Chapter 3:
ATM Networks

TOPICS
– The ATM header
– The ATM protocol stack
– The physical layer
– ATM switch architectures
– ATM adaptation layers
– IP over ATM
Asynchronous Transfer Mode (ATM)

- The word *Asynchronous* in ATM is in contrast to *Synchronous* Transfer Mode (STM) that was proposed earlier on, which was based on the SONET/SDH hierarchy.
- *Transfer Mode* refers to a telecommunication technique
• ATM was standardized by ITU-T (old CCITT) in 1988 as the transfer mode of B-ISDN
• It can carry a variety of different types of traffic, such as
  – Voice
  – Video
  – Data
At speeds varying from fractional T1 to 2.4 Gbps
• These different types of traffic have different Quality-of-Service (QoS) requirements, such as:
  – *Packet loss*
  – *End-to-end delay*

• ATM, unlike IP networks, can provide each traffic connection a different type of quality of service.
Some features of ATM

- Connection-oriented packet-switched network
- Fixed cell (packet) size of 48+5 bytes
- No error protection on a link-by-link
- No flow control on a link-by-link
- Delivers cells in the order in which they were transmitted
The structure of the ATM cell

UNI cell format

1 2 3 4 5 6 7 8

<table>
<thead>
<tr>
<th>Byte</th>
<th>GFC</th>
<th>VPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>VPI</td>
<td>VCI</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>VCI</td>
<td>PTI</td>
</tr>
<tr>
<td>5</td>
<td>HEC</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Information payload

NNI cell format

1 2 3 4 5 6 7 8

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<tr>
<th>Byte</th>
<th>VPI</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>VPI</td>
</tr>
<tr>
<td>3</td>
<td>VCI</td>
</tr>
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<td>HEC</td>
</tr>
<tr>
<td>53</td>
<td></td>
</tr>
</tbody>
</table>

Information payload
Fields in the ATM cell header

- GFC
- Connection identifier: VPI/VCI,
- Payload type indicator (PTI)
- Cell loss priority (CLP)
- Head error control (HEC)
ATM connections

- Identified by the combined fields
  - *virtual path identification* (VPI), and
  - *virtual channel identification* (VCI)

- VPI field:
  - 256 virtual paths at the UNI interface, and
  - 4096 virtual paths at the NNI interface.

- VCI field:
  - a maximum of 65,536 VCIs.
• VPI/VCI values have local significance. That is, they are only valid for a single hop.
• A connection over many hops, is associated with a different VPI/VCI value on each hop.
• Each switch maintains a switching table. For each connection, it keeps the incoming and outgoing VPI/VCI values and the input and output ports.
Label swapping

A

ATM switch 1

VPI=30
VCI=41

ATM switch 2

VPI=30
VCI=53

VPI=40
VCI=62

30 41 1
30 53 4
40 62 2
10 89 3

ATM switch 3

VPI=10
VCI=89

VPI=50
VCI=77

10 89 1
50 77 6

D

C

B

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PVCs and SVCs

• Depending how a connection is set-up, it may be
  – *Permanent virtual circuit* (PVC)
  – *Switched Virtual circuit* (SVC)

• PVCs are set-up administratively. They remain up for a long time.

• SVCs are set-up in real-time using ATM signalling. Their duration is arbitrary.
Payload type Indicator

- **PTI**  **Meaning**
  - 000  User data cell, congestion not experienced, SDU type=0
  - 001  User data cell, congestion not experienced, SDU type=1
  - 010  User data cell, congestion experienced, SDU type=0
  - 011  User data cell, congestion experienced, SDU type=1
  - 100  Segment OAM flow-related cell
  - 101  End-to-end OAM flow-related cell
  - 110  RM cell
  - 111  Reserved
Head Error Control (HEC)

- **Correction mode**:
  - No error detected (No action)
  - Single bit error detected (correction)

- **Detection mode**:
  - No error detected
  - Multiple bit error detected (cell discarded)
  - Error detected (cell discard)
The ATM protocol stack

<table>
<thead>
<tr>
<th>voice</th>
<th>Video</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATM adaptation layer</td>
<td>ATM layer</td>
<td>Physical layer</td>
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</tbody>
</table>
The physical layer

• The physical layer transports ATM cells between two adjacent ATM layers.

