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Simulation Study on Multi-Hop Jitter Behavior in Integrated ATM Network with CATV and Internet*

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SUMMARY The project of interconnecting CATV in Hyogo Prefecture, Japan has started since March, 1998. In this project, there are three CATV companies in Hanshin area; Kobe, Nishinomiya and Amagasaki. An ATM switch is equipped in each company and these CATVs are connected serially in the above order. Each company provides the video service to the rest of companies using the MPEG2 over ATM. Each MPEG2 stream is sent to the other two CATV companies according to the function of multicast implemented in ATM switch. In the coverage of each CATV, subscribers utilize Internet connection using cable modems as well as standard CATV broadcasting service. In this paper, we present the outline of the research project in Hyogo Prefecture, Japan, and examine the jitter processes of MPEG streams of the testbed network by the simulation. In our testbed network, cells with two types of requirement for QoS are multiplexed; cells for MPEG2 which require the real-time transmission and those for Internet packets which are much more sensitive for the cell loss ratio. We investigate the jitter processes under some scenarios and show how the jitter process is affected by the Internet traffic and the other cell streams of MPEG2. Furthermore, we study the effect of the number of ATM switches on the jitter process when more CATV networks are added serially.
key words: *ATM, CATV, internet, MPEG2, multicast, jitter*

1. Introduction

In this paper we present the wide area project aiming the inter connection of presently existing CATV networks in Kobe, Nishinomiya and Amagasaki through three ATM switches. We summarize our project and investigate the jitter performance of the constructed ATM network by the simulation study.

After the destructive disaster of Hanshin-Awaji earthquake, we have recognized that it is significantly important to construct the robust information infrastructure for transmitting large volume of emergent information on rescue calls, supply schedules, safe refuge places, and so on. It has been reported [10] that the coaxiable cable for CATV was less damaged even by the earthquake of magnitude seven and that the optical fiber cable laid on the rail way had not been damaged. From these reasons, the project of interconnecting CATV and Internet has been planned in Hanshin area since 1996. The main objective of the project is to construct the robust interactive information network with optical fibers laid on the rail way, and with coaxial cables which have been deployed in the wide area.

On the other hand, recently, there exists rapidly growing interest in the inter-connection of CATVs which integrates broadcasting and communication services aiming to support multimedia traffic. ATM technique and optical fiber trunk lines are promising for this purpose and adopted in this project, which is the first trial in Japan to provide both broadcasting and communication services.

The pioneering challenge in this project is to efficiently integrate these two kinds of traffic stream of entirely different characteristics. The effectiveness of traffic management and control mechanisms in the integrated circumstance of broadcasting and communication data traffic through ATM networks is the crucial matter to be studied. The efficient use of available bandwidth is also an important subject to be covered in the project.

The construction of the testbed for the project was completed at the end of February, 1998 and the experiment has been started since March, 1998. This research project has been named as "Research and Development on Traffic Modeling and Management/Control Techniques for the Integration of Broadcasting and Communication Services through Optical Fiber Trunk Lines Cascading CATV Networks." The research has been performed by Kobe Multi-node Integrated Connection Research Center (KOMIC [12]), which has been established by Telecommunications Advancement Organization of Japan (TAO). KOMIC research center carries out advanced research and development towards the effective integration of broadcasting and communication traffic through ATM network connecting three existing CATVs with optical links.

Furthermore, the application of the outcome of this project enables the sharing of information pertinent to everyday life as well as the broadcasting of local programs produced by one of the CATVs. It also functions as a reliable infrastructure corresponding to a variety of local needs to mutually back up the CATVs through inter-connection by optical fiber trunk lines, in emergency cases when the facilities of one of the CATVs is damaged by natural disaster such as earthquakes.

The research and development areas of this project

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are as follows.

1. Simulation Technology for ATM Network
   The qualitative evaluation of the effect of hops through ATM network on the performance measures such as transmission delay and jitter is carried out by simulation [5].
2. Image Transmission Technology through ATM network
   a. Image transmission experiment in emulated traffic environment
   b. Image transmission experiment in real traffic environment
3. Robust Image Transmission Technology for Transmission Delay and Jitter
   Based on performance measurements of image transmission experiments in the real traffic environment and simulation studies on ATM networks, robust technology will be discussed and developed.

In this paper, we examine the jitter processes of decoding points by the simulation. According to [7], we consider the inter-arrival time of tagged MPEG cells to the destined decoder. Here we define the jitter as the variance of inter-arrival time of tagged MPEG cells.

In our testbed, cells with two types of requirement for QoS are multiplexed: cells for MPEG2 which require the real time transmission and those for Internet packets which are much more sensitive for the cell loss ratio. In the following, we refer to the cells for MPEG2 as the MPEG cells and the cells for Internet packet as the Internet cells. In our simulation model, each MPEG stream is connected under CBR class and it is copied and sent in accordance with the multicast function of the ATM switch. All connections for MPEG2 and Internet streams are established with PVC. The tagged MPEG stream contends the output port with the other MPEG stream and the Internet packet stream. We investigate the jitter processes under some scenarios and show how the jitter process is affected by the Internet traffic and the other cell streams of MPEG2. Furthermore, we study the effect of the number of ATM switches on the jitter process when more CATV networks are added serially.

