Analysis of Call Admission Control Schemes for Long Term Evolution Networks

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Abstract—Network congestion is an issue of great concern to both network providers and users in all wireless communications systems. It adversely affects the Quality of Service (QoS) of the network thereby making the network providers lose some good fortune and leaving the users unsatisfied. This paper proposes to analyze some network congestion control schemes that depend on Call Admission Control (CAC) in Long Term Evolution (LTE) networks. The aim is to offer critically analyzed data to network providers in order to properly guide them in determining when and how to allocate the scarce radio resources to different calls. This is in a bid to minimize network congestion and ensure priority of very important calls. This paper adopts an analytical approach in the comparison of high profile CAC schemes and graphically displays the correlation. It uses resource utilization, Call Blocking Probability (CBP), Call Dropping Probability (CDP) and delay as the Key Performance Indicators (KPIs) to evaluate the performance of each of the schemes under consideration. The analytical results show that for resource utilization, “Call Admission Control for Two-Tier LTE Macro/Pico Cellular Networks” (CACM/P) scheme achieves about 97% utilization, followed by “An Efficient CAC scheme for LTE & LTE-A Networks” (ECAC) with 95%, then “Analytical Modeling of LTE-based Network Capacity for Public Safety Communications” (AM_LTE) with 60% and “Markov Model-based Adaptive CAC Scheme for 3GPP LTE Femtocell Networks” (MMACAC) with only 15% resource utilization. Considering CDP, MMACAC, ECAC, “An Adaptive Call Admission Control With Bandwidth Reservation for Downlink LTE Networks” (Ad_CAC) and “A reservation-based call admission control scheme and system modeling in 4G vehicular networks” (R_CAC) have 5%, 25%, 30% and 31% CDPs respectively. Similarly for CBP, MMCAC, ECAC, R_CAC and Ad_CAC schemes offer 6%, 27%, 45% and 49% CBP respectively. In terms of delay, “Allocation Algorithm based on CAC Scheme for LTE Network” (AA_CAC) offers 13.2%, “Users’ classification-based CAC with adaptive resource reservation for LTE-A networks” (UC_CAC) produces 24.8% and AM_LTE gives 97.8% delay for high priority calls.

Keywwords— Call Admission Control, Call Blocking Probability, Call dropping Probability, Congestion control, Delay, Long Term Evolution, Resource utilization

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1 INTRODUCTION

Wireless communications networks in general suffer some forms of setbacks such as insecurity, congestion among other issues. Network congestion occurs when there are inadequate network resources to cater for all the users requesting for network resources at a given time. Consequently, it gives rise to system overload leading to reduced QoS of the individual calls in the network or overall network failure [15]. In an uncontrolled wireless network, every call is entitled to compete for the verily scarce network resources. LTE network as a wireless and fourth generation network is not immune from network congestion. In LTE network, congestion is controlled at the access point of the network (eNodeB) using the CAC schemes. The figure below shows the general physical architecture of a typical LTE network.

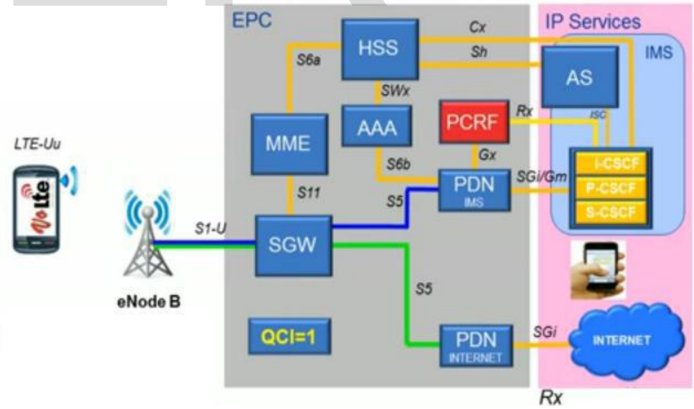

Fig.1: LTE Physical Architecture [20]

Interestingly, every call in a network is not of equal importance to the network users and the network providers and similarly, their call-holding times are different. LTE network allows for sharing of the network resources across the users in a manner defined by the network provider using CAC. Traditionally, CAC is a Radio Resource Management (RRM) scheme that can be used to proactively control congestion at the access point of a network [15], thereby giving priority to any calls the network providers choose. CAC ensures the QoS of the already admitted calls in LTE networks. Fig. 2 below shows eNodeB with admitted and admission seeking calls.

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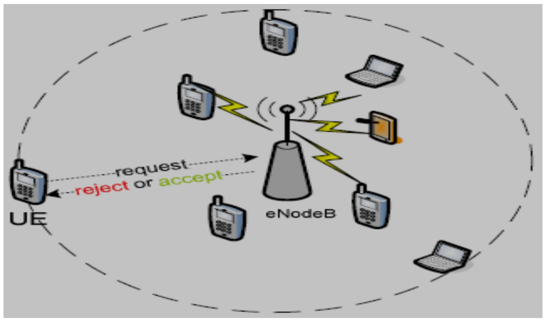

Fig. 2: Architecture of eNodeB with different UE [9]

This paper aims at analyzing various CAC Schemes in LTE networks using different QoS parameters as KPIs. The remaining parts of this paper are organized as follows: section II presents related literature to the study, section III discusses the research methodology while section IV presents the results alongside their discussions and finally section V draws the conclusion of this paper.

