Audiovisual Multimedia Services: MPEG-2 Over ATM

The ATM Forum

Topics

- MPEG Overview
- Issues and Challenges
- ATM Forum Decisions
- Summary
- Future Work
MPEG Overview

- MPEG (Moving Pictures Experts Group)
  - MPEG is a set of standards addressing:
    - compression of video and audio signals
    - synchronization of video and audio signals during the playback of MPEG data
- The ATM Forum has focused its effort on carrying MPEG-2 traffic over ATM networks

MPEG-2 Applications

- Real-time services
  - Digital video Cable TV networks
  - Video conferencing
  - Interactive TV
- Non real-time services
  - Multimedia CD-ROMs
  - Embedded audio/video in e-mails
Generic MPEG-2 System

Real time MPEG-2 Encoder

MPEG-2 Decoder

Video Monitor Encoder

Any Network

Video Server with previously encoded MPEG-2 programs

OR

MPEG-2 Packetization at Encoder

- MPEG-2 Program Stream
  - Variable length MPEG-2 packets
  - Can only contain a single program

- MPEG-2 Transport Stream
  - 188 byte MPEG-2 packets
  - Can contain multiple programs

Program = event with a common time-base
MPEG-2: Time-Stamps

- Time-stamps are used to reconstruct the source clock at the decoder and to maintain timing relationships between video and audio information packets.
  - Time-stamps are inserted into the MPEG-2 packets during the encoding and multiplexing process.

![Diagram of MPEG-2 Encoder and Decoder System]

MPEG-2 Decoder System

- Decoder receives the MPEG-2 Transport Stream.
- Presentation Time Stamp (PTS) is used for synchronization.
- Coded Video and Coded Audio are decoded by separate decoders.
- Clock Recovery and System Time Clock (STC) are used for time synchronization.
- The decoded video is displayed on the monitor.
Why Standardize MPEG-2 over ATM?

- ATM-based networks will be used to carry real-time multimedia traffic
- ATM technology was developed with the intent of seamlessly carrying ALL types of traffic
  - Not all of the issues to accomplish this have been addressed yet
- Standards-based solutions must be specified for these networks
  - Without this, interoperability of multiple multimedia ATM networks will not be possible

MPEG-2 over ATM: Issues and Challenges

- “MPEG-2 Systems, Video, and Audio all have a timing model in which the end-to-end delay from the signal input to an encoder to the signal output from a decoder is a constant. This delay is the sum of encoding buffering, multiplexing, communication or storage, de-multiplexing, decoder buffering, decoding, and presentation.”

  MPEG-2 Systems International Standard

- An ATM network introduces delays that are variable and random.

  Numerous ATM Pundits
MPEG-2 over ATM: Issues and Challenges

- Issues include:
  - Application specific?
  - How to recover the MPEG-2 timing?
  - Use of error detection, correction, and/or concealment?
  - Which layer for what functionality?
    - Cost of implementation?
    - Efficiency of transport?

These issues lead to the selection of the AAL to carry MPEG-2 and the signalling parameters needed to ensure the Quality of Service.

Application - Specific Quality

- All issues mentioned affect the quality of the broadcasted video and audio
- Solution to these issues will depend on the quality required by each application

In desktop video-conferencing, a lesser degree of quality may be tolerated.

In broadcast residential video, a higher quality is desired.
Cell Delay Variation: Concept

- Due to queuing of ATM cells throughout the network, buffer delay through the ATM layer and AAL layer, and latency across bus interfaces, ATM cells will not arrive at the MPEG-2 decoder with a constant delay.

Arrival times of ATM cells with constant delay

![Constant Delay Diagram]

Arrival times of ATM cells that experience Cell Delay Variation

![Variable Delay Diagram]

When an ATM cell does not arrive at the expected time, this is known as Cell Delay Variation or "jitter"
Effect of CDV on MPEG-2: Clock Recovery

MPEG-2 Clock Recovery Circuit at Decoder

- MPEG-2 Program Clock Reference (PCR) with excessive cell delay variation could cause the MPEG-2 clock recovery circuit (i.e. phase-lock loop) to generate the incorrect MPEG-2 System Clock Frequency and System Time Clock.
- Incorrect System Time Clock (STC) and System Clock Frequency could result in undesirable quality on the video monitor.

