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QoS Enhancement Mechanism in CBR HDTV Transport Stream Packet Communications over Lossy ATM Network

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ABSTRACT

In ATM network, CBR HDTV TS experiences network jitter and data loss. The jitter is originated from queueing at network nodes and from previous data losses. To reduce the jitter originated from data losses, we propose that the receiver maintain a de-jitter timer. The expiration time of the timer is proportional to the cell time of the source traffic plus the standard deviation of the 1-point CDV of the received ATM cells. Moreover, to enhance the granularity of the error or loss detection mechanism in the AAL5 PDUs, we also modified the AAL5 PDU trailer fields so that each cell comprising the AAL5 PDU has a sequence number field. The simulation results show that the peak-to-peak PDV of the AAL5 PDU by the proposed method is less than 69.4% to that by AAL5. Moreover, the AAL5 user - HDTV decoder - receives the same or more error-free transport packets in the proposed algorithm than those in the ITU-T AAL5 for the same network simulation environment. The proposed mechanism is mapped into AAL5 that employs the SSCS for CBR HDTV application.

I. Introduction

ATM is the vital network protocol in the implementation of B-ISDN (Broadband Integration Digital Network). To communicate the user data via ATM network, the user data is processed to form AAL PDU(ATM Adaptation Layer Protocol Data Unit)s. At the transmitter, the AAL PDU is segmented into 53-byte ATM cells and routed to the receiver in the ATM network. At the receiver side, the ATM cells are reassembled into an AAL PDU and then sent to the application layer. The AAL is subdivided into five different types according to the demanded service quality of user data. The AAL1 is provided to transmit the CBR(Constant Bit Rate) traffic and it has a countermeasure such as SRTS (Synchronous Residual Time Stamp) against the jitter generated in ATM network. However, the SRTS technique is not applicable when a common network clock is not available for the use as a reference clock. Thus, the AAL1 is not used in the nationwide network consisted of several different carriers and unsynchronized clocks. Furthermore, since the signaling in the call set-up process is done under AAL5, ATM network interface needs to support both types of adaptation layers (AAL1 and AAL5) to communicate using AAL1. Thus, the AAL5 is adopted as the ATM adaptation layer for the single program transport packet stream (SPTS) by the ATM forum [1]. The HDTV generates 19.39 Mbps CBR multi-program transport packet streams (MPTS) [2] and is expected to make use of the same ATM adaptation layer as SPTS uses. However, according to the AAL5 specified in ITU-T, the receiver AAL discards the entire AAL PDU even when a single bit error or loss occurs among the cells comprising the AAL PDU. Even when the corrupted data delivery option is supported, the opportunity to recover the PDU is limited. The effect of cell losses is augmented by data error propagation in elementary streams that are encoded in MPEG-2 or AC-3. We modified the AAL5 PDU trailer fields so that each cell

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composing the AAL5 PDU has a sequence number field. This enhances the granularity of the error (or loss) detection mechanism to cell level and the TS loss is kept at minimum as the network TS loss. The AAL5 has no countermeasure against the jitter originating from the cell losses in the ATM network. The real time data such as CBR HDTV TS packet or CBR MPEG-2 video TS stream requires the de-jittering process in the AAL5 at the receiver side. We propose that the receiver AAL maintain a timer whose expiration time is proportional to the cell time of the source traffic plus the standard deviation of the 1-point CDV of the received ATM cells to reduce the jitter originated from cell losses in ATM network. In section 2, the current research on the transfer the HDTV TS over ATM network is described. In the section, transportation mechanisms of CBR HDTV TS packets over AAL5 and over multimedia AAL proposed by Hubaux are explained. In Section 3, the proposed mechanism is described. The compatibility of the proposed mechanism to AAL5 is dealt in Section 4. The performance evaluation and comparison between ITU-T AAL5, Hubaux's mechanism and the proposed mechanism are done in Section 5. Finally, the conclusion is given in Section 6.

