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Adaptive Cost-Based Handover Decision Algorithm for User Equipment Battery-Life Aware Load Balancing in LTE Network

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Abstract – *The demand for higher data rate and lower cost is making the use of Long Term Evolution (LTE network) more popular in recent years. In this paper, we deal with an adaptive cost-based handover decision algorithm for user equipment battery-life aware load balancing in LTE. The algorithm has a simple cost function decision engine to reduce computational complexity and network overhead while load balancing and optimizing the battery life of the user's equipment. The cost function comprises of load and power related parameters which are cell load, uplink transmission power as well as Reference signal received power (RSRP). A weight factor (bounded between zero and one) for each cost function parameter has an initial (constant) or adaptive (dynamic) value depending on the user equipment battery's state of charge. Whenever the algorithm is run, a cell with dominant cost value is chosen to serve as the new target cell so as to avoid load imbalance of the network. The parameters for performance testing are handover and new call blocking rate, the number of handovers and load distribution index. The proposed algorithm is compared with two related works. Results obtained show that the proposed algorithm has better performance over the other two schemes compared. In particular, over 90% is achieved in terms of load distribution index which is higher than that of the two other schemes compared.*

***Keywords**: Cost Function, Handover, Load Balancing, Long Term Evolution, Self-Organizing Network*

Nomenclature

f_c	Carrier frequency
C_m	Environmental correction factor
μ	Mean
α	Path loss compensation factor
Δ_{RRC}	Radio resource control based cell specific correction factor
σ	Standard deviation
Δ_{UES}	User specific correction factor
σ^2	Variance

I. Introduction

The rapid increase in service demands of wireless mobile communications users globally has lead to the introduction of several wireless communication standards by various working groups [1]. One of such working groups is the Third Generation Partnership Project (3GPP) that proposed and designed a new radio access technology called Long Term Evolution (LTE) [2], [3].

LTE network was designed as part of the 3GPP release8 to provide simple and cost-effective network architecture with high specifications for capacity, coverage and mobility to cope with emerging new services that earlier cellular communication networks could not support effectively.

Using LTE network, a peak cell data rate of up to 100 Mbps and 50 Mbps for downlink (DL) and uplink (DL) respectively under different network deployment scenarios and mobility conditions is achievable.

Consequently, 3GPP built LTE DL and UL transmission access technology to use orthogonal frequency division multiple access (OFDMA) and single carrier frequency division multiple access (SC-FDMA) respectively for better capacity [4]. In order to achieve LTE specifications, advanced algorithms for radio network planning are required which may not be necessary for the traditional cellular communication network. Therefore, the use of more network parameters and devices to be deployed and maintained is inevitable.

The process of tuning these increasing network parameters, devices and other optimization processes manually is costly in terms of network access, deployment, and overall maintenance which are less desired. The costs are generally grouped into two namely, capital expenditure (CAPEX) and operational expenditure (OPEX) [5].

One good method of achieving the goal of reducing CAPEX and OPEX in LTE is the introduction of an automated self-organizing network (SON) technology in the system. SON is purposely meant for self-configuration, self-optimization and self-healing processes of the system. Self-configuration operation handles the initial phase of automatic configuration of

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cells and network devices before entering into the operational phase. The self-optimization phase involves the adaptation and optimization to varying environmental situations of the network and user equipment (UE) during the operational stage. Self-optimization related issues in the context of cellular network such as LTE usually fall under at least, one of the following area: handover, load balancing, network coverage and capacity parameter optimization. Self-healing phase is concerned with automatic cell switch (on/off) for energy saving of the network, logging and reporting of different measurement data by the user. Others are data saving in the server and cell outage compensation.

As rightly observed, most SON solutions focus primarily on the network and not much has been done to cover the problems of the users as well. The interest of this paper is on the development of a new handover algorithm which is both network and UE aware.

The awareness of the proposed algorithm from the network's point of view is focused on load balancing management while that of the UE's point of view is on battery life management.