2 RELATED LITERATURE

In [1] the authors state that LTE-based Public Safety Networks (PSNs) can easily get congested since some of the resources are used to provide priority for public safety calls. The paper formulates an admission control scheme that selectively handles the admission of PSN calls into the commercial LTE in a congested network [1]. It uses an approach that, during congestion, it allows resources to be reserved for users with good channel quality whereas users with bad channel quality are denied access to the network [1]. In order to evaluate the channel quality of the bearers, Signal-to-Interference-plus-Noise Ratio (SINR) is used in [1] as defined in (1).

$$SINR_{m,d}(x,y) = \frac{p_d}{I + N_0} \tag{1}$$

Where Pd represents the received power from the base station d, the total interference power of other base stations is represented by I and N0 is the additive white Gaussian noise. The findings indicate that the developed scheme enhances throughput by 36%, reduces the rate of rejection by 73% compared with its reference scheme and thereby utilizes the resources very well.

Poor QoS and Grade of Service (GoS) are usually the aftermath of network congestion and they make users dissatisfied [2]. The authors outline some CAC techniques available and show how each could be employed to address a particular objective in any applications. In [2], the authors explain that when packet k is sent from UE, i to eNodeB j, the delay is calculated as given in (2).

$$D_{ij}^{k} = T_{arrival}^{k} - T_{departure}^{k} \tag{2}$$

In [2], throughput is defined as expressed in (3) below.

$$R_i = \frac{\sum_{k=1}^{N}\sum_{l=1}^{M} x_i}{T_{sum}} \tag{3}$$

Where x_i is the number of bits received correctly and T_{sum} is the sum of Transmission Time Interval (TTI) which forms the simulation time. In LTE networks, CAC policy is based on the criterion expressed in (4) [2]:

$$\sum_{k=1}^{m} N_k + N_{new} \le N_{total} \tag{4}$$

Where N_{total} is total system Physical Resource Blocks (PRBs) and N_k and N_{new} are the number of PRBs per TTI needed by active calls and incoming calls respectively. In [2], the authors conclude that in many cases, CAC is joined with other radio resource management techniques for an informed solution.

Lately, reservation-based and bandwidth degradation schemes have become inefficient because of their modeling approach which starves low priority calls such as best effort (BE) calls [3]. These schemes underutilize network resources which leads to starvation of BE traffic. In [3], the authors propose a new CAC scheme that uses an adaptive threshold value to vary the resources in a congested network scenario so as to address resource underutilization issue and that of starvation of BE traffic. The paper uses bandwidth reservation and degradation methods in order to allow higher number of users into the network even in the face of resource scarcity. Bandwidth degradation is employed when there is insufficient bandwidth in the network to meet up with the users' needs. The degradation for each class j is given in [3] as expressed in (5).

$$BW_j^{\deg raded} = BW_i^{\max} - D_j^{level} \tag{5}$$

Where $BW_j^{\deg raded}$ represents the degradable bandwidth for j class, $BW_j^{\max}$ is the available bandwidth while D_j^{level} is the current level of degradation. So the maximum size of degradable bandwidth is given in [3] as shown in (6) below.

$$BW_j^{\deg size} = \frac{BW_i^{\max} - BW_i^{\min}}{D_j^{level}} \tag{6}$$

Where $BW_j^{\deg size}$ denotes the maximum size of degradable bandwidth for j th class, $BW_i^{\min}$ is the minimum bandwidth available. The results indicate that the proposed model in [3] outperforms its reference model in the areas of number of admitted users and QoS [3].

For some years, many CAC algorithms have been developed to meet up with the increasing needs of the users so as to manage users' requests in LTE networks properly [4]. The paper [4], reviews the existing schemes and classifies them into four various groups. The following are the groups: "Bandwidth Reservation (BR), Bandwidth Degradation (BD), BR and BD and Non-BR and Non-BD (NBR-NBD)" [4]. The aim of the review is to expose some open issues in CAC formulation for future research. For every class, the method of operation, the merits and demerits are given for each scheme. It also presents a comparative analysis of the schemes in question. The result of the analysis shows a clearer picture of the problems inherent in CAC formulation [4].