Ⅱ. The Previous Work on the Communications of the HDTV TS over ATM Network

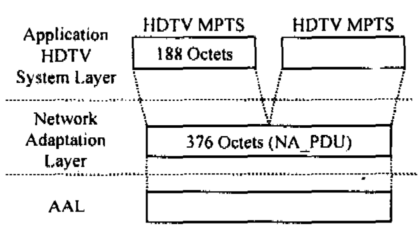

Fig. 1 PCR-unaware TS encapsulation in Network Adaptation

2.1. Network Adaptation

The network adaptation performs data manipulation and control data communication between application layer and AAL. The network adaptation for MPTS is not yet specified and we assume that the PCR(Program Clock Reference)-unaware TS encapsulation\decapsulation is performed in the network adaptation, which is true in the network adaptation for SPTS. Two 188-byte TS packets are concatenated to from one CPCS-SDU as shown in Figure1.

2.2. The HDTV TS Communications using AAL5

In the transmitter end, the CPCS sublayer receives 376-byte SDU from the application layer and appends an 8-byte trailer containing a CRC-32 parity check, a length indicator and padding bytes for boundary alignment. The structure of a CPCS-PDU is shown in Figure 2.

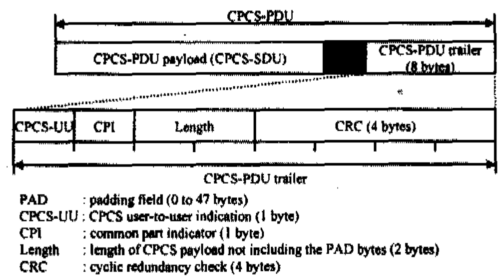

Fig. 2 Structure of CPCS-PDU

Then, the CPCS-PDU is segmented into eight ATM-SDUs each of which size is 48 bytes. The eight ATM-SDUs are sent to ATM layer in sequence and the last ATM-SDU has a parameter, M(More) whose value is zero. The parameter M indicates the end of the CPCS-PDU and is used to delineate the boundary of the CPCS-PDU. In the receiver end, whenever the SAR sublayer receives 48-byte ATM-SDU from ATM layer, it delivers the ATM -SDU to CPCS sublayer. The ATM-SDUs are stored in reassembly buffer in the CPCS sublayer. There is an option on CPCS operation : corrupted data delivery option [3]. When the option is not supported, the ATM-SDUs are stored in reassembly buffer until the ATM-SDU is delivered whose parameter M value is zero if the data size in reassembly buffer is not greater than predefined maximum size

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(Max_SDU_Deliver Length). When an ATM-SDU is delivered whose value of parameter M is zero, the data in reassembly buffer is assumed to be a CPCS-PDU and the CPCS sublayer initiates the CPCS-PDU validation procedure. The validation procedure includes CRC check, CPI check, padding field check and Length field check. If the assumed CPCS-PDU passes all the error check, the CPCS-PDU is delivered to the application layer. Otherwise, the assumed CPCS-PDU is discarded. When the corrupted data delivery option is enabled, the assumed CPCS-PDU is delivered to application layer with its RS(Reception Status) parameter, albeit the CPCS-PDU is detected to have some errors in the validation procedure if the size of data in reassembly buffer is not greater than predefined maximum size (Max_Corrupted_SDU_Deliver_Length). The RS parameter reports the existence of errors and if any, the kind of errors in the CPCS-SDU delivered to the application layer. In this procedure, the detection of data loss is performed in PDU level and any cell loss comprising a CPCS-PDU introduces the CPCS-PDU loss. Because a CPCS-PDU contains two TS packets, this procedure shows higher data loss than the data loss(cell loss) at the network level. Even when the corrpted data delivery option is enabled, the recovery of the erroneous CPCS-SDU is done just in two cases. When the cell loss occurs in the payload(CPCS-SDU) of CPCS-PDU, two TS may be recovered if and only if the CPCS-SDU is delivered with error indication after reassembly buffer overflow error occurred. This means that the previous reassembly buffer overflow has truncated the current CPCS-SDU. If the cell loss occurs in the trailer of CPCS-PDU, the parameter M is not zero until the next CPCS-PDU is delivered to CPCS sublayer. This leads concatenation of two(or more) CPCS-PDUs. In this case, the last CPCS-PDU may be recovered. As described, even when the corrupted data delivery option is enabled, the opportunity to recover the CPCS-SDU is limited and the TS loss in the application layer is higher than that in the network level. Furthermore, the AAL5 does not provide any de-jittering mechanism but an optional RAS(ReASsembly) timer. However, the timer does not function as a de-jitter timer in the AAL5 when the corrupted data delivery option is not supported, and even when the option is enabled the value of timer is not specified for applications. TS delay variation beyond 3msec may lead system clock synchronization failure if network adaptation does not absorb the CDV [4].

