Jitter Behavior of MPEG2 Stream in Self-similar Traffic of ATM Network Integrating CATV and Internet

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Abstract

The experimental network for the project of interconnecting CATV in Hyogo Prefecture, Japan started from March, 1998. In this project, three CATV companies in Hanshin area, Kobe, Nishinomiya and Amagasaki are connected serially with optical fiber via ATM switches. In this network, the jitter process of MPEG2 stream is investigated experimentally. In addition, the simulation model is also developed for the performance evaluation of the future extended network. Recently, it was reported that the cell stream of our experimental network exhibits the self-similar nature over the several time-scales. In this paper, we construct the simulation model of the testbed network focusing on the generation of self-similar traffic, and investigate the relation between the self-similar traffic and the jitter of MPEG2 cells.

1 Introduction

The experimental network for the project of interconnecting CATV in Hyogo prefecture, Japan started from March, 1998. The research has been performed by Kobe Multi-node Integrated Connection Research Center (KOMIC), which has been established by Telecommunications Advancement Organization of Japan (TAO).

In this project, there are three CATV companies in Hanshin area, Kobe, Nishinomiya and Amagasaki (see Figure1). 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. MPEG2 connections are established with PVC CBR, while Internet connections are established with SVC.

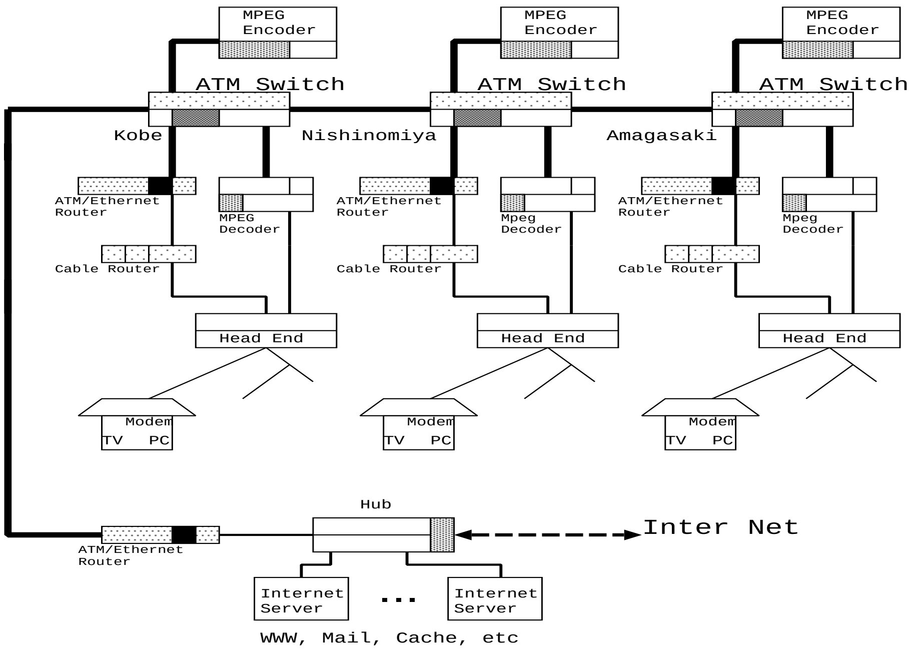


Figure 1: Facilities

In this network, there are two types of cells with different requirements for QoS. The one is for MPEG2 which requires the real time transmission, and the other is for Internet which is much more sensitive for the cell loss probability. In the following, we refer to the cells for MPEG2 as the MPEG cells and the cells for Internet packet as the Internet cells. The main objective of this project is to investigate the jitter process of MPEG cells. For details of this project, readers are referred to [1].

In [1], we developed the simulation model using OPNET. We implemented the function of multicast on the ATM switch module, and constructed the modules of MPEG2 encoder/decoder and Internet server/client. Using these modules, we constructed the simulation model of the experimental networks and examined the inter-arrival time of tagged MPEG cells to the destined decoder. From the simulation result, we showed how the tagged MPEG stream is affected by other MPEG and Internet cells and the number of ATM switches.

