Load balancing call admission control algorithm (CACA) based on soft-handover in 5G Networks

Aymen I. Zreikat,
College of Engineering and Technology
American University of the Middle East
Kuwait
aymen.zreikat@aum.edu.kw

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***Abstract*— Soft-Handover or connected-before-break is a procedure where the user equipment (UE) is always connected to the radio link with no need for synchronization with adjacent cells. Therefore, the user equipment (UE) is connected softly with more than one NodeB at the same time. Due to many reasons such as orthogonality in long-term evolution (LTE), which is based on orthogonal frequency division multiplexing (OFDM), soft-handover is not supported by fourth-generation (4G) systems. On the other hand, 5G systems can support seamless soft-handover between the original cell and neighboring cells. To guarantee a seamless handover in 5G systems with an acceptable quality of service (QoS) for end-users, an intelligent call admission control (CACA) algorithm should be provided. Therefore, a new multi-cell CACA is 5G systems is presented in this paper. The presented CACA is taken into consideration the "cell breathing" phenomena that cause the overloaded cell coverage to shrink. The admission of the user is based on a minimum bit rate to be achieved, a maximum distance from the base station, and a maximum number of active users in the cell. Considering different interference factor values, the presented numerical results reveal the effectiveness of the suggested CACA in balancing the load over the whole network by transferring the traffic from overloaded cells to the neighboring cells with less load, and hence, the overall network performance is improved. To validate the effectiveness of the CACA, some comparative results are shown with and without applying the proposed CACA.**

Keywords—Call Admission Control Algorithms (CACA), Soft-handover, 5G Networks, cell breathing, load balancing.

I. Introduction

In the past few decades, mobile and wireless communication technologies have had an enormous effect on human life in different aspects. However, many significant research challenges still need to be considered and addressed before the deployment of the new technology [1] such as 5G. 5G stands for the 5th generation mobile networks that are evolving very fast technology to be the new era after 1G, 2G, 3G, and 4G. The expected design of this network is to provide customers with up-to-date technology that connects people and devices everywhere, anytime. This new technology is supposed to provide end-users with a multi-Gbps data rate with higher capacity, low latency, new services, and improved network performance. The new specification of the 5G standard is being discussed by the third generation partnership group (3GPP) release-18 which is supposed to be finalized by end of 2021 [2]. Besides, 5G NR (New Radio) is a new radio access technology developed by the 3GPP-38 series for the 5G mobile network. It was designed to be the global standard for the air interface of 5G networks.

In the past years, handover techniques are used several times in the literature [3]. There are two procedures in the handover process. The first one is called hard handover where the mobile station (on-call) is connected only with one cell station, if the handover is needed then the mobile station needs to switch into a new cell with a different frequency. On the other hand, in soft handover, the mobile station (on-call) is connected simultaneously to more than base stations, and therefore, when the handover procedure is needed then the mobile station will switch automatically to the new base station working on the same frequency.

As an extensive effort done by mobile operators to maximize spectral efficiency while maintaining acceptable QoS levels in the network, real challenges are related to the deployment of traffic between macro-cells and other small cells in the network in heterogeneous wireless networks. This status will create a new issue called cell breathing where the coverage of the cell is reduced due to traffic offloading between cells or user requirements or channel conditions. Therefore, a based-soft handover call admission control algorithm is needed to take into consideration this issue while balancing the load all over the whole network.

II. Related Work

Soft and hard handovers in mobile communication systems have been studied intensively in the literature from different prospective and in different generations of mobile networks. Early studies [4-8] have discussed this issue in 5G systems. In [4], an intelligent handover algorithm is suggested for the best decision of handover process using mobile ultra-high-definition video streaming while using mobile cameras in environmental surveillance. The comparative results show that the suggested algorithm improves throughput, latency, and packet loss during the switching process. A dual connectivity principle for mobile equipment (ME) is suggested in [5] based on the deep learning principle to make the mobile station connected and receive a signal from more than one base station at the same time. This procedure will guarantee a better quality of service for mobile users since the deployment of small cells will increase the occurred number of handovers and therefore better management of handover procedures is needed. The given numerical results show that the proposed scenario improves the throughput and BER gain and hence improves the QoS for end-users. A heterogeneous mobile-based network management algorithm is suggested in [6] to guarantee a seamless handover process and effective use of network resources between users. The proposed internet device is based on the Telematics principle to connect heterogeneous networks in different environments. A 5G control/user (C/U) decoupled plane algorithm in railway heterogeneous systems is suggested in [7] to overcome the increase of capacity demand in railway systems. The algorithm is based on the following principle; while the C-plane handover procedure occurs in macro-cells, the U-plane of small cells will have a smooth soft-handover process without any interruption. The same procedure is repeated for U-plane where C-plane will have in turn a smooth handover process. Low outage probability results are gained while authors apply this scheme.

