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Mobile Basestations as a Capacity Enhancement Approach to Improve the Fairness of Traffic in LTE Networks

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***Abstract*— The incredible increase in wireless data traffic makes it crucial to search for approaches to further improve spectrally efficient systems such as LTE networks in low bands using advanced spectral efficiency techniques. Limitations on hardware implementation and channel conditions, as well as the increase in system complexity due to the use of advanced techniques, may lead to limits on the viability of such approaches. To solve the problem of growing usage of wireless data, capacity enhancement approaches are considered, such as moving up in frequency into the unused spectrum in which huge bandwidths are available. Comparing with approaches that rely on the use of highly complex techniques, moving up frequency may be a promising approach to guaranteeing the fairness of traffic and achieving high data rates. A capacity enhancement approach to enhancing fairness of traffic in LTE networks by utilising the unused bandwidths of idle or less dense basestations toward crowded areas by dynamic mobility of basestations is proposed in this paper. The approach is empirically tested to show the easy evolution to higher system capacities and improve the spectral efficiency where data demands further increase. A simulation method is utilised in this paper, and the simulation is carried out using an NS2 simulator, and the results presented in the simulation section are based upon a number of runs.**

Keywords—LTE; Mobile Basestation; Capicity Enhancement Approach; CoMP; NS2

I. INTRODUCTION

The continuous increase in data traffic in cellular networks is occurring at an exponential rate and demands further improvement in the efficiency of spectral systems and efficient utilisation of higher frequency bands [1, 2]. Increasing node development density by using high power macro nodes (macro basestations) is utilised as a solution to deal with the problem of capacity and coverage in the LTE network. However, several challenges are associated with the deployment of traditional macro basestations. The significant reduction of cell splitting gains due to already severe intercell interference can be considered as one of the challenges of such an approach. Besides, the expenditure of high capital costs associated with high power macro basestations limits the feasibility of the approach. To overcome the challenges of traditional high power basestations, another approach, of utilising an LTE heterogeneous network, is proposed. A mix of traditional high-power basestations and low-power basestations is utilised to solve the capacity problem. Pico, femto, and/or relay basestations are an example of the deployment of low-power nodes, which are utilised to increase the node density and achieve system gains. With the advantages of such a mixed approach comes challenges, in which this type of network is characterised by huge differences in the transmit power used by different types of nodes. Severe intercell interference between the macro and low-power basestations is the main disadvantage of this solution due to different power classes, which make low power basestations (pico, femto, and relay) less advantageous compared to the high power basestations (macrocells) [3]. Moreover, developing an effective way of sharing physical resources such as time or frequency with macrocell is an open challenge. Avoiding the creation of coverage holes in the macro network caused by low power basestations is also an unsolved problem.

This paper introduces an innovative approach, which is to make the basestations in the LTE networks self-aware, self-adaptable and intelligent. In a conventional cellular network, basestations will serve a number of mobile terminals using the strongest received signal strength (RSS), while the unwanted signals received from other basestations are usually preserved as interference. To mitigate this problem, intelligent LTE equipment is desired to provide cognitive coordination and management of resources among basestations, which can offer a significant enhancement in throughput and user experience as compared to a conventional system. Another problem which motivates this work is the fluctuation in the traffic load among the network basestations, in which areas with higher density of users will result in more extensive load to the basestations and high blocking probability for newly arriving user equipment, as compared to less dense areas, where some basestations will be idle or under low load. Consequently, a very unfair distribution of data rates will occur across user terminals. For these gaps and limitations, this paper provides several contributions, as follows: 1) This paper contributes to the knowledge of the literature by providing an important discussion of related work in enhancing the capacity of the LTE network and its advantages and disadvantages. 2) This paper also introduces the concept of fairness of traffic among different basestations. 3) Furthermore, this paper proposes a model to balance the load between

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different basestations in the LTE network by using the dynamic movement of basestations to the denser areas of users and consequently will enhance the network capacity. 4) This paper also contributes to enhance the system throughput, packet lose, and the load of the system even in the case of high dense networks. Besides, these performance metrics are used to prove the system viability.