On the other hand, it has been shown that the traffic such as Ethernet LAN, WAN, and ATM has the statistical characteristics of self-similarity and long-range dependency (LRD) [3], [4], [5]. Our recent study[12] has reported that the experimental network of our project exhibits the self-similar characteristics over several time-scales. In general, the traffic with LRD degrades the network performance and hence it is important to characterize the traffic for investigating the performance measure such as cell loss probability, transmission delay, and jitter process. Though Markovian process is often used for the network modeling for analytic simplification, the Markovian process such as Poisson has only a low correlation over a long enough time-scale.

In this paper, we present the improved simulation model of the experimental network taking the self-similar process into consideration, and investigate the relation between the self-similar traffic and the jitter process of the MPEG cells. According to [6] we define the jitter as the variance of Inter-arrival time of tagged MPEG cells.

The outline of this paper is as follows. In Section 2, we briefly show the results of Hurst parameter estimation in [12]. In Section 3, we present our simulation model with self-similar input and present the result of the simulation in Section 4. Finally, we conclude our work in Section 5.

2 Estimating Self-Similarity of Testbed Network

In this project, an ATM analyzer (HP E4210B) used for measuring the cell stream. It's equipped in Kobe CATV office and captures the traffic from Kobe to Nishinomiya and vice versa. The analyzer records the time-stamps of cells coming in and going out. The measured data includes the time-stamps accurate to within 10μsec.

In [12], we estimated the Hurst parameter of the cell streams from Kobe to Nishinomiya and vice versa on the experimental network . We call the former data stream "Right stream" and the later "Left stream". We estimated the Hurst parameter of measured data using four estimating methods. These are Aggregated Variance, Absolute Value, R/S and Periodogram methods. For the details of estimating methods, readers are referred to [2], [5], [10], [11]. We show the graphical results of these methods for a Right stream in Figure 2.

The estimation results of measured data are shown in Figure 3. In Figure 3, the horizontal axis represents the name of the sample data. R-1, R-2 and R-3 are the measured data of Right stream, and L-11, L-12, L-13, L-21, L-22 and L-23 are the measured data of Left stream. The vertical axis of Figure 3 means the estimated Hurst parameter. The attributes of these data are shown in Table2. In [12], we showed that the value of Hurst parameter was affected by the Internet cell. We estimated that the Hurst parameter of Right stream is around 0.6 to 0.8 while that of Left stream is about 0.6. Hence for the simulation, it is important to model the Internet cell generating process.

3 Simulation Model

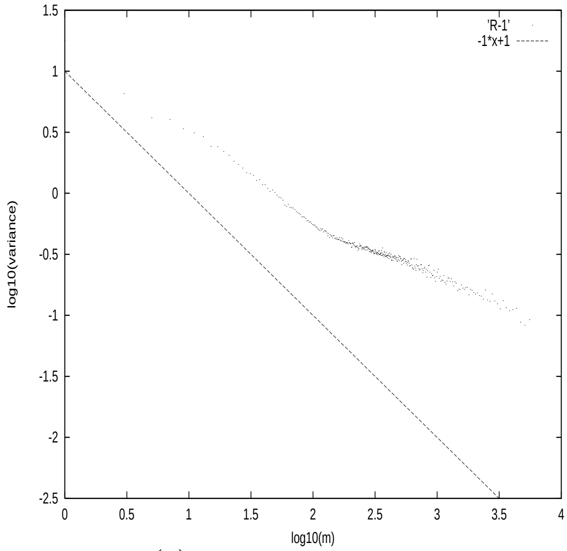
In our simulation study, we used OPNET, a comprehensive software environment for modeling, simulating, and analyzing the performance of communications networks, computer systems and