Recent studies [9-12] have discussed this issue from different aspects. In [9] the authors take advantage of the 5G architecture where serving gateway (SGW) and packet data gateway (PGW) is responsible for all control functions. Therefore, they have developed an algorithm to consider the trade-off between SGW controller and handover frequency within some constraints on latency levels. The demonstrated results show that this algorithm minimizes the number of handovers between different SGW controllers. Due to some limitations in the handover process in multi-cell cellular systems concerning interference, transmission power, and eNodeBs status, the authors in [10] suggested a cooperative approach called time division of arrival to handle the handover process based on calculating the distance between the source and destination cell to find the suitable neighboring cell to perform the handover. The demonstrated results prove that the suggested algorithm outperforms other proposed algorithms in the literature. The authors in [11] suggested a mobility management algorithm to handle rebinding-based hard-handover and multi-homing-based soft handover to solve the mobility issues during the handover process. This approach is evaluated via round trip time, throughput, and packet loss parameters. Based on this approach, the numerical results show that mobility issues in heterogeneous networks can be solved without any need to reconfigure the end-to-end session. To void poor received signal and interference issues in 5G networks, the authors in [12] have suggested a new wide-band mmWave approach to take advantage of the mmWave properties where the cell is divided into two areas, the inner one is served by microwave band and the outer one is served by mmWave band. Compared to other approaches, the suggested scheme improves cell coverage and reduces interference levels.

III. SYSTEM MODEL

A. Model Assumptions

1. 5G multi-cell structure is shown in the analysis, however, the simulation is applied on a single cell scenario where the cell is divided into three virtual zones with maximum capacity given to the whole cell. The total cell capacity is given to the inner zone as it represents a dense urban area with dense traffic. Half of the capacity is given to zone 2 which represents an urban area and the final 25% of the traffic is given to zone 3 which represents a suburban area.

2. The arrival to the cell is assumed to Poisson with arrival rate, λ. The traffic load is considered in the simulation concerning the area of the zones ($\alpha_i * \lambda$, $i = 1 ... zone\ i$), and the concentration of users in the cell.

3. Based on [13], a cyclic prefix-based OFDM waveform is assumed for broad separation of the signals.

4. The analysis is based on the soft handover principle in 5G networks where the user equipment (UE) is connected softly with more than one NodeB at the same time as shown in Fig. 1. Considering that the signals will be communicated but no resources will be allocated until the UE is fulfilling the admission requirements defined by NodeB that are expressed in our model as minimum bit rate threshold and minimum distance. Multi-cell deployment is assumed in this research work as shown in Figure 1 where the user equipment (UE) is softly connected with more than one NodeB at the same time, however, during the soft handover process, UE will be connected only to one NodeB based on the strongest signal which is calculated in the model based on a threshold of minimum bit rate, minimum distance and interference levels between the cell and other neighboring cells.

5. The interference level, ε is calculated based on the basic noise and the interference caused by the non-orthogonality of the codes. Also, a service factor parameter, S is considered in the analysis which represents the ratio of the spreading factor of the codes concerning the required signal-to-noise ratio of this service (i.e. S= SF/SNR).

B. Capacity Analysis

The capacity bounds are derived in [14] assuming an ideal free space propagation. The maximum transmission power of the UE is limited and dependent on the interference levels and the number of active users in the cell. Therefore, the maximum distance, *dmax* is derived which represents the distance between the UE and the base station that should be satisfied to achieve the required QoS for end-users. The maximum distance is a function of the number of active users in the cell, n, because based on cell breathing phenomena, for an additional user to be accepted in the cell the cell coverage will be reduced and when the user leaves the cell, the coverage will be increased again. Therefore, *dmax* and can be defined as:

$$d_{max}(n) = \frac{\lambda}{4\pi} \cdot \sqrt{\frac{P_{Smax}}{N_0} \cdot (S - (n-1) \cdot \varepsilon\ )} \quad (1)$$

Where

λ is the wavelength

P_{Smax} is the maximum transmission power of the UE

N_0 is the thermal noise.

S is the spreading factor (the ratio between the bandwidth of the user signal and the transmit bandwidth) = SF/SNR.

ε is the interference factor.