The remaining parts of this paper are organized as follows. Section II gives an overview of related work. Section III outlines the proposed model. Section IV presents the simulation results. Conclusions of the paper and suggestions of future directions for improvement are provided in Section V.

II. RELATED WORK

Recently, different research models have been proposed to enhance capacity in LTE with the aim of enabling the LTE's entities to evaluate their needs directly or through the use of equipment such as the CoMP technique to enhance the fairness of traffic in the network. Kishiyama et al. [4] propose an efficient utilisation approach for both lower and higher frequency bands by separating the frequency between wide and local areas. Their approach is used to solve the problem of scarcity of spectrum in the lower frequency bands. Thus, the exploration and utilisation of higher frequency bands may be significant in the future for LTE. They propose to use lower frequency bands to provide mobility and basic coverage: besides, authors propose to provide high-speed data transmission in local areas by the utilisation of separate frequency bands, such as higher frequency bands. They consider the use of a wider spectrum bandwidth in the higher frequency bands in local areas and their specific technologies for smaller or denser cell deployments. However, some limitations may accompany this approach, such as the difficulty of accommodating the higher frequency bands in terms of radio frequency equipment, antenna size, and coverage limitations.

The work in [5] proposes use of cognitive basestations in LTE networks to enhance the functionality of femtocell basestations. Specifically, femtocell basestations will be able to perform several functionalities which are traditionally supported by the macrocell basestations in order to alleviate signaling-heavy operations and control more efficient radio resource management protocols. The idea of utilising cognitive basestations aims to make the femtocell basestations act autonomously and support a diversity of service requirements. Consequently, this will result in production of more sophisticated basestations which are capable of increasing the LTE network coverage by supporting considerably higher data rates. The use of unlimited basestation antennas in evolved wireless networks is proposed by [6] to achieve more enhanced throughput over systems which use limited basestation antennas. In such an approach, even though the assumption of an unlimited number of antennas at the basestation can significantly simplify the analysis of the system and illustrate the desirable effects of operating with a large excess of antennas, issues such as the optimal number of antennas are not discussed. Besides, the cost associated with this approach can be large and also is not effectively mentioned. The approach of utilising multiple and dynamic mobile basestations which have the ability to periodically change their locations according to network density as a method of transferring coverage is considered by several researchers to increase the performance of wireless networks [7]. From the discussion above, the principle of adding multiple basestation antennas even with a very noisy channel estimate is always beneficial. The effects of fast fading and disappearance of uncorrelated noise make it easy to recover from low SNR conditions by adding a sufficient number of antennas [6]. However, the introduction of more basestations with more intelligent capability to become self-aware and self-adaptable in terms of changing their behaviour according to the number of users, other basestations, and dynamic changes in radio frequency can form a strong motivation. Therefore, a simple and cost-effective approach is proposed to enhance the capacity of the LTE network by utilising the concept of using multiple and mobile basestations in order to use the unused bandwidth caused by non-operational or less dense basestations.

Self-organized and self-optimized using artificial intelligence capabilities have recently introduced in the literature to enhance the capacity approaches of the LTE network[8, 9]. Self-optimisation of coverage and capacity in LTE networks through base stations' downtilt angle adjustment is a solution introduced by Razavi et al [8], to enable the network enhancing its capacity. The proposed method is based on fuzzy reinforcement learning techniques with the aim to operate in a fully distributed and autonomous fashion without any need for a priori information or human interventions. The coverage performance of the network is analysed by Han et al. [9] under different deployment density of small cells. They apply the capability of the ant colony algorithm (ACA) to find the optimal pilot Tx power of each small cell through the minimization of the cost function. The authors show that, the use ACA can reduce the ratio of coverage hole and enhance the proportion of coverage overlap compared to the fixed coverage scheme.

