# Multi-Criteria Load Balancing Decision Algorithm for LTE Network

Salawu Nathaniel[1,2], Sharifah Hafizah Syed Ariffin[1], Ali Farzamnia[1], Abolarinwa Joshua Adegboyega[1,2]

[1] UTM-MIMOS Centre of Excellence, Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM)

[2] Telecommunication Engineering Department, Federal University of Technology, Minna, Nigeria
salawunathaniel@gmail.com, sharifah@fke.utm.my, ali-farzamnia@ieee.org, abolarinwajoshua@yahoo.co.uk

***Abstract*—Long Term Evolution (LTE) is a cellular system designed to support user mobility even at high speed. When a mobile user moves from one cell to another cell during active service session, handover technology is employed to transfer its connections from the previous cell to the new cell for effective Load balancing of the entire network. However, handover of a mobile user therefore is a serious factor when considering user mobility management in LTE network. This is to provide services with stringent tolerance with best handover latency to enhance network quality. Presently, an optimised load balancing mechanism in LTE network is still left as open issue as far as 3GPP is concerned. For optimum use of network resources, an effective load balancing framework is required before handover process could be beneficial. In this work, we provided the detail framework requirement of multi-Criteria Load balancing Decision Algorithm in LTE. We captured our criteria using multiple parameters for effective mobility load balancing. The scheme allows for an optimized load distribution effect in the network by adjusting handover margin at the appropriate time. Our results provide better performance in terms of the network throughput and network load distribution index when compared with network without proper load balancing scheme.**

***Keywords-LTE, Load balancing, Handover, Cost Function, Radio Resource Management.***

## I. INTRODUCTION

The rapid growth in the use of mobile cellular communication systems has resulted in fast increase in terms of network complexity, operational and maintenance cost. Despite the need for users freedom of mobility, it is also important that the network provide optimal Quality of Service (QoS) as perceived by the user. The $3^{rd}$ Generation Partnership Project (3GPP) has propose a new radio access technology called Long Term Evolution (LTE) that will be easily translated to one the $4^{th}$ Generation radio access technology in few years to come [1]. 3GPP has defined the requirements for an evolved UTRAN (evolved UMTS Terrestrial Radio Access Network or simply e-UTRAN) right from the beginning of the specification stage. LTE system is sometimes called 3.9 G and is expected to provide a spectral efficiency that is about two to three times higher than that of 3GPP release 6. LTE system will offer up to 100Mbit/s with scalable spectral bandwidth up to 20 MHz. LTE systems use Orthogonal Frequency Division Multiple Access (OFDMA) in the downlink transmission and Single-Carrier Frequency Division Multiplexing Access (SC-OFDMA) in the uplink transmission [2]. LTE system architecture is built on the principle of decentralized configuration for effective coordination of Radio Resource Management (RRM) functionalities residing in the Evolved Node B (eNB).

RRM in LTE can be enhanced to provide a good Quality of Service (QoS) as perceived by the mobile user. One easy way of doing this is by ensuring adequate load balancing of the neighbouring cells in the network. Load balancing [3] refers to a situation whereby cells that are highly loaded called (loaded cells) shed their traffics to low loaded (unloaded) neighbouring cells so as to provide for effective use of radio resource in the overall network. Load balancing issue however, is still an open problem in LTE network and detailed research efforts are needed in this direction.

Furthermore, the network load must be balanced between loaded and unloaded cells to properly mitigate network degradation. This problem can be solved using a cost function estimator manager in the network (within the eNode) for effective load balancing of the network. The cost function estimator takes into account the power consumption in each adjacent cells (serving and target cells), service time in each adjacent cell, velocity of users equipment in each adjacent cell and class of service in each adjacent cell. This function helps us to initiate handover decision to the right cell based on the computed weighted value as given by the cost function. The dominant computed cost function value will be used to auto tune handover parameter for the load balancing optimization process.

In this paper, we propose an effective cost function estimator that takes into account the power consumption difference between adjacent cells (serving and target cells), service time, velocity of users equipment and class of service of each neighbouring cells. The result of the estimates show which cell is loaded or unloaded before an appropriate handover process is triggered.

