

Resource reservation and dynamic admission control for distributed multimedia systems

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Abstract

In the literature, different approaches have been proposed to achieve an admission control which can highly guarantee a Quality of Service (QoS) in distributed multimedia systems. Through this paper, we propose a new method for admission control in distributed multimedia systems namely a feedback control architecture for distributed multimedia systems (FCA-DMS). This method is based on (i) continued knowledge of the network and of the video servers' workload, and (ii) the supervision and auto-adaptation of system load. The network and the video servers' workload are computed by a QoS controller integrated in the master server of the FCA-DMS architecture. Our proposed solution consists of maintaining an up-to-date broad view of the system's behaviour from the collected measurements to databases of available video servers and to databases of available videos and their locations. We run extensive simulations to test the validity of our solution. The simulation results show that our solution leads to a good QoS with all workload conditions. This performance results from the continuous supervision of admission of client queries according to the real workload variations.

Keywords: *Distributed Multimedia Systems, Admission Control, Feedback Control Loop, Quality of Service*

1. Introduction

In recent years, distributed multimedia systems have increasingly constituted a considerable part of multimedia networks. These types of systems require real-time processing of data, i.e., they must be completed before fixed dates. Equally, they process a high mass of data and try to guarantee a high Quality of Service (QoS) in the streams presented to the end users.

Multimedia application administrators face the challenge of satisfying the QoS expected by end users while providing efficient resource utilization.

Several methods have been proposed, such as bandwidth fair sharing [1], concurrency control, admission control [2],

scheduling control and congestion control [3]. In this paper, we focus on admission control of clients' requests in distributed multimedia systems, namely in FCA-DMS (Feedback Control Architecture for Distributed Multimedia Systems) architecture [4]. For most clients requesting multimedia streams, the inability to initiate a video request is perceived as more tolerable than the unexpected termination of QoS level. Consequently, admission control in which clients request a video are not automatically admitted. Even if resources and videos are available, it is necessary to ensure that sufficient resources are available to provide an acceptable QoS level. For many years, admission control of client requests in distributed multimedia systems has been classified among the active research areas [5][6]. Several and different solutions have been proposed to provide a good QoS to end users while maximizing resource utilization. Almost all of such solutions are hampered by the difficulty of knowing all necessary parameters for admitting clients' requests.

In this paper, we consider the problem of admission control given a particular processing of clients' requests according to the category of clients and the availability of resources. Our goal is to provide a solution that is applicable in feedback control architectures for distributed multimedia systems and that is enough to be widely applicable in distributed multimedia systems and can be implemented in real-time.

In the next section, we describe the components of FCA-DMS architecture in more details and explore the admission control solutions proposed in the literature. In Section 3, we describe our new Specific Admission Control Method to FCA-DMS architecture. Section 4 is dedicated to our experimental setting. We expose the different results of simulations that show an important

performance of our proposed method. Finally, in Section 5, we conclude our paper and we give some perspectives.

2. Related work

2.1 FCA-DMS architecture

In order to stabilize and converge to the QoS requested by the end customer, we have adapted a QoS management method used in Real Time Database Systems (RTDBSs) [7][8]. Our research is based on a feedback control loop that guarantees the QoS on the client side.

The proposed FCA-DMS architecture includes three components:

- a master server that receives the clients' requests, monitors the system state, chooses the available video servers and is able to satisfy the demand and finally, adjusts the video streams in order to maintain the QoS initially fixed,
- the video servers that send the video streams to clients and operate according to the control of the master server,
- the clients receive the video streams from the video server selected by the master server and send requests to the master server. When a state change occurs, they periodically send a feedback report to the master server.

We describe, in the following, the typical functioning of FCA-DMS architecture when a video stream is requested by a client. At first, requests arrives to the master server to get a video on the part of clients interested by the video streams, but also with a certain QoS level. Second, the request is broadcasted by the master server to all video servers. Only the unsaturated video servers containing the requested video streams in their disks (available video servers) respond to the master server and inform it of their availability. The master server selects one video server to meet the client's demand, depending on the QoS provided by each video server. After the selection of the video server, a stream is opened between the selected video server and the concerned client. Finally, the client periodically sends a retroaction report to the master server in order to provide an idea about the quality of the received video stream. When necessary, the client asks to adapt the QoS. In this case, the master server informs the video server to continue sending the video stream, but with a modified QoS. The operation continues until the reception of all the film by the client.