LTE compatible UEs are mostly mobile devices equipped with sophisticated data processing components and battery to power them. Interestingly, user's demands for increasing and varying multimedia service are being matched with the advancements in UE's designs for better efficiency. Unfortunately, UEs are mostly stand alone devices whose power capacity derivable from their battery system is limited. Till date, UEs still have the challenge of limited power supply for either data processing, transmission or reception. This is because the advancement in UE battery technology is not able to match the advancement in data processing, transmission and reception in communication networks over the years.

Beside UE's battery life resources, the network resource is another limited resource whose method of access can be optimized for the benefits of the network operator and the subscribers. The SON solution for this as stated earlier is to provide a good load balancing scheme for the network. Load balancing is simply the process of fair sharing of the network traffics among the lightly and heavily loaded cells for efficient use of the available radio resource across the entire network.

Channel borrowing and load distribution are the two main widely used load balancing methods in the literature. Channel borrowing is not an option for LTE system because it has frequency reuse factor of 1 due to the use of OFDMA access technology [6].

There are two main methods of load distribution in LTE. It is either by adjusting the transmitting power of the cell also known as enhanced node B (eNB) or through the use of handover adjustment. In this paper, we would adopt the use of handover method since it is an aspect of SON functionality that can handle the issues of load balancing and power management that is the major concern of this research.

Handover process in LTE system is simply the seamless connection transfer of UE from the serving eNB to another eNB earlier processed a target cell based a given handover guiding rule. In communication system generally, handover could be soft (connect new before breaking the old link) or hard (disconnect old link before connecting new link) depending on the method of connection transfer. LTE handover process has the main goal of providing a simple, timely and reliable connection transfer. Unlike soft handover, a hard handover is most appropriate for the LTE network because of its simplicity. Handover control done entirely by the network is called Network Assisted Handover controlled (NAHOC) while UE-assisted handover controlled (UEAHOC) is that which is done with the assistance of the UE. In this paper, we prefer UEAHOC based algorithm. UEAHOC is effective when reduction of computational processes of the network is of importance to reduce network overhead. Furthermore, UEs have clear and real-time information about their parameter status to be used for accurate handover decision execution.

Considering the problem statement analyzed above, this paper presents in this research an adaptive cost-based handover decision algorithm for user equipment battery-life aware load balancing in LTE network. The cost base function is simple in terms of computational complexity which is a major drawback of so many handover algorithms in the literature. It relies on the dominant parameter factors that are directly related to load balancing performance of the network such as the RSRP, UE's uplink transmission power and load status of the cell. The adaptive nature of the scheme in the ability to adjust cost function weights dynamically based on the residual battery voltage of the UE. The load balancing performance parameters used to evaluate the proposed algorithm are new call blocking rate, handover call blocking rate, the number of handovers, and load distribution index. The minimization achieved in the load balancing performance parameters as seen from the results is the milestone of this research.

The remaining parts of the paper are organized as follow. Section II gives the related works in literature and in section III, the system model was presented. Section IV describes the proposed adaptive cost function formulation and in section V, the simulation and result discussion were presented. Finally, the paper's conclusion is presented in section VI.

II. Related Works

Generally, several related LTE handover decision enhancement exist in literature [4], [7]-[16]. Specifically, requirements of LTE handover and performance modeling are well explained in [4], [10], [14]. Close observation shows that there are three components and three stages for LTE X2 and S1-interfacehandover performance procedure. To perform a successful handover, a specific functionality is executed in each stage to enhancing the quality of connection and mobility of both the static and mobile users in the network. LTE handover which is based on hard handover if not properly designed can cause complicated and imperfect handover decision that can degrade the Quality of Service (QoS). However, a lot of previous works in this area lack simple and clear direction of how the problems of service providers as well as the subscriber could be addressed jointly.

In [9], [12], [13], handover procedure between LTE macrocell and fem to cell were studied. The attention of these works is major on the modification of signaling procedure for effective handover execution. Here, prediction of user speed, selection of target fem to cell and QoS were focused. Though, results were achieved, load and UEs battery life management were not considered.

