A New QoS Mapping Mechanism for MPEG Video Transport in a DiffServ Domain

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Abstract - **In this paper, we present a new QoS mapping mechanism for MPEG video transport in a DiffServ domain. In this mechanism, QoS indexes are defined based on the loss and delay requirements of each video flow. In agreement with these QoS indexes, the video packets are mapped in the classes of the AF service. The efficiency of this mechanism was evaluated by means of modeling and simulation of MPEG-4 video transmission over a DiffServ domain. The results show that the proposed QoS mapping can take advantages of the DiffServ architecture, making possible an improvement in the video quality according to the user and application needs.**

I. INTRODUCTION

The increasing volume and evolving types of Internet applications have been demanding enhanced services, both in terms of performance and quality of service (QoS), from the Internet. The current best-effort (BE) service model of the Internet is not suitable for fast growing video-based applications such as, videoconference, advanced scientific visualization and telemedicine, distance learning, and others [1].

In order to supply the QoS demand in the Internet, the Internet Engineering Task Force (IETF) proposes the Differentiated Services (DiffServ or DS) architecture [2]. This architecture offers a scalable model based on aggregated traffic flows. Through service classes, it offers a differentiated treatment to the several flows in the Internet, in agreement with the needs of bandwidth, delay, jitter and packet losses.

The packets IP, when entering in a DS domain, are classified in agreement with header information. This classification defines the marking of the DS field [3], which determines the treatment received by the package along the network in agreement with the established PHB (Per-Hop Behavior). Amongst the PHBs standardization proposal, it has PHB EF (Expedited Forwarding) [4] and PHB AF (Assured Forwarding) [5].

In this paper, it is evaluated how the DS architecture can support the forwarding of MPEG video streams, providing a differentiation among them. Moreover, a new QoS mapping mechanism for MPEG video transport in a DS domain is proposed. In this mechanism, the packet marking is made in agreement with frame type and with desired quality for this video. Through the combination of these two factors, QoS indexes are defined and they represent the requirements of each video stream in terms of loss and delay. In agreement with this index of QoS, the packets are mapped in the AF service classes. Hence, making possible a quality differentiation among the several video streams transported.

The remaining of this paper is organized as follows. In Section 2, the frame loss effect in a MPEG video stream is analyzed. Section 3 presents the QoS mapping mechanism for MPEG video transport in a DS domain. Section 4 presents the simulation model to evaluate the proposal. In Section 5, the obtained results are presented. Some final considerations are discussed in Section 6.

II. THE DATA LOSS IMPACT IN VIDEO QUALITY

The MPEG compression standard makes use of existent redundancy inside of individual pictures (intraframe compression), and enters adjacent pictures (interframe compression) of a video sequence. These pictures are codified in I, P and B frames. I-frames just use intraframe compression; P-frames are codified making reference to previous I and P frames using interframe compression, possessing a better compression rate in relation to I-frames; B-frames are codified with reference to previous and posterior I and P frames, possessing a high compression rate. The frame sequence is disposed in a denominated Group of Pictures (GoP), which is initialed by an I-frame and characterized by the parameters M and N, respectively the distance among P-frames and the distance among I-frames. The Fig. 1 shows a GoP configuration with M=3 and N=12, together with the existent dependence among each frame.

Video applications, which use MPEG compression techniques, become very vulnerable to data losses [6]. In this case, the packet loss in a frame can be expressed in the impossibility of this to be decoded in its destination. If an I or P frame is not considered decoded, all the frames that depend on them are not also considered decoded. For example, an MPEG video sequence with I-frames every 15 frames, if an error occurs while transmitting an I-frame, the effect persists for 15 frames, or 500 ms, which is quite noticeable to a viewer.

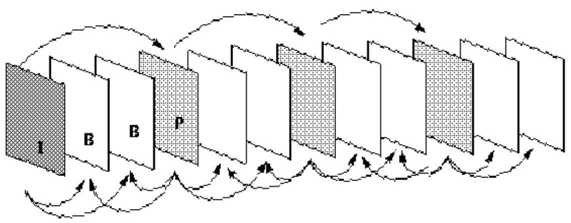

Fig. 1. MPEG frames sequence disposed in a GoP.

The error propagation in a MPEG stream is due to the hierarchical structure present in a GoP. The P and B frames are dependent of previous and posterior frames. Moreover, an end P-frame can be correctly decoded only if all previous P-frames have been correctly decoded. The error propagation phenomenon will affect the video quality and, without appropriate actions for the data loss control, the QoS can reach unacceptable levels.