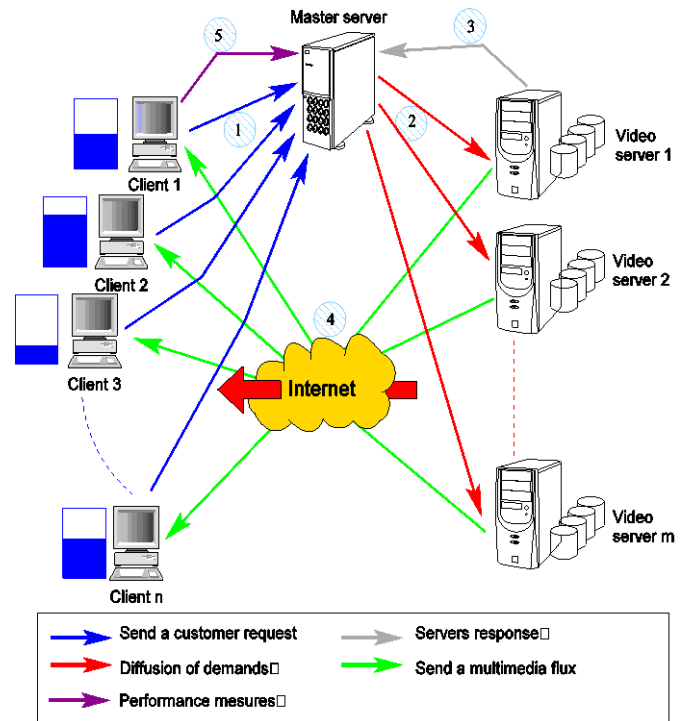


Fig. 1 Functional model of the FCA-DMS architecture

Depending on the load system conditions, such as the congestion of servers and network, the feedback loop is proposed in order to adapt the QoS and to converge it to the desired value.

2.2 Feedback control loop

In order to stabilize the system during the instability periods, the feedback loop has been proposed as a solution [9]. This solution relies on observation and auto-adaptation. Indeed, the method is based on observing the system's performance and the achieved availability of resources. Moreover, it verifies if the QoS initially required is consistent with the observed QoS. For instance, in VoD (Video on Demand) [10], the system checks if the video streams have arrived and presented to end users without interruptions with the requested QoS. On the other hand, the auto-adaptation consists of adapting the system's performance by adjusting some network and video resources [11] according to the QoS requested by to clients. For example, the system may decrease or increase the number of sent frames. In this manner, the feedback loop ensures some system stability [12].

2.3. The admission control problem

Several studies in the literature have been proposed to address the admission control problem [13][14]. In the first approach, the traffic descriptors are used as solutions to admission control of client's demands. The primarily idea is to theoretically fix the current system workload, by using traffic descriptors. Based on measured values, the admission control decides whether or not to let the demand come into the system. Such an approach must know the real traffic descriptors and the arriving requests [15]. The second approach uses survey reports in order to produce the traffic model that the current source is on the edge to transmit across. This approach is referred to as an active technique [16]. The third approach aims to assess the current workload for each system component, relying mainly on measurements in order to achieve its objective. These solutions are dubbed MBAC (measurement-based admission control) and are categorized as passive techniques [17][18]. Such approaches do not need to know the current traffic.

3. Admission control in FCA-DMS

Distributed multimedia applications manage large quantities of data, such that each client waits for a response to its demand. They require a similar admissions control for all clients requesting a new video and for all clients requesting a QoS modification [19].

The approaches that have been proposed to remedy the problem of admission control [20][21] do not effectively treat our problem of admission control in FCA-DMS architecture.

The proposed approaches create a set of procedures that do not consistently work together in coherent manner.

3.1. The proposed scheme

Our proposed method is a Specific Admission Control Method to the FCA-DMS architecture. This method provides guarantees for most system resources, and uses all measurements performed by the other components of the master server.

The proposed approach can provide admissions control for the FCA-DMS architecture, generally for all distributed multimedia systems, hence addressing the following challenges: resource allocation and multiple algorithms for scheduling policies.

