IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received May 8, 2017, accepted June 3, 2017, date of publication June 8, 2017, date of current version July 3, 2017.

Digital Object Identifier 10.1109/ACCESS.2017.2713451

An Adaptive Call Admission Control With Bandwidth Reservation for Downlink LTE Networks

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This work was supported by research under Grant UPM-FRGS-08-02-13-1364FR.

ABSTRACT In recent years, consumers of 4G cellular networks have increased exponentially as they discover that the service is user-friendly. Due to the large users and their frequent demands, it is necessary to use the limited network resources that guarantee the eminent standard quality of service (QoS). Call admission control (CAC) scheme has a major impact in assuring QoS for different users with various QoS requirements in 4G networks. Recently, the reservation-based scheme and bandwidth degradation schemes were proposed with the aim to provide effective use of network resources and assure QoS requirements to admitted calls. However, in spite of these several objectives, these schemes are not efficient as a result of the modeling and approximation method that starve the best effort (BE) traffic. The dynamic threshold value approach adjusts handoff call and new call based on time-varying conditions resulted in a waste of network resources, where bandwidth are reserved for handoff call, but at the network environment, there is little or no handoff calls. In this paper, we propose a novel CAC scheme to provide effective use of network resources and avoid the starvation of BE traffic. The scheme introduces an adaptive threshold value, which adjusts the network resources under heavy traffic intensity. In addition, we proposed reservation and degradation approach to admit many users when there is a limited number of bandwidth, which also achieved effective utilization of network resources. Simulation results show that the proposed scheme significantly outperforms the reservation-based scheme and bandwidth degradation schemes in terms of admitting many calls and guaranteeing QoS to all the traffic types in the network. Numerical results imitate to experimental results with insignificant differences.

INDEX TERMS Call admission control, call blocking probability, call dropping probability, handoff, quality of service.

I. INTRODUCTION

The rapid growth of cellular networks through various technologies necessitated the introduction of promising technology by the 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE). LTE employs Orthogonal Frequency Multiple Access (OFDMA) and Multi-user Multiple-Input Multiple-Output (MU-MIMO) technologies to increase users high data rate, provide wide area coverage, and improve spectral efficiency [1]. To achieve these mentioned objectives, there are great challenging issues in relation to meeting Quality of Service (QoS) requirements and to reduce network congestion. In order to solve the above-mentioned problems, there is the need to have an effective radio resource management (RRM).

Call Admission Control (CAC) is one of the fundamental techniques for RRM. CAC scheme is the process of accepting a new call or handoff call in the network while regulating QoS of the existing calls without degrading any call drops. Handoff call refers to the method of transferring an ongoing call or data session from one channel to another in a cellular network without compromising QoS requirements [2]. To satisfy user QoS requirements the CAC scheme arranges handoff call to the network by considering the available bandwidth. Hence, some amounts of bandwidth are reserved for incoming handoff call and assign the outstanding to new calls. An effective CAC scheme must concurrently provide efficient network resources utilization and an excellent QoS to the admitted users.

The work in [3] proposed a channel-borrowing scheme in which the best effort (BE) traffic borrows the bandwidth reserved for high-priority calls. Henceforth for the purpose of this paper, we call [3] as the Reservation-Based scheme. The Reservation-Based scheme used modeling and approximation processes for its CAC scheme. However, modeling of individuals and approximation of key system parameters is inefficient for the wireless network, due to the starvation of user traffic. Additionally, the scheme dynamically reserved some amount network bandwidth for handoff call using time varying status. However when some bandwidth is borrowed and reserved for handoff call, it may happen that the network has only a few or no handoff calls, then those network resources may be underutilized or wasted; consequently, this results in ineffective use of network resources.

In this paper, we propose a novel CAC scheme named, An Adaptive Call Admission Control with Bandwidth Reservation for Downlink LTE Networks to amend the inefficiency of Reservation-Based. Firstly, the mechanism determines new CAC criteria based on traffic types. In the new CAC criteria, to create opportunities for the new calls, bandwidth degradation approach is introduced when the networks have scarce resources under heavy load scenario. Subsequently, an adaptive threshold value is applied to reserves available bandwidth for handoff calls by considering its traffic strength intensity.

The major contributions of this paper are threefold. First, is maximizing the throughput of the BE traffic which is blocked because of lack of efficient utilization of network resources. The second contribution is the reducing of call blocking probability (CBP) and call dropping probability (CDP) by using an adaptive threshold value which adjusts the network status. Lastly, an analytical model using two levels Markov chain was developed to measure the performance of the proposed scheme.

The organization of this paper is as follows. In the next section, we provide an overview of the related works. The proposed algorithm is presented in section III. In section IV an analytical study is illustrated. Results and discussion are described in section V, while conclusions and future directions are given in section VI.

