Allocation Algorithm based on CAC Scheme for LTE Network

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Abstract
To reduce network congestion and to guarantee a certain level of Quality of Service (QoS) for service requests, Call Admission Control (CAC) as a part of Radio Resource Management (RRM) aims to accept or reject a call based on available resources. In this paper, we proposed new CAC and resources allocation schemes for Long Term Evolution (LTE). The proposed CAC scheme gives the priority of Handoff Calls (HC), without totally neglecting the requirements of a New Calls (NC). The main objective of this approach is to provide QoS and to prevent network congestion. Simulation results show that the call admission control scheme leads to increased session establishment success and resource utilization compared with existing admission control and resources allocation schemes. Moreover, the resources allocation scheme achieves a considerable gain in the system throughput and fairness.
Keywords
Call admission control; QoS; Scheduling; LTE; Uplink; Throughput.

1. Introduction

The Orthogonal Frequency Division Multiple Access (OFDMA) and Single Carrier Frequency Division Multiple Accesses (SC-FDMA) are the respective techniques used for radio transmission and reception in LTE and Long Term Evolution Advanced (LTE-A) networks for the Downlink (DL) and Uplink (UL) directions, respectively. SC-FDMA offers improvements in terms of spectral efficiency and throughput while satisfying several types of services. Indeed, The LTE and LTE-A systems are expected to provide peak data rates in the order of 50 and 500 Mbit/s in uplink, respectively [1]. In the LTE and LTE-A uplink directions, the total bandwidth is divided into multiple sub-bandwidths. These sub-bandwidths are regrouped in Physical Resource Blocks (PRBs). A PRB is defined by a couple of frequency and time domains. In fact, a PRB is 0.5 ms in length (one slot in the time domain) and contains a contiguous set of 12 subcarriers (180 kHz in the frequency domain) for each OFDM symbol. Therefore, this PRB is the basic transmission unit of a user’s data in both uplink and downlink directions. In order to provide quality of services (QoS) for different kinds of services in packet switched networks, RRM can be of a great importance.

LTE standards do not specify any Call Admission Control (CAC) and resources allocation algorithms have to be defined and so are left to the vendors and the researchers to implement them [2],[3]. The CAC decides whether the eNodeB accepts or rejects the call requests of User Equipments (UEs) by considering the cell capacity. The scheduler, then, selects the accepted requests to be scheduled in the following Transmission Time Interval (TTI) based on their QoS requirements. For the allocation scheme, the eNodeB needs some channel quality information perceived by each UE. This is achieved by sending Sounding Reference Signal (SRS) from UEs to the eNodeB so that the latter can compute the Channel Quality Indicator (CQI) values of each PRB for each UE.

In this paper, we propose a new CAC scheme that handles the HC and NC and increases session establishment success and resource utilization. Then, we present a new scheduler that treats both Guaranteed Bit Rate (GBR) and Non Guaranteed Bit Rate (NGBR) traffics, by taking the maximization throughput and the user fairness into consideration.

The rest of this paper is organized as follows: section II presented pre-studied CAC and resources allocation algorithms. The system model, proposed CAC and resources allocation algorithms were introduced in section III. The simulation results and discussions were detailed in section IV. Finally, we drew our conclusions in section V.

II. LITERATURE REVIEW

II.1 CAC ALGORITHMS

The LTE Uplink CAC algorithms have been discussed by many academic and industrial researchers. The existing CAC algorithms can be classified into non-prioritized and prioritized.

II.1.1 Non-prioritized CAC algorithm

In the non-prioritized CAC algorithms, the eNodeB handles HC in the same way as NC; each call, independently of its type, is blocked if no PRBs are available.

Authors in [4], proposed a CAC scheme using the Fractional Power Control (FPC) formula agreed in 3GPP [5]. The CAC scheme based on the FPC and the path gain determines whether a user requesting admission can be accepted or not. The admission criterion for a new user is the sum of the PRBs required by a new user requesting admission and existing users is less than or equal to the threshold, which is the total number of PRBs in the system bandwidth. The drawback of this CAC scheme is that it

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does not take into account the prioritization between the calls (handles HC in the same way as NC) while basing their QoS requirements. Hence, the thresholds management is static. So, it is difficult to guarantee the HC required dropping probability.

Another non-prioritized CAC algorithm is proposed in [6]. In this work, a high priority is given to the real time (RT) service packets approaching the delay deadline. However, no differentiation is made between new and handoff requests. Additionally, to reduce the call dropping probability, other CAC algorithms that take into consideration neighboring cells information have been suggested.

In [7], the authors proposed a Greedy Choice with a bandwidth availability Aware Defragmentation (GCAD). This CAC algorithm accepts all the new requests. Thus, a lower priority admitted request is preempted. The preemption process has a negative effect; it can leave little useless gaps in the data subframe.

In [8], the authors proposed two CAC schemes taking into account mobility within and between cellular users. These proposed CAC schemes are applicable only for an NC of real-time traffic type. RT calls have the same bit rate. These RT calls will be accepted until over flow. Non-real-time (NRT) calls and Best Effort (BE) calls receive the same number of subcarriers. Finally, BE calls complete the service for a larger number of subcarriers. The drawback of these CAC schemes are that they handle only the NCs.

In [9], the authors proposed a threshold to handle the NC call. A newly arriving call is blocked if the number of calls is higher or equal to this predefined threshold. The drawback of this CAC scheme is that it handles only the NCs.

II.1.2 Prioritized CAC algorithm

The prioritized CAC algorithms perform admission control relying on estimation of radio channel status and available PRBs. After this estimation, the dynamic CAC should give prioritized admission to HC. Then the HC dropping probability is lower than that of NC. For correct estimation of the HC required bandwidth and arrival time, its information should be diffused to adjacent eNodeBs.

A new method to reduce the handoff blocking probability is proposed in [10]. This method relies on an adaptive call admission control scheme that prioritizes the HC over NC and provides QoS guarantees. However, the QoS is guaranteed only for HC without guaranteeing QoS for NC.