III. THE PROPOSED MODEL

A. Basic Concepts

In this approach, we consider a densely deployed LTE network in which the basestations' coverage overlaps and traffic load fluctuates over time and space. The network consists of N of wireless nodes or terminals denoted as UEs in the network, and M basestations, which are denoted as eNode-Bs (eNBs) and which are regularly placed in a unit area. The eNBs are neither data sources nor data receivers. They are only used as relay nodes and engaged in routing and forwarding data for the mobile nodes. We assume that the eNBs are connected together by a wired network and that the link in the wired network is capable of managing all of the traffic; thus, there are no bandwidth constraints in the wired network. All of the eNBs are assumed to have the same energy level and same consumption technique. Due to the increased cost and consumption of power caused by eNB movement, this approach assumes that eNBs are designed as light basestations with low transmit power and can be deployed indoors or outdoors in an unplanned manner when hot-spot areas are not expected. A location-based user density approach is used to determine the initial position of basestations at feasible sites. The number of user UEs in a specific area is used to define the density of an eNB. Each UE will be associated with one eNB based on the received signal strength (RSS metric) and on arrival to the specified area. The rate requirement is fixed for each UE, denoted by r_i for UEi. When UEi is associated with eNBj, the spectral efficiency is denoted as ωij and the bandwidth b_{ij} needed is given by Eq. 1.

$$b_{ij} = \frac{r_i}{\omega_{ij}} \tag{1}$$

When a new UE arrives, if there is not enough bandwidth to be allocated to the desired eNB, the UE will be blocked. Therefore, the objective of this work is to minimise blocking probability and provide services to every UE by utilising fairness concepts in distributing traffic load and coverage through the dynamic movement of the eNBs under low loads. An algorithm which is proposed in [10] is utilised to select idle or low load basestations by generation of a 0-1 matrix, $X = [X_{ij}]$, where $X_{ij} = 1$, which means that the UE i is associated with eNBj: otherwise $X_{ij} = 0$. As each UE can only be served by one eNB, the sum of each column in X is 1. As there are many UEs which arrive in the network lifetime, each active eNB will reserve some bandwidth for the newly arrived UEs. The proportion of bandwidth reserved in eNBj is denoted as α_j, where $\alpha_j \in [0,1]$ and consequently the idle bandwidth for eNBj is given by Eq. 2.

$$\tilde{B}_j = (1 - \alpha_j).B_j \tag{2}$$

The number of UEs associated with eNBj is denoted as μ_j and the traffic load, denoted as L_j, of eNBj is given by Eq. 3.

$$L_j = \sum_{i \in \mu_j} \frac{b_{ij}}{B_j} \tag{3}$$

where b_{ij} is the bandwidth needed by UE i, and B_j is the total bandwidth for eNBj.

After receiving network information on the idle or low dense basestations, the selected basestation eNB j wants to move to the desired location at time (t), which is denoted as eNB $\mathrm{j_{mov}}$. UEs served by basestation eNB j are handed over to the neighbouring or nearest relay of eNBj, denoted as eNB N to serve the UEs. Thus, the handover traffic of the eNB j which is moving out of the serving area would be served by eNBj's neighbor, which is denoted as eNB n, in which $n \in N$.The traffic load for the neighbour of eNB j, which is denoted by $\mathrm{L}_{j(mov)}$, is given by Eq. 4.

$$L_{j(mov)} = \sum_{i \in \mu_n} \frac{b_{in}}{B_n} \tag{4}$$

Each UE will select the eNB by itself according to the measured channel conditions and the traffic load of eNBs in the area. As the eNBs in the area reserve bandwidth for newly arrived UEs, the reservation parameters of traffic load information and bandwidth can be obtained by broadcasting control signals from eNBs. The UEs regularly select the eNB with a high load and high spectral efficiency. A predefined threshold is used to specify the maximum load for allowing the UE i to be associated with eNBj, which means the UEs prefer those eNBs with high load and high spectral efficiency, but not to exceed the predefined threshold. The algorithm components and the procedure of basestation movement are described in the next subsections.