II. REALTED WORKS

Reservation CAC has gathered a lot of momentum in LTE networks; hence researchers have proposed several works towards such direction. In [4], CAC scheme that relies on adaptive multilevel bandwidth allocation of non-real-time (NRT) calls is proposed. The algorithm utilizes the available radio resources to provide QoS. However, channel control allocation is ignored which resulted in high CBP and low resource utilization. The authors in [5], proposed an interference-aware spectrum handover scheme for a cognitive radio network. The scheme aims to maximize the network capacity and minimize the spectrum. The heuristic algorithm was designed using Branch and Bound approach to solve spectrum handover problem. A channel reservation and preemption (CRP) model using overlapping regions in a cellular network with multiple sectors is presented in [6]. Directional antennas are installed on enodeB which divide the coverage into equal sized sectors. The scheme aims to minimize the call dropping probability of the handoff call by using efficient usage of available channels in the sector.

The work in [7], investigated the effect of group vertical handoff in heterogeneous networks. The congestion game approach was introduced to solve the issue of network congestion in group mobility scenarios. The approach uses two learning algorithms to attain the nash equilibrium point in a stochastic situation. CAC algorithm for cellular networks with direct and dynamic monitoring of QoS performance is proposed in [8]. The algorithm aims to meet the QoS requirements by estimating system delay detail and the residual throughput is calculated based on the total achieved throughput. It achieves efficient resource utilization. In [9], an opportunistic CAC for wireless broadband cognitive networks is presented. The scheme designed a framework and an optimization technique is formulated considering the demand for each service provider and cognitive subscribers.

The work in [10] proposed a CAC reservation algorithm which looks resource variations into account, whereby resources are assigned to users based on QoS and channel quality. The algorithm considers two kinds of applications named wide-band and narrow-band. Extra resources needed are predicted and reserved to avoid QoS degradation for the incoming call. However, LTE environment has different cell sizes and reserving resources in such situation causes poor resources utilization. In [11], Quality of Experience scheme which statically or dynamically reserves network resources was proposed. To sustain undetectable quality fluctuation throughout the handover for LTE networks, the scheme dynamically reserves resources based on prior knowledge. However, this scheme resulted in increased system complexity and inefficient resource utilization due to mobility prediction.

Several CAC schemes are proposed [12], [13] which considered bandwidth reservation from mobility prediction perspective. Mobility prediction scheme for the cellular network was developed in [12]. The scheme uses Hidden Markov Model (HMM) to analyze users mobility in temporal scale and large spatial. The proposed scheme was combined with threshold-based statistical bandwidth multiplexing strategy to enhance system performance. Initially, mobile reservation protocol starts the session with mobile host sending a service request to the active cell. The active cell verifies whether the available channels are free then request is granted; otherwise, the request is forbidden. A framework and scheme for bandwidth reservation were proposed in [14]. The scheme integrates user mobility and available bandwidth model to predict paths to destinations, times when users enter/exit cells along predicted paths, and available bandwidth in cells on predicted paths. The scheme achieves low complexity, making the proposed framework real for practical implementation in mobile networks. However, this scheme generated a lot of traffic overhead. The authors in [13] proposed a mobility-prediction-aware bandwidth reservation scheme. The scheme estimated the time windows for a user to perform hand-offs along the path to his destination. It then estimated the available bandwidth required during the time windows. The scheme achieves low handoff call drops and maintains sufficient new call blocks while keeping effective utilization of resources. However, the estimation accuracy and reservation technique are questionable: how do you distribute resources to diverse kinds of users in a predictive way.

In [15] threshold behavior for CAC was investigated. The scheme uses multi-threshold approaches for resource distribution and reservations: Tri-threshold reservation and dual threshold bandwidth reservation. The scheme operates based on complete sharing method whereby overall bandwidth is shared by many service classes. This scheme achieves maximum channel utilization and guarantees service to different traffic. However, the scheme is only implemented under a fixed channel allocation while ignoring dynamic channel allocation which causes system complexity and a lot of overhead. Utility-Based Scheduling and CAC for LTE (3GPP) networks was suggested in [16]. In this scheme, there are two classes of traffic users: real-time (RT) and NRT users which are scheduled depending on channel utility function. The channel can be classified as a good or bad channel using received signal strength (RSS). Initially, the RSS value is calculated and when reserved bandwidth exceeds a threshold value, then the channel condition is considered as good channel otherwise, it is considered as a bad channel. Allocating of resources for RT users is done using the utility function, whereas channel state marginal utility function is used for the NRT user. The scheme offers channel quality and arranges the handover calls over new calls for all classes of traffic users. However, the scheme uses a limited number of user equipment (UE) in their proposed scenario.