In [5], a CAC scheme for LTE networks that allows multimedia services with various categories of traffic is proposed. Before admitting any call, the scheme categorizes such a call into either a real time or a non-real time call, predicts the quality of the channel using the received signal strength (RSS). It eventually marks the call either as a new call (NC) or a handover call before deciding on its admission status [5]. It also allows preemption of low priority call in order to prioritize more important calls. The channel quality is usually calculated using Signal–to–Interference plus Noise Ratio of the User Equipment (UE) as shown below [5].

$$SINR_n = P_n^s / (N_0 x W_{sc} + \sum\nolimits_{i \neq s} P_n^i) \qquad (7)$$

Where n is the index of the subcarrier, P_n^s is the received power from the serving eNodeB for subcarrier n, N_o is the noise density and W_{sc} is frequency spacing. For every user equipment (UE), the effective Signal–to–Interference plus Noise Ratio is used to measure the channel quality and it is expressed in [5] as given in (8) below.

$$SINR_{eff} = 2^{MIC} - 1 \qquad (8)$$

Where MIC is evaluated by taking the mean capacity of all N subcarriers of PRB as given in (9) below [5]:

$$MIC = 1/N \sum\nolimits_{n=1}^{N} \log_2(1 + SINR) \qquad (9)$$

The result shows an increased number of accepted high priority users with improved system throughput [5].

Many CAC schemes lack maximum traffic delay tolerance [6]. Because of that, the author of [6] proposes an efficient CAC algorithm that allows for adjustment of user priority depending on network situation, user category and delay tolerance of the traffic. The aim is to maximize both bandwidth utilization and operators' profit. Mathematical models are used to formulate the problem. The total blocking probability for a k-type call is the summation of the normal blocking probability and the timeout probability and is given in (10) [6] as:

$$TBP_k = TP_k + BP_k \qquad (10)$$

In [6], system utilization is defined as given in (11):

$$U = \frac{N_c}{N} \qquad (11)$$

Where (N_C) is the mean number of total currently occupied RBs and (N) is the sum total of the number of RBs in a radio frame. The mean queue delay for k request type W_k is expressed in (12) [6] as:

$$W_k = \frac{\text{sum waiting time of request k}}{Total \text{ no of arrived request k}} \qquad (12)$$

From the results of the simulation, the proposed scheme outperforms its reference scheme since it is able to strike a balance among QoS provisioning, system utilization and users' privileges as given by network operators [6].

In [7], the authors propose a "users' classification-based call admission control with adaptive resource reservation for LTE-A networks". The aim is to improve resource utilization and enhance revenue generation. It adopts an approach that dynamically assigns resource blocks to a user depending on the class of the user and the user's QoS need in form of maximum delay tolerance. The users are grouped either as Golden users or Silver users and the service of each user is categorized as real time (RT) and non-real time (NRT) services [7]. The author defines total blocking probability, system utilization and queue delay as given in (10), (11) and (12) respectively. The results show that the paper strikes a good balance among system utilization, users' privileges and QoS when compared with its reference model [7].

The authors in [8] propose an adaptive CAC algorithm which depends on higher order Markov chains to properly manage CBP in LTE-based femtocell networks. Such a network allows multimedia services that have various traffic classes with varying resource needs. In [8], the blocking probability $P_{b,new,i}$ for a new call is given as in (13) below:

$$P_{b,new,i} = \sum_{s \in sb_{new,i}} P(s) \qquad (13)$$

In a similar way, the call dropping probability is also give in [8] as:

$$P_{d,han,i} = \sum_{s \in sd_{han,i}} P(s) \qquad (14)$$

The authors of [8] define the system utilization U as in (15):

$$U = \sum_{j=1}^{J} U_i \qquad (15)$$

The analytical results indicate that an insignificant CBP can be achieved using the proposed algorithm with no compromise on bandwidth utilization.

In [9], a new LTE CAC algorithm is proposed which categorizes calls into handover and new calls (HCs and NCs). The algorithm prioritizes handover calls during admission and with some levels of regards for new calls in order to ensure QoS and avoid congestion in the network. The paper aims at meeting the packet delay needs of HC and NC for both Guaranteed Bit Rate (GBR) and Non Guaranteed Bit Rate (NGBR) traffic types. The scheme accepts or rejects a new call depending on its QoS needs. The result from the simulation indicates that the algorithm does well in the areas of resource utilization and call dropping probability.

The authors in [10] present a mathematical method of evaluating the capacity of a network for voice traffic in public safety networks that depend on LTE. Markov birth and death processes are used in their network modeling. To guarantee the needed GoS for the network users, the least amount of bandwidth needed for various priority categories of users is evaluated using the expression below [10].

$$B = C x B_w x R \qquad (16)$$

Where C is the capacity of the carrier per cell site, B_w is channel bandwidth and R is reuse factor. In a similar way, the delay T_d suffered by traffic is expressed in [10] as shown in (17)

$$T_d = \frac{Pd_{N_{k(>0)}} x T_h}{N_k(1-\rho N_k)} \tag{17}$$

Where $\rho N_k = \frac{N_c}{N_k}$ is utilization of channel

According to the authors, the results obtain from the study share some common attributes and differences when compared with its reference model.

