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QoS-Aware Call Admission Control (QA-CAC) Scheme for LTE Networks.

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***Abstract*—Quality of Service (QoS) provisioning is a critical challenge in any wireless broadband (WiBB) network. LTE being a WiBB network technology aimed at providing adequate network resources for speedy transmission of applications with varying QoS requirements. It uses radio resource management (RRM) techniques such as call admission control (CAC) for resource utilization and to guarantee these QoS requirements. In this paper, a novel call admission control scheme is proposed to guarantee the QoS of calls and also increase the throughput of Real-time (RT) calls. The scheme allocates maximum bandwidth requirements to both RT and NRT calls at the point of admission. It then degrades all admitted NRT calls when a call arrives and there are insufficient resources to admit the requested call. Several simulation experiments were conducted with the aid of Vienna LTE system level simulator and the results reveal that the proposed scheme achieved superior performance in terms of throughput and blocking rate of RT traffic compared to the benchmark scheme**

Keywords—QoS, Call Admission Control, LTE, Throughput, Blocking rate.

I. INTRODUCTION

There is a rapid growth of mobile users with diverse multimedia applications and different Quality of Service (QoS) requirements. QoS provisioning is a critical challenge in any wireless network technology. LTE is one of such wireless technologies developed by third-generation partnership project (3GPP) that is aimed at providing adequate network resources for speedy transmission of applications with varying QoS requirements. It is also focused on delivering high data rates for multimedia applications and also improving flexibility and spectral efficiency [1]. LTE employs the Orthogonal Frequency Division Multiplexing Access (OFDMA) at the downlink channel and Single Carrier Frequency Division Multiple Access (SC-FDMA) at the uplink channel. It also supports Multiple Input Multiple Output (MIMO) technology [2]. MIMO technologies are used to increase the high data rate, provide wide area coverage as well as to improve the spectral efficiency [3]. These can be achieved using an efficient radio resource management (RRM) technique such as call admission control (CAC).

Call admission control is one of the key and important techniques of radio resource management (RRM). It is a process of accepting a new or handoff call in a network while regulating the QoS of an active or ongoing call without degrading any call drop [4]. Call requests are normally classified as new calls and handoff calls. A new call is a process whereby user equipment (UE) is requesting for connection into the network while a handoff call is a type of call request where an active UE needs to be transferred from one evolved Node B (eNB) to another without compromising the QoS of the user.

Several CAC schemes have been proposed by different researchers to address many challenging issues in resource management [3], [5]-[10]. Recently, in [3] an adaptive CAC with bandwidth reservation for LTE downlink networks was proposed to provide efficient resource utilization and prevent the best effort (BE) traffic starvation. It allocates maximum required bandwidth to RT calls and minimum required bandwidth to NRT calls at the point of admission. Bandwidth is degraded from admitted Real-Time (RT) calls when a new call arrives and the available bandwidth is insufficient to admit it. The scheme increases the throughput of BE traffic and reduces both call blocking rate and call dropping rate of BE traffics. However, the scheme reduces the throughput of RT traffics and also increases the dropping rate of RT traffics due to the degradation procedure applied to them when there are insufficient resources to admit a new call.

In this paper, we propose a CAC scheme to increase the throughput of calls and also reduce the dropping rate of both RT and Non-Real Time (NRT) calls. The scheme introduces a prior checking mechanism to reduce the wastage of available network resources. The mechanism will ensure that the bandwidth to be degraded from admitted calls will be enough to admit the new call request, thereby reducing the wastage of available network resources. The simulation results show that the proposed scheme as it is able to increase the throughput of RT traffics and also reduces the dropping rate of RT compared to the benchmark scheme.

The organization of this paper is as follows. In the next section, an overview of related literature is provided. Section III presented the proposed scheme while section IV presented the simulation results and discussion. Finally, section V presented the conclusion of this paper.

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II. RELATED WORKS

In this section, some of the call admission control schemes proposed for LTE networks are reviewed as follows:

In [5], a call admission control scheme for high-speed vehicular communications to reduce new call blocking and handoff call dropping probability for RT and NRT traffic. The scheme was based on Resource Blocks (RBs) reservations which reserves resources for ongoing calls and new calls. A call is accepted when the requested RBs are less than or equal to the available resources. Otherwise, if the RBs are not sufficient, then the remaining RBs will be reserved for future or expected incoming calls. The scheme accepts a future or expected an incoming call when the required resources are equal or less than the available resources i.e. reserved resources and available resources else the call is rejected. The scheme reduces call blocking and call dropping probabilities of calls but fails to utilize network resources efficiently because the reserved resources may not be fully utilized by future calls.

