DigiPoints Volume 1

Leader Guide

Module 12 – Asynchronous Transfer Mode

Summary

This last module of *DigiPoints, Volume 1*, covers ATM, and provides an end-to-end data communications model that draws on all twelve chapters of this volume.

Outcomes

Students who complete this lesson will know the basic attributes and characteristics of the cell-based packet technology known as ATM. They will have been introduced to the concept of "bandwidth on demand" and the way that ATM provides it. Finally, students will be shown how data is communicated between a dial-up telephone connection and a cable modem connection to the Internet, using an end-to-end data communications model.

Objectives

Upon successful completion of the module, the student should be able to:

- Describe how ATM technology differs from a packet or Frame Relay system.
- Explain how Asynchronous Transfer Mode is carried on a synchronous transport such as SDH or SONET.
- Identify the six basic fields found in the ATM header.
- Explain how ATM fulfills bandwidth on demand.
- Identify the ATM Protocol Layers and relate them to the OSI Model.
- Explain the relationship of ATM to Broadband ISDN (B-ISDN).
- Explain the purpose of ATM Adaptation Layers, and identify the five ATM Adaptation Layer types.
- Describe the process and the network elements involved when sending data from a terminal with a dial-up connection to a terminal with a cable modem connection via the Internet.

Prerequisites

Students should have read Chapter 12 of *DigiPoints, Volume 1*.

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Length

90 minutes

Pre-assignment for Students

None

Materials/Preparation for Instructor

- One workbook per student
- Visual Aids
- Instructor should read Chapter 12 of *DigiPoints, Volume 1.*

Supplies/Equipment

- Dry Erase Board/Markers, chalkboard or flipchart
- Masking Tape
- Pointing Tool
- Tent Cards

Audience

The intended audience will be mid- to senior-level technicians or other associates who are seeking an understanding of digital basics.

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Module Outline

This is an introductory level module that will provide a review of the following topics:

Objectives 1
Introduction 2
Asynchronous Transfer Mode 3
Bandwidth on Demand 6
ATM Protocol Layers 7
ATM Adaptation Layer Types 10
Connection Modes 11
ATM Summary & Limitations 12
Putting it all Together: An End-to-End Data Communications Model 13
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Objectives

EXPLAIN

REFER TO WB 12.1

Tell students that when they have completed this module, they will be able to accomplish these objectives.

- Describe how ATM technology differs from a packet or Frame Relay system.
- Explain how Asynchronous Transfer Mode is carried on a synchronous transport such as SDH or SONET.
- Identify the six basic fields found in the ATM header.
- Explain how ATM fulfills bandwidth on demand.
- Identify the ATM Protocol Layers and relate them to the OSI Model.
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Introduction

ASK DISCUSS

What type of technology is this, i.e., circuit switched or packet switched?

Answer:

◊ *Packet Switched*

Use as intro and as a way to evaluate skill base of students.

What is ATM designed to carry?

Answer:

◊ *Voice, data, video*

What does "open standards" mean to providers?

Answer:

◊ *Interoperability of equipment from multiple vendors.*

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Asynchronous Transfer Mode

What is ATM?

DISPLAY VA 12.1
DISCUSS WB 12.2

ATM is a cell-switched technology.

- Cell is a fixed-length PDU.
- ATM cell is 53 bytes long.
- It is similar to another cell-based technology called SMDS.
  - ◊ SMDS was designed for computer data, not multimedia.

ATM is a de facto standard that provides for:

- Voice, Video, Data.
- End-to-End OAM&P with multiple vendors.
- Works with all multimedia forms.
- Designed to be used with SONET and SDH.

OAM&P = Operations, Administration, Maintenance, and Provisioning

DISPLAY VA 12.2
DISCUSS WB 12.3

SONET & SDH

Synchronous **O**ptical **NET**work

Synchronous **D**igital **H**ierarchy

SONET OC-3 same as SDH STM-1

Prepare for this section by reviewing SONET in Module 5. To help students see the relationship of frame repetition rate to the STM-1 rate, lead them in calculating the bit rates of SDH STM-1 and SONET OC-3. Show ratio of overhead to information.

DISPLAY VA 12.3
DISCUSS WB 12.4

"Synchronous" refers to the fact that the STM-1 frame is repeatedly transmitted 8000 times per second.

- SONET/SDH is different from TDM technique.
- TDM uses bit stuffing to go to higher rates (e.g., T1 to T3).
- Cannot find a T1 in a T3 without demultiplexing.

SONET/SDH uses no bit stuffing.

- Can find lower-level signal in multiplexed signal without demultiplexing (e.g., any T1 in an STM-1).
- Makes possible cost effective add/drop.

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DISPLAY VA 12.4

ATM Benefits

"Asynchronous" in ATM refers to the way users place information on the network.