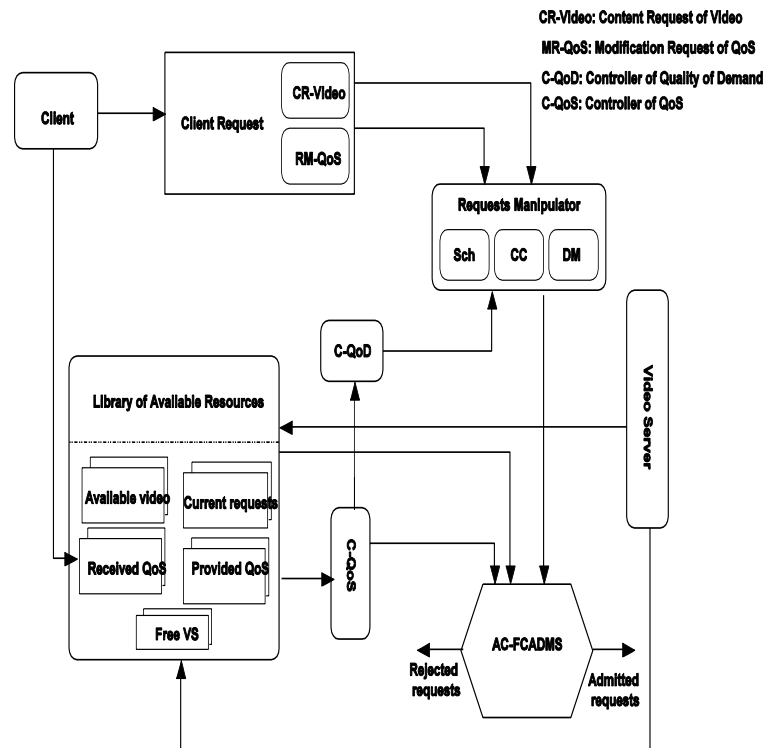


Fig. 2 Admission control approach for FCA-DMS architecture

The challenges introduced by our method are illustrated as follows. First, it must provide a simple use in order to communicate these requirements in terms of QoS, response time and set of resources it requires for receiving an acceptable QoS. Second, it must also communicate with the server of databases in order to have an overview of the available system resources [22] and their properties of QoS guarantee. Third, it must incorporate a measurement algorithm in order to continuously monitor the communication between the different components of FCA-DMS in a way to obtain the different measurements, and a decision algorithm which determines whether to accept or not the client request, based on performance prediction and on measures received from the QoS controller (C-QoS) and to Library of Available Resources (LAR). Finally, it must perform a periodic analysis (timing) that takes into consideration the different properties of clients' requests.

Figure 2 provides an overview of our proposed architecture for admission control in FCA-DMS. A client requests a video with an acceptable QoS, and if necessary, it requests a QoS modification. The client communicates with the admission controller using the RM-QoS (Request of QoS Modification) and CR-Video (Contents Request of Video). The CR-Video provides the video, the required QoS and the processing requirements. The RM-QoS

captures the necessary constraints to satisfy the requested QoS such as the allocation of necessary resource. If the selected video server is saturated, then the policy aims the replication strategy illustrated in [23], to meet the requested QoS.

All components in Figure 2 communicate with each other. Once the decision to reject or accept a client request is made, the information will propagate to all system's components. Such decentralized system provides a connection between all components of the FCA-DMS architecture. The measurement algorithm determines the system resources that may be allocated to the client. This continues until the entire video stream is received by the client, with the requested QoS.

The measurement algorithm takes into account the measurements from the Library of Available Resources (LAR), C-QoS (Controller of QoS), C-QoD (Controller of Quality of Demand) and Requests Manipulator (RM), which aims to attribute system resources to the client.

The LAR describes the state of the system resources and their availability and, with the aid of the RM, describes their synchronizing properties.

The scheduler (Sch) is used to choose the next client request that must be examined. The RM deals with all client requests. The concurrency controller (CC) deals with the case when many requests compete for the same resource that is not widely available. Consequently, CC examines and selects the demand which has the highest priority. Before any processing of a new client request, a requests controller (RC) must verify the availability of the requested content.

Based on information found in the databases server, C-QoS, C-QoD and RM, the measurement algorithm attempts to allocate system resources to the client.

We have based our method on the MBAC solution [24]. However, our method includes knowledge bases that come in between the decision algorithm and the measurement algorithm.

