

Performance Analysis of Adaptive Joint Call Admission Control to Support QoS in Heterogeneous 4G Wireless Networks

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ABSTRACT- Call admission control (CAC) is one of the basic mechanisms for ensuring high quality of service (QoS) offered to the user in Wireless Heterogeneous Networks (HetNet). Based on the available network resources, it estimates the impact of accepting or blocking a new session request. Many CAC algorithms have been proposed in the literature but they were all limited by the available bandwidth. This paper analyses the bandwidth adaptation technique for the Adaptive Joint CAC (AJCAC) algorithm; it is proposed as a solution for congestion; where the AJCAC algorithm degrades the bandwidth of some ongoing users to make room for new incoming ones. A restoration process must take place when the network is underutilized; where the algorithm restores the maximum bandwidth service to the degraded users. In this paper the bandwidth degradation process was investigated and evaluated using a system-level MatLab simulation. The results showed that as the degradation in the bandwidth increases the adaption required in the network increases. On the other hand, degradation in the QoS results in a decrease in the blocking probability.

Keywords: Heterogeneous Networks, Call Admission Control, Bandwidth Adaption, QoS Restoration, QoS Degradation, Congestion.

المستخلص - التحكم في قبول المكالمات يلعب دورا هاما في الشبكات اللاسلكية غير المتجانسة، لأنه أحد الميكانيكيات الأساسية لضمان جودة الخدمة المقدمة للمستخدم. و اعتماداً على موارد الشبكة المتوفرة يتم تقدير الآثار المترتبة على قبول أو رفض أية مكالمات جديدة. في هذه الورقة تم تطبيق و تحليل تقنية "التخصيص المتأقلم" في الخوارزمية المشتركة المتأقلمة للتحكم في قبول المكالمات محل لمشكلة الازدحام ، حيث تقوم هذه الخوارزمية بإنقاص سعة بعض المستخدمين الحاليين لافساح المجال لمستخدمين آخرين جدد. و بعد أن يقل التزامم في الشبكة يجب على خوارزمية التحكم في دخول المكالمات القيام بعملية ترميم، بحيث تعيد خدمة السعة القصوى الى مستخدميها الذين تعرضوا لانقاص سعتهم من قبل، تم تحليل هذين المفهومين وتقييمهما في هذه الورقة من خلال برنامج محاكاة باستخدام لغة البرمجة ماتلاب. كذلك تمت دراسة و تقييم التباين في تدهور جودة الخدمة الناتجة عن تقليل السعة للمستخدمين أثناء عملية التخصيص المتأقلم. اظهرت النتائج انه كلما ازداد التدهور في السعة ازداد التأقلم المطلوب في الشبكة ومن ناحية اخرى يؤدي التدهور في جودة الخدمة الى انخفاض في معدل رفض المكالمات.

INTRODUCTION

Radio resource management (RRM) strategies are responsible for an efficient utilization of the resources in any Radio Access Network (RAN). In heterogeneous networks a policy-based approach is usually assumed for Common RRM (CRRM) operations. One of the most important common radio resource management (CRRM) mechanisms used in wireless networks is call admission control (CAC) [1]. The goal of an efficient call admission control algorithm is to ensure the quality of service (QoS) of the ongoing connections, while at the same time, to care for the optimal utilization of the

available radio spectrum. Call admission control schemes are the decision making part of the networks aiming at providing users with services of guaranteed quality, something that leads also to reduced network congestion and call blocking probabilities and thus to more efficient resource utilization [4].

Joint call admission control JCAC algorithm is a CRRM algorithm, it makes a decision on whether an incoming call can be accepted or not. It also decides on the suitability of the available radio access networks to accommodate the incoming call [2].

In this paper a bandwidth adaptation technique for the Adaptive Joint CAC (AJCAC) is Analysed. The AJCAC algorithm degrades the bandwidth of some ongoing users to make room for new incoming ones. A restoration process must take place when the network is underutilized; where the algorithm restores the maximum bandwidth service to the degraded users.

CALL ADMISSION CONTROL ALGORITHMS

Call admission control algorithms are specified based on both the bandwidth allocation policy used and the resource management operation. Table 1 show the three different CAC algorithms used in heterogeneous networks operating on two different RATs and serving two different classes of calls.

