Layers of The ATM Model

CS: Convergence sublayer
SAR: Segmentation and reassembly sublayer
TC: Transmission convergence sublayer
PMD: Physical medium dependent sublayer
## Functions of ATM Layers/Sublayers

<table>
<thead>
<tr>
<th>OSI layer</th>
<th>ATM layer</th>
<th>ATM sublayer</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4</td>
<td>AAL</td>
<td>CS</td>
<td>Providing the standard interface (convergence)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SAR</td>
<td>Segmentation and reassembly</td>
</tr>
<tr>
<td>2/3</td>
<td>ATM</td>
<td></td>
<td>Flow control</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cell header generation/extraction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Virtual circuit/path management</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cell multiplexing/demultiplexing</td>
</tr>
<tr>
<td>2</td>
<td>TC</td>
<td></td>
<td>Cell rate decoupling</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Header checksum generation and verification</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cell generation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Packing/unpacking cells from the enclosing envelope</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Frame generation</td>
</tr>
<tr>
<td>1</td>
<td>PMD</td>
<td></td>
<td>Bit timing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Physical network access</td>
</tr>
</tbody>
</table>
ATM Adaptation Layer (AAL) Types

In order for ATM to support a variety of services with different traffic characteristics and system requirements:

- It is necessary to adapt the different classes of applications to the ATM layer.
- This function is performed by the AAL, which is service-dependent.
- Four types of AAL were proposed, but two of these (3 and 4) have now been merged into one, AAL 3/4:
  - **AAL 1**: Supports connection-oriented, constant bit rate, time-dependent services.
  - **AAL 2**: Supports connection-oriented services that do not require constant bit rates.
  - **AAL 3/4**: Intended for both connectionless and connection oriented variable bit rate services.
  - **AAL 5**: Supports connection-oriented variable bit rate data services.
    - More efficient compared with AAL 3/4 at the expense of error recovery and built in retransmission.
ATM Integrated Services

ATM Workstation
ATM Cells
ATM VPI
SMDS
SMDS/ATM Cells
Ethernet Switch
Frame Stream
Frame Relay Network
Frame Stream
Router
TCP/IP
PPP
Packet Video
Variable Video Stream
Video Stream
Video Stream
Voice Stream
Voice Stream

Video Cell
Data Cell
Voice Cell
Switch Fabric
AAL4
AAL5
AAL3
AAL2
AAL1
## Original Obsolete Service Classes Supported

By

**ATM Adaptation Layer (AAL)**

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing</td>
<td>Real time</td>
<td>None</td>
<td>Real time</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Real time</td>
<td>None</td>
<td>Real time</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Real time</td>
<td>None</td>
<td>Real time</td>
<td>None</td>
</tr>
<tr>
<td>Bit rate</td>
<td>Constant</td>
<td>Variable</td>
<td>Constant</td>
<td>Variable</td>
</tr>
<tr>
<td>Mode</td>
<td>Connection orientated</td>
<td></td>
<td>Connectionless</td>
<td></td>
</tr>
</tbody>
</table>

**Table:**

- **A:** Real time, None
- **B:** Real time, Variable
- **C:** Real time, Constant
- **D:** Real time, None

---

**Note:**

- Each service class is defined by its timing, bit rate, and mode.
- The ATM Adaptation Layer (AAL) supports these original obsolete service classes.
## ATM Service Categories

<table>
<thead>
<tr>
<th>Service Category</th>
<th>Typical Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant Bit Rate (CBR) or Deterministic Bit Rate (DBR)</td>
<td>Uncompressed video Real-time, QoS guarantees</td>
</tr>
<tr>
<td>Real-Time Variable Bit Rate (rt-VBR)</td>
<td>Real-time videoconferencing</td>
</tr>
<tr>
<td>Non-Real-Time Variable Bit Rate (nrt-VBR) or, Statistical Bit Rate (SBR)</td>
<td>Multimedia email</td>
</tr>
<tr>
<td>Available Bit Rate (ABR)</td>
<td>Resource exploitation, feedback control</td>
</tr>
<tr>
<td>Unspecified Bit Rate (UBR)</td>
<td>Best effort, no guarantees Background file transfer</td>
</tr>
<tr>
<td>ATM Block Transfer (ABT)</td>
<td>Burst level feedback control</td>
</tr>
</tbody>
</table>
## Characteristics of ATM Service Categories

<table>
<thead>
<tr>
<th>Service Characteristic</th>
<th>CBR</th>
<th>RT-VBR</th>
<th>NRT-VBR</th>
<th>ABR</th>
<th>UBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth guarantee</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Optional</td>
<td>No</td>
</tr>
<tr>
<td>Suitable for real-time traffic</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Suitable for bursty traffic</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Feedback about congestion</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