3.2. Application of measurement algorithm

The measurement algorithm endlessly supervises the movement of the connection between all components of FCA-DMS architecture in order to obtain the necessary measures. These measures must respond has such a deadline (short time), and must consider the ongoing traffic in order to continuously update these data.

The RM measures the actual number of client requests that are admitted by the CC, Sch and DM and sends them to AC-FCADMS. This value is denoted A_I (requests/ms). Together with another performance parameter, say R_I representing the number of requests that are rejected by the CC and by the Sch and finally by the DM.

We see that the first filtering of client requests was made by the RM. The requests admitted by RM will be sent to AC-FCADMS.

However, AC-FCADMS may set the number of admitted client requests based on measurements sent by the LAR, C-QoS and C-QoD. For each time window of 100 ms, the AC-FCADMS measures the value A (requests/ms) representing the number of requests admitted by the RM and admitted by the AC-FCADMS.

A second performance parameter is considered, say R representing the total number of requests that are rejected by the RM plus the sum of total number of requests that are rejected by AC-FCADMS (R_2).

Both measured values A and R yield a pair of data measures referred to as pairs (A, R).

3.3. Arrival of client requests in the system

In this section, we use the MBAC method [24] for admission control in FCA-DMS architecture. The MBAC method is based on the characterization of the evolution of performance parameter as a function of actual throughput. Then, we propose that R is the final performance parameter and A is the total of admitted client requests. Consequently, the evolution is denoted by the function:

$$R = f_R(A)$$

In our architecture, the arrivals of client requests follow the *Poisson process*. This makes the inter-arrival of client requests asynchronous and distributes the arrivals of requests over the study period. The Poisson process has as advantage, on the one hand, to translate the arrival times of client requests by a stochastic process, and on the other hand, to possess similar properties to requests arrivals in queue of data servers, networks, etc.

In distributed multimedia systems, and particularly in our FCA-DMS architecture, the requests models of clients are events that randomly occur and that are independent of each other.

The arrival of client requests is performed by a generator program of requests arrivals whose operation is as follows:

$$X(N_t=k) = e^{-\lambda} \cdot \frac{\lambda^k}{k!}$$

- X is the random variable which allows the determination of the number of times that the event occurs in period t.
- k represents integer values.
- λ is the average of client requests arrival (λ ∈ R+).

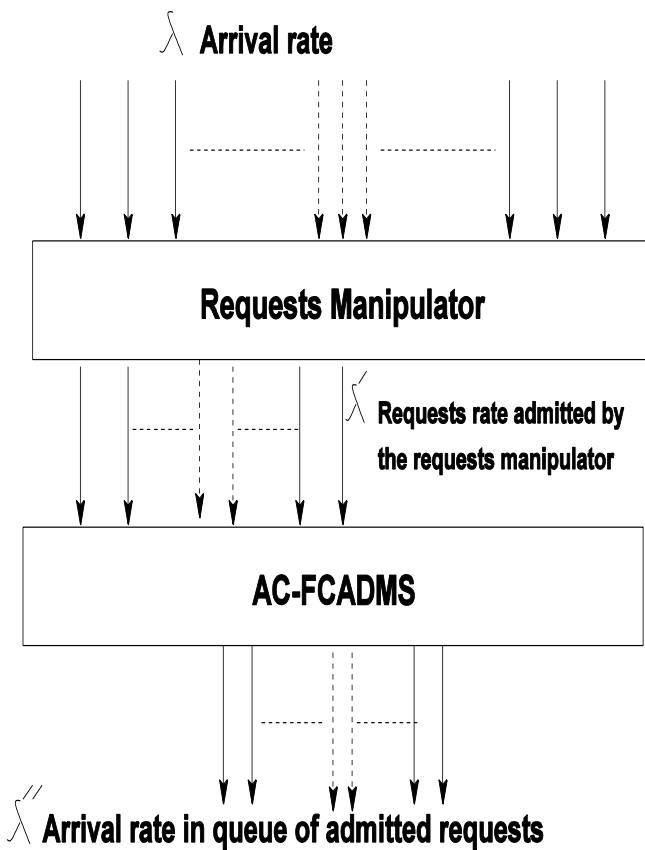


Fig. 3 Transformation of arrivals rate.

The admission control module that we employed is based on two stages of control (Requests manipulator, AC-FCADMS). The distributed multimedia systems are systems for which the load can increase to a high saturation threshold and cannot schedule all client requests. To guard against these situations, we propose a method of double admission control to meet the QoS requested by clients.

