ATM
Asynchronous Transfer Mode
...revisited
ACN 2007
ATM GOAL

To establish connections between an arbitrary number of hosts ... 

... over channels that fulfills a certain QoS – level.

-> ATM networks make it possible!
Basics

- ATM characteristics
- Addressing, Routing, Signaling
- ATM header structure
- ATM Layer
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer

How does an ATM-network look like?

![ATM Network Diagram]
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer

What kind of service is used?

connection oriented

- Virtual Channels/Circuits (VC)
- VC establishing before transmission (connection setup -> PVC, SVC)
- (VPI + VCI) to identify such a Virtual Channel
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer

Packet switched

- 53-byte packets -> cells
  (5 byte header, 48 byte payload)
- fixed cell size
  advantages: hardware implementation, parallelization, improve queue-control, find cell boundaries ...
- transferred asynchronous???
How work the switches?

- statistical multiplexing of the cells
  - many VCs on one link (port)
  - no disordering of cells!

```
+-----------------+                      +-----------------+
| De-multiplexing | | switching    | | multiplexing   |
| (VCl_in, port)  | | fabric       | | (QoS)          |
|                 | | table        | | (VCl_out, port)|
+-----------------+                      +-----------------+
```

discard

output
6 categories of services: (ATM Forum)

- CBR – constant bit rate
- VBR-RT – variable bit rate-real time
- VBR-NRT – variable bit rate-non real time
- ABR – available bit rate
- UBR – unspecified bit rate
- GBR – guaranteed bit rate (extension to UBR)
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer

- ABR (Available bit rate):
  - Source follows network feedback.
  - Max throughput with minimum loss.
- UBR (Unspecified bit rate):
  - User sends whenever it wants. No feedback. No guarantee. Cells may be dropped during congestion.
- CBR (Constant bit rate): User declares required rate. Throughput, delay and delay variation guaranteed.
- VBR (Variable bit rate): Declare avg and max rate.
  - nrt-VBR (non-real time): Stored video.
each of that service defines several of the traffic parameters:

- PCR – peak cell rate
- BT – burst tolerance
- MCR – minimum cell rate
- SCR – sustainable cell rate
- MBL – maximum burst length

QoS parameters:

- CLR – cell loss ratio
- CDV – cell delay variation
- CTD – cell transfer delay
- Mean CTD – mean cell transfer delay...
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer

How do we attain a certain QoS – level?

**signaling process:**
- negotiate traffic parameters (specify service category) and QoS parameters
  
  = CAC (call admission control) -> reject/accept VC
- allocate resources: bandwidth, buffer ... on the VC

**transfer process:** (traffic shaping -> end-stations)
- flow control
- congestion control
  
  fields in the ATM header

Compare to Traffic Policing (GCRA) Generic Cell Rate Algorithm
QoS Terms II

- **Generic Cell Rate Algorithm GCRA(I,L)**
  - $I =$ Increment = Inter-cell Time = Cell size/PCR
  - $L =$ Limit → Leaky bucket of size $I + L$ and rate 1

Leaky Bucket Algorithm

- If $F < 0$: Non-Conforming Cell
- If $F > L$: Conforming Cell
- $F = X - (t - LCT)$
- $X = F + I; LCT = t$
- $F = 0$
How do we attain a certain QoS – level?

**ATM ABR Congestion Control: EFCI:**
- **EFCI:** *explicit forward congestion indication:*
  - Based on negative feedback ("bad things are happening") to sender
  - Congested node (queue length > threshold) marks EFCI bit in sender-to-receiver cell
  - Receiver sees EFCI set and notifies sender
  - Sender *decreases* cell rate:
    - ACR: allowed cell rate
    - $ACR = \max(ACR \times \text{multiplicative decrease}, MCR)$
  - Sender *increases* cell rate if no negative feedback in an update interval:
    - $ACR = \min(ACR + \text{additive_increase}, PCR)$

*EFCI bit: second bit of the three-bit PTI field*
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer

How do we attain a certain QoS – level?

ATM ABR Congestion Control: **explicit rates**

- Sender declares every Nth cell as "RM" cell:
  - RM: resource management
  - Records its PCR, allowed_cell_rate in RM cell
  - ER (explicit rate) field in RM cell: used by switches to set source rate

- Switch on sender-to-receiver path: if congested
  - Determine new rate for that source (consider PCR, ACR)
  - set ER field to indicate new rate only if new rate less than current ER value

Sender

Receiver
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer

SUMMARY

- Connection-Oriented, Packet-Switched Service
- Fixed Cell Size
- Statistical Multiplexing at the switches
- Negotiating QoS-level for each connection
- Control mechanisms based on ATM header info
**ATM header UNI/NNI (ATM Layer)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>3</th>
<th>1</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFC</td>
<td>VPI</td>
<td>VCI</td>
<td>PTI</td>
<td>CLP</td>
<td>HEC</td>
</tr>
</tbody>
</table>