In [11], two types of calls are handled: HC and NC. This scheme prioritizes the HC and adaptively reserves own actual resources needed. In [11], the system efficiency is improved and the QoS requirement is guaranteed to priority calls (HC). This scheme resulted in inefficient resource utilization and increased blocking probability of a new call.

Oyebisi et al. proposed in [12], a new CAC policy for wireless mobile multimedia networks. The proposition is based on the use of dynamic guard channel allocation scheme. It provides a QoS that guarantees both new and handoff calls. But, the scheme needs a lot of buffers to deal with real-time multimedia traffic since this CAC scheme serves one of the calls in the handoff queue when resources become available. So, if there are no available resources, call requests are queued until resources will be available later. Authors in [13] proposed an adaptive CAC framework for wireless cellular networks. This CAC scheme can reduce the handoff dropping probability. However, the deployment and computation of bandwidth allocation consumes an amount of time and causes an increase in the handoff latency.

II.2 UPLINK SCHEDULING ALGORITHMS

This section includes an overview of the main existing LTE scheduling algorithms.

Angel et al. proposed in [14] three Channel-Dependent Scheduling (CDS) algorithms for SC-FDMA with PF-based utility function. These algorithms are namely the First Maximum Expansion (FME), the Recursive Maximum Expansion (RME), and the Minimum Area Difference (MAD). The Authors in [14] modeled and simulated three scheduling algorithms in both local and wide area scenarios while ensuring the contiguity constraint in the frequency resources allocation. The main drawback of their work is its inability to provide QoS satisfaction for different users in an equitable way.

In [15], the authors proposed two recursive maximum expansion scheduling algorithms for SC-FDMA, namely Improved Recursive Maximum Expansion (IRME) and Tree-based Recursive Maximum Expansion (ITRME) . Contrary to the RME proposed in [14] a new criterion is suggested to expand neighboring PRB by introducing a ranking threshold in IRME. Multiple paths are reserved in an ITRME scheme besides the ranking threshold to increase the flexibility of the resource allocation. These scheduling algorithms aim to guarantee a higher spectral efficiency as well as a less complex calculation but the authors do not consider fairness among users.

In [16], a scheduling scheme called Round Robin-CQI (RR-CQI) is presented. It combines the main ideas of Best-CQI and Round Robin (RR) schedulers. The performance of the RR-CQI was improved in terms of the throughput and fairness. However, the authors do not consider differentiation between services. In [17], the authors proposed a multiclass scheduler. Its objective is to support QoS and proportional fairness. The authors rely on a marginal utility and a generalized utility functions to guarantee this objective. Furthermore, the complexity of this scheduling algorithm has not been studied, and the resource allocation is at the granularity of the subcarriers.

Another work based on QoS scheduling is proposed in [18]. The authors proposed two algorithms: a Single-Carrier Scheduling Algorithm (SC-SA) and a Multi-Carrier Scheduling Algorithm (MC-SA). The objective of these two scheduling algorithms is to guarantee the throughput and delay requirements of each of these requests. However, in this work the complexity of SC-SA and MC-SA is not studied. In [19], two heuristic algorithms were proposed taking into account the proportional fairness, channel conditions and the data rate required by users. These two scheduling algorithms guarantee the contiguity constraint and provide the PRBs with the highest utility for the UE. Nevertheless, the authors do not consider fairness and differentiation between services.In [20], a novel algorithm is proposed to maximize the throughput and guarantee the user fairness. In this research work, the authors' main issue is to maximize the throughput. So, they follow the Tabu method to search a better allocation through ensuring the maximum global throughput. The proposed opt-tabu scheduler receives the matrix values as input. These matrix values are calculated according to the proportional fair scheduling. Then, opt-tabu scheduler assigns the PRBs with the highest utility to the UE. In [20] the complexity of opt_tabu has not been studied.The objective of [21] is to model and simulate new resource allocation algorithms based on a multiuser diversity. The authors consider the design of resource allocation algorithms via the weighted sum-rate utility maximization, which accounts for finite user queues (buffers) and a practical Modulation and Coding Scheme (MCS). The comparative study shows that the proposed new resources allocation algorithms have many advantages such as improving the average spectral efficiency and complexity. But the authors do not consider fairness among users.Authors in [22] try to improve the traditional uplink scheduler (RR and PF) using efficient resource allocation techniques. This research work aims to optimize the QoS and provide a better resource allocation based on the calculated user weight through a utility function. The simulation results show a low packet loss and a good user throughput but fail to meet the QoS requirements at higher cell capacity. For example when the number of users exceeds 50, this scheduler fails to meet the QoS requirements.A new scheduling algorithm named as Opportunistic Dual Metric (ODM) is proposed in [23]. The ODM prioritizes the users with a good channel condition for scheduling without neglecting users with bad channel conditions. However, this scheduler cannot consider differentiation between services.

Another scheduling scheme called Allocate As Granted-robust (AAG-R) is proposed in [24]. The authors take the robust MCS constraint into consideration. AAG-R algorithm aims to satisfy the data rate requirement of users and guarantee a higher system throughput. However, the authors do not consider fairness among users.

DISCUSSION OF REVIEWED WORKS

A summarized study of the aforementioned works is illustrated in Table I and Table II. From these tables, we can draw the following conclusions:

-CAC schemes treat all calls equally (HC and NC) and do not differentiate them relying on their type. This is the case of proposed CAC schemes in [4], [6],[7],[8] and [9].

-CAC schemes prioritize the HC over NC. So, they neglect the NC. This is the case of CAC schemes elaborated in [10], [11], [12] and [13].

- Schedulers do not consider QoS requirements of different applications and multiclass traffics. So, they handle the GBR and NGBR traffics with same principle. This is the case of schedulers elaborated in [14],[16],[19],[20],[21],[22] and [23].

- Schedulers do not consider fairness among users. This is the case of schedulers elaborated in [15], [19] and [24].

