ATM (& B-ISDN)

(ATM = Asynchronous Transfer Mode)

- ATM is a connection-oriented, cell-based technique for the transfer of information
- ATM is not equivalent with B-ISDN
- The concept of QoS is important
- ITU-T (I-series) vs. ATM Forum recs/specs
Why use ATM?

Conventional circuit switched connection:
- After initial setup no processing in network nodes
- Fixed bit rates, fixed time delay

Conventional packet switched connection:
- Flexible bandwidth allocation due to statistical multiplexing, varying time delay
- Complex processing in network nodes

ATM somewhere inbetween:
- Minimal node processing, statistical multiplexing
Characteristics of ATM

ATM is a connection-oriented technique \(\Leftrightarrow\) the information in form of cells is routed through the network along a single path. Cells are always received in sequence.

The digital information is packed into ATM cells (5 octets header + 48 octets payload). Cells are transmitted through the network independently. Statistical multiplexing is possible.

An ATM connection is by definition unidirectional.

ATM supports (will support) higher layer service adaptation, different degrees of QoS and traffic management.
ATM is not equivalent with B-ISDN

ATM is a transmission technique which can be employed anywhere, wherever the network conditions permit:
   a) A company can implement its own ATM network, leasing physical lines from a network operator.
   b) A network operator could use ATM for internal traffic (so long as certain QoS conditions are fulfilled).
   c) Network operators may also provide fixed ATM connections for certain subscribers on a permanent contract basis (Permanent Virtual Circuits = PVC)

⇔ no signaling required, traffic management is optional!
B-ISDN is not equivalent with ATM

B-ISDN is often equated with ATM since B-ISDN is (at least in practice) based on ATM.

However, B-ISDN is a public network. In B-ISDN, there are the following two options:

a) Permanent Virtual Circuits (PVC), set up by the operator on a long-term contract basis

b) Switched Virtual Circuits (SVC), controlled by user signaling (ITU-T Q.2931).

Before a public switched ATM network can be implemented, a number of complex issues must be solved (standardized).
## Protocol reference model for B-ISDN

<table>
<thead>
<tr>
<th>Control plane</th>
<th>User plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher protocol layers</td>
<td>Higher protocol layers</td>
</tr>
<tr>
<td>AAL layer</td>
<td>AAL layer</td>
</tr>
<tr>
<td>ATM layer</td>
<td></td>
</tr>
<tr>
<td>Physical layer</td>
<td></td>
</tr>
</tbody>
</table>

- **Management plane**
- **Convergence sublayer (CS)**
- **Segmentation and re-assembly sublayer (SAR)**
- **STM-N or cell-based**
ATM network connection

**Originating node**
- Upper layer
- AAL
- ATM layer
- Physical layer

**ATM network nodes**
- ATM switching within the ATM layer
- ATM layer
- Phy

**Terminating node**
- Upper layer
- AAL
- ATM layer
- Physical layer

**UNI**
- VPI 1, VCI 1
- NNI
- VPI 2, VCI 2
- UNI
- VPI 3, VCI 3
Functions of the Physical layer

1. The *physical medium sublayer* (lower sublayer) handles and adapts bits as they are fed to the physical medium (e.g., electro-optical conversion)

2. The *transmission convergence sublayer* (upper sublayer) converts the flow of cells from the ATM layer into a continuous bit stream (and vice versa), involving:
   - Cell rate decoupling (bit rate adaptation)
   - Cell delineation (generally using HEC)
   - Mapping of cells into, e.g., the VC-4 payload
   - Calculation and verification of HEC
Functions of the ATM layer

1. To create the ATM cell by generating / adding a header to the information field received from the AAL (and performing the reverse operation at the receiving end)

2. To multiplex and demultiplex the ATM cell flows from different connections using appropriate identifiers (VCI and VPI) located in the cell headers

3. To perform cell switching, routing, and/or relaying within the ATM network (also using VCI and VPI)

4. To provide mechanisms for flow control and other traffic management functions.
ATM cell header structure (UNI)

<table>
<thead>
<tr>
<th>Octet</th>
<th>GFC</th>
<th>VPI</th>
<th>VCI</th>
<th>VCI</th>
<th>PTI</th>
<th>CLP</th>
<th>HEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>VPI</td>
<td>VCI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>VPI</td>
<td>VCI</td>
<td>VCI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>VPI</td>
<td></td>
<td></td>
<td>VCI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>VCI</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HEC</td>
</tr>
</tbody>
</table>