The work in [17] proposed a QoS approach for an adaptive CAC scheme for the multiclass service wireless cellular network. The scheme employs a measurement-based online monitoring approach prediction model which governs the amount of bandwidth to be borrowed from the calls or returned to the calls. The scheme achieves improved bandwidth utilization, reduces both CBP and CDP. However, execution of this scheme consumes a lot of time which results to increase of handoff latency. The authors in [18] proposed a distributed resource reservation scheme for handover failure reduction. The network condition information which is locally available at the individual cell is utilized to serve handover protection (HOP) resources in distributed and dynamic way. For each individual cell, numerous HOP resources are reserved and each cell is allowed to distribute downlink user traffic through the reserved HOP resources only. The HOP resource reservation is accomplished using two-step-reservation: locally unique identity and network status information. The scheme significantly achieves the reduction in handover failure rate by about 40% to 70% when the traffic intensity is low. However, different load scenarios are ignored. In [19] the authors proposed an efficient CAC scheme based on adaptive resource reservation. The scheme dynamically adjusted users priority based on the present network status. Users are categorized as Golden users and Silver users, and the type of service per user is classified as RT and NRT services. The scheme achieved a better balance between users privileges, QoS provisioning and system utilization compared to other schemes.

The work in [20] introduced degradation degree and degradation ratio (DD-DR) for adaptive multimedia in wireless/mobile networks. To effectively use the network resources the scheme employed CAC framework and a K-level bandwidth adaption approach to guarantees the application QoS requirements. However, this scheme considered the condition of single service type in QoS provisioning and degradation problems from the service providers perspective. The authors in [21] proposed a general framework to find out the optimal degradation and admission policies for multiclass traffic in next-generation wireless networks (Degraded-Framework). The goal of the framework is to maximize the net revenue by admitting new users; while the cost of degradation was estimated to be negative revenue. Nevertheless, the framework did not distinguish between new calls and handoff calls; nor had they studied the effect of handoff at all. The work in [22] investigated the bandwidth degradation (BW-Degradation) approach to minimize CBP for mobile network systems. The scheme employs a degradable mechanism in which many users are allocated with bandwidth in order to decrease the CBP while not violating QoS requirements for existing users to an unacceptable degree.

Therefore, it is important to note that previous studies in the above literature focus on CAC scheme with bandwidth reservation among user traffic without considering bandwidth degradation [3]–[19]; whereas [20]–[22] introduces bandwidth degradation approaches to improve the efficiency of the resource utilization and guarantee QoS requirements for NC and HC. However, the CAC mechanism for bandwidth reservation and degradation approaches applied starved many users when the traffic load changes, accordingly, this resulted in ineffective usage of network resources, worsened degradation ratio, the high increase of CBP and CDP. To address this, we proposed An Adaptive Call Admission Control with Bandwidth Reservation for Downlink LTE Networks to eradicate the preceding problems.

III. PROPOSED ALGORITHM

In this work, a novel CAC scheme is proposed as an improvement of Reservation-Based scheme. Moreover, the shortcomings of Reservation-Based scheme are described. The scheme defined its CAC benchmark based on modelling, approximation method, and the BE traffic which reserved bandwidth for the high-level priority call. However, the BE traffic are not admitted into the network throughout the borrowing period which resulted in the starvation of this traffic. Therefore, the starvation of this traffic leads to increases of handoff CBP and CDP. Furthermore, the scheme dynamically distributes channels for an individual cell or reserved certain quantity of channels from the overall channels in the cell for handoff call using time-varying condition. However, when new calls and handoff calls occur repeatedly then some network resources may be left unutilized and this results in ineffective usage of network resources.

Therefore, to solve the aforesaid obstacles a new CAC approach is proposed. The proposed scheme uses different traffic loads to admit new users and employs a threshold QoS provisioning approach to increase the efficient bandwidth utilization. The basic concept of our proposed scheme is taken into consideration that user traffic has different adaptive threshold QoS requirements. Thus a CAC criterion is adjusted by using the available bandwidth to increase the number of admitted calls with adaptive QoS. Moreover, RT traffic has high priority hence their handoff or new call bandwidth requirements can be described as:

$$a_i = BW_i^{max} \tag{1}$$

where a_i denote the call admission criteria for call i while BW_i^{max} represent the maximum bandwidth for call i.

If handoff or new call belongs to NRT or BE traffic, their bandwidth requirement is calculated as follows:

$$a_i = BW_i^{min} \tag{2}$$

where BW_i^{min} denote the minimum bandwidth requirement for call i.

Furthermore, when the available bandwidth cannot be enough to admit new call, bandwidth degradation approach is applied to RT traffic since they were assigned enough; this will save the BE traffic from starvation. Therefore, to compute bandwidth degradation for each class j considers the given equation below:

$$BW_j^{degraded} = BW_j^{max} - D_j^{level} \tag{3}$$

where $BW_j^{degraded}$ denote degraded bandwidth for class j, BW_j^{max} represent available bandwidth and D_j^{level} is the present degradation level.

However, Equation (3) must satisfy Equation (4) as given below:

$$BW_j^{max} - D_j^{level} \geq BW_i^{min} \tag{4}$$

Therefore, the maximum bandwidth degradation size is derived as follows:

$$BW_j^{degsize} = \frac{BW_j^{max} - BW_j^{min}}{D_j^{level}} \tag{5}$$

where $BW_j^{degsize}$ represent maximum bandwidth degradation size of class j.