The rest of the paper organization follows. Section II presents LTE system architecture while section III highlights some previous works. Section IV gives handover procedure in LTE and Section V presents our propose multi-Criteria Load balancing Decision Algorithm. Section VI presents the load balancing algorithm. Section VII presents the verification of the research. Finally, the paper's conclusion is presented in section VIII.

## II. LTE SYSTEM ARCHITECTURE

LTE system architecture is a flat IP based architecture. It comprises of eNodeBs, Mobility Management Entity (MME) and System Architecture Evolution (SAE) Gateway [4]. The detailed LTE architecture is presented in Fig. 1. The eNodeBs and MME/SAE Gateway are linked together by the S1 interface. The X2 interface connects one eNodeB to another eNobeB in the network. The X2 interface takes care of communication exchange between adjacent eNodeBs and it is also responsible for User plane when temporary user downlink data is to be sent during handovers handover user from one eNodeB and another. Handover in LTE [5] can be executed between cells of a single eNodeB called intra-eNodeB handover and between eNodeBs of the same MME/S-GW called inter-eNodeB or intra- MME handover. The last one is handover between eNodeBs of different MMEs. Inter-eNodeB handover which do not involve changing MME is usually performed over X2 interface.

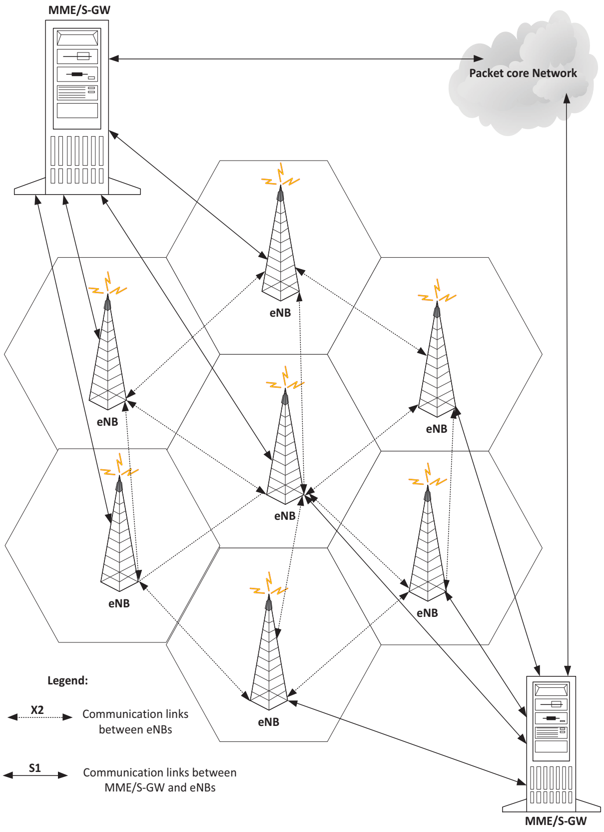


Fig. 1: Load Balancing Architecture for LTE System.

Based on the architecture given in Fig. 1, we considered a system model assumed to comprise of an LTE cellular network with seven cluster cells as shown in Fig. 2. The centrally place cells is denoted as cell number one and it is surrounded by six other neighbouring cells numbered two to seven respectively [6]. Each cell in the network has a cell nest to it whose signal maybe received by its user. In this work, we consider eNB and cell to have the same meaning. Twelve neighbouring OFDM subcarriers are clustered into one physical resource block (PRB). PRB is the smallest unit that can be assigned to each user in one sub frame which is 1ms. Other assumptions of our model is that, each user at the border cell is aware of instantaneous signal strength of it serving cell and its neigbour using a pilot detection mechanism with appropriate reporting to the its serving eNBs periodically. Serving eNB is responsible for allocating one PRB to each user it is servicing without the consideration of fading diversity among PRBs. Furthermore, neighbouring eNBs load status information is exchanged periodically through X2 interface as required in LTE architecture.

