MEASUREMENT OF ATM LAYER QUALITY OF SERVICE PARAMETERS USING OAM CELLS

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ABSTRACT

The measurement of the quality of service in ATM* networks involves the activation of the ATM layer management OAM functions. Once an ATM connection is set up, in-service performance monitoring based on OAM cells can be used to measure and estimate the ATM layer QoS parameters. In-service measurement of ATM layer QoS parameters such as cell delay variation, cell transfer delay, cell loss ratio, etc., is necessary to verify on one hand, if the network is meeting the requested QoS and on the other hand, if the users are receiving their promised QoS. Congestion conditions in ATM switches may cause gradual deteriorations in the quality of virtual paths or virtual channel connections in an ATM network. QoS measurement using OAM cells can accurately measure the overall quality of monitored ATM layer QoS parameters in order to detect such deteriorations before the service quality has dropped bellow an acceptable level. Several factors such as network load, congestion, bottlenecks, and incremenTS in network load may affect the cell delay variation of video transmissions in an ATM network. In this work, several ATM layer QoS parameters have been measured on a VBR video source using OAM cells. The simulation resulTS obtained show that with low network loads, the contribution of each individual ATM switch to the local and to the end-to-end CDV is not significant. In the presence of a bottleneck switch, the CDV presented by this switch becomes the dominant one at both local and end-to-end sides. When the network load is between 0.5 and 0.6, small incremenTS in network load do not alter the buffer performance of the non-congested ATM switches, and low values of CDV can be obtained. In contrast, it was found that there is a critical load between 0.65 and 0.7 where small incremenTS in network load may force the CDV to grow abruptly.

RESUMEN

La medición de la calidad de servicio en redes ATM involucra la activación de funciones OAM de administración de la capa ATM. Una vez que una conexión ATM es establecida, el monitoreo en-línea basado en celdas OAM puede ser activado para medir y estimar los parámetros de calidad de servicio de la capa de ATM. La medición en-línea de parámetros tales como la variación del retardo de celdas, el retardo de transmisión, la razón de pérdida de celdas, etc., es necesaria para verificar, por un lado, si la red está cumpliendo con la calidad de servicio requerida y, por el otro, si los usuarios están recibiendo la calidad de servicio solicitada. Condiciones de congestión en switches ATM pueden causar degradaciones graduales en la calidad de las trayectorias y conexiones virtuales en una red ATM.

*See the table I of Acronyms on the page 152

La medición de la calidad de servicio usando celdas OAM puede medir con exactitud la calidad de los parámetros monitoreados de la capa ATM con el fin de detectar dichas degradaciones antes de que la calidad de servicio haya caído por debajo de un nivel aceptable. Varios factores, tales como la carga de la red, congestión, "cuellos de botella" e incrementos en la carga de la red, pueden afectar la variación del retardo de celdas de transmisiones de video en una red ATM. En este trabajo, varios parámetros de calidad de servicio de la capa ATM han sido medidos en una fuente de video tipo VBR usando celdas OAM. Los resultados de simulación muestran que con cargas de red bajas, la contribución individual de cada switch ATM al CDV local y al CDV terminal-a-terminal no es significativa. Cuando un "cuello de botella" en un switch está presente, el CDV presentado por este switch es el dominante en ambos casos local y terminal-a-terminal. Cuando la carga de la red está entre 0.5 y 0.6, incrementos pequeños en la carga no alteran el rendimiento de los switches ATM no congestionados y, por lo tanto, valores bajos de CDV pueden ser obtenidos. Por el contrario, se encontró que existe una carga crítica entre 0.65 y 0.7 donde incrementos pequeños en la carga de la red pueden forzar al CDV a crecer abruptamente.

KEYWORDS: Operation and Maintenance, Cell Delay Variation, Variable Bit Rate, Quality of Service.

