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Enhanced Channel Borrowing Call Admission Control Scheme for LTE Networks

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Abstract: Long Term Evolution (LTE) was developed to support real-time services like multimedia, VoIP, online gaming, etc., with different quality of service (QoS) requirements. To achieve this QoS, mobile users should be accepted into the network with committed bandwidth, considering device mobility and the varying application requirement. Thus, the need for an efficient Radio Resource Management technique such as Call Admission Control (CAC). When a new Handoff Call (HC) arrives, and there are no adequate resources to admit it, the existing scheme, pre-empt the ongoing Non-real time (NRT) new call to free up resources to admit the HC. However, the reclaimed bandwidth from the ongoing call may not be completely required by the incoming call, and this will lead to wastage of resources and consequently causes a decrease in throughput. In this paper, we proposed an Enhanced Channel Borrowing Call Admission Control (ECB-CAC) scheme for LTE network to address the problem in the existing scheme. The proposed scheme introduces a dynamic reserved channel allocation and revoke technique that reclaims the required bandwidth enough to admit the incoming call from the ongoing NRT new call. The proposed scheme was evaluated against the benchmark scheme using simulation experiments. The results show that the performance of the ECB-CAC was significantly better than the benchmark scheme in terms of throughput, Call Dropping Percentage (CDP), and Call Blocking Percentage (CBP).

Keywords: *LTE, radio resource management, call admission control, CAC, QoS, Throughput, CBP, and CDP.*

1. Introduction

Long Term Evolution (LTE) is a standard for 4G wireless broadband technology developed by Third Generation Partnership Project (3GPP) that proffers high-speed broadband internet access to wireless network users. The LTE system architecture consists of two major components: Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and Evolved Packet Core (EPC). The E-UTRAN has two types of nodes: evolved Node B (eNB) that serve as a base station (BS) and user equipment (UE) that serves as the communication device. Each eNB offers access for a certain number of UEs over a wireless channel, which creates a cell (Maharazu et al., 2017). The EPC connects the E-UTRAN with other IP networks such as the Internet. It is also responsible for routing, scheduling, mobility, handover processes, and (CAC (Priya & Franklin, 2012). Some of the main objectives of LTE are to guarantee QoS requirements and minimize network congestion for different types of users (Maharazu et al., 2017). To achieve the objectives, the role of Radio Resource Management techniques comes into play.

Radio Resource Management (RRM) is employed by LTE to guarantee good QoS for user applications at both network and user levels (Ahmed, 2005). It comprises different techniques such as scheduling, power control, and CAC. CAC is concerned with the arrival of (new and handoff) calls as they are either granted or denied access to the network based on predefined criteria, considering the network load and availability of resources (Ahmed, 2005). More so, CAC is a process of admitting or rejecting New Call (NC) requests as well as HC requests into the network while maintaining the QoS of already existing calls (Yese et al., 2019). The main objective of the CAC scheme is to ensure efficient resource allocation and monitor resource utilization when the network is congested as well as to manage the bandwidth with respect to the total number of call requests at the BS (Yese et al., 2019).

Several CAC schemes have been proposed for efficient resource management in LTE (Ali et al., 2015; Chadchan & Akki, 2011; Chowdhury et al., 2013; Franklin, 2012; Omitola & Srivastava, 2017; Qian et al., 2009; Ramjee et al., 1997; Tarek & Nidal, 2009). Recently, Omitola and Srivastava (2019) proposed a channel borrowing CAC (CB-CAC) scheme for LTE/LTE-Advanced femtocell-macrocell networks to enhance the quality of service (QoS) for handover calls (HCs). This scheme categorizes calls into new calls (NCs) and HCs, with NCs further classified as real-time (RT) or non-real-time (NRT). To improve efficiency, the CB-CAC scheme allows an NRT call to borrow a channel from the pool reserved

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for HCs when necessary. However, it employs a preemptive mechanism where an arriving HC can reclaim its reserved channel by preempting an NRT call using it. While this strategy utilizes channel resources more efficiently, maintains QoS for HCs, and decreases the dropping and blocking rates for NRT calls, it introduces two key drawbacks. First, the strict prioritization of HCs increases the blocking rate for RT calls. Second, system throughput can decrease because reclaiming a channel for an incoming HC may interrupt an NRT call that was not fully utilizing the channel's capacity.