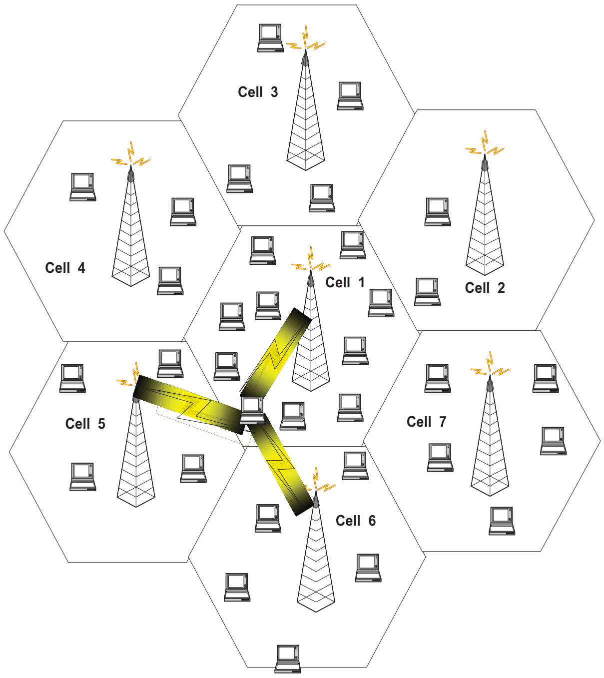


Fig. 2: Proposed Load Balancing Network Model for LTE System.

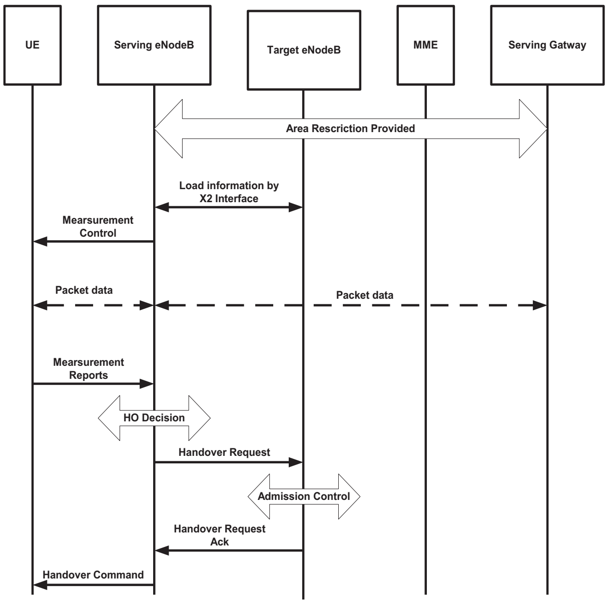
## III. PREVIOUS WORKS

Mobility load balancing in LTE systems has not been widely research into in recent times. Hence, more research into load balancing is require to meet the RRM requirements of the LTE system that will later translate to one of the 4G candidate networks. It on this premise, we consider it necessary to present some of the few works in literature that have been done in this area. Authors in [1] presented handover adaptation for dynamic load balancing in 3GPP LTE system. They investigated the auto- tuning of LTE mobility algorithm by adapting handover parameter of each base station according to its radio load and the load of its adjacent cells. Although there was achievements in increase of user throughput and gain in call admission rate, the scheme is however not scalable. Distributed mobility load balancing algorithm was presented in [7]. The authors achieved by dynamically adjusting RRM parameters based on the source cell load and its neighbouring cell condition. This work however has price to pay in terms of network signalling. In [8], an algorithm evaluation of load balancing in downlink LTE self-optimizing networks was presented. The work evaluated the network performance of the algorithm using load of a cell as input with its associated handover parameters used as controls. Different network scenarios where simulated for this research for performance evaluation. Authors in [9] presented a game theoretic approach for load balancing in cellular radio network. In their work, load balancing problem was addressed using a game-theoretic approach. They tuned each cell in the worst case, to decide independently on the amount of cell load that optimizes its payoff in an uncoordinated manner and consider whether the resulting Nash equilibrium would weaken the gains achieved. Furthermore, they changed the performance of the players using the linear pricing system to have a more attractive stability. LTE network was used to simulate this work for performance evaluation. Though, they achieved capacity increase in the obtained results but not without network degradation in terms of performance with respect to the network stability obtained by linear pricing approach.

