Comparison of MPEG data transferring schemes in ATM networks

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Abstract

In this paper we consider MPEG2 (Moving Pictures Expert Group 2) data transferring schemes using AAL5 (ATM Adaptation Layer 5) connections through which the PS (Program Stream) layer multiplexes PES (Packetized Elementary Stream) streams. We investigate the performance of the multiplexing schemes PS and TS (Transport Stream) in terms of the transfer efficiency. The PS transfer scheme is generally considered for reliable networks whereas the TS transfer scheme is proposed for error-prone networks. In this paper we propose an appropriate criterion that can be used for a decision on which method performs well under which environments for MPEG2 stream transfer. The QoS (Quality of Service) issues concerning the packet length and packet loss are also discussed. © 1997 Elsevier Science B.V.

Keywords: MPEG 2; ATM; TS; PS; AALS

1. Introduction

The Moving Pictures Expert Group (MPEG) is the widely accepted standard for multimedia data compression and packetization. Specifically MPEG2 is designed for various kinds of video from current TV to HDTV. The MPEG2 standard comprises audio, video and system. In the MPEG2 system standard two schemes are proposed for multiplexing PES packets: TS (Transport Stream) and PS (Program Stream). TS was proposed to transfer streams for unreliable media whereas PS was proposed for reliable media. Fig. 1 shows the MPEG2 data flow in the MPEG2 system coding part.

B-ISDN is expected to support all types of communications like telephone, fax, computer and even television. For this end all data will be segmented into small fixed sized packets, so called ATM cells, the size of which is 53 octets. There exists the AAL (ATM Adaptation Layer) layer between the ATM layer and the user data layer. Currently three kinds of AALS are standardized; AAL1 for real-time CBR (Constant Bit Rate) services, AAL3/4 and AAL5 for non real-time bulky data transfer service. AAL5 is the simplified version of AAL3/4 [1].

Since B-ISDN adopted ATM as the standard transfer scheme for various kinds of services including image, MPEG and ATM need to be considered together. In [2], Sun showed some examples of how to transfer MPEG2 streams over ATM networks, and compared these in the context of timing information recovery, bit error and cell loss. When B-ISDN is implemented over ATM networks, most terminals are expected to be equipped with ATM network interfaces for data communications that support either AAL3/4 or AAL5. For real time data transfer such as voice and video, AAL1 may be the first candidate that can be considered. As AAL3/4 and AAL5 are expected to be rolled out in advance and to be incorporated with AAL1 for data transfer services, they will cause additional complexities in the hardware/software architecture. That is why we consider the transfer of MPEG2 streams over either AAL3/4 or AAL5 connections without resorting to AAL1 connections in this paper.

Current hardware architectures consisting of a TS processor and an AAL5 processor allow easy implementation of TS-AAL5 connections [9–14]. The TS packet length is fixed at 188 octets including the header of 4 octets. The appearance of AAL5 that was proposed for reliable data transferring environments made error control processes at destination simple. Data transfer over AAL5 connections may not be an attractive choice under highly erroneous environments since AAL5 was originally designed to provide services for reliable data transferring environments. Thus it may be reasonable to consider PS stream transfer over AAL5 connections since both are proposed for reliable transferring environments. The primary advantage of PS transfer via AAL5 connections is its simplicity and consistency in the connection of MPEG and ATM. When an MPEG2 server transfers MPEG2 programs to users, it can
avoid unnecessary data conversion of PS to TS for transfer.

In this paper we mainly consider the performance of the PS-AAL5 connection and discuss its merit over the TS-AAL5 connection in terms of the transfer efficiency. In terms of error control functions we compare AAL1, AAL3/4 and AAL5 in Section 2. The purpose is to provide objective comparison study results because when a host has packets to transfer over AAL5 connections, at first it needs to determine which AAL type is best suited for data transfer. In Section 3 we determine the optimal length of the AAL5-CPCS packet to obtain the maximum transfer efficiency according to the cell loss rate, followed by conclusions.

2. Comparison of the error control functions of AAL layers

In this section we summarize error control functions of the AAL layers that have been studied in [3] and [4]. The performance comparison that will be considered later will be based on this study.