Table 1: CAC Algorithms

Algorithm/Type	Bandwidth allocation	Resource Management	Acronym
1	Fixed	Independent	FICAC
2	Fixed	Joint	FJCAC
3	Adaptive	Joint	AJCAC

In Algorithm Type 1, the two RATs operate independently, in each RAT a fixed amount of bandwidth (maximum bandwidth) is allocated for each class of calls all the time, thus this algorithm is referred to as Fixed Independent CAC (FICAC); it is also considered as the reference state. In Algorithm Type 2, a joint CAC scheme is considered, where the entire bandwidth of both RATs is divided into two partitions. Each partition is dedicated to a particular class of calls. When a new call arrives, its class is detected. It is then directed to the corresponding partition [4]. The call will be assigned to the partition if it has enough resources, otherwise the call will be blocked. Admitted calls are assigned a fixed maximum basic bandwidth unit (BBu). This algorithm is called the Fixed Joint CAC (FJCAC). In algorithm type 3 the same partitions of (FJCAC) are used but, an adaptive bandwidth allocation mechanism is applied when the network is oversubscribed [4]. Maximum basic bandwidth unit (BBumax) is allocated to calls when the network is underutilized whereas minimum basic bandwidth unit (BBumin) is allocated to calls when the network is oversubscribed. When a new call arrives, its class is detected. It is then directed to the corresponding partition. If the partition capacity is capable of

serving the new call it will be assigned to it. If the partition capacity is above a predefined threshold-called the adaption threshold-it is considered oversubscribed and it will degrade the bandwidth of some ongoing calls to free some radio resources to accommodate the new call. If there are no more ongoing calls to degrade, the new call will be blocked [5].

When the incoming traffic is below a predefined threshold-called the restoration threshold- the AJCAC performs a restoration process in which the calls whose bandwidth was degraded (or as many of them as possible) are restored to their maximum bandwidth [6].

SYSTEM MODEL FOR PERFORMANCE EVALUATION

In this system model, s servers were considered with no waiting room. Calls arrive in a Poisson process with rate λ . The service time of each call has an exponential distribution with mean $1/\mu$. Calls that arrive when all servers are busy are blocked and lost, so the system considered is a loss system. The state of the system is defined by the number of calls present in the system. The state space is finite and it follows a birth-and-death process [7].

The blocking probability of the CAC algorithms is calculated using the Erlang-B formula or Erlang's loss formula, given by the following:

$$P_s = \frac{\left(\frac{a^s}{s!}\right)}{\sum_{j=0}^s \left(\frac{a^j}{j!}\right)} \quad (1)$$

where P_s is the blocking probability, a is the offered traffic and s is the number of servers. The system model considers two different coexisting RATs, example of possible RATs are cellular global system for mobile communications (GSM), General Packet Radio Service (GPRS), Universal Mobile Telecommunications System (UMTS) or wireless local area networks (WLANs) [3][8]. The system considers a complete partitioning policy where the entire available bandwidth of the two different coexisting RATs is partitioned into pools. Each pool is dedicated to a particular traffic class of calls. Two types of call classes were also considered: calls class 1 (voice) and call class 2 (video), both having a service time $\mu=0.5$. Both RATs are capable of serving the two types of calls but with different percentages. Table 2 summarizes

the RAT and partitions sizes considered in this paper.

Table 2: Partitions Bandwidth FJCAC and AJCAC

Resources	Partition 1 (Calls Class 1)	Partition 2 (Calls Class 2)	Total Bandwidth of RAT
RAT 1 Bandwidth	25	5	30
RAT 2 Bandwidth	5	55	60
Total Bandwidth of Partition	30	60	N/A

Each class of call has two possible Basic Bandwidth Units (BBU), Maximum Bandwidth Unit (BBu_{max}) and Minimum Bandwidth Unit (BBu_{min}). Table 3 shows the BBU of each class of call.

Table 3: Basic Bandwidth Units BBU

Basic Bandwidth Unit BBU	Calls Class 1 (voice)	Calls Class 2 (video)
BBu_{max}	2	7
BBu_{min}	1	3

SIMULATION ANALYSIS

Three case studies were simulated to test the effect of the adaption, restoration and degradation processes on the blocking probability:

Case study 1: AJCAC QoS Adaption Process

In this QoS adaption process, the AJCAC algorithm degrades the bandwidth of some ongoing users to make room for new incoming ones. Three different Adaption thresholds were chosen to evaluate their effect on the network performance. The adaption thresholds used for class 1 calls are 73%, 80% and 86%.

