ATM

Asynchronous Transfer Mode
Protocol Architecture (diag)

- Management Plane
- Control Plane
- User Plane
- Higher Layer
- ATM Adaptation Layer (AAL)
- ATM Layer
- Physical Layer
Reference Model Planes

- **User plane**
  - Provides for user information transfer

- **Control plane**
  - Call and connection control

- **Management plane**
  - Plane management
    - whole system functions
  - Layer management
    - Resources and parameters in protocol entities
ATM Connection Relationships
ATM

— Virtual channels and virtual paths

- **Virtual channel connections** (VCC): logical connections in ATM
  - a VCC is analogous to a virtual circuit in X.25
  - VCCs are the basic unit of switching in an ATM network
  - VCCs are also used for user-network exchange, i.e. control signaling, and for network-network exchange, i.e. network management and routing.

- **Virtual path connection** (VPC): a bundle of VCCs that have the same endpoints
  - i.e. all of the cells flowing over all the VCCs in a single VPC are switched together.
Advantages of using virtual paths

- **simplified network architecture:**
  - transport function can be separated into those dealing with an individual virtual channel and those dealing with a group of virtual logical connections, i.e. the virtual path

- **increased network performance and reliability**

- **reduced processing and short connection setup time**
  - *once the virtual path is set up, much of the work is done.* When capacity in the virtual path is reserved in anticipation of later calls, new virtual channels can be established. This is done via simple control functions at the endpoints of the virtual path.

- **flexible network services**
  - virtual paths are visible to the user, i.e. user can define closed user groups or closed networks of virtual-channel bundles.
Call Establishment Using VPs
Virtual Channel Connection

Uses

• Between end users
  — End to end user data
  — Control signals
  — VPC provides overall capacity
    • VCC organization done by users

• Between end user and network
  — Control signaling

• Between network entities
  — Network traffic management
  — Routing
ATM Cells

- Fixed size
- 5 octet header
- 48 octet information field
- Small cells reduce queuing delay for high priority cells
- Small cells can be switched more efficiently
- Easier to implement switching of small cells in hardware
ATM Cell Format

(a) User-Network Interface

(b) Network-Network Interface
ATM

ATM Cell Formats: user - network, network - network

PTI: 000 – user data, no congestion, SDU type 0
001 – user data, no congestion, SDU type 1
010 – user data, congestion, SDU type 0
011 – user data, congestion, SDU type 1
100 –
101 –
110 –
111 –

Network control

SDU = service data unit

GFC = Generic flow control
VPI = Virtual path identifier
VCI = Virtual channel identifier
PTI = Payload type identifier
CLP = Cell loss priority
HEC = Header error checksum

Hal96 fig. 10.7
ATM

— ATM cell format

- Generic flow control (GFC)
  - used in user-network interface only
  - enables local switch or remote concentrator unit to regulate the entry of cells by the user into the network

- Virtual path identifier (VPI)
  - used for identification and routing purposes within the network
  - 8 or 12 bits for respective cells (user-network or network-network)

- Virtual channel identifier (VCI)
  - 16 bit for channel identification and routing purposes

- Payload type indicator (PTI)
  - different types of information can be carried in the cell
  - cells with user data have a 0 in the msb

- Cell loss priority (CLP)

- Header error checksum (HEC) 8 bit CRC on first 4 Bytes
Header Error Control

- 8 bit error control field
  - HEC = Header Error Control
- Calculated on remaining 32 bits of header
- Polynomial is $X^8 + X^2 + X + 1$
- Allows some error correction
HEC Operation at Receiver

HEC: Header Error Control

Figure 11.5  HEC Operation at Receiver
Effect of Error in Cell Header

Flowchart:
- **Incoming Cell**
  - Error in Header? (Yes/No)
    - Yes: Error Detected?
      - Yes: Error Determined to be Incorrectable?
        - Yes: Discarded Cell
        - No: Successful Correction Attempt
      - No: Unsuccessful Correction Attempt
      - Yes: Apparent Valid Cell with Erroned Header (unintended service)
    - No: Current Mode?
      - Yes: Detection Mode
      - No: Correction Mode
- Valid Cell (intended service)
Impact of Random Bit Errors
Transmission of ATM Cells

- ... 
- 622.08Mbps 
- 155.52Mbps 
- 51.84Mbps 
- 25.6Mbps 

- Cell Based physical layer 
- SDH based physical layer
ATM

—On-demand connections
  • initiated by user device
  • send request for a *switched virtual connection* (SVC) to central control unit called *signaling control point* (SCP)
  • SCP manages transmission bandwidth and switched connections thought the network.
  • SCP receives *signaling messages* over separate permanent VCs.