Table I. Acronyms

ACRONYMS	
ATM Asynchronous Transfer Mode	MPEG-2 Moving Pictures Expert Group encoder
BEDC Block Error Detection Code	MISCN Misinserted Cell Number
BER Block Error Result	OAM Operation and Maintenance
BONeS Block Oriented Network simulator	QoS Quality of Service
CBR Constant Bit Rate	SECBR Severely Errored Cell Block Ratio
CER Cell Error Ratio	SECBN Severely Errored Cell Block Number
CDV Cell Delay Variation	SIF Source Intermediate Format
CLR Cell Lost Ratio	TS Time Stamp
CMR Cell Misinsertion Rate	TSr Time Stamp (reception)
CTD Cell Transfer Delay	TSt Time Stamp (transmission)
LOSTCN Lost Cell Number	TUCN Total User Cell Number
MCSN Monitoring Cell Sequence number	VBR Variable Bit Rate
MPEG Moving Pictures Expert Group	

1. INTRODUCTION

ATM networks are expected to support various types of traffic including voice, data, and CBR and VBR video, in addition to multimedia traffic. In ATM networks, the information is asynchronously transmitted using virtual connections where cells follow a fixed route and their sequence integrity is respected. Cells are forwarded from one switch to another along the ATM connection. Due to queuing, cells of a given connection experience different transfer delays along the network. This phenomenon is referred as *Cell Delay Variation* (*CDV*) [1, 2]. Because of the asynchronous nature of the ATM technique, *CDV* is a critical QoS parameter in ATM networks [3], especially for real-time applications where source and destination are required to remain synchronized [4]. In ATM networks, in-service monitoring methods are based on operation and maintenance (OAM) cells. The in-service performance monitoring technique proposed in standards [5, 6] for ATM networks, consists of the insertion of OAM cells between blocks of N user cells at any virtual path or virtual channel termination or connecting point, and then may be copied or extracted at any similar point at the end of the connection or the segment being monitored, as figure 1 illustrates. Each OAM cell contains information about its preceding block of user cells. At the destination, this information is compared with the received block of user cells in order to estimate QoS parameters such as cell transfer delay, cell delay variation, cell loss ratio, etc. [7, 8].

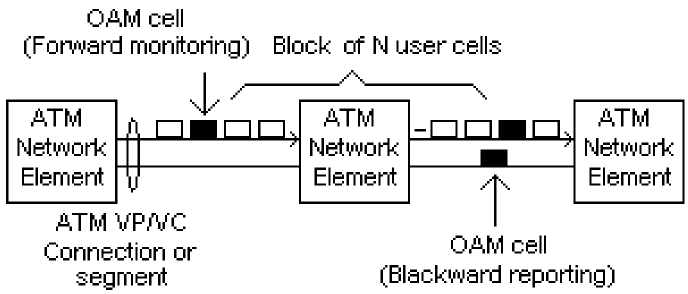

Figure 1. In-service performance monitoring method

This information may be locally recorded and/or to the source node using an OAM cell by activating the backward reporting function [9-11], as illustrated in figure 2. The recommended block sizes (N) are 128, 256, 512, and 1024 user cells.

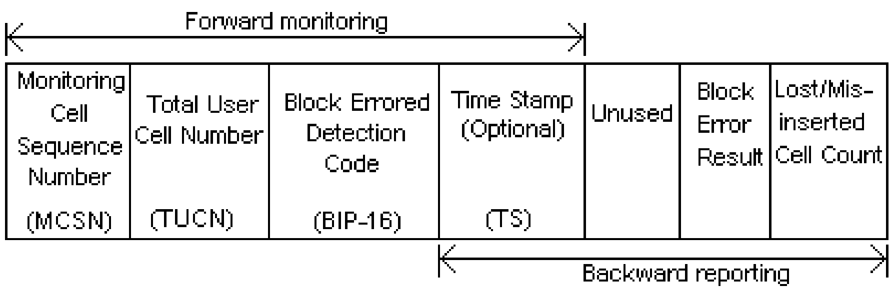

Figure 2. OAM cell format

From figure 2, we can observe that "time stamp" (*TS*) is an optional field, but it may be used to represent the time at which the OAM cell was inserted, so it is intended to be used for cell delay measuremenTS.