Jitter in ATM networks has been studied extensively and several analytical models were proposed. One of pioneering works was done by [11] where the jitter is characterized by the random delay component. The departure process was analyzed by assuming the Markovian behavior of the delay component. [6], [7] analyzed the departure process of the tagged cell under which the tagged cell stream is multiplexed with the background stream. In [3], the authors considered the message transmission where the message consists of consecutive cells. They analyzed the message delay process which is defined as the time elapsing from the arrival epoch of the first cell of the message to the epoch when the last cell is transmitted.

[3] and [7] considered the jitter behavior under the multiple-node case, where the tagged cell stream is superposed with the background stream. They analyzed it by the approximation technique or performing the simulation due to the analytical difficulty. As for the multiplexing environment, most of researches considered only tagged and background streams for simplicity of the model. In our study, however, we consider all connections of MPEG stream and Internet one. Note that most of Internet traffic is generated through CATV network. We investigate how the tagged MPEG stream is affected by other MPEG stream and Internet one.

The paper is organized as follows. In Sect. 2, we explain the testbed system constructed in Hyogo Prefecture. In Sect. 3, we show our simulation model in detail and give the explanations of modules developed for the simulation. In Sect. 4, we present the simulation results.

2. Testbed Network and Its Equipments

The outline of the testbed system is as follows (see Fig. 1).

There are three CATV companies in Hanshin area; Kobe, Nishinomiya and Amagasaki. An ATM switch is equipped in each CATV and these CATVs are connected serially in the above order. Each company provides the video service to the rest of companies using the MPEG2 over ATM. The video service includes not only the standard video but the TV program broadcasting. Each MPEG2 stream is sent to the other two CATV companies according to the function of multicast implemented in ATM switch. In the area where companies provide the CATV service, fifty subscribers receive the standard CATV broadcasting. In addition, those subscribers are able to access the Internet using the cable modem. That is, Internet services such as E-mail, ftp and Web-browsing are supported through the CATV network. In the coverage of each CATV, fifty subscribers utilize Internet connection using cable modems as well as standard CATV broadcasting service.

Now we present the details of our testbed network in the following subsections.

2.1 Optical Transmission Path

In order to transmit massive volume of broadcasting and communication data at a high speed through Kobe, Nishinomiya and Amagasaki, optical fiber cables have been laid along the railway of the Hanshin Railroad Co. for major portions and electric poles for the rest of them.

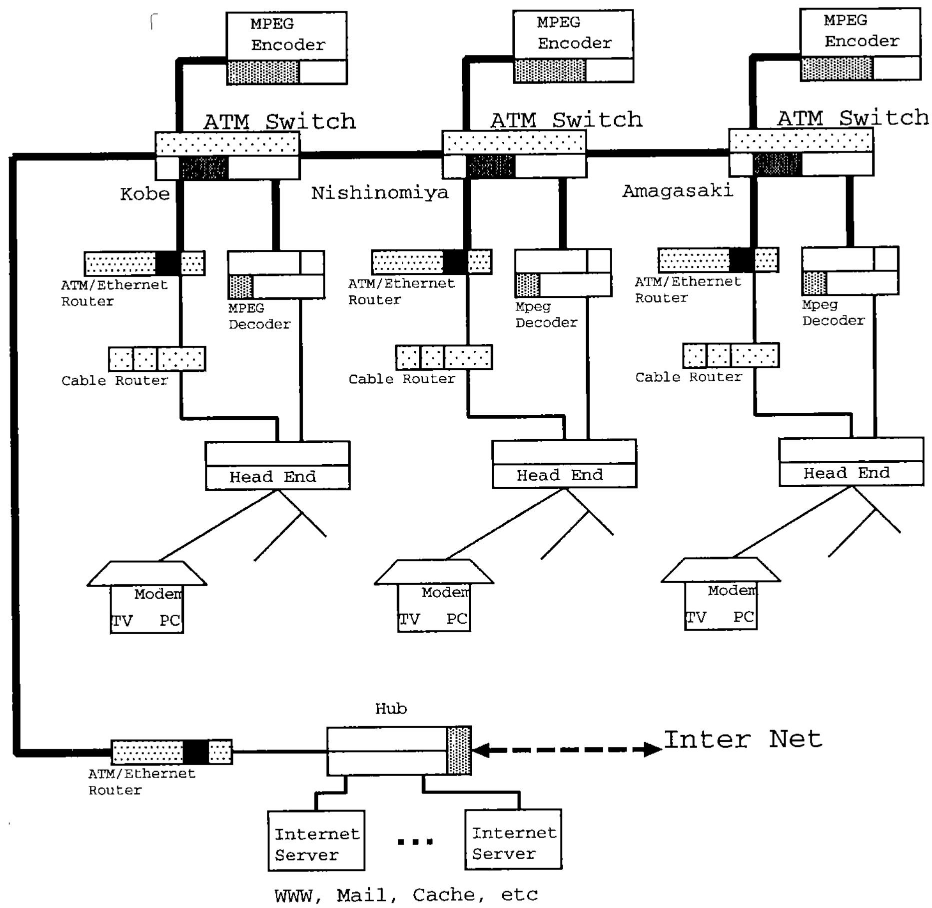

Fig. 1 Testbed network in Hyogo pref.