2.3 The HDTV TS Communications using the real time multimedia network adaptation and AAL

Previously, a network adaptation and an AAL for real time multimedia are proposed by Hubaux [5]. In this procedure, the AAL provides selective FEC(Forward Error Correction) for TSs that contains important data such as syntactic data(header) and timing information. The AAL also supports cell level sequence numbering mechanism so that dummy cell is inserted into the position where cell loss occurred within a CPCS-PDU. However, the CRC field is not provided in the CPCS-PDU so that the bit error is not checked. Furthermore, to support selective FEC, the network adaptation has to identify the TSs that need FEC. This function is service specific and is not generic in network adaptation. Meanwhile, in the HDTV TS communications, the TS that contains crucial data such as PSI(Program Specific Information) is transmitted in duplicated form and the timing data such as PCR(Program Clock Reference) is repeated at least 100msec interval. In such a case, the FEC is redundant and the de-jittering mechanism is more critical in the CBR HDTV application.

Ⅲ. New Mechanism for CBR HDTV TS Communications over ATM network

3.1. Sequence Numbering Mechanism

AAL5 does not provide enough protection mechanism against errors because it was mainly

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designed for applications such as file transfer that have robust transport protocol. AAL5 only provides a bit error detection mechanism based on CRC calculated on a PDU basis. Because the error (or loss) detection mechanism operates at PDU level, the whole PDU, containing two HDTV TS packets, in reassembly buffer is discarded when CRC checksum errors or length errors are detected. This leads to an excessive data loss seen by the application (HDTV decoder side). This mechanism is clearly not suitable for HDTV application because only a single cell loss causes the loss of two TS packets.

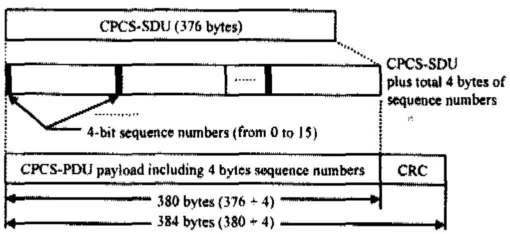

Fig. 3 Structure of CPCS-PDU using sequence number

To cope with this unwanted loss, a different scheme is considered. The idea is to attach sequence numbers to every cell comprising CPCS-PDUs. To make this possible, the function of each field of the CPCS-PDU trailer is reconsidered. The CPCS-UU field is used to transfer private data transparently via ATM network. Thus, this field is available for general purpose in HDTV system. In addition, CPI field in the trailer is used only to make the trailer length to eight bytes. Moreover, two bytes length field is redundant because the HDTV TS has a fixed size of 188 bytes and two TSs are encapsulated using PCR-unaware encapsulation scheme. The size of CPCS-SDU is negotiated and known at the call set-up process as a Forward Maximum CPCS-SDU size parameter[6]. Therefore, 4 bytes in the trailer are available for other functions, and we use these 4 bytes to store and transfer sequence numbers of segmented cells. Each cell comprising a CPCS-PDU contains a sequence number field of 4 bits wide. Hence, the sequence number fields in eight cells which comprise one CPCS-PDU occupy 4 bytes of the trailer. The remaining 4 bytes of the trailer are used for CRC checksum for the entire CPCS-PDU including sequence numbers and the payload. The modified structure of CPCS-PDU which has sequence number fields is shown in Figure 3.

This scheme reduces the data loss at the receiver's AAL, because it enhances the granularity of the data loss detection to the cell level. The sequence numbers are used by the receiver to monitor cell arrivals, and to find out exactly how many cells have been lost along with their position within a CPCS-PDU. The main advantage of this mechanism is that the corrupted PDUs are not discarded and data loss is kept at minimum as the network TS loss. In this scheme, dummy cell insertion mechanism is used at the receiver side, so that the dummy cells are inserted wherever cell losses are detected. This mechanism guarantees the integrity of a CPCS-PDU size. Because the sequence number field is 4-bit wide, burst cell loss beyond 16 cells is not detected by the sequence number check. However, the de-jitter timer which is described in the next subsection, sets up a time limit on the completion of CPCS-PDU and if burst cell loss beyond 16 cells occurs, the de-jitter timer expires to deliver CPCS-PDU whose vacant cell positions are filled with dummy cells. Once PDU is constructed without any dummy cells, then CRC checksum is checked to see if there is a bit error. Then, 4-byte CRC field is truncated and all sequence numbers are removed so that pure CPCS-PDU payload (CPCS -SDU) is extracted.