In this paper, the authors proposed an Enhanced Borrowing Call Admission Control (ECB-CAC) scheme for LTE network to improve its performance. The scheme introduced a dynamic reserve channel allocation and revoke technique to reduce bandwidth wastage, thus increasing throughput, by allocating the required number of channels to admit the incoming call. A simulation experiment was carried out to evaluate the performance of the ECB-CAC scheme against the benchmark scheme using the Vienna LTE System Level Simulator. The results showed that the ECB-CAC performs better in terms of throughput, CDP, and CBP.

The remaining paper is organized as follows: the next section provides a literature review on some related CAC schemes. Section III illustrates the proposed scheme. The simulation results are discussed in section IV and lastly, section V gives a concluding remark.

2. Literature Review

This section presents a literature review of some related CAC schemes for LTE networks.

The authors of ref. no. (Chadchan & Akki, 2011) proposed a Priority-Scaled (PS) pre-emption mechanism that employs Allocation and Retention Priority (ARP). The scheme employs a Priority-Scaled (PS) Minimum QoS Pre-emption Algorithm (PS-MQPA) and a Total Pre-emption Algorithm (TPA). Upon the arrival of an NC, two parameters are computed: R_{Total} and R_{Min} where R_{Total} is the resources that can be acquired by total pre-emption of Low Priority Pre-emptible Active Bearers (LP-PABs). R_{Min} is the resources that can be acquired by reconfiguring all LP-PABs to minimum QoS needs. The scheme rejects an NC if R_{Total} is not enough to fulfill its QoS needs. The TPA pre-empts all the resources from LP-PABs if after the pre-emption of the PS-MQPA the resources are yet to be sufficient. The HCDP is decreased for LP-PABs but the QoS requirement of higher priority calls is reduced to their minimum service rates due to the application of the pre-emption algorithm.

The authors of ref. no. (Khabazian et al., 2012) proposed a scheme to avoid degradation of QoS requirement of calls. The scheme does pre-emption in two phases: partial and full. At the partial pre-emption phase, low priority calls and overloaded resources of high priority calls are pre-empted to their respective Guaranty Bit Rate (GBR) while at full pre-emption phase, all the resources assigned to low priority calls are degraded in priority order. When the resources obtained after the partial pre-emption are inadequate. If the resources are insufficient after the full pre-emption, the call is rejected. The scheme reduces the degradation of the QoS requirement of calls but it increases the call dropping Percentage of low priority calls.

The authors of (Priya & Franklin, 2012) proposed an Extensive Dynamic Bandwidth Allocation Call Admission Control (DBA-CAC) Scheme to reduce call dropping Percentage as well as ensuring QoS requirements of both NC and HC are satisfy. In the scheme, a prediction technique was introduced to reserve some resources for a call by considering its previous status. There are two phases in which the scheme operates, which are, the arrival and departure phases. Whenever there is a call request, the scheme degrades the existing NRT calls to admit the HCs and NCs that are in the queue. While at the departure phase, more resources are given to the NRT calls to maximize system utilization. In the event where there are not enough resources, the scheme degrades the NRT calls that were arranged in descending order to service the RT calls. While if there are enough resources, the RT calls are admitted, else, they will be blocked. Resource utilization is improved in the scheme as resources are regained whenever there is a call termination. However, the scheme failed to treat NRT calls fairly because of the degradation mechanism employed.

The authors of (Chowdhury et al., 2013) proposed an adaptive bandwidth allocation to improve QoS and reduce call drops as well as admitting calls based on a fair share of network resources. The scheme admits an NC or HC request based on their traffic class. The scheme degrades a certain amount of bandwidth from the ongoing NRT calls to admit more HC calls only while blocking the NC if the minimum allocated bandwidth to accept an NC is greater than the allocated bandwidth of already admitted calls. The scheme decreases HCDP and bandwidth utilization is maintained. But there is an increase in the NCBP because of the higher priority given to HCs.

Thus, in (Ali et al., 2015) an Adaptive CAC Scheme based on higher-order Markov chains was proposed to efficiently handle the new call Blocking Percentage (NCBP). The scheme deploys the Markov chain model for resource allocation every arrival call in a cell will be assigned a maximum value of resources, if the cell is overloaded, some of the calls (low priority calls) in the cell will receive lower resource blocks than the requested resource blocks. For the acceptance of an HC request the allocated resource blocks of some ongoing calls (low priority calls) will be degraded. The scheme reduces NCBP for each class of traffic and maintains resource utilization. However, low priority calls were treated unfairly because of the degradation scheme used which results in poor QoS.