Table II. Estimation of ATM QoS parameters

ATM QoS parameter	Definition	Estimated with OAM cells
CER	$\frac{\text{Errored Cells}}{\text{Successfully Transferred Cells + Errored Cells}}$	$\frac{BER}{TUCN+BER}$
SECBR	$\frac{\text{Severely Errored Cell Blocks}}{\text{Total Transmitted Cell Blocks}}$	$\frac{SECBN}{MCSN}$
CLR	$\frac{\text{Lost Cells}}{\text{Total Transmitted Cells}}$	$\frac{LOSTCN}{TUCN}$
CMR	$\frac{\text{Misinserted Cells}}{\text{Time Interval}}$	$\frac{MISCN}{T_m}$
CTD	Total transmission delay + processing delay + queueing delay	$TS_r - TS_t$
CDV	1- point CDV = cell's reference arrival time - cell's actual arrival time or 2- point CDV = absolute cell transfer delay - reference cell transfer delay	ck – ak xk - d1,2

BER = block error result
SECBN = number of severely errored cell blocks
LOSTCN = number of lost cells
Tm = measurement time interval
TSr = time when the OAM cell was received
MISCN = number of misinserted cells

2. ESTIMATION OF ATM LAYER QoS PARAMETERS

The ATM layer cell transfer QoS parameters can be estimated from the in-service performance monitoring procedure based on OAM cells [12, 13] (see table II) as follows: At the transmitting-end of the ATM connection or segment, a block error detection code (*BEDC*) is computed on a specific block of user cell payloads. Once the block error detection code (*BEDC*) has been generated, this and other fields like the total user cell number (*TUCN*), the monitoring cell sequence number (*MCSN*), and optionally the time stamp (*TS*) are inserted in the payload of an OAM cell (see figure 2) and sent to the destination by activating the *forward monitoring* function, immediately after the block of user cells. At the receiving-end of the ATM connection or segment, the block error detection code (*BEDC*) is recomputed over the received block of user cells and the result is compared to that contained in the OAM cell. A mismatch would indicate that the block has experienced one or more errors during transmission. Also, the number of user cells received is compared to the number of user cells transmitted (*TUCN*), encoded in the incoming OAM cell to determine whether any cells were lost or misinserted during transmission. If the number of received user cells is greater than the number encoded in the *TUCN* field, then cells were misinserted. Likewise, if it is less than the value encoded in the *TUCN* field, cells were lost. These results may be locally recorded and/or reported back to the source in an OAM cell, by activating the *backward reporting* function. Time stamp (*TS*) is an optional field but it may be used to represent the time at which the OAM cell was inserted in the block of user cells (*TSi*), so it is intended to be used for cell delay measurements. We used this field to measure the QoS parameters local *CTD*, end-to-end *CTD*, local *CDV*, and end-to-end *CDV*.

3. MEASUREMENT OF ATM LAYER QoS PARAMETERS

For the measurement of ATM layer QoS parameters, we used an asynchronous measurement method which does not rely on synchronised clocks at the measurement points. In [14, 15], we reported that in-service monitoring using OAM cells can accurately measure the quality of service in ATM networks. In order to measure the end-to-end *CDV* using OAM cells, the input-to-output cumulative cells delays (*D0*, *D1*, etc.) were measured at every ATM switch using time-stamped OAM cells. Then, the associated fixed propagation delays previously calculated were added to the measured cell delays and the resulting cell transfer delays (*CTD0*, *CTD1*, etc.) were stored in empty OAM cell fields. For example, the first switch stores the *CTD0* in the field 0, the second switch stores the value that results from adding *CTD0* to *CTD1* in the field 1, and so on, as figure 3 illustrates.

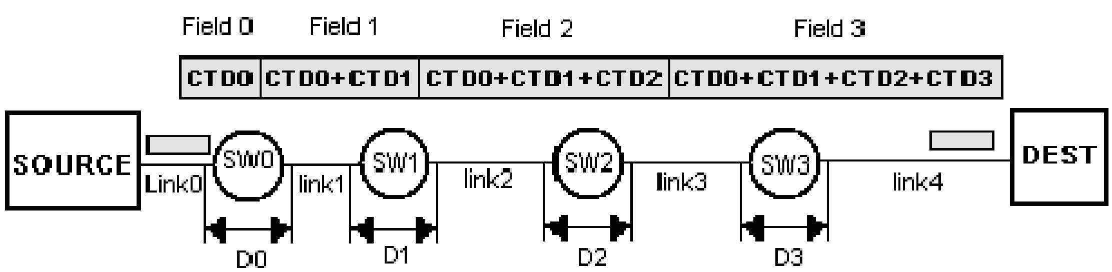

Figure 3. Measurement of the end-to-end CDV

At the destination, the end-to-end *CTD* and consequently the end-to-end *CDV* were obtained and computed. The cumulative *CDV* measured at the destination node corresponds to the end-end *CDV*. Finally, using the formula (1) the end-to-end CDV was obtained.