Assuming that the cell coverage is defined by a radius, r then the maximum number of active users in the cell can be defined as:

$$n_{max}{}^{(r)} = \left(\left(S - \frac{N_0 \cdot (4\pi r)^2}{P_{Smax} \cdot (\lambda)^2} \right) \cdot \varepsilon \right) + 1 \quad (2)$$

A. Call Admission Control Algorithm (CACA)

The call admission control algorithm is based on the soft-handover principle. It includes the following five steps that are shown in Fig. 3:

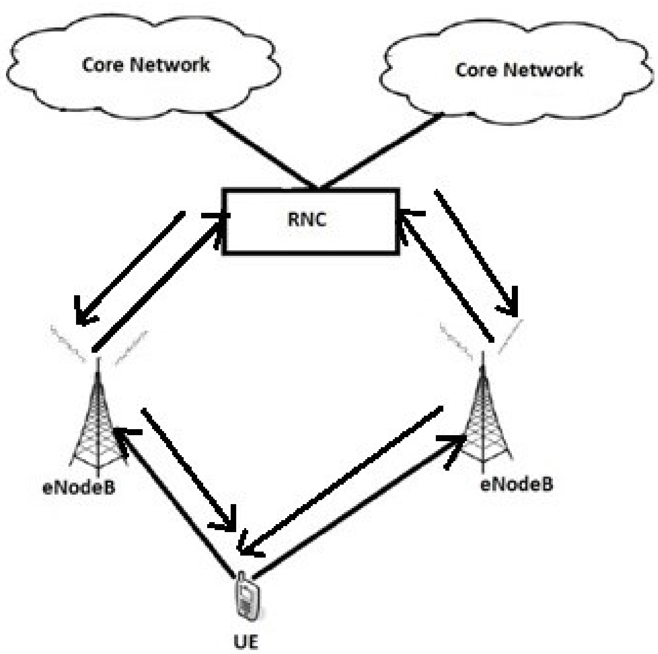

Fig. 1: Soft-Handover principle

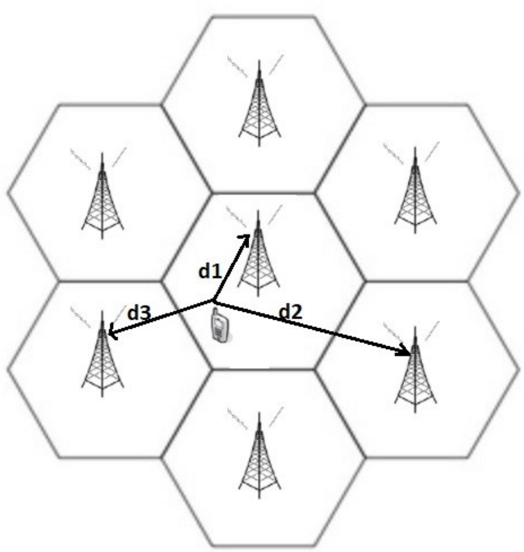

Fig. 2: Multi-cell deployment

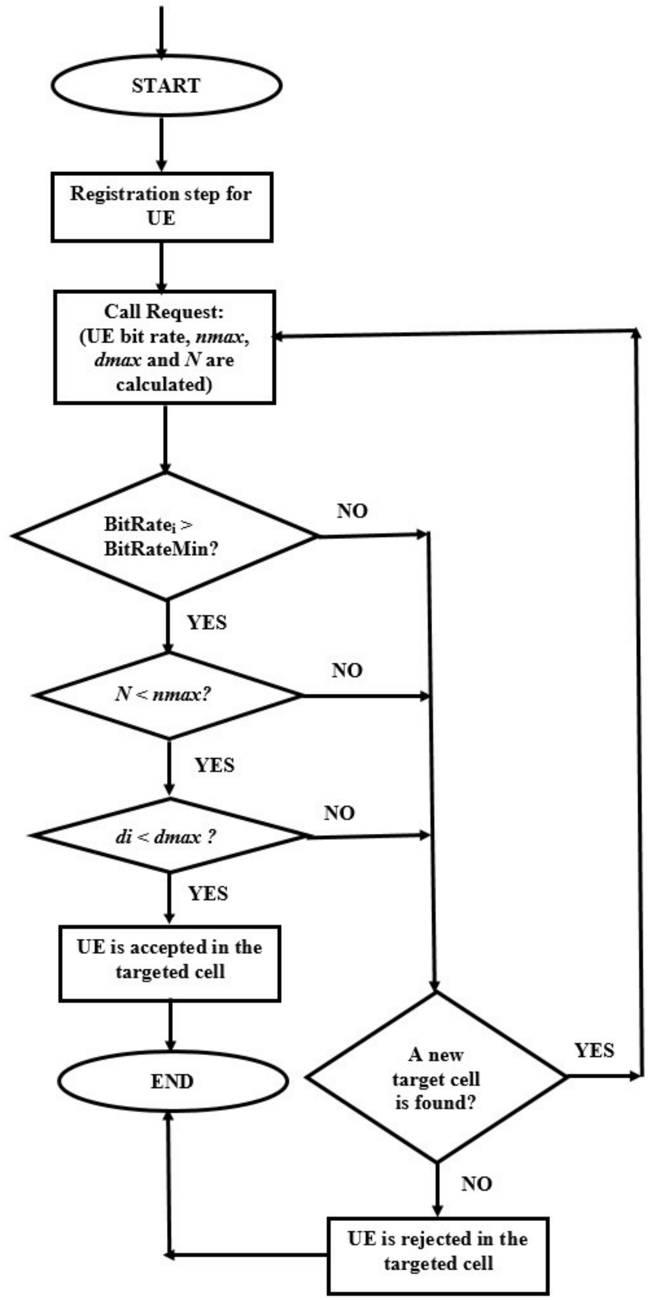

Fig. 3: Flowchart for the CACA

Step 1. (Registration step) UE should register by measuring the signal power to all accessible NodeBs. Then UE will select the best three signals to connect to.

Step 2. (Admission step) assuming the given structure in Fig. 2 and based on the soft-handover principle, the UE will be connected to more than NodeB at the same time. According to Fig. 2, UE is connected with three NodeBs but no exchange of resources will take place until the UE satisfies the requirements for admission in either of the NodeBs. There are three conditions for UE to be accepted in the cell:

1. A minimum bit rate, *BitRateMin* is defined in the cell, UE is admitted if the bit rate of this connection is greater than

the threshold minimum bit rate to be satisfied. This means; if Bitrate is the bit rate of user *i* then:

If $(Bitrate_i > BitRateMin)$

2. After accepting this admission, the number of active users in the cell, N should be less than nmax:

If $(N < nmax)$

3. If the distance of the candidate user, *di* after admission is less than the maximum distance, *dmax.* If the UE satisfies the above three conditions, then go to step 4 else go to step 3.