To accept a new call or handoff into the network using the proposed criterion, the bandwidth allocated to an admitted new call or handoff is represented as $BW_{i,handoff}(t)$ and $BW_{newcall}(t)$ over time.

A handoff call $handoff - call_{accept}(t)$ is accepted into the network when the following condition is satisfied

$$handoff - call_{accept}(t) = (BW_{i,handoff} + BW_{handoffcall}(t) + BW_{newcall}(t) \leq BW_{total} \tag{6}$$

where $BW_{i,handoff}$ is the admission criteria for call i

A threshold value is introduced, adopted from [23], to change the reservation bandwidth using various traffic loads for handoff calls. The threshold block new request when the number of call is higher than the threshold value.

$$th_{adaptive} = (\tau handoff * K) * BW_{req} \tag{7}$$

where $th_{adaptive} = \frac{\lambda_{RT}}{\mu_{RT}}$ represent the traffic load, λ_{RT} and μ_{RT} denote the arrival rate and mean service for handoff call respectively.

Moreover, BW_{req} is the required bandwidth for each handoff call, while K is the reservation bandwidth factor, K ∈ (0, 1).

A new call $new - call_{accept}(t)$ is accepted into the network when the below condition is satisfied

$$new - call_{accept} = (BW_{i,new} + (BW_{handoffcall}(t) + BW_{newcall}(t) \leq BW_{total} - th_{adaptive} \cap (BW_{i,new} \leq BW_j^{degraded})) \tag{8}$$

where $BW_{i,new}$ is the new admission criterion for call i, and $BW_j^{degraded}$ is the degradation level for each call. The first term on the right-hand side (RHS) aims that existing and new calls are not above total bandwidth for the new call. While the last term at the RHS ensures that new calls are admitted even when there is inadequate number of bandwidth.

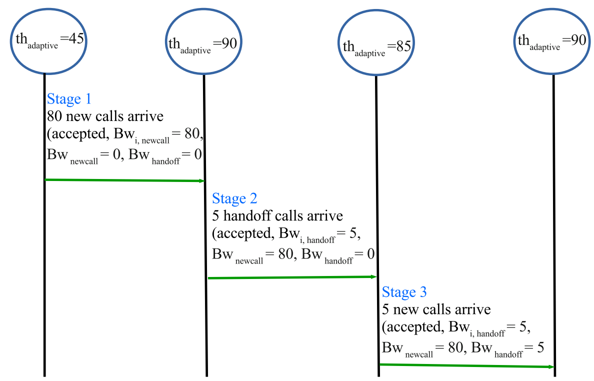

FIGURE 1. Proposed scheme case study scenario with Adaptive threshold.

A simplified case study scenario is illustrated in Fig. 1 where we assume the total bandwidth of the network is 100 (BW_{total} = 100) and at the initial stage, the network is empty. Suppose that 80 new calls, 5 handoff calls, and 5 new calls arrive consecutively. Both schemes are assumed to have between 0 and 90 threshold values respectively with an initial threshold value of 45 units.

For the Reservation-Based scheme 5 new call ($BW_{i,new}$) and 5 handoff calls ($BW_{handoffcall}$) are rejected, resulting in 10 units of networks resources left unused and cannot be used again for new call admission. Therefore, ineffective bandwidth resource utilization occurred. But, our scheme significantly improves such situation by admitting new calls to the network resulting in efficient bandwidth resource utilization. Algorithm 1 represents the pseudocode for the proposed An Adaptive Call Admission Control with Bandwidth Reservation for Downlink LTE Networks.

Algorithm 1 An Adaptive Call Admission Control With Bandwidth Reservation for Downlink LTE Networks

Input:
TTT :Transmission time interval
HC : Handoff call
NC : New call
RT : Real-time traffic
K : Reservation factor
SMT : Simulation time
BW_{RT}^{min} :Bandwidth requirements for RT
$BW_{RT}^{degrade}$: Degraded bandwidth for RT
D_{RT}^{level} : Degradation level for RT
$th_{adaptive}$: Threshold value
Initializations
Set K = 1 or 0, traffic types =2, traffic classes = 3,
While TTI is within SMT **do**
Compute HC according to Equation (6)
Update $th_{adaptive}$ based on Equation (7)
If Equations (6) and (7) hold **then**
    Accept handoff call
else
    reject handoff call
end if
Compute NC according to Equation (8)
if $(BW_{RT}^{degraded} - D_{RT}^{level} \leq BW_{RT}^{min})$ **then**
    accept new call
else
    reject new call
end if
End(while)