CAC is useful in minimizing network congestion and ensuring QoS for call requests by accepting or rejecting a call depending on available network resources [11]. The authors in [11] propose a new CAC and bandwidth allocation algorithms with the CAC scheme prioritizing Handoff Calls (HC) over new calls, though with some regards for New Calls (NC). The allocation algorithm is interested in ensuring good throughput and fair resource allocation. The paper aims at guaranteeing QoS and avoiding network congestion. In [11] the system throughput is evaluated as given in (18):

$$th_{sys} = \frac{B}{T_{sim}} \tag{18}$$

Where B is number of successfully transmitted bits and T_{sim} is the total simulation time. It is stated that the fairness index of the system is calculated using Jain's formula and this index is defined as given in (19) [11].

$$F(\square_1, \square_2, \ldots, \square_n) = \frac{(\sum_{j=1}^{n} \square_j)^2}{n x \sum_{j=1}^{n} (\square_j)^2} \tag{19}$$

Where n is the total number of UE and $\square_j$ is the amount of resources allocated to user j.

From the simulation results in [11], the proposed algorithms indicate improvement in the areas of call blocking probability, call dropping probability, delay, number of users served, system throughput and fairness index.

Many CAC schemes exist in LTE networks, addressing different network issues such as radio resource availability, diversity of services [12]. Due to inadequacy of the exiting schemes, the authors in [12] propose a new algorithm named "Efficient Bandwidth CAC (EB_CAC)". The scheme accounts for QoS, improved resource utilization and at the same time enhances the level of satisfaction of users. The algorithm accepts real time (RT) handover calls regardless of congestion status of the network and channel quality. It turns the congestion thresholds to favor both calls with good channel quality and RT calls without starving non-real time calls. The results of the simulation in [12] show that the proposed scheme does better than its reference schemes in the aspects of system throughput and number of admitted real time users.

With Device-to-Device (D2D) communications, UEs in a close range can share pieces of information [13]. For devices to communicate among themselves, the bandwidth resources are needed. A good admission control (AC) algorithm with radio resource allocation (RRA) scheme is useful in avoiding co-channel interference and guarantee QoS. In [13], the authors propose a joint AC and RRA scheme which ensures a lasting QoS support to UE and D2D information exchange. The aim is to optimize revenue for the service provider and provide QoS to the already admitted users. Channels and transmission powers are temporarily allocated to the already admitted users by the RRA scheme. Later, a simple RRA scheme is also used to unbundle the channel and power assignment. The results indicates that the proposed scheme performs better than existing ones by improving cellular and D2D connections to 40% and decreasing power consumption by at least 50% [13].

Two-tier networks having LTE as a high range network and Picocells as low range networks with low power can be economically viable in improving the capacity of LTE-A network [14]. In [14], the authors propose a two-tier CAC algorithm that integrates LTE-A/Picocells so as to maximize resource utilization and guarantee improved blocking and dropping probabilities. The metric parameters used are the total loss probability and utilization of the system. Total loss probability, PL_T is the summation of blocking probability of a call and the timeout probability of unblocked calls of the same kind. It is described in [14] as expressed in (20).

$$PL_T = BP_T + (1 - BP_T)TP_T \tag{20}$$

Where BP_T is the blocking probability, TP_T is the timeout probability. Also, the resource utilization U is given in [14] as shown in (21).

$$U = \frac{\sum all \text{ occupied RBs}}{Total \text{ cell load capacity}} \tag{21}$$

The proposed CAC algorithm is compared and evaluated in single and two-tier LTE-A networks [14]. The findings indicate that with the two-tier CAC scheme, resource utilization is high while the blocking probability is significantly reduced [14].

Previously proposed CAC algorithms allow resource reservation for prioritized calls in mobile networks but sometimes the reserved resources end up being wasted particularly if none of the prioritized calls comes [15]. The authors in [15] propose a bandwidth borrowing mechanism that allows low priority calls (best effort calls-BE) to borrow from the reserved resources with the agreement to relinquish same on arrival of a high priority call. If a BE call is preempted, it will be put on queue only to start its service when there is an available bandwidth. The paper aims at modeling an algorithm and determining its workability using CBP and CDP. From the system models of [15], CBP and CDP are derived mathematically and the CDP is as expressed in (22) below:

$$CDP = \sum_{\substack{(n_1,n_2,n_3):n_2+n_3<C-T \\ n_1+n_2+n_3=c}} P(n_1, n_2, n_3) \tag{22}$$

The finding shows that the resource borrowing scheme reduces the CBP reasonably but with little increase in CDP [15]. The results of the proposed algorithm are almost same with those of its reference model.