GFC ... generic flow control (only UNI, NNI: GFC is part of VPI)
VPI ... virtual path identifier
VCI ... virtual channel identifier
PTI ... payload type identifier (EFCI-bit)
CLP ... cell loss priority
HEC ... header error checksum (CRC-8)
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – **ATM Layer**

The ATM **Reference Model**

- **Physical Layer**
  - **Bit Stream**
  - **ATM Cell**
    - **ATM Header**: 5 bytes
    - **Payload**: 48 bytes
    - **Total**: 53 bytes

- **ATM Layer**
  - **Data Stream**
  - **higher-layer applications** (e.g. HTTP->TCP->IP)

- **AAL**
  - **Management Plane**
  - **Control Plane**
  - **User Plane**

- signalling
ATM Layer

- Common Flow Control (*generic flow control* GFC)
- Cell Switching (based on VPI/VCI)
- Cell Multiplexing, De-multiplexing

Physical layer

- TC: Cell rate de-coupling, HEC generate/verify transmission frame adaptation, cell delineation,
- PMD: Bit-*timing*, Physical Medium
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Layer

• **TC Transmission convergence**
  • Cell rate de-coupling by adding idle cells: Sender and receiver have to operate independent in terms of cell-clock (⇒ „asynchronous“ in terms of ATM)
  • HEC: generate and verify the header error checksum HEC
  • cell delineation
    • Via cell delimiter
    • Via HEC-correlation,
• Physical media dependent (examples)
  • n*56/n*64 kbps
  • 1.5 / 2 Mbps (T1/E1)
  • 6 / 8 Mbps (T2/E2)
  • 25 Mbps
  • 45/34 Mbps (E3/T3)
  • 155 Mbps (OC3c)
  • 625 Mbps (OC12)
  • ...
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – **ATM Adaptation Layer (AAL)**

- segment data stream into **PDUs** (protocol data unit; likely to be application dependent)
- encapsulate a PDU (header and/or trailer)
  - > **CS-PDU**
- segment the CS-PDU into **SDUs** (service data unit)
- encapsulate a SDU (header and/or trailer)
  - > 48 byte payload
ATM characteristics – Addressing, Routing, Signaling – ATM Header

ATM Adaptation Layer

How a PDU, SDU and the corresponding header/trailer looks like is defined in 4 AAL-types:

<table>
<thead>
<tr>
<th>AAL 1:</th>
<th>CBR; voice, audio, video</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAL 2:</td>
<td>multiplexing of more streams; voice, audio, video (low bit-rate)</td>
</tr>
<tr>
<td>AAL 3/4:</td>
<td>ABR; data</td>
</tr>
<tr>
<td>AAL 5:</td>
<td>ABR; data (evolved from AAL 3/4, eliminates much overhead)</td>
</tr>
</tbody>
</table>
Switching Packets

**Datagram** or **connectionless** approach
- Every packet contains the complete destination address
- Forwarding table contains information for a switch how to forward a packet
- Data can take different path and can arrive out of order
- Hard to create the forwarding table in large networks

**Virtual circuit** or **connection oriented**
- Requires the setup of a virtual connection of two hosts before any data is sent
- Virtual circuit identifier (VCI) identifies the connection in combination with a virtual circuit (VC) table
- Data takes the same path and arrives in sequences
- 2 connection types: **Permanent vs. switched**
Switching Packets

**PVC** – Permanent virtual circuit
- Network administrator establishes and deletes virtual circuits

**SVC** – Switched virtual circuit
- A host sets up and deletes virtual circuit without the involvement of a network administrator -> **Signaling**

**Advantages:**
- Universal connectivity
- More efficient resource utilization

**ATM – Signaling:**
- The exchange of information specifically concerned with the establishment and control of connections in an ATM network is called signaling.
UNI vs. NNI

UNI: User-network interface;
P-NNI: Private network-network interface

User-to-network interaction
Network-to-network interaction

ATM switch

User-to-user interaction
ATM characteristics – Addressing, Routing, Signaling –
ATM Header structure – ATM Adaptation Layer

**Signaling:**

- Host A
- Ingress Switch
- Egress Switch
- Host B
- Topology state
- Destination address
- Source address

Traffic and QoS parameter
UNI vs. NNI

ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer

Cell header (5 Byte)

GFC (4 bit)

8 bit

16 bit

HEC (8 bit)

Cell payload (48 Byte)

Cell format (UNI)

GFC (4 bit)

8 bit

16 bit

HEC (8 bit)

Cell format (NNI)

Cell format (UNI)

Cell format (NNI)
Virtual Path and Virtual Channel

- ATM Physical Link
- Virtual Path (VP)
- Virtual Channels (VC)

ATM Physical Link Contains Multiple VPs
Virtual Path (VP) Contains Multiple VCs
Virtual Channel (VC) Logical Path Between ATM End Points

Connection Identifier = VPI/VCI
How do we establish a VC?

