A VARIABLE QOS-AWARE(VQA-CAC) ALGORITHM FOR LTE NETWORKS

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Abstract

Long Term Evolution (LTE) network is one of the broadband wireless access technologies, which is considered as an all IP network to provide Quality of Service (QoS) guarantee for end users according to the Third Generation Partnership Project (3GPP) specifications. The 3GPP specifications define QoS parameters for each type of traffic, but do not specify QoS algorithms such as Radio Admission Control (RAC) and scheduler. Several RAC and scheduling algorithms have been proposed to provide QoS while efficiently utilize network resources. However, these algorithms are inappropriate to guarantee QoS to diverse applications due to changes in population density or application distributions as well as dynamic characteristics of network traffic such as minimum rate and delay requirements. In this paper, a variable QoS-Aware (VQA-CAC) algorithm will be proposed to reduce the waste of resources while ensuring QoS to diverse applications by introducing a dynamic degradation mechanism. Discrete Event Simulator (DES) will be used to evaluate the performance of the proposed algorithms such as LTE Simulator and OPNET. Substantial simulations will be extensively conducted to evaluate the performance of the proposed algorithms in comparison to the existing CAC and scheduling algorithms. Simulation results will be compared in terms of throughput, average delay and packet loss as well as new call blocking and handoff dropping rate probabilities. The results will show that the proposed algorithms provide QoS guarantee to subscribers/users' satisfaction and increase revenue of service to providers.

Keywords—QoS, Call Admission Control, LTE, Throughput, VQA.

1.0 Introduction

In recent times, the number of mobile subscribers and the volume of traffic generated by them have heavily increased. 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]. The LTE network is built on a flat architecture called the Service Architecture Evolution. The Architecture consists of the radio access network and the Evolved Packet Core (EPC). On the other hand, the EPC provides the overall control of the UE and establishment of the bearer, which consists of Mobility Management Entity (MME), Serving Gateway (SGW), and Packet Data Network Gateway (PGW). The MME controls handover within LTE, user mobility, and UEs paging as well as tracking procedures on connection establishment.

The SGW performs routing and forwarding of user data packets between LTE nodes as well as handover management between the LTE and other 3GPP technologies. The PGW connects the LTE network with other IP networks around the globe and provides the UEs access to the internet [2]. The radio access network known as the Evolved-Universal Terrestrial Radio Access Network (E-UTRAN) comprises of the eNB and the UE. The UE represents the different types of devices used by the users while the eNB performs radio resource management (RRM) such as RAC and scheduling.

The LTE technology is rolled out by the telecommunication service providers in places like Nigeria to provide broadband service, but such services covers only few major cities of different shapes and sizes from the small areas with high population density to vast geographical areas that are sparsely populated. Therefore, suitable dimensioning of the whole access network is critical to ensure the overall cost is minimized while specified data rates are ensured to all users in respective of their geographical locations.

The dimensioning of a network may change its characteristics. For instance, the traffic load at the core network or the traffic demand of a base station increases beyond the forecast due to changes in population density or application distributions. In such situations, a network with unsuitable QoS algorithms may fail to manage these dynamic changes and thus leads to poor QoS for service applications.

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 [3]. MIMO technologies are used to increase the high data rate, provide wide area coverage as well as to improve the spectral efficiency [4]. 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 [5]. 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 [4], [6]-[11]. Recently, in [4] 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, a CAC scheme is proposed 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.

2.0 Related Works on Call Admission Control Schemes

The CAC scheme is a fundamental component that guarantee QoS for applications in LTE networks. The primary aim of this scheme is to admit a large number of connections into the network with their QoS requirements, while the minimum QoS requirements of the existing connections will not be affected, as well as an efficient utilization of network resources. Therefore, the CAC scheme is a process in which a new or a handoff connection is accepted into the network with the QoS guarantee as well as assuring that the QoS of the existing connections are not degraded. Several CAC schemes have been proposed to address the problems that affect service class applications.

In [12], a novel resource allocation scheme is proposed to retain throughput of mobile users during mobility. The scheme divides the coverage area into concentric regions R1, R2 and R3 where each region uses a fixed Adaptive Modulation and Coding (AMC) scheme. It reserves resources for new calls and RT calls in migration by limiting number of calls. The remaining resources are fairly shared among NRT calls. The scheme ensures each mobile user accepted by the system maintains its throughput. However, it increases blocking and dropping probabilities when the number of limited calls is high.