In [16], the authors propose a CAC mechanism that uses signal-to interference plus noise ratio (SINR) in "LTE Heterogeneous Broadband Wireless Access Network (Het-BWA-Nets)". A Mathematical model that operates on Continuous Time Markov Chain (CTMC)' is developed to measure the functionality of the proposed algorithm using CBP, CDP, Connection Outage Probability (COP) and resource Utilization. The new CBP and Handover CDP are given in (23) and (24) respectively [16].

$$NCBP\_class = \sum_{s=s_{iB}}^{s=s_{kB}} \pi(i, j, k)(s) \tag{23}$$

$$HCBP\_class = \sum_{s=s_{iD}}^{s=s_{kD}} \pi(i, j, k)(s) \tag{24}$$

Where $s = s_{iB}$ and $s = s_{iD}$ represent the steady state probabilities of the different states. Also the bandwidth utilization is given in [16] as expressed in (25).

$$U = \frac{\sum_{s \in s} (i.B_j + j.B_j^{\max} + k.B_k^{\min})\pi(i, j, k)}{B} \tag{25}$$

The proposed algorithm offers nice improvements in CBP, CDP, and COP and with 76.70% enhancement in system resource utilization [16].

The enormous volume of users with their ever-growing demands in LTE networks is an issue of consideration in terms of QoS provisioning [17]. To guarantee the QoS required by users in the face of limited network resources, the authors of [17] propose a CAC algorithm whose decision is fuzzy-based. The algorithm works with the available network resource blocks and assigns additional ones if need be. The users are classified into three depending on the requested services. The classification is done immediately a user makes a request. The results show that the scheme in [17] does better than other existing schemes in the aspect of call drops, cell power, throughput and delay with 328, 44.2071dBm, 1,294,932bps and 0.1103s respectively. The scheme shows the least call blocking probability of 0.0527 for handover calls and 0.2901 for new calls. For handover calls and new calls, it offers a call dropping probability of 0.0528 and 0.3357 respectively [17].

So many requests from various user devices can cause serious network congestion in LTE networks [18]. Also, many congestion control schemes have been defined by 3GPP but without laid down settings and modalities in 3GPP standards, thereby leaving it open for network operators to determine. In [18], the authors propose two congestion management schemes that effectively minimize network congestion. The paper uses acceptance ratio, overload degree and waiting time as its metric parameters. The mean waiting time, $\bar{w}_{t_i}$ of a request in a network entity during t_i is expressed in (28) as [18]:

$$\bar{w}_{t_i} = \frac{\bar{Q}_{t_i} + N_c}{\lambda_{t_i}(1 - P_{t_i}(K))} \tag{26}$$

Where average number of requests is $\bar{Q}_{t_i}$, N_c is number of requests to be served, P_{t_i} is probability of having j requests at time t, λ_{t_i} is arrived requests during time.

The findings from the simulation show that the proposed scheme has 20-40% enhancement in terms of acceptance ratio, degree of overload and waiting time compared to its reference scheme [18].

The improvement in wireless communications system has given rise to increased number of users of the network [19]. The network providers are faced with the issue of providing diverse services to the teeming users of the network with good QoS in mind and revenue generation in view. In [19], the authors propose an integrated scheme which combines all the existing schemes into one called "CACTOR". The scheme is intelligently built to adjust according to the changing needs of the users [19].

3 METHODOLOGY

This research work adopts a comparative approach in its analysis of some high performing CAC schemes for LTE networks as a means of congestion control. The schemes involved in this research work follow a given pattern of classifying calls into real time and non-real time calls. All the CAC schemes adhere to the simple underlying principle that guides the use of CAC scheme. The principle is mathematically explained in (4) above. The approach includes first, picking some schemes with the most relevant KPIs to this study are and sorting the schemes out according to the levels of improvement shown by their results. In each scheme, the x and y coordinates of every graph representing each of the various parameters is read using a tool called WebPlotDigitizer-4.2 (version 4.2). The reading is done for every single individual parameter in each of the schemes involved. The data generated from this reading are used in the simulation of the schemes. The simulation (representation) is carried out using python3 programming language through a python Integrated Development Environment (IDE) software for windows operating system called PyCharm – community edition, version 2019.3.1 x64.

The graphs of this study are plotted using software called MatPlotLib which combines some features of MATLAB with those of Python programming language. The same PyCharm IDE serves as the interface between the authors and the MatPlotLib software. In order to achieve accurate results, the authors assume the schemes to have a common basis of comparison in terms of equal number of admitted calls at any given time. This is very necessary to ensure that there is little or no room for errors while taking the measurement, despite the minor variations that exist.

Fig.3 below shows the general LTE model used in this study.

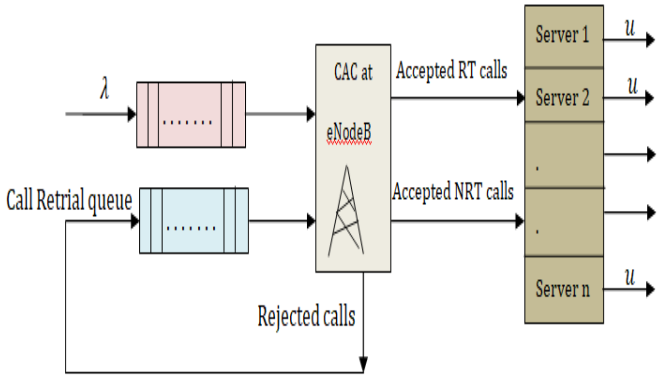

Fig. 3: The common LTE model for the schemes

The algorithm otherwise called the pseudo codes used in this research paper is written in python3 programming language and is as show below. Here, if a scheme has any of the KPIs, it is represented with 1 and if not, it is represented with 0. If result is improved, it is represented with 1 and 0 if otherwise. The same idea is used for availability of data and graphicness.