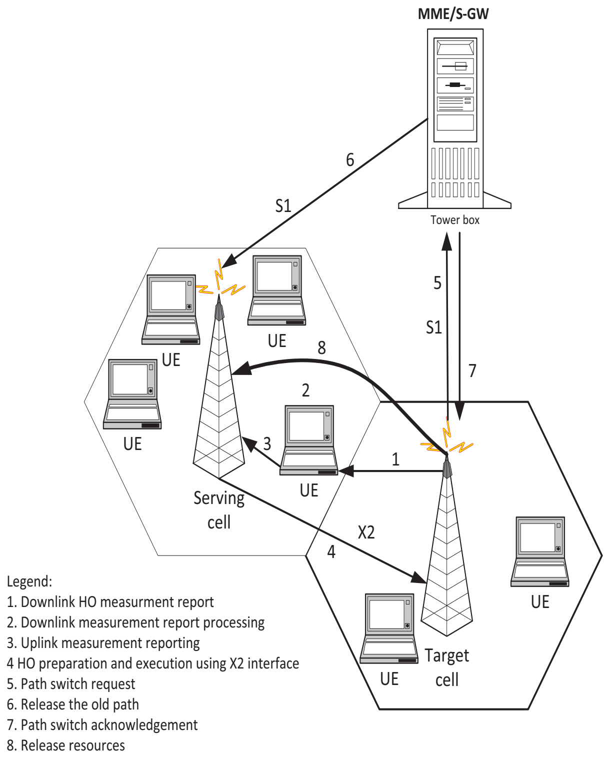
## IV. HANDOVER PROCEDURE IN LTE NETWORK

Handover procedure in LTE system [10], [6] is shown in Fig. 3 . The procedure begins with a handover preparation that is managed by RRM function based on the measurement reporting of user Equipment (UE) to the serving eNB. The UE occasionally performs downlink radio channel measurements using the reference symbols (RS). The RS can be measured in terms of reference symbols received power (RSRP) or reference symbols received quality (RSRQ) [4]. In active mode, handover procedures in downlink can be S1 or X2. X2 handover procedure is for services exchange between two eNBs. However, S1 is used when X2 is not available. For handover to be initiated, there must be set up requirements for the UE for decision making. When these conditions are no longer in favour of the UE, it sends corresponding measurement report to triggered handover event. Furthermore, the measurement report specifies the cell to which the UE in serving cell has to be handed over called the target cell. There are three basic triggering stages based on the measurement report. These are handover initialization, handover preparation, and handover execution. The handover initialization involves signaling exchange between serving and target eNB. This message flow is enhanced by admission control of the UE in the target cell. After successful handover initialization, handover decision will be accepted to prompt handover Command to be issued to the UE.

After the handover command is issued, the connection between UE and the serving cell will be released. The UE will finally latch on to the target eNB for service access using random access channel (RACH). Delay is reduced in handover procedure to the target cell by providing a dedicated RACH to the UE. After full connection of the UE to the target eNB, an uplink scheduling transmit will be granted to the UE. The UE acknowledge the message by responding with a handover Confirm reply to end the completion of the handover procedure.



(a) General Time line message flow



(b) Specific Message flow Steps between Serving and Potential Target Cell.

Fig. 3: Handover Procedure in LTE System.

## V. MULTI-CRITERIA LOAD BALANCING DECISION ALGORITHM FORMULATION

Multi-criteria cost function approach has not been widely used in literature to solve load balancing problem in LTE. Most authors use single factor when considering network load balancing. In [4], load balancing was mitigated by considering only the Signal to Interference and Noise Ration (SINR) of every user to determine when and how the load should be managed. Authors in [1] presented adaptive hysteresis scheme where only the load differences between the target and the serving cells were considered. In this work, cell load balancing is based on load information via the X2 interface as seen in Fig. 1. Furthermore, handover signalling was considered for load balancing of IEEE 802.16 network [11]. The algorithm enables load balancing via relay stations through the estimation of handover signalling in the network.

Having studied some of these works in literature, we decided to use a cost function that consider more than one parameter to bring about an enhanced load balancing scheme .Our work consider some other factors in determining the cell load cost for better performance. We took the following parameters into account for our scheme: power consumption in adjacent cells (serving and target cells), service time of in adjacent cells, velocity of users equipment in each adjacent cells and class of service in each cell. Similar to cost function in [10], we summarise the function as

$$L = \sum_{i=1}^{i=k} W_i N_i \tag{1}$$

Where $W_i$ is a weight for $i$th normalized function $N_i$. $k$ gives the maximum number of the normalized functions in consideration. It is important to note that the sum of all weights must be equal to 1. The normalized value of $N_i$ is fixed between 0 and 1 so as to bound the estimated load function $L$ between 0 and 1. For further simplification, (1) can be broken down as

$$L(p,t,v,c) = W_p \cdot N_p + W_t \cdot N_t + W_v \cdot N_v + W_c \cdot N_c \tag{2}$$