III. PROPOSAL OF A QOS MAPPING MECHANISM FOR MPEG VIDEO

In agreement with the previous Section, it is verified the necessity of a differentiated MPEG video frames transport. This differentiation must be made with the intention of preserving the most important elements in a MPEG stream. Another key factor in the video transport is the possibility to have a differentiation in agreement with the QoS requirements of each application [7]. Moreover, this differentiation can become a pricing mean, in other words, it is paid more for a better quality.

Therefore, for the MPEG video transport in a DS domain, there must be a packet marking in agreement with the frame type and differentiation possibility among the video streams. Thus, this paper presents the proposal of a new QoS mapping mechanism for MPEG video transport in a DS domain.

In this mechanism, the packet marking is made in agreement with frame type and with the desired quality for the video. Through the combination of these two factors, QoS indexes are defined and they represent the preference of each video stream in terms of loss and delay. These indexes can be associated to the necessity of application, to the necessity of the user or to the quality level for which one desires to pay.

Fig. 2 presents the model for this mapping mechanism. The video streams are initially associated to a QoS index. After that, the packets are marked with a drop precedence and forward to a queue in agreement with received index. Assured Forwarding (AF) service was used to offer different levels of forwarding for IP packets from a DS domain user. The AF service provides delivery of IP packets in four independent classes (AF classes), where for each class is allocated a certain amount of resources (buffer space and bandwidth). Within each AF class, an IP packet can be assigned one of three different levels of drop precedence (Table I). The mechanism Random Early Detection (RED) [8] of three levels was adopted in the AF queues, that is responsible for the differentiation in the packets dropping. The three levels are labeled of green, yellow or red, referring to the low, medium and high drop precedence, respectively.

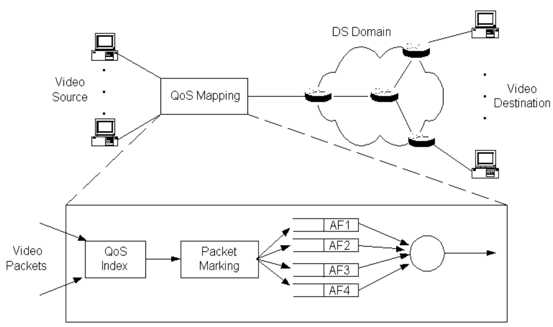

Fig. 2. QoS Mapping Mechanism.

TABLE I
AF SERVICE CLASSES.

Drop Precedence	**AF1 Class**	**AF2 Class**	**AF3 Class**	**AF4 Class**
Low	AF11	AF21	AF31	AF41
Medium	AF12	AF22	AF32	AF42
High	AF13	AF23	AF33	AF43

Considering only an AF class, a series of possibilities for video packet marking there might be in accordance with frame type. These possibilities are shown in Table II. Thus, with the study of performance based on modeling and simulation, described in the next Section, it is intended to evaluate the quality level obtained by each video stream in relation to the associated QoS index.

TABLE II
MPEG MAPPING POSSIBILITIES IN AN AF CLASS.

QoS Index	AFx1	AFx2	AFx3
0	I	P	B
1	I	P+B	
2	I		P+B
3	I+P		B
4	I+P	B	
5	I+P+B		
6		I	P+B
7		I+P	B
8		I+P+B	
9			I+P+B

IV. SIMULATION MODEL

The simulations were made with Network Simulator - NS [9], in its version ns-2. The modules add to the basic version of the ns-2, making possible the use of different mechanisms for the support to the differentiated service simulation. It was developed a module for the proposed QoS mapping mechanism.

A. Scenario and Parameters of Simulation

The network scenario adopted in the simulations is presented in Fig. 3. There is a variable number of video sources connected to a DS domain. These sources generate packets based on a public available MPEG-4 frame trace file [10]. It is used the Starwars-IV movie sequence, encoded with high quality and MPEG-4 encoding, which has a mean bit rate of 0.28 Mbps and peak rate of 1.9 Mbps. Each frame is fragmented into packets of 200 octets. The traffic sources and destination nodes are connected to DS domain for 10 Mbps links. The interior nodes in DS domain are connected for 10 Mbps links and for a "bottleneck" link of 1.024 Mbps.