**Addressing:**
- unique for each host
- 20 bytes (6 byte MAC included)
- 3 types (DCC, ICD, NSAP)
- ...
3 different ATM-addressing schemes are defined

- **Data country code** (DCC) Format (20 Byte)
- **International code designator** (ICD) Format (20 Byte)
- **Network service access point** (NSAP) by E.164 (20 Byte)

**E.164** is an ITU-T recommendation which defines the international public telecommunication numbering plan used in the PSTN
ATM characteristics – Addressing, Routing, Signaling – ATM Header
structure – ATM Adaptation Layer

NSAP    network service access point
AFI     authority and service identifier
IDI     international domain identifier
ICD     international code designator (BSI)
DCC     data country code (ISO)
IDP     initial domain part (AFI + IDI)
DSP     domain specific part
ESI     end system identifier
SEL     selector (like link type field)
Signaling:

- to define the route from the source host to the destination host -> VC
- calculate a desired VC according to:
  - source address and destination address
  - topology state (nodes, links)
  - traffic and QoS parameters ...
  - -> DTL (Desired Transit List)
- source routing
- generalized Dijkstra algorithm (OSPF)
Connection Setup
1. host A sends a setup message
   (destination address, traffic and QoS parameter, high-level protocol bindings, ...)
2. ingress switch calculates a DTL and adds it to the message (routing)
3. the setup message follows the DTL to every switch specified, setting up the table in the switch fabric
4. host B sends the message back (also table setup)
ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer

Switch 1

<table>
<thead>
<tr>
<th>VCI-in</th>
<th>port</th>
<th>VCI-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>7</td>
</tr>
</tbody>
</table>

(VCI) with local validity
Every switch along the path specified by the DTL and the destination host can reject the VC. This might require another try by the ingress switch, a so-called crank-back. When there is a node or link failure, the VC is terminated and needs to be re-established. VC teardown occurs with a teardown message.
Point-to-Point (PTP) Connection

- Data may flow in one or both directions (unidirectional or bi-directional)
Point-to-Multipoint (PTM) Connection

- Data is replicated by the network
- Data flows only from Root to Leaves

“Root”

“Leaves”
Inititate a PTP Connection

 мер UNI 4.0 specifies the signalling protocols used across UNI [http://www.atmforum.org/]

 мер UNI 4.0 specification is based on the Q.2931 public network signalling protocol developed by the ITU-T
Initiate a PTP Connection

ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer
Accept a Connection

ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer
Reject a Connection ...
User clears a connection ...

ATM characteristics – Addressing, Routing, Signaling – ATM Header structure – ATM Adaptation Layer
Network clears a connection...
Overview Multipoint Connection …

- Initiated by a setup message from the root node to a single leaf node.
- Root can send Add Party and Drop Party messages to add/delete leaves in an existing connection.
- Leaf-Initiated Join Capability: Leaf node can join existing connection with or without the intervention of the root node.
UNI Specifications …

UNI 4.0: The functions are a superset of UNI3.1 and include both - a mandatory core of functions and many optional features:
- Anycast Services
- Explicit signalling of QoS across the UNI
- MPC (MPOA Client): Leaf initiated joins are supported
**ILMI**

- *Integrated Local Management Interface* provides diagnostic, monitoring and configuration services across the UNI.
- ILMI uses the Simple Network Management Protocol (SNMP) and a Management Information Base (MIB).
- It allows neighbouring hosts to determine various characteristics of each other e.g. the size of each other’s connection space, …
ILMI Address Registration

Here is My MAC Address (ESI) (00c0.acdc.3124.efa8)
What is My ATM Prefix?

Here is Your ATM Prefix 47.0090......
ISDN Signalling (vs. ATM)

- Separate user plane and control plane
  - \( \text{BRA: 2 B-ch. á 64 kbps, D-ch. 16 kbps} \)
  - \( \text{PRA: 30 B-ch. á 64 kbps, D-ch. 64 kbps} \)

<table>
<thead>
<tr>
<th>OSI layer</th>
<th>Network</th>
<th>Q.931</th>
<th>X.25</th>
<th>X.25</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Packet level</td>
<td>Packet level</td>
</tr>
<tr>
<td>Data link</td>
<td></td>
<td></td>
<td>LAP-D (Q.921, HDLC)</td>
<td>X.25</td>
</tr>
<tr>
<td>Physical</td>
<td></td>
<td></td>
<td>Layer 1 (I.430, I.431)</td>
<td>X.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Signal</td>
<td>Packet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Control plane, D-channel</td>
<td>User plane, B-channel</td>
</tr>
</tbody>
</table>
ISDN Signalling (vs. ATM)