A channel borrowing CAC scheme has been proposed in two-tier LTE/LTE-Advanced networks in (Omitola & Srivastava, 2017) to efficiently manage the low priority calls by employing a borrowing mechanism. The scheme supports NC and HC and further classifies them into RT and NRT in which the HCs were given more priority. A call is admitted when there are available resources, but in the case of no available resources, a channel borrowing is employed so that the NRT (low priority calls) can borrow from the reserved channel whenever it is not in use. This is by making sure that the HCs utilize the entire reserved channel anytime they arrive by preempting the NRT calls, thereby subjecting the NRT calls to wait in the queue. The scheme utilizes the available channel resources more efficiently and maintaining the QoS of HCs. It also decreases the call dropping and blocking percentages for NRT calls. However, the scheme causes an increase in the blocking rate of RT calls due to the strict prioritization of HCs.

The authors of (Omitola & Srivastava, 2019) proposed a Channel Borrowing CAC (CB-CAC) scheme in LTE/LTE-Advanced Femtocell-Macrocell networks to enhance the QoS of HC. The CB-CAC starts by identifying incoming calls as either NC or handoff calls. NCs are calls that are originated by UEs directly connected to the serving eNodeB, while HCs are ongoing calls for moving UEs that are being handed over from one eNodeB to another. A call can either be an RT or NRT call. Therefore, each NC and HC can be RT or NRT depending on the type of application from which the call is originated from. So, the scheme classifies calls as; NC-RT, NC-NRT, HC-RT, and HC-NRT. HCs are prioritized over NCs to ensure continuity of ongoing transmission. When calls arrive, the benchmark scheme reserves 20% of the total bandwidth and uses the remaining 80% to admit all calls regardless of their QoS affiliation. As soon as the bandwidth is exhausted, the reserved bandwidth is used to admit HCs. When there is no HC, the reserved bandwidth is used for NC-NRT. If an HC arrives when the reserved bandwidth is being used by NC-NRT, the CB-CAC preempts all NC-NRT calls using the reserved bandwidth, recovers their allocated bandwidth, and uses it to admit the incoming HC. The scheme utilizes the available channel bandwidth more efficiently and maintaining the QoS of HCs. It also decreases the call dropping and blocking percentages for NRT calls. However, the scheme causes an increase in the blocking rate of RT calls due to the strict prioritization of HCs. The scheme also causes a decrease in throughput because it reclaims the entire reserved bandwidth which may not be completely used by the incoming HCs.

In this paper, we proposed an Enhanced Channel

Borrowing Call Admission Control (ECB-CAC) scheme to improve the performance of (Omitola & Srivastava, 2019) by increasing throughput and reducing both the blocking and dropping rate of NRT NCs.