Step 3. (Try other cells step) assume that the UE did not satisfy the above three conditions in step 2 then UE will be transferred to another cell and step 2 for admission will be repeated. If a new cell is found go back to step 2, else go to step 5.

Step 4. (Accept the call) the call be accepted. Go to step 6.

Step 5. (Reject the call) the call will be rejected. Go to step 6.

Step 6. End.

IV. SIMULATION RESULTS WITH DISCUSSIONS

The simulation results are produced by the MOSEL-2 simulation language [15]. The modeling specification and evaluation language, MOSEL is developed by the MOSEL group which I belong to at the department of computer science 5, University of Erlangen, Germany. MOSEL package is under LINUX operating system. Attached to the MOSEL package, Intermediate Graphical Language (IGL) software which is responsible for preparing the figures in a pleasant shape. Besides, with IGL it is possible to save the figures in encapsulated postscript version (.eps) or (.pdf) to be easily accessed by windows. Fig. 4 demonstrates the six steps of modeling specification and evaluation that are taken by MOSEL-2 to model the proposed CACA and find the presented results in this section. Besides, the simulation parameters are given in Table 1.

TABLE 1. SIMULATION PARAMETERS

Parameter	Value
Number of zones /cell	3
Number of codes, *N*	64
Average Session Size, *ASS*	71 Kbytes
Maximum cell capacity	100 Mbit/s
Service Factor, *S=SF/SNR*	32
Cell radius, *r*	4 km, 7 km, 10 km
Assumed minimum bit rate in the cell (threshold)	10 Mbit/s
Spreading factor, *SF*	64 chips/symbol
Maximum transmission power, *Psmax*	125 *mW*
Basic Noise, N_0	-80 *dBm*
Signal to noise ratio, SNR	2 *dB*
Interference factor, ε	0.40, 0.60, 0.70,0.90
Poisson duration, $1/\mu$	100 s
Max bit rate	Zone 1-100 Mbit/s, Zone 2-50 Mbit/s, Zone 3-25 Mbit/s