GFC  Generic Flow Control  HEC  Header Error Control
VPI  Virtual Path Identifier  PTI  Payload Type Indicator
VCI  Virtual Channel Identifier  CLP  Cell Loss Priority

NNI (between ATM network nodes):  GFC => VPI
Virtual Path/Channel Connection

See Figure G.3.3 in ”Understanding Telecommunications”

NOTE – VCI\textsubscript{a} and VCI\textsubscript{b} represent two of the possible values of VCI within the VP link with the value VPI\textsubscript{x}. Similarly, VPI\textsubscript{x} and VPI\textsubscript{y} refer to two of the possible values of VPI within the physical layer connection.
Function of PTI bits (UNI)

4 3 2
0 0 0 User data cell, no congestion. ATM user-to-ATM-user indication = 0
0 0 1 User data cell, no congestion. ATM-user-to-ATM-user indication = 1
0 1 0 User data cell, congestion experienced. ATM-user-to-ATM-user indication = 0
0 1 1 User data cell, congestion experienced. ATM-user-to-ATM-user indication = 1

1 0 0 OAM F5 segment associated cell
1 0 1 OAM F5 end-to-end associated cell
1 1 0 Resource management cell
1 1 1 Reserved for future VC functions

can be used in AAL functions (not really part of ATM layer)
ATM Adaptation Layer (AAL)

Implemented in the terminal nodes only (network aspects are not addressed, these are covered by the ATM layer)

**CS:** flow and timing control, error correction, handling of lost and misinserted cells, (also SAR functionality)

<table>
<thead>
<tr>
<th>SAR: payload</th>
<th>hdr</th>
<th>SAR-PDU</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATM cell payload</td>
<td>hdr</td>
<td>ATM Layer PDU</td>
</tr>
</tbody>
</table>
## Service classes vs. AAL protocols

<table>
<thead>
<tr>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
<th>Class D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing sensitive</td>
<td>Timing insensitive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBR</td>
<td>VBR (Variable bit rate)</td>
<td></td>
<td>CL</td>
</tr>
<tr>
<td>Connection-oriented</td>
<td></td>
<td>AL 1</td>
<td>AAL 2, AAL 3/4, AAL 5</td>
</tr>
</tbody>
</table>

- Speech
- Circuit emulation
- LAN emulation
- Frame relay
AAL protocols

AAL 1: constant bit rate, minimum delay (variation)

AAL 2: variable bit rate, minimum delay (variation)

AAL 3/4: variable bit rate, not time sensitive, complex
         (primarily for SMDS, CBDS services)

AAL 5: variable bit rate, not time sensitive
       less complex, better error control than AAL 3/4
       no retransmission mechanisms
       (Frame relay, LAN emulation, signaling)
AAL 5

"Internet compatible" => popular, replacing AAL 3/4

- CPCS-PDU
  - payload
  - pad
  - hdr
- SAR-PDU
  - last SAR-PDU => PTI LSB = 1
- Length of payload, CRC error checking
- ATM cell
# ATM layer service performance

<table>
<thead>
<tr>
<th>ITU-T I.371 &quot;Transfer Capability&quot;</th>
<th>ATM Forum TM4.0 &quot;Service Category&quot;</th>
<th>Typical use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deterministic Bit Rate (DBR)</td>
<td>Constant Bit Rate (CBR)</td>
<td>Voice transmission</td>
</tr>
<tr>
<td>(for further study)</td>
<td>Real-Time Variable Bit Rate (RT-VBR)</td>
<td>Compressed video signal transmission</td>
</tr>
<tr>
<td>Statistical Bit Rate (SBR)</td>
<td>Non-Real-Time Var. Bit Rate (NRT-VBR)</td>
<td>Statistical multiplexing (data services)</td>
</tr>
<tr>
<td>Available Bit Rate (ABR)</td>
<td>Available Bit Rate (ABR)</td>
<td>Resource efficient transmission mode</td>
</tr>
<tr>
<td>(no equivalent)</td>
<td>Unspecified Bit Rate (UBR)</td>
<td>Best effort, no guarantees</td>
</tr>
<tr>
<td>ATM Block Transfer (ABT)</td>
<td>(no equivalent)</td>
<td>Burst level feedback control</td>
</tr>
</tbody>
</table>
**DBR / CBR:** Specified for connections that require a certain amount of bandwidth, characterized by a Peak Cell Rate (PCR) value that is continuously available during the entire connection lifetime. The source may emit cells at or below the PCR at any time and for any duration (or may be silent).