The AJCAC class 1 calls partition is of size 30 BBU, and a class 1 call has a maximum bandwidth of 2 BBU, this means that the partition has 15 channels; each channel is assumed to serve one call. For utilization purposes; two channels will not participate in the adaption process.

Figure 1 illustrates the adaption process for class 1 calls when applying an Adaption Threshold of 80% (80% of 15 total calls=12 calls). In this case when the traffic exceeded 80% of the maximum bandwidth (e.g when the network has more than 12 calls) two calls are degraded from 2 BBu_{max} to 1 BBu_{min} (1 BBu_{min} is the minimum bandwidth assumed) releasing a total of 2 BBU to be assigned

to the new incoming call. The process continues until there are no more channels to be degraded. At the end of the adaption process 6 new channels with BBu_{max} will be created, which means that the network now have a total of 21 channels instead of only 15 channels. Figure 2 shows blocking probabilities of the class 1 adaption thresholds.

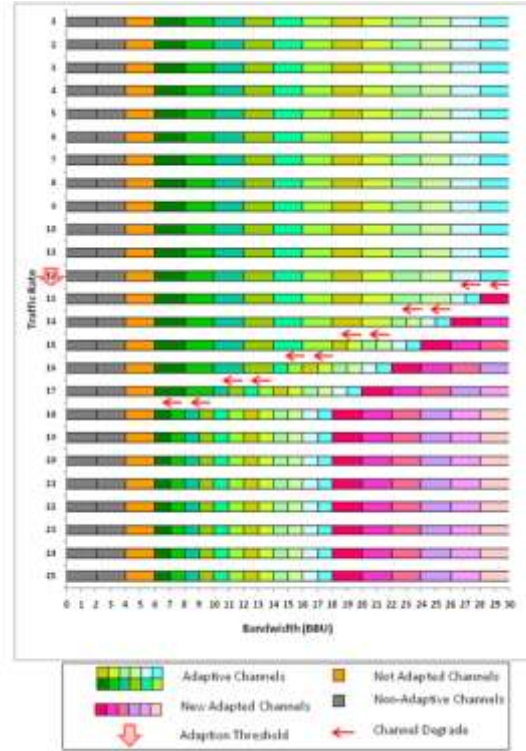


Figure 1: Class 1 Calls Adaption Process (Threshold=80%)

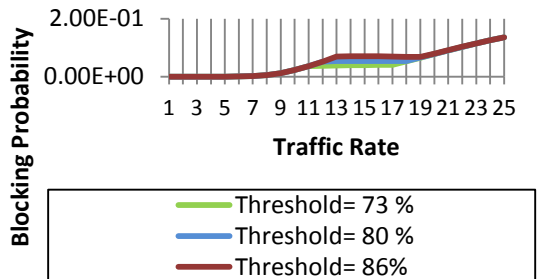


Figure 2: Blocking Probability of Class 1 QoS Adaption Thresholds

The figure shows that the lower is the threshold; the lower is the blocking probability for the incoming users, which is desirable by the service providers. But the lower is the threshold means that the existing ongoing users will soon encounter a bandwidth degradation, which means a poor QoS

from the user point of view. On the other hand, higher thresholds ensure a better QoS for the ongoing calls as they can maintain their maximum bandwidth services for a longer period but, it results in higher blocking probability for the new incoming calls.

The AJCAC class 2 calls partition is of size 60 BBU, and a class 2 call maximum bandwidth equals to 7 BBU, this provides the RAT partition with 8 maximum BBU channels and 4 extra unused BBUs. The adaptation thresholds used in class 2 calls are 62%, 75% and 87%.

Figure 3 illustrates the adaption process for class 2 calls when an Adaption Threshold of 75% was used (75% of 8 total calls=6 calls). The calls are degraded from 7 BBU_{max} to 3 BBU_{min}(minimum bandwidth assumed in this case study). In this case when the traffic exceeded 75% of the maximum bandwidth (e.g. when the network has more than 6 calls) one channel will be degraded from 7 BBU_{max} to 3 BBU_{min} releasing 4 BBU.