Effect of CDV on MPEG-2: Buffer Size?

- The magnitude of the maximum cell delay variation determines the size of the buffer needed at the decoder:
  - If buffers are too small, could lose MPEG-2 packets due to overflow.
  - If buffers are too large, unnecessary cost in receiver.

If buffers are too small

If buffers are too large

Diagram:

Data

Data

Data

Data
Handling of CDV at Decoder

- If the clock recovery circuit at the MPEG-2 decoder “fails” due to excessive CDV, a “dejittering” function may be used.
  - This dejittering function will smooth out the CDV enough so that the decoder can operate correctly.

Issues and Challenges: Errors in Bit Stream

- When running real-time applications, retransmission of errored packets is not an option.
- Error detection, correction, and/or concealment methods must be used.
  - Options include cyclical redundancy check (CRC), forward error correction (FEC), “freeze frame,” and others.
Which Layer for What Functionality?

- AAL Type 1
- AAL Type 5
- AAL Type 2

AAL1

1 byte 47 bytes

| AAL1 Header | Payload |

- Header functions include:
  - Lost cell detection
    - Used by Adaptive Clock Method
  - Byte alignment
    - Allows channelized circuit emulation, such as channelized DS1
  - Time stamp
    - Used for end-to-end clock synchronization, e.g., Synchronous Residual Time Stamp method
MPEG-2 with AAL1?

- AAL1’s Synchronous Residual Time Stamp (SRTS) not applicable for timing recovery in MPEG-2 environments
  - Common clock needed for SRTS might not be available in MPEG-2 network
- AAL1’s optional Forward Error Correction (FEC) capability with interleaving not desirable due to added delay and expense of processing
- AAL1 support in hardware not as widespread as AAL5 support
- AAL1 good choice for backwards compatibility with ISDN networks
- Efficiency is very good when segmenting MPEG-2 transport stream packets into AAL1 protocol data units (PDUs)
  - 1 MPEG-2 transport stream packet (188 bytes) fits exactly into 4 AAL1 PDUs, with no extra padding: PDU efficiency = 97.9%

AAL5

- 48 bytes of data per cell
- Uses a PTI bit to indicate last cell
- Only one packet at a time on a virtual connection
- 8 byte trailer
MPEG-2 with AAL5?

- Does not have timing synchronization capability
  - Must use MPEG-2 clock timing synchronization capability
- Cyclical Redundancy Check (CRC) can detect errors
- Due to universal support, cost of AAL5 implementation is currently the best among all AALs
  - AAL5 will be used for signalling and LAN emulation also
- Efficiency is variable when segmenting MPEG-2 transport stream packets into AAL5 protocol data units (PDUs)
  - Dependent on the number of MPEG-2 transport stream packets carried in one AAL5 PDU

MPEG-2 using AAL5 Efficiency

<table>
<thead>
<tr>
<th># of MPEG-2 Transport Stream Packets into AAL5 PDU</th>
<th>Required # of ATM Cells</th>
<th>Required # of AAL Padding Bytes</th>
<th>PDU Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>44</td>
<td>78.3%</td>
</tr>
<tr>
<td>2-13</td>
<td>8-52</td>
<td>0-44</td>
<td>97.9%</td>
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<tr>
<td>14</td>
<td>55</td>
<td>0</td>
<td>99.7%</td>
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<td>15</td>
<td>59</td>
<td>4</td>
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<tr>
<td>16</td>
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<td>8</td>
<td>99.5%</td>
</tr>
<tr>
<td>17</td>
<td>67</td>
<td>12</td>
<td>99.4%</td>
</tr>
</tbody>
</table>
MPEG-2 with AAL2?