The authors in [6] proposed a fuzzy approach call admission control to improve network resource utilization, reduce call blocking and call dropping probabilities and ensures that the QoS of both new and ongoing calls is met. The scheme only deals with data services i.e. lower priority calls. The scheme performs a channel aggregation when a new or handoff call request arrives. It assigns a channel or combination of channels to a call request to meet the expected throughput that is required to service the call request. The scheme directly assigns one or more channels to a request that is admitted. It queued call requests that are not admitted and then performs a combination of channels to service the request, otherwise, the request is blocked or dropped after four trials of the channel combination. The scheme reduces call blocking and dropping probability for data services that have lower priority. It also ensures QoS provisioning for both new and handoff calls of data services. However, the scheme increases call blocking and call dropping probabilities of higher priority calls.

A Markov model-based adaptive call admission control scheme to reduce the new call blocking probability was proposed in [7]. The scheme formulates the resource allocation problem as a Markov chain model. It considers call request as RT and NRT, connectivity as new call and handoff call. The scheme uses the physical resource blocks allocation strategy by dynamically reserves resources for handoff calls based on traffic conditions and uses the remaining available resources to accept all types of calls. It degrades lower priority calls under heavy traffic or when the system congested to accept more calls. Lower priority calls are always degraded when higher priority calls arrive and there are no sufficient resources to admit them. The scheme decreases call blocking probability for higher priority class and also guaranteed fair resource sharing among different traffic types. However, the scheme fails to utilize resources efficiently. It also starves lower priority calls due to the degradation strategy applied to them whenever a higher priority call arrives.

The authors in [8], proposed an Efficient Bandwidth Call Admission Control (EB_CAC) to reduce call blocking probability of calls and satisfy the QoS requirements for real-time and non-real time traffics. The scheme estimates channel quality based on RSS to determine good and bad channels. The scheme classifies RT call type as either RT_HC or RT_NC and admits an RT_HC request if there are sufficient PRBs without considering the channel condition and Bandwidth Occupational Ratio (BOR). The scheme rejects NRT requests if there are no sufficient PRBs on the system. It further classifies NRT requests into NRT_HC and NRT_NC and NRT_HC are admitted independently of their channel quality with a blocking probability ratio. NRT_NC having bad channels are accepted with a blocking probability ratio and NRT_NC having good channels are also accepted with a blocking probability ratio. The scheme guarantees QoS for different service classes but NRT request experience high dropping rate due to priority given to RT requests.

The work in [9] proposed an efficient call admission control scheme to increase resource utilization and reduces call dropping probability of different user requests. The scheme classifies incoming requests into HC and NC and gives higher priority to HC without neglecting the NC. It uses a system priority approach for four service classes; NC-NGBR, HC-NGBR, NC-GBR, and HC-GBR. The scheme checks whether there are available physical resource blocks (PRBs) in the network to admit either a new call or a handoff call. It accepts a new call if the number of requested PRBs is less than the available PRBs in the network, otherwise, the request is rejected. Furthermore, the scheme accepts a handoff call request if the number of requested PRBs is less than the available PRBs and the reserved PRBs for HCs in the network, otherwise, the request is rejected. The scheme increases PRB utilization and also reduces call dropping probability for HCs but it wastes resources because, in a situation where there are no frequent arrivals of HCs, the reserved PRBs are wasted.

The authors in [10] presented a Delay Aware and Users' categorizing based Call Admission Control with adaptive Resource Reservation (DA-UC-ARR) scheme to guarantee QoS and increase resource utilization. The scheme categorizes users as Golden (G) and Silver (S) users and classifies service types of each user as RT and NRT. It virtually reserves a set of PRBs for each service type. The scheme admits a request when there are available PRBs to service the request else, all the requests are admitted into a waiting queue provided the queue is not filled up otherwise the request is rejected. It drops a queued request if it exceeds its predefined queuing time limit. The scheme further determines the adaptive priority of all non-empty queues using the total number of physical resource blocks (PRBs) currently used by all users, number of virtual reserved PRBs, Maximum tolerable delay and Current latency. It gives the highest priority to the queue with the minimum AP and the queue is served first. The scheme guarantees QoS and efficiently utilizes resources because of the virtual resources reservation strategy used. However, requests with the lowest priority which are the NRT and BE traffics experience a high blocking rate and sometimes even starved due to priority given to higher priority requests.