By using the sequence number mechanism, the location of cell loss in the PDU is known to the receiver AAL. Furthermore, it is also known that which TS packet in the constructed PDU is corrupted one. The receiver AAL sends this data-corruption information to the application layer by setting the transport_packet_error_indicator field to one in the TS packet header. Since the location of 1-bit transport_packet_error_indicator

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field is fixed in a HDTV TS packet as shown in Figure 4, the position of this field in the received CPCS-PDU is always mapped to a fixed bit position of cells whose sequence numbers are 0, 3, 8 and 11.

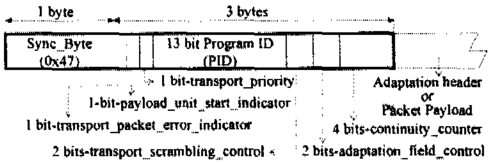

Fig. 4 Link header format for the GA system transport packet

In this scheme, the granularity of data loss is enhanced to TS packet level so that the dummy cell inserted in the CPCS-PDU corrupts only the TS packet containing the dummy cell. Hence, the number of error-free TS packets received at the HDTV decoder system is increased.

3.2. De-jittering Mechanism by a de-jitter timer

When HDTV TS is transferred via ATM network, cells experience network jitter originated from queueing, or jitter from the loss of prior cell(s). This jitter at the cell level causes a cumulative jitter at the PDU level. Since HDTV system operates at the PDU level, this jitter may cause a miss-synchronization of the program clock at the HDTV decoder system.

Each cell with delay originated from pure delay or accumulated cell losses, is assembled to form a complete CPCS-PDU with PDU Delay Variation (PDV). This PDV is seen as a jitter to the HDTV decoder system, and it may deteriorate the quality of the HDTV data when it is presented. The jitter generated by accumulated cell losses is reduced by using a de-jitter timer.

The timer makes an upper bound in waiting the arrival of next cell, so that PDV is reduced to the difference between the upper bound and the PDU reference arrival time in 1-point PDV.

When receiver AAL starts to receive cells from ATM layer, the CDV is calculated by the receiver AAL from the actual cell arrival time and the reference cell arrival time. Then, the timer is initialized with the value as below when the standard deviation of 1-point CDV at the receiver AAL is stabilized.

Timer_limit (upper bound)
= 8.0 (7.0 cell slot + standard deviation of CDV of the cells received in cell slot)

Where, 7.0 is the cell time of 19.39Mbps source traffic in terms of 155.52Mbps SDH or SONET cell slot.

We define a cell slot as total network clock cycles needed to transmit an ATM cell consisted of 53 bytes, and the cell slot in 155.52Mbps SDH or SONET is calculated as below.

1 Cell Slot = 1/155.52M x 53 x 8 2.726 usec

The cell time of source traffic of 19.39Mbps in terms of 155.52Mbps network is calculated as follows.

Cell time of source traffic of 19.39Mbps
= 155.52M/19.39M x (188 x 2 + 8) /(53 x 8)
≅ 7.264 cell slot
≅ 7.0 cell slot
= 19.082 usec

Timer-limit for each cell is given a margin of standard deviation of CDV, and is multiplied by 8, since one CPCS-PDU is composed of eight cells.

If a CPCS-PDU is constructed before the timer reaches the timer-limit then the PDU is sent to the application layer, and timer is restarted with new timer-limit using updated standard deviation of CDV. If a CPCS-PDU is not constructed before timer expires, then sequence number of last received cell is checked, so that empty cell spaces in the reassembly buffer are filled with dummy cells and CPCS-PDU containing dummy cells is sent to the application layer. Once timer has been expired, timer is not restarted until next cell is actually received. When a cell is received, the sequence number of the received cell is

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checked to see if the received cell is the one that comprises the expired PDU or the one that belongs to a new PDU. In the first case, the cell is discarded and the receiver waits for the cell that belongs to a new PDU. In second case, receiver AAL decides the position of the received cell in the CPCS-PDU, and fills dummy cells in the empty cell space prior to the position of the received cell. Simultaneously, the timer-limit is set in accordance with the sequence number of the cell received. Eight consecutive dummy cells in the reassembly buffer are not delivered to the application layer because they contain no valid data.