The algorithm

```
if (scheme==1):
    Consider it for analysis
        if (results==1):
            It has the necessary potentials for analysis
        elif (data availability==1):
            Further scrutinize it
        elif (graphicness ==1)
            Accept it and plot its graph on the x-y planes
        else:
            It does not have all the qualities necessary for the
                analysis
else:
    Reject the scheme for analysis.
```

The flowchart accompanying the algorithm is as shown in fig.4 below.

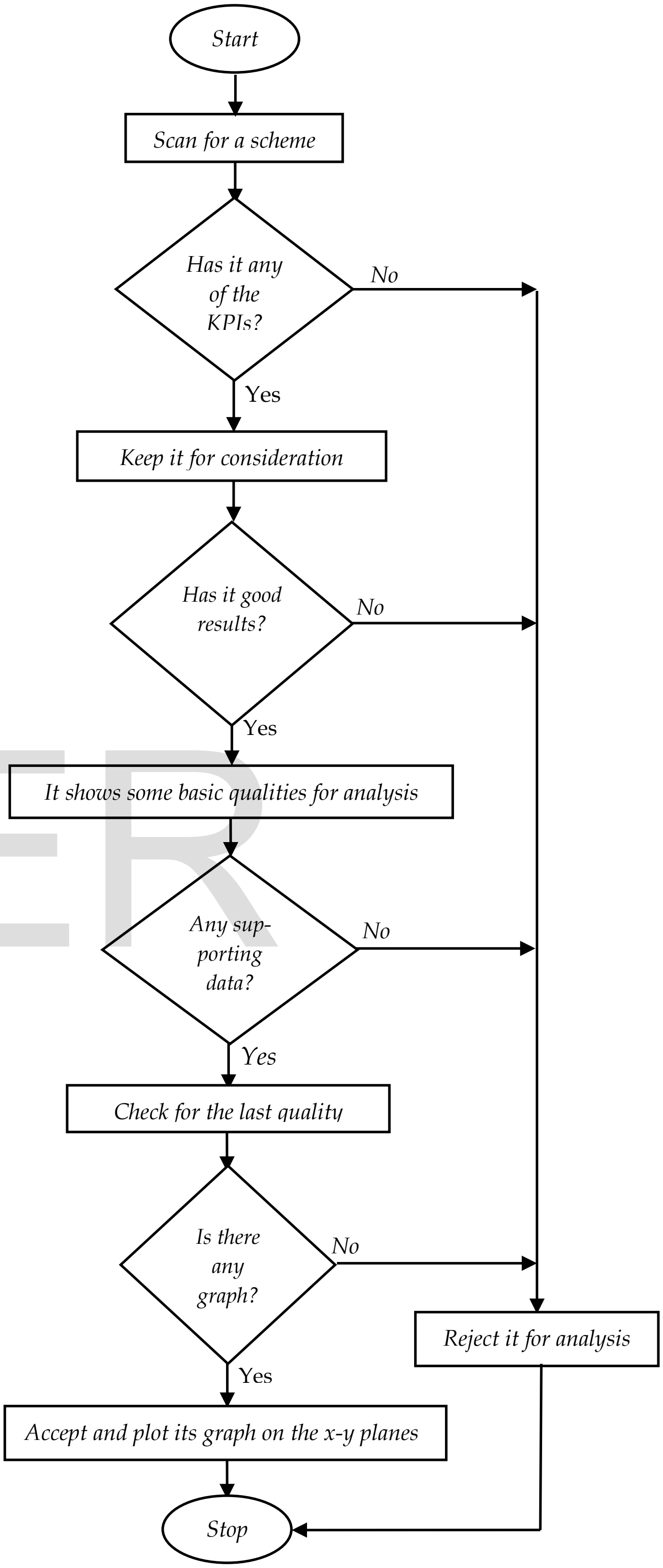

Fig. 4: The model flowchart

4 THE RESULTS AND DISCUSSION

The results of the simulation of the various schemes under consideration and their accompanying discussions are presented in this section.

4.1 The Simulation Parameters

In order to compare the performance of the schemes, the simulation parameters are generated from the various data of the different schemes under considered. Detailed information on the configuration of the parameters is given in tables 1 to 4 below. In the tables below, x1,…xn represent the variables on x-axes while y1,…yn represent the variables on the y-axes of each graph.

For resource utilization, the data are presented as shown in table 1 and the accompanying graphs are plotted as given in fig. 5.