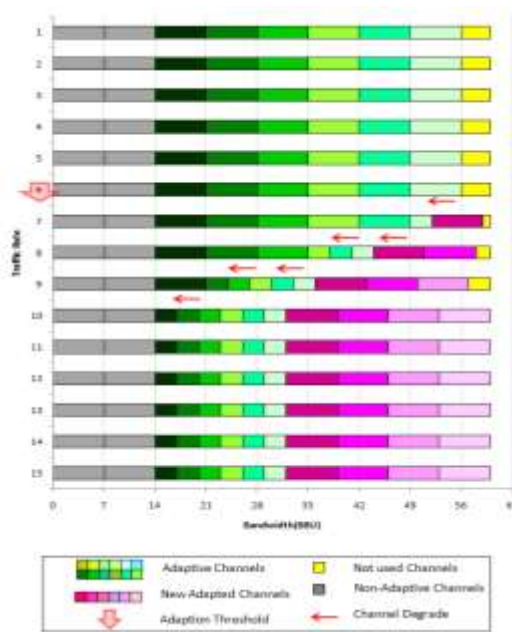


Figure 3: Class 2 Calls Adaption Process (Threshold=75%).

Using these released BBUs together with the 4 extra unused BBUs a new channel of 7 BBU is created, leaving one extra BBU unused in this stage. This process is repeated until there are no more channels to degrade. At the end of the adaption process 4 new channels with BBU_{max} are created. The network now has a total of 12 channels instead of only 8 channels. The adaption produced 50% extra

channels to the network. Figure 4 shows the blocking probability of the three adaption thresholds for class 2 calls.

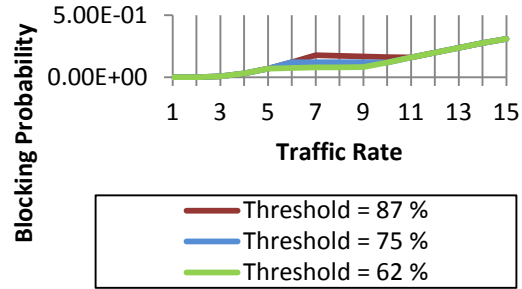


Figure 4: Blocking Probability of Class 2 QoS Adaption Thresholds

From Figure 2 and 4 the following two extreme situations must be avoided when choosing the appropriate adaption threshold for a network:

- Choosing a very high adaption threshold means that the adaption process will start late and the ongoing users will have a maximum bandwidth services for a longer period meanwhile, the new incoming users will encounter a high blocking probability, which is not desired from the service provider’s point of view.
- Choosing a very low adaption threshold means that the adaption process will start early and the ongoing users are more vulnerable to QoS degradation which is not desirable from the user point of view.

Case study 2: AJCAC QoS Restoration Process

The restoration process must take place when the network is underutilized; where the algorithm restores the maximum bandwidth service to the degraded users. In this case study, three different restoration thresholds were evaluated to choose the most appropriate one to be used in a network. The restoration thresholds used in class 1 calls are 66%, 71% and 76%.

Figure 5 illustrates the restoration process of class 1 calls when a threshold of 71% was used (71% *21 total channels = 15 channels). When the traffic is below 71% of the total bandwidth (the network received less than 15 calls) one adapted channel is released (releasing 2 BBU). The released 2 BBU are used to upgrade two current calls from 1 BBU_{min} to 2 BBU_{max}. The process continues until all adapted channels are released. At the end of the restoration

process the network would have its 15 original maximum-bandwidth channels.

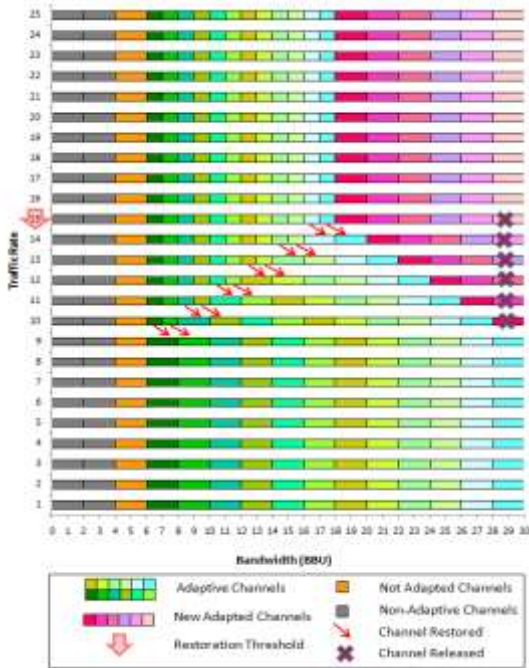
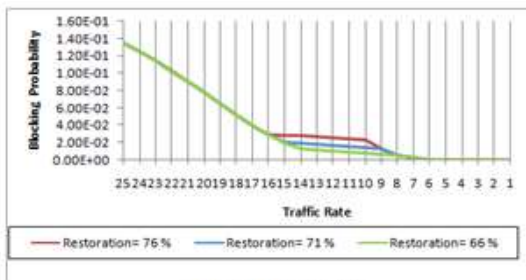
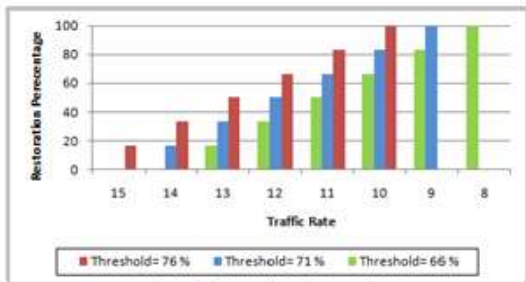


