ATM

Topics

Introduction
ATM Architecture Overview
ATM Cell
ATM Connections
Addressing and Signaling
ATM Layer Services
IP over ATM
Introduction

Broadband Integrated Services Networks

• In the mid-1980s, the ITU-T (formerly CCITT) initiated a standardization effort to merge voice, video and data on a single network.

• The goal was to replace all existing networks (telephony networks, Cable TV network, data networks) with a single network infrastructure. The effort was called B-ISDN (Broadband Integrated Services Digital Networks).

• The technology selected for B-ISDN was Asynchronous Transfer Mode (ATM) and SONET/SDH (Synchronous Optical Network/Synchronous Digital Hierarchy).
Traditional Network Infrastructure

Company A
- Telephone network
- Data network
- Video network
- Residential user x

Company B

B-ISDN

Company A
- Broadband Integrated Services Network (B-ISDN)

Company B
- Residential user x
ATM: The official definition

- **CCITT Definition (I.113, Section 2.2)**

  - A transfer mode in which the information is organized into cells; it is asynchronous in the sense that the recurrence of cells containing information from a particular user is not necessarily periodic.

Why “asynchronous”?

**Synchronous transfer mode** (= Time division multiplexing)
- Each source gets period assignment of bandwidth
  - good: fixed delays, no overhead
  - bad: poor utilization for bursty sources

**Asynchronous transfer mode** (= Statistical multiplexing)
- Sources packetize data. Packets are sent only if there is data
  - good: no bandwidth use when source is idle
  - bad: packet headers, buffering, multiplexing delay
ATM's Key Concepts

- **ATM uses Virtual-Circuit Packet Switching**
  - ATM can reserve capacity for a virtual circuit. This is useful for voice and video, which require a minimum level of service.
  - Overhead for setting up a connection is expensive if data transmission is short (e.g., web browsing).

- **ATM packets are small and have a fixed sized**
  - Packets in ATM are called **cells**.
  - Small packets are good for voice and video transmissions.

  ![Cell Structure](image)

  **Cell is 53 byte long**

53 Byte Cells

- **Why 53 Bytes?**
  A 48 byte payload was the result of a compromise between a 32 byte payload and a 64 byte payload.

- **Advantages**
  - Low packetization delay for continuous bit rate applications (video, audio).
  - Processing at switches is easier.

- **Disadvantages**
  - High overhead (5 Bytes per 48).
  - Poor utilization at lower line rates links.
ATM Standardization

- Until 1991, standardization occurred within CCITT (now: ITU-T) in a series of recommendations in the I series
- In 1991, ATM Forum was formed as an industry consortium
  - ATM Forum starts to prepare specifications to accelerate the definition of ATM.
  - Specifications are passed to ITU-T for approval
  - Since 1993, ATM Forum drives the standardization process
- IETF publishes Request for Comments (RFCs) that relate to IP/ATM issues

Uses of ATM

- B-ISDN vision
- ATM on the desktop
- Internet vision
- Fast Ethernet
- ATM on the desktop
- IP-over-ATM
- ATM Enterprise backbones
- MPLS (in core)
- HFC networks
- GigEthernet
- Special purpose applications with QoS demands
- DOCSIS
- Access Networks (xDSL)
- Frame Relay transport
- Voice trunking
ATM Architecture
Overview

The ATM Reference Model

- ATM technology has its own protocol architecture

```
Control Plane  User Plane
Upper Layer  Upper Layer
ATM Adaptation Layer (AAL)
ATM Layer
Physical Layer
```

- End-to-end layer
- Transfer of Cells
- Transmission of Bits
Layers of ATM

Function of the Layers

- Convergence
- Segmentation and Reassembly
- Generic Flow Control
- Cell VPI/VCI translation
- Cell multiplexing and demultiplexing
- Cell header generation and extraction
- HEC header sequence generation and verification
- Cell delineation
- Transmission frame generation and recovery
- Bit timing
- Physical medium

AAL
ATM
TC
Physical
PM

TC: transmission convergence
PM Physical medium
ATM Layer

- The ATM Layer is responsible for the transport of 53 byte cells across an ATM network

- Multiplex logical channels within a physical channel

ATM Layer

The ATM Layer can provide a variety of services for cells from an ATM virtual connection:

- **Constant Bit Rate (CBR)**
  - guarantees a fixed capacity, similar to circuit switching
  - guarantees a maximum delay for cells

- **Variable Bit Rate (VBR)**
  - guarantees an average throughput and maximum delay

- **Available Bit Rate (ABR)**
  - guarantees ‘fairness” with respect to other traffic