2.2 Transmission Facilities

In order to achieve high speed transmission in the network which integrates broadcasting and communication data, an ATM switch fabric having high speed switching capability and easy scalability has been installed at each CATV company. MPEG2 encoder/decoder system enables transmission of images and visual data of broadcasting TV programs in a digital compressed form through ATM networks. Owing to this technology, broadcasting programs as well as local programs produced by one of the three CATVs can be shared among them, which makes it possible to develop an advanced image transmission system. Furthermore, network monitoring and analyzing equipment including ATM analyzer is provided to facilitate the transmission experiments effectively.

2.3 Internet Facilities in CATV System

Approximately fifty households are selected from among CATV subscribers and provided with cable modems for Internet access so that the characteristics of Internet traffic are clarified.

2.4 Internet Server Facilities

Internet related servers such as a WWW server for information retrieval and a mail server for mail delivery are also equipped in the network so that the qualitative evaluation of the effect of Internet traffic on other types of traffic, especially on moving image traffic can be performed in a real environment. WWW server is also utilized to announce the outline and outcome of the project.

2.5 Monitoring and Measuring Equipments

Simulation tools and high performance workstations are prepared to develop simulation models and to execute simulation programs. An ATM analyzer is also equipped to monitor and analyze traffic streams from multimedia sources in the real system, which makes it possible to monitor and to measure the QoS of transmission in the integrated environment from theoretical and practical points of view.
Remark: Note that our ATM network has a serial topology. For the future plan, about ten CATV companies will be connected serially since those are located

serially along the Hanshin railway. From the economical point of view, the serial connection of CATV companies seems to be reasonable. If we focus our attention on the construction of more robust network against the disaster, we have to discuss the network topology from various points of views. However our main purpose here is to investigate the effect of the multi-hop jitter behavior of MPEG stream multiplexed with the Internet cells.

3. Simulation Model

In our simulation study, we used OPNET [8], a comprehensive software environment for modeling, simulating, and analyzing the performance of communications networks, computer systems and applications, and distributed systems. In this section, we describe the modules originally implemented for our simulation model and also show the parameters used in those modules.

3.1 Modules

Though OPNET provides the extensive modules for modeling the communications networks, it was needed to develop the original modules for realizing the certain features in our integrating network system. In our simulation model, we have implemented the following modules.

1. MPEG2 encoder
2. MPEG2 decoder
3. ATM switch
4. Client module which generates the Internet cell
5. Module of Internet Server

In the following, we show above modules in detail.

3.1.1 MPEG2 Encoder

MPEG2 encoder module generates the MPEG cell according to the certain probability distribution function. When MPEG2 encoder generates the MPEG cell, it sets the specified flag in the header of the cell, according to which the ATM switch functions for the multicast transmission. In Table 1, the parameters used in this module are presented.

3.1.2 MPEG2 Decoder

This module accepts the MPEG cells transmitted from the MPEG2 encoder. It also measures inter-arrival times of the MPEG cells generated by each MPEG2 encoder. The data are obtained by the function of Probe of OPNET.

3.1.3 ATM Switch

The module of ATM Switch simulates the switching function of arriving cells and performs the multicast if it is requested. The procedure of the multicast is presented in Sect. 3.2. In Table 2, the parameters set in the module are presented.

The standard module of ATM switch provided by OPNET supports SVC and does not support PVC. Thus, we have developed the new module of ATM switch which realizes the pseudo PVC. We also have implemented the function of multicast on the switch module. The multicast process is performed at each ATM switch module when the cell with multicast request arrives. According to this module, routing for both MPEG and Internet cells are performed and copying of MPEG cell are processed.

3.1.4 Client Module which Generates the Internet Cell

This module generates the Internet cell under which the inter-cell-generation time is distributed according to the exponential distribution. When the module generates the cell, it sets the flag by which the cell is identified as a Internet cell. On the other hand, if the client module accepts the cells sent by the Internet server, accepted cells are discarded and lost. In Table 3, the parameters set in the module are presented.

3.1.5 Module of Internet Server

When this module receives the Internet cell generated

Table 1 Parameters of MPEG2 encoder (PDF: Probability distribution function).

Parameter Name	Description
Inter-arrival time	Mean inter arrival time of MPEG cell
Inter-arrival pdf	PDF of inter arrival time of MPEG cell
source_number	Identifier of module

Table 2 Parameters of ATM switch.