Hence, there is a need for a CAC scheme that supports both HC and NC and increases session establishment success and resource utilization. To tackle these objectives, we design a new CAC scheme. Mainly, we use HC and NC queues. Then, we attribute the high priority for primary queue without neglecting the NC. Indeed, we adjust the threshold, according to the network conditions, to guarantee that sufficiently resources will be available for the HC. Finally, transmissions will be performed based on our proposed scheduler named Robust Uplink Packet Scheduling Algorithm (RUPSA). This scheduler handles both GBR and NGBR traffics. The principle of our proposal as well as its performance analysis will be discussed in the next sections.

3. System model and Proposed scheduling algorithms

III.1 SYSTEM MODEL

We consider the Evolved Packet System (EPS) with one eNodeB (is the entity in charge of performing the resource allocation), m PRBs and n active UEs. The EPS bearers are classified into two types: GBR and NGBR. The objective of the CAC functionality is to determine whether a new EPS bearer can be activated (CAC is responsible of accepting or rejecting a connection depending on network available resources). In our system model, the number of users is 120 and their position are uniformly distribution at the starting of simulation. The random-walk model is considered as the mobility model. Requests arrive at eNodeB as Poisson processes with parameter λ. Then service time is measured by an exponential distribute with mean $1/\mu$.

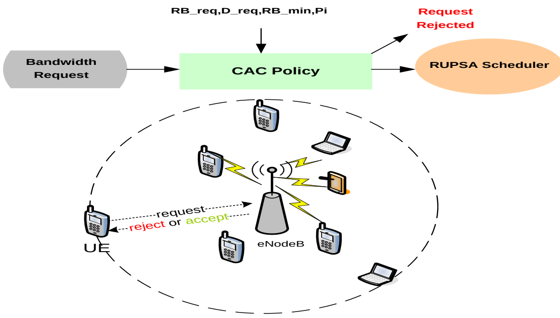

Figure.1.CAC policy process

The packets coming to the network from mixed traffic, are classified into two queues GBR and NGBR classes. Then, each class of packet will be delivered in independent queue. These two queues will be served on the basis of RUPSA. An illustration of the proposed CAC and uplink scheduling transmissions is shown in Figure1 and Figure 2.

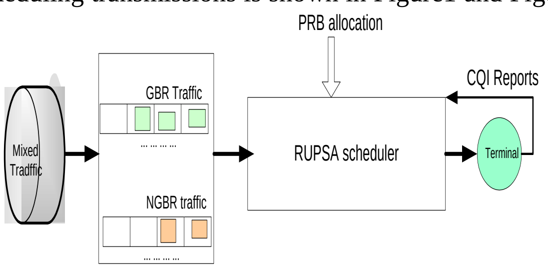

Figure.2.RUPSA illustration

In our proposed algorithm RUPSA, we introduce a weighting factor ρ which represents the portion of the reserved resources blocks for GBR users for the total available PRBs. By using the weighting factor, we guarantee that sufficiently resources will be available for the GBR users.

III.2 PROPOSED SCHEMES

In this section, we present a new CAC and scheduling algorithms for an LTE system.

III.2.1 CAC Scheme

In this subsection we propose a CAC scheme for the LTE network, which provides a PRBs allocation policy that takes into account the distinction between incoming traffic for each class and prioritizes HC, without neglecting **NC**. The objective of the CAC scheme is to improve resource utilization and decrease the dropping probability. The input of our CAC scheme is the following QoS parameters: $D_{req(k)}$, $D_{max_{GBR}}$, $D_{max_{NGBR}}$, RB_{req}, RB_{min}, RB_{avail}, $RB_{reser_{GBR}}$, Pr, $lengHC$ and ρHC.

Where :

$D_{req(k)}$: The delay of user request k

Table I. Comparative Study of Existing Cac Algorithms

Non-prioritized CAC schemes			Prioritized CAC schemes		
Ref.	**Strengths**	**Limitations**	**Ref.**	**Strengths**	**Limitations**
[4]	-Proposes a new CAC scheme utilizing the fractional power control (FPC) formula.	-Treats all users equally (HC and NC) and does not differentiate them relying on their type of call. -Difficult to guarantee the required dropping probability of HC.	[10]	-Proposes a new CAC method to reduce the handoff blocking probability. - Guarantees QoS for HC.	-The QoS requirement for NC is neglected.
[6]	-Proposes a new CAC for LTE systems with heterogeneous services. -The proposed CAC based on PRB scheduling can adaptively adjust the threshold according to the network conditions.	-No distinction is made between originating and handoff requests.	[11]	-Proposes new scheme -Handles two types of calls HC and NC. -Reserves the actual resources needed for HC. -The system efficiency is improved and the QoS requirement is guaranteed to priority calls (HC).	-Results an inefficient resource utilization. -Increases blocking probability of NC.
[7]	-Proposes a CAC GCAD. - Takes into account a set of three traffic classes with different priority levels. -Respects the QoS constraints defined in terms of end-to-end delay to higher priority flows.	-Can leave little useless gaps in the data subframe.	[12]	-Proposes a new CAC policy for wireless mobile multimedia networks. -Provides a quality of service guarantee to both new and handoff calls.	-Needs a lot of buffers to deal with a real-time multimedia traffic.
[8]	-Proposes two CAC schemes taking into account mobility within and between cellular users.	-These proposed CAC schemes are applicable only for NCs.	[13]	-Proposes an adaptive CAC scheme for wireless cellular networks. -Can reduce the handoff dropping probability.	-The deployment and computation of bandwidth reallocation consumes an amount of time and results in an increase the handoff latency.
[9]	-Proposes new CAC scheme	-This proposed CAC scheme is applicable only for NCs			