2.1. Bit error

There are FEC (Forward Error Correction) and CRC (Cyclic Redundancy Check) functions for the AAL layers as shown in Table 1 that can be used to detect and recover errored bits.

If FEC is used for error protection, data packets suffer considerable delay due to the processing time for FEC. FEC can also be implemented at the SSCS (Service Specific Convergence Sublayer) layer of AAL3/4 or AAL5. This means that FEC is not the merit of AAL1’s own. For bit error detection the 10-CRC and the 32-CRC are proposed for AAL3/4 and AAL5, respectively. As proved in [3] and [4], the 32-CRC for AAL5 shows a better error detection capability than the 10-CRC for AAL3/4.

2.2. Cell loss

Table 2 shows cell loss recovery and detection functions for the AALs.

AAL3/4 segments a large message of data into several ATM cells. The first ATM cell of an AAL3/4 PDU carries BOM (Begin of Message), the last ATM cell carries EOM (End of Message) and the intermediate cells carry COM (Continuation of Message). In AAL5, the probability that a packet errored in the LI (Length Indicator) field is delivered to the upper layer without the error being detected is doubly protected by the 32-CRC and the LI.

2.3. Cell order protection

It is very rare for cells to be out of order at destination in ATM networks because ATM routing is virtual connection oriented [7]. But if the networks undergo some reconfiguration management like self healing, there exists a little chance of cells being out of order or misinserted during the transfer. Three functions have been proposed for the AALs to protect cell order.

The performance of using the SN (Sequence Number) for cell order protection is examined in [5]. [6] proved that the 32-CRC also detects two cells being in the wrong order with the probability of 1 for a packet length of shorter than 4 Gbit, which is much longer than the practically considerable packet length. In the case of more than two cells being in the wrong order, the probability that the 32-CRC cannot detect it is extremely low. As examined previously we can notice that although the 32-CRC is simple and has only one error control function for AAL5, it works as well as the others.

Table 1

<table>
<thead>
<tr>
<th>Function</th>
<th>AAL1</th>
<th>AAL3/4</th>
<th>AAL5</th>
</tr>
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<tbody>
<tr>
<td>Recovery</td>
<td>FEC</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Detection</td>
<td>FEC</td>
<td>10-CRC</td>
<td>32-CRC</td>
</tr>
</tbody>
</table>

Table 2

<table>
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<th>Function</th>
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<td>×</td>
</tr>
<tr>
<td>Detection</td>
<td>FEC</td>
<td>SN, BOM, COM, EOM LI</td>
<td>32-CRC, LI</td>
</tr>
</tbody>
</table>
3. Mapping of MPEG2 multiplexed streams into ATM cells via AAL5

In this section we examine the TS mapping into the AAL5 SDU first, which was proposed in the ATM Forum, and the PS mapping into the AAL5 SDU. Then we will find the optimal AAL5-CPCS (Common Part Convergence Sublayer) packet length to achieve the maximum transfer efficiency.

3.1. MPEG2 stream mapping into the AAL5 SDU

There have been some trials for transfer of MPEG2 streams over ATM networks. In the ‘5/8 cell PCR (Program Clock Reference) aware proposal’ [8], two forms of the AAL5-CPCS SDU (Service Data Unit) are proposed. The packet length of the first SDU form is set to 384 octets that corresponds to the length of two TS packets. In this form PCR information either is included in the latter TS packet or is not provided. The length of the other SDU form is fixed at 240 octets corresponding to only one TS packet with PCR information. This method provides small jitter for transfer of PCR information. Fig. 2 shows the actual mapping diagram for TS packet mapping into the AAL5-CPCS SDU.

Other AAL5 CPCS SDU sizes such as greater than 2 TS packets can be considered too. But this mapping requires PVC (Permanent Virtual Circuit) connections or signalling negotiations at network provisioning [15].

The AAL5-CPCS SDU will be quite long enough to contain one PS packet. Otherwise the length of the PS packet should be limited to 64-k octets, which is the generally accepted value for the AAL5-CM SDU length. Fig. 3 shows the actual mapping diagram for PS packet mapping into the AAL5-CPCS SDU.