- Insertion is by cell, not bit or byte, at the physical layer.
- Provides bandwidth on demand.
- Bandwidth used as required.
- More efficient, less bandwidth waste.

Later section on Bandwidth on Demand includes an exercise to show how this works.

DISPLAY VA 12.5
DISCUSS WB 12.5

ATM Cell Structure

53 bytes: 5 bytes header, 48 bytes user information.

User information manipulated at higher OSI Layers.

- Exceptions: Maintenance cells and cells with Adaptation Layer data

***Prepare by reviewing layered protocol models, Chapter 7, p.142 in* DigiPoints, Volume One.**

Header is key to ATM operations.

Fields provide routing information, cell priorities in route queues, and error control.

- GFC = Generic Flow Control
- VPI & VCI = Virtual Path Indicator and Virtual Channel Indicator (routing)
- PTI = Payload Type Indicator
- CLP = Cell Loss Priority
- HEC = Header Error Control

Virtual Circuits and Virtual Paths

Virtual circuit is the way ATM routes data between points.

- Not hard-wired.
- Route can be different for each time data is sent (switched) or the same (permanent).

Virtual circuits consist of virtual channels and virtual paths.

- Virtual channels are "pipes within a pipe"
- Larger pipe is the virtual circuit.

A later section on Connection Modes illustrates this concept with analogy of a letter sent via US mail.

Permanent Virtual Circuits vs. Switched Virtual Circuits

- PVC specifies a predetermined route (connection-oriented).
- SVC provides dynamic route allocation (connectionless).
- SVC provides for variable Quality of Service.

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Bandwidth on Demand

ASK

How many ATM cells can be carried by an STM-1?

Answer:

◊ *Over 353,000*

Use the board to guide the students in calculating this information.

DISPLAY VA 12.6
DISCUSS WB 12.6

A user is not locked into a particular time slot or groups of time slots as in TDM.

The number of user cells placed on a line during a frame (125 microseconds) or set of frames determines the user's bandwidth.

Lead a discussion of bandwidth calculations while referencing VA 12.6

Instructor Note: These are critical points to understanding ATM. Emphasize that placing cells on the line when required makes this technology asynchronous and since each user can place as many cells on the line as needed, ATM achieves "Bandwidth on Demand."

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ATM Protocol Layers

DISPLAY VA 12.7
DISCUSS WB 12.7

Instructor Note: The purpose of this section on ATM protocol layers is to show that ATM achieves its bandwidth versatility and the ability to carry multimedia information by a relatively complex set of rules (protocol). Position this material as useful background about the "inner workings" of ATM, which will be helpful when students are reading other ATM references.

DISPLAY VA 12.8
DISCUSS WB 12.8 AND WB 12.9

The ATM protocol model was developed separately from the OSI Model.

- It evolved from the B-ISDN model
- ITU specifications
- Control & User Planes used, as in Frame Relay

Review of previous chapter's Frame Relay section may be needed

ATM Protocol model also includes a management plane.

Management plane has two functions:

- Plane Management coordinates activities across all planes.
- Layer Management handles operations and maintenance flows.

CONTINUE TO DISPLAY VA 12.8

B-ISDN Protocol Layer Functions

Three layers used within ATM.

- Physical Layer
- ATM Layer (OSI Layer 2)
- ATM Adaptation Layer (OSI Layer 2)

Higher layers are specific to B-ISDN.

- Used for Signaling & Routing

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CONTINUE TO DISPLAY VA 12.8

Physical Layer

Two sublayers

- Physical Medium (PM)
  - ◊ PM - Functions similar to OSI Physical Layer.
- Transmission Convergence (TC)
  - ◊ TC functions
    - ◊ Generates transmission frame
    - ◊ Maps cells into payload bytes
    - ◊ Identifies cell boundaries
    - ◊ Calculates HEC
    - ◊ Cell insertion/suppression
    - ◊ Creates operations and maintenance cells

ATM Layer

- Generates cell header
- Multiplexes/Demultiplexes cells
- Translates VPI & VCI information
- Flow Control

CONTINUE TO DISPLAY VA 12.8

ATM Adaptation Layer (AAL)

The AAL is responsible for:

- Interfacing to higher protocol levels.
- Transporting other protocols over ATM.

Primary functions include:

- Handling transmission errors
- Handling segmentation
- Flow Control
- Timing Control
- Handling lost or misread cells
- Definition of service classes
  - ◊ Service classes are combinations of timing relationships, bit rate, and connection mode.

DISPLAY VA 12.9
DISCUSS WB 12.10

There are five types of AAL – aligned with service classes.

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Each AAL type aligned with different format ATM cell.