—Permanent VC (PVC)
  • useful if number of servers is large
  • PVC is established between workstations & servers and central forwarding point called *connectionless server*. 
ATM

- Call Processing
  - Two types of traffic in ATM LAN
    - traffic between multiservice workstations and their associated servers
    - traffic between bridges/routers that are the interface to the legacy LANs
  - Two types of calls for multiservice workstations
    - connection oriented
    - connectionless
ATM

—Connection Oriented

• Caller contacts Signaling Control Point (SCP) with destination address and data parameters.
• SCP forwards to dest.
• If dest. accepts, then SCP setup up Virtual Path Identifier/Virtual Channel Identifier (VPI/VCI) across network.
ATM

—Connectionless

• two methods to support interworking between ATM workstations and a workstation that is connected to a legacy LAN:
  – LAN Emulation (LE)
    • LE client (LEC), LE server (LES), LE configuration server (LECS), LE Broadcast and unknown address Server (BUS)
    • Use an LE ARP protocol to determine destination ATM address, establish connection and use until idle for timeout
  – IP over ATM
    • Use LE as a router
Cell Based Physical Layer

- No framing imposed
- Continuous stream of 53 octet cells
- Cell delineation based on header error control field
Cell Delineation State Diagram

- **HUNT**
  - Bit by bit
  - Correct HEC
- **PRESYNC**
  - Cell by cell
  - Incorrect HEC
  - \( \alpha \) consecutive incorrect HEC
- **SYNC**
  - Cell by cell
  - \( \delta \) consecutive correct HEC

- State Diagram Flow:
Impact of Random Bit Errors on Cell Delineation Performance

Average amount of time that receiver will maintain synchronization in the face of error

In-sync time $T_d(\rho)$ in cell units

Bit error probability ($\rho_e$)

for 155.52 Mbps

$\alpha = 9$

$\alpha = 7$

$\alpha = 5$

$10^{-6}$ $10^{-5}$ $10^{-4}$ $10^{-3}$ $10^{-2}$

$10^5$ $10^{10}$ $10^{20}$ $10^{30}$ $10^{40}$

$1$ second

$1$ minute

$1$ day

$10^{10}$ years

$10^{20}$ years
Acquisition Time v Bit Error Rate

Average amount of time to acquire synchronization as a function of error rate
SDH Based Physical Layer

- ATM can be used over
  - SDH = *Synchronous Digital Hierarchy* or
  - SONET
- Imposes structure on ATM stream
  - e.g. for 155.52Mbps
  - Use STM-1 (STS-3) frame
- Can carry ATM and STM payloads
  - STM = *Synchronous transfer mode*
- Specific connections can be circuit switched using SDH channel
- SDH multiplexing techniques can combine several ATM streams
payload capacity is $260 \times 9 = 2340$ octets
since 2340 is not an integer multiple of 53, cells may cross payload boundary
ATM Service Categories

• Real time
  — Constant bit rate (CBR)
  — Real time variable bit rate (rt-VBR)

• Non-real time
  — Non-real time variable bit rate (nrt-VBR)
  — Available bit rate (ABR)
  — Unspecified bit rate (UBR)
Real Time Services

- Amount of delay
- Variation of delay (jitter)
Constant Bit rate

• Fixed data rate continuously available
• Tight upper bound on delay
• Uncompressed audio and video
  — Video conferencing
  — Interactive audio
  — A/V distribution and retrieval
rt-variable bit rate

- Time sensitive application
  - Tightly constrained delay and delay variation
- rt-VBR applications transmit at a rate that varies with time
- e.g. compressed video
  - Produces varying sized image frames
  - Original (uncompressed) frame rate constant
  - So compressed data rate varies
- Can statistically multiplex connections
**nrt-variable bit rate**

- May be able to characterize expected traffic flow
- Improve QoS in loss and delay
- End system specifies:
  - Peak cell rate
  - Sustainable or average rate
  - Measure of how bursty traffic is
- e.g. Airline reservations, banking transactions
Unspecified bit rate

- May be additional capacity over and above that used by CBR and VBR traffic
  - Not all resources dedicated
  - Bursty nature of VBR
- For application that can tolerate some cell loss or variable delays
  - e.g. TCP based traffic
- Cells forwarded on FIFO basis
- Best efforts service
Available bit rate

- Application specifies peak cell rate (PCR) and minimum cell rate (MCR)
- Resources allocated to give at least MCR
- Spare capacity shared among all ARB sources
- e.g. LAN interconnection
ATM Adaptation Layer

• Support for information transfer protocol not based on ATM

• PCM (voice)
  — Assemble bits into cells
  — Re-assemble into constant flow

• IP
  — Map IP packets onto ATM cells
  — Fragment IP packets
  — Use LAPF over ATM to retain all IP infrastructure
Adaptation Layer Services