An optimized performance evaluation of LTE hard handover algorithm with average RSRP constraint was proposed in [11]. Analysis of handover effect for a number of optimized handover parameters was done. Parameters used were simulated under different UE speeds. The results have improvement in terms an average number of handovers per UE per second and handover delay. However, their proposal did not address the issue of power consumption of the UE. Also, the work was based on NAHOC making high signaling overhead inevitable.Works presented in [16] and [17] have close similarities. Both proposals were based on layer 3 filtering for LTE handover execution. Received Signal Strength (RSS) and Carrier to Interference Ratio (CIR) were used as the key parameters for the handover execution. Therefore, UE's power consumption and load control of the network were not primary problems and were not addressed here.

Isolated works on battery life optimization proposals were given in [18] and [19] to solve the problems of energy consumption of UEs. The aim of authors in the work presented in [18] was meant to tune LTE handover parameters to the best settings for best handover performance. It was intended for efficient delivery of non-real-time services with bursty traffic on LTE network. This work achieved power savings also without noticeable impact on the user's experience. User inactivity timer (UIT), connected and Idle Mode Discontinuous Reception (DRX) were parameters used to achieving their aim. The research was evaluated by the method of field testing in a live LTE network using an optimal deployment scenario. The problem of load control is also not addressed here.

In [19], a novel mechanism that enhances UE's battery life performance was researched. The work was based on a cell reselection scheme that decides on which cell the UE should be connected when in an idle mode state.

The study proposed the use of a real 3G UTRA network measurements to guarantee the procedure of decreasing UE's energy consumption. The proposal uses dynamic intra-search signal of the neighbor cell and its threshold measurements for the optimization process.

The system analysis covers both UTRA and E-UTRA LTE network architecture.

Although results show substantial improvement, details of the handover procedure for the research were not presented. Authors in [20]-[22] presented energy aware load balancing schemes using different handover procedures respectively. Here, the main focus of their proposals was on load balancing and energy savings of the network rather than the UE. In addition, their works have the common problem of computational complexity which usually increases the network's overhead.

One simple way of solving computational complexity in a communication system is to use cost function based mechanism. As such, cost function based methods were adopted by authors in [23]-[25] for handover procedure in LTE network.

Although improved results were obtained at various levels, new and enhanced methods are still required by a number of other researchers in this area. Other, authors in literature used handover timer to ensure proper handover decision procedure. More specifically, handover timer is considered as the base of handover enhancement of authors in [26]-[28]. However, the drawback of UE's power management still remains.

With the known literature given above, it is certain that not much work have been done to jointly address the problem of load balancing and UE's power consumption using a cost-based handover procedure. Therefore, the proposed idea in this work is a worthwhile contribution in this field of research.

III. System Model

Many factors are responsible for UE's power consumption in a network [29]. These are power consumption due to data transmission (uplink packet transfer) and reception, backlit screen, processor operations and system's memory. Among all these lists, the data transmission and backlit screen consume more power. Since the main focus of the work is on the communication system and one of the research goals is to optimize battery life performance of the UE, the aspect of power consumption due to uplink data transmission is a good parameter to consider. UE's uplink transmission power is therefore used as one of the key parameters for the handover decision algorithm. Before the calculation of uplink transmission power, path loss between the user and some other relevant parameters need to be known.

It will be shown later that the uplink power transmission of the UE depends on transmission path loss largely.

Just as path loss is important for the estimation of the uplink transmission power of the UE, it is also important for the estimation of Reference signal received power (RSRP) usually used in the traditional handover decision process. RSRP is another important parameter to consider in handover management in LTE because it is associated with link quality of the networks.

Path loss depends highly on the position (distance) of the UE in relation to the reference cell since energy normally spread along as the transmission distance increases. One of the methods of position location of mobile users in a communication network is through the use of mobility models. However, we assume for simplicity that the UEs are not moving just are the eNBs are fixed. Therefore, only their x and y geographical coordinates are required for their position calculations.