- Class A – Circuit emulation – voice telephony
- Class B – Variable bit rate, audio & video
- Class C – Connection oriented data transfer – Frame Relay
- Class D – Connectionless transfer – SMDS

DISPLAY VA 12.10
DISCUSS WB 12.11

Sublayers within the ATM Adaptation Layer

Two sublayers

- Segmentation & Reassembly – SAR
- Convergence – CS

SAR

- Places PDUs greater than one ATM cell into sets of ATM cells.
- PDUs come from either higher layers or CS layer.
- Five different AAL types defined.

CS

- Fragments larger PDUs for SAR layer.

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ATM Adaptation Layer Types

DISPLAY VA 12.11
DISCUSS WB 12.12

There are five AAL protocol types.

- Type 1 – Class A, circuit emulation, clock recovery.
- Type 2 – Class B, adds trailer bits for user data payload and CRC.
- Type 3/4 – connection and connectionless services. Segments larger frames. ST and MID subfields added.
  - ◊ Allows more user data in each cell.
- Type 5 – 32 bit CRC in CS PDU.
  - ◊ Improves line efficiency

DISPLAY VA 12.12
DISCUSS WB 12.13

Type 5 requires layers to replace the usual AAL Convergence Sublayer.

- Service Specific Coordination Function Sublayer
- Service Specific Connection-Oriented Protocol Sublayer

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Connection Modes

DISPLAY VA 12.13
EXPLAIN AND DISCUSS

Instructor Note: Position this section as review and summary of the parts of the ATM cell and the types of routing specified by ATM.

ATM cell is like a letter being sent via US mail.

- Header is like the address on the envelope.
- Payload is like the letter inside the envelope.
- Connectionless service is like US mail routing.
  - ◊ Only guaranteed points within route are beginning and end.
- Connection-oriented service is like a courier route.
  - ◊ Same all the time.

ATM Summary & Limitations

DISPLAY VA 12.14
DISCUSS WB 12.14

- End-to-end multimedia communications
- Switched virtual circuit capability

BUT

- Standards not stable
- New hardware is costly
- Legacy systems are still operating

Standard Instability

- Proposed in 1986
- Recommended in 1989
- Specifications revised every 3-6 months
- Minor changes can be costly
- Different vendors sell different versions of the specification
- Customer can become trapped in one vendor solution
- Since 1996, revised once per year

ATM in Public Network Backbones

- Substantial in telco internal environment
- Used as backbone for Frame Relay
- ATM offerings coming from telco companies

ATM in Private Network Backbones

- Vendors are offering and customers are buying for private ATM networks

ATM-LAN Interfaces

- Via LAN switch with ATM port
- *Data Communications*, July 1997, reported that few problems exist

ATM in Cable Telecommunications Networks

- Early ’90s, after telcos tried it
- Trials with advanced digital set tops
- Works well, set top expensive
- Current view is to bring ATM up to the Network Interface Unit.

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Putting it all Together: An End-to-End Data Communications Model

DISPLAY VA 12.15
DISCUSS WB 12.15

E-mail example using the Internet.

- User A – Telco customer, 56 kbps modem to connect to corporate LAN
- User B – Cable customer with Cable Modem and NIC in PC. 10 Mbp access speed to cable ISP

Take time and go over this visual aid with students.

Network Architecture

User A

- Dial-up modem
- Twisted pair or equivalent to telco switch – narrowband service
- Access corporate LAN through modem pool
- Modems at corporate are nodes on LAN
- LAN accesses – Corporate ISP via a router
- Corporate ISP connects to public ATM Network – part of internet

User B

- Always connected via CATV fiber and/or coax plant
- Cable modem terminates at headend to a router or data switch
- This connects to Cable ISP
- Cable ISP is a node on public Frame Relay network – part of the Internet
- ATM and Frame Relay are interfaced within the Internet.

DISPLAY VA 12.16
DISCUSS WB 12.16

E-Mail Transfer

From User A to B

- Mail address: user name + Fully Qualified Domain Name (FQDN)
- User A connects to Corporate LAN
- Logon to Corporate LAN
- Send e-mail – LAN routes to ISP
- ISP forwards e-mail to User B via Internet
- E-mail is routed as a series of PDUs via ATM and Frame Relay
- Arrives at Cable ISP which stores message awaiting recovery

Example: FQDN scte.org.

Full address: userb@scte.org

Write this on board.

Prepare for potential questions on modem signaling by reviewing Module 2, and for questions on OSI levels by reviewing Module 7

DISPLAY VA 12.17
DISCUSS WB 12.17

User B logs on

- Headend router forwards request for e-mail to Cable ISP.
- Cable ISP connects User B to mailbox
- User B makes request at application layer (OSI Layer 7)

Real-Time Connections

Both users on line with their e-mail addresses

Example: Chat rooms

- Users must coordinate when on line or be advised
- ISP router assigns a temporary internet address to each user.
- ISP dynamically sends PDUs to each address vs. mailbox

Use the network diagram portion of 12.16 to explain this

Other Applications

- IP Telephony

  Instructor Note: IP telephony involves a much more complex architecture than e-mail retrieval. Gateways between the Public Switched Telephone Network and the Internet, for example, are needed to cross-reference dialed phone numbers to Internet addresses. IP telephony is covered in Volume 2 of DigiPoints.