In [3], an Adaptive Call Admission Control with Bandwidth Reservation scheme was proposed to provide efficient resource utilization and prevent best-effort traffic starvation. The scheme classifies call requests as RT and NRT. It allocates maximum required bandwidth to RT calls and minimum required bandwidth to NRT calls at the point of admission. The scheme degrades bandwidth from admitted RT calls when a call arrives and there is no enough bandwidth to admit the call. It ensures that all the admitted calls at least retain their minimum bandwidth requirement to avoid call drop. The scheme increases the throughput of BE traffic and reduces the dropping rate of the best-effort traffic. However, the scheme reduces the throughput of RT traffics and also increases the dropping rate of the RT traffics.

In this paper, we proposed a QoS-aware call admission control (QA-CAC) scheme to improve the performance of [3] by increasing the throughput and reducing the blocking rate of the RT calls.

III. PROPOSED QA-CAC SCHEME

In this work, a new call admission control scheme is proposed to address the challenges of the CAC scheme proposed in [3]. Firstly, the shortcomings of the benchmark scheme are mentioned. The scheme allocates maximum resources to RT traffic and minimum to NRT traffics at the point of admission. When the available resources are not sufficient to admit a new call, the scheme degrades the existing RT traffic to their minimum to admit the new call. If the sum of the available and degraded resources are adequate to admit the new call, the call is admitted otherwise dropped. The scheme decreases the throughput of RT traffics as a result of the delay incurred when they are degraded.

Therefore, to address the shortcomings of the benchmark scheme, the QA-CAC scheme is proposed. The proposed scheme allocates the maximum bandwidth requirement to NRT and allocates minimum bandwidth requirements to RT calls at the point of admission. For RT call requests, the maximum bandwidth requirement is described as:

$$Call_{RT} = BW_{max} \tag{1}$$

Where $Call_{RT}$ denotes an RT call and BW_{max} represent the maximum bandwidth for an RT call.

Similarly, for NRT call requests, the maximum bandwidth requirement is denoted as:

$$Call_{NRT} = BW_{max} \tag{2}$$

Where $Call_{NRT}$ denotes an NRT call and BW_{max} represent the maximum bandwidth for an NRT call.

Furthermore, call requests are admitted into the network, if there are sufficient resources i.e. if the requested bandwidth is less than or equal to the total available bandwidth as described in equation 3:

$$BW_{req} \leq BW_{avail} \tag{3}$$

Where BW_{req} is the requested bandwidth and BW_{avail} is the available bandwidth.

If there is insufficient bandwidth to admit a new call request, then a ***degradation mechanism*** is applied to all admitted calls. The degradable bandwidth for a call can be computed as:

$$BWC_{deg} = BWC_{max} - BWC_{min} \tag{4}$$

Where BWC_{deg} is the degradable bandwidth for a call, BWC_{max} is the maximum bandwidth requirement for a call and BWC_{min} is the minimum bandwidth requirement for a call.

Note that, while degrading the admitted calls, the degradation mechanism will ensure that calls are not degraded below their minimum bandwidth requirements as shown in equation (5):

$$BWC_{deg} \geq BWC_{min} \tag{5}$$

Where BWC_{deg} is the degradable bandwidth for a call and BWC_{min} is the minimum bandwidth requirement for the call.

After the degradation is applied, the sum of degraded bandwidth is then used to admit the requested calls. But before the admission, the sum of degraded bandwidth is checked if it is less than or equal to the requested bandwidth as shown in equation (6):

$$\sum BW_{deg} \geq BWC_{req} \tag{6}$$

Where $\sum BW_{deg}$ is the sum of degraded bandwidth from admitted calls and BWC_{req} is the requested bandwidth of a call.