The network scenario is shown diagrammatically in Fig. 1. It has a cluster of 7 cells with the middle cell heavily loaded and others lightly loaded. With our proposed algorithm, the lightly loaded cells are able to share the load from the heavily loaded cell to ensure fair distribution of loads otherwise called load balancing among all the cells.

Let us assume that a user and eNB are in the same x-y plane with geographical coordinates of (X_{UE} , Y_{UE}) and (X_{eNB} , Y_{eNB}) respectively. The distance between the user and the eNB can be represented as given in Eq. (1):

$$d_k = \sqrt{\left(X_{UE} - X_{eNB}\right)^2 + \left(Y_{UE} - Y_{eNB}\right)^2} \quad (1)$$

The RSRP by the UE from each cell is a function of the distance between the cell and the UE. Therefore, the RSRP in of UE in the i^{th} eNB can be expressed as:

$$RSRP_i = f_i\left(d_k\right) = P_i - L_i - f\left(\mu,\sigma\right)_i \quad (2)$$

where $f_i\left(d_k\right)$ is the signal propagation model function between the eNB and the UE by distance d_k , P_i is the transmission power of the eNB, L_i is the path loss propagation model between the eNB and the UE. $f\left(\mu,\sigma\right)_i$ is the shadow fading effect. Shadow fading effect is modeled as a random variable that follows a Gaussian distribution with a mean of zero and variance σ^2 . There are many propagation path loss models in the literature [30]. However, in this work, we consider urban path loss model (COST231-Hata model) given as:

$$\begin{aligned} L_i = {} & 46.3 + 33.9 \times log_{10}\, f_c - 13.82\, log\, h_{tx} + \\ & -\alpha\left(h_{rx}\right) + \left(44.9 - 6.55\, log\, h_{tx}\right) log\, d_k + C_m \end{aligned} \quad (3)$$

where f_c is the carrier frequency (MHz), h_{tx} is the height of eNB's antenna (m), $\alpha\left(h_{rx}\right) = 3.2\left(log\,11.75 h_{rx}\right)^2 - 4.97$ is the antenna correction factor for the urban environment (dB), h_{rx} is the height of UE's antenna (m) and d_k is the separation distance between the Cell and the UE (km). C_m is environmental correction factor (dB). For medium sized city and suburban area, $C_m = 0$.