- **Constant Bit Rate (CBR)**
- **Real-Time Variable Bit Rate (rt-VBR)**
- **Non-Real-Time Variable Bit Rate (nrt-VBR)**
- **Available Bit Rate (ABR)**
- **Unspecified Bit Rate (UBR)**
### Sample ATM Quality of Service Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Acronym</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak cell rate</td>
<td>PCR</td>
<td>Maximum rate at which cells will be sent</td>
</tr>
<tr>
<td>Sustained cell rate</td>
<td>SCR</td>
<td>The long-term average cell rate</td>
</tr>
<tr>
<td>Minimum cell rate</td>
<td>MCR</td>
<td>The minimum acceptable cell rate</td>
</tr>
<tr>
<td>Cell delay variation tolerance</td>
<td>CDVT</td>
<td>The maximum acceptable cell jitter</td>
</tr>
<tr>
<td>Cell loss ratio</td>
<td>CLR</td>
<td>Fraction of cells lost or delivered too late</td>
</tr>
<tr>
<td>Cell transfer delay</td>
<td>CTD</td>
<td>How long delivery takes (mean and maximum)</td>
</tr>
<tr>
<td>Cell delay variation</td>
<td>CDV</td>
<td>The variance in cell delivery times</td>
</tr>
<tr>
<td>Cell error rate</td>
<td>CER</td>
<td>Fraction of cells delivered without error</td>
</tr>
<tr>
<td>Severely-errored cell block ratio</td>
<td>SECBR</td>
<td>Fraction of blocks garbled</td>
</tr>
<tr>
<td>Cell misinsertion rate</td>
<td>CMR</td>
<td>Fraction of cells delivered to wrong destination</td>
</tr>
</tbody>
</table>
Probability Density Function For ATM Cell Arrival Times

- Minimum
- CDV
- CTD
- Cells lost or delivered too late

1-\(\alpha\)
\(\alpha\)

Transfer time

Probability
ATM Model Layers & AAL Sublayers

AAL has two stages:

- **Convergence Sublayer (CS):** Provides the necessary error control and sequencing as well as the sizing of information from applications. The CS is further composed of a common part (CPCS) and a service specific part (SSCS).
- **A service-independent Segmentation And Reassembly (SAR) sublayer:** Breaks CPCS-PDUs into 48-byte ATM cell payloads and attaches the five-byte header.
Headers, Trailers Added To A Message In ATM Networks

Output by application

Header

Output by convergence sublayer

Output by SAR sublayer

Output by ATM layer

ATM header

SAR header sublayer header

SAR sublayer trailer

Header

Trailer

Message

Convergence sublayer trailer

Unused
ATM Layer Headers

ATM layer header at User-Network Interface UNI

ATM layer header at Network-Network Interface NNI

GFC: General Flow Control
VPI: Virtual Path Identifier
VCI: Virtual Channel Identification

PTI: Payload Type
CLP: Cell Loss Priority
HEC: Header Error Check
AAL 1

- Class A traffic: real-time constant bit rate, connection-oriented, such as uncompressed audio and video.
  - No time-outs, retransmissions, or error-detection provided.
- Convergence sublayer (CS):
  - Detects lost and mis-directed cells.
  - Breaks messages into 46 or 47 byte units given to SAR
- Segmentation Reassembly Sublayer (SAR)
  - 3-bit cell Sequence Number (SN)
  - 3-bit Sequence Number Protection (SNP) or checksum.
  - P cells used to preserve message boundary, pointer field used to provide new message offset (pointer = 0 to 92).

AAL 2

- Used for Class B: variable bit rate compressed audio/video traffic with error-detection.
- Similar to AAL 1, no special CS protocol.
- SAR
  - SN (sequence number), IT (information type): start, middle or end of message. LI (Length Indicator) if payload is less than 45 bytes. CRC
  - No field sizes included in the standard AAL 2, thus not often used.
The AAL 1 SAR-PDU Format

(5-byte ATM cell header added to SAR-PDU to form ATM cell)

The AAL 2 SAR-PDU Format

(5-byte ATM cell header added to SAR-PDU to form ATM cell)
AAL 3/4

- Supports Class C/D traffic: variable bit rate, delay-tolerant data traffic requiring some sequencing and/or error detection.
  - Reliable or unreliable stream or message modes.
- Originally two AAL types, connection-oriented and connectionless, which have been combined.
- Only AAL protocol to offer multiple sessions on a single virtual circuit.
- Suffers from high overhead:
  - 8 bytes to each message (CS) and 4 bytes in each cell (SAR).
- Convergence Sublayer (CS):
  - Messages up to 65535 bytes from application are padded into multiples of 4 bytes then a header and trailer is added.
  - CS Header: CPI (common part indicator), Btag (beginning Tag, one byte incremented by one for each new message), BA Size (for buffer allocation).
  - CS Trailer: Etag (same value as Btag, for message framing), Length
  - Message with headers cut into 44 byte chunks to SAR.
- SAR
  - ST (segment type), first, middle, end, only cell of a message.
  - 4-bit SN Sequence Number, 10-bit MID (Multiplexing ID).
  - 6-bit LI (Length Indicator) size of payload in bytes, 10 bit CRC.
Multiplexing Several Sessions Onto One Virtual Circuit In ATM Networks
AAL 3/4 CPCS-PDU: Convergence Sublayer Message Format