IV. ANALYTICAL STUDY

This section described the analytical model for our proposed CAC scheme. Using this model we derive CDP and CBP for the different traffic classes and extensive experimental simulation is carried out to verify its accuracy. In this model, we have one base station called evolved NodeB (eNodeB) and several UEs, as illustrated in Fig.2 some UEs are within the cell and are requesting for the new call, while others are outside the cell hence requesting for handoff call. When there is an incoming handoff or new call the UEs request for the available bandwidth from the eNodeB. We have two different types of calls in our model: (a) Handoff call, an example is RT traffic with highest priority (b) New call, consists of NRT traffic and BE traffic with lowest priority respectively. Each of this traffic has different QoS requirements and therefore

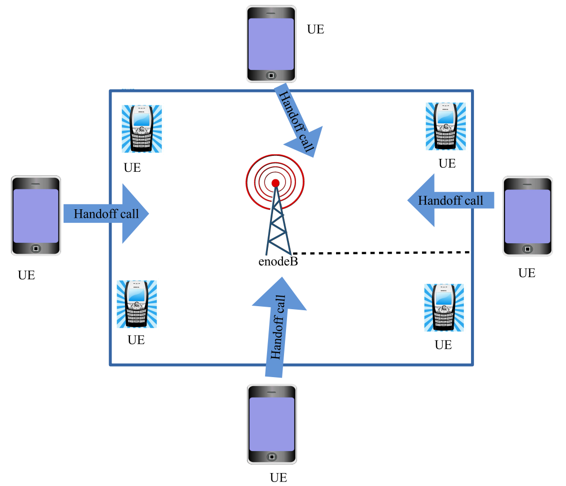

FIGURE 2. Simulation topology.

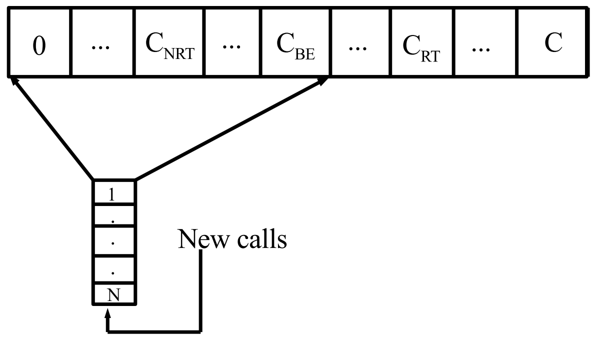

FIGURE 3. System architecture.

owes QoS guarantees to enable them a request for the new call or handoff call. At the eNodeB, a CAC mechanism is employed which admits new call and reserves bandwidth for handoff calls, when there is unused bandwidth, while admitted calls are degraded to their lowest level. Otherwise, neither of the calls is admitted. Accordingly, the user call might either be effectively handed off to a new base station or just dropped when it is about to depart the current cell. As we had mentioned above, the handoff calls have priority over new calls since the termination of handoff call in progress is more frustrating, less tolerable and less desirable than blocking a new call. This can be achieved by limiting a new call into the cell when the total number of user calls or the total occupied bandwidth is greater than the threshold value. In Fig. 3 we describe the model of the proposed scheme.The new call CBP and the handoff CDP are used as evaluation measures for the proposed scheme. These probabilities are obtained by modelling the proposed using two level Markov chain transition diagram as illustrated in Fig. 4.

Furthermore, to obtain CDP, CBP, global balance equation, and a steady probability of the proposed scheme let makes the following assumptions. The arrival rate of handoff call (λ_{RT}), new calls (λ_{NRT}) and BE traffic (λ_{BE}) used Poisson distribution while their mean service uses exponential distribution with parameters as $C_{RT}\mu$, $C_{NRT}\mu$ and $C_{BR}\mu$ respectively while the queue size of new calls is represented as N.

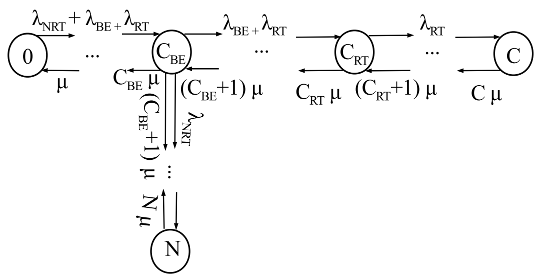

FIGURE 4. Markov chain state transition diagram.

The state space of the proposed model is based on the number of calls accepted and the degraded level of new call. The possible states of our model is represented as $S = \{0, C_{BE}, C_{RT}, C\}$. When the number of channels i in Fig. 4 are busy then the probability P(i) can be obtained from the transition diagram. The global balance equations can be derived as follows:

$$i\mu P_{(i)} = (\lambda_{NRT}+\lambda_{BE}+\lambda_{RT})P(i-1), \quad 0 \le i \le C_{BE} \tag{9}$$
$$i\mu P_{(i)} = \lambda_{NRT}P(i-1), \quad C_{BE} < i \le N \tag{10}$$
$$i\mu P_{(i)} = (\lambda_{BE}+\lambda_{RT})P(i-1), \quad C_{BE} < i \le C_{RT} \tag{11}$$
$$i\mu P_{(i)} = \lambda_{RT}P(i-1), \quad C_{RT} < i \le C \tag{12}$$