The effect of our method on the arrival of clients' demands is shown in Figure 3. We note that the arrival rate of client requests (λ) is transformed by the requests manipulator at an arrival rate λ' ≤ λ. Consequently, the probability to receive N' arrivals of client requests in the AC-FCADMS during a time interval t is transformed to:

$$X(N'_t=k) = e^{-\lambda'} \cdot \frac{(\lambda')^k}{k!}$$

The arrival rate is transformed, on the other hand, by the AC-FCADMS at an arrival rate λ ≤ λ' ≤ λ''. Finally, the probability to receive N'' admitted client requests during a time interval t is now:

$$X(N''_t=k) = e^{-\lambda''} \cdot \frac{(\lambda'')^k}{k!}$$

3.4. Application of decision algorithm

The decision algorithm decides on the client request acceptance taking into account a prediction of system performance. Based on the function f_R, the decision algorithm seeks to evaluate the expected performance of the system performance that must be increased by the new client request.

If a new client request is accepted, and this request is characterized by a QoS rate r, then the new value of R will be R̂. Then we have:

$$\hat{R} = f_R(\hat{A} + r)$$

Where f_R defines the evolution of R against the value A. Â reflects the adjusted performance of the ongoing workload.

We could see afterwards how our decision algorithm is formulated: A new client request is accepted if:

$$\hat{R} + n_1 V_{a1} + n_2 V_{a2} \leq R_p$$

R_p is the minimum performance required to meet the QoS requested by the client (in terms of rate of received frames, jigue, delay), V_{a1} is the tolerable variation of R₁, V_{a2} is the tolerable variation of R₂, n₁ is an adjustment parameter at requests manipulator and n₂ is an adjustment parameter at AC-FCADMS.

The system performance \hat{A} is calculated by the ratio between the minimum capacity required by client request in the system and the available capacity in the system for each 100 ms. The system performance is given by the following formula:

$$\frac{\sum_{t=0}^{Nb-RMQoS} ModifCap + \sum_{j=0}^{Nb-RVC} VideoCap}{QPT}$$

- Nb-RMQoS represents the requests number of QoS modification,
- Nb-RVC indicates the requests number of new videos,
- ModifCap denotes the consumption of a QoS modification request,
- VideoCap denotes the consumption of a new video request,
- QPT indicates the system ability.

The requests manipulator and AC-FCADMS uses the data coming from the library of available resources to regularly calculate the system load. When the load reaches the 80% threshold, the manipulator requires a first filtering of arriving requests at the system, then AC-FCADMS blocks the access of client requests up to recovery of tolerated threshold.

Definitely \hat{A} requires to be constantly updated. When several new clients' requests arrive, or whenever a new client request is admitted, the \hat{A} value is forthwith updated.

4. Simulations and results

In this section, we call our admission control method SACM-FCADMS. We characterize our method on the admission control management by a double control of clients' requests, and by relying on observation and auto-adaptation.

The objective of this section is to expose the simulation results associated with our study. We have implemented our architecture with a simulator, such that we characterize the functioning mechanisms that occur between the different links in our SACM-FCADMS method. Finally, we compare the simulations results in terms of QoS guarantee, when we apply the KBAC method [24] on the one hand, and when we apply a double admission control on the other hand.

In our simulations, we treat the MPEG-2 type of video compression. A video stream compressed to MPEG-2 is

coded depending on three types of frames (cf. Figure 4): *I-frames (I)*, *P-frames (P)* and *B-frames (B)*.

We chose Java as a programming language because it enjoys broad support on many platforms, and it is actually used in most of distributed architectures.

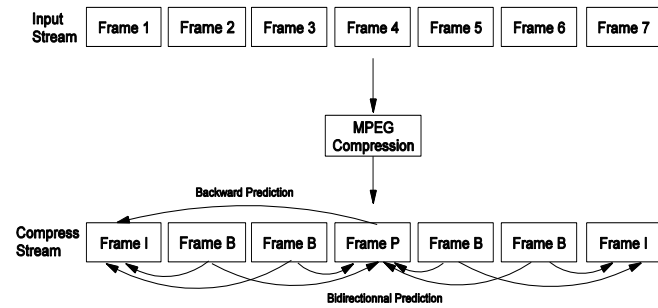


Fig. 4 MPEG compression.