Table 1. Radio Resource Utilization

MMACAC		CAC/MP		AMLTE		ECAC	
x1	y1	x2	y2	x3	y3	x4	y4
00	0.00	04	0.00	00	0.26	00	0.00
20	0.12	20	0.78	20	0.36	20	0.58
40	0.14	40	0.95	40	0.36	40	0.76
60	0.14	60	0.96	60	0.41	60	0.77
80	0.15	80	0.97	80	0.45	80	0.83
100	0.15	100	0.98	100	0.51	100	0.90
120	0.15	120	0.98	120	0.60	120	0.95

Table 2 shows the data for Call Dropping Probabilities of the different schemes and their graphs are given in fig. 6 below.

Table 2: Call Dropping Probabilities

MMACAC		Ad_CAC		R-CAC		ECAC	
x1	y1	x2	y2	x1	y1	x2	y2
0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2.0	0.00	2.0	0.03	2.0	0.26	2.0	0.00
4.0	0.01	4.0	0.05	4.0	0.28	4.0	0.10
6.0	0.03	6.0	0.10	6.0	0.29	6.0	0.15
8.0	0.04	8.0	0.18	8.0	0.31	8.0	0.22
10.0	0.05	10.0	0.30	10.0	0.31	10.0	0.25

Table 3 below presents the data generated from the Call Blocking Probabilities of the different schemes and the accompanying graphs are shown in fig. 7.

Table 3: Call Blocking Probability

MMACAC		Ad_CAC		R-CAC		ECAC	
x1	y1	x2	y2	x3	y3	x4	y4
0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2.0	0.02	2.0	0.03	2.0	0.10	2.0	0.00
4.0	0.03	4.0	0.07	4.0	0.22	4.0	0.20
6.0	0.04	6.0	0.15	6.0	0.30	6.0	0.22
8.0	0.06	8.0	0.27	8.0	0.37	8.0	0.25
10.0	0.06	10.0	0.49	10.0	0.45	10.0	0.27

The data extracted from the schemes for the analysis of delay are as displayed in table 4 and their graphs are in fig. 8 below.

Table4. Delay

AM_LTE		AA_CAC		UC_CAC	
x1	y1	x2	y2	x3	y3
00	0.00	10	1.03	06	0.00
20	0.55	20	1.04	19	0.00
53	2.47	40	1.14	27	0.12
60	3.00	60	1.26	53	0.93
86	4.90	80	1.30	80	1.57
100	7.02	100	1.32	107	2.16
120	9.78	120	1.32	120	2.48

4.2 Performance Results

In the areas of resource utilization, fig. 5 below shows the graphical comparison of the following schemes; CACM/P, AM_LTE, MMACAC and ECAC.

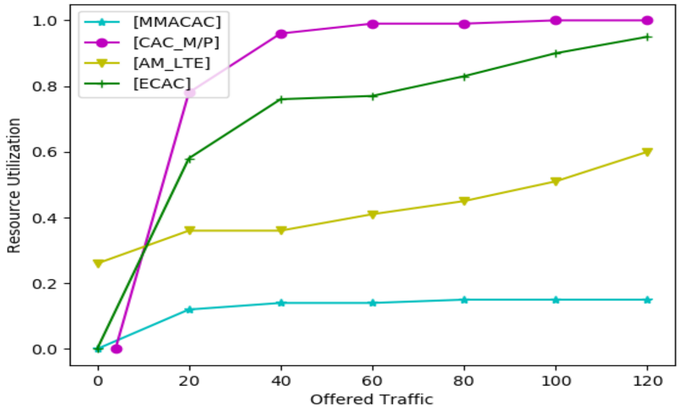

Fig. 5: Resource Utilization against Number of Users

The analytical results show that in resource utilization, CACM/P scheme achieves about 97% resource utilization, followed by ECAC with 95%, then AM_LTE with 60% and MMACAC scheme presents the worst case scenario with only 15% resource utilization.

Considering Call Dropping Probabilities, Ad_CAC, R_CAC, MMACAC and ECAC schemes are compared as shown in fig. 6 below.

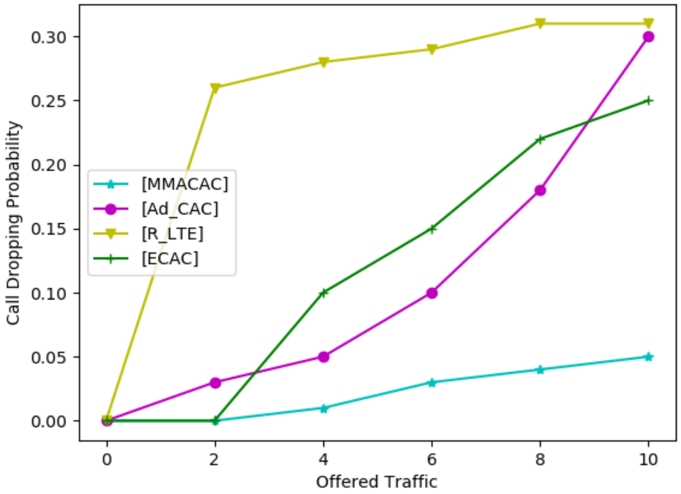

Fig. 6: Call Dropping Probability versus number of users

The results proved that for Call Dropping Probabilities, MMCAC, ECAC, Ad_CAC and R_CAC have 5%, 25%, 30% and 31% Call Dropping Probabilities respectively.