Table 1: Measured Data

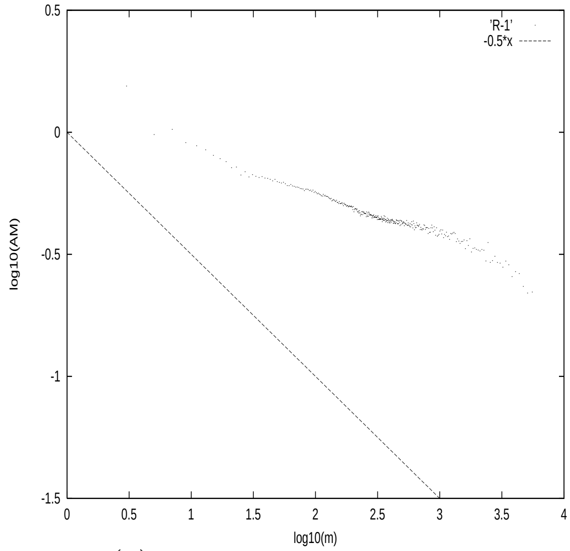
Result of Measure for ATM cell stream			
The date of Measure : 8, Jan, 1999 13:00 ~ 14:00			
Data name	Measured span	Direction	Bitrate(Mbps)
R-1	6.0910829	Right	9.124
R-2	5.5301356	Right	10.049
R-3	6.3653521	Right	8.731
L-11	6.3312494	Left	8.778
L-12	6.4701180	Left	8.589
L-13	6.7403174	Left	8.245
L-21	3.6361174	Left	15.284
L-22	3.5231654	Left	15.774
L-23	3.4062480	Left	16.315

Table 2: The Internet Cell Property of Measured Data

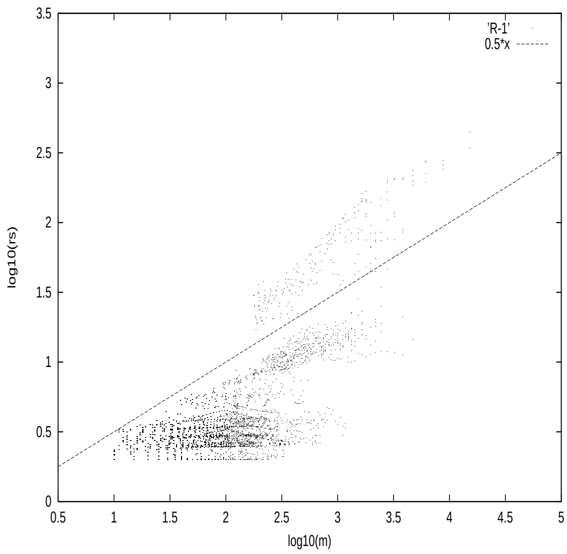
The Result of Internet cell measurement in The ATM Cell Stream			
Data name	Number of	Amount of Internet cell(%)	Average Bitrate of Internet cell (Mbps)
R-1	33804	25.8	2.353
R-2	42785	32.6	3.280
R-3	29455	22.5	1.962
L-11	16312	12.4	1.092
L-12	13562	10.3	0.888
L-13	8856	6.7	0.557
L-21	9770	7.5	1.139
L-22	9318	7.1	1.121
L-21	13716	10.5	1.707