Parameter Name	Description
ATM Switch Fabric Delay	Switching time in ATM switch
sw_number	Number of copies of MPEG cell and index for routing
copy_port	Port number to which MPEG cell and copied cell are sent.
server_port	Port number for Internet server
client_port	Port number for the destination client corresponding to sw_number
path_port	Port number for Internet cells

Table 3 Parameters of client module (IC: Internet cell).

Parameter Name	Description
Inter-arrival time	Mean inter-generating time of IC
Inter-arrival pdf	PDF of inter-generating time of IC
source_number	Identifier of module

by the client, the module returns the Internet cell to the client.

Remark: In our simulation, we did not implement the TCP/IP protocol which is provided by OPNET as a default module. The standard ATM modules of OPNET support only SVC and we tuned the parameters for realizing the pseudo PVC of MPEG stream. In this situation, the simulation time we realized on the SUN-4 workstation is about three to five seconds while the run time for a simulation program is over two hours. When we used the TCP/IP module, it was hard to set the SVC for Internet path and to transmit Internet cells within five seconds of simulation time. From this reason, we implemented the Internet-cell generator which generates cells directly at ATM layer. However, this does not simulate the real TCP/IP application and hence implementing the TCP/IP modules on our simulation program is one of the important issues to be improved for future study of our testbed network.

3.2 Multicast of ATM Switch

In this section, we present the multicast procedure implemented on our simulation model.

If the MPEG cell is sent to each CATV station without multicast, it wastes the bandwidth of the link between ATM switches as shown in Fig. 2. On the other hand, if the MPEG cell is sent using the multicast function of ATM switch, it provides the effective utilization of the bandwidth of each link (see Fig. 3). It also causes to reduce the number of cells to be switched at the ATM switch. This load reduction of the ATM switch is more effective when the number of ATM switches increases.

There have been a number of researches concerning the ATM multicast [2], [4]. We have implemented the following multicast procedure on the ATM switch module (see Fig. 4). The copy network is equipped in front of the ATM switch and this network copies the required amount of cells from the original MPEG cell.

In this procedure, the cell which is not for the multicast also goes through the copy network and hence it causes to increase the delay of the cell transmission. The strong point of this procedure is that it is easy to implement on OPNET.

3.3 Simulation Model

Using the modules described in the previous subsection, we finally construct the simulation model of the testbed network as shown in Fig. 5. Here, assumptions and parameters set in the simulation are all based on the technical specification prescribed by Hyogo Prefecture.

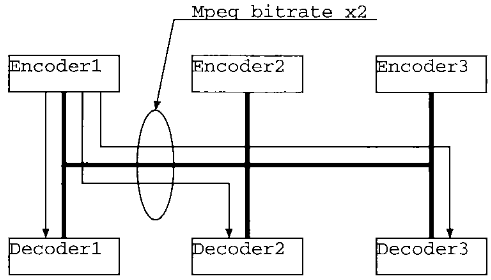

Fig. 2 Transmission without multicast.

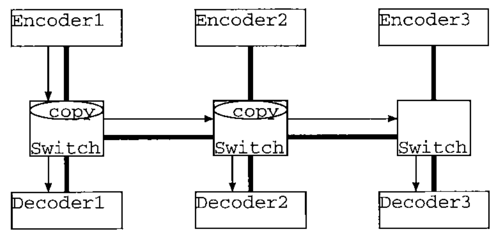

Fig. 3 Transmission with multicast.

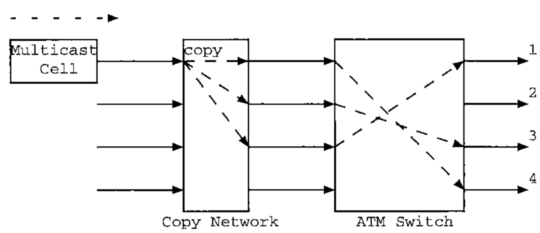

Fig. 4 Copy network implemented on simulation.

In Fig. 5, jitters 1 to 3 are modules of MPEG2 encoders. Jitter 1 is corresponding to Kobe, jitter 2 to Nishinomiya, and jitter 3 to Amagasaki. As for the cell-generating rate of the MPEG2 encoder, λ, the range 3 to 14 Mbps is specified. Hence we investigate the jitter process with the three values of the generation rate: 4, 8, and 13 Mbps, respectively.

The tagged MPEG stream is generated with the constant bit rate λ and the others are generated according to the Poisson process with rate λ. This avoids the dependence of the initial time of the MPEG cell generating process. Since the size of a cell is equal to 53 bytes, we set the values of Inter-arrival time for MPEG encoder module as shown in Table 4. In the real MPEG encoder, the raw data stream is considered as bursty because of the different sizes of I, P, and B pictures. As for the MPEG encoder with the function of MPEG2 over ATM, which is equipped in our testbed network, the output stream is realized as the CBR owing to the feedback control within the encoder. Hence we don't need to consider the GOP level for modeling the MPEG stream.