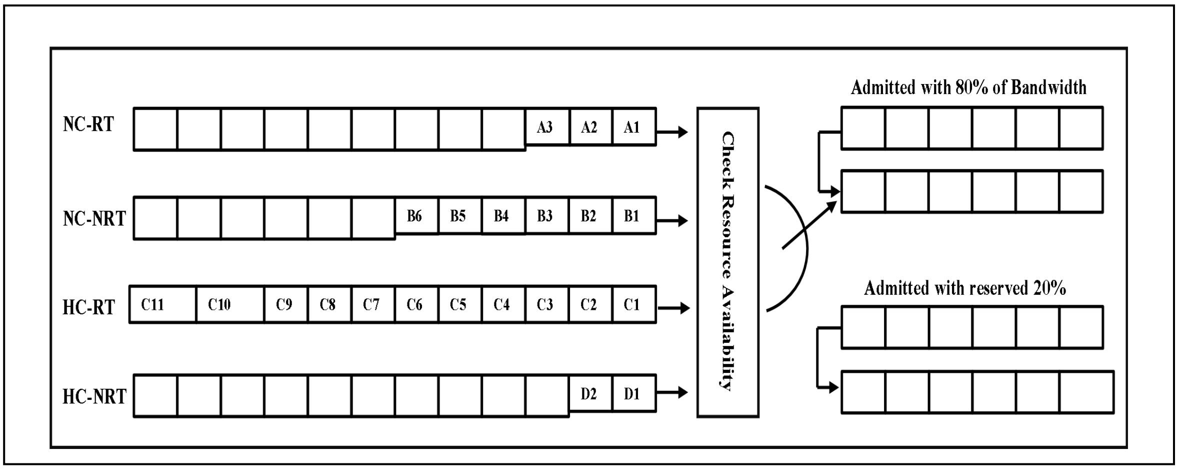

Fig. 1: The State of CB-CAC before call admission

2.1 Enhanced Channel Borrowing Call Admission Control (ECB-CAC) Scheme

This section describes the proposed ECB-CAC scheme. First, the weakness of the benchmark scheme (CB-CAC) is presented. The CB-CAC starts by identifying incoming calls as either new calls (NC) or handoff calls. NCs are calls that are originated by UEs directly connected to the serving eNodeB, while HCs are ongoing calls for moving UEs that are being handed over from one eNodeB to another. A call can either be an RT or NRT call. Therefore, each NC and HC can be RT or NRT depending on the type of application from which the call is originated from. So, the scheme classifies calls as; NC-RT,

NC-NRT, HC-RT and HC-NRT. HCs are prioritized over NCs to ensure continuity of ongoing transmission.

When calls arrive, the benchmark scheme reserves 20% of the total bandwidth and uses the remaining 80% to admit all calls regardless of their QoS affiliation (see Equations 1 and 2).

$$B_{reserved} = 0.2 B_{total} \quad (1)$$

Where $B_{reserved}$ is the reserved bandwidth for HC and B_{total} is the total system bandwidth

$$B_{available} = 0.8 B_{total} \quad (2)$$

Where $B_{available}$ is the available system bandwidth for all calls.

As soon as the bandwidth is exhausted, the reserved bandwidth is used to admit HCs. When there is no HC, the reserved bandwidth is used for NC-NRT. If an HC arrives when the reserved bandwidth is being used by NC-NRT, the CB-CAC preempts all NC-NRT calls using the reserved bandwidth, recovers their allocated bandwidth, and uses it to admit the incoming HC. For a clearer understanding of how the scheme works, Figures 1, 2, and 3 are used to demonstrate its operations.

Fig. 1 shows how calls are classified based on their type (HC or NC) and QoS (RT or NRT). For this example, we assume that each RT has a size of 66B and NRT has a size of 1500B. We also assume that the total system bandwidth is 10KB. Therefore, available bandwidth is 8KB and reserved bandwidth is 2KB. After admittingA1(NC-RT)→B1(NC-NRT)→C1(HC-RT)→D1(HC-NRT)→A2(NC-RT)→B2(NC-NRT→C2(HC-RT→D2(HC-NRT→A3(NC-RT→B3(NC-NRT)→C3(HC-RT) calls using the available bandwidth, the available bandwidth was exhausted. The scheme used the reserved bandwidth to admit the remaining HCs (C4→C5→C6→C7→C8→C9-→C10→C11) and one NC-NRT (B4). At this point, all bandwidth has been exhausted, and calls B5 and B6 are left unadmitted as shown in Fig. 2.

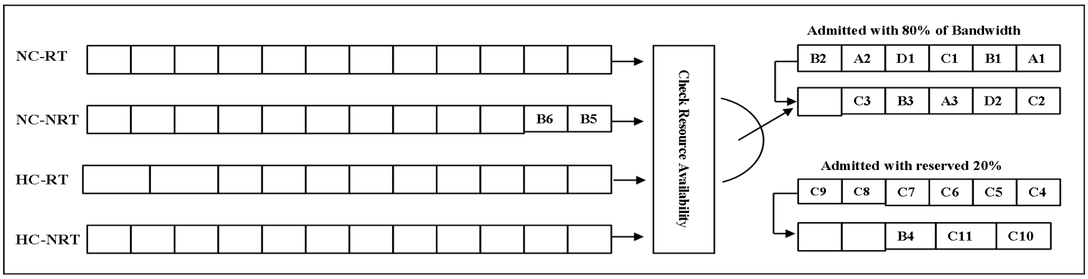

Fig. 2: The State of CB-CAC after call admission

When a new HC (C12) arrives (see Fig. 3), and there is no bandwidth enough to admit it, the scheme preempts the existing NC-NRT calls (B4) admitted using the reserved bandwidth. The allocated bandwidth to B4 is recovered and used to admit the incoming C12 as shown in Fig. 4.