B. The Basestation Movement Metrics

Quality of service measurement of the wireless channels by the mobile users (UE) to the basestations is very important concept. It is required that the UE is always equipped with the capability to measure the quality of the link by either tracking the mobility and monitoring the signal strength or by sharing the channel state information (CSI) for adopted link. However, there are different categories of measurement in wireless networks that can be used as a metric for moving the basestations. Measurements can be typically directional between mobile users and basestations, such as in the angle of arrival (AOA), or related to relative distances between mobile users and basestations, such as the time of arrival (TOA), the time difference of arrival (TDOA), and the received signal strength (RSS) [11]. All of these measurements can be used as metrics of movement to make a dynamic mobile basestation which has the ability to amend their locations based on changes in the environment. In this approach, we assume that both the UEs and eNBs are equipped with intelligent capabilities such as coordinated multipoint (CoMP) transmission and reception techniques introduced in [3] in which for each UE, there are multiple eNBs which can communicate with it and it can be possible for neighbouring eNBs to transmit signals as desired. UEs can perform a handover operation based on the signal strength received from each eNB. As well as this, there is the assumption eNBs may be able to identify the dynamic characteristics of the UEs and change their location based on these characteristics. Handoff operation between locations is handled as the user moves and mobile basestation moves to the desired dense areas to avoid the severe limitations caused by such operations in both the number and efficiency of service flows.

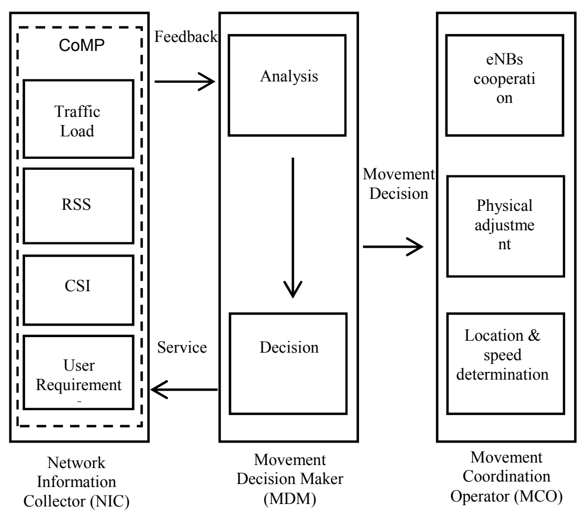

Fig. 1. The Proposed Algorithm Components

C. The Basestation Movement Components and Procedure

To implement this approach, we need to specify the components which are used to build the model illustrated in Fig. 1 above. The first component is the network information collector (NIC), which is a virtual component in the network, and can either be implemented in the gateway or distributed into the basestations or the user equipment. The NIC will first sense the network state information to decide whether to move the desired basestation, such as traffic load, channel conditions, and user requirements. This information can be collected using the CoMP technique, as mentioned earlier. A number of control messages will be utilised to accomplish the information collection stage. After collecting the required information, another component is the movement decision maker (MDM), which is used to achieve the movement decision stage. The MDM is responsible for analysing whether there are opportunities for moving the desired basestation or not and consequently making decisions based on this analysis. If the decision for movement has been made, a coordination stage with the neighbouring basestations would be conducted through the movement coordination operator (MCO). The MCO's role is to assure that no coverage gaps will accrue by moving the desired basestation through the cooperation between basestations, such as by using the relay technique which is utilised in 3GPP LTE-A as an important technique to help fill the coverage gaps which might be caused by moving the eNBs, by relaying the traffic from the eNB under heavy load to the eNB under light load. Besides this, it is also used to announce any required physical adjustments such as managing transmit power and antenna settings. The last stage is movement, and involves allowing the basestation to dynamically move to the desired location at a suitable speed based on the information collected from the main components.

After sensing of the network information by the collector components, the movement decision maker decides to move the basestation under a light load. The movement coordinator then coordinates the cooperation between the basestations, and other parameters required for movement. The detailed procedure of the algorithm is described as follows.