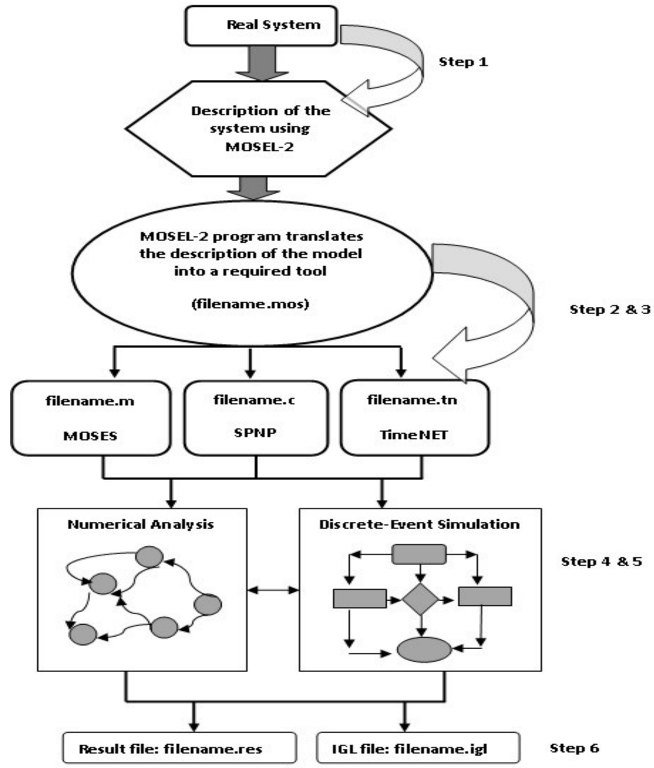

Fig. 4: Modeling and evaluation steps by MOSEL-2

The analysis is divided into three groups. The figures demonstrate network performance for different performance parameters such as blocking probability, utilization, delay, average bit rate, throughput, and the system capacity which is demonstrated by the maximum number of active users in the cell. The performance parameters are shown in the figures against different interference factors, ε in one group of results (Fig. 5-9), against cell radius, *r* in the second group of results (Fig. 10-12) and the comparative group of results are from Fig. 13 to Fig. 15 to compare the network performance with and without applying the proposed CACA. In Fig. 5, the blocking probability is shown at different values of ε. One can notice that the blocking probability is increased when ε is high (i.e. 0.90), it reaches 0.0008 at a maximum offer bit rate of 262 Mbit/s. On the other hand, at the same rate, it reaches 0.0004 when the interference factor is 0.40. Therefore, when ε is high, more users will be blocked in the system because more calls will be transferred to the neighboring cells. Similar behavior is shown in Fig. 6 for the delay figure. For example, at a bit rate of 52 Mbit/s with a high interference value ($\varepsilon = 0.90$), the delay is 1 *ms*, decreased to around 0.25 *ms* at higher rates. Nevertheless, the delay measures are still within the acceptable limits given by 3GPP. Ideal delay values are given at lower values of ε (0.40 and 0.60). For example, when $\varepsilon = 0.40$, optimal delay values are shown at different bit rates (around 0.12 *ms*). Again, when the interference level increased between users, more calls will be forwarded from the current cell to other neighboring cells and therefore, the number of handovers are increased. The effect of ε is also reflected in the cell average bit rate in Fig. 7

and the utilization in Fig. 8. When a few number of users are in the cell (i.e. when traffic is low), the average bit rate in the cell is high (i.e. around 10 Mbit/s). When the traffic load increases, the number of requests increases which causes an increase in the interference level between users, and therefore, the average bit rate decreases. In Fig. 8, below 122 Mbit/s bit rate the interference level makes difference in the cell utilization, afterward (i.e. above 122 Mbit/s), the load will be balanced over the whole network and therefore, the interference effect will be minimized at different levels. As a result of this, cell utilization reaches a stable value at different bit rate values no matter the interference factor value is. However, the average bit rate is still achieved regardless of the interference levels as the CACA is balancing the load between different cells and therefore, the capacity of the network is maximized in ideal conditions where the interference level is low as shown in Fig. 9. At a low interference value (i.e. ε = 0.40), the number of active users in the cell starts at 30 users at a low bit rate and reaches 70 users at high bit rate values. The same capacity of 30 users is achieved at the maximum bit rate when the interference factor level increased to 70 % or 90 %. Fig. 9 shows that the interference factor has a major influence on the network capacity and therefore, this factor should be eliminated to maximize the network capacity.