4.1. Estimating of arrival rate of clients requests

In our experiments, we suppose that the incoming clients' requests are not known a priori. In many cases, knowledge of clients' requests can be derived through use and/or the transmission of a token bucket. Nevertheless, this method (token bucket) is not easy to parameterize and may produce imprecise results for admission control (since the decision algorithm uses an imprecise value for r). In this study, we choose a rather simple approach that does not need any signalling as it is only based on clients requests. In the following, we describe the approach used by the system to estimate the arrival rates of new clients requiring admission.

We have assumed in the previous section that arrivals of clients' requests follow a *Poisson process*. The system's load varies depending on the video streams sent to end clients and also varies according to requests arriving at the master server (variation of λ value). In order to ensure effective assessment of new arrivals requests in the system, we repeat the experiment 100 times for each value and obtain a sample of 100 values of system performance. Otherwise, get results which reflect the QoS levels with different workloads of system.

Because of memory overload problems, it is not easy to get important periods of simulation and a great number of measured values at each instant. In order to deal with such problems, we determine the steps number. Then the system calculates the necessary time over which it computes the measures average. For example, in case of a simulation of 1000 time units with 10 measurements, the simulator has to maintain the average of measured value taken for a determined parameter every 100 time units (1000/10).

4.2. Description and parameters of simulation

In order to observe and compare the performance of our admission control method (SACM-FCADMS) we include in our experiments the results that should be obtained by the simulations and in all load conditions. The great advantage of our admission control method is to effectively filter clients' requests. Otherwise, SACM-FCADMS should arrive at a maximum use of system resources rate and should accept the maximum number of requests, but with a maximum guarantee of QoS requested by the client.

When $\lambda=0.1$, the number of requests arriving during the simulation is 140. This number passes on about 1500 requests in case of $\lambda=2$. The system's workload is bound to the rate of client requests that arrive to the requests manipulator. The admission control has a crucial role in the FCA-DMS architecture as it is the case generally in all architectures of distributed multimedia systems [25]. Therefore, it is necessary to generate and modify well-defined constraints (cf. Table 1). Indeed, in our simulator, the end user can set the number and content of each video server according to requested characteristics.

Measured parameters are:

- *Served-frames rate* is the ratio among the number of *received* frames with the requested QoS and all sent frames;
- *Received-frames rate* answer to the report among the number of *received* frames and the number of sent frames throughout the simulation;
- *Useful-frames rate* is the report among the number of *received* frames added to not *rejected* frames and the number of all sent frames;
- *Waiting-frames rate* represents the ratio among the number of *not rejected* frames (*and not received*) and the number of all sent frames;

4.3. Simulations results

The efficiency of our SACM-FCADMS approach, according to the current system load, is to adjust and stabilize the QoS to the veritable conditions of a multimedia application. Specially, the system must adapt the QoS in case of dynamic arrival of clients' requests, i.e. if the number of clients' requests changes over time.

We show the effectiveness of our method on different rates of frames. For this reason, we have chosen to compare our simulation results using our SACM-FCADMS method, then without using an admission control method, and finally with the MBAC method. These comparisons of

simulations results are shown graphically in Figures 5, 6, 7 and 8, with all system workloads.

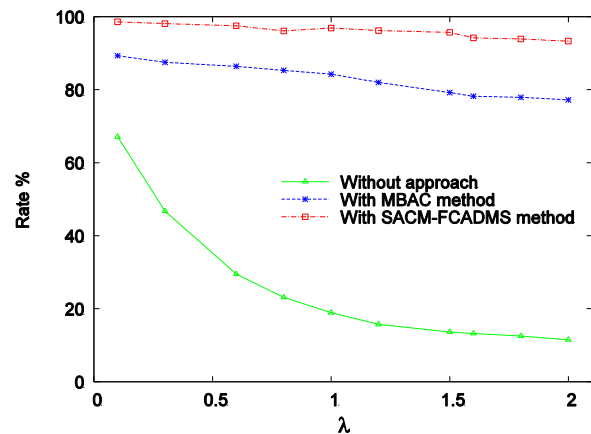


Fig. 5 Rate of useful frames

The best simulation results are obtained when using the SACM-FCADMS method (Figure 5). We see in Figures 5, 8 that for all workload conditions, i.e., for all variations of $\lambda > 0$, we have the best performances on the waiting-frames rate and on useful frames rate. The rate of received frames is the most significant, i.e. 86.7%.