Algorithm 4-1: Basestation Movement Algorithm

For each new UE i ***Do***
  Initialize $L_j = 0$, $X_{ij} = 0$
  Calculate the b_{ij} , $\tilde{B}_j$, L_j according to Eq. 1, 2, and 3.
  If $(L_j B_j + b_{ij} \le \tilde{B}_j)$ ***Then***
   Associate UE $i$with eNBj
  Else
   Block UE i
   For all eNBs in the network ***Do***
    Calculate the $L_j B_j$ ratio
     If $(L_j B_j = 0) \parallel (L_j B_j \le ratio\_threshold)$ ***Then***
      Move the eNB under low load towards the eNBj
   associate the UE i in $\mu_j$to the moved eNB
   Use Neighboring eNB to fill coverage holes
    End If
   End For
   End If
  End For

IV. SIMULATION AND RESULTS

A. Simulation Settings

Our simulation uses the NS2 simulator [12], which is an open-source simulator designed as event-driven, for research into computer communication networks. It involves various modules to help study several network components, such as physical layer components. It can support researchers to reliably model massive wired and wireless systems by modifying existing models or adding new protocols. These features are useful for our research to extend the LTE network with an intelligent mobile basestation and allow integration of the proposed capacity enhancement model components. This integrated NS2 simulator is used to test the validity of the proposed algorithm. An experiment to test the proposed approach and its applicability to the LTE network is conducted.

An LTE network environment with two types of nodes; wired and wireless mobile nodes, is simulated. The first type of network comprises a server and gateways which behave according to wired protocols, while the other type comprises a set of mobile nodes which act as transceiver nodes to the gateways. The main aim of the experiment is to consider the contribution of the proposed approach in enhancing the capacity of future LTE networks and introduce basestations with the capability for acting intelligently in detecting the connected mobile nodes' requirements and resources. Consequently, the work tests the impact of the approach on network performance in terms of throughput, packet loss, and system load.

The simulation is conducted via the NS2 simulator. A network with 8 nodes placed in a unit area of 1000×1000 is simulated. One node acts as a server and connects to 3 basestation eNBs with wired links, besides 4 mobile nodes which act as user equipment UEs and are connected to the eNBs using wireless links, and which randomly move in the area around the eNBs. Only 4 UEs are used in this simulation scenario for simplicity of use and accurate evaluation of the proposal. The traffic between basestations and mobile nodes transmits packets with a Constant Bit Rate (CBR). The packet size is 512 bytes and the simulation time is 150s. Fig. 2 shows the network structure and Table 1 shows the parameters used in configuring the network for this experiment.

Table IV-1 Network configuration

Parameter	Value
Nodes	8
Area	1000 X 1000 m
Speed	10 m/s
eNodeB coverage area	100 m
Movement	Random waypoint
Routing Protocol	DSDV
MAC	802.11
Transmitting capacity	2 Kbps, 4 Kbps
Number of active users	4
Application	CBR
Packet size	512 B
Simulation time	150 s

B. Experimental Results

In this section, results and analysis are presented for the comparison of two different scenarios; one without moving the basestation and one moving the basestation. A discussion of the