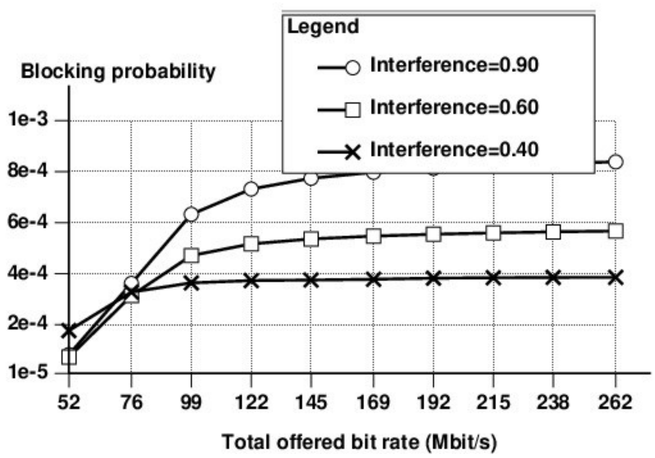

Fig. 5: Blocking probability for different interference factors, ε

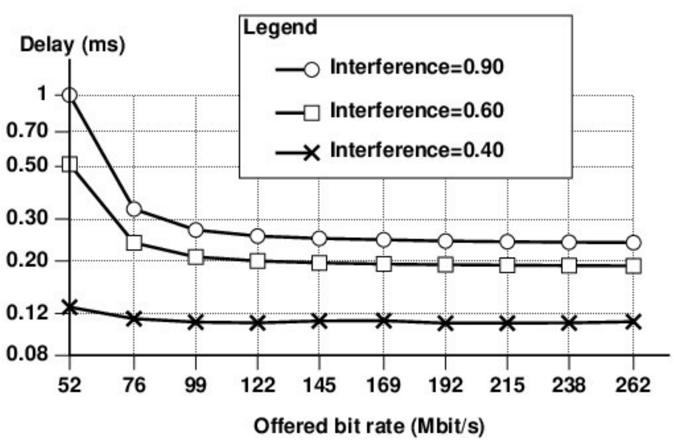

Fig. 6: Delay for different interference factors, ε

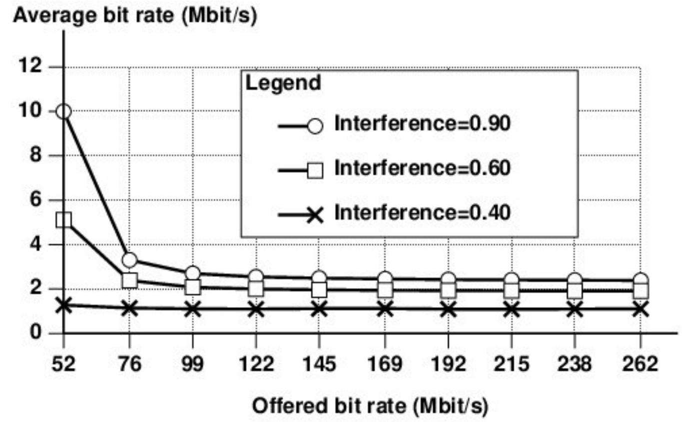

Fig. 7: Average bit rate for different interference factors, ε

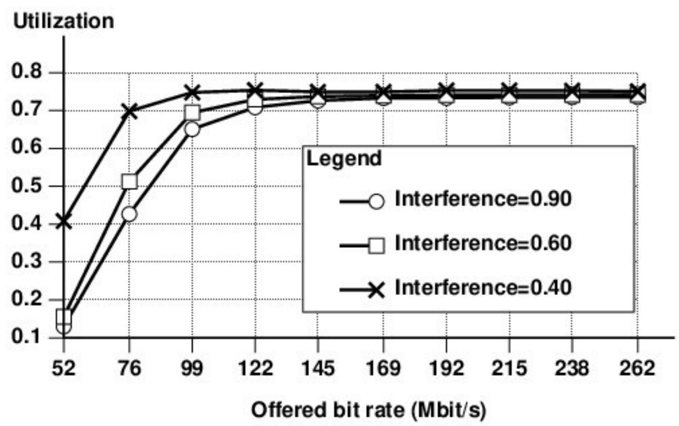

Fig. 8: Utilization for different interference factors, ε

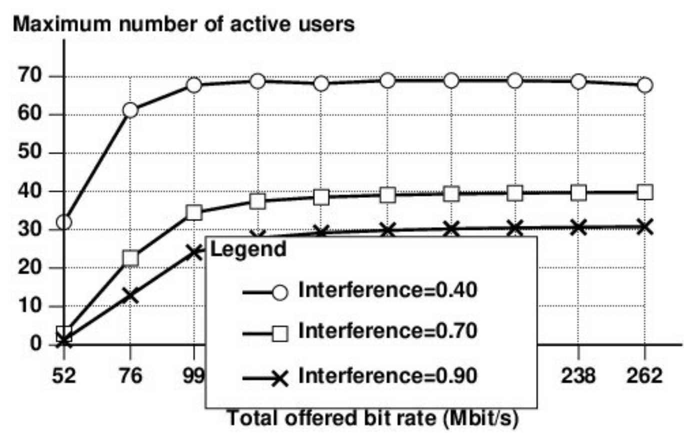

Fig. 9: Utilization for different interference factors, ε

The second group of results (Fig. 10- Fig. 12) evaluates the network performance for different cell radius, *r* values. Looking at Fig. 10, one can notice that when the radius of the cell is small (4 *km*), ideal values of the blocking probability are achieved. This means that because the cell is small in size, the number of users is low and therefore, the CACA will transfer small number of users from the current cell. As a result of this, cell breathing phenomena that cause the coverage of the cell to be shrink, is avoided. Now, this status will not occur with bigger size cells. When the cell radius is large, then the cell can serve