Call Admission Control and Traffic Policing Mechanisms for the Wireless Transmission of Layered Videoconference Traffic from MPEG-4 and H.263 Video Coders

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ABSTRACT

In this paper we explore, via an extensive simulation study, the performance of Call Admission Control (CAC) and Traffic policing mechanism proposed for transmitting multiple-layered videoconference movies over a wireless channel of high capacity, depending on the user's needs and requests. We focus both on MPEG-4 and H-263 coded movies, and in the latter case our scheme achieves high aggregate channel throughput, while preserving the very strict Quality of Service (QoS) requirements of the video traffic.

1. INTRODUCTION-SYSTEM MODEL

High-speed packet-switched network architectures have the ability to support a wide variety of multimedia services, the traffic streams of which have widely varying traffic characteristics (bit-rate, performance requirements). The main goal of wireless communication is to allow the user access to the capabilities of the global packet-switched network at any time without regard to location or mobility.

In this work, we design and evaluate a scheme which multiplexes MPEG-4 and H.263 video streams (Variable Bit Rate, VBR), respectively, in high capacity picocellular systems with the picocell diameter of the order of a few dozen meters. We consider MPEG-4 movies with two coding layers (high and low bit rate), and H.263 movies with three coding layers (high, medium and low bit rate).

Within the picocell, spatially dispersed source terminals share a radio channel that connects them to a fixed base station. The base station 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 base station) 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 (in this study we investigate the case where video traffic is the only traffic in the system. Nevertheless, high capacity wireless channels are often used for integrating voice and video traffic, and the frame duration is chosen to be equal to the time a voice terminal needs to generate a new voice packet [5,8]. Assuming that the speech codec rate is 32 Kbps and that the packet length is equal to the size of an ATM cell, yields the the frame duration of 12 ms), and accommodates 256 information slots. The channel rate is 9.045 Mbps. Each information slot accommodates exactly one, fixed length, packet that contains video information and a header.

We consider the channel to be error-free and without capture.

1.1 MPEG-4 and H-263 Streams

The MPEG group initiated the new MPEG-4 standards in 1993 with the goal of developing algorithms and tools for high efficiency coding and representation of audio and video data to meet the challenges of video conferencing applications. The MPEG-4 standards differ from the MPEG-1 and MPEG-2 standards in that they are not optimized for a particular application but integrate the encoding, multiplexing, and presentation tools required to support a wide range of multimedia information and applications. In addition to providing efficient audio and video encoding, the MPEG-4 standards include such features as the ability to represent audio, video, images, graphics, text, etc. as separate objects, and the ability to multiplex and synchronize these objects to form scenes. Support is also included for error resilience over wireless links, the coding of arbitrary shaped video objects, and content-based interactivity such as the ability to randomly access and manipulate objects in a video scene. [2]

In our study, we use the trace statistics of actual MPEG-4 streams from [3]. 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:

a) the high quality version, which has a mean bit rate of 400 Kbps, a peak rate of 2 Mbps, and a standard deviation of the bit rate equal to 434 Kbps, and
b) the low quality version, which has a mean bit rate of 90 Kbps, a peak rate of 1 Mbps, and a standard deviation of the bit rate equal to 261 Kbps.

New video frames arrive every 40 msecs. We have set the maximum transmission delay for video packets to 40 msecs, with packets being dropped when this deadline is reached. That is, all video packets of a video frame (VF) must be delivered before the next VF arrives. The allowed video packet dropping probability is set to 0.0001 [1,5].

H.263 is a video standard that can be used for compressing the moving picture component of audio-visual services at low bit rates. It adopts the idea of PB frame, i.e., two pictures being coded as a unit. Thus a PB-frame consists of one P-picture which is predicted from the previous decoded P-picture and one B-picture which is predicted from both the previous decoded P-picture and the P-picture currently being decoded. The name B-picture was chosen because parts of B-pictures may be bidirectionally predicted from the past and future pictures. With this coding option, the picture rate can be increased considerably without increasing the bit rate much [4].

In our study, we use the trace statistics of actual H.263 streams from [3], 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:

a) the high quality version, which has a mean bit rate of 256 Kbps, a peak rate of 1.4 Mbps and a standard deviation of the bit rate equal to 505 Kpbs.
b) the medium quality version, which has a mean bit rate of 64 Kbps, a peak rate of 320 Kbps and a standard deviation of the bit rate equal to 127 Kpbs.
c) The low quality version, which has a mean bit rate of 16 Kbps, a peak rate of 84 Kbps and a standard deviation of the bit rate equal to 46 Kbps.

In this case, the maximum transmission delay for the video packets of a video frame is equal to the time before the arrival of the next video frame (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), with packets being dropped when the deadline is reached. The allowed video packet dropping probability is again set to 0.0001 [1].

1.2. Actions of Video Terminals and Base Station Scheduling

Video terminals *convey their requirements to the base station by transmitting them within the header of the first packet of their current video frame.* 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 <u>the earliest available</u> information slots to the video terminals, which, if needed, keep these slots in the following channel frames, until the next video frame (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.