- **Unspecified Bit Rate (UBR)**
  - service is on a “best effort” basis

- **Guarantees Frame Rate (GFR)**
  - Throughput guarantee for multiple cell frames
ATM Adaptation Layer (AAL)

- AAL encapsulates user-level data
- Performs segmentation and reassembly of user-level messages

ATM Cells
**ATM Cells**

- 4-bit Generic flow control
- 8/12 bit Virtual Path Identifier
- 16 bit Virtual Channel Identifier
- 3 bit Payload Type
- 1 bit Cell Loss Priority
- 8 bit Header Error Control
- 48 byte payload
- **GFC field only in UNI cells**

<table>
<thead>
<tr>
<th></th>
<th>GFC</th>
<th>VPI</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>VPI</td>
<td>VCI</td>
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<td>4</td>
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<td>5</td>
<td></td>
<td>HEC</td>
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<tr>
<td>6-53</td>
<td>Payload</td>
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</table>

**UNI Cell**

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**ATM Cells**

- 4-bit Generic flow control
- 8/12 bit Virtual Path Identifier
- 16 bit Virtual Channel Identifier
- 3 bit Payload Type
- 1 bit Cell Loss Priority
- 8 bit Header Error Control
- 48 byte payload
- At NNI: GFC byte is used for additional VPI

<table>
<thead>
<tr>
<th></th>
<th>VPI</th>
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<tr>
<td>2</td>
<td>VPI</td>
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<td>3</td>
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<tr>
<td>4</td>
<td>VCI</td>
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<td>5</td>
<td>PT</td>
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<tr>
<td>6-53</td>
<td>Payload</td>
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</tbody>
</table>

**NNI Cell**

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ATM Connections

A Packet Switch

Packet

Packet switch

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Forwarding with VCs

Part 1: VC setup
from X to E

<table>
<thead>
<tr>
<th>n_in</th>
<th>V_in</th>
<th>n_out</th>
<th>V_out</th>
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<tbody>
<tr>
<td>X</td>
<td>5</td>
<td>C</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>E</td>
<td>3</td>
</tr>
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</table>

Forwarding the packet

<table>
<thead>
<tr>
<th>n_in</th>
<th>V_in</th>
<th>n_out</th>
<th>V_out</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>5</td>
<td>D</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>B</td>
<td>5</td>
</tr>
</tbody>
</table>

Part 2: Forwarding
the packet

<table>
<thead>
<tr>
<th>n_in</th>
<th>V_in</th>
<th>n_out</th>
<th>V_out</th>
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</thead>
<tbody>
<tr>
<td>D</td>
<td>5</td>
<td>E</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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Virtual Paths and Virtual Circuits

VPI identifies virtual path (8 or 12 bits)
VCI identifies virtual channel in a virtual path (16 bits)

VPI/VCI assignment at ATM switches

<table>
<thead>
<tr>
<th>port</th>
<th>VPI/VCI</th>
<th>VPI/VCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3/24</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>1/24</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>2/17</td>
<td>3</td>
</tr>
</tbody>
</table>

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Addressing and Signaling

ATM Endsystem Addresses (AESA)

- All ATM addresses are 20 bytes long
- Source and destination address are supplied when setting up a connection
- ATM endpoints use the NSAP (Network Service Access Point) format from ISO OSI
- Three different types of addresses
  - NSAP encoding for E.164: ISDN telephone numbers (e.g., 001-434-9822200)
  - DCC format: for public networks
  - ICD format: for private networks
ATM Endsystem Addresses (AESA)

AFI (1 byte): Authority and Format Identifier
Tells which addressing scheme to use

IDI (2-8 bytes): Initial Domain Identifier
Identifies a domain within scope of addressing authority

HO-DSP (4-10 bytes): High-order bits of domain specific part
similar to network prefix of IP address

ESI (6 bytes): Endsystem identifier
similar to host number of IP address

SEL (1 byte): Selector
for endsystem use only

 Formats of an ATM address

AFI: Authority and Format Identifier
IDI: Initial Domain Identifier
DCC: Data Country Code
ICD: International Code Designator
E.164: ISDN (telephone) Number

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Example: Default Assignment of ATM addresses by Cisco Systems

47.00918100000001604799FD01.0050A219F03B.0

Which Address Format To Use?