$$EndtoEndCDV = \sqrt{\frac{\sum\Big((EndtoEndCTDi) - \overline{(EndtoEndCTD)}\Big)^2}{N}} \quad , \qquad (1)$$

where the end-to-end cell transfer delay is:

$$EndtoEndCTDi = CTD0 + CTD1 + CTD2 + CTD3 + \ldots + CTDn \tag{2}$$

Alternatively, the local CTD and consequently the local *CDV* were measured at each individual ATM switch using different time stamps. Here, as the OAM cell passes through each ATM switch, the switch writes each measured ingress-to-egress cell delay (*D0, D1*, etc.) in an empty time stamp field so that, the OAM cell can record the cell transfer delays experienced at individual switches along the ATM connection and, similar to that explained above, using the formula (3) the local *CDV* can be obtained and computed.

$$LocalCDVn = \sqrt{\frac{\sum\left(CTDi - \overline{CTD}\right)^2}{N}} \quad , \tag{3}$$

where $CTDi$ is the cell transfer delay of the *i-th* cell, $\overline{CTD}$ is the mean value of the cell transfer delay, and *N* is the total number of cells transmitted.

4. SIMULATION RESULTS

This section shows the simulation results obtained from the measurement of the QoS parameters: local *CDV* and end-to-end *CDV*, in an ATM network using OAM cells. Figures 4 to 9 show the measurements of the *CDV* experienced by a VBR video traffic source. Firstly, we study the effect of network load on *CDV*. Secondly, we study the impact of a bottleneck switch on *CDV*. Thirdly, we study the influence of increments in network load on *CDV*. Then, we study the impact of all congested switches on *CDV*. Finally, the effect of the number of ATM switches on the CDV is studied. In these experiments, the local and the end-to-end *CDV* were measured in an ATM network composed of four ATM switches, using a set of network loads, from 0.5 to 0.7 with increments of 0.05. The system used to carry out the experiments (see figure 3) was modelled with a block-oriented network simulator (BONeS), which is a graphically-oriented, general-purpose simulation language for modelling and simulating communications networks, including ATM networks [16]. The measurements of the local *CDV* and the end-to-end *CDV* were carried out on a VBR video source of 5 Mb/s. The traffic of the VBR video source was generated by a real MPEG-2 encoder with a fixed quantizer step size. The quantizer step size was chosen such that SIF (source intermediate format) image sequences (352 x 288 lines, 25 Hz) were coded at a mean bit rate of approximately 5 Mb/s. Also, the traffic generated by a number of Ethernets LANs with burstiness of approximately 2 was used as the background traffic, along with an insertion rate of 1 OAM cell every 128 user cells.

Figure 4 shows the *CDV* obtained from a network configuration of four ATM switches with network loads of 0.5 for all links. The graph shows that, for low network loads both the local and the end-to-end *CDV* are small. Also, the amount of *CDV* introduced by each switch (local CDV) is approximately the same. The local *CDV* represents the value of the *CDV* measured from the input to the output of each switch. The end-to-end *CDV* represents the cumulative value of delay variations from the source node to the destination node; that is why its value always increases. In this graph, the value of the *CDV* at the last switch (SW3) corresponds to the end-to-end *CDV*.