• It is subdivided into
  – *transmission convergence* (TC) sublayer
  – *physical medium-dependent* (PMD) sublayer.
The transmission convergence (TC) sublayer

- **HEC cell generation and verification**
  - Implements the HEC state machine
- **Decoupling of cell rate**
  - Maintains a continuous bit stream by inserting idle cells
- **Transmission frame generation and recovery**
  - Such as SONET frames
- **Cell delineation**
**Cell delineation** is the extraction of cells from the bit stream received from the PMD sublayer.
• **Physical medium dependent (PMD)**
  – *Timing function*
    • Used to synchronize the transmitting and receiving PMD sublayers.
  – *Encoding/decoding*
    • PMD may operate on a bit-by-bit basis or using block coding such as 4B/5B and 8B/10B schemes.
ATM physical layer interfaces

- SONET/SDH
- Plesiochronous digital hierarchy (PDH)
- Nx64 Kbps
- Inverse multiplexing for ATM (IMA)
- Asymmetric digital subscriber line (ADSL)
- APON
The ATM layer

• The ATM layer is concerned with the end-to-end transfer of information, i.e., from the transmitting end-device to the receiving end-device.

• Below, we summarize its main features.
Connection-oriented packet switching

- The ATM layer is a connection-oriented point-to-point packet-switched network with fixed-size packets (known as cells).
- A connection is identified by a series of VPI/VCI labels, as explained above, and it may be point-to-point or point-to-multipoint.
- Cells are delivered to the destination in the order in which they were transmitted.
Cell switching in ATM networks is carried out at the ATM level

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No error and flow control on each hop

- Low probability of a cell getting lost or delivered to the destination end-device in error.
- The recovery of the data carried by lost or corrupted cells is expected to be carried out by a higher-level protocol, such as TCP.
- When TCP/IP runs over ATM, the loss or corruption of the payload of a single cell results in the retransmission of an entire TCP PDU.
Addressing

- Each ATM end-device and ATM switch has a unique ATM address.
- Private and public networks use different ATM addresses. Public networks use E.164 addresses and private networks use the OSI NSAP format.
- ATM addresses are different to IP addresses.
Quality of service

- Each ATM connection is associated with a quality-of-service category.
- Each quality-of-service category is associated with a set of traffic parameters and a set of quality-of-service parameters.
- The ATM network guarantees the negotiated quality-of-service for each connection.
Congestion control

• In ATM networks, congestion control permits the network operator to carry as much traffic as possible without affecting the quality of service requested by the users.

• It consists of call admission control and a policing mechanism.
The ATM adaptation layer

• The purpose of AAL is to isolate higher layers from the specific characteristics of the ATM layer.

• AAL consists of the
  – *convergence* sublayer, and the
  – *segmentation-and-reassembly* sublayer.
The AAL sublayers

Convergence Sublayer

Service Specific Convergence Sublayer (SSCS)

Common Part Sublayer (CPS)

Segmentation and Reassembly

SAP
ATM Adaptation Layer 1 (AAL 1)

• This AAL can be used for applications such as:
  – *circuit emulation services*
    • It emulates a point-to-point TDM circuit over ATM
    • Used to provide an interconnection between two PBXs over a private or public ATM network
The SAR encapsulation for AAL 1

- **SAR Header**
  - SN
  - SNP
  - 47 bytes

- **Payload**
  - CSI: 1 bit
  - Sequence count: 3 bits
  - CRC-3: 3 bits
  - Parity: 1 bit

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The AAL 1 CS functions:

1. **Handling of cell variation**
   - Due to queueing delays, inter-arrival times of cells vary (jitter).

   - CS writes received data into a buffer, and then delivers the information to the application at constant bit rate.
2. *Processing of the sequence count*
   - The sequence count values are processed by CS in order to detect lost or misinserted cells. Detected misinserted cells are discarded. In order to maintain bit count integrity of the AAL user information, it may be necessary to compensate for lost cells by inserting dummy SAR-PDU payloads.

3. *Forward error correction*
   - For video and high quality audio forward error correction may be performed in order to protect against bit errors. This may be combined with interleaving of AAL user bits to give a more secure protection against errors.
4. Transfer of timing information

a. Synchronous residual time stamp (SRTS):
   CS conveys to the receiver in the CSI field the difference between a common clock derived from the network and the sender’s clock

b. Adaptive clock method:
   The receiver writes the received information into a buffer and reads out from the buffer. If its clock is fast/slow the occupancy in the buffer will be below/over the median
5. **Structured and unstructured data transfers**

Two CS-PDU formats have been defined:

*a. CS-PDU non-P format:*

Constructed from 47 bytes of information supplied by an AAL user

*b. CS-PDU P format:*

Constructed from a 1-byte header and 46 bytes of information supplied by an AAL use.

The header consists of a 7-bit pointer (*SDT pointer*) and 1 even bit parity.
Circuit Emulation Services

- The structured and unstructured data transfers are used in Circuit Emulation Services (CES), which emulate a T1/E1 link over ATM.
- CES is implemented in an *interworking function* (IWF).