- Is the place-holder for variable bit-rate video transmission
- Is still undefined in international standards bodies

ATM Forum Decisions for Phase 1

- Prioritization of Applications needed for first phase of specifications
  - Deployment time-frame of MPEG-2 applications?
- What type of MPEG-2 streams will ATM carry?
  - Transport Stream Packets or Program Stream Packets?
- Which AAL to carry MPEG-2 streams?
- The appropriate signalling parameters and values, which are application dependent, will also need to be specified
What’s Been Decided in the ATM Forum for the Phase 1 Specification?

- First application targeted is Video-on-Demand
  - This requires high quality to the consumer
- Constant bit rate (CBR) encoded MPEG-2 Transport Streams will be segmented and carried in ATM cells
  - This is a Constant Packet Rate MPEG-2 bit-stream
  - CBR Transport Streams appear to be most common form of the MPEG-2 bit streams for this application
- AAL5 will be used to carry MPEG-2 Transport Stream Packets

Why AAL5 for Constant Bit-Rate Encoded MPEG-2 for Phase 1?

- AAL5 is the most prevalent AAL today, with virtually all ATM equipment supporting it
  - Low cost of AAL5 solutions was key
- As long as QoS is bounded, end-to-end timing relationships can be transmitted using the MPEG-2 time-stamps, without a need for the AAL to convey this
- With ATM networks targeting a bit-error rate (BER) of <=10^-10, error correction techniques may not be needed
  - For a 5Mb/s MPEG-2 bit stream, this corresponds to 1 “error event” every 32 minutes
  - Can be handled by error detection and/or concealment
AMS System Structure

Connect Control

ATM Forum Signalling 4.0 (Q.2931)

SSCF UNI Q.2130

SSCOP UNI Q.2110

AAL 5

ATM

AMS System Structure

Connect Control

Video

Audio

Private Data

ATM Forum Signalling 4.0 (Q.2931)

H.222.1

H.222.0/ISO/IEC 13818.1

Transport Stream

Network Adaptation

AAL 5

ATM
### AMS System Structure

- **Connect Control**
- **Video**
- **Audio**
- **Private Data**
- **User to User Control**
- **Session Control**

**ATM Forum Signaling 4.0 (Q.2931)**

**SSCF UNI Q.2130**

**SSCOP UNI Q.2110**

**H.222.1**

**H.222.0/ISO/IEC 13818.1 Transport Stream**

**Network Adaptation**

**AAL 5**

**ATM**

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### VOD Reference Configuration

- **SERVER**
- **SETTOP/PC/IWU**

**ATM**

**H.222.1**

**AAL 5**

**ATM Connection Control**

**Session Related Control**
Network Adaptation

- All equipment conformant with this specification shall support the following network adaptation:
  - The MPEG-2 Single Programs Transport Stream (SPTS) packets shall be mapped into the ATM Adaptation Layer Type 5 (AAL5) with a NULL Service Specific Convergence Sublayer.
  - One to N MPEG-2 Transport Streams (TS) packets are mapped into an AAL5-SDU.
  - For Switched Virtual Circuits (SVCs), the value of N is established via ATM Signalling 4.0 at call setup using the AAL5 Maximum CPCS-SDU negotiation procedure. The AAL5 Maximum CPCS-SDU size that is signalled is N*188 bytes (N being the number of TS packets).
  - For Permanent Virtual Circuits (PVCs), the default value on N is two (Maximum CPCS-SDU size = 376 bytes). Other values of N may be selected by bilateral agreement between the settop user and the server via network provisioning.
  - In order to insure a base level of interoperability, all equipment shall support N = 2 (CPCS-SDU size = 376 bytes).