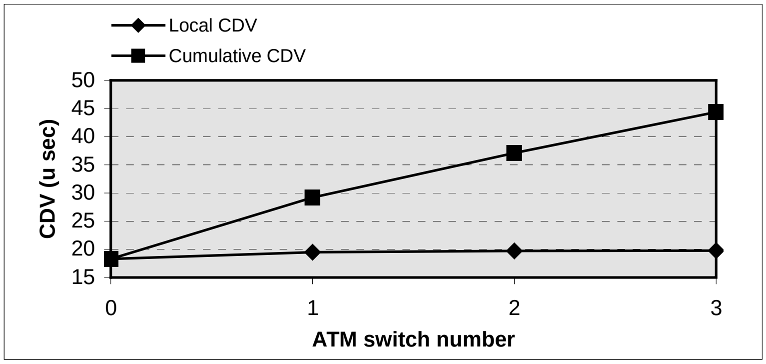

Figure 4. CDV *with network loads of 0.5 for all links*

Figure 5 shows the *CDV* obtained from a network configuration of four ATM switches with a bottleneck switch. The network load at the bottleneck switch (SW1) was 0.7 while at SW0, SW2, and SW3 the network load was 0.5. The graph shows that the local *CDV* at SW1 is high compared to the local *CDV* at SW0, SW2, and SW3 respectively. Also, we found out that the end-to-end *CDV* was similar to the local *CDV* at SW1; that is, the end-to-end *CDV* is mainly dominated by the *CDV* introduced by the congested switch (SW1). The contribution of the other switches to the end-to-end *CDV* was not significant. This is because the load associated to these switches was low (L = 0.5).

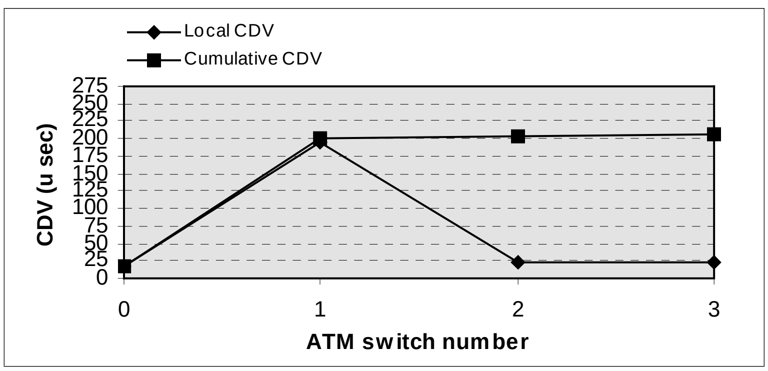

Figure 5. CDV *with network loads of 0.5, 0.7, 0.5, 0.5*

Figures 6, 7, and 8 show the behaviour of the local and the end-to-end *CDV*, when the ATM network experiences incremenTS in network load. The aim of this experiment was to observe how both measures of *CDV* react to small network load incremenTS. Here, the same bottleneck switch configuration showed in figure 5 was used. We increased the network load at SW0, SW2, and SW3 from 0.5 to 0.65, without reaching 0.7. We found out that as the network load increases both the local and the end-to-end *CDV* increases. However, for network loads of 0.55 and 0.6 (see figures 6 and 7) the contribution of all switches, except for the congested one to the end-to-end *CDV* is small. These incremenTS are not significant. It means that, small incremenTS in network load do not alter the buffer performance of the non-congested switches and therefore, low values of *CDV* are obtained.

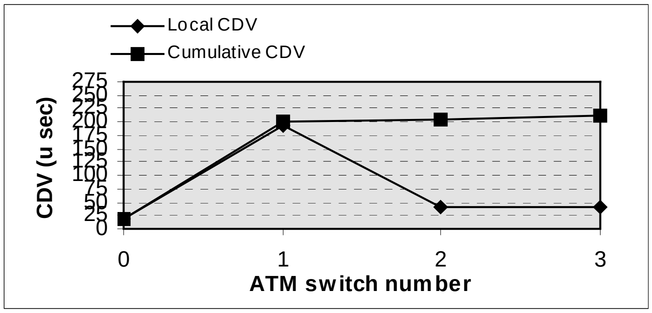

Figure 6. CDV *with network loads of 0.5, 0.7, 0.55, 0.55*

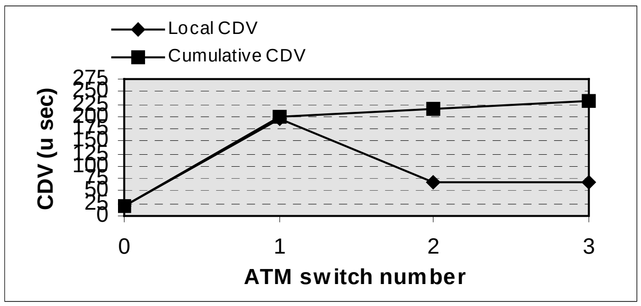

Figure 7. CDV *with network loads of 0.5, 0.7, 0.6, 0.6*

In contrast, for network loads of 0.65 (see figure 8) both local and end-to-end *CDV* grow faster and for small incremenTS in network load, higher values of *CDV* are obtained. At this point, as the network load becomes higher, the impact of it on the buffer performance of the non-congested ATM switches becomes more important.