3.2. Optimal packet length

The packet length of 188 octets is used to transfer TS packets over MPEG2 connections. The size is four times 47 octets corresponding to the pay-load length of the AAL1 packet. As AAL1 is designed to support real time CBR (Constant Bit Rate) traffic, it is easy to transfer TS packets over AAL1 connections. This means that since the network delay is kept at a minimum, the scheduling mechanism at the source and destination hosts can be simply designed. As mentioned earlier, however, employing both AAL3/4 or AAL5 and AAL1 increases the workload and implementation complexities of a terminal. It is inevitable to implement either AAL3/4 or AAL5 for data transfer functionalities. Even though we are motivated to consider the MPEG2 data transfer over AAL3/4 or AAL5, we will mainly examine the packet transfer of PS and TS over AAL5 connections in this paper. This is because AAL3/4 is not comparable to AAL5 in context of efficiency.

We define the data transfer efficiency as

\[ E_t = \frac{D}{D+H} \]  

(1)

where \( D \) and \( H \) represent the lengths of user data and...
overhead, respectively. In the case of AAL5, $D$ is the length of the AAL5-CPCS SDU and $H$ is the length of trailer of the AAL5-CPCS PDU, i.e. 8 octets. To find the optimal AAL5 packet length in units of numbers of cells, assume that an AAL5 packet is segmented into $N$ ATM cells including the padding. If the cell loss probability, $P_L$, is given for the network, the successful transferring probability of the AAL5 packet is given by

$$E_2 = (1 - P_L)^N \left( \frac{D}{H + D} \right) (1 - P_L)^N$$

If the receiving AAL5 layer detects any cell loss from the received AAL5 packet by using 32-CRC, it discards the received AAL5 packet since it does not have any error recovery function. This means that even a cell loss among the $N$ cells of the AAL5 packet corresponds to the loss of whole $N$ cells. Combining these we can obtain the transfer efficiency as follows:

$$E_2 = \left( \frac{D}{H + D} \right) (1 - P_L)^N$$

Considering that the ATM layer cell consists of 48 octets of user data and 5 octets of header, we can obtain the optimal packet length of AAL5, $N_{opt}$, by letting $\partial E_2/\partial N = 0$. $N_{opt}$ to achieve the maximum transfer efficiency is given by

$$N_{opt} = \frac{1 + \sqrt{1 - \frac{24}{\ln(1 - P_L)}}}{12}$$

Fig. 4 shows the optimal packet length according to the cell loss probability.

The AAL5 packet length of 4000 (cells) is optimal when the cell loss probability is equal to $10^{-8}$. If the cell loss probability is greater than $10^{-6}$, $N_{opt}$ is less than 8 (cells). Therefore, the currently adopted AAL5 packet length for MPEG2 data transfer—either one or two TS packets into an AAL5 packet (5/8 Cell PCR proposal)—is optimal only when the cell loss probability is $5 \times 10^{-2}$.

3.3. TS vs PS

Now we examine the overheads of TS and PS packets to calculate the transfer efficiency $E_2$. The PES layer is a common part of TS and PS. We suppose that the payload of TS (or PS) is PES packets in this comparison. A TS packet has 4 octets of header and 188 octets of user information while a PS packet has about 30 octets of overhead and the variable length of user information. To transfer timing information between source and destination, a field of the PS packet header is designed for SCR (System Clock Reference) whereas the adaptation field of the TS packet header carries the PCR value. At the receiver timing synchronization is performed by SCR in the case of PS and by PCR in the case of TS; the receiver checks whether there is a PCR in the TS packet (or SCR in the case of the PS packet), to the corresponding value. The accumulation of timing error between sender and receiver can be avoided by setting the PCR (or the SCR) every certain time interval.

The PCR field in the TS packet is optional so that it can be included if needed. In general, an additional TS packet is transmitted whenever the PCR information is needed. As this generates an additional AAL5 packet without any real user data, it lowers the transfer efficiency. But there is always the SCR field in the PS packet header. When TS packets are packed into AAL5-CPCS packets, two to a maximum of $N_{TS}$ TS packets can be assembled for an AAL5 packet. Here we consider only the 5/8 Cell PCR aware proposal that allows transmission of two TS packets at a time.