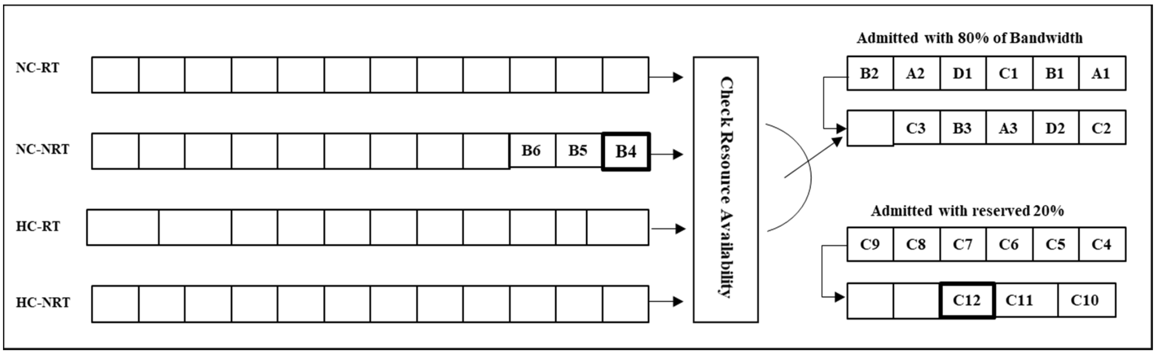

Fig. 3: Arrival of new HC-RT call

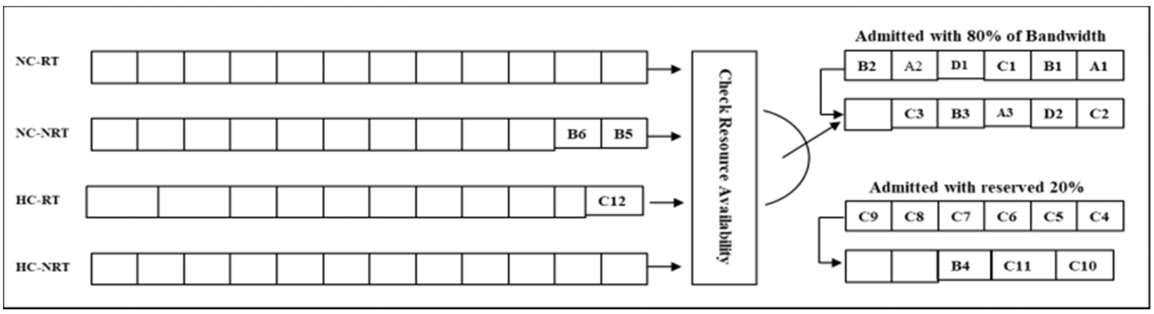

Fig. 4: Preemption of call B4 to Admit C12

Complete preemption of B4 causes wastage of the 1434B of the bandwidth. Because the size of C12 is 66B and that of B4 is 1500B. Therefore, the CB-CAC increases call dropping and blocking Percentage especially when there are more NCs compare to HCs.

To address the weakness identified in CB-CAC, this paper proposes an ECB-CAC that reclaims the exact bandwidth required by incoming HC from existing NC-NRT that was admitted using the reserved bandwidth. This way, compared to CB-CAC, the NC-NRT is not completely preempted. Also, the bandwidth will be properly utilized. However, total preemption occurs only when there are many incoming HCs with required bandwidth greater than or equal to bandwidth in use by the existing NC-NRT. Therefore, for an existing NC-NRT call to be preempted, Equation 3 has to be satisfied.

$$HC_{req}^{nrt} \leq \sum (B_{reserved}^{nc-nrt}) \qquad (3)$$

where HC_{req}^{nrt} is the bandwidth required by HC-NRT and $B_{reserved}^{nc-nrt}$ is the reserved bandwidth in used by NC-NRT.

Fig. 5 and Algorithm 1 further illustrate the operation of the scheme.