more users without affecting the cell coverage. In all the above circumstances, the CACA can maximize the network performance at different cell radiuses as shown in Fig. 11 and Fig. 12. The utilization figure is shown in Fig. 11. It is obvious now that the CACA works effectively at higher bit rates. As you can see in Fig. 11, changing the size of the cell matters only when the requested bit rate is small (i.e. < 122 Mbit/s) because when the bit rate is increased, the cell will be overloaded with traffic and therefore, the CACA starts working to distribute the load before the cell breathing phenomena occurs. Minimum delay results are achieved in Fig.12 when the radius of the cell is small. This is realistic because with a small radius, the cell needs to serve a fewer number of users and therefore, the coverage of the cell is preserved.

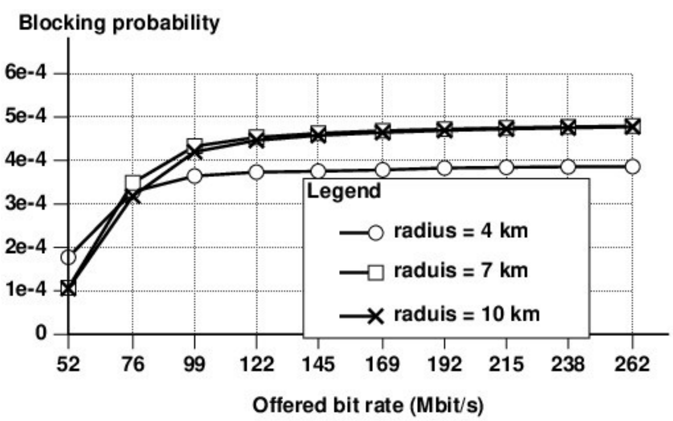

Fig. 10. Blocking probability for different cell radius, *r* values.

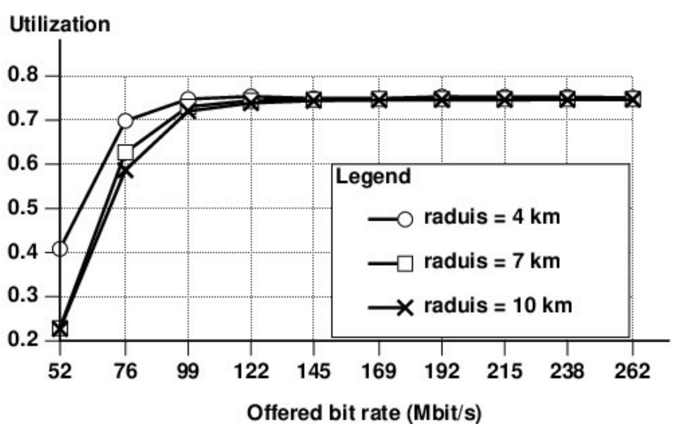

Fig. 11. Utilization for different cell radius, *r* values.

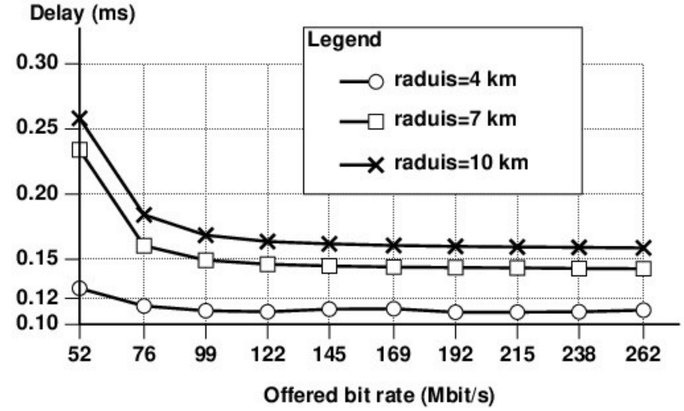

Fig. 12. Delay for different cell radius, *r* values.