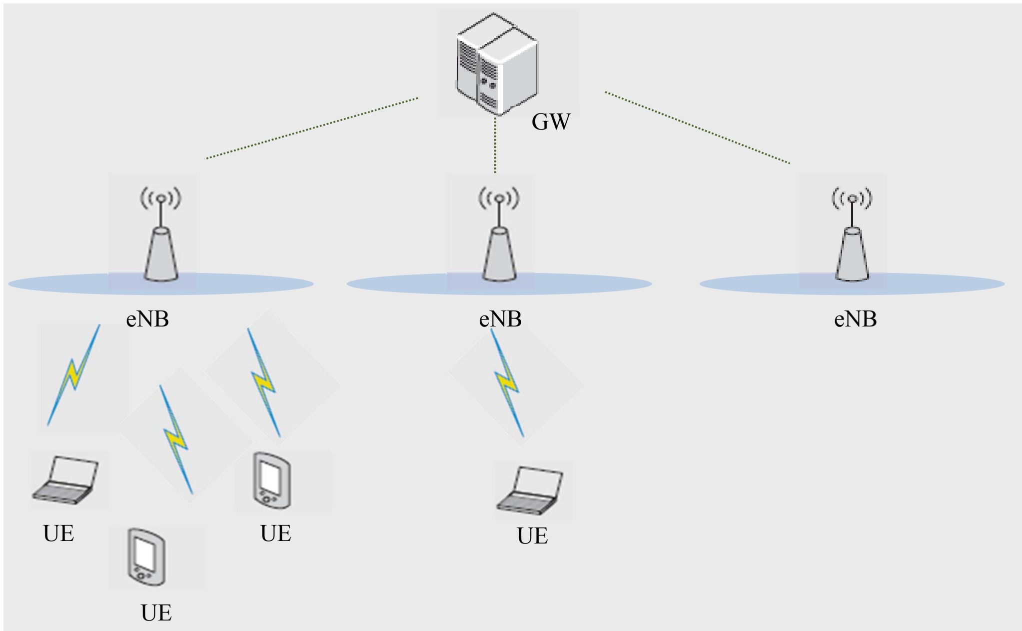

Fig. 2. Network Structure

results of both scenarios on the network performance is also provided. The simulation results are shown in Figures 3 to 7, which introduce the performance of three important measurements of the LTE network in terms of throughput, packet loss and system load.

In this experiment, the aim is to allow the LTE network to benefit from the intelligence capability of basestations to dynamically move to dense areas: thus, an important evaluation metric is to consider the adaptation of the proposed approach in enhancing the network performance, as shown in Figures 3, 4, 5, 6 and 7.

In Fig. 3, the x-axis displays the time of simulation in seconds. The y-axis shows the percentage of the network throughput of both scenarios, with and without moving the basestation. The figure shows that the throughput for the proposed approach when moving the basestation towards a dense area is better than the scenario in which the basestations are fixed in their initial location. For near to the first 50 seconds, the performance in each scenario almost converges to the same percentage because the basestations take time to identify the coverage hole and start to move to the desired location. However, with increase in time, the performance of the moving network in terms of throughput outperforms the fixed basestation scenario. With moving basestations, the simulation reaches approximately 80,000 while without moving the basestation, the throughput reaches only 75000.

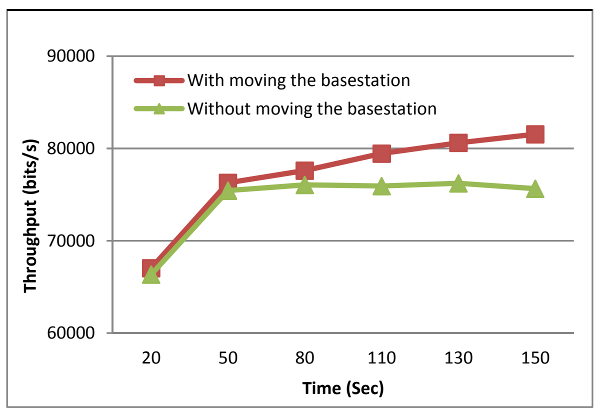

Fig. 3. Throughput Network Performance With and Without Moving the Basestations over the Time of the Simulation

Similarly, Fig. 4 displays the percentage for packet loss of both moving and stationary basestation scenarios. The x-axis shows the time of the simulation, while the y-axis shows the packet loss percentage. The packet loss metric in the network behaves in nearly the same manner as in the previous figure. In the early time of simulation, the performance of the scenarios is closely similar. Meanwhile, as the time progresses, the basestations can use their capability to serve more users and fill the coverage gap in which a lower packet loss ratio is caused in the moving basestation scenario compared with a higher packet loss ratio in the fixed location basestation scenario, in which nearly 60% of packets will be lost.