Table II. Comparative study of scheduling algorithms related work

Ref.	Strengths	Limitations
[14]	-Proposes three channel dependent scheduling algorithms. -Evaluates the performance of these algorithms in local and wide areas.	-Does not consider multiclass traffics.
[15]	-Proposes two channel dependent scheduling algorithms. -Guarantees a higher spectral efficiency as well as a low increase of calculation complexity.	-Does not consider fairness among users.
[16]	-Presents a new scheduling algorithm. -Provides better balance between system throughput and fairness issues.	-Does not consider differentiation between services.
[17]	-Proposes a new multiclass scheduler, where they consider different classes. - Supports QoS and proportional fairness.	-The complexity is not studied. -Does not consider the resource unit for allocation (PRB).
[18]	-Develops two algorithms that differentiate between services.	-The complexity of SC-SA and MC-SA scheduler is not studied.
[19]	-Proposes two heuristic models based in the function utility to satisfy the contiguity constraint and guarantee the proportional fairness.	-Does not consider the fairness and differentiation between services.
[20]	- Presents a novel packet scheduling algorithm for LTE networks based in Tabu method.	-The complexity of a new scheduler is not studied. -Does not consider differentiation between services.
[21]	-Proposes new multiuser resource allocation algorithms. -Improves average spectral efficiency and complexity.	-Does not consider differentiation between services.
[22]	-Improves the traditional scheduler algorithms (RR and PF) using efficient resource allocation techniques. -Achieves a low packet loss and a good user throughput.	-Fails to meet QoS requirements at higher cell capacity.
[23]	-Guarantees a good throughput and fairness.	-Does not consider differentiation between services.
[24]	-Takes robust MCS constraint into consideration. - Provides higher system throughput.	-Does not consider fairness among users.

$D_{max_{GBR}}$: The delay budget which is the upper delay bound of GBR traffic

$D_{max_{NGBR}}$: The delay budget which is the upper delay bound of NGBR traffic

RB_{req}: The required number of PRBs

RB_{min}:The minimum number of required PRB

RB_{avail} : The number of available PRBs

$RB_{reserGBR}$:The number of reserved PRBs for the GBR traffic

Pr: The type of call , HC or NC

$lengHC$: The length of HC queue

ρHC: The threshold size of the HC queue

When the call arrives to the network; the eNodeB is capable to identify its type at any time *t* based on the receiving QoS parameters. In our work, we provide a CAC scheme that takes into account the distinction between incoming traffic for each class and prioritizes HC over NC, without neglecting NC.

Then, we assign two service classes for the coming calls (GBR and NGBR traffic) depending on their QoS parameters. The algorithm proposes a system of priority for the four service classes in the increasing direction: NC-NGBR, HC-NGBR, NC-GBR and HC-GBR. The calls coming in mixed traffic in similar types (HC or NC) to an overloaded cell will be classified into specific queues (HC queue and NC queue). Since, the latency of these calls depends on the type of traffic, the calls will be handled differently. In the ideal case, all calls in a cell should be allocated RB_{req} whenever possible. However, in overloaded cell, some of the calls receive a lower bandwidth than requested.

For the NC buffered in the NC queue, initially, the "**lengHC<ρHC**" condition must be checked to satisfy the HC prioritization over the NC. The flow chart of our proposed scheme is shown in Figure3.

The CAC algorithm steps are as follows:

Step 1: Calls arrive specifying their QoS parameters like $\boldsymbol{D_{req(k)}}, \boldsymbol{D_{max_{GBR}}}, \boldsymbol{D_{max_{NGBR}}}, \boldsymbol{RB_{req}}, \boldsymbol{RB_{min}}$ $RB_{avail}, RB_{reser_{GBR}}, Pr$, lengHC and ρHC.

Step 2: The call type (NC or HC) is determined.

Step 3: **(a)** If the number of PRBs is sufficient then the call is accepted.

(b) Else

(i) If this call is NC, the condition ***leng**$_{HC}$*<**ρ**$_{HC}$ is checked. If true then proceed to next step, else the call is rejected.

(ii) If this call is HC, then proceed to next step.

Step 4: LTE call type (GBR or NGBR) is determined.

Step5: The condition on the latency delay is checked ($D_{req(k)} < D_{max_{GBR}}$ if the call is GBR type or $D_{req(k)} < D_{max_{NGBR}}$ if it is an NGBR call), if true then proceed to next step, else the call is rejected.

Step6: The condition on the sufficiency PRBs is checked (if this call is NC-GBR type then $RB_{req(k)} < RB_{reserGBR}$ is checked, else if this call is HC-GBR $RB_{req(k)} < RB_{avail}$ is checked, else if this call is NC-NGBR or HC-NGBR then $RB_{req(k)} < (RB_{avail} - RB_{reserGBR})$ is checked

(a) For the NCs, If no resources are available the call is rejected, else the call is accepted.

(b) For the HCs, proceed to next step

Step7: The condition on the sufficiency of PRBs versus RB_{min} is checked ($RB_{min} < RB_{avail}$ is checked for HC-GBR calls and $RB_{min} < (RB_{avail} - RB_{reserGBR})$ is checked for HC-NGBR calls.