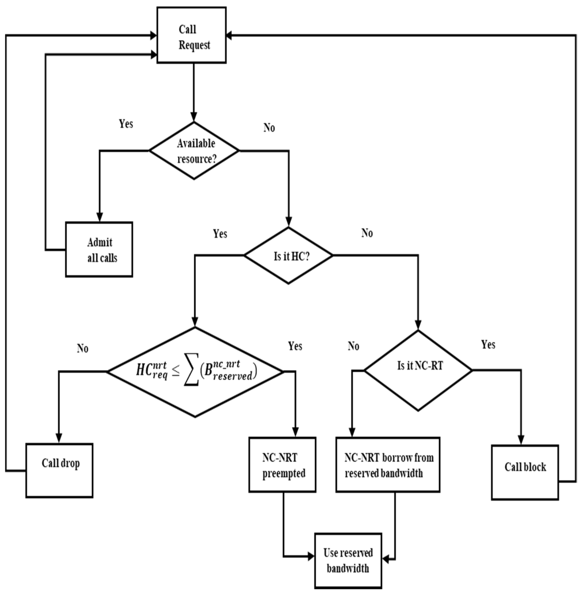

Fig. 5: Diagrammatic description of the ECB-CAC Algorithm

Algorithm 1 presents the pseudo-code for the ECB-CAC Scheme.

Algorithm 1: **ECB-CAC** algorithm

Input: NC/HC, RT, NRT, and Simulation Time
Initializations
While Transmission Time Interval is within Simulation Time
do
  for NC
    compute NC according to equation (2)
      if it is true **then**
admits NC
      else if it is NC-NRT
Borrow from reserved bandwidth
      else
don't borrow from reserved bandwidth
end if
  end for
  for HC
    compute HC based on equation (1)
      if equation 1 or 2 holds **then**
admits HC
else
Do not admit
      end if

22. **end for**
23. **end while**
24. **Output:** Connection of call

2.2 Performance Evaluation

Figure 6 depicts the simulation topology for comparing the performance of the two schemes i.e. the benchmark and ECB-CAC scheme. The Topology setup comprises one eNodeB, an application server, and some UEs connected to the eNodeB for different simulation setups. The server generates two traffics each from a different application. Each UE carries a single traffic type at a given time instance. Table 1 gives the simulation parameters used in the simulation process.

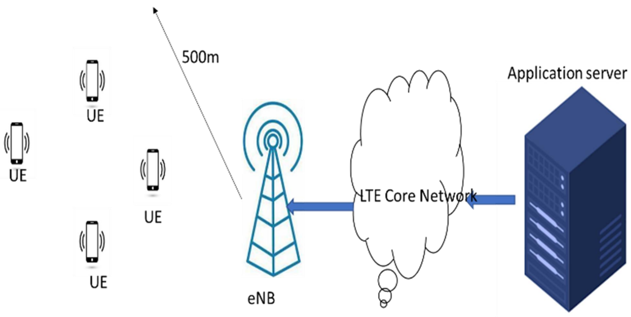

Fig. 6: Simulation Experiment Topology

Table 1: Simulation Parameters

Parameter	Value
System Bandwidth Capacity	10240B
Average call duration	150seconds
Call Arrival	Poisson Process
Simulation time	1000ms
Frequency	2Ghz
Number of UEs	4, 8, 12, 16, 20.
UE Speed	Varies
Cell Coverage	500m

The total bandwidth used for the simulation is 10240B,20% of the total bandwidth was reserved for the high priority calls while the remaining 80% to admit all calls. The total simulation time of 1000ms was used as adopted from the benchmark scheme with results obtained from 10 simulation trials and averaged. The simulation parameters used were also adopted from the benchmark scheme as shown in table 1 as different simulation experiments were conducted for 4, 8, 12, 16, and 20 UEs.

The result of throughput for NRT new originating calls is illustrated in Fig. 7 for both the proposed scheme and the benchmark scheme. The throughput initially was the same in the proposed scheme and benchmark scheme owing to the lower traffic intensity. However, as the traffic increases the proposed scheme admits more calls. This is because before pre-emption, the scheme checks if the reserved bandwidth in use by the NRT new originating calls is enough to admit the incoming HC otherwise there will be no pre-emption and the NRT new originating call would be left to continue using the reserved resource which increases the throughput of the NRT new originating calls. Therefore, there exist a difference of 15.83% between the benchmark scheme and the proposed scheme.