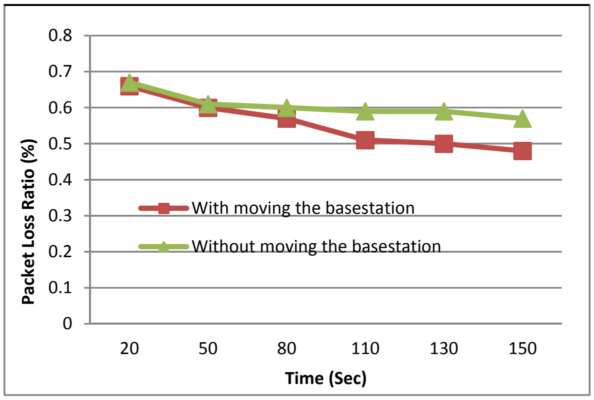

Fig. 4. Packet Loss Ratio in the Network With and Without Moving the Basestations over the Time of the Simulation

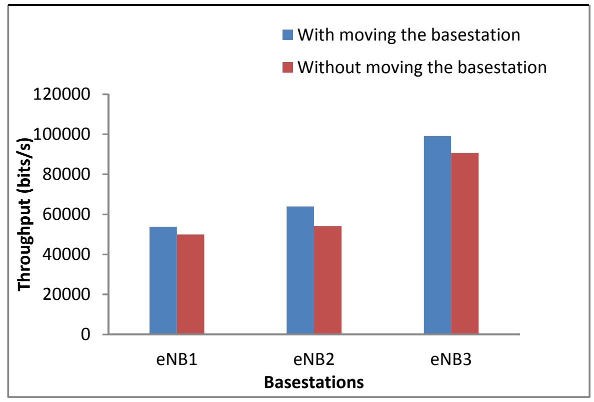

Fig. 6. Comparison of Throughput between eNBs With and Without Moving the Basestations

In Fig. 5, a comparison of the performance metric for throughput between the user equipment with and without moving the basestations is shown. It is obvious from the figure that the throughput for each set of user equipment is enhanced by moving the desired basestation to the dense area, and consequently this leads to improvement in the traffic between the basestations and the user equipment and reduces the probability of blocking.

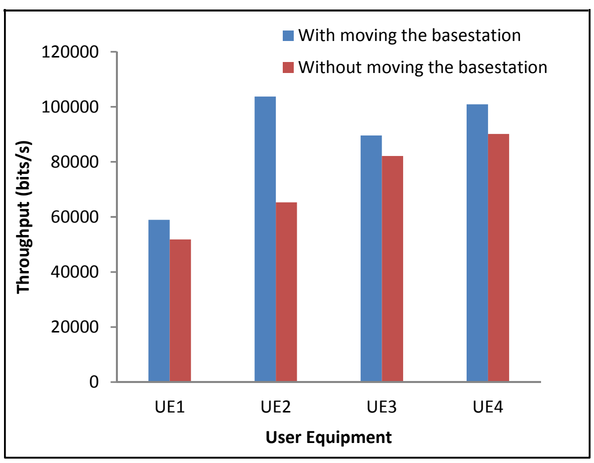

Fig. 5. Comparison of Throughput between User Equipment With and Without Moving the Basestations

Similarly, Fig. 6 shows a comparison of the throughput of each basestation participating in the network with and without movement to new locations based on the system's requirements. The figure demonstrates that the throughput when moving the basestations is always better than the throughput when the system is static and not responding to the needs of newly arriving user equipment through the participating basestations.