Typical applications:

1. Voice (standard 64 kbit/s PCM)
2. Video (uncompressed)
3. Circuit Emulation Services (CES), e.g. carrying PDH signals over ATM connections

This category is mainly intended for (but not restricted to) tightly constrained CTD and CDV services (see next slides).
**DBR:** The ITU-T recommends that this *Transfer Capability* be used for *QoS Class 1* with stringent QoS requirements and the following performance objectives (see next three slides):

- **Cell Transfer Delay (CTD):** mean CTD < 400 ms
- **Cell Delay Variation (CDV):** difference between upper and lower $10^{-8}$ quantiles of CTD < 3 ms
- **Cell Loss Ratio (CLR):** $< 3 \times 10^{-7}$

(the following also for QOS *Class 2* and *Class 3*)

- **Cell Error Ratio (CER):** $< 4 \times 10^{-6}$ ($< 4 \times 10^{-7}$ proposed)
- **Cell Misinsertion Rate (CMR):** $< 1 / \text{day}$
- **Severely Errored Cell Block Ratio (SECBR):** $< 10^{-4}$
QoS classes (ITU-T)

Whereas the ATM Forum utilizes individual QoS parameters, the corresponding ITU-T network performance parameters are associated with four QoS classes (see ITU-T I.356):

<table>
<thead>
<tr>
<th>ATM transfer capabilities</th>
<th>Applicable QoS class</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBR, SBR1, ABT/DT, ABT/IT</td>
<td>Class 1 (stringent class)</td>
</tr>
<tr>
<td>DBR, SBR1, ABT/DT, ABT/IT</td>
<td>Class 2 (tolerant class)</td>
</tr>
<tr>
<td>SBR2, SBR3, ABR</td>
<td>Class 3 (bi-level class)</td>
</tr>
<tr>
<td>Any transfer capability</td>
<td>U class (no QoS parameters)</td>
</tr>
</tbody>
</table>

*QoS class should not be confused with Service class (A…D).*
## NPO:s of QoS classes (ITU-T)

ITU-T I.356 p.24

<table>
<thead>
<tr>
<th>Netw. perf. parameter</th>
<th>QOS Class 1</th>
<th>QOS Class 2</th>
<th>QOS Class 3</th>
<th>QOS U Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTD</td>
<td>400 ms</td>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>CDV</td>
<td>3 ms</td>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>CLR</td>
<td>3 E-7</td>
<td>E-5</td>
<td>E-5</td>
<td>U</td>
</tr>
<tr>
<td>CER</td>
<td>4 E-6</td>
<td>4 E-6</td>
<td>4 E-6</td>
<td>U</td>
</tr>
<tr>
<td>CMR</td>
<td>1 / day</td>
<td>1 / day</td>
<td>1 / day</td>
<td>U</td>
</tr>
<tr>
<td>SECBR</td>
<td>E-4</td>
<td>E-4</td>
<td>E-4</td>
<td>U</td>
</tr>
</tbody>
</table>

U - unspecified
**RT-VBR:** Specified by the ATM Forum for services with stringent time requirements ("real-time applications"), like CBR / DBR above, but with variable bit rate.

**NRT-VBR:** Specified by the ATM Forum for variable bit rate services without stringent time requirements ("non-real-time applications").

In both VBR service categories, we need to specify the following traffic parameters:

- Peak Cell Rate (PCR)
- Sustainable Cell Rate (SCR)
- Maximum Burst Size (MBS)

ITU-T utilizes the traffic parameter *IBT* instead of *MBS*. 
The ITU-T version of NRT-VBR. Consequently, this Transfer Capability is used for variable bit rate services with no stringent time requirements. Available as SBR1…SBR3.