Network Adaptation: Base Level of N = 2

- When an AAL5 PDU contains two 188-octet SPTS Packets, the CPCS-PDU is 384 octets and maps into 8 ATM cells with zero CPCS padding octets.
  - An AAL5 CPCS-SDU which has length of 376 octets
  - An AAL5 trailer of 8 octets
Network Adaptation: AAL-5 Action on Corrupted PDUs

- When a receiver receives a corrupted AAL5 CPCS-PDU, systems performance MAY be improved by passing the corrupted data, together with an indication that it is corrupted, from the adaptation layer to the demultiplexer layer, rather than simply discarding the data in the adaptation layer.
- This is an end station implementation option.

ATM Layer Traffic Shaping

- Traffic at the egress of the server shall be shaped to conform to the CBR traffic contract negotiated with the ATM network
- Traffic shaping is required to occur on a per VC basis
ATM Signalling

- The following signalling parameters are needed by the VoD application and shall be passed through both private and public ATM networks:
  - Asymmetrical upstream and downstream bandwidth requirements
  - QoS Parameters (individual parameters or QoS Classes)
  - Constant Bit Rate (CBR) operation
  - Bearer Class = BCOB-X
  - The AAL5 Maximum CPCS SDU size
  - ATM Forum VoD Application ID
  - Generic Identifier Transport I.E. contains a parameter that indicates the correspondence of the VC to a certain previously established request carried outside ATM signalling

Who Else is Working the Issues?

- ISO/IEC JTC1/SC29/WG11
  - MPEG Systems Group
- ITU-T SG9
  - B-ISDN video
- ITU-T SG13
  - AAL work
- ITU-T SG16
  - ITU-T SG16 experts group for video coding and systems in ATM and other environments
- Numerous standards bodies
  - ANSI, ETSI, etc.
- Various Forums and Alliances
  - DAVIC
AMS Phase 1 and Standards

ITU Study Group 15
H.222.1
Multimedia Multiplex for ATM

AMS VOD Specification
1.0

ITU Study Group 9
J.82
Transmission of CBR MPEG-2 over ATM

Summary

- A key challenge of transporting MPEG-2 data over ATM networks is Cell Delay Variation
- The ATM Forum’s AMS Phase 1 focus was VOD using AAL5 to transport constant bit-rate encoded MPEG-2 transport stream packets
- Many standards groups worked together toward this solution
Future Work

AMS Phase 2 will focus on the following activities

- Broadband Multimedia Services encompassing
  - Video Conferencing
  - Interactive Distance Learning
  - Multimedia Desktop
- VBR-Encoded MPEG-2 over ATM
- Interworking

Acronyms

- AAL: ATM Adaptation Layer
- ATM: Asynchronous Transfer Mode
- AMS: Audiovisual Multimedia Services
- BCOB-X: Broadband Connection-Oriented Bearer Service Class X
- BER: Bit Error Rate
- BHLI: Broadband High-Layer Information
- BLLI: Broadband Low-Layer Information
- CBR: Constant Bit Rate
- CDV: Cell Delay Variation
- CD-ROM: Compact Disk - Read Only Memory
- CRC: Cyclical Redundancy Check
Acronyms (continued)

- FEC: Forward Error Correction
- I-CDV: Instantaneous Cell Delay Variation
- ISDN: Integrated Services Digital Network
- IWU: Interworking Unit
- LPF: Low Pass Filter
- Mb/s: Mega-bit per second
- MPEG: Moving Pictures Expert Group
- MTU: Maximum Transfer Unit
- PCR: Program Clock Reference
- PDU: Protocol Data Unit
- PES: Packetized Elementary Stream
- PTS: Presentation Time Stamp

Acronyms (continued)

- PVC: Permanent Virtual Circuit
- QoS: Quality of Service
- SSCF: Service Specific Convergence Facility
- SSCOP: Service Specific Connection-Oriented Protocol
- SRTS: Synchronous Residual Time Stamp
- STC: System Time Clock
- SVC: Switched Virtual Circuit
- VBR: Variable Bit Rate
- VCO: Voltage Controlled Oscillator