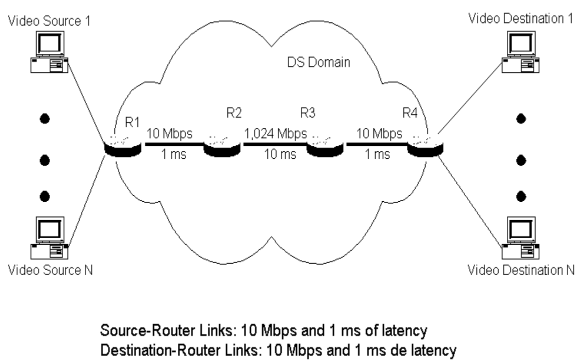

Fig. 3. Network Scenario

In DS domain input, the packets marking is made in agreement with the QoS index established for each video streams. The routers R1, R2 and R3 use RED mechanism with three levels for active queue management. The RED parameters include a minimum threshold, a maximum threshold and a maximum drop probability (*min_*, *max_*, *Pmax*). In this case, it is observed the values: for the red packets (0.2**qlen*, 0.4**qlen*, 0.1); for the yellow packets (0.4**qlen*, 0.6**qlen*, 0.05); and (0.6**qlen*, 0.8**qlen*, 0.025) for the green packets. The variable qlen indicates the total queue length, which is kept equivalent to 100 packets.

B. Evaluation Metrics

For the evaluation of the received video frame integrity, it was considered that a picture is decodable, when a minimum fraction dt (decodable threshold) of the data in each frame is received. Further, a frame is considered decodable if and only if all the frames it depends on are also considered decodable [11]. Therefore, when dt=0.50, up to 50% of the frame data can be lost, that the frame is still considered decodable. In the same manner, with dt=0.75, 25% of the data from a frame may be absent due to loss in the network. In the case of dt=1.00, only a lost packet is enough for the frame to be considered undecodable. This criterion allows the consideration of a number of error resilience and error concealment features of MPEG [12].

In agreement with these considerations, in order to evaluate the video transport in a DS domain, it is considered the fraction of data decoded to indicate the video quality. Fraction of decodable frames reports the number of decodable frames over the total number of frames sent by the source. Besides this metric, the delay was used, considering the time consumed by the network for the packet transport at source until the destination.

V. SIMULATION RESULTS

Following, it is presented and analyzed the simulation results accomplished to evaluate the performance of the proposed QoS mapping mechanism.

A. Multiple Video Sources in an AF Class

In this first set of simulations, a variable number of video sources was considered transmitting in a DS domain. The video quality delivery in destination was measured in function of the percentage of pictures decoded presented by one source. For this source, the QoS index is varied from 0 to 9 (QoS-0 QoS-9) in agreement with Table II. The other sources were maintained with QoS-0 index. It was used AF1 class for the video stream transport.

The next graphs relate the percentage of pictures decoded in relation to QoS index. For each index, this percentage was measured taking into account three values of decodable threshold: dt=1.00, dt=0.75 and dt=0.50.

Fig. 4 and 5 show, respectively, the results when 3 and 5 video sources transmit simultaneously. The QoS indexes were placed in decreasing order in agreement with the quality presented. In the case of 3 video sources, the quality difference among the sources is not so accentuated, because it refers to a scenario with small traffic load. For 5 video sources, in spite of having a larger quality degradation, a larger differentiation is observed among the video streams.

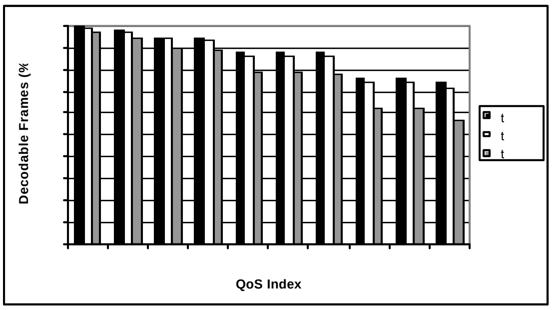

Fig. 4. Percentage of decodable frame with 3 video sources simultaneous.

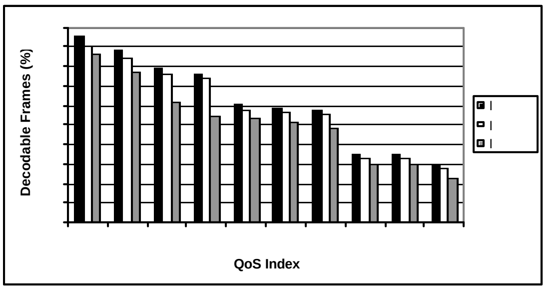

Fig. 5. Percentage of decodable frames with 5 video sources simultaneous.