- Videoconferencing
- Premium real time applications
  - ◊ Premium services bring premium prices

Summary

DISPLAY VA 12.18
DISCUSS WB 12.18

- Asynchronous Transfer Mode
- SONET/SDH
- ATM Cell
- Bandwidth on Demand
- ATM Protocol
- B-ISDN Protocol
- Adaptation Layer
- End-to-End Data Communications

Review these items

REFER TO WB 12.19 THROUGH WB 12.20

Have students answer the study questions at the end of Module 12. Review the answers.

Answers in Appendix

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Appendix

Answers to the questions at end of student workbooks.

1. Describe the ATM cell. Include the function of each of the fields in the ATM cell header.

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The ATM cell is 53 bytes long, consisting of a 5 byte header and 48 bytes of user information. The header fields have the following functions:

GFC: Generic Flow Control. This field is read and recognized by public ATM network equipment to control short-term traffic overloads.
VPI and VCI: Virtual Path Indicator and Virtual Channel Indicator. These fields provide routing information. The UNI uses an 8-bit VPI, while the NNI uses a 12-bit VPI. The VCI is always 16 bits long.
PTI: Payload Type Indicator. This field indicates whether the cell contains user data or network information, such as failure or alert conditions. The third bit in this field is used by another part of the ATM protocol to indicate the last cell of a multi-cell message. The PTI field is what makes it possible to have special cells for end-to-end system monitoring, reporting, and maintenance.
CLP: Cell Loss Priority. This bit may be set to "1" to indicate a low priority cell that may be discarded when there is network congestion. For variable bit rate services such as compressed video, this bit is critical to maintaining synchronization. It would be set to "0" for all cells carrying synchronization information.
HEC: Header Error Control. These 8 bits provide a Cyclic Redundancy Check (CRC) covering the first 4 octets of the header. It can be used for error detection or error correction.

2. What is the difference between the Plesiochronous Digital Hierarchy and the Synchronous Digital Hierarchy? Give an example of each.

Formatted: Bullets and Numbering

Plesiochronous means that switches and digital cross connect systems within this hierarchy are synchronized to an external timing source. PDH systems multiplex lower speed data streams onto high-speed transmission facilities by a system of bit stuffing that compensates for differences in timing between the low speed inputs. The North American Digital Hierarchy (DS-x signals) are an example.

Synchronous means the timing is built into the physical layer. SDH systems maintain timing throughout the multiplexing hierarchy without any randomly inserted stuffed bits between lower speed data. SONET is an example.

3. Derive the STM-1 signal bandwidth from its repetition rate.

Formatted: Bullets and Numbering

Given that the STM-1 signal repeats 8,000 times per second, the bit rate is: 2,430 octets x 8 bits per octet x 8,000 times per second, or 155.52 Megabits per second.

4. What is the mechanism for communication of operations and maintenance information in ATM?

Maintenance information is contained in special ATM cells.

5. If the ATM transport mechanism provides a 125 microsecond frame, calculate the number of ATM cells per frame needed to provide 6.144 Mbps of bandwidth. Do the same for 384 kbps of bandwidth.

2 cells per frame for 6.144 Mbps; 1 cell per 8 frames for 384 kbps.

6. What are the three basic layers to the B-ISDN protocol, and what are their purposes?

The three basic layers to the B-ISDN protocol reference model are the physical layer, the ATM layer, and the ATM Adaptation Layer. Although the correlation is not exact, the functions of the physical layer are comparable to the functions of OSI Layer 1, which is also called the Physical Layer. The functions of the ATM layer and the ATM Adaptation Layer are comparable to OSI Layer 2.

7. How and where in the B-ISDN protocol is Frame Relay service provided over ATM?

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The mechanism for Frame Relay service transport is provided in the ATM Adaptation Layer. Service class C provides for the combination of timing, bit rate and connection mode between source and destination that includes Frame Relay switching.

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8. You have been asked by your management to set up a data communications network for moving data from a PC attached to a cable modem to a public switched ATM network. What factors must you consider as you begin your design?

Some factors:

- *Become an ISP or use a commercial ISP.*
- *Rate of data transfer*
- *Access speeds to the ATM network*
- *Potential contention from multiple PCs on the cable company's high-speed data service*
- *Brand of cable modem*
- *Manufacturer support of all equipment*

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