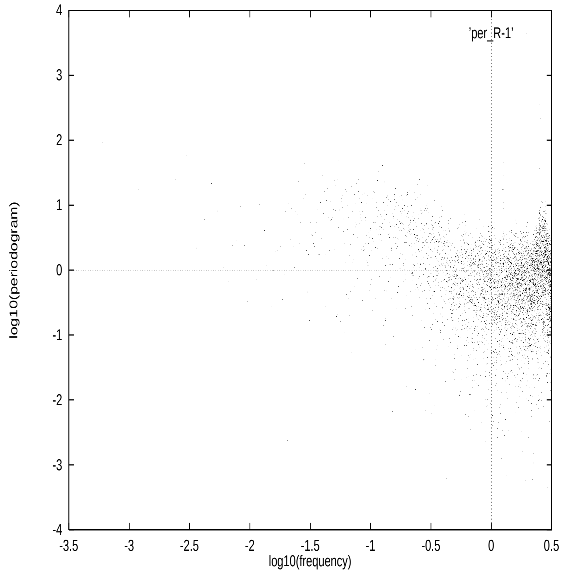
(a) Variance Method



(b) Absolute Value Method



(c) R/S Method



(d) Periodogram Method

Figure 2: Result of Four Methods for R-1

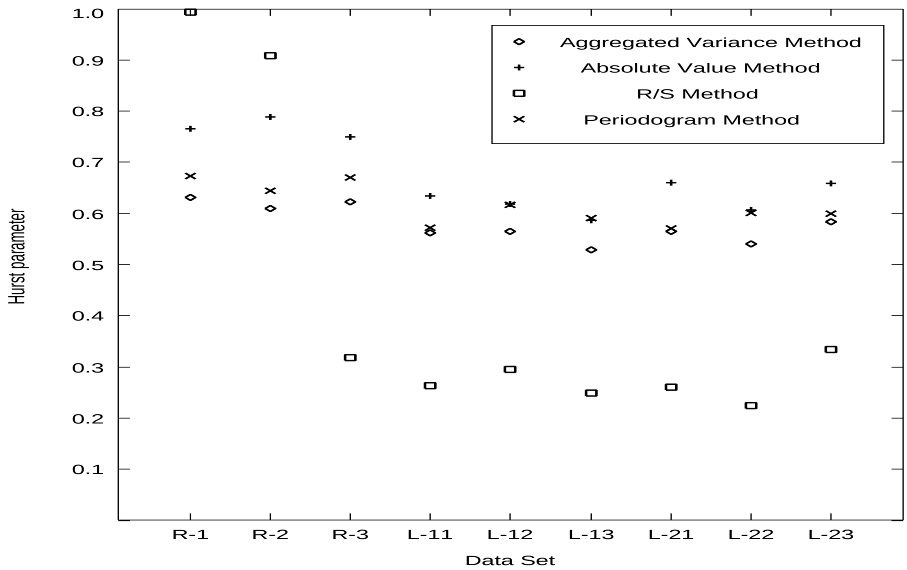


Figure 3: Estimation of Hurst Parameter

distributed systems. In this paper, we use the modules based on [1], and reconstruct the module of Internet Server. In [1], we made the following modules.

1. MPEG2 encoder
   This module generates the cells for MPEG2 according to the exponential or deterministic distribution.

2. MPEG2 decoder
   This module receives the cells for MPEG2 generated by MPEG2 encoder, and measures the cell interarrival time.

3. Client module which generates the Internet cell
   This module generates the Internet cell according to the exponential distribution.

4. Module of Internet Server
   When this module receives the cell for Internet generated by the client, the module returns the Internet cell to the client.

5. ATM switch
   The multicast function is implemented. ATM switch is equipped with the output buffer.

3.1 Module of Internet Server

In [12], we made the module of Internet Server which generates Internet cells according to the Pareto distribution. The Pareto distribution is reported to be the best model of the document size distribution for WWW service [7]. We assumed that the Internet server generates cells according to the Pareto distribution when the request cell arrives at the server. However, we observed very high self-similarity ($H > 0.9$) with this module.

In this paper, we modify this module using Fractional Gaussian Noise (FGN). For making FGN data we use the Fourier Transform method [9]. We set the parameters for generating the FGN data so as to match the average and variance of measured data. We consider the discrete-time stochastic process whose unit length of time is equal to 10^{-5}sec. Let X_n denote FGN random variables at time n. Our improved module of Internet Server generates X_n cells at time n. The weak point of using FGN is that the generated sequence contains negative values. We selected the parameter sets for generating FGN carefully such that the number of negative values are less than 10% of that of the generated sequence. Then we regard the negative value as zero.

3.2 Module of ATM Switch

In [1], we constructed the ATM switch is implemented the multicast function. In this study, we modify the output buffer in the ATM switch and investigate the jitter process under the two cases. The case 1 is that the ATM switch is equipped with two output buffers. MPEG and Internet cells are put into these output buffers separately. In this case the service discipline of two buffers is round-robin. The case 2 is that the ATM switch is equipped with one output buffer. In this case, MPEG cells contend with Internet cells in same buffer section.