AAL 3/4 SAR-PDU Format
(5-byte ATM cell header added to SAR-PDU to form ATM cell)
Common Part Convergence Sublayer (CPCS)

AAL-3/4 CPCS-PDU

A more detailed view
## Segmentation and Reassembly Sublayer (SAR)

### SAR-PDU Format for AAL 3/4

<table>
<thead>
<tr>
<th></th>
<th>ATM Cell Header</th>
<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>SAR-PDU Header</td>
<td>2 bytes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAR-PDU</td>
<td>44 bytes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAR-PDU Trailer</td>
<td>2 bytes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Segment Type (ST):**
  - 10 = Beginning of Message (BOM)
  - 00 = Continuation of Message (COM)
  - 01 = End of Message (EOM)
  - 11 = Single Segment Message (SSM)

- **Multiplexing Identification (MID) 10 bits**

- **Sequence Number (SN) 4 bits**

- **Length Indication (LI) 10 bits**

- **Cyclic Redundancy Check (CRC) 10 bits**
AAL 3/4 Operation

• Step 1:
  1. Pad application data to multiples of 4 bytes.
  2. Add CPCS-PDU header (4 bytes) and trailer (4 bytes).

• Step 2:
  1. Segment to 44 bytes.
  2. Pad last cell to 44 bytes.
  3. Add SAR-PDU header (2 bytes) and trailer (2 bytes) to make 48 bytes.

• Step 3:
  - Add 5 byte ATM cell headers.
AAL 5

- Other AAL (1 - 3/4) protocols were designed by the telecommunications industry without specifically addressing the requirements of the computer industry and suffered from:
  - High overhead, complexity, short message checksum (10 bits).
- Original AAL5 name: SEAL (Simple Efficient Adaptation Layer).
- Supports connection-oriented variable bit rate data services.
- Offers reliable and unreliable services to applications.
- Both message and stream modes supported.
- Convergence Sublayer (CS):
  - No CS header just a trailer.
  - 1-byte UU (user to user), used by higher layers.
  - 2-byte length of actual payload without padding.
  - 4-byte CRC
  - Message with headers cut into 48 byte chunks to SAR.
- SAR
  - No additional headers or trailers are added here.
Common Part Convergence Sublayer (CPCS)

AAL 5 CPCS-PDU Header

From 1 to 65535

CPCS-PDU Payload (CPCS-SDU)  Pad  CPCS-UU  CPI  Length  CRC

8 bytes

CPCS-PDU Trailer

- Pad (0 to 47 bytes)
- CPCS User-to-User Indication
- Common Part Indicator (1 byte)
- Length of Payload (2 bytes)
- Cyclic Redundancy Check (CRC) 4 bytes

EECC694 - Shaaban
AAL 5 Operation

• Step 1:
  1. Pad such that SDU plus 8-byte CPCS-PDU trailer will be multiple of 48 bytes.
  2. Add CPCS-PDU trailer.

• Step 2:
  – Segment to 48 bytes.

• Step 3:
  – Add 5 byte ATM cell headers and mark the last one with the EOM bit.
## Differences Between AAL Protocols

<table>
<thead>
<tr>
<th>Item</th>
<th>AAL 1</th>
<th>AAL 2</th>
<th>AAL 3/4</th>
<th>AAL 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service class</td>
<td>A</td>
<td>B</td>
<td>C/D</td>
<td>C/D</td>
</tr>
<tr>
<td>Multiplexing</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Message delimiting</td>
<td>None</td>
<td>None</td>
<td>Btag/Etag</td>
<td>Bit in PTI</td>
</tr>
<tr>
<td>Advance buffer allocation</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>User bytes available</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>CS padding</td>
<td>0</td>
<td>0</td>
<td>32-Bit word</td>
<td>0–47 bytes</td>
</tr>
<tr>
<td>CS protocol overhead (bytes)</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>CS checksum</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>32 Bits</td>
</tr>
<tr>
<td>SAR payload bytes</td>
<td>46–47</td>
<td>45</td>
<td>44</td>
<td>48</td>
</tr>
<tr>
<td>SAR protocol overhead (bytes)</td>
<td>1–2</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>SAR checksum</td>
<td>None</td>
<td>None</td>
<td>10 Bits</td>
<td>None</td>
</tr>
</tbody>
</table>