Figure 5: Class 1 Calls Restoration Process (Threshold=71%)



a Blocking Probability



b Restoration Percentage

Figure 6: Class 1 QoS Restoration Thresholds

Figure 6.a shows the blocking probabilities of class 1 calls using three different restoration thresholds. Figure 6.b represents the restoration percentage of each threshold used. Restoration percentage is the percentage of the restored users to the total

degraded users. For example from Figure 6.b; when the traffic is 10 calls, a network using a 76% restoration threshold would be fully restored (100%) while a network using a 71% restoration threshold would have restored only 83% of its degraded bandwidth. At the same time the 66% threshold network would have restored only 50% of its degraded bandwidth.

From Figure 6.a and 6.b it can be concluded that the optimal value of the restoration threshold is around 71%, since it provides a low blocking probability and an excellent restoration percentage. The restoration thresholds used for class 2 calls are 66%, 75% and 83%.

Figure 7 illustrates the restoration process for class 2 calls when a threshold of 75% was used. The calls are upgraded from 3 BBumin to 7 BBumax(75% *12 total channels = 9 channels). When the traffic is below 75% of the total bandwidth (the network received less than 9 calls) one adapted channel is released (releasing 7 BBU). Three BBU of the released 7 BBU are used to upgrade one current call from 3 BBumin to 7 BBumax the remaining 3 BBUs are not used in this stage. The process continues until all adapted channels are released. At the end of the restoration process the network would have its 8 original maximum-bandwidth channels.

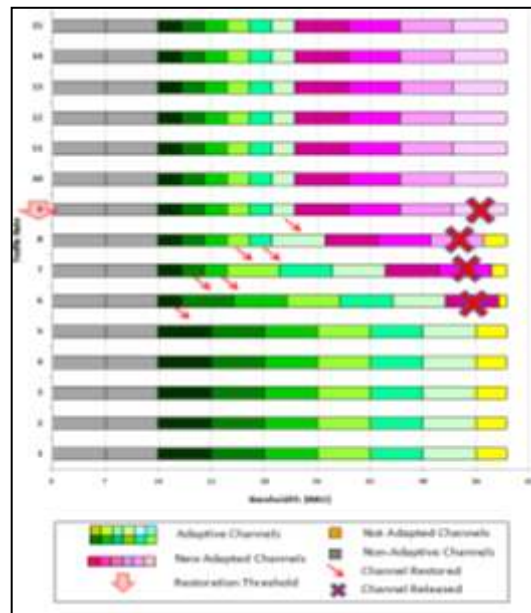


Figure 7: Class 2 QoS Restoration Thresholds

Figure 8.a and 8.b shows that the optimal restoration threshold for class 2 calls is around

75%. This threshold combines low blocking probability with excellent restoration percentage.