- Handle transmission errors
- Segmentation and re-assembly
- Handle lost and misinserted cells
- Flow control and timing
Supported Application types

- Circuit emulation
- VBR voice and video
- General data service
- IP over ATM
- Multiprotocol encapsulation over ATM (MPOA)
  - IPX, AppleTalk, DECNET
- LAN emulation
ATM Protocol Layers

- Protocol Layers

![ATM Protocol Layers Diagram]

Management Plane

Control Plane

User Plane

Layer Management Plane Management

Higher Layer

ATM Adaptation Layer (AAL)

ATM Layer

Physical Layer
ATM Protocol Layers

- AAL (ATM adaptation layer)
  - Designed to interface between users and ATM.
  - Responsible for marshaling/unmarshaling data into/out-of cells
  - Different types needed, depending on service
    - AAL 1 (guaranteed bit rate, e.g. voice, connection oriented)
    - AAL 2 (variable bit rate, e.g. compressed video, connection oriented)
    - AAL 3/4 (connectionless)
    - AAL 5 (simple and efficient adaption layer SEAL)
ATM Protocol Layers

- ATM Layer
  - Responsible for routing and bridging
  - Includes buffering and switching
  - VC setup and termination
ATM

ATM adaptation layer

<table>
<thead>
<tr>
<th>Service type</th>
<th>AAL 1</th>
<th>AAL 2</th>
<th>AAL 3/4</th>
<th>AAL 5</th>
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<tbody>
<tr>
<td>Timing relationship</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
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<tr>
<td>Bit rate</td>
<td>Constant</td>
<td>Variable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td>Connection-oriented</td>
<td>Connectionless</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hal96 fig. 10.12

AAL

SAR Sublayer protocols

CS protocols

Timing and cell loss recovery (AAL 1/2)
Cell loss detection (AAL 3/4/5)

Segmentation and reassembly

SAP 1
SAP 2
SAP 3/4
SAP 5

Satisfies interface requirements
Processes cell payload

SAP 1
SAP 2
SAP 3/4
SAP 5

ATM

Physical

Processes cell header
Transports cells

CS = Convergence sublayer
SAR = Segmentation and reassembly
AAL Protocols

AAL

- AAL User
- Convergence Sublayer (CS)
- Segmentation and Reassembly (SAR) Sublayer
- ATM Layer
- Physical Layer

User Data

CS PDU

SAR PDU

ATM cell

SAR PDU

ATM cell

SAR PDU

ATM cell

SAR PDU

ATM cell
Segmentation and Reassembly

PDU

(a) AAL Type 1

(b) AAL Type 3/4

(c) AAL Type 5

SN = sequence number (4 bits)
SNP = sequence number protection (4 bits)
ST = segment type (2 bits)
MID = multiplexing identification (10 bits)
LI = length indication (6 bits)
CRC = cyclic redundancy check (10 bits)
AAL Type 1

- Constant bit rate (CBR) source
- SAR packs and unpacks bits
- Block accompanied by sequence number
AAL Type 2

- VBR
- Analog applications
AAL Type 3/4

- Connectionless or connected
- Message mode or stream mode
AAL Type 5

- Streamlined transport for connection oriented higher layer protocols
CPCS PDUs

(a) AAL Type 3/4

CPCS-PDU header | CPCS-PDU payload | pad | CPCS-PDU trailer

CPI | Btag | BASize | AL | Etag | Length

CPI = common part indicator (1 octet)
Btag = beginning tag (1 octet)
BASize = buffer allocation size (2 octets)
AL = alignment (1 octet)
Etag = end tag (1 octet)
Length = length of CPCS-PDU payload (2 octets)

(b) AAL Type 5

CPCS-PDU payload | pad | CPCS-PDU trailer

CPCS-UU | CPI | Length | CRC

CPCS-UU = CPCS user-to-user indication (1 octet)
CPI = common part indicator (1 octet)
Length = length of CPCS-PDU payload (2 octets)
CRC = cyclic redundancy check (4 octets)
Example AAL 5 Transmission

CPCS = common part convergence sublayer
SAR = segmentation and reassembly
PDU = protocol data unit
CPCS-T = CPCS trailer
ATM-H = ATM header
SDU = Service Data Unit type bit

ATM cell

ATM-cell payload

SDU 1
SAR-PDU payload
SAR-PDU

SDU 0
SAR-PDU payload
SAR-PDU

SDU 0
SAR-PDU payload
SAR-PDU

Higher layer PDU
CPCS-PDU payload
pad
CPCS-PDU
CPCS-PDU

SDU 0
SAR-PDU payload
SDU 0
SAR-PDU payload
SDU 0
SAR-PDU payload
Summary

• Asynchronous Transfer Mode (ATM)
• architecture & logical connections
• ATM Cell format
• transmission of ATM cells
• ATM services