- Currently each service provider makes its own choice
  - This introduces problems (SVC compatibility)

- Most ATM switches support multiple formats

- ATM Forum prepares standards to translate addresses at network boundaries (NNI interfaces)
  - Interworking of ATM Networks (IAN)
ATM UNI Signaling

- Significant Signaling Protocols

- ATM Forum:
  - UNI 3.0. UNI signaling protocol for point-to-point connections.
  - UNI 3.1. Supports point-to-multipoint connections.
  - UNI 4.0. Supports Leaf initiated join multipoint connections
  - PNNI. for network node signaling

- The ATM Forum signaling specifications are based on the Q.2931 public network signaling protocol developed by the ITU-T.
  - specifies a call control message format
    - message type (setup, call proceeding, release)
    - Addresses
    - AAL parameters
    - Quality of Service (QoS)

Basic Signaling Exchange: Setup of a SVC
Basic Signaling Exchange: Tear down

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ATM Layer Services
**ATM Services at the ATM Layer**

The following ATM services have been defined:
- **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)**
- **Guaranteed Frame Rate (GFR)**

**ATM Network Services**

<table>
<thead>
<tr>
<th>Traffic Parameters</th>
<th>QoS Parameters</th>
</tr>
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<tbody>
<tr>
<td>Service</td>
<td>Bandwidth</td>
</tr>
<tr>
<td>CBR</td>
<td>PCR</td>
</tr>
<tr>
<td>rt-VBR</td>
<td>PCR, SCR</td>
</tr>
<tr>
<td>nrt-VBR</td>
<td>PCR, SCR</td>
</tr>
<tr>
<td>ABR</td>
<td>PCR, MCR</td>
</tr>
<tr>
<td>UBR</td>
<td>PCR*</td>
</tr>
<tr>
<td>GFR</td>
<td>PCR, MCR, MBS, MFS</td>
</tr>
</tbody>
</table>

- CDVT characterizes an interface and is not connection specific
- PCR in UBR is not subject to CAC or UPC

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Constant Bit Rate (CBR)

- For applications with constant rate requirements: video and audio
- Very sensitive to delay and delay variations
- Adaptation Layer: AAL1

Variable Bit Rate (rt-VBR, nrt-VBR)

- For applications with variable rate requirements: compressed audio and video (rt-VBR) data applications (nrt-VBR), such as transactions
- Adaptation Layer: AAL2, AAL 3/4, AAL5

Example: 30 sec MPEG-1 trace (from Terminator)
- Peak rate: 1.9 Mbps
- Avg. rate: 0.261 Mbps
Available Bit Rate (ABR)

- For applications that can tolerate changes to rate
- Interconnection of LANs
- Transmission rate (ACR) changes between MCR and PCR
- ACR is set by a feedback algorithm (to be discussed)
- Adaptation Layer: AAL 5

Unspecified Bit Rate (UBR)

- "Best effort service"
  - No bandwidth, loss, or delay guarantees
  - UBR gets the bandwidth that is not used by CBR, VBR, ABR
- No UPC and no feedback
- Applications: Non-critical data applications (file transfer, web access, etc.)
- Adaptation Layer: AAL 5
Guaranteed Frame Rate (UBR)

- For non-real-time applications which guarantee a minimum rate guarantee
- Recognizes AAL5 boundaries
  - Frame consists of multiple cells
  - If a cell is dropped, remaining cells from that frame will be dropped as well
- Minimum rate (MCR) is guaranteed by network, the rest (up to PCR) is delivered on a best effort basis.
- Adaptation Layer: AAL5

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IP-over-ATM
Issues with sending IP traffic over ATM

• Address resolution:
  - IP address $\leftrightarrow$ VPI/VCI
  - IP address $\leftrightarrow$ ATM address

• Emulation of broadcast operation on IP subnetworks

• Routing

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IP Networks 1 (simplified)

$\rightarrow$ Recall: IP is a datagram packet switching network

- Hosts and routers are connected to “subnet”. Subnets are connected by routers.
- IP packets (datagrams) to hosts on the same subnet are send directly
- IP datagrams to hosts on a different subnet are sent to a router
Sending datagram to host on the same subnet (assume Ethernet)
→ Host must translate IP address into MAC address
  (MAC address = physical address)
→ ARP protocol performs function:
  → Sender broadcasts ARP message
  → Destination replies

Solutions for IP-over-ATM

- Classical IP over ATM → by IETF
- Next Hop Resolution Protocol (NHRP) → by IETF
- LAN emulation (LANE) → by ATM Forum
- Multiprotocol over ATM → by IETF
Classical IP over ATM

- ATM network card is treated like an Ethernet card
- ATM Network consists of multiple logical subnets
- IP datagram is encapsulated and then passed to AAL5

Logical IP Subnetwork (LIS)

- Each host has a VC to the ATMARP server
  - ATMARP translates between IP and ATM addresses
- Each host connects to another host on the same LIS with a dedicated VC
- IP datagrams to hosts on a different subnet are sent to router
Problem with Classical IP-over-ATM

- ATMARP server only resolve addresses for a single LIS
- Traffic from A to B goes through two IP routers, even though both hosts are on the same ATM network