Table 1. Comparison of Mechanisms for communication of CBR HDTV TS over ATM network

Item / Mechanism	Granularity of data loss	Recovery of CPCS-PDU	Function of Network adaptation	De-jitter Method
AAL5 (no corrupted data delivery option)	CPCS-PDU	No	TS Encapsulation	No
AAL5 (corrupted data delivery option enabled)	CPCS-PDU	Limited	TS Encapsulation	Optional RAS timer (not specified)
Hubaux's Mechanism	ATM Cell	Error-free TS detection in CPCS-PDU	TS Encapsulation Selective FEC request(TS demultiplex)	No
Proposed Mechanism	ATM Cell	Error-free TS detection in CPCS-PDU	TS Encapsulation	De-jitter Timer

Ⅳ. Compatibility Issues

The fact that the function of Service Specific Convergence Sublayer(SSCS) is left undefined for CBR HDTV application is the key to the mapping of the proposed mechanism to AAL5. The SSCS is located between network adaptation and CPCS in AAL5. We propose that the enhancement of granularity of data loss detection be performed in SSCS and the de-jittering mechanism be carried out by the RAS timer in CPCS of AAL5. To make it possible, the SSCS for CBR HDTV application needs to support the following functions. In this section, we assume that the corrupted data delivery option is enabled and the optional RAS timer in CPCS is supported.

Firstly, the SSCS should insert and detect of sequence numbers into/from a SSCS-SDU.
At the transmitter end, two TSs are encapsulated to form a 376-byte SSCS-SDU in network adaptation. The SSCS inserts 4-bit sequence number as shown in Figure 3. The SSCS signals to underlying CPCS that only 4-byte CRC check sum needs to be attached at the end of the CPCS-SDU to form a CPCS-PDU. To accommodate such a request from the SSCS, the generation of each field in the CPCS trailer has to be controllable. At the receiver end, a CPCS-SDU is delivered to the SSCS with 8-byte CPCS trailer in RS parameter [3]. This means that a complete CPCS-PDU is delivered to the SSCS. The SSCS detects the position of data loss by checking sequence number of each cell and inserts dummy cell to maintain bit count integrity.
Secondly, the SSCS should set the transport_packet_error_indicator field in the link header of HDTV TS packet. In the process of sequence number check, the SSCS determines if the data loss is localized in one TS or not. The 1-bit transport_packet_error_indicator field in the link header of HDTV TS packet is set to one at the SSCS to indicate the existence of error(loss) in the corresponding TS.

In AAL5, the timer expires on a cell basis, i.e. whenever a cell arrives, the timer is (re)started and the RAS timer is stopped when a CPCS-PDU is delivered to the SSCS. Once the RAS timer in the CPCS expires, the CPCS delivers the assumed CPCS-PDU in reassembly buffer to the SSCS - the 8-byte trailer is delivered in RS parameter and the timer is stopped. The RAS timer operates as the de-jitter timer if we use it to expire on a CPCS-PDU basis and not on a cell basis and if we set the expiration time of the RAS timer to the value which is described in Section 3.2. The RAS timer delineates the boundary of a CPCS-PDU when a burst cell loss occurs or the cell is lost whose value of parameter M is zero. This means that the RAS timer reduces the

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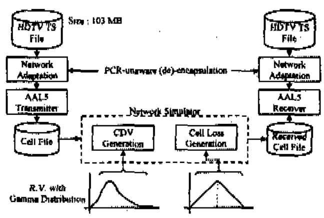
chances that two or more CPCS-PDUs are concatenated by the cell loss whose value of parameter M is zero and the sequence number check in SSCS is performed in the proposed manner. The cell time of the source traffic is known when a connection set-up process is completed. The 1-point CDV of the received cell may be evaluated in the management plane by monitoring OAM cells that are sent periodically from the management plane in the transmitter end.

V. Performance Evaluation



Assumption [7]

- virtual path consists of output-queue switches with arbitrary size of buffers
- propagation/processing delay does not affect the delay variation.
- The reference connection shares at least a portion of its total paths with other background connections
- 1-point CDV is modeled to have a probability density function of Gamma distribution function.