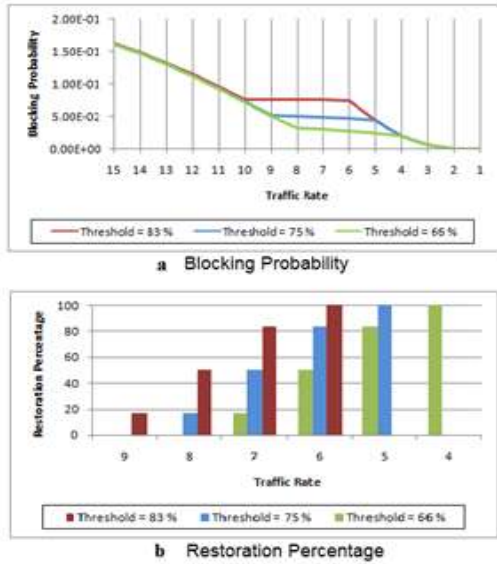


Figure 8: Class 2 QoS Restoration Thresholds

Case study 3: AJCAC QoS Degradation Process

In this case study, the process of degrading the QoS during the adaption process for calls class 2 is investigated. The BBu_{min} was varied while the BBu_{max} remained fixed. Table IV shows the different parameters used.

Table 4: Maximum and Minimum BBU Values

Parameter	Value (BBU)
BBu_{max}	7
BBu_{min}	3
	4
	5

Figure 9 demonstrates the different aspects that can help in choosing an optimal value for the minimum bandwidth in a degradation process.

Figure 9.a shows the minimum QoS percentage of the three suggested minimum bandwidth values. The minimum QoS percentage is the percentage of bandwidth that remains for a degraded user to the total maximum bandwidth. The figure also depicts the QoS degradation percentage which is calculated as the percentage of bandwidth deducted from a degraded user to the total maximum bandwidth. The adaption percentage of each of those three suggested minimum bandwidth is shown in figure 9.b; it is the percentage of the expansion in the network after the end of the adaption process.

Figure 9.c illustrates the corresponding blocking probability of each of the suggested minimum bandwidth values.

Figure 9 concludes that a lower minimum bandwidth BBu_{min} value results in a poorer QoS for ongoing calls. Ongoing calls will release most of its bandwidth during the adaption process to make space for incoming calls. This also results in a lower blocking probability which is desired by the service provider.

On the other hand, a higher minimum bandwidth BBu_{min} value results in a more convenient QoS for ongoing calls. Ongoing calls in this case will release only a small portion of their bandwidth to free space for new incoming calls. This results in a higher blocking probability which is not desired by the service provider.

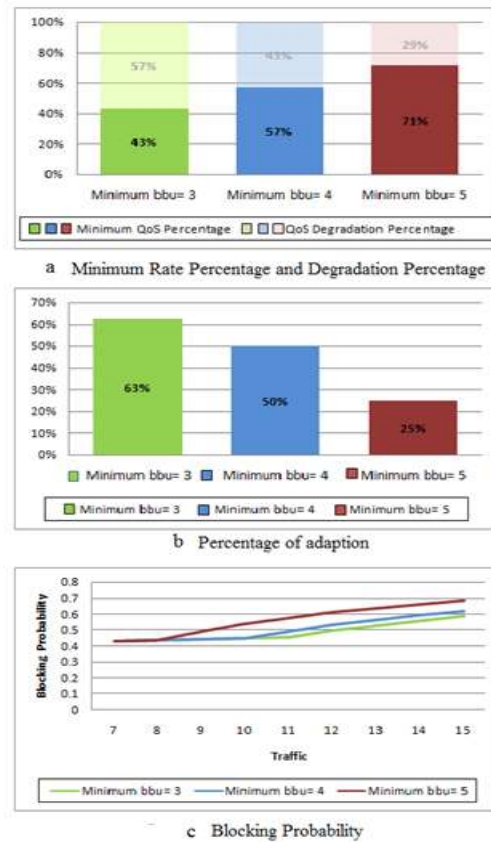


Figure 9: Result of Varying BBu_{min}

CONCLUSIONS

The coexistence of different cellular networks in the same geographical area necessitates a common radio resource management (CRRM) for enhanced QoS provisioning and efficient radio resource utilization. Joint call admission control (JCAC)

algorithm became a vital tool for CRRM environments.

In this paper a bandwidth adaptation technique for the Adaptive Joint CAC (AJCAC) is analysed. A MATLAB system-level simulation was implemented to evaluate the different AJCAC QoS processes; the adaption, restoration and the degradation. The results showed that in the adaption and restoration processes a high threshold results in a high blocking probability for incoming users but provides good QoS for existing ones. While a low threshold insures a low blocking probability for the incoming users but a bad QoS for the ongoing ones.

The results also showed that as the degradation in the bandwidth increases, the adaption required in the network increases. On the other hand, degradation in the QoS results in decreasing the blocking probability.

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