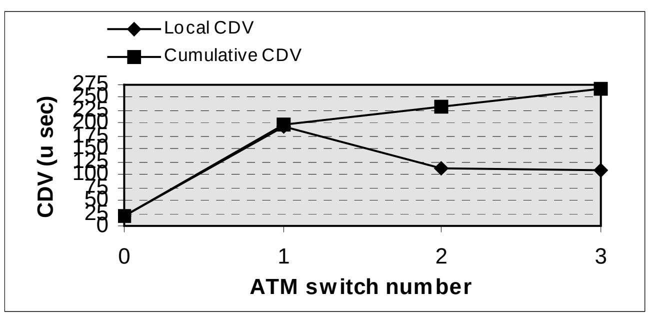

Figure 8. CDV *with network loads of 0.5, 0.7, 0.65, 0.65*

Figure 9 shows the *CDV* obtained for a network configuration where all ATM switches are congested (L = 0.7 all links). In this case, for such high network loads both the local and the end-to-end *CDV* increased significantly and similar to figure 8, small incremenTS in network load have much influence on the buffer performance of the non-congested ATM switches. Hence, small incremenTS in network load may force the *CDV* to grow abruptly.

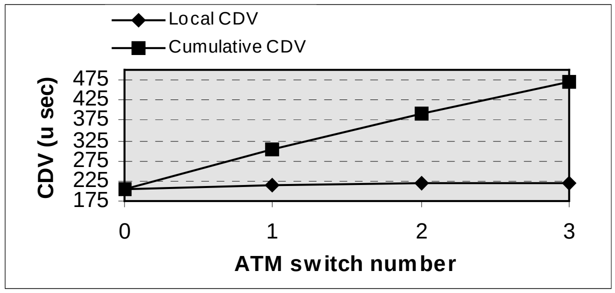

Figure 9. CDV *with network loads of 0.7 for all links*

The local *CDV* was approximately the same for all switches in all cases. It means that, when the same network load is applied to a number of ATM switches connected in tandem, the contribution of each switch to the local *CDV* is the same. In addition, it was expected that the end-to-end *CDV* was either equal or greater than the sum of the local *CDVs* (approximately 800 μ *secs*). However, the end-to-end CDV obtained was less than the sum of local *CDVs* (approximately 475 μ *secs*). That could be expensive in such way: Since all switches are heavily congested the ATM switch buffers are filled up, having as a result smoothed traffic at the output of each switch, and consequently a decrement in the end-to-end *CDV*. Figures 10 and 11 show the behaviour of the local and the end-to-end *CDV* when the number of switches increases. This experiment is an extension of the four ATM switches network configuration presented in figure 9. Figure 10 shows the *CDV* obtained from a network configuration with 8 ATM switches connected in tandem, while figure 11 shows the case for 16 ATM switches. Both figures show that as the number of switches increases, the end-to-end *CDV* becomes higher. Opposite to the local *CDV* that remains approximately the same for all switches. This means that the local *CDV* does not depend on the number of switches connected in tandem, it depends on the network load associated to a particular switch.