After the degradation is applied on all admitted calls, the degraded bandwidth is then used to admit the requested calls, but at this point, all calls are admitted with the minimum bandwidth requirements. This will prevent further degradation of admitted calls, therefore increasing the number of calls to be admitted and reducing the number of calls be blocked. The QA-CAC scheme is diagrammatically represented in figure 1 and the pseudo-code is presented in algorithm 1.1

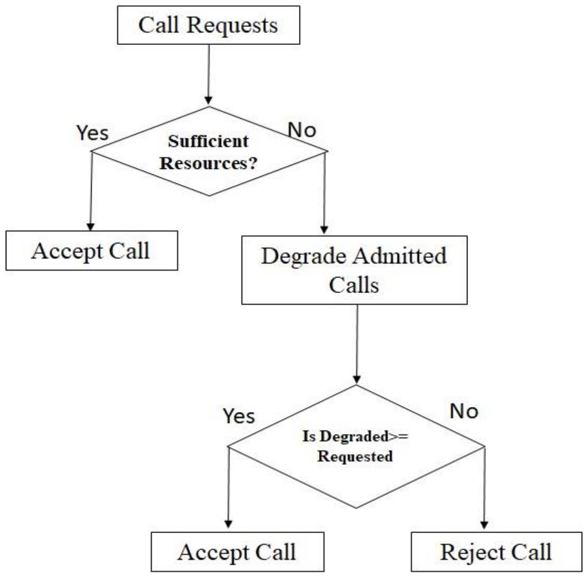

Fig. 1: Diagrammatic description of the QA-CAC scheme

Algorithm 1.1: QA-CAC scheme

```
Input:
$Call_{RT}$: RT Call request
$Call_{NRT}$: NRT call request
Initializations
for $Call_{RT}$ check
    if equation (3) is satisfied then
        accept $Call_{RT}$
    else
        degrade admitted Calls then
    end if
    if equation (6) is satisfied
        accept $Call_{RT}$
    else
        reject $Call_{RT}$
    end if
end for
for $Call_{NRT}$
    if equation (3) is satisfied then
        accept $Call_{NRT}$
    else
        degrade admitted Calls then
    end if
    if equation (6) is satisfied
        accept $Call_{NRT}$
    else
        reject $Call_{NRT}$
    end if
end for
```

IV. PERFORMANCE EVALUATION

In this section, the QA-CAC is compared with the benchmark scheme in terms of throughput and call blocking ratio of RT calls. The simulation results were obtained with the aid of the Vienna LTE system-level simulator. The simulator is open-source and released free for an academic and non-commercial purpose [11]. The simulation parameters were adopted from [3] as shown in Table 1.

TABLE 1. SIMULATION PARAMETERS [3]

Parameter	Value
System Bandwidth	5MHz
Number of RBs	25
TTI	1ms
Call Arrival	Poisson Process
Simulation period	1000s
Transmission scheme	2x2 MIMO, OLSM
Cyclic prefix used	Normal cyclic prefix
UE distribution	Uniform

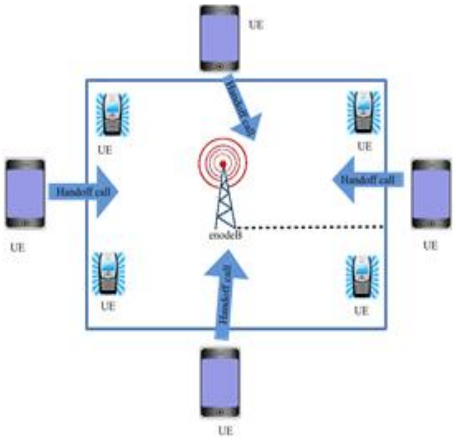

Fig. 2: Simulation Topology of the Experiment [3]

The total bandwidth used for the simulation is 5MHz with 25 resource blocks (RBs) per slot of 12 subcarrier spacing. The simulation time used is 1000s while the results were obtained by taking the average over 5 times of simulation. The simulation topology in [3] was also adopted as shown in figure 2 which consists of one eNodeB (eNB) and 30 user equipment (UE's) distributed around the eNB. Call requests are classified into different classes based on their QoS requirements and call types. Based on QoS requirements, the calls are categorized into RT and NRT traffic where RT has the highest priority. An example of RT can be live streaming while that of NRT can be an email. The arrival rate for RT and NRT follows a Poisson distribution.