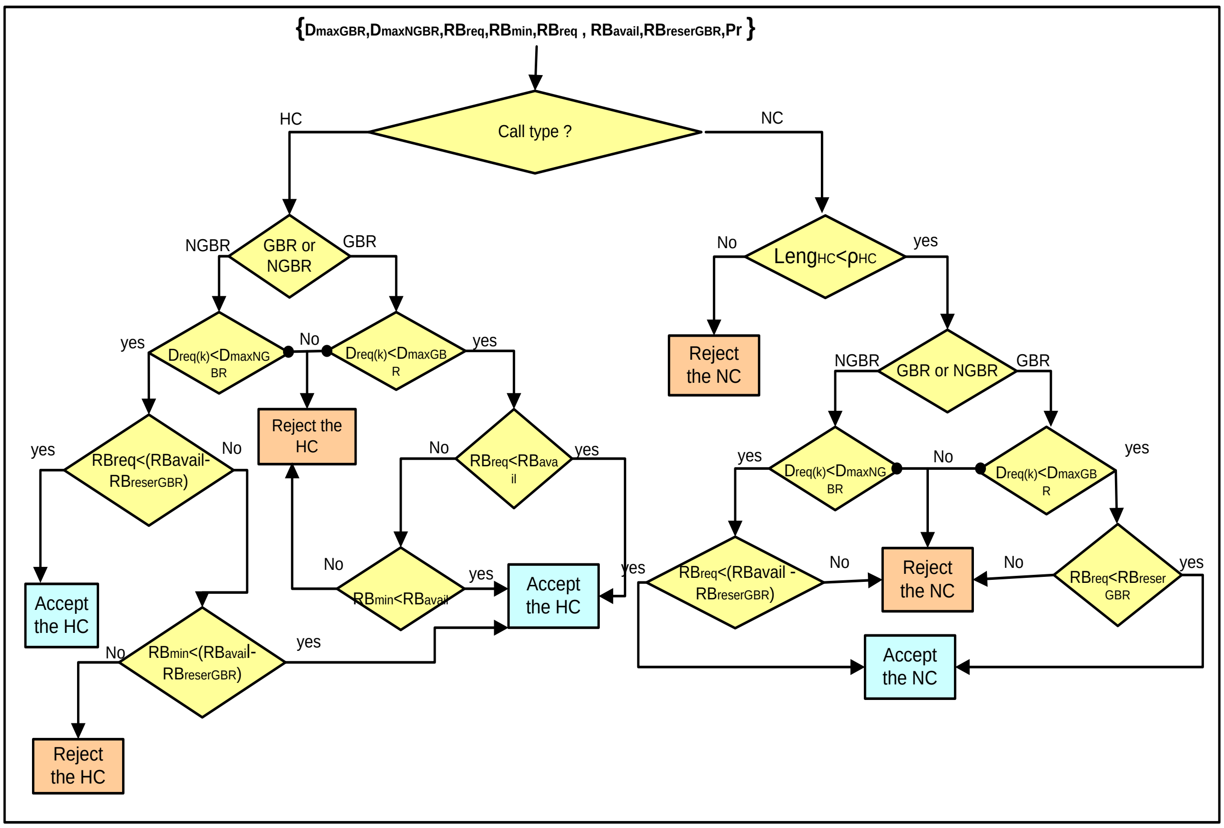

Figure.3. Flow Chart of the proposed CAC algorithmScheduling Scheme

In this subsection, we present our proposed algorithm (RUPSA) for an Uplink LTE system. RUPSA serves GBR and NGBR packets, classified into two independent queues, using the proposed priorities function (7). The proposed priorities function handles two principal objectives: throughput and fairness.

RUPSA aims to maximize the throughput. So, the first optimization problem can be mathematically defined as follows:

$$Max \sum_{i=1}^{n} \omega_i R_i \quad (1)$$

$$\mathbb{C}_i \cap \mathbb{C}_j = \emptyset, \ \forall i \neq j, \ i \in I \text{ and } j \in I \quad (2)$$

$$\mathbb{C}_1 \cup \mathbb{C}_2 \ldots \cup \mathbb{C}_n \subseteq \mathbb{C} \quad (3)$$

Where R_i is the average throughput for user i, ω_i is the QoS weight for user i, $\mathbb{C}$ is the set of available PRBs, $\mathbb{C}_i$ is the set of PRBs assigned to user i, n is the total number of users and I is the set of users. The constraint of this algorithm is to assign each PRB to only one user i without any overlap.

We define the weighting factor ω_i as follows:

$$\boldsymbol{\omega_i} = \begin{cases} \boldsymbol{\rho} & \boldsymbol{for\ GBR\ traffic} \\ \boldsymbol{1-\rho} & \boldsymbol{for\ NGBR\ traffic} \end{cases} \quad \textbf{(4)}$$

Where ρ represents the portion of the reserved resource blocks for GBR traffic among available PRBs.
In addition to the throughput maximization, our second objective is to guarantee fairness basing on the fairness scheduling method proposed in [22] (see equation 5).

$$\mathrm{F}_{\boldsymbol{i}} = \frac{\boldsymbol{R_i}}{GBR_i} \quad \textbf{(5)}$$

Where $\mathrm{F_i}$ the capability weight is calculated at each TTI and $\mathrm{GBR_i}$ is the guaranteed bit rate of the user's application or service flow. In this work, we modified equation (5) differently as follows:

$$\mathrm{F}_{\boldsymbol{i}} = \boldsymbol{R_i} / \boldsymbol{\Re_{i(req)}} \quad \textbf{(6)}$$

Where $\Re_{i(req)}$ represents the minimum required throughput. Two cases are considered:

- $\Re_{i(req)}$ represents the guaranteed bit rate for GBR users [26]
- $\Re_{i(req)}$ representsthe minimum throughput that would be considered acceptable for NGBR users.

Let R_i^{alloc} be the number of bits that can be transmitted in a subframe for user *i*. As a result, during a subframe *s*, the eNodeB should try to allocate PRBs in a way that allows R_i^{alloc} bits to be transmitted on average.The number of bits that can be transmitted by the allocated PRBs depends on the corresponding CQI values as shown in Table III.
Before allocating PRBs, the eNodeB has to decide about the priority of each user *i*. So, in each TTI, the user with the highest priority metric, using equation (7), is selected to schedule. We define the priority metric as follows:

$$\boldsymbol{P_i(s)} = \mathrm{F}_{\boldsymbol{i}} \times \boldsymbol{\omega_i} \times \frac{\boldsymbol{R_i^{alloc} - R_i(s-1)}}{\boldsymbol{R_i^{alloc}}} \quad \textbf{(7)}$$

The equation (7) represents the function priority calculated each TTI. By this function two objectives are handled: fairness is presented by $\mathrm{F}_{\boldsymbol{i}}$ and the throughput is presented by $\frac{\mathrm{R_i^{alloc} - R_i(s-1)}}{\mathrm{R_i^{alloc}}}$.