The steady probability P(i) can be derived as:

$$P_i = \begin{cases} \dfrac{(\lambda_{NRT}+\lambda_{BE}+\lambda_{RT})^i}{i!\mu^i}p(0) \\ \qquad\qquad 0 \le i \le C_{BE} \\ \dfrac{(\lambda_{NRT})^{i-C_{BE}}(\lambda_{NRT}+\lambda_{BE}+\lambda_{RT})^{C_{BE}}}{i!\mu^i}P(0), \\ \qquad\qquad C_{BE} < i \le N \\ \dfrac{(\lambda_{NRT}+\lambda_{RT})^{i-C_{BE}}(\lambda_{NRT}+\lambda_{BE}+\lambda_{RT})^{C_{BE}}}{i!\mu^i}P(0), \\ \qquad\qquad C_{BE} < i \le C_{RT} \\ \dfrac{(\lambda_{RT})^{i-N}(\lambda_{NRT}+\lambda_{BE}+\lambda_{RT})^{C_{BE}}}{i!\mu^i}P(0), \\ \qquad\qquad C_{RT} < i \le C \end{cases} \tag{13}$$

The summarized steady-state probability of the proposed model is δ 0,C_{BE}, C_RT, C and characteristic function is given as π (0, C_{BE}, C_{RT}). Equations 14 below avoid the model being in an invalid state.

$$\pi(0, C_{BE}, C_{RT}, C) = \begin{cases} 1, & (0, C_{BE}, C_{RT}, C) \in S \\ 0, & \text{otherwise} \end{cases} \tag{14}$$

Furthermore, normalized condition for the proposed model is given as:

$$\sum(0, C_{BE}, C_{RT}, C) \in S\delta(0, C_{BE}, C_{RT}) = 1 \tag{15}$$

Therefore, the CDP and CBP are computed as:

$$CDP = \sum_{i=0}^{C_{RT}} P(i) \tag{16}$$

$$CBP = \sum_{i=0}^{C_{BE+N}} P(i) \tag{17}$$

V. SIMULATION RESULTS AND DISCUSSION

In this paper, the performance of the proposed scheme is compared with the Reservation-Based scheme, DD-DR, Degraded-Framework and BW-Degradation. The simulation results are obtained with the help of system level simulator [24] which is an open source simulator released for the academic and non-commercial purpose only. The performance of the proposed scheme is measured in terms of CBP, CDP, throughput and degradation ratio. The simulation scenario consists of one hexagonal cell with 500 m radius. The total bandwidth used is 5 MHz with 25 resource block per slot of 12 subcarriers spacing. The call request can be classified into different classes based on their QoS requirement and call types. Based on QoS requirements the calls can be categorized as HC and NC. The HC these are RT traffic with the highest priority and the best example is live streaming. On the other hand, the NC is differentiated into two types of traffic: NRT traffic example YouTube and the BE traffic example email. The arrival rate for both RT and NRT is in the form of a Poisson distribution with the service mean exponentially distributed. The total simulation time is 1000 s while the results are obtained by taken the average over 20 times of simulation. Table1 summarized the simulation parameters.

TABLE 1. Simulation parameters.

Parameter	Value
System bandwidth	5 MHz
Number of RBs	25
TTI	1 ms
Call arrival	Poisson process
Simulation Period	1000s
Speed of the user	4.16 m/s for moving user
Transmission scheme	2X2 MIMO, OLSM
Cyclic prefix used	Normal cyclic prefix
UE distribution	Uniform
λ_{NRT}, λ_{BE},λ_{RT}	1

Fig. 5 illustrates the throughput of the proposed scheme and other schemes for the BE traffic type. It can be observed that both schemes have similar performance pattern due to the low traffic intensity (arrival rate 1-2.4). But when the traffic intensities are increased, the performance ranges between 2.5-10 arrival rates, the proposed scheme shows its superiority compared to Reservation-Based scheme with up to 23.94% improvement, DD-DR (48.15%), Degraded-Framework (60.38%) and BW-Degradation (80.25%) respectively. The improvement was caused due to the fact that our scheme tries to avoid starvation of the BE traffic throughout the high traffic intensity period; similarly, when there is inadequate bandwidth then degradation approach is employed to admit the BE traffic.

Fig. 6 represents the New call CBP for both the proposed scheme, Reservation-Based scheme, and bandwidth degradation schemes. It indicates that from 1 to 2 arrival rate, the performance for the both schemes was the same exception of DD-DR. This was attributed to using low traffic

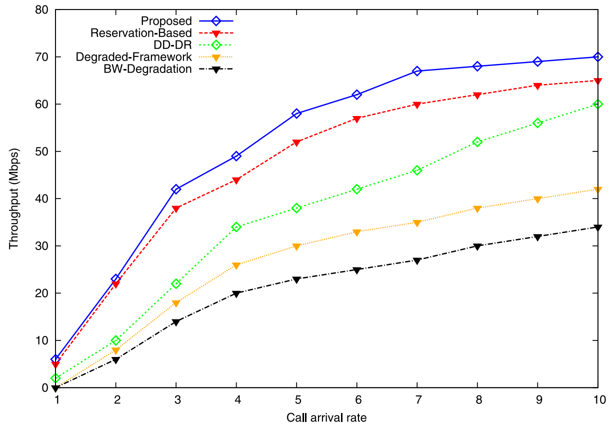

FIGURE 5. Throughput of BE traffic type.