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• **Unstructured service**
  
  – The entire DS1/E1 signal is transported by packing it bit by bit into the 47-byte payload of a CS-PDU non-P format, which is then carried by an ATM cell.

  47 bytes -> 376 bits -> less than 2 DS-1 frames (193 bits/frame)
ATM Adaptation Layer 2 (AAL 2)

- Defined for delay sensitive applications with a low bit rate, such as voice and voiceband traffic (facsimile, modem traffic)
- AAL 2 is used to interconnect two distant public or private telephone networks over an ATM network.
• At the sender, AAL 2 multiplexes several streams onto the same ATM connection
• At the receiver, it de-multiplexes the date from the connection to the individual streams.
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The SSCS and CPS sublayers

- The AAL 2 services are provided by the convergence sublayer, which is subdivided into the
  - Service Specific Convergence Sublayer (SSCS)
  - Common part sublayer (CPS).
Functional model of AAL 2 (sender side)

- Each stream is served by a separate SSCS which is associated with a CID
SSCS for AAL 2 trunking

• A specialized SSCS has been developed to support “ATM trunking using AAL 2 for narrowband services”.

• It is described in Chapter 12
CPS-packets and CPS-PDUs

- A transmitting SSCS uses a timer to decide when to pass on the data to CPS.
- Data from an SSCS is packed into a **CPS-packet**
- CPS-packets from different SSCSs are packed into a **CPS-PDU**, which is exactly 48 bytes and it is carried in an ATM cell
Packing CPS-packets into CPS-PDUs
The structure of the CPS-packet and CPS-PDU
The CPS-packet fields

- **Channel identifier (CID) - 8 bits:**
  - Identifies a channel. Same value is used for both directions.
  - CIDs are allocated using the AAL negotiation procedures (ANP)

- **Packet payload type (PPT) - 2 bits:**
  - Indicates whether it carries voice or network management data

- **Length indicator (LI) - 6 bits:**
  - Default maximum length of the CPS-packet payload is 45 bytes.

- **Header error control (HEC) - 5 bits:**
  - Pattern is: $x^5 + x^2 + 1$.

- **User-to-user-indication (UUI) - 3 bits:**
  - Used to transfer information transparently between the peers.
CPS-PDU fields

**Offset field** (*OSF*) (6 bits)

- Used to identify the beginning of a CPS-packet. It points to the first new CPS-packet in the CPS-PDU payload
- In the absence of a new CPS-packet, it points to the beginning of the pad
- The value of 47 indicates that there is no beginning of a CPS-packet in the CPS-PDU.
An example

```
#1
OSF =0

#2
OSF=21

#3
OSF=9

#4
```

```
20
20
20
20

48
27
21
21

35
26
9

20
20
20
20
```
ATM adaptation layer 5 (AAL 5)

- Very popular AAL due to its simplicity
- A user-PDU is encapsulated and then broken up to fragments, each carried by an ATM cell
- AAL 5 consists of
  - Convergence sublayer (CS)
    - SSCS
    - CPS
  - Segmentation and reassembly (SAR).
CPS

- Provides a non-assured transfer operation.
- User-PDUs of a length up to 65,535 bytes can be transferred.
- Erroneous CPS-PDU can be detected at the receiver’s side. No recovery of an erroneous CS-PDU takes place. Instead, an indication is sent to the higher-level application.
CPS encapsulation

<table>
<thead>
<tr>
<th>User-PDU</th>
<th>Pad</th>
<th>CPS-UU</th>
<th>CPI</th>
<th>Length</th>
<th>CRC-32</th>
</tr>
</thead>
</table>

- **Pad**: from 0 to 47 bytes, so that the entire CPS-PDU becomes an integer multiple of 48 bytes. The User-PDU can be up to 65,535 bytes.
- **CPS User-to-user indication (CPS-UU)**: 1-byte field
- **Common part indicator (CPI)**: 1-byte field for future use
- **Length**: 2-byte field gives length of User-PDU.
- **CRC pattern**: 4-byte field contains the FCS calculated using the pattern $x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1$. 

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SAR sublayer - transmitter

- SAR segments a CPS-PDU into a sequence of 48-byte segments.
- No additional encapsulation
- Each segment is carried in the payload of an ATM cell
- Last cell has its PTI marked with SDU=1.
SAR sublayer - Receiver

• SAR appends payloads of the ATM cell into a buffer until
  
1. It encounters an SDU=1 in PTI field
   • It checks the CRC and then passes the PDU to the application above with an indication as to whether it is correct or not.

2. Buffer is exceeded
   • It passes the PDU to the application above with an indication that buffer was exceeded.