Call-Admission-Control and Traffic-Policing Mechanisms for the Transmission of Videoconference Traffic From MPEG-4 and H.263 Video Coders in Wireless ATM Networks

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***Abstract*—In this paper, we explore, via an extensive simulation study, the performance of a call-admission-control (CAC) and traffic-policing mechanisms proposed for transmitting multiple quality encoded videoconference movies over a wireless asynchronous transfer mode channel of high capacity, depending on the user's needs and requests. Both the CAC algorithm and the traffic-policing mechanism are novel mechanisms proposed for the first time in this paper. For their implementation, we use an estimation of the equivalent bandwidth of the movies, which has been introduced in the past. We focus on both MPEG-4 and H.263 coded movies, as the integration of such video streams has not been studied in the relevant literature. In the case of H.263 movies, our scheme achieves high aggregate channel throughput, while preserving the very strict quality-of-service requirements of the video traffic.**

***Index Terms*—Call-admission control (CAC), H.263 video, MPEG-4, traffic policing, wireless asynchronous transfer mode (ATM) networks.**

I. Introduction

THE combination of wireless networks and asynchronous transfer mode (ATM) technology aims at combining the advantages of wireless communication and the users' freedom of movement, with the capability of serving different traffic types and the guarantee of quality of service (QoS) that ATM provides. This combination is not easy, because ATM has been designed for environments that are very different from those of wireless networks [1]. Therefore, it is clear that it is necessary to design specific techniques for the wireless segments of an ATM path, in order to guarantee QoS that is comparable to that of wired ATM connections.

In the work presented in this paper, we design and evaluate a scheme that multiplexes MPEG-4 and H.263 video streams (VBR), respectively, in high-capacity picocellular wireless systems. We consider MPEG-4 movies with two coding layers (high and low bit rates) and H.263 movies with three coding layers (high, medium, and low bit rates).

The subject of the integration of voice sources only and voice sources with data sources has been studied extensively [2]–[5] and the subject of voice/video and voice/video/data integration has also been studied, although less, in recent years [6], [7]. Our scheme is one of the first in the literature to study the integration of MPEG-4 and H.263 video streams.

This paper is organized as follows. In Section II, we present our system model, in Section III our call-admission-control (CAC) and traffic-policing mechanisms, and in Section IV we present and discuss our simulation results.

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II. System Model

Within the picocell, spatially dispersed source terminals share a radio channel that connects them to a fixed base station (BS). The BS allocates channel resources, delivers feedback information, and serves as an interface to the mobile switching center (MSC). The MSC provides access to the fixed network infrastructure. We focus on the uplink (wireless terminals to BS) channel, but the nature of our ideas can easily be implemented on the downlink channel as well.

The uplink channel time is divided into time frames of equal length. Each frame has a duration of 12 ms ([6], [7]) and accommodates 256 information slots. The channel rate is 9.045 Mb/s (from [6]). Each information slot accommodates exactly one fixed-length packet of ATM size that contains video information and a header.

We assume that the channel is error free and without capture, in order to investigate which is the maximum channel throughput that our mechanism can accomplish under various traffic loads.

A. MPEG-4 and H.263 Video Streams

In our study, we use the trace statistics of actual MPEG-4 [8] streams from [9]. The video streams have been extracted and analyzed from a camera showing the events happening within an office. We have used two coding versions of the movie:

1) high-quality version, which has a mean bit rate of 400 Kb/s, a peak rate of 2 Mb/s, and a standard deviation of the bit rate equal to 434 Kb/s;

2) low-quality version, which has a mean bit rate of 90 Kb/s, a peak rate of 1 Mb/s, and a standard deviation of the bit rate equal to 261 Kb/s.

New video frames (VFs) arrive every 40 ms. We have set the maximum transmission delay for video packets to 40 ms, with packets being dropped when this deadline is reached. That is, all video packets of a VF must be delivered before the next VF arrives. The allowed video packet-dropping probability is set to 0.0001 [6], [7].