We must consider that when the application of our admission control method integrated in master server causes some rejects of client requests, these rejected requests will no longer be treated in the current system and will not be involved in our simulations.

In case of progression of the system workload (increasing of client requests), we determine that there is no great effect on the useful frames, on the waiting frames, and on the received frames. The fact that our approach is founded on supervision and auto-adaptation principles clearly explains this performance result. The supervision principle consists of results control obtained when client requests arrive in the system and verifying if the QoS initially requested is coherent with the QoS currently perceived.

We observe a progressive lowering of the rate of received frames and useful frames when using the MBAC method (see Figure 5 and Figure 6), in all workload conditions (heavy workload, light workload).

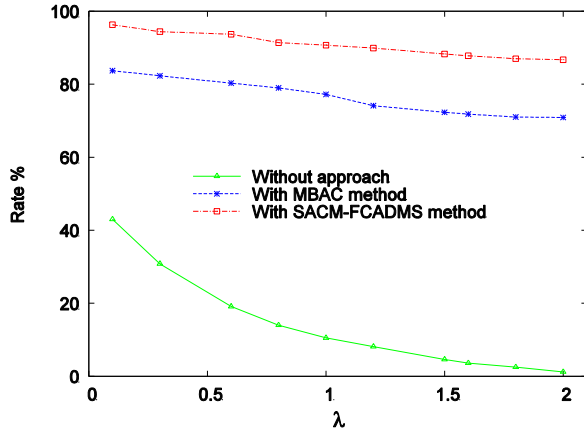


Fig. 6 Rate of received frames

We determine that there is no great effect on the useful frames, on the waiting frames and on the received frames, in case of progression the system workload (increasing of client requests). The fact that our approach is founded on supervision and auto-adaptation principles clearly explains this performance result. The supervision principle consists of results control obtained when client requests arrive in the system and verifying if the QoS initially demanded is coherent with the QoS currently perceived.

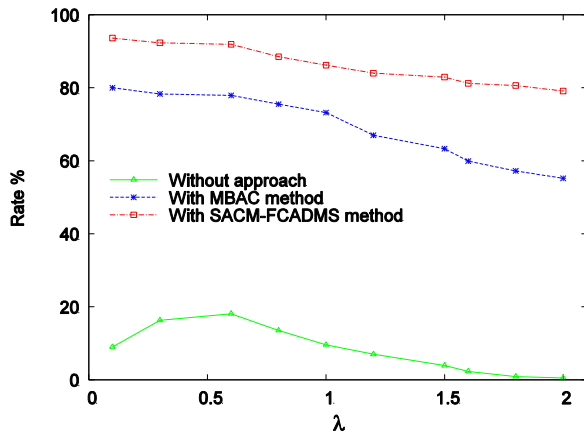


Fig. 7 Rate of served frames,

We observe a progressive lowering of the rate of received frames and useful frames, when using of MBAC method (see Figure 5 and Figure 6), in all workload condition (heavy workload, light workload).

Our SACM-FCADMS solution produces satisfactory performances since it practically always responds to the demanded QoS. We can notice that it presents performance results near to ideal results of ideal admission control.

Table 1. Simulation parameters.

Notation	Definition	Values
system characteristics		
T-Sim	Simulation time	100 units
Nb-measures	Measurements number	[15,100]
Video streams characteristics		
Nb-video	Video number	[15,200]
Nb-GoP	GoP number by video	[20,100]
Nb-P	Number of P frames by GoP	[3, 9]
Ds-P	Number of B frames between two successive P frames	[2, 6]
Client request		
λ	Arrival rate of clients requests	[0.1, 2.0]
QoS	Quality of service (frames per unit time)	[25, 35]
Bs	Buffer size	[40, 60]
Tm-service	Service waiting	[1, 20]
Video server		
Nb-VS	Number of video servers	[5, 100]
β	Debit of video server (frames per unit time)	[100, 200]
V	Video server capacity (number of videos)	[1, 20]
Master server		
C-req	Current requests	[150, 1400]
A-video	Available video server	[5,100]
λ'	Arrival rate of clients requests in AC-FCADMS	[0.1, 2.0]
λ	Rate of admitted clients requests	[0.1, 2.0]

More accurately, the SACM-FCADMS method fulfils the rate of received frames more than 83% in all load conditions. Our method reduces the delays of video streams.