Again, we need to specify the following traffic parameters:

- Peak Cell Rate (PCR)
- Sustainable Cell Rate (SCR)
- Intrinsic Burst Tolerance (IBT), a function of PCR, SCR and MBS (ITU-T I.371, p.20)

SCR is an upper bound on the average cell rate of an ATM connection, defined over a ”long” time interval.

MBS is the maximum number of consecutive cells allowed at the peak cell rate.
**ABR**: A relatively new concept. Based on flow control from the network (employing *Resource Management* = *RM cells*). In ABR, we need to specify the following traffic parameters:

- Peak Cell Rate (PCR)
- Minimum Cell Rate (MCR)

*MCR* is a bound (0 < MCR < PCR) on the cell rate that the network supports under all conditions. The cell rate of the source may be 0 … MCR at worst, 0 … PCR at best.

Typical applications:

- LAN emulation / LAN interconnection
- File transfer (critical applications)
Available Bit Rate (ABR)

- Peak cell rate (PCR) (may not be exceeded by source)
- Minimum cell rate (MCR) (always guaranteed by network)
- Zero cell rate

Service costs more

Service costs less
**UBR:** No QoS requirements. The only traffic parameter of interest is the PCR.

UBR supports a high degree of statistical multiplexing.

Typical applications:
- File transfer (non-critical applications)
- E-mail

**ABT:** An *ATM block* is defined as a group of cells located between two RM cells.

*ABT with delayed transmission (ABT/DT):* the Block Cell Rate (BCR) of each ATM block is negotiated separately.

*ABT with immediate transmission (ABT/IT):* no feedback from the network \(\Rightarrow\) cells can be discarded.
### Service Category attributes (ATM Forum)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>ATM Layer Service Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBR</td>
</tr>
<tr>
<td><strong>Traffic Parameters</strong></td>
<td></td>
</tr>
<tr>
<td>PCR</td>
<td>specified</td>
</tr>
<tr>
<td>SCR, MBS</td>
<td>n/a</td>
</tr>
<tr>
<td>MCR</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>QoS Parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Max CTD</td>
<td>specified</td>
</tr>
<tr>
<td>Max pp CDV</td>
<td>specified</td>
</tr>
<tr>
<td>CLR</td>
<td>specified</td>
</tr>
<tr>
<td><strong>Other attributes</strong></td>
<td></td>
</tr>
<tr>
<td>Feedback</td>
<td>Unspecified</td>
</tr>
</tbody>
</table>
No simple one-to-one mapping always possible between:

- Service classes A … D (upper layers)
- AAL 1, AAL 2, AAL 3/4, AAL 5 (AAL)
- 4 Transfer capabilities / 5 Service categories (ATM layer)
- 4 QoS classes / QoS parameters (network)
Traffic management in ATM

The role of traffic management is to protect the network and terminals from congestion in order to achieve certain network performance objectives (NPO:s).

An additional role is to promote the efficient use of network resources (efficient bandwidth resource allocation).

Recs/Specs:  

| ITU-T: I.371 | ATM Forum: TM 4.0 |

Terminology:  

4 transfer capabilities / 5 service categories  
traffic parameters (PCR, SCR, MCR, MBS)  
network performance parameters  ↔  
4 QoS classes / individual QoS parameters
Traffic management (cont.)

1. Negotiation of traffic contract before transmission

Traffic contract involves traffic descriptors and network performance / QoS parameters or QoS classes

2. Traffic control mechanisms (enforcement of contract)

Connection Admission Control (CAC): the network decides if a connection request can be accepted

Usage Parameter Control (UPC): the network detects violations of negotiated parameters and takes appropriate action (e.g., cell discarding or cell tagging)

Feedback control (e.g., flow control of ABR service)
ATM internetworking

Terminal                  IWF                  ATM network                  Terminal

Upper layer

Service specific protocol (SSP)

PHY

Upper layer

SSP

SSCS

CP AAL

ATM

PHY

ATM

ATM

PHY

Service specific UNI  Service specific CS  Common part AAL  ATM UNI