We assume that TS transmits timing information as frequently as PS. Since the optional timing information in the TS packet is contained in the adaptation field followed by 4 octets of header, this increases the overhead and the TS packet carrying timing information has a different packet structure from other TS packets. We also assume that one out of $N_{TS}$ TS packets is designated to carry timing information, and cells for TS packets with timing information are not lost. Note that the TS packet with timing information is mapped into 5 ATM cells and filled with stuffing bits. Then the overall TS-AAL5 transfer efficiency is given by

$$E_{TS} = \left( \frac{D}{184} + \frac{D}{184} \right) \left( \frac{53}{48} + \frac{53 \times 5}{184} \right) (1 - P_L)^N_{TS}$$

$$E_{TS} = \frac{1}{1.152 + \frac{1.44(1 - P_L)^N_{TS}}{N_{TS}}}$$

$E_{TS}$ counts the TS overhead, the TS timing information overhead, the AAL5 overhead and the ATM cell header.

Now consider the AAL5 header of 8 octets and the PS header of 30 octets to obtain the PS transfer efficiency. If we assume that a PS packet maps into an AAL5 packet of user
data, we can write $E_{PS}$ as follows:

$$E_{PS} = \left(\frac{48}{53}\right)\left(\frac{48N}{38}\right)(1 - P_L)^N$$  \hspace{1cm} (7)

Fig. 5 represents the TS transfer efficiency against the cell loss probability. It shows the increase of 8.5% in the efficiency when the PCR interval is changed from 10 to 100 TS packets. For example if 10 PCR packets are transmitted every second in a 6-Mbps MPEG2 stream transfer, about 400 TS packets are generated between the two PCR packets. It also shows that the efficiency for the 100 TS packets of PCR interval is not that much different from that for the 1000 TS packets.

Fig. 6 shows the efficiency against the PCR generation interval with the assumption of the cell loss probability of $10^{-8}$ and $5 \times 10^{-2}$. Note that the latter is the optimal probability when the '5/8 Cell PCR aware proposal' is applied. As $N_{TS}$ increases and the cell loss rate decreases, $E_{TS}$ converges to 86.6%.

Fig. 7 shows the efficiency of the PS transfer against the cell loss rate. If the size of PS packet is fixed at 10,000 (cells), the performance is not acceptable at the cell loss rate of greater than about $10^{-5}$.

Fig. 8 indicates that the optimal efficiency can be obtained when the packet length is maintained at some region depending on the cell loss rate. The efficiency is deteriorating as the cell loss rate increases. As the PCR field is optional for the TS packet, we assume that the PCR packet generation frequency of TS is the same as the SCR packet generation frequency of PS for fair comparison.

Fig. 9 shows the efficiency of PS and TS against the packet length with the assumption of the cell loss rate of $10^{-8}$. As the packet size is becoming larger, the efficiency of
PS and TS converges to 90.6% and 86.6%, respectively. PS is more efficient than TS in the region of packet length of between 2 and $4 \times 10^6$ ATM cells. The PS packet size of larger than $4 \times 10^5$ ATM cells is not shown in the figure due to the scale in Fig. 10 (impractically long for implementation).

In Fig. 11 the transfer efficiency of PS is compared with that of TS against the cell loss rate, assuming that the PS packet size is fixed at 4000 (cells) and that the PCR generation interval for the TS stream is 1000 TS packets. PS outperforms TS if the cell loss probability is lower than $10^{-5}$. As expected all the results show that TS performs better than PS in error-prone networks because the PCR transmission is optional and the packet size is small. However, if we consider high speed ATM networks with the low error rate, PS is the promising scheme for data transfer because the packet size can be set long enough.

4. Conclusion

In this paper we mainly considered the AAL5 connection and PS rather than TS as the multiplexing scheme for MPEG2 stream transfer. AAL5 showed its superiority to other AAL types in terms of error control functionality. We obtained the formula to calculate the optimal packet length of the AAL5-CPCS PDU and the formula for the maximum transfer efficiency. PS showed better transfer efficiency than TS under reliable data transferring conditions, where the error rate is less than $10^{-5}$ and the packet length is 4000 ATM cells. The efficiency of the PS mapping into the AAL5-CPCS packet is better by 4% than that of the TS mapping. In data conversion PS also caused less complexities than TS, which results in the reduced processing load at MPEG servers. Simulations considering real networking scenarios are left for further works.

References