Table III.THE CQI PARAMETRS[22]

CQI index	Modulation	Code rate *1024	efficiency	Bits per PRB per subframe
1	QPSK	78	0.1523	21.931
2	QPSK	120	0.2344	33.754
3	QPSK	193	0.3770	54.288
4	QPSK	308	0.6016	86.630
5	QPSK	449	0.8770	126.288
6	QPSK	602	1.1758	169.315
7	64QAM	378	1.4766	212.630
8	64QAM	490	1.9141	275.630
9	64QAM	616	2.4063	346,507
10	64QAM	466	2.7305	393.192
11	64QAM	567	3.3223	478.411
12	64QAM	666	3.9023	561.931
13	64QAM	772	4.5234	651.370
14	64QAM	873	5.1152	736.589
15	64QAM	948	5.5547	799.877

The steps of the proposed scheduling algorithm are as follows:

Step 1: Initialize the set $\mathbb{C}$ of the available PRBs for allocation.

Step 2: Calculate the priority of users set ***I*** based on equation **(7)**

Step 3: Select the user *i* with the highest priority calculated by equation **(7).**

Step 4: Assign the PRB with the highest CQI value to selected user *i*,
(a) If the number of bits that can be transmitted by the allocated PRBs is smaller than the number of bits granted by the minimum required throughput ($\Re_{\mathrm{i(req)}}$), then search and include free adjacent PRBs on both sides to increase the number of bits until the number of required bits is achieved.
(b) Otherwise, cancel this allocation and search the PRB corresponding of the second highest CQI value. Allocate this PRB, to the selected user (step3).

Step 5: Remove the set of PRBs allocated to user *i* from the $\mathbb{C}_i$:$\mathbb{C} = \mathbb{C} - \mathbb{C}_{\boldsymbol{i}}$

Step6: Remove the user *i* from set *I : I=I-i*

Step7: Repeat the steps from 2 to 6 until all PRBs are allocated or all users are served.

The complexity analysis of scheduling algorithms is based on the number of iterations an algorithm achieves when searching for the final allocation (user-PRB). RUPSA, allocates each PRB after completing a linear search on the PRBs and UEs in order to find the UE-PRB pair that maximizes the priority value (equation 7). Consequently, the complexity of the algorithm is ***O(nm)***. Recall that *n* is the total number of users and *m* is the total number of PRBs.

4. Results and Discussion

In this section we present the simulation results obtained by applying the proposed algorithms in section *III.*

IV.1 Simulation Parameters

In order to study the performance of the proposed CAC scheme, we use the standard generated in 3GPP deployment evaluation parameters [27]. More details on the configuration parameters used in this simulation are given in Table IV.

Table IV.SIMULATION PARAMETERS

Parameters	Value
System bandwidth	20 MHz
Subcarrier spacing	15 KHz
Number of subcarriers per PRB	12
Number of available PRB	100
Transmission time interval(TTI)	1 ms
Total number of used subcarriers	1200
Carrier frequency	2.5 GHz
Frame duration	10 ms
Slot duration	0.5 ms
Number of users	50
ρ	0.7
Simulation Time	1000 TTIs
Link adaptation ACM Modulation	BPSK, QPSK,16-QAM, 64-QAM
Scheduling algorithms	RR, AAG-R, RME and RUPSA

IV.2 Simulation Results

In this subsection, we evaluate the performance of our proposed schemes in terms of HC dropping probability ,NC blocking probability, served users, system throughput, end to end delay and fairness.

IV.2.1 Handoff call dropping/New call blocking probability

HC dropping probability (HCDP) is defined as the fraction of handoff attempts that are denied access because of lack of resources. NC blocking probability (NCBP) is defined as the fraction of NCs that are blocked because of lack of resources.

In Figures 4 and 5, we can see that if we increase the number of UEs, it leads to increase in HCDP and in NCBP. This is because the increase in the number of occupied PRBs causes the loading of the network.

Figure 4 shows the HCDP and NCBP for GBR traffic of our proposed scheme and that proposed in [10]. It is clear that if we apply the proposed CAC scheme a decrease in the blocking rate is guaranteed compared to the solution proposed in [10]. The growth starts from a number of users equal to 20 for our proposed CAC algorithm.

When applying our scheme, the probability reaches a value of 27 % for NC and 25% for HC for a number of users equal to 120 compared to a blocking probability of 48% and 45% for NC and HC, respectively with the scheme CAC proposed in [10]. In Figure 5, we can observe that the application of our CAC scheme improves the values of blocking probabilities for two types of calls (HC and NC) for the NGBR traffic. In fact, using the proposed CAC scheme, the blocking probabilities reach the order of 32% and 30% for NC and HC respectively. while in [10], the achieved rates are 51% and 47% for NC and HC respectively.

Comparing between results in Figures 4 and 5, it is clear that the HCDP and NCBP values for the GBR traffic are lower than the HCDP and NCBP for the NGBR traffic. This is expected and can be explained by the introduction of the priority notion between the various service classes in terms of latency tolerance ($D_{max_{GBR}}$ and $D_{max_{NGBR}}$). Moreover, the NCBP of the GBR traffic reaches higher values than the HCDP and this is can explained by the priority given to HC over NC in admission decision.