Fig. 5 A simple ATM network simulation model

In this section, we evaluate the performance of the proposed algorithm using sequence number along with a de-jitter timer. The performance is compared with that of ITU-T AAL5 and with that of Hubaux's mechanism. Throughout the simulation, the corrupted data delivery option is not supported in AAL5 and the selective FEC is not provided in Hubaux's mechanism.

The model works on a file basis, as shown in Figure 5. The input file at the transmitter is the HDTV TS file with the size of 103Mbytes. This HDTV TS file contains 547,252 TS packets. Then this file is processed to form the ATM cell format. Since we do not simulate the Physical layer of the ATM network, the generated data is written to the transaction file. Then this file is read by the network simulator and the CDV and losses are generated. The prior study [7] shows that the traffic via ATM network experiences a CDV with a Gamma distribution when all background traffic have the CBR characteristics. In this prior study, the simulation is done on assumption that the path from the transmitter side to the receiver side consists of a number of nodes each of which is modeled as an output-queue switch and contains an arbitrary size of buffers. In addition, the propagation delay between nodes and the processing delay is assumed to be constant and does not contribute to delay variation. Furthermore, this model assumes that the reference connection shares at least a portion of its total paths with other background connections. Assuming the same network environment, we generate CDV to have a Gamma distribution with desired mean and variance by the network simulator. At the same time, the cell loss is generated to simulate the lossy ATM network. Since the loss at the network tends to occur in burst, the cell losses are generated with the probability density function as shown in Figure 6.

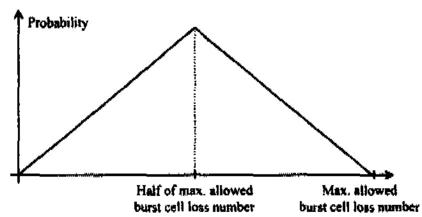


Fig. 6 Probability density function for burst cell loss generation

As the final procedure of the simulation, the transaction file is handled by the AAL receiver model to extract the original HDTV TS file from the transaction file. In this final procedure, the number of total error-free TS packets and peak-to-peak PDV are extracted as the performance parameters of three different algorithms.

The performance evaluation is done in two phases. First, evaluation by the number of error-free TS packets is considered. Secondly, the evaluation is done by the PDV at the receiver side. In either case, some parameters are fixed so that comparison of the proposed algorithm is done under the same condition.

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Throughout the simulation, the mean of 1-point CDV generated by the network simulator is fixed to 7.0 cell slot and the fixed parameters for comparison in the same condition are stated wherever needed.

5.1. Evaluation by the number of error-free TS packets received

In the first place, maximum number of burst cell loss is fixed to 16, and the variance of 1-point CDV is varied. Figure 7 and 8 show the number of error-free TS packets received by three different algorithms.

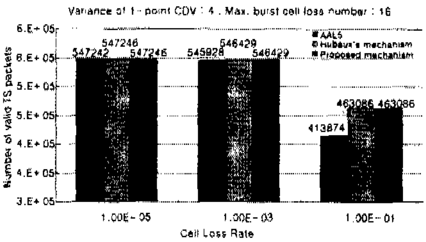

Fig. 7 Variance of 1-point CDV : 4, Max. burst cell loss number : 16

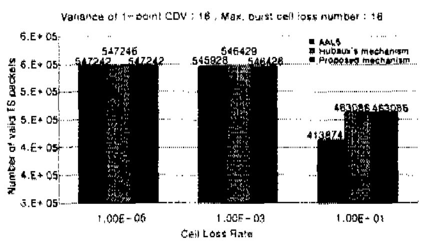

Fig. 8 Variance of 1-point CDV : 16, Max. burst cell loss number : 16

When cell loss rate is 1.0e-5 or 1.0e-3, the differences between three algorithms are not distinctive, in both cases the variance of 1-point CDV is varied from 4 to 16. However, when cell loss rate is increased to 1.0e-1, the differences between three algorithms in the number of error-free TS packets become more distinctive. This is because the AAL5 discards two TS packets when one or more cells comprising the TS packets are lost. Since Hubaux's mechanism guarantees the integrity of CPCS-PDU, total number of error-free TS packets is much greater than that of the AAL5. However, the proposed mechanism, gives slightly less number of total error-free TS packets than that of Hubaux's mechanism, since the de-jitter timer expiration makes an extra loss along with the network loss when a cell arrives late. The result shows that the proposed mechanism does increase the number of error-free TS packets for practical cases, without degrading much from the result that is obtained in Hubaux's mechanism.