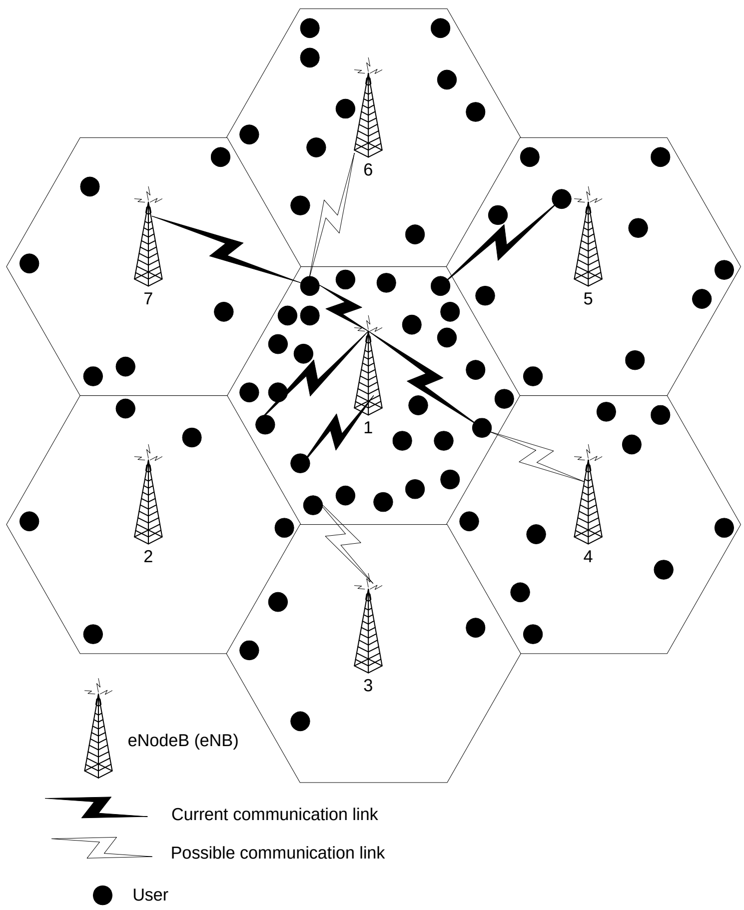

Fig. 1. System scenario

Eq. (2) can be written as:

$$RSRP_i = P_i - \begin{bmatrix} 46.3 + 33.9\, log_{10}\, f_c - 13.82\, log\, h_{tx} + \\ -\alpha\left(h_{rx}\right)9 + \left(44.9 - 6.55\, log\, h_{tx}\right) log\, d_{i,k} + C_m \end{bmatrix} + - f\left(\mu,\sigma\right)_i \quad (4)$$

The transmission and reception of information by UE in communication system require the use power [20], [31]. Therefore, the power usage of the UE for data transmission to optimize its battery efficiency is considered. Base on 3GPP design, the UE is capable of setting its total uplink transmission power (in dBm) in the i^{th} eNB using Eq. (5) [32]:

$$P_{UE,i} = min\left\{ \begin{matrix} P_{max}, \begin{bmatrix} P_o + \alpha P_l \\ (open-loop-factor) \end{bmatrix} + \\ + \begin{bmatrix} \Delta_{RRC} + f\left(\Delta_{UES}\right) \\ (dynamic-offset-factor) \end{bmatrix} + \left[10\, log_{10}\left(N\right)\right] \end{matrix} \right\} \quad (5)$$

where P_{max} is the maximum uplink transmission power of the UE, α (cell specific) and P_o (which could be cell or user specific) are factors upon which power control compensation parameter depends on, αP_l is the path loss compensation parameter is the P_l is the path loss on the downlink evaluated at the UE which includes shadowing without fast fading. Δ_{RRC} is the cell-specific factor govern by radio resource control, Δ_{UES} is the user specific correction with a periodically closed loop mechanism in the uplink component. N is the number of apportioned PRBs to the UE within a Transmission Time Interval (TTI). The concept of uplink transmission power budget of UE in an LTE system is based on a mixed open loop and closed loop power control mechanism.

The major usefulness of the compensation parameter α is to allow different UEs to operate at different optimal levels of Signal to Interference and Noise Ratio (SINR). This depends largely on the path loss value between the respect UEs and the serving cell and it is useful for reducing any inter-cell interference so generated. For simplicity of this research, we assume all the UEs to be homogeneous. Consequently, we can use only the open loop compensation factors of Eq. (5) for the UE's uplink power transmission in which P_o is adjusted to be the same for all the UEs in the network.

Therefore, the uplink transmission power of a UE is only a function of its path loss which includes shadowing and bandwidth. In addition to the previous parameter used, the last parameter used is the status of the cell load.

The cell load status in a network is a measure of the amount of occupied bandwidth when compared with the total amount of bandwidth assigned to the cell. Clearly, cell load is the cell load is the ratio of a total number of scheduled resource blocks to the total number of resource blocks available in a cell.

IV. Adaptive Cost Function Formulation

In a cellular communication system which LTE network belongs, handover issues generally comprise of three phases. These are handover measurement phase, handover decision phase and lastly, handover execution phase. The first phase which is the handover measurement phase deals with the collection all measured handover parameters as inputs for onward processing by the second phase. The second phase processes the inputs according to the algorithm's set of rules to make an accurate handover decision for the last (final) phase. The final phase completes the handover process according to the decision reached at the end of the second phase. The Block diagram showing the most relevant components of the UEAHOC handover procedure is shown in Fig. 2.