In [13], a Preemption and Congestion Control scheme is proposed to reduce call blocking and dropping probabilities. The scheme first arranges the bearers according to priority. Then, the bearers with the lowest priorities are fully preempted one at a time by employing load reduction technique to obtain target resources. The scheme significantly improves the dropping and blocking probabilities but it is unfair because lower priorities bearers may be fully preempted while others are still over-provisioned.

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 [6].

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 chances of calls but fails to utilize network resources professionallysince the reserved resources may not be fully used 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 scheme to reduce the new call blocking probability called Markov model-based adaptive call admission control scheme was proposed in [8]. It formulates the resource allocation problem as a Markov chain model. The scheme considers call request as RT and NRT, connectivity as new call and handoff call. It 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. The scheme 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, it fails to utilize resources professionally. It also starves lower priority calls due to the degradation strategy applied to them whenever a higher priority call arrives.

An Efficient Bandwidth Call Admission Control (EB_CAC) to reduce call blocking chances of calls and satisfy the QoS requirements for real time and non-real time traffics was proposed in [9]. Thiswas as a result to estimates channel quality based on RSS to determine good and bad channels.

This classifies RT call type as either RT_HC or RT_NC and admits an RT_HC request if there are adequate PRBs without considering the channel condition and Bandwidth Occupational Ratio (BOR). It rejects NRT requests whenever there are no adequate PRBs on the system. The schemefurther classifies NRT requests into NRT_HC and NRT_NC and NRT_HC are admitted independently of their channel quality with a blocking chances 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.

In [11], a Delay Aware and User Categorizations Adaptive Resource Reservation-based Call Admission Control (DA-UCARR- CAC) is proposed to increase the network's resource utilization. The DA-UCARR- CAC classifies users into Gold and Silver and flows to RT and NRT, which translates to four types of bearers namely: Golden users with real-time flows (G-RT), Silver users with real-time flows (S-RT), Golden users with non-real time flows (G-NRT) and Silver users with non-real time flows (S-NRT) and reserves virtually predefined RBs for each class. It accepts a request if the resources required are less than the available RBs otherwise it admits the requests into a queue if resources are in sufficient. The queued requests are accepted according to their computed AP when RBs are available. The scheme utilizes available RBs, delay tolerance, user categorization and flow type to compute the AP of a request. The scheme achieves a better balance between system utilization and QoS provisioning but calls with highest AP experience a high blocking probability.

In [4], an Adaptive Connection Admission Control is proposed for heterogeneous services. The scheme adaptively adjusts transmission guard interval according to the QoS requirements to give high priority to RT call approaching deadline. It assigns resources to RT call based on QoS. The scheme accepts NRT calls in the absence of handover calls and in presence of low network load. The scheme maintains a low call blocking ratio of the ongoing connections of different classes under small number of users. However, the scheme is unfair because of higher priority given to RT calls.

In this paper, a VQoS-aware call admission control (VQA-CAC) scheme is proposed to improve the performance of [4] by increasing the throughput and reducing the blocking rate of the RT calls.

3.0 ProposedVQA-CAC Scheme

\In this work, a new call admission control scheme is proposed to address the challenges of the CAC scheme proposed in [4]. 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 is 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:

$$Call_{RT} = BWmax \qquad (1)$$

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:

$$Call_{NRT} = BWmax \qquad (2)$$

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:

$$BW_{req} \leq BWavail \qquad (3)$$

Where BW_{req} is the requested bandwidth and BW_{avail} is the available bandwidth.Where there is insufficient bandwidth to admit a new call request, then a *degradationmechanism* is applied to all admitted calls. The degradable bandwidth for a call can be computed as:

$$BWC_{deg} = BWC_{max} - BWC_{min} \qquad (4)$$

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):

$$BWC_{deg} \geq BWC_{min} \qquad (5)$$

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 therequested 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):

$$\Sigma BW_{deg} \geq BWC_{req} \qquad (6)$$

Where ΣBW_{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 VQA-CAC scheme is diagrammatically represented in figure 1 and the pseudo-code is presented in algorithm 1.1