We also use, in our study, the trace statistics of actual H.263 streams [10] from [9] and, in particular, the streams of the same movies that we study with MPEG-4 encoding. We have used three coding versions of the movie:

1) high-quality version, which has a mean bit rate of 256 Kb/s, a peak rate of 1.4 Mb/s, and a standard deviation of the bit rate equal to 505 Kb/s;
2) medium-quality version, which has a mean bit rate of 64 Kb/s, a peak rate of 320 Kb/s, and a standard deviation of the bit rate equal to 127 Kb/s;
3) low-quality version, which has a mean bit rate of 16 Kb/s, a peak rate of 84 Kb/s, and a standard deviation of the bit rate equal to 46 Kb/s.

In this case, the maximum transmission delay for the video packets of a VF is equal to the time before the arrival of the next VF, with packets being dropped when the deadline is reached (the interframe period in the H.263-encoded movies is not constant as in MPEG-4 encoding; it is an integer multiple of 40 ms). The allowed video packet-dropping probability is again set to 0.0001.

B. Actions of Video Terminals and BS Scheduling

Video terminals that have been admitted into the system *convey their requirements to the BS by transmitting them within the header of the first packet of their current VF.* To allocate channel resources, the BS maintains a dynamic table of the active terminals within the picocell.

If a full allocation is not possible, the BS grants to the video users as many of the slots they requested as possible (i.e., the BS makes a partial allocation). The BS keeps a record of any partial allocations so that the remaining requests can be accommodated whenever the necessary channel resources become available. In either allocation type case (full or partial), the BS allocates the earliest available information slots to the video terminals, which, if needed, keep these slots in the following channel frames, until the next VF arrives.

Reserved slots are deallocated immediately. This implies that a video terminal holding a reservation signals the BS upon the completion of its transmission.

III. CAC and Traffic-Policing Mechanisms

Along an ATM network, the bit streams of different sources are multiplexed for further transmission or switching. The resulting bit stream is the statistical superposition of the stochastic processes describing the individual source streams. This process is referred to as statistical multiplexing.

A CAC mechanism is necessary, especially in the case when the system has to deal with high load situations. When a new terminal attempts to enter the system, the absence of a CAC mechanism could lead to a system overload and, subsequently, to severe packet dropping for all terminals already supported by the system at that time. A traffic-policing mechanism is necessary in the case when a terminal violates the "traffic agreement" (exceeds its mean or peak bandwidth requirements), which it has made at the system's entrance.

In our study, we investigated an approach on the subject of CAC and traffic policing for both cases of movies (MPEG-4 and H.263), which was a combination of the two mechanisms, described as follows.

CAC: For each new request from a video terminal to enter the system, the *equivalent bandwidth* of the superposition of the MPEG-4 (or H.263) movies was calculated. The calculation was based on the approximate formula presented in [11].

The equivalent bandwidth of the superposition of the movies has to be less than the available bandwidth on the link; therefore, in our study, if the expected equivalent bandwidth, with the addition of the new video stream, is less than the channel rate (equal to 9.045 Mb/s), then the new video terminal was allowed to enter the system.

If, on the other hand, the expected equivalent bandwidth surpasses the channel rate, then we have examined the behavior of the system when implementing two different versions of our CAC algorithm, as follows.

1) In the first version, the new video terminal is asked to "decrease" its demands (move to a lower quality coding, if possible). If the problem persists, then another video terminal of high-quality coding is asked to "decrease" its demands. If, finally, all high-quality coding video terminals that had entered the system decreased their demands and the equivalent bandwidth of the superposition still surpasses the channel rate, then the new request is rejected. Of course, the policy of asking connections to reduce their bit rate in order to accommodate further connections might not be appropriate in certain cases, e.g., in the case when the users who are already accepted in the system have paid for high-quality video service. Still, the main goal of studying this first version of our CAC algorithm is to investigate the behavior of the system and the maximum value of the system throughput under different video loads; this is the reason for the "demand-decreasing" policy adopted in our system.
2) In the second version, we have taken into account the abovementioned problem. We consider the case in which a percentage of the video terminals with higher quality coding do not agree to decrease their demands and the system ensures that they acquire the guaranteed bandwidth and QoS. In this case, we also allow medium-quality movies to decrease their demands to low quality, in order to "compensate" for the existence of high-quality movies in the system.