Where $W_p$ is the weight associated with power consumption in each adjacent cells (serving and target cells), $N_p$ is the normalized function for the power consumption each adjacent cells (serving and target cells respectively), $W_t$ is the weight associated with service time in each cell, $N_t$ is the normalized function for the service time in each cell, $W_v$ is the weight associated with the velocity of UE in each cell, $N_v$ is the normalized function for the velocity of UE in each cell and $W_c$ is the weight associated with the class of service in each cell. This is assumes to be 1 for real time and for non real time, it is assumed to be 0. This is due to higher priority that is normally associated to real time services in a network. $N_c$ is the normalized function for the class of service in each cell. The normalized values for each parameter considered are calculated as shown as follows:

$$N_p = \frac{P_u}{P_t} \qquad 0 \le N_p \le 1 \tag{3}$$

Where $P_u$ is the power consumption of the cell serving the UE and $P_t$ is the power consumption of the eNodeB.

$$N_t = \frac{T_u}{T_t} \qquad 0 \le N_t \le 1 \tag{4}$$

Where $T_u$ is the service time requested by UE and $T_t$ is the sum total of UEs service time required by the service cell.

$$N_v = \frac{V_u}{V_t} \qquad 0 \le N_v \le 1 \tag{5}$$

Where $V_u$ is the velocity of the UE and $V_t$ is the sum total of all the UEs velocities within the cell.

For class of service, $N_c = 0$ For non real time class of service class because of lower priority and $N_c = 1$ For real time class of service class because of higher priority.

## VI. LOAD BALANCING ALGORITHM

The load balancing mechanism of the RRM is presented in the flow chart as seen in Fig. 4. The load balancing controller resides in the eNode to monitor load of each cell in the network. Once the system is initialised, the load balancing controller in the eNodeB detects all associated cost function parameters for the weight computation. The serving cell in the algorithm is where UE is currently attached while the target cell is where the UE intents to attach itself. The load information estimation is done periodically as determined by the service provider or network vendor. Any time a cell has load equals or greater than 90% of its total load carrying capacity, it is considered as over loaded cell. Hence, handover of the excess load to the unloaded cell as govern by the proposed algorithm is done. But if a cell load is less than 90% of its total load carrying capacity, the cell is consider ok and there may not be need for load shedding to a its neighbour.

## VII. VERIFICATION

We verify our proposed algorithm through matlab simulation software. The most relevant parameter settings is as shown in Table I. The UEs are randomly generated and placed in each cell as seen in Fig. 2. The activities of each UE in its respective cell contribute to the cell load as guided by equation (1). The simulations was conducted in an LTE scenario having seven eNBs in which maximum walking speed is assumed to be 5Km/h with several UEs at a time.

The results obtained from this research are briefly presented in Fig. 5 and Fig. 6. We compared the proposed algorithm with a scenario without mobility load balancing situation in terms of network throughput and network load distribution index respectively.