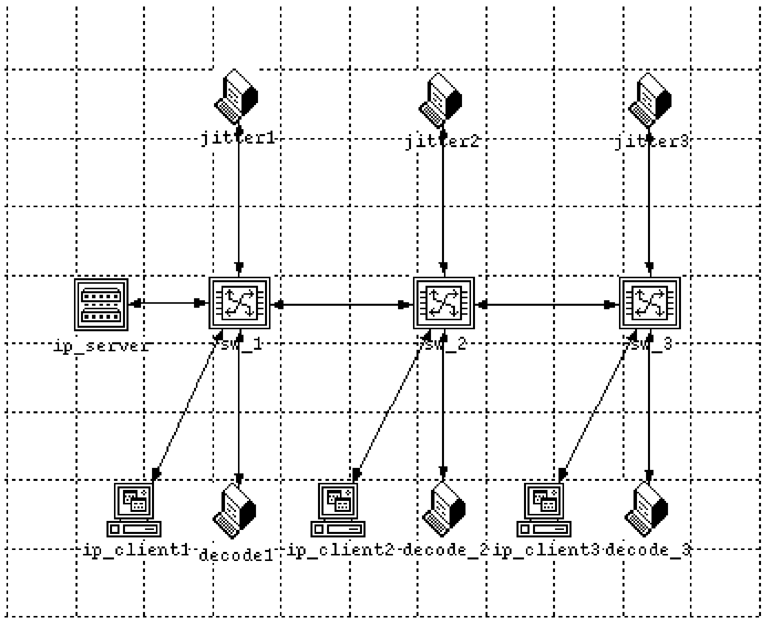


Figure 4: Network Model on OPNET

4 Simulation and Result

Using the modified module described in the previous subsection, we finally construct the simulation model of the experimental network as shown in Figure 4.

In Figure 4, jitters 1 to 3 are modules of MPEG2 encoders. Jitter 1 to 3 are corresponding to Kobe, Nishinomiya and Amagasaki, respectively. Decodes 1 to 3 are the modules of MPEG decoder. Sw 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 6Gbps as the value of the switching capacity and set the cell switching time in ATM switch equal to $53 \times 8/(6 \times 10^9) \simeq 7.0 \times 10^{-8}$ (sec). The capacity of all links is equal to 156Mbps.

In Figure 4, ip_server is the module of the Internet server. Ip_clients 1 to 3 are the modules of Internet client. At first, in order to confirm that our modified modules generate the self-similar traffic, we run the simulation with only Internet cell stream from Internet server to client at Amagasaki, and investigate the Hurst parameter H of the stream from Kobe to Nishinomiya. We set the parameters of the stream from Internet server based on the result of [12] as shown in Table3.

Table 3: Parameter Sets of FGN for Module of Internet Server

Parameter	value
Hurst Parameter	0.7
Mean Cells within a Slot(10^{-5}sec)	0.05514
Variance of Cells within a Slot	0.16082
Number of Sample Points	1048576

Figure 5 shows the result for Variance method of Internet stream from Internet server. From this figure, we get the Hurst parameter as $H = 0.67$. The reason why we get the smaller value of Hurst parameter is that we have regarded the negative value as 0. Although resulting Hurst parameter becomes small, the self-similar traffic is realized by our modified module. In the following, referred values of Hurst parameter are those under which FGN data are generated.

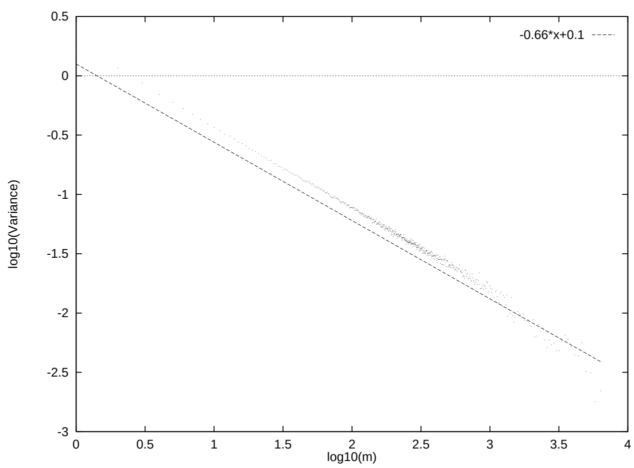


Figure 5: Result of Variance Method

Next, we investigate the jitter process at the three decoder points for MPEG cells from Kobe.

As for the cell-generating rate of the MPEG2 encoder, we set 6.771 Mbps, that is, we set the interdeparture time to 6×10^{-5}sec. The service type of MPEG2 cells is CBR. In order to study the relation between the self-similarity of Internet and MPEG cells, we run the simulation with parameter sets of Hurst parameter and MPEG bitrate shown in Table 4. We make the 23.53Mbps Internet stream by adding ten 2.353Mbps MEPG streams with different seeds of random numbers.