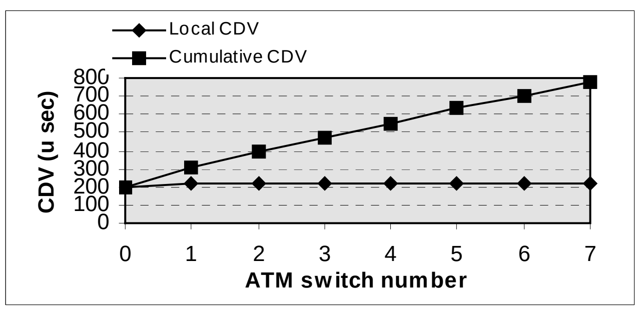

Figure 10. Effect of 8 switches in tandem on the CDV

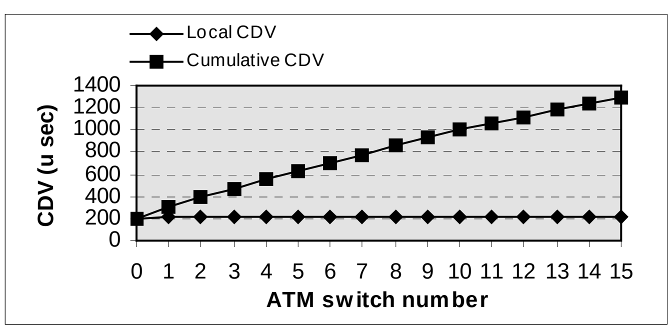

Figure 11. Effect of 16 switches in tandem on the CDV

5. CONCLUSIONS

In this work, the ATM layer QoS parameters of a VBR video source has been measured using OAM cells. Regarding the effect of the network load on the cell delay variation, we can conclude that with low network loads, the contribution of each individual ATM switch to the local and the end-to-end *CDV* is not significant. For the case when the ATM network has a bottleneck switch, the *CDV* presented by this switch becomes the dominant one at both local and end-to-end sides. Also, when the network load is between 0.5 and 0.6, it was found out that small increments in load do not alter the performance of the ATM switch buffers, and therefore, low values of *CDV* can be obtained. In contrast, it was found that there is a critical load between 0.65 and 0.7 where small increments in the network load may force the *CDV* to grow abruptly. On the other hand, it was found that when the same network load is applied to a number of ATM switches connected in tandem (8 and 16 switches), the contribution of each individual switch to the *CDV* is the same. In addition, the local *CDV* does not depend on the number of switches connected in tandem; it depends on the network load associated to a particular switch.

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Authors Biography

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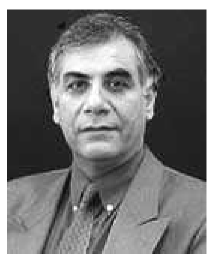
Is a full-time memBER of the research staff of the Unit of Control and Instrumentation at the Institute for Electrical Research (IIE), Cuernavaca, Mexico since 1986 to date. He received the B.Sc. degree in Communications and Electronics from the National Polytechnic Institute, Mexico, in 1985; the M.Sc. degree in the Telecommunications and Electronics from CICESE Research Centre, Ensenada, B.C., Mexico, in 1991; and the Ph.D. degree in Electronic Systems Engineering from the University of Essex, England, in 1999. He has published several national and international conference and journal papers on themes related to Quality of Service (QoS), Asynchronous Transfer Mode Networks (ATM), Local Area Networks (LANs), Wireless LANs, and Mobile Networks, respectively. He has been a Lecturer of several B.Sc. and M.Sc. Communications and Computer Networks courses at CENIDET, Cuernavaca, Mexico from 1991 to 1994, and more recently at ITESM Campus Cuernavaca, Mexico since 2000 to date.His main research interesTS are Quality of Service in Multimedia Communications Networks, Wireless and Mobile Networks.



Mohammed Ghanbari

Is a professor at the Department of Electronic Systems Engineering at the University of Essex, UK., with the main research interest in the areas of Video Networking. He graduated from Aryamehr University of Technology, Tehran, Iran, with a B.Sc. degree in Electrical Engineering in 1970, and M.Sc. degree in Telecommunications and Ph.D. degree in Electronics from the University of Essex, England in 1976 and 1979 respectively. After 10 years of working in Radio and Television broadcasting he started his academic career in 1986 as a Research Fellow working on Video coding for Packet Networks. He was then appointed as a Lecturer at the Department of Electronic Systems Engineering, University of Essex, in 1988 and promoted to Senior Lecturer, then Reader, in 1993 and 1995, respectively. He was appointed a personal chair in 1996. He is well known for his pioneering work on two-layer video coding for ATM networks, now is known as SNR scalability in MPEG-2 video codecs. He has registered three international patenTS on various aspecTS of video networking.