Traffic policing: To avoid a situation in which a video terminal would "pass" the CAC mechanism but would violate its declared mean and peak parameters and cause excessive video packet dropping for all admitted video terminals, an additional mechanism was implemented. Each minute, the system checked the average video packet dropping (each video terminal informs the BS of its own packet dropping). If it exceeded the upper limit of 0.0001 in average video packet dropping in two consecutive checks (i.e., for two consecutive minutes), then, as with the CAC policy, two different versions of the mechanism were implemented in the system.

TABLE I
H.263 VIDEO, WITH THE USE OF THE CAC ALGORITHM (CASE WITH TWO TYPES OF MOVIES)

256K movies	64K movies	16K movies	Total number of movies	Throughput (%)
6	0	0	6	21.37
5	3	0	8	29.53
	0	19	24	30.86
4	7	0	11	31.28
	0	42	46	32.63
3	12	0	15	30.77
	0	73	76	35.62
2	20	0	22	33.95
	0	112	114	40.09
1	31	0	32	38.21
	0	165	166	46.92
0	57	0	57	47.05
	0	290	290	60.46

In the first version, the "demand-decreasing" policy (as in the first version of CAC) was implemented once more, starting from the movie, which entered the system last.

In the second version, the policy was the same as in the second version of CAC, again starting from the movie, which entered the system last. This mechanism will be referred to as the "traffic-policing mechanism."

The choice of a 2-min window was made after extensive simulations. We have experimented with "smaller" and "larger" time windows; both choices proved unsatisfactory. The reason for the inadequacy of both the "smaller" and the "larger" windows was that the time was not suitable for the system to reach "objective" decisions.

In the case of "smaller" windows (i.e., two consecutive checks, each in less than 1 min), the window was so small that an occasional problem of the system exceeding the upper limit for a short time period resulted in the application of the "demand-decreasing" policy, although there was no need for it—the average video packet dropping fell below 0.0001 almost immediately afterward.

In the case of the significantly "larger" windows (i.e., two consecutive checks, each more than 3 min), the problem of the system exceeding the upper limit of 0.0001 was often identified with delay and the QoS guaranteed to the users was violated for an unacceptable amount of time. In the case of windows marginally larger than the one chosen (i.e., two consecutive checks, each more than 1 min but less than 3 min), the system's results were almost identical to the ones achieved by our choice.

IV. RESULTS AND DISCUSSION

In all our experiments, we assume that each video request has equal probability (50%) of high- or low-quality (MPEG-4 coding) and has equal probability (33.3%) of high, medium, or low quality (H.263 coding).

Our simulation results have shown that the method presented in [11] for calculating the equivalent bandwidth of the superposition of the movies greatly overestimates the actual bandwidth requirements. This "problem" is not restricted to just this method, but has been encountered in other methods as well (e.g., the authors in [12] comment on their own method as overestimating the actual bandwidth requirements). Although a somewhat conservative CAC mechanism is preferable to underestimating the bandwidth requirements of connections (which could result in network congestion), the use of the CAC policy in our mechanism proves to lead to significant channel-throughput deterioration. Therefore, we have additionally examined the same cases of MPEG-4 and H.263 video loads with the use only of the traffic-policing mechanism and, as shown in Tables I and II and Figs. 1 and 2, the improvement in channel throughput was substantial (more than 10% in many cases).