In all figures, we describe the case of fewer workload (i.e., $\lambda = 0.1$), generally more than 140 clients requests, arriving to the case of best workload (i.e., $\lambda = 2$), than 1500 clients requests. The results of the MBAC method and our SACM-FCADMS method broadly differ depending on the

definite adjustment parameter (\hat{A} , \hat{R} parameters, in our method).

Particularly, in case of heavy system workload, our solution greatly affects the rate of received frames. Thereafter, we treat, at different workloads, the SACM-FCADMS functioning on three gaps of λ , $\lambda \in [1.5, 2]$ (high workload), $\lambda \in [0.8, 1.4]$ (average workload) and $\lambda \in [0.1, 0.7]$ (light workload).

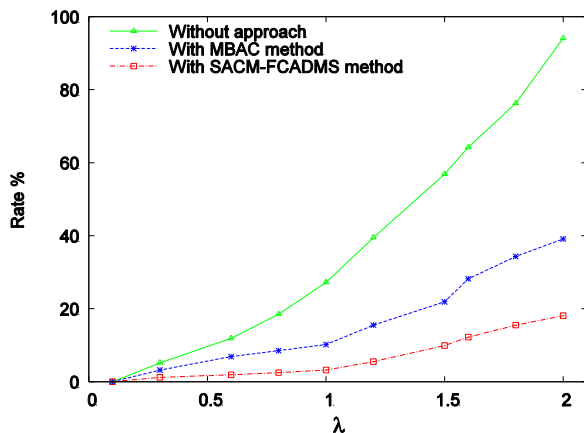


Fig. 8 Rate of waiting frames.

We have achieved a significant gain for the useful frames and the received frames, in applying the SACM-FCADMS method. As a result, our solution is a powerful solution to remedy to the problems of system congestion, particularly of master server congestion, in all overload status.

We can see the overall performance of different methods to admission control, in Table 2 that concerns simulation numerical results. From these observations, we notice that the SACM-FCADMS solution provides satisfactory results. Notably, it leads to a number of received frames in the case of $\lambda = 2$ (i.e., high workload) near 96%. On the other hand, it shows that our solution of admission control constantly provides good results ($\lambda \in [0.1, 2]$).

When using our proposed method according to the rate of received frames, the waiting time of fresh frames is reduced and has an important rate, i.e. 84%. By decreasing the system load, this guarantees to meet the QoS required by clients. The proposed approach reduces the number of lost frames, in case of heavy system workload, by reducing the clients' requests that risk losing their required QoS.

Table 2. Simulation numeric results.

λ	% useful-frames	% received-frames	% served-frames	% waiting-frames
Without approach				
0.1	67.1	43	9.2	0.4
1	18.9	10.5	9.6	27.2
2	11.5	1.3	0.5	94.1
With MBAC method				
0.1	89.3	83.71	79.96	0.00
1	84.24	77.26	73.19	10.17
2	77.87	77.26	55.31	39.11
With SACM-FCADMS method				
0.1	98.61	96.48	93.61	0.00
1	96.93	89.92	86.19	3.18
2	93.34	96.74	79.08	18.10

5. Conclusion

The last evolutions in distributed multimedia systems and the selection of admission control solutions have addressed the problem of the QoS guarantee and the optimal use of system resources. They have met the challenge of input of an important number of client requests in the system even though existing approaches do not manage the current traffic of system. The MBAC method and the SACM-FCADMS method proposed in this paper have been tested on a wide variety of workloads (see Table 2).

The proposed approach is based on double admission control to manage QoS in distributed multimedia systems, especially in FCA-DMS architecture.

We have shown the significance of our admission control approach in FCA-DMS architecture and in distributed multimedia systems. This proposed approach gives a priority to certain client requests in the system, in order to increase its reliability and robustness and to converge towards the QoS specified by the client. We have also proposed a way to integrate our method in FCA-DMS model.

We have integrated in this architecture our approach in order to render to real-time video streams a deterministic temporal guarantee according to the temporal constraints.

However, we have presented the results showing the ratio differences with and without integration of our method.

Our future work consists in proposing an optimal strategy of videos installation in video servers as well as bringing some fault tolerance at the master server level.

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