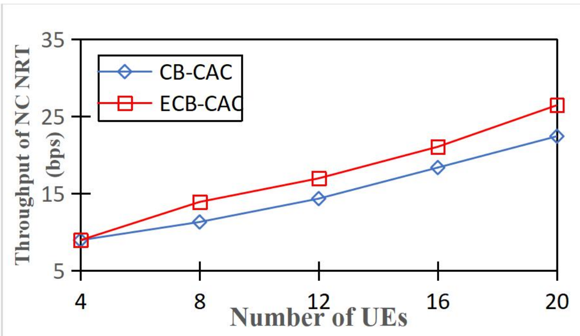

Fig. 7: Throughput Achieved by the two algorithms for NRT-NCs

Fig. 8 illustrates the dropping ratio achieved by the two schemes for NRT NC. It reveals that when the traffic intensity is low, both schemes drop almost the same amount of calls but when the traffic intensity is high, the ECB-CAC scheme drops fewer calls than the benchmark scheme. This is because the proposed scheme didn't pre-empt the NRT NC unless the reserved bandwidth in use by the NRT new call cannot be enough to admit the incoming HC. Thus, the ECB-CAC scheme reduces the dropping rate of NRT NC by 15.2%

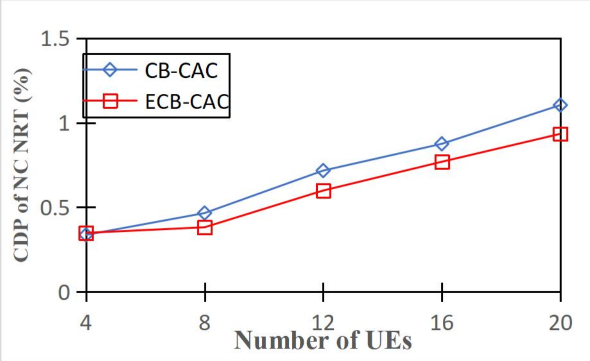

Fig. 8: CDP Achieved by the two algorithms for NRT-NC

The result of call blocking Percentage (CBP) for NRT new calls for both CB-CAC and ECB-CAC schemes is illustrated in fig. 9. It can be seen that when the traffic intensity is both low and high, the ECB-CAC blocks fewer NRT new calls than the benchmark scheme. This is as a result of the allocation and revoked mechanism introduced, which allocates the required number of bandwidths needed by the higher priority calls instead of allocating the whole reserved bandwidth. The ECB-CAC scheme has a CBP of 29.19% when compared with the benchmark scheme.

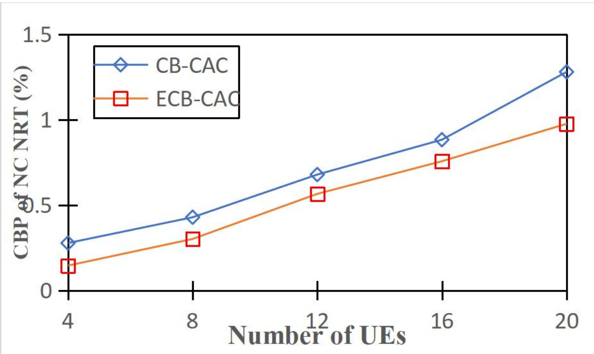

Fig. 9: CBP Achieved by the two algorithms for NRT-NC

3. Conclusion

In this paper, we proposed an enhanced channel borrowing CAC scheme to address the problem of reclaiming the entire reserved channel bandwidth which may not be completely used by the incoming call. The scheme employed a dynamic reserve channel allocation and revoke technique to reduce bandwidth wastage. The technique allocated the required number of channels to admit the incoming HC and thereby increasing throughput. A simulation experiment was carried out to evaluate the performance of the ECB-CAC scheme against the benchmark scheme using the Vienna LTE System Level Simulator. The simulation results indicate that the proposed scheme outperforms the existing scheme by increasing the throughput of NRT calls by 15.83%, decreases the CDP of NRT calls by 15.2%, and decreases the CBP by 29.19%. However, our scheme considers only a single cell with specific simulation parameters. Our future work is to extend the work by changing simulation parameters in a multi-cell model that allows us to evaluate if we can take advantage of the information of other cells to increase the system capacity and possibly reduce the blocking percentages as users may have service from a less congested cell.

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