The first part of our simulations was conducted by implementing the first version of the CAC and traffic-policing mechanism on the system. Tables I and II present the simulation results of our scheme when integrating only two types of H.263 video streams: high-quality coding streams with medium- or low-quality coding streams, respectively. Table I presents the simulation results when the CAC algorithm (at the "entrance" of the system) is used. Table II presents the results when the CAC algorithm is not in use and only the traffic-policing mechanism is implemented. As shown in both tables, the channel throughput increases dramatically when the number of high-quality (256-K) movies in the system is decreased and replaced by lower (medium- and low-) quality movies. Also, for a given number of high-quality movies, the throughput achieved with the combination of high- and low-quality movies is higher than the throughput achieved with the combination of high- and medium-quality movies (by 1%–13% in Table I and by 1%–7% in Table II). These results are explained by the fact that the 256-K movies are the more "demanding" ones, because they do not only have the largest mean bit rate, but they are also the burstier ones, as they have a larger peak-to-mean ratio than the other two types of movies. Therefore, the best throughput results are achieved when more of the less-demanding movies are present in the system.

Figs. 1 and 2 present the results of our scheme when integrating all types of H.263 coding movies, with and without the use of the CAC algorithm, respectively. In all the cases presented in these two figures, as it is expected from the traffic-policing mechanism that we introduce for permitting a new video terminal to enter the system, the steady-state condition for the

TABLE II
H.263 VIDEO, WITHOUT THE USE OF THE INITIAL CAC ALGORITHM (CASE WITH TWO TYPES OF MOVIES)

256K movies	64K movies	16K movies	Total number of movies	Throughput (%)
10	0	0	10	31.7
9	2	0	11	38.14
	0	15	24	39.69
8	4	0	12	37.7
	0	28	36	39.83
7	7	0	14	37.32
	0	46	53	41.23
6	12	0	18	37.82
	0	68	74	41.83
5	19	0	24	40.21
	0	97	102	44.18
4	28	0	32	43.59
	0	134	138	46.01
3	38	0	41	47.97
	0	182	185	54.92
2	50	0	52	54.5
	0	235	237	62.44
1	61	0	62	58.88
	0	275	276	67.13
0	76	0	76	60.54
	0	329	329	67.82

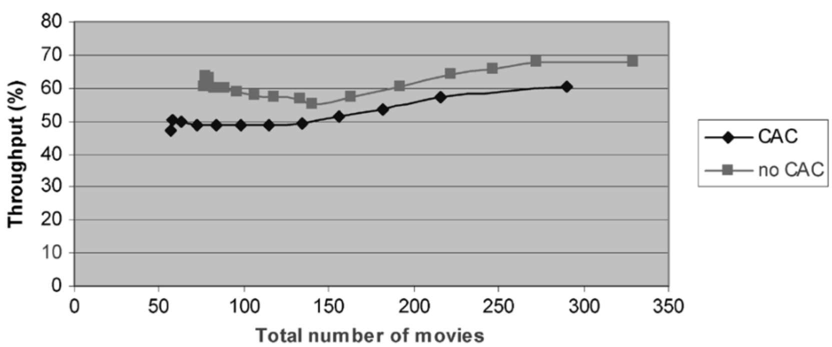

Fig. 1. Throughput versus total number of movies for H.263 video, with and without the use of the CAC algorithm.

system consists of medium- and low-quality movies only (no high-quality movies exist in the system). This happens because all high-quality movies are asked to decrease their demands for the system to accommodate as many more video users as possible. The superiority of the system's results when CAC is not in use is evident from both figures.