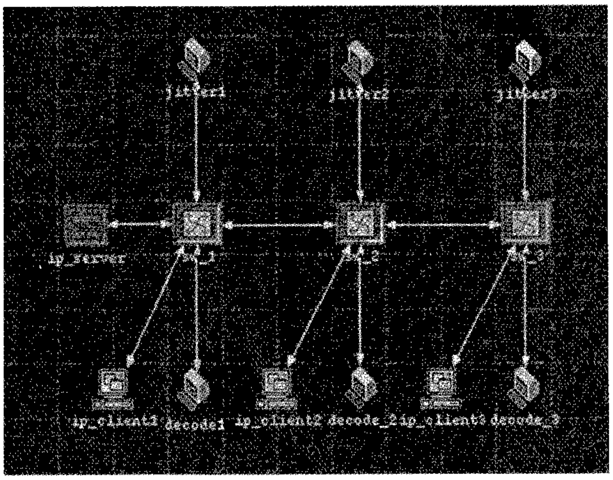

Fig. 5 Network model on OPNET.

Table 4 Values of bit rate of MPEG encoder.

Case	Value (second)
1	$53 \times 8/(4 \times 10^6) \simeq 1.0 \times 10^{-4}$
2	$53 \times 8/(8 \times 10^6) \simeq 5.0 \times 10^{-5}$
3	$53 \times 8/(13 \times 10^6) \simeq 3.0 \times 10^{-5}$

In Fig. 5, decodes 1 to 3 are the modules of MPEG decoder. sws 1 to 3 are the modules of ATM switch. In the testbed network, the switching capacity is assumed to be at least 5 Gbps. Hence we chose 6 Gbps as the value of the switching capacity and set ATM Switch Fabric Delay in Table 2 equal to $53 \times 8/(6 \times 10^9) \simeq 7.0 \times 10^{-8}$ (sec.).

The capacity of all links is equal to 156 Mbps and we assume no propagation delay of the link. The links for MPEG and Internet streams are all established under CBR class.

In Fig. 5, ip_server is the module of the Internet server. ip_clients 1 to 3 are the modules of Internet client. As for the bit rate of the Internet cell, let N denote the number of ATM switches. We assume that all ip_clients generate Internet cells with the same bit rate. In addition, the arriving Internet cell to the server is returned to the client. Thus, the maximum bit rate with which the client generates the Internet cell, W, is given by $156/2N$ (Mbps). For example, if $N = 3$, the maximum bit rate is given by

$$W = \frac{156}{2 \times 3} = 26\,\text{Mbps}.$$

To investigate how the Internet cell affects the jitter process, we set the bit rate of the Internet cell equal to 0, $156/4N$, and $156/2N$ (Mbps), respectively. We assume that all Internet clients generate cells according to exponential distribution with the same rate.

Finally, we investigate the jitter process when N is equal to 3, 4, and 5, respectively. In the cases of $N = 4$ and 5, the ATM switches are added serially to the right direction. That is, 4th ATM switch is equipped on the right side of Amagasaki. Similarly, 5th ATM switch is equipped on the right side of 4th one.

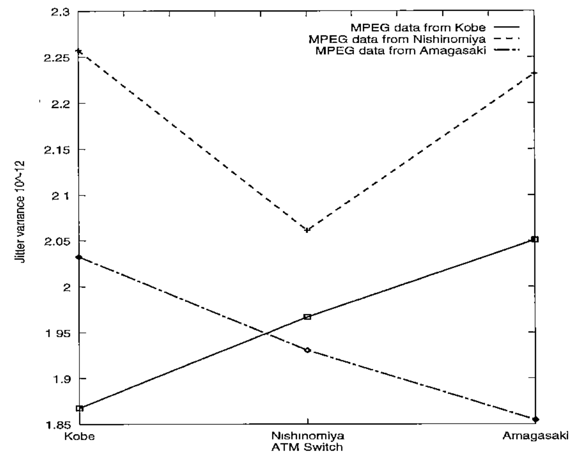

Fig. 6 Jitter values: MPEG = 4 Mbps, IP = 0 bps.

Table 5 Parameters list of simulation (MC: MPEG cell, IC: Internet cell).

Figure	N	MC (Mbps)	IC (Mbps)
6	3	4	0
7	3	4	13
8	3	4	26
9	3	8	0
10	3	8	13
11	3	8	26
12	3	13	0
13	3	13	13
14	3	13	26
15	4	8	13
16	5	8	13

4. Simulation Results

We show the simulation results in Figs. 6 to 16. In all figures, the horizontal axis represents the location of the CATV company and the vertical axis means the jitter value, i.e., the variance of inter-arrival time of tagged MPEG cells (second^2). Note that the scale of the vertical axis is in the order of 10^{12}. In Table 5, we summarized the parameters of Figures.

First, we show the mean inter-arrival time of MPEG cell at each MPEG2 decoder in Table 6. From this table, it is observed that inter-arrival times of MPEG cells are almost same.

In Figs. 6 to 8, we show the jitter values with MPEG cell rate equal to 4 Mbps when the Internet cell rate is set to 0, 13, and 26 Mbps, respectively.