With the intention of evaluating environments with different levels of traffic, it is used 10 and 20 simultaneous video sources. Fig. 6 presents the results for 10 video sources and, the Fig. 7, for 20 sources, where a bigger degradation is observed in the video quality. However, a differentiation is still remained among the QoS indexes used and it is noticed a change in the order of the same ones in relation to the results obtained previously.

Considering the QoS indexes showed in Table II, it was proceeded the simulation of the environment with 10 simultaneous video sources, each one with a distinct QoS index. The results obtained are shown in Fig. 8. Through these results is possible to observe the existent differentiation among each QoS index.

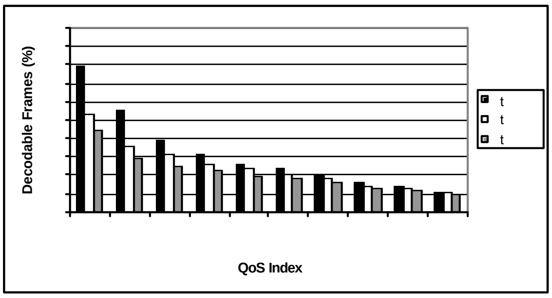

Fig. 6. Percentage of decodable frames with 10 video sources simultaneous.

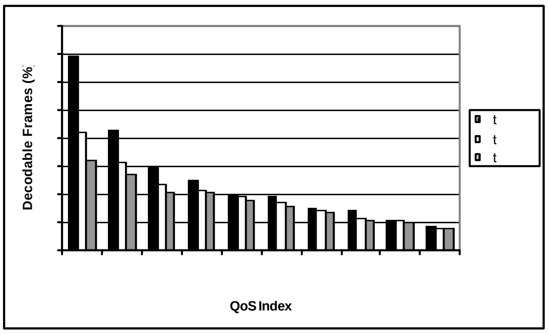

Fig. 7. Percentage of decodable frames with 20 video sources simultaneous.

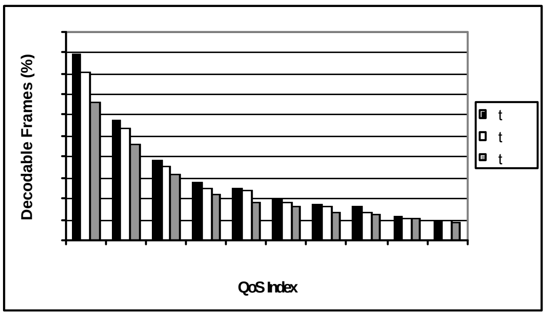

Fig. 8. Percentage of decodable sources with 10 video sources simultaneous and distinct QoS indexes

Analyzing the results obtained for the several situations, it is verified that among some QoS indexes a very accentuated differentiation doesn't exist. Some results are very close to the others. This situation can be observed in low and high load traffic in the network. For example, in Fig. 4 and 5, the QoS-2 and QoS-6 indexes, present the same results practically. Even in situations of larger congestion, it isn't observed a great differentiation. This is also observed for other groups of QoS indexes. In this way, it was selected some indexes that could present a larger differentiation degree among them. Being these, the QoS-0, QoS-1, QoS-2, QoS-4, QoS-5 and QoS-9 indexes.

Then, a quality classification can be established for these indexes in agreement with the presented quality. Fig.

9 presents the results when 6 video sources transmit simultaneously, in agreement with these selected indexes.

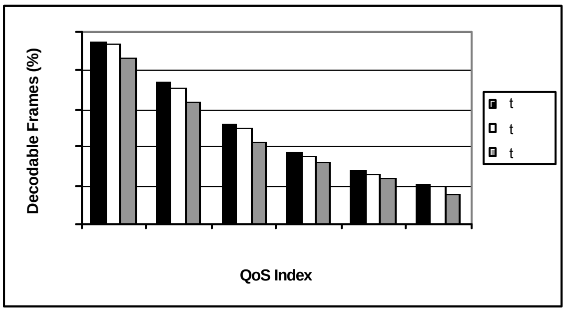

Fig. 9. Percentage of decodable frames with 6 video sources simultaneous and QoS indexes selected.

So far, the differentiation among the video streams was analyzed in terms of data loss. Below, it is analyzed the behavior of these flows in terms of delay.

For delay evaluation, the measurements have been made considering the six QoS indexes selected. The results obtained are shown in Table III. It was considered in the same way than the previous simulations, the video transport of 3, 5, 10 and 20 simultaneous video sources.

TABLE III
MEAN DELAY ACCORDING TO QOS INDEXES.