Considering the results presented in Fig. 1, it should be noted that, when no CAC exists, the results showing that the channel throughput is higher have been produced when one of two types is the dominant one in the system [i.e., when either the medium-quality (64-K) movies or the low-quality (16-K) movies mainly use the channel bandwidth]; when both types of movies contribute more or less equally to the use of the channel bandwidth, the channel throughput decreases. This can be explained by the fact that the high burstinesses of the two types of movies, combined with their different traffic characteristics, lead to the decrease of the channel throughput. This phenomenon is encountered neither in the results presented in Fig. 1 when the CAC is implemented, nor in Table I; because the very strict CAC policy does not allow the maximum possible number of movies to enter the system, it "normalizes" the results. This is why the throughput achieved by the system (Fig. 1, CAC) increases in an almost linear fashion with the increase of the number of movies present in the system.

The "dominant movie type" phenomenon mentioned earlier is also not encountered in the results shown in Table II, where high-quality movies are integrated with medium- or low-quality movies, because the burstinesses of the lower quality movies are overcome by the much higher mean bit rate and burstiness of the high-quality (256-K) movies.

The second part of our simulations was conducted by implementing the second version of the CAC and traffic-policing mechanism on the system. As mentioned in the description of our mechanisms, in these simulations, we consider the case in which a percentage of the video terminals with higher quality coding do not agree to decrease their demands and the system ensures that they acquire the guaranteed bandwidth and QoS. As declared in our system description, the probability for a requesting video terminal to be of high, medium, or low quality is equal to one third. The first column of Tables III and IV shows, for all cases examined, the minimum percentage of the total number of movies, which is guaranteed to the users who deny

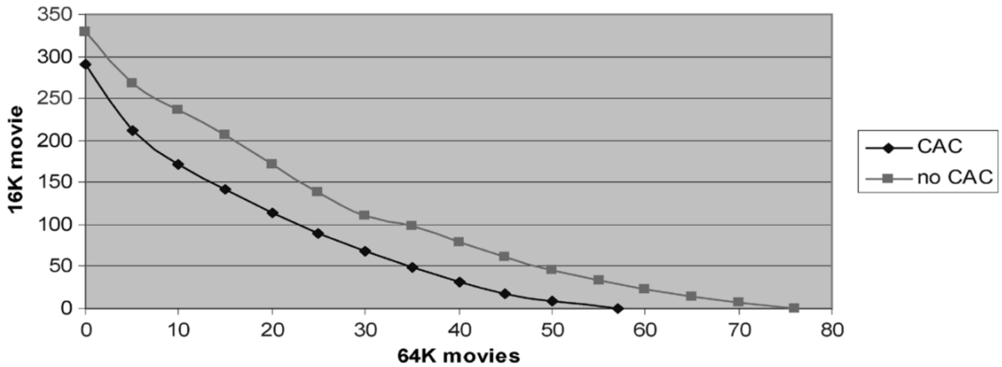

Fig. 2. Combination of 64- and 16-K movies for H.263 video, supported by the system with and without the use of the CAC algorithm.

TABLE III
H.263 VIDEO. ALL TYPES OF MOVIES, CAC ALGORITHM, FIXED PERCENTAGE OF HIGH- AND MEDIUM-QUALITY MOVIES

Minimum Percentage (High, Medium) (%)	256K movies	64K movies	16K movies	Total number of movies	Throughput (%)
(10,10)	4	4	20	28	32.11
(10,33.33)	3	9	15	27	27.43
(10,56.66)	2	12	6	20	20.01
(20,33.33)	3	5	7	15	22.81
(20,46.66)	3	7	5	15	25.07
(33.33,33.33)	4	4	4	12	25.76

TABLE IV
H.263 VIDEO. ALL TYPES OF MOVIES, NO CAC ALGORITHM, FIXED PERCENTAGE OF HIGH- AND MEDIUM-QUALITY MOVIES

Minimum Percentage (High, Medium) (%)	256K movies	64K movies	16K movies	Total number of movies	Throughput (%)
(10,10)	6	6	39	51	42.79
(10,33.33)	5	15	27	47	42.24
(10,56.66)	4	23	13	40	41.85
(20,33.33)	6	9	12	27	34.53
(20,46.66)	5	12	8	25	33.68
(33.33,33.33)	6	6	6	18	31.36

to decrease their demands from high to medium quality and to the users who deny to decrease their demands from medium to low quality (i.e., all other high- and medium-quality users move on to low quality).