For the second case, the variance of 1-point CDV is fixed to 16, and the maximum number of burst cell loss is varied. The result is shown in Figure 8 and 9.

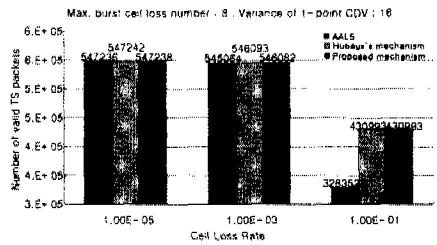

Fig. 9 Variance of 1-point CDV : 16, Max. burst cell loss number : 8

In this case, the difference in performance of Hubaux's mechanism and that of the proposed mechanism is also undistinguishable and both show the same or a better performance than that of the AAL5. However, in case where cell loss rate is 1.0e-1, which is not a practical case, as maximum number of burst cell loss increases, the difference in number of error-free TS packets among three difference mechanisms decreases. The reason is that when burst cell loss size increases, the probability increases that the cell losses are concentrated on CPCS-PDU basis. However, the overall performances of three different mechanisms show that the two modified algorithms have the same or a better overall performances irrespective of the network environment in a viewpoint of the number of error-free TS packets received.

5.2. Evaluation by the PDV at the receiver side

In the first place, maximum number of burst cell loss is fixed to 16, and the variance of

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1-point CDV is varied. The difference in peak-to-peak PDV between each algorithm is shown is Figure 10, 11 and 12. All value of PDV is expressed in cell slot unit assuming 155.52Mbps SONET or SDH.

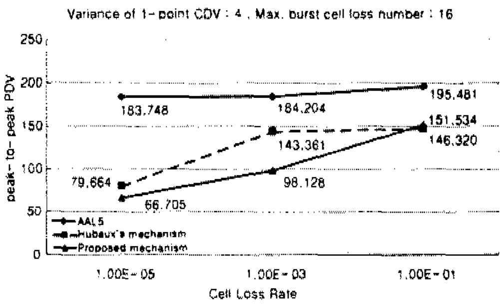

Fig. 10 Variance of 1-point CDV : 4, Max. burst cell loss number : 16

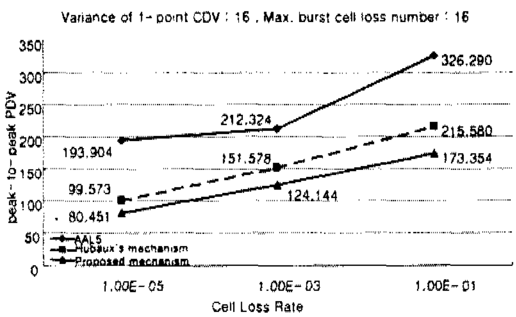

Fig. 11 Variance of 1-point CDV : 16, Max. burst cell loss number : 16

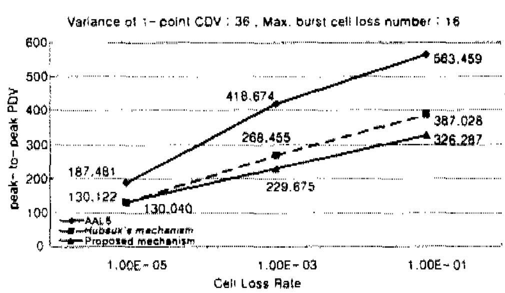

Fig. 12 Variance of 1-point CDV : 36, Max. burst cell loss number : 16

Since Hubaux's mechanism guarantees the CPCS-PDU integrity, the variations of inter-departure time between consecutive CPCS-PDUs in the receiver are reduced in comparison with those of AAL5. However, the proposed mechanism using both sequence number and a de-jitter timer further reduces this peak-to-peak PDV by limiting the waiting time for cells. However, in the case where variance of 1-point CDV is four with cell loss rate of 10e-1, this is not true as shown in Figure 10. In this case, the variance of 1-point CDV is small compared to the cell slot of 7.0 and the difference of peak-to-peak PDV between Hubaux's mechanism and the proposed mechanism becomes negligible. In addition to the result given above, the absolute values of peak-to-peak PDV of all three models increase when variance of 1-point CDV and cell loss rate increase. This is an obvious result since the PDV is calculated at PDU level, and considering the PDV is an accumulated variance of 1-point CDV at the cell level.