The graphical display of the schemes compared in terms of CBP is shown in figure 7 with the Ad_CAC, R_CAC, MMACAC and ECAC schemes being featured.

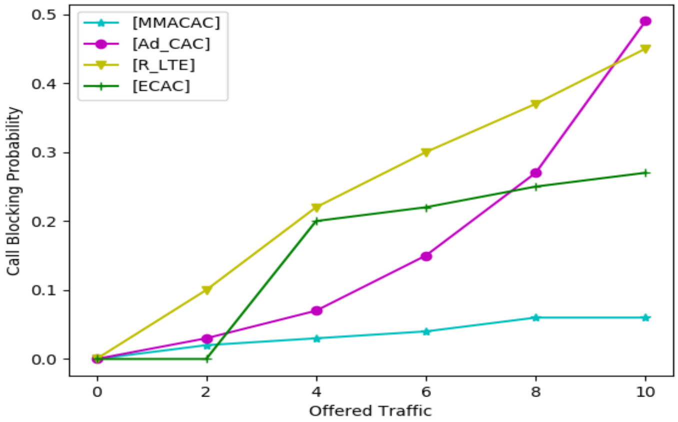

Fig. 7: Call Blocking Probability against number of users

Similarly for CBP, MMCAC has the best performance with 6% CBP followed by ECAC with 27%, R_CAC with 45% and lastly Ad_CAC with 49% CBP. Fig. 7 shows their performances.

Fig. 8 below shows the relationship among AA_CAC, UC_CAC and AM_LTE schemes in terms of delay.

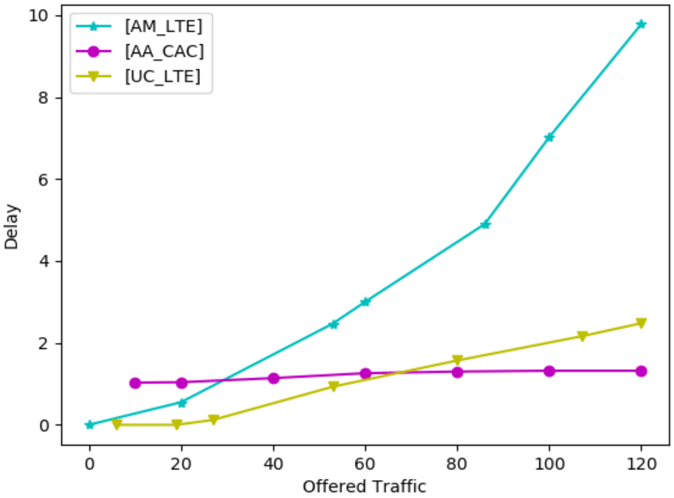

Fig. 8: Delay against number of users

From the result, AA_CAC scheme offers 13.2% followed by UC_CAC with 24.8% and the worst is AM_LTE scheme with 97.8% delay for high priority calls.

Most of the schemes reviewed are not fair to BE calls and they include: [1], [5], [6], [7], [8], [9], [10], [13], [14], [15], [16], [17], [18] and [19]. Those that are fair to BE calls are: [3] and [11]. The scheme considered in [20] is only good in terms of architecture, [4] is concerned with mere review and [10] talks about Public Safety Networks.

5 CONCLUSION

This paper proposed the analysis of key network congestion management schemes that rely on Call Admission Control (CAC) in LTE networks. The aim was to offer critically analyzed data to network providers in order to guide them properly in determining when and how to allocate the scarce radio resources to different calls. The motivation for this paper was to minimize network congestion and ensure priority of very important calls. A comparative analytical method was adopted as the approach for analyzing the schemes, using resource utilization, CDP, CBP and delay as the metric parameters. The analytical results showed that CACM/P scheme achieved about 97% resource utilization; MMCAC scheme offered the best performance in terms of Call Blocking and Dropping Probabilities with only 5% for CDP and 6% for CBP. Considering delay, AA_CAC scheme offered the least delay with 13.2% for high priority calls. From the results of this research, it could be implied that, there is no scheme with 100% performance guarantee for any of the Key Performance Indicators (KPI), meaning that there is always room for a tradeoff among the KPIs for a hybridized scheme to be achieved. Unfortunately, none of the schemes considered has developed any efficient approach on how to dynamically prioritize Public Safety Networks (PSNs) using threshold algorithm for LTE-based PSNs. A preemptive CAC scheme for LTE-based Public Safety Networks would be considered as a future topic of our research.

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