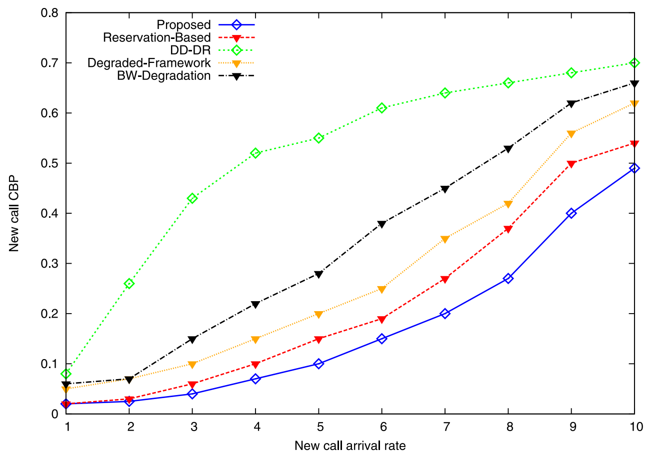

FIGURE 6. New call CBP.

intensity, but with an increase of traffic intensity, the proposed scheme outperforms the Reservation-Based scheme by reducing the new call CBP by 29.68%, Degraded-Framework (39.89%) and BW-Degradation (45.62%) respectively. The main reason behind this reduction is that a new CAC criteria were introduced which avoid the starvation of BE service types and prevent reservation of too many resources for HC. Additionally, an efficient network utilization of network resources was shown by the proposed scheme which is attributed to adopting an adaptive threshold value, contrary to the dynamic threshold value used by Reservation-Based scheme and other bandwidth degradation schemes resulting in inefficient usage of network resources. Furthermore, the proposed scheme during degradation state grants many new calls to be admitted into the network.

Figure 7 describes the Handoff call CDP for the Reservation-Based scheme, bandwidth degradation schemes and proposed scheme. At initial arrival rate, both schemes illustrate the same performance because the intensity of the traffic is low. However, when the traffic intensity increased the proposed schemes has an outstanding performance compared to the Reservation-Based Scheme with the decrease of CDP by 23.82%, DD-DR (58.54%), Degraded-Framework (25.86%) and BW-Degradation (45.87%) respectively.

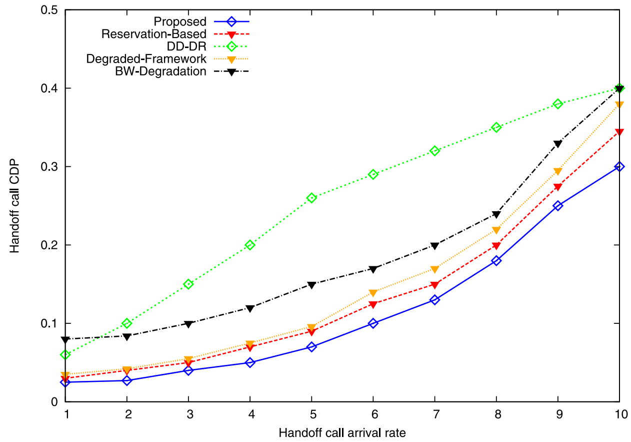

FIGURE 7. Handoff call CDP.

This is because the proposed scheme was able to adaptively adjust the reservation bandwidth threshold value when there is a frequent arrival of HCs based on traffic intensity. Unlike the Reservation-Based scheme which adjusted a dynamic reservation bandwidth threshold for handoffs based on the arrival of HCs and NCs together with the departure of Handoff calls. With the new CAC introduced, the proposed scheme guarantees the QoS requirement of different services.

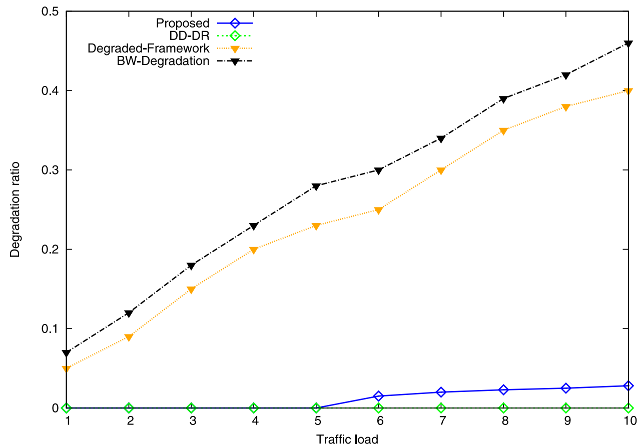

FIGURE 8. Degradation ratio.