In Fig. 6, we observe that the jitter values are symmetrical at the decoder point of Nishinomiya. In this case, there are no Internet cell streams in the network and hence the MPEG traffic are symmetrical at Nishinomiya. We also observe that the jitter values of MPEG data generated at Kobe and Amagasaki becomes large

Table 6 Mean inter-arrival time of MPEG cell (10^{-5}s, MPEG cell = 13 Mbps, internet cell = 26 Mbps).

From / To	Kobe	Nishinomiya	Amagasaki
Kobe	$3.00 \pm (7.29 \times 10^{-4})$	$2.99 \pm (3.75 \times 10^{-3})$	$3.00 \pm (4.06 \times 10^{-3})$
Nishinomiya	$3.00 \pm (1.53 \times 10^{-3})$	$2.99 \pm (7.70 \times 10^{-4})$	$3.00 \pm (1.32 \times 10^{-3})$
Amagasaki	$3.00 \pm (1.97 \times 10^{-3})$	$3.00 \pm (1.56 \times 10^{-3})$	$3.00 \pm (7.34 \times 10^{-4})$

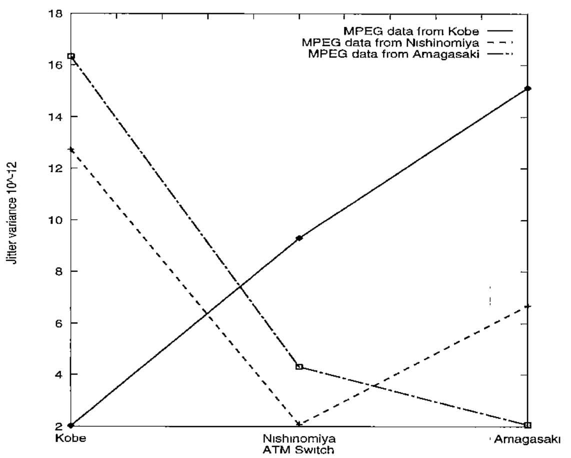

Fig. 7 Jitter values: MPEG = 4 Mbps, IP = 13 Mbps.

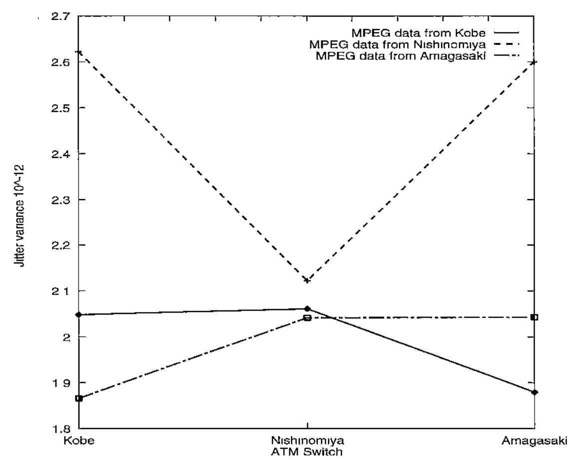

Fig. 9 Jitter values: MPEG = 8 Mbps, IP = 0 bps.

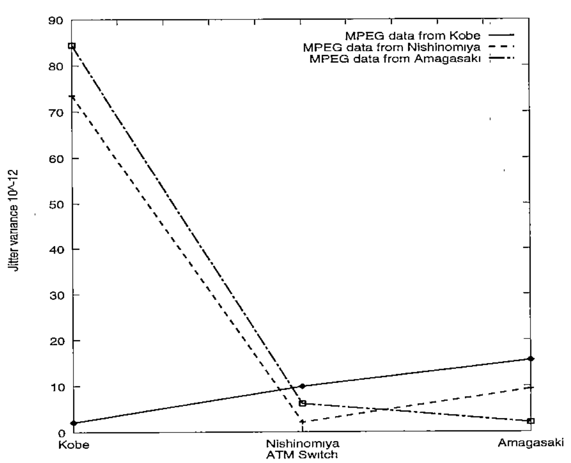

Fig. 8 Jitter values: MPEG = 4 Mbps, IP = 26 Mbps.

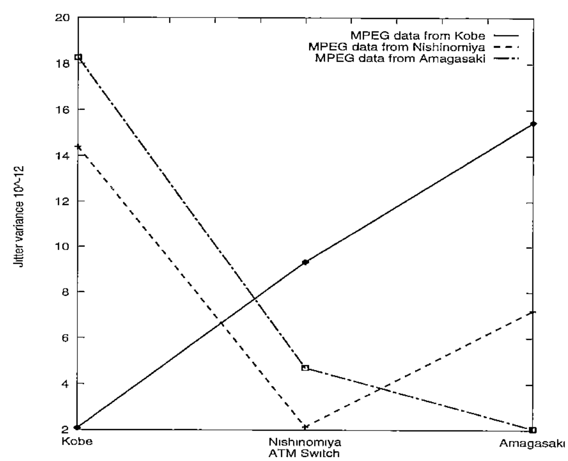

Fig. 10 Jitter values: MPEG = 8 Mbps, IP = 13 Mbps.

as the number of ATM switches increases.