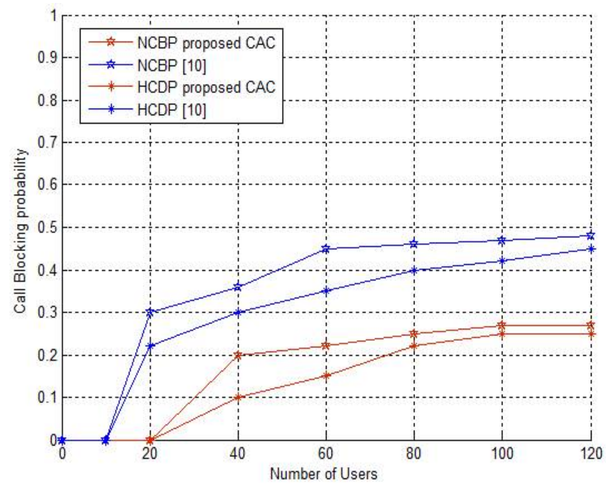

Figure.4.New call blocking/Handoff call dropping probability for GBR Traffic

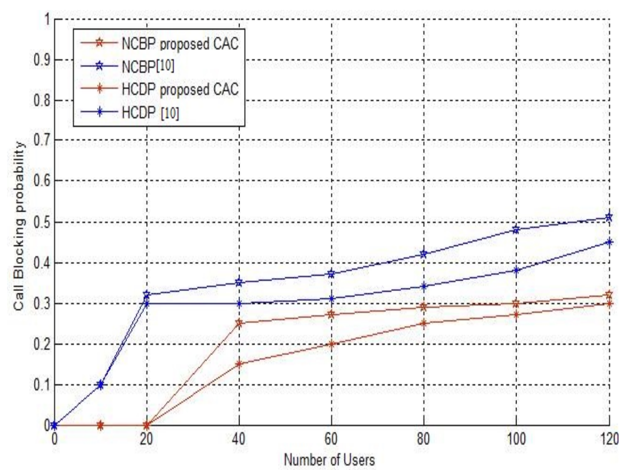

Figure.5.New call blocking/Handoff call dropping probability for NGBR Traffic

IV.2.2 Physical resource blocks utilization

The physical resource blocks utilization is the ratio of the number of allocated PRBs for the users in the system during the whole simulation time. The result of the PRB utilization according to the number of the UEs is shown in Figure 6.

If we apply our CAC scheme, the PRB utilization can achieve 96% whereas this value is only 75% in the CAC method defined in [10]. This gain (of about 21%) is observed for simulations involving more than 120 UEs. The best use of the PRBs is due to the concept of resource allocation algorithm, which adjusts the allocation of resource intelligently.

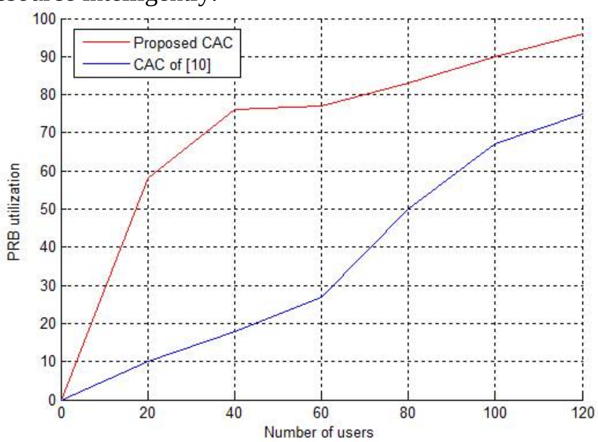

Figure.6.PRB utilization

IV.2.3 Served users

The results of the served number versus the total number of users as shown in Figure 7. It is clearly observed that the RUPSA scheme serves an interesting number of users. This is because the RUPSA adjusts the allocation of resource adaptively. Indeed, the RUPSA can schedule more users by giving the needful PRBs for each one. This allow to accept much more number of users and maximize the total number of used PRBs.

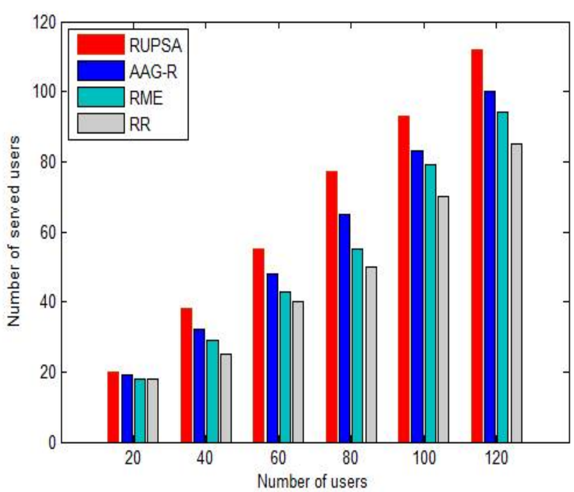

Figure.7.Served users

IV.2.4 System Throughput

The system throughput is measured as the total number of bits successfully transmitted over the total simulation time. It is generally expressed in bits per second. The system throughput is calculated by equation (8) as in [25]:

$$th_{sys} = \frac{B}{T_{sim}} \qquad (8)$$

Where B is the total number of bits successfully transmitted over the air interface from the UEs and T_{sim} is the total simulation time.

Figure 8 shows the average system throughput of RR, RME, AAG-R and RUPSA algorithms as a function of the number of users. As we explained in the previous subsection, the RUPSA scheme can serves much more number of users compared to others algorithms. Serving more users requires harness the maximum of available resources blocks which increasing the overall throughput. In addition, RUPSA use the equation (7) to distinguish between users (less or more prioritize). On comparing with AAG-R scheduler, it is observed that RUPSA scheduler achieves highest throughput. For The RME, PRBs are more likely to be assigned to users with higher CQI values. But, most of the PRBs are wasted. On the contrary, UEs with lower CQI values can only transmit at low data rate because they get only very few PRBs. The RR algorithm is in fourth position. This is expected because neither the user requirement nor the channel quality is considered by the RR.

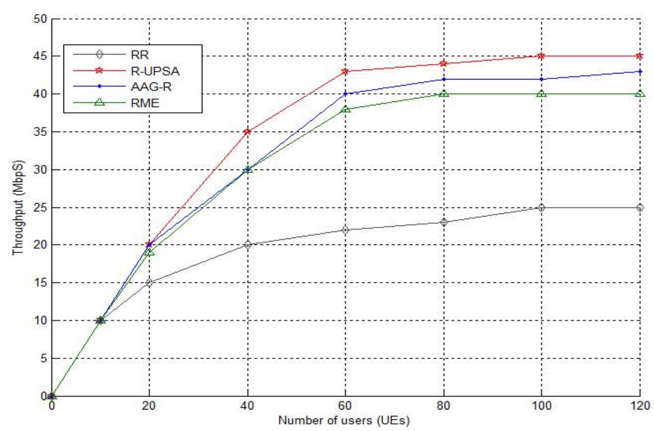

Figure.8. System throughput

IV.2.6 Fairness index

The fairness of the approaches was evaluated by the Jain's fairness index. The definition of this index is stated in [28],[25]. We can also calculate this fairness index as:

$$F(\mathbb{C}_1, \mathbb{C}_2, \ldots \mathbb{C}_n) = \frac{(\sum_{j=1}^{n} \mathbb{C}_j)^2}{n \times \sum_{j=1}^{n} (\mathbb{C}_j)^2} \qquad (9)$$

Where n represents the total number of UEs and $\mathbb{C}_j$ is the number of resources assigned to user j. Jain's fairness index returns a value between 0 and 1. Value 1 represents the best fairness in the system.