Table 4: Parameter Sets

Figures	Hurst Parameter	Internet Bitrate (Mbps)
6(a)	0.5, 0.6, 0.7, 0.8	2.353
6(b)	0.5, 0.6, 0.7, 0.8	23.53
6(c)	0.5, 0.6, 0.7, 0.8	2.353
6(d)	0.5, 0.6, 0.7, 0.8	23.53

In Figures 6(a) to 6(d), the horizontal axis represents the location of the CATV company and the vertical axis means the jitter value. Figure 6(a) shows the simulation results in the case that Hurst parameter is equal to 0.5, 0.6, 0.7 and 0.8, respectively, and Internet bitrate equal to 2.353Mbps. We set two buffers for MPEG and Internet cells in ATM switch module. From this figure, we can observe that the jitter value becomes small at Nishinomiya and Amagasaki as the value of Hurst parameter increases. In general, the traffic with large Hurst parameter causes the growth of the buffer contents. When the Internet bitrate is small, the Internet cells with large Hurst parameter tends to make the buffer length for Internet cells large. Since the service discipline of output buffers is round-robin, large buffer length of Internet cells tends to smooth the output process of MPEG cells. We also observe that jitter value is largest at the decoder point of Nishinomiya. This is because there are no bursty inputs of Nishinomiya ATM switch whose destination is Amagasaki. The MPEG2 stream from Kobe is regulated by the output buffers of Kobe and Nishinomiya and hence resulting jitter value of Amagasaki is smaller than that of Nishinomiya.

In Figure 6(b), we show the simulation result when Hurst parameter is equal to 0.5, 0.6, 0.7 and 0.8 under Internet bitrate equal to 23.53Mbps. We set two buffers for each QoS in ATM switch module. From this figure, we can see the same tendency for the fluctuation of jitter values in the previous case. However the jitter value becomes large when the Hurst parameter is getting large. Note that the range of jitter values is 1.09 to 1.19, which is smaller than Figure 6(a). That is, the jitter values are almost same under various values of Hurst parameter. From this result, we can see that the jitter value is not affected by Hurst parameter when the bitrate of Internet is large.

Next we investigate one buffer case within the ATM switch module. In one buffer case, MPEG cells contend with Internet ones for the occupation of the buffer. On the other hand, a buffer is allocated for each type of cells in the case of two buffers. We show the results under Internet bitrate equal to 2.353Mbps in Figure 6(c) and those of 23.53Mbps in Figure 6(d). In both figures, we can see the same tendencies of Figure 6(a) and 6(b). However the jitter values of 6(c) (resp. 6(d)) are larger than those of 6(a) (resp. 6(b)). This is due to one output buffer within ATM switch.