Fig. 7 shows the offered load of the network which indicates to the average rate at which traffic arrives. It is calculated by dividing total of packet sent over total runtime and can be used as a metric to evaluate the whole performance in the network. As shown in Fig. 7, the offered load for the system when moving the basestations is higher than the offered load for the system without moving the basestations. Consequently, this enhancement in the offered load leads to better achieved throughput, link quality and traffic

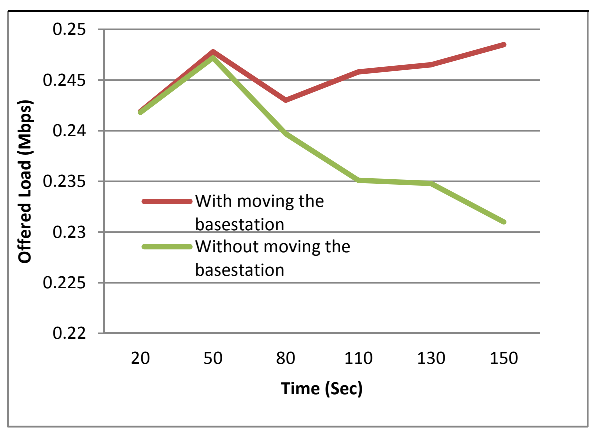

Fig. 7. Offered Load Percentage in the Network With and Without Moving the Basestations over the Time of Simulation

C. *Analysis of the Algorithm*

LTE mobile networks are characterised by an incredible increase in the use of wireless data traffic. Further, improvements in spectral efficiency using capacity enhancing approaches is a highly important type of research in the network, including such approaches as advanced spectral efficiency techniques. However, limitations in hardware implementation and channel conditions, as well as the increase in system complexity occurring due to the use of advanced techniques, may lead to limits on the viability of such approaches. Therefore, any proposed model or algorithm for enhancing the capacity of the network must reflect the trade-offs between achieving the capacity enhancement objective and issues related to network performance such as blocking newly arriving mobile nodes or causing coverage holes in the network. The proposed algorithm uses the decision making strategy to enhance movement decisions based on network information and user requirements as collected by suitable components. Besides this, it is able to use cooperation techniques among basestations to recover any coverage holes caused by moving the basestations. Some physical adjustments needed as a result of that movement may be viable to help continue network activities, reduce blocking probabilities, and enhance the network's performance. However, as in all the mobility models, the means of movement and/or speed of mobility can raise difficulties in the applicability of this approach, in which mobile basestations can take hours to migrate to the desired location. This is because of the design constraints of the basestations, which make it difficult to increase their speed of travel, which can increase cost and consumption of power. However, in this approach, the basestations are assumed to be designed as light basestations with low transmit power, and can be deployed indoors or outdoors in an unplanned manner when hot-spot areas are not expected. Further, basestation cooperation is extremely important in ensuring the efficiency of this approach. In the absence of basestation cooperation and coordination, additional interference can be caused, as well as, the production of additional coverage holes. Therefore, a coordination component is utilised in the proposed algorithm to cover such problems and ensure the quality of service to newly arrived UEs in which neighbouring basestations can act as relays to relay packets of existing UEs in the area surrounding basestations which have moved.

V. CONCLUSIONS

A capacity enhancement approach is introduced to enhance the fairness of traffic in LTE networks. The basestations are equipped with intelligent capabilities to dynamically sense dense areas of mobile users and consequently move towards the desired areas with more mobile users. A location-based approach is introduced to select the most effective position of basestations in order to fill any coverage gaps in the LTE network. The model is a cost-effective approach in which the capacity of the network uses unused bandwidth from non-operational or less dense basestations by dynamically moving them to dense areas. Fairness of traffic approach is investigated to ensure that LTE terminal or user equipment is able to effectively send traffic with high quality of service. The network performance metrics were computed to test the validity of the approach. Throughput, packet loss ratio and the network load of the LTE network were tested using an NS2 simulator to show the increased network gain. The approach used, simulation, and experiment in this paper were sufficient to show the capability of the basestations for being intelligent and able to change their locations dynamically based on the behaviour of the terminal or user equipment. Extensive work on finding effective solutions to the problem of capacity enhancement approaches will be considered as our main future direction. Another future direction is to consider the problem of movement models and different speeds, as well as the number of mobile basestations moving in an area by using more effective ways of merging intelligent capabilities into future LTE networks.

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