In Fig. 7, the jitter value of MPEG cell from Kobe becomes large as the number of ATM switches increases. The jitter value of MPEG cell from Nishinomiya to Kobe is larger than that to Amagasaki. This is because the Internet traffic mainly centers on Kobe. Also, the jitter value of MPEG cell from Amagasaki is becoming large as the number of ATM switches increases. In particular, the increase of the jitter at Kobe is larger than that at Nishinomiya because of the aggregation of the Internet traffic at Kobe.

Figure 8 is the case that the bit rate of the Internet cell is largest in the three figures. Figure 8 shows the same tendency of Fig. 7. Note that at the decoder of Kobe, the jitter values are quite larger than those of Fig. 7. This means that the Internet cell with high bit rate largely affects the jitter at the decoder of Kobe.

Figures 9 to 11 are with the bit rate of the MPEG cell equal to 8 Mbps under Internet cell equal to 0, 13, and 26 Mbps, while Figs. 12 to 14 are with 13 Mbps of MPEG cell under 0, 13, and 26 of Internet cell. We can observe the same tendencies of Figs. 6 to 8.

Now we compare above figures under the same bit rate of Internet cell. Figures 6, 9 and 12 are under the case that there is no Internet stream in the network. When the bit rate of MPEG cell becomes large, the jit-

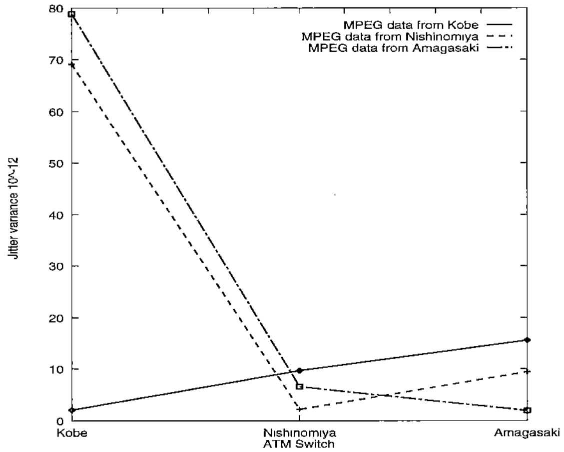

Fig. 11 Jitter values: MPEG = 8 Mbps, IP = 26 Mbps.

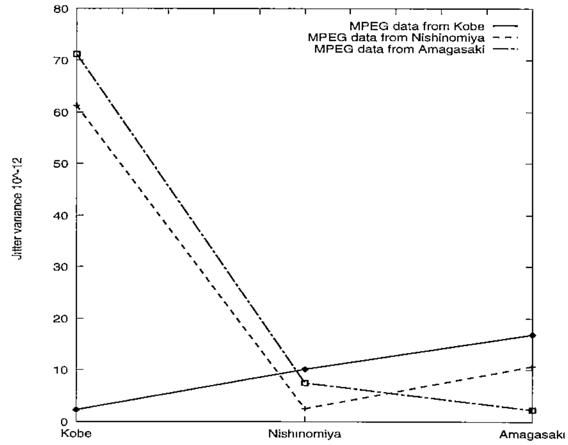

Fig. 14 Jitter values: MPEG = 13 Mbps, IP = 26 Mbps.

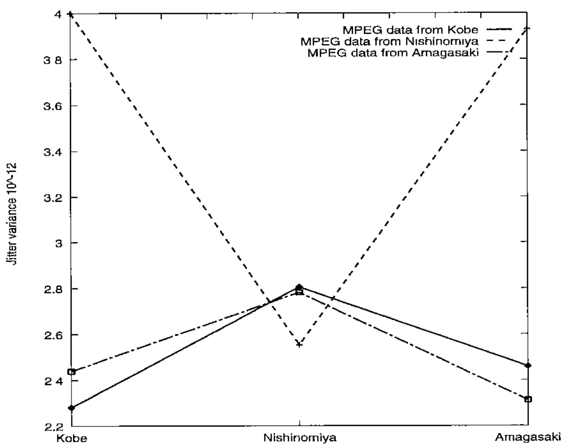

Fig. 12 Jitter values: MPEG = 13 Mbps, IP = 0 bps.

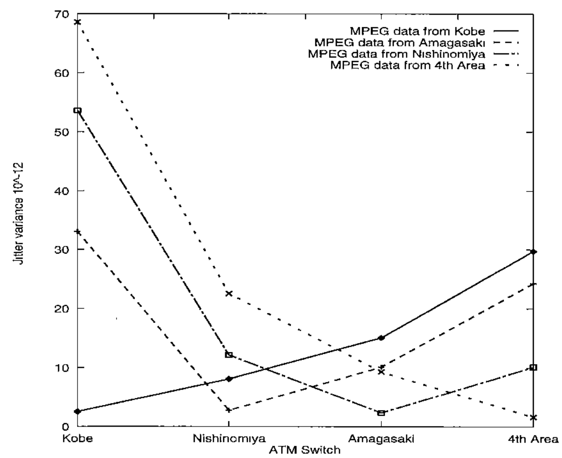

Fig. 15 Jitter values: MPEG = 8 Mbps, IP = 13 Mbps, 4 areas.