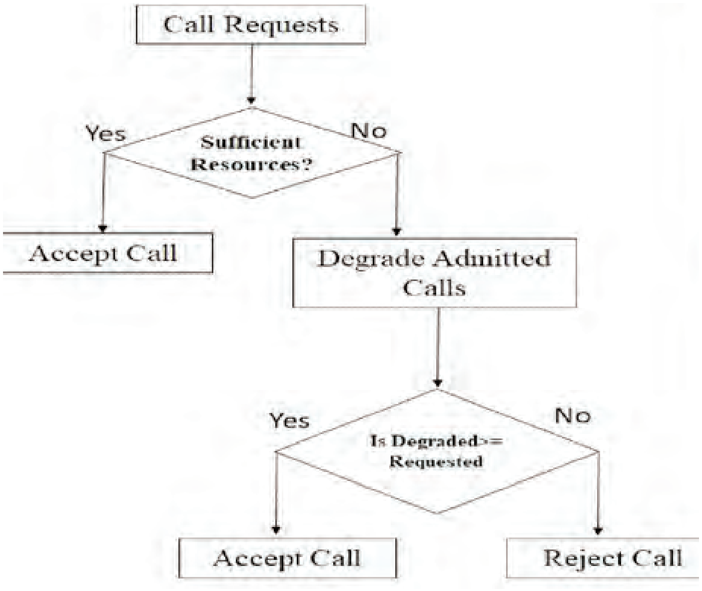

Fig. 1: Diagrammatic description of the VQA-CAC scheme [1]

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

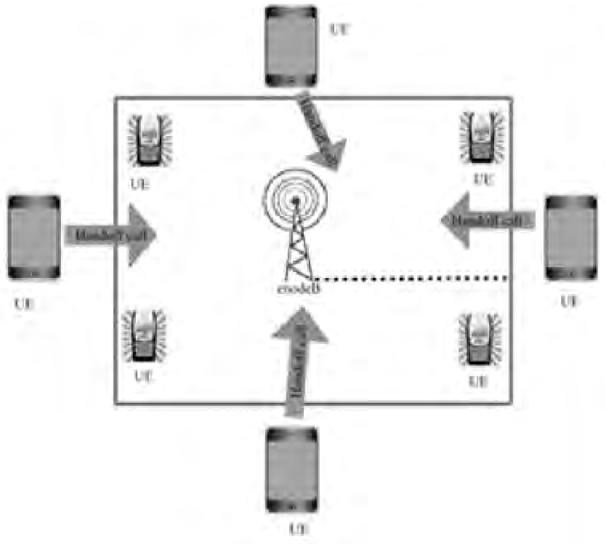

Fig. 2: Simulation Topology of the Experiment [4]

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 [4] 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.

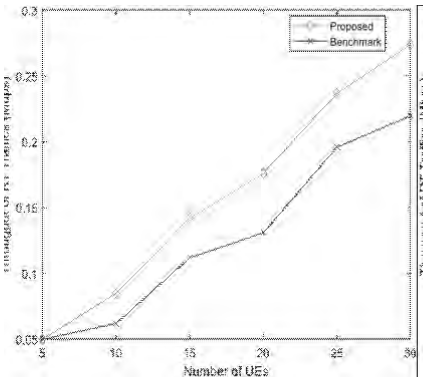

Fig. 3: Throughput achieved by the two schemes for RT calls

Figure 3 illustrates the throughput of RT calls for the benchmark scheme and that of the VQA-CAC scheme. The figure demonstrates that the VQA-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 VQA-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 VQA-CAC scheme increases the throughput of RT calls by 25.0%.

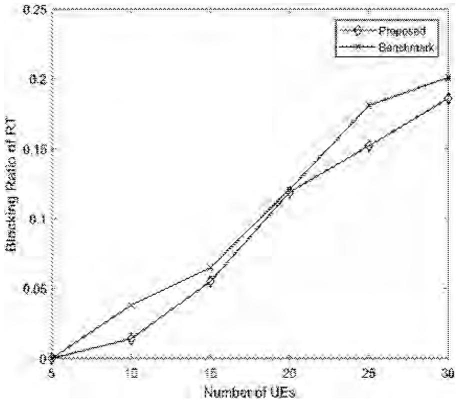

Fig. 4: Blocking Ratio achieved by the two schemes for RT calls

Figure 4 demonstrates the blocking rate of RT calls of the VQA-CAC scheme as compared to the benchmark scheme. The figure shows that the VQA-CAC scheme blocks fewer RT calls compared to the benchmark scheme. VQA-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 VQA-CAC scheme reduces the blocking rate of RT traffics by 15.2%.

Conclusion

In this paper, the VQA-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 and If 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. The scheme 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 VQA-CAC scheme The results demonstrate that the VQA-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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