It should be noted that all the results presented in Tables III and IV correspond to the highest number of high-quality movies, which suffices for satisfying the percentage limits for each type of movies. As shown from these results, in almost all the cases examined—with the exception of the (10%, 10%) case, where low-quality movies are the dominant type in the system—the system is unable to achieve high throughputs and the throughput results are considerably lower than those presented in Tables I and II. This is because of the existence of all three types of bursty movies, instead of two types (as in Tables I and II), as well as the fact that, by "obeying" the percentage limits for each movie type the system is not allowed to use all of its bandwidth; some time slots remain empty, leading to a throughput decrease. By comparing the results of Tables III and IV, we once again observe that the results are significantly better in the absence of the CAC policy.

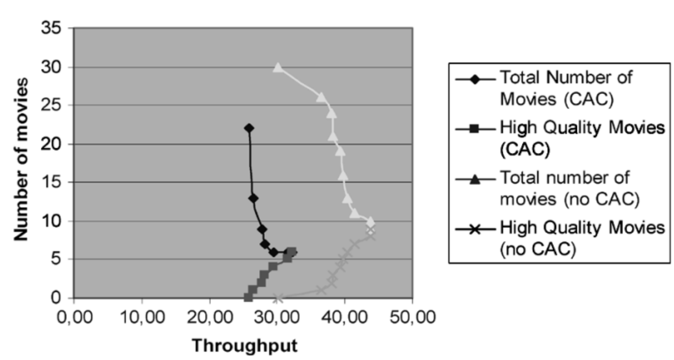

Fig. 3. MPEG-4 video, with and without the use of the CAC algorithm.

Finally, Fig. 3 presents the results of our scheme when integrating the two types of MPEG-4 coding movies, with and without the use of the second version of CAC and traffic-policing mechanisms. It is clear from these figures that the throughput achieved by our scheme is greater in the cases in which high-quality movies are the "dominant" type of movies in the system. In the case when we use the CAC algorithm, the throughput achieved by the system when only low-quality movies are present is less than 30%, whereas when the number of high-quality movies increases and becomes equal to the total number of movies (i.e., only high-quality movies are present in the system), the throughput increases significantly (an 8% increase). Similarly, in the case when we do not use the CAC algorithm, the throughput achieved by the system when only low-quality movies are present is about 30%, whereas when only high-quality movies are present in the system the channel throughput increases by 15%. These results seem to contradict the corresponding results for the H.263 movies, where the existence of high-quality movies in the system leads to the lowest throughput. Still, the explanation for these results is the very high burstiness of the low-quality MPEG-4 movies (peak/mean ratio larger than 10, more than double compared to the peak/mean ratio of the high-quality MPEG-4 movies). This burstiness is responsible for the very low throughput when only low-quality MPEG-4 movies are present in the system. On the contrary, in the case of H.263 movies, the low-quality movies have a peak/mean ratio smaller than that of the high-quality movies, which justifies the results for that type of movies.

Three general comments that need to be made about all our results are as follows.

1) All the results refer to the system working at its "limit," i.e, the average video packet dropping is in most cases very close to the 0.0001 threshold, because our simulation continues to generate requesting video terminals until the system is full.

2) The very bursty nature of the video streams is responsible for the system's inability to achieve high channel throughput results.

3) Although the results achieved by the system deteriorate when the CAC mechanism is in use, the sole implementation of a traffic-policing mechanism in the system is unable to prevent video terminals from entering the system at will and, subsequently, will lead to congestion and quality degradation for all system terminals. This is unacceptable, even for the small period of time until the traffic-policing mechanism is activated. Therefore, a CAC mechanism is necessary, although a less-conservative CAC policy should be adopted in order to provide satisfactory results along with the admission control.

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