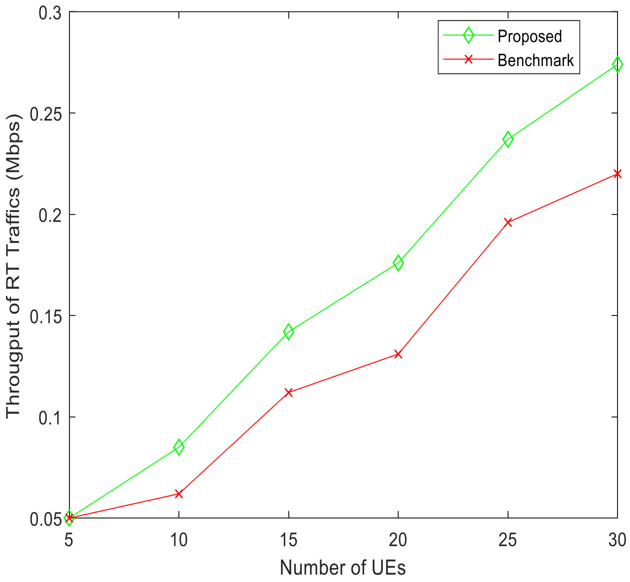

Fig. 3: Throughput achieved by the two schemes for RT calls

Figure 3 illustrates the throughput of RT calls for the benchmark scheme and that of the DA-CAC scheme. The figure demonstrates that the DA-CAC scheme increases the throughput of RT traffic compared to the benchmark scheme by admitting more RT calls. It can be observed that when the traffic intensity is low, both the schemes perform well by admitting calls. But when the traffic intensity increases, the DA-CAC scheme admits more RT calls than the benchmark scheme. This can be traced to the maximum bandwidth that is allocated to RT traffics at the point of admission and the degradation that is applied on all admitted calls when there is insufficient bandwidth to admit a new call request. The DA-CAC scheme increases the throughput of RT calls by 25.0%.

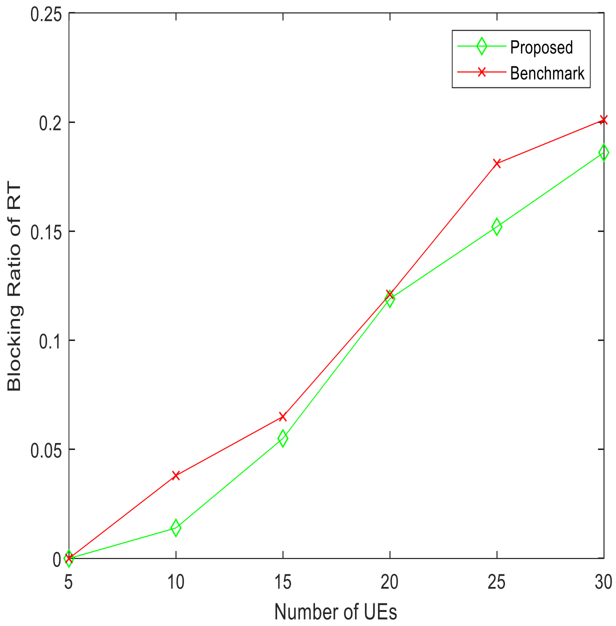

Fig. 4: Blocking Ratio achieved by the two schemes for RT calls

Figure 4 demonstrates the blocking rate of RT calls of the DA-CAC scheme as compared to the benchmark scheme. The figure shows that the DA-CAC scheme blocks fewer RT calls compared to the benchmark scheme. DA-CAC scheme drops less RT calls 15.2% both when the traffic intensity is low and when the traffic intensity is high. This improvement is as a result that after degradation is applied on all admitted calls and subsequent calls are admitted with their minimum requirement. The minimum requirement for RT calls is less than that of NRT calls thereby making more NRT calls to be blocked. The DA-CAC scheme reduces the blocking rate of RT traffics by 15.2%.

V. CONCLUSION

In this paper, the DA-CAC scheme is proposed for LTE networks to increase the throughput of both RT calls as well as reduce the blocking rate of RT calls. The scheme allocates maximum bandwidth requirements for both RT and NRT traffics at the point of admission. When the available bandwidth is not sufficient to admit a new call request, the scheme degrades all admitted calls because they were given their maximum at the point of admission. It then admits subsequent calls with their minimum bandwidth requirements. Simulation experiments were carried to evaluate the performance of the benchmark scheme with that of the DA-CAC scheme. The results demonstrate that the DA-CAC scheme increases the throughput of RT calls and also reduces the blocking rate of the RT calls compared to the benchmark scheme.

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