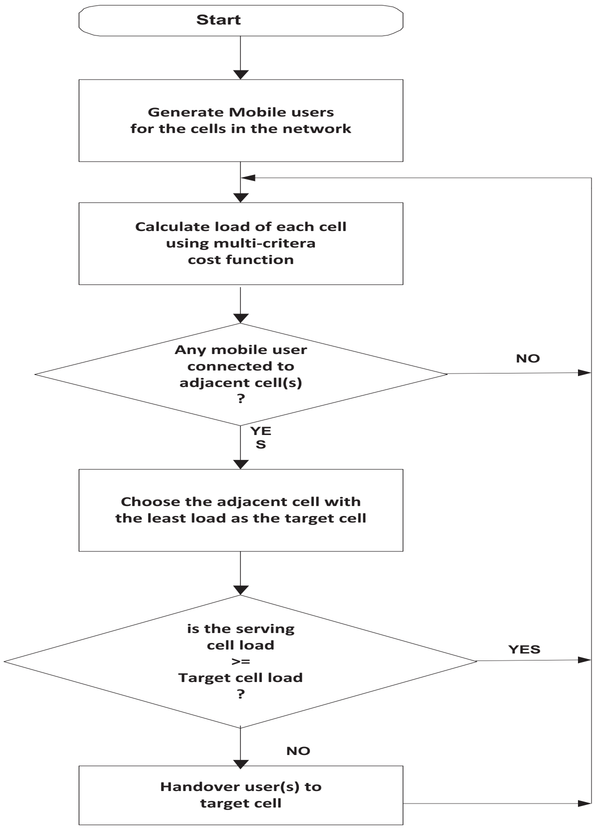


Fig. 4: Load balancing algorithms.

TABLE I: SIMULATION PARAMETERS

| Simulation parameters | Settings |
|---|---|
| System bandwidth | $10MHz$ |
| Cell layout | Macro cells, Hexagonal |
| Transmit power of eNB | 46 $dBm$ |
| Antenna type | Omni directional |
| Distance dependent path loss | $128.1 + 37.6 \log 10R(km)$ |
| Cell capacity | 20 UE |
| Log-normal Shadowing standard deviation | 8.9 $dB$ |
| Maximum speed | $5km/h$ |
| UE | Uniform |
| distribution | (Randomly generated) |

Fig. 5 shows the variation of the overall network throughput against the percentage of the network load. Our solution shows appreciable increase over the scenario without MLB. As seen from Fig. 5, our algorithm provides better overall network throughput more than the scenario without MLB as from the point the network load reached 20% and above.

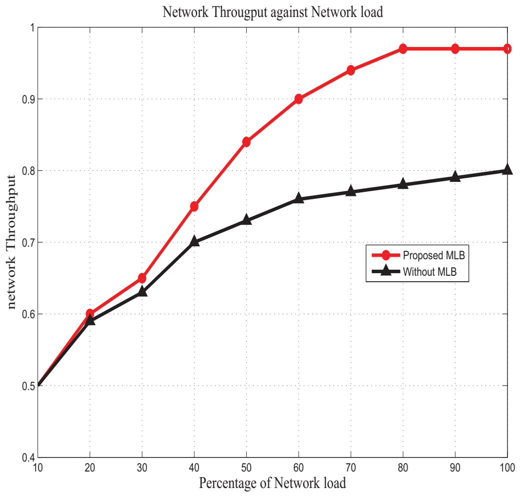


Fig. 5: Network throughput.

Fig. 6 shows the variation of the overall network load distribution index against the percentage of the network load. The load distribution index gives the idea how close the cell load is balanced in the entire network. The further the value gets close to 1 the further the cell loads are balanced. conversely, if the cell loads are not balanced, the value tends toward 0 depending on the degree of load disproportion of the cells in the network. It can be observed from Fig. 6 that much more was obtained with our algorithm as compare d with the situation without MLB scenario.

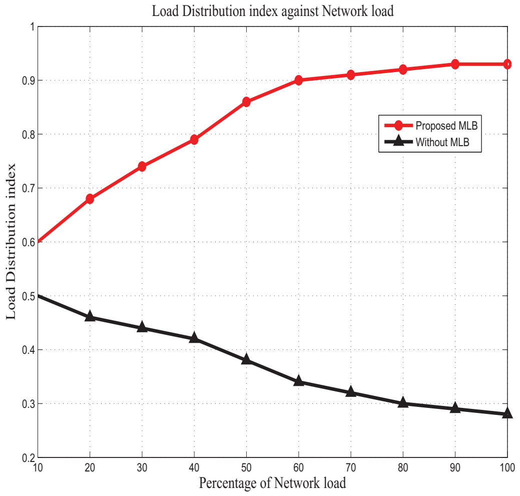


Fig. 6: Network Load distribution index.

## VIII. Conclusion

In this paper, a new multi-Criteria Load balancing Decision Algorithm in LTE is proposed. The proposed scheme uses more than one parameter for its load balancing unlike in other works in literature where only one parameter is mostly considered for load balancing. These parameters considered in our research are power consumption in each adjacent cells (serving and target cells), service time in each adjacent cells, velocity of users equipment in each adjacent cells and class of service in each cell. Furthermore, we presented an algorithm that will aid the use of the cost function and the simulation show an appreciable achievement over network without MLB.

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