2. CALL ADMISSION CONTROL AND TRAFFIC POLICING MECHANISMS

In our study, we investigated an approach on the subject of Call Admission Control and Traffic Policing for both cases of movies (MPEG-4, H.263), which was a combination of two mechanisms:

1) 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 work presented in [6]. If the expected equivalent bandwidth, with the addition of the new movie, was less than the channel rate (9.045 Mbps), then the new video terminal was allowed to enter the system. If, on the other hand, the expected equivalent bandwidth surpassed the channel rate, then the new video terminal was asked to "decrease" its demands (move to a lower quality coding, if possible). If the problem persisted, then another video terminal of high quality coding was asked to "decrease" its demands. If, finally, all high quality coding video terminals which had entered the system decreased their demands and the equivalent bandwidth of the superposition still surpassed the channel rate, then the new request was rejected.
2) To avoid a situation where 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, a second mechanism was implemented within the system. Each minute, the system checked the video packet dropping, and if it exceeded the upper limit of 0.0001 in two consecutive checks (i.e., for two consecutive minutes), then the previous "demand decreasing" policy was implemented once more, starting from the movie which last entered the system. This policy will be referred to, in the rest of the paper, as the "Traffic Policing mechanism".

3. RESULTS AND DISCUSSION

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

Our simulation results have shown that the method presented in [6], 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 it has been encountered in other methods as well (e.g., the authors in [7] comment on their own method as overestimating the actual bandwidth). 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 a very significant channel throughput deterioration. Therefore, we have simulated 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 1-6, the improvement in channel throughput was substantial (more than 10% in many cases).

Tables 1 and 2 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 1 presents the simulation results when the CAC algorithm (at the "entrance" of the system) is used. Table 2 presents the results when the CAC algorithm is not in use, and only the Traffic Policing mechanism is implemented.

Similarly, Tables 3 and 4 present the results of our scheme when integrating all types of H-263 coding movies, with and without the use of the CAC algorithm. In this case, as expected from our policy for permitting a new video terminal to enter the system, the steady state condition for the system consists of medium and low quality movies only, because all high quality movies are asked to decrease their demands for the system to accommodate as many more video users as possible.

Finally, Tables 5 and 6 present the results of our scheme when integrating the two types of MPEG-4 coding movies, with and without the use of the initial CAC algorithm.

As expected, the very bursty nature of the video streams is responsible for the system's inability to reach high channel throughput results.

A comment that needs to be made about the results presented in Table 4 is that the channel throughput is higher when one of two types is the dominant one in the system (i.e., when either the medium quality movies or the low quality movies mainly use the channel bandwidth). On the contrary, 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 the two types of movies, combined with the low mean bit rates of both types of movies, lead to the decrease of the channel throughput. The same phenomenon is not encountered in the results shown in Table 2, where high quality movies are integrated with medium or low quality movies, because the burstinesses of the movies is balanced by the much higher mean bit rate of the 256-Kbps movies.

4. CONCLUSIONS

In this work, we have proposed and investigated the performance of a mechanism proposed for transmitting multiple-layered videoconference movies over a wireless channel of high capacity, depending on the user's needs and requests. Our scheme, which is one of the first in the literature to study the integration of MPEG-4 and H.263 video streams, is shown to achieve high aggregate channel throughput in many cases of traffic load, while preserving the Quality of Service (QoS) requirements of each traffic type.

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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

Table1. H-263 video, with the use of the CAC algorithm. (case with high quality 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	37.83
	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	62.84
1	61	0	62	58.88
	0	275	276	67.13
0	76	0	76	60.54
	0	329	329	67.82

Table 2. H-263 video, without the use of the initial CAC algorithm. (case with high quality movies)

64K movies	16K movies	Total number of movies	Throughput (%)
57	0	57	47.05
50	8	58	50.14
45	18	63	49.88
40	32	72	48.96
35	49	84	48.69
30	68	98	48.55
25	90	115	48.81
20	114	134	49.44
15	141	156	51.34
10	172	182	53.72
5	211	216	57.32
0	290	290	60.46

Table 3. H-263 video, with the use of the CAC algorithm.

64K movies	16K movies	Total number of movies	Throughput (%)
76	0	76	60.54
70	7	77	63.68
65	14	79	63.02
60	23	83	60.07
55	34	89	59.99
50	46	96	58.56
45	61	106	57.89
40	78	118	57.21
35	98	133	56.73
30	110	140	55.31
25	138	163	57.29
20	172	192	60.22
15	207	222	63.88
10	237	247	65.72
5	268	273	67.75
0	329	329	67.82

Table 4. H-263 video, without the use of the CAC algorithm.

High Quality	Low Quality	Total number of movies	Throughput (%)
6	0	6	32.3
5	1	6	31.7
4	2	6	29.4
3	4	7	28.3
2	7	9	27.8
1	12	13	26.4
0	22	22	25.9

Table 5. Mpeg-4 video, with the use of the CAC algorithm.

High Quality	Low Quality	Total number of movies	Throughput (%)
9	0	9	43.9
8	2	10	43.8
7	4	11	41.5
6	7	13	40.4
5	11	16	39.7
4	15	19	39.3
3	18	21	38.3
2	22	24	38.0
1	25	26	36.5
0	30	30	30.1

Table 6. Mpeg-4 video, without the use of the CAC algorithm.