To validate the results, figures from 13 to 15 show comparative results for blocking probability, delay, and throughput with and without applying the CACA. Without applying the CACA means that the CACA is only based on the threshold minimum bit rate and ignoring other factors that are considered in the proposed CACA. Looking at Fig. 13, one can notice that at a lower rate (< 122 Mbit/s) the CACA does not work properly as the number of handovers that occur will be at a minimum rate, when the traffic increases, the probability that handovers occur increases. Therefore, above 122 Mbit/s the CACA starts working effectively. Fig. 14 shows that delay results are maintained at all traffic rates even if no handovers are occurring as the CACA is working in all circumstances on balancing the load over the whole network. The overall improved cell performance can be noticed from Fig. 15 where the cell throughput is maximized at different traffic rates. Starts with 40 Mbit/s at a lower bit rate, reaches around 77 Mbit/s at higher bit rate values.

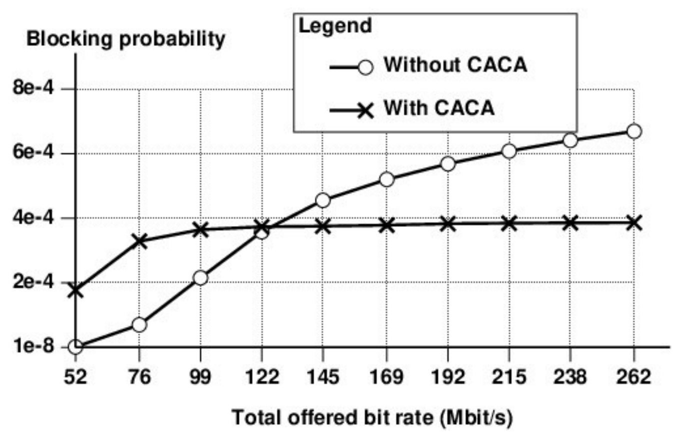

Fig. 13. Blocking probability-comparative results

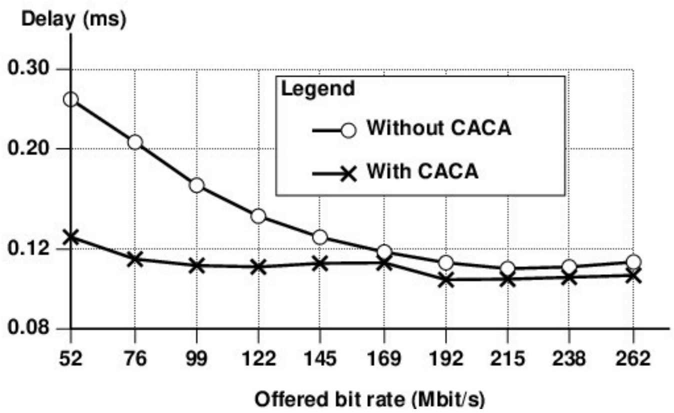

Fig. 14. Delay-comparative results

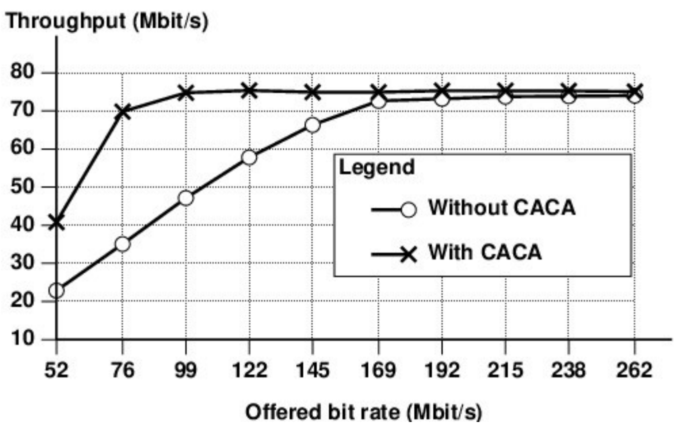

Fig. 15. Throughput-comparative results

V. CONCLUSION AND FUTURE WORK

An intelligent multi-cell CACA is proposed in this research work to assure a seamless soft handover procedure in 5G systems. The CACA limits the user admission based on three conditions; a threshold value for a minimum bit rate to be achieved, a maximum distance, *dmax* from the base station, and a maximum number of active users in the cell, *nmax*. Considering different interference levels, the presented numerical results reveal the effectiveness of the suggested CACA in balancing the load over the whole network by transferring the traffic from overloaded cells to the neighboring cells with less load, and hence, the overall network performance is improved. To validate the effectiveness of the CACA, some comparative results are shown with and without applying the proposed CACA. In future work, different traffic scenarios can be suggested such as homogeneous traffic distribution over all cells. Besides, in an extended version of this work, different propagation environments can be studied, therefore, the environmental factors for urban, suburban, and rural will be included in the capacity formulas to study the system in more realistic environments.

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