These simulation results show that the peak-to-peak PDV is reduced by sequence numbering mechanism, and is further reduced by the use of a de-jitter timer along with the sequence numbering mechanism.

For the second case, it is considered that variance of 1-point CDV is fixed to 16, and the maximum number of burst cell loss is varied. The result is shown in Figure 11, 13, and 14.

In these cases, the result is similar to that of when variance of 1-point CDV is varied with maximum number of burst cell loss fixed. Peak-to-peak PDV is reduced distinctively when sequence numbering mechanism is used. The peak-to-peak PDV is further reduced by the use of a de-jitter timer along with the sequence number mechanism for most of the cases. However, when maximum number of burst cell loss is 24 and cell loss rate is 1.0e-1, the difference of the peak-to-peak PDV values of the two modified models become negligible. The difference in peak-to-peak PDV between two modified algorithms becomes negligible when burst cell loss size is sufficiently large such that burst cell loss size encompasses a number of CPCS-PDUs and the PDV by this burst cell loss

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dominates over the PDV by non-burst cell loss. This is because a CPCS-PDU which is composed of eight consecutive dummy cells in reassembly buffer is not delivered to the application layer. However, only considering the practical scenarios, the de-jitter timer gives an advantage in reducing the peak-to-peak PDV hence enhancing the overall performance.

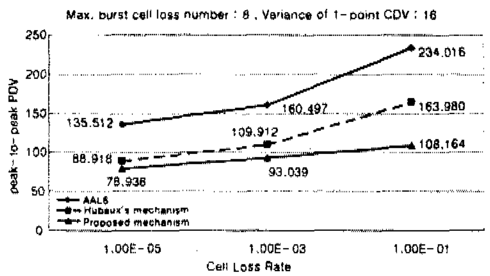

Fig. 13 Max. burst cell loss number : 8, Variance of 1-point CDV : 16

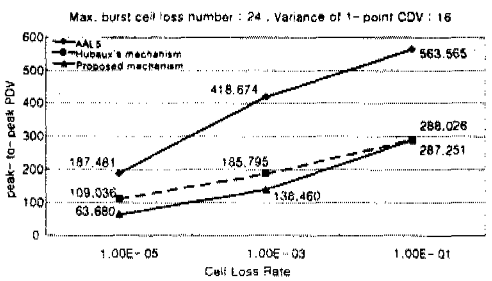

Fig. 14 Max. burst cell loss number : 24, Variance of 1-point CDV : 16

Putting these results together, the proposed mechanism using a de-jitter timer along with the sequence number gives better performance by reducing the peak-to-peak PDV without degrading the number of error-free TS packets distinctively.

Ⅵ. Conclusion

In this paper, we proposed a new mechanism for the communications of CBR HDTV TS packets via ATM network. Simulations are performed for various scenarios with two performance parameters-total number of error-free TS packets and peak-to-peak PDV. In the evaluation by the number of error-free TS packets, the maximum difference between the Hubaux's mechanism and the proposed mechanism is 11 TSs, which is negligible considering that the total number of TS packets transmitted is 547,252. The application layer receives the same or greater number of error-free TS packets by the proposed algorithm than that by AAL5 in all simulation conditions. For the practical cases, where cell loss rate is equal to or less than 1.0e-3, the peak-to-peak PDV introduced by the proposed algorithm is less than 69.4% to that by AAL5. Moreover, the peak-to-peak PDV by the proposed mechanism is always smaller than that by Hubaux's mechanism. The results presented in this paper show that the proposed mechanism gives improved data loss and peak-to-peak PDV figures in the communications of CBR HDTV TS compared to AAL5 and Hubaux's mechanism. The proposed algorithm is mapped into AAL5 with SSCS for CBR HDTV application.

The proposed algorithm needs to be further tested in different network traffic environments to evaluate its performance in both peak-to-peak PDV and the number of error-free TS packets at the receiver side.

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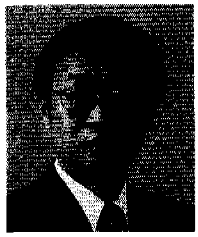

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