPI (4 bits)</td>
<td>VCI (4 bits)</td>
</tr>
<tr>
<td>VCI (8 bits)</td>
<td></td>
</tr>
<tr>
<td>VCI (4 bits)</td>
<td>PT (3 bits)</td>
</tr>
<tr>
<td>HEC (8 bits)</td>
<td></td>
</tr>
</tbody>
</table>

Payload (48 bytes)

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### ATM Cell Switching

#### ATM Switching

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>video 25</td>
<td>video 75</td>
</tr>
<tr>
<td>voice 32</td>
<td>voice 67</td>
</tr>
<tr>
<td>data 32</td>
<td>data 39</td>
</tr>
<tr>
<td>video 61</td>
<td>video 67</td>
</tr>
</tbody>
</table>

#### Switch Matrix

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

#### Connection Table

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>
Two Levels of ATM Switches

Digital Cross Connect
Only switches virtual paths

Sw = switch
ATM Protocol Architecture

- 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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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 \( \text{CBR} \)
B. Variable bit-rate applications \( \text{VBR} \)
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

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>handling lost / misdelivered cells</td>
<td>C</td>
<td>re-assemble frames / bit stream</td>
</tr>
<tr>
<td>B</td>
<td>timing recovery (class A,B)</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td></td>
<td>interleaving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAR</td>
<td>split frames / bit stream into cells</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>re-assemble frames / bit stream</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations

AAL = ATM 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

ATM layer

Transmission convergence sublayer

Physical medium dependent sublayer

Physical medium
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>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</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

SAP 1 SAP 2 SAP 3/4 SAP 5

Satisfied interface requirements
Processes cells

Segmentation and reassembly

CS = Convergence sublayer
SAR = Segmentation and reassembly

ATM
Physical
## 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>
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

<table>
<thead>
<tr>
<th>b₁</th>
<th>b₂</th>
<th>b₃</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Convergence sublayer

<table>
<thead>
<tr>
<th>47</th>
</tr>
</thead>
</table>

SAR sublayer

<table>
<thead>
<tr>
<th>H</th>
<th>1</th>
<th>47</th>
</tr>
</thead>
</table>

ATM layer

<table>
<thead>
<tr>
<th>H</th>
<th>5</th>
<th>48</th>
</tr>
</thead>
</table>

User data stream

CS PDUs

SAR PDUs

ATM Cells

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AAL 3/4 CS and SAR PDUs

(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>

(bytes)

(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>

(bits) (bytes)

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

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

Assume null

User message

Information

H

2 4

Information

2 4

PAD

T

2 4

2 44 2

...
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 (bytes)</td>
<td>4</td>
</tr>
</tbody>
</table>

SAR Format

48 bytes of Data

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

ATM Header

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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