Figure 8 illustrates the degradation ratio for the proposed algorithm compared with recent and relevant schemes in respect to bandwidth degradation with the aim to minimize the degradation ratio. It can be observed that the proposed scheme and DD-DR are in total agreement when the traffic load ranges 1-5. This was attributed to both the two schemes uses adaptive threshold values to adjust the network conditions. As the traffic load increases (6-10), congestion on the network also increased. User traffic with low priority will be blocked. However, this causes the proposed scheme to suffer an increase in its degradation ratio when compared to the DD-DR. The proposed scheme shows significant gain compared to Degraded-Framework (96.72%)

higher and 97.18% higher compared to BW-degradation. The major reasons behind these increments were attributed to the Degraded-Framework uses the static mix of calls for different classes and the later adjusted the network condition dynamically, while our proposed scheme adjusted the network condition adaptively.

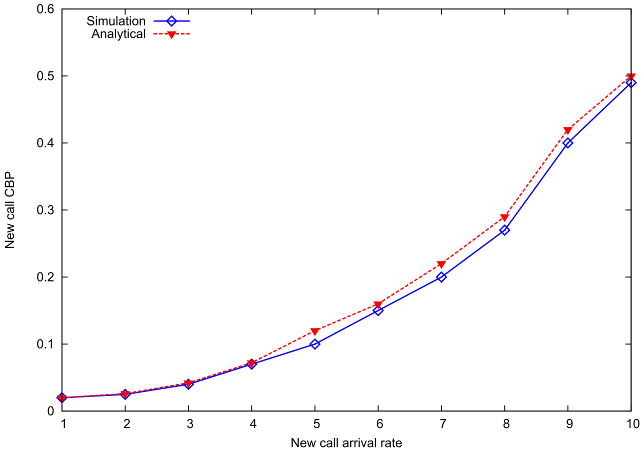

FIGURE 9. **Simulation and analytical results for New call CBP.**

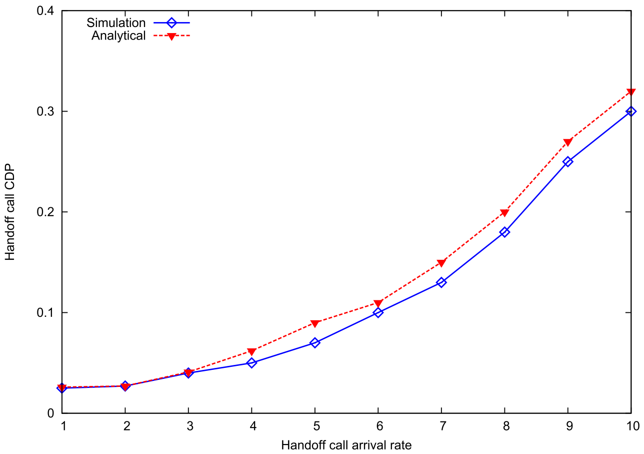

FIGURE 10. **Simulation and analytical results for Handoff call CDP.**

Figs. 9 and 10 show the comparison of the simulation results compared with numerical results to validate the analytical model under study. As observed the numerical results emulate the simulation results with insignificance variations caused due to the inability to model all the parameters analytically. In Fig. 9 Simulation and analytical results for New call CBP there is only 3.15% variation, while in Fig.10 Simulation and analytical results for Handoff call CDP has 5.50%. Therefore, the analytical study presented is valid in terms of its correctness and accuracy.

VI. CONCLUSION AND FUTURE WORK

In this paper, we have proposed an Adaptive Call Admission Control with Bandwidth Reservation for Downlink LTE Networks to prevent starvation of user traffic and improve the effective usage of network resources in LTE networks. The new scheme introduced CAC criteria to avoid starvation of user traffic. The criteria use bandwidth degradation to admit many users when there are insufficient network resources to accommodate new users. The proposed scheme in addition to its bandwidth degradation included an adaptive threshold value which adjusted the network conditions to enable efficient used of network resources. Extensive simulation experiments were conducted to evaluate the effectiveness of the proposed scheme. A mathematical model was introduced using CBP and CDP to validate the experimental results of the proposed scheme. Simulation results and numerical results are in total agreement with negligible differences. Results also show the outstanding performance of the proposed scheme as it was able to achieve an improvement of data throughput, reduces CBP, CDP and degradation ratio as compared to the Reservation-Based scheme and other bandwidth degradation schemes. This further indicates that the proposed scheme achieves higher resource utilization and provides effective QoS assurance for downlink LTE networks. In the future, we intend to look at how to manage the energy efficiency of user traffic and eNodeB for an effective handover.

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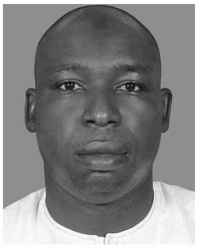

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