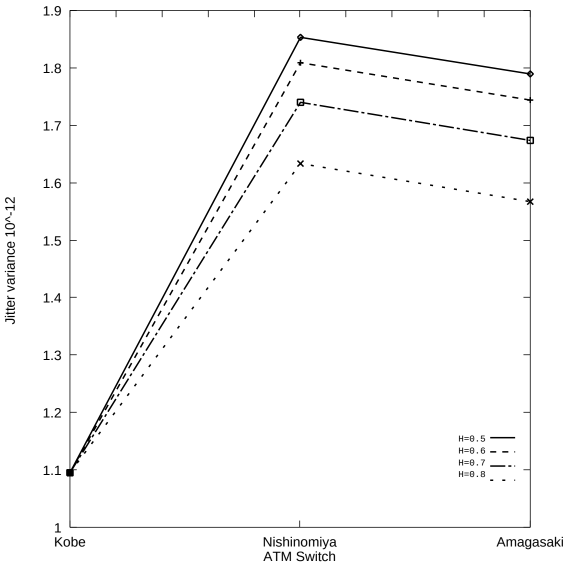


Figure 6(a): Jitter values: Internet stream bitrate= 2.353Mbps, Two Buffer Case

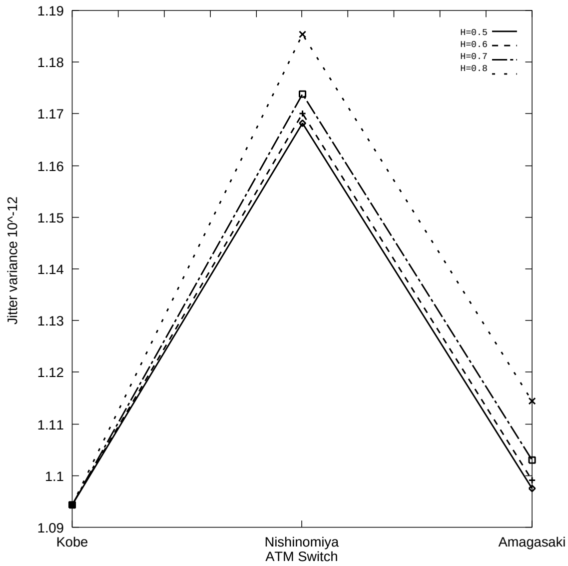


Figure 6(b): Jitter values: Internet stream bitrate= 23.53Mbps, Two Buffer Case

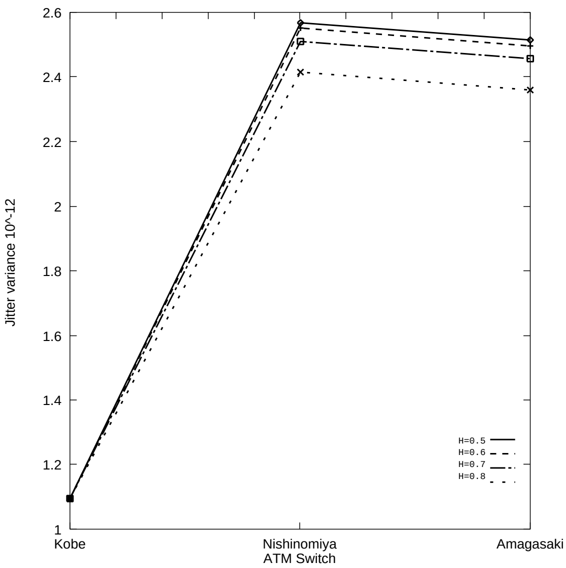


Figure 6(c): Jitter values: Internet stream bitrate= 2.353Mbps, One Buffer Case

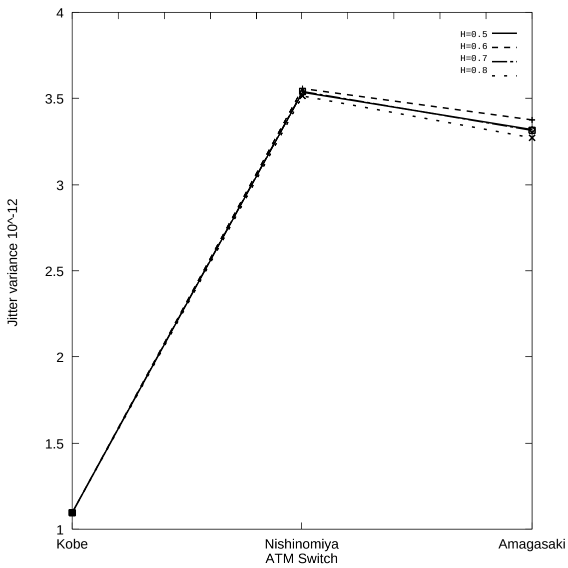


Figure 6(d): Jitter values: Internet stream bitrate= 23.53Mbps, One Buffer Case

5 Conclusion

In this paper, we constructed the simulation model of the experimental network taking the self-similar process into consideration, and investigated the relation between the self-similar traffic and the jitter process of the MPEG cells.

From the simulation results, we observed that the jitter process is affected by the Hurst parameter when the Internet bitrate is small, while not affected when the Internet bitrate is large.

It is an important issue to evaluate the quality of decoded pictures under our simulation results. [8] reported that the tolerated value of cell delay variation (CDV) for 1.5Mbps MPEG NTSC video is 6.5ms while that of 20Mbps HDTV video is 1ms. But the tolerated value of MPEG2 is not clear. The worst deviation observed in Figure 6(d) equals to about $\sqrt{3.5594 \times 10^{-12}} \simeq 1.9\mu$s and it looks to satisfy the QoS requirement for MPEG2. However more researches of the QoS requirement for MPEG2 in terms of the jitter value are needed.

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