Figure 9 shows the fairness results for the schedulers RR, AAG-R, RME and RUPSA. The maximum of Jain's fairness index is obtained by the RR scheduler. This is logical because RR assigns almost the same number PRBs for all UEs. Moreover, we observe that RUPSA achieves interesting results. This is explained by the fact that RUPSA serves the users according to their priorities as shown in equation (7). This equation contains factor F_i that provides the fairness among users. AAG-R and RME are in third and fourth position, respectively. The users that will receive resources are those with the best channel conditions.

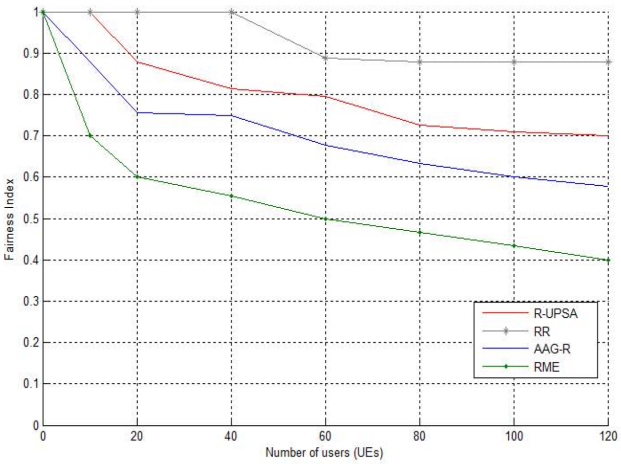

Figure.9.Fairness index

IV.2.6 End to end delay

The results in Figure 10 show the end-to-end delay as a function of the total number of users in the system. The end-to-end delay is composed of the queuing, propagation and transmission delays. In our case, the propagation and transmission delay are the same for all schedulers. However, the queuing delay is related to the scheduler strategy. The RUPSA outperforms the other schedulers in terms of the end-to-end delay. This is explained by this scheduler serves the interesting number of users. Then, the packets queuing delays is lower compared to other schedulers.

IV.2.7 Packet Loss Rate (PLR)

The Packet Loss Rate is the ratio of the number of packets lost over the number of sent packets. We can also calculate this packet loss rate as:

$$\frac{\boldsymbol{Pack_{los}}}{\boldsymbol{Pack_{sent}}} \qquad \textbf{(10)}$$

Where $Pack_{los}$ presents the number of lost packets and $\text{Pack}_{\text{sent}}$ is the number of sent packets. The packet loss rate is shown in Figure 11. The RUPSA scheduler provides a better performance in terms of packet loss rate than the RR, RME and AAG-R schedulers. This is explained by this scheduler serves the interesting number of users. So, each user has the opportunity to get PRBs.

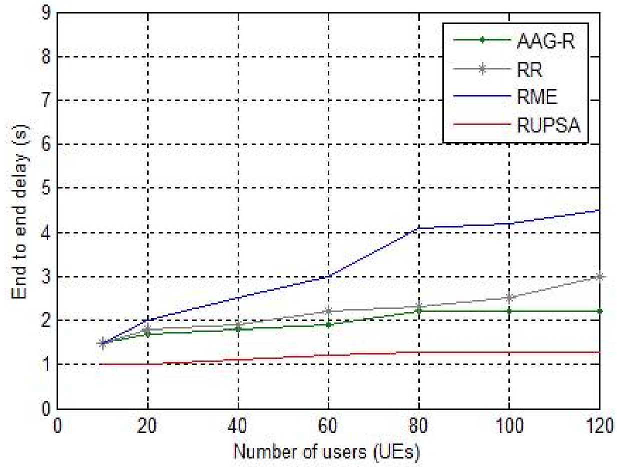

Figure.10.End to end delay

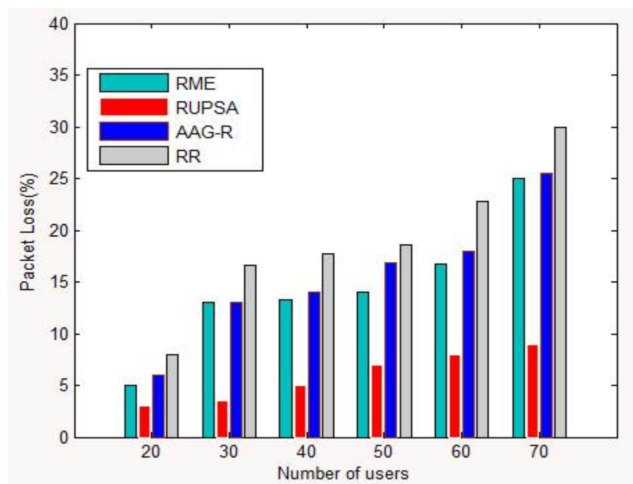

Figure.11.Packet loss rate

5. Conclusion

In this paper, we proposed some new CAC and scheduling algorithms. The CAC scheme aims to handle the NC and HC and the scheduling scheme aims to maximize the systems throughput, assign a fair distribution of PRBs and handle GBR and NGBR traffic in LTE Uplink systems. The performance of these algorithms was evaluated, considering LTE configuration parameters. The Simulation results show that the proposed schemes perform well in terms of the obtained a low dropping and blocking probability, system throughput, fairness index, served users and delay.

As a future work, we propose to adapt these algorithms in the femtocell and micocell systems and handle these algorithms in an LTE-A environment.

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