Nº. Sourc	**QoS Indexes**					
	QoS-5	**QoS-4**	**QoS-1**	**QoS-0**	**QoS-2**	**QoS-9**
3	63.90	61.27	61.01	51.47	49.73	48.52
5	94.77	89.86	90.50	77.73	76.71	62.94
10	116.89	109.66	111.12	116.07	123.47	55.41
20	131.18	127.40	125.23	136.48	142.93	48.36

Analyzing the results obtained, it is verified that a differentiation doesn't exist in relation to delay in the same proportion than obtained for data loss. In other words, the QoS index that presented the best quality did not get the best performance in relation to delay. It is still observed that the same behavior for different configurations of network load traffic was not kept.

B. Video Streams in Different AF Classes

In the next set of simulations, the behavior of the video streams submitted the separate queues will be analyzed, in other words, in different AF classes. For this a Weighted Round Robin (WRR) [13] queue scheduler was used. In this case, the AF1 queue was configured with weight 4, AF2 weight 3, AF3 weight 2 and AF4 weight 1. The video sources were equally distributed among the AF classes, as shown in Table IV.

TABLE IV
VIDEO SOURCE DISTRIBUTION IN AF CLASSES.

Drop Precedence	**AF1**	**AF2**	**AF3**	**AF4**
Low	I	I	I	I
Medium	P	P	P	P
High	B	B	B	B

First, 4 video sources were used, one in each AF class. The percentage of pictures decoded for each class is shown in Fig. 10. A differentiation is observed among the flows in agreement with AF class used. This differentiation is obtained through the attribution of different weights to each queue by the WRR scheduler. Increasing the network traffic load, it was used 8 video sources, two sources in each AF class. The result is shown in Fig. 11. In this case, it happens a larger degradation in video quality, maintaining the differentiation in agreement with the class type.

In Table V, the behavior of these video flows is shown in relation to delay. A correspondence is observed between the class and the delay in the sense of having a low delay for the class of high priority. Being so, the choice of AF class will determine a high or low delay. And the packet marking in agreement with drop precedence, in each class, will determine a low or high loss for the video stream.

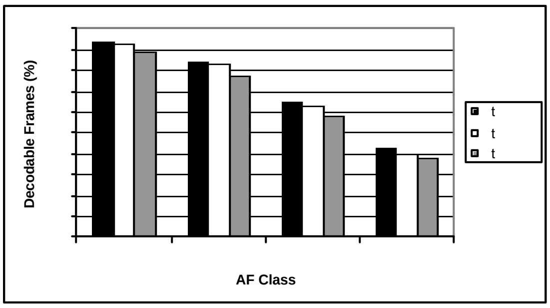

Fig. 10. Percentage of decodable frames with 4 video sources, one in each AF class.

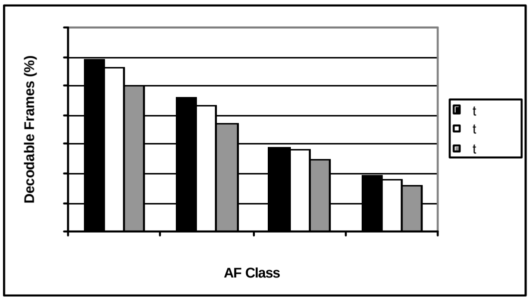

Fig. 11. Percentage of decodable frames with 8 video sources, two in each AF class.

TABLE V
MEAN DELAY FOR VIDEO TRANSPORT IN DIFFERENT AF CLASSES.

Nº. Sources	QoS Indexes			
	AF1	**AF2**	**AF3**	**AF4**
4	82.73	144.98	280.03	577.22
8	168.68	249.90	400.51	939.81

VI. CONCLUSIONS

This paper presents the evaluation of a new QoS mapping mechanism for MPEG video transport in a DS domain. The results show that the QoS mapping proposed can take advantage of the DiffServ architecture making possible an enhancement to end-to-end video quality according to the user and applications needs. With this mechanism, it is possible to have different quality levels for the transported video, within the same AF class. It was observed that inside of a same AF class the delay variation among the video streams was not a factor that makes possible a differentiation in the quality. When it was used different queues (different AF classes), it was possible a delay differentiation. In this way, inside of a same AF class is possible to vary the quality in relation to data loss and, in different classes this differentiation is also gotten in terms of delay. For example, if an application needs high quality and short delay, this can be transported in the AF1 class with a QoS index. Otherwise, if the delay isn't a main parameter, then this application can be transported with the same QoS index, however in the AF2 class.

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