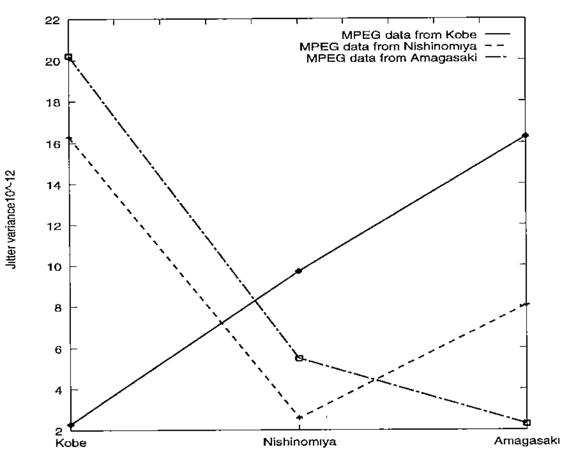

Fig. 13 Jitter values: MPEG = 13 Mbps, IP = 13 Mbps.

ter value of MPEG cell from Kobe (Amagasaki) is getting large at the decoder at Nishinomiya but becoming small at Amagasaki (Kobe). (Fig. 12 is remarkable.) That is, the jitter does not always becomes large when the number of ATM switches increases. One of the reasons is that when the MPEG cell traverses the cascaded ATM switches under the homogeneous traffic environment, the jitter tends to decrease (see [1] in details).

Figures 7, 10 and 13 are under the case that the bit rate of the Internet cell equals to 13 Mbps. The tendency of the variations of curves is same. Note that the ranges of the jitter value under three figures are not so different when the bit rate of MPEG cell is getting large. This means that the Internet cell affects the jitter value more largely than the MPEG cell. We can observe the same tendency in Figs. 7, 10 and 13.

Figures 15 and 16 represent the jitter values under N, the number of ATM switches, equal to 4 and 5, respectively. In both figures, the MPEG bit rate is equal to 8 Mbps and the bit rate of Internet cell equal to 13 Mbps. From the figures, we can see the same tendencies of previous figures where the stream of Internet cell exists. In particular, jitter values at the decoder of Kobe become quite large when $N = 5$. This suggests that the Internet servers or gateways must be distributed in certain areas if the small jitter values at all decoder points is desired. Otherwise, we have to develop the certain scheme, such as the new protocol for MPEG2 transmission or the new function of the ATM switch, for making the jitter small.

5. Conclusion

In this paper, we presented the wide area project in Hyogo Prefecture and showed the outline of the testbed network constructed in Kobe, Nishinomiya and Amagasaki. We also investigated the jitter processes with the simulation study and presented the effects of the bit rates of Internet and MPEG cells and the number of ATM switches.

It is an important issue to evaluate the quality of decoded pictures under our simulation results. [9] reported that the tolerated value of cell delay variation (CDV) for 1.5 Mbps MPEG NTSC video is 6.5 ms while that of 20 Mbps HDTV video is 1 ms. But the tolerated value of MPEG2 is not clear. The worst deviation observed in Fig. 16 equals to about $\sqrt{1.8 \times 10^{-10}} \simeq 13.4\,\mu s$ and it looks to satisfy the QoS for MPEG2. However more researches of the QoS requirement for MPEG2 in terms of the jitter value are needed. Here we have following issues related to the QoS for our future research:

- Investigate the QoS requirement of MPEG2 video in terms of the jitter values.
- How does the number of ATM switches affect the jitter of MPEG cell?
- What size of the buffer of MPEG2 decoder is needed for absorbing the jitter effects? This issue is also related to the cost problem.

Since the project just started, there are no data of the real traffic on the testbed network. To validate our simulation model, we have to collect the data of the jitter in the real traffic environment and to compare it with the simulation results presented in this paper. This is the next theme of our research.

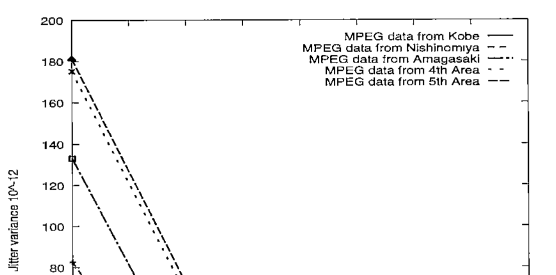

Fig. 16 Jitter values: MPEG = 8 Mbps, IP = 13 Mbps, 5 areas.

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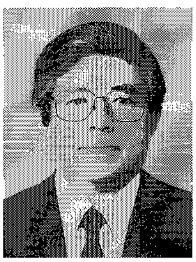

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