The adaptive cost function formulated is the decision engine of the algorithm. The algorithm uses the cost function information parameters as input to make a decision of selecting the cell with the dominant value as the target cell. For better comprehension, we present in Eq. (6) the handover decision cost function formulation for the UE's in the i^{th} eNBas:

$$C_{i,} = W_{p,} \times f_{i,}\left(P_{UE}\right) + W_{load,} \times f_{i,}\left(L_{load}\right) + \\ + W_{rsrp,} \times f_{i,}\left(RSRP\right) \quad (6)$$

where W_p is the weight assigned to the normalized function of UE's uplink transmission power denoted as $f_i\left(P_{UE}\right)$, W_{load} is the weight assigned to the normalized function of the cell load denoted as $f_i\left(L_{load}\right)$ and W_{rsrp} is the weight assigned to the normalized function of the RSRP denoted as $f_i\left(RSRP\right)$. For the successful evaluation of Eq. (6), it is required that each parameter of cost function should be normalized since they are not homogeneous in nature. These normalization processes are presented below as follows. Given the UE's uplink transmission power, the normalized function of UE in the i^{th} eNB given as:

$$f_i\left(P_{UE}\right) = e^{-\left(\frac{P_{UE}}{P_{max}}\right)} \quad (7)$$

where P_{UE} is given in Eq. (5) and P_{max} is the maximum uplink transmission power of UE. This normalized value gives a direct characterization effect of the UE's uplink transmission power on the battery power. The proposed handoff decision scheme can reduce the amount of UE's battery drain by avoiding picking the eNB whose path loss requires high transmission power of the UE.

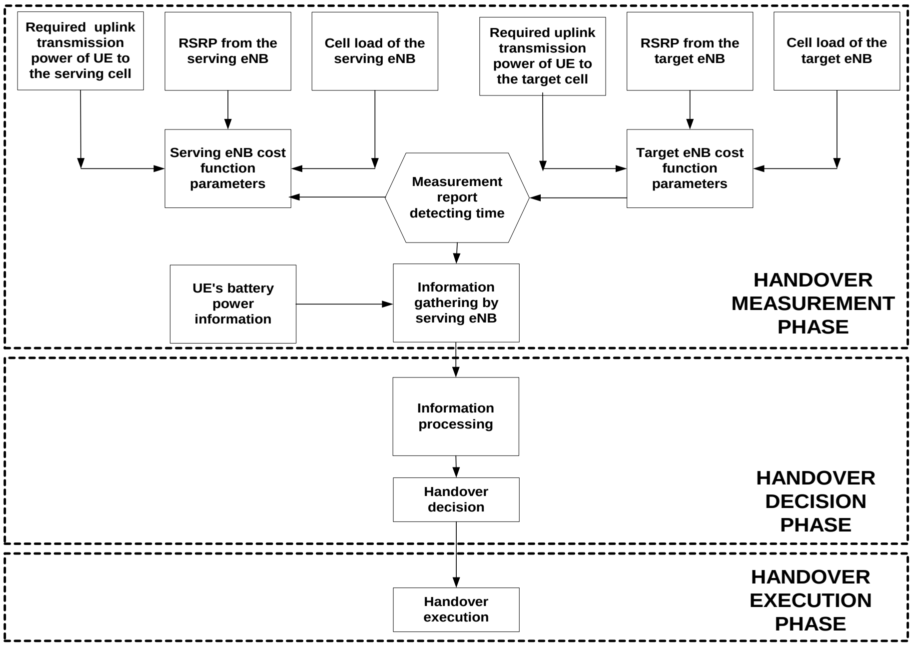

Fig. 2. The proposed UE-assisted handover block diagram

Similarly, the normalization of the cell load parameter of the i^{th} cell is given as in Eq. (8):

$$f_i\left(L_{load}\right) = e^{-\left(\frac{N_{occupied}}{N_{total}}\right)} \quad (8)$$

where $N_{occupied}$ is the number of scheduled PRBs in a cell and N_{total} is the total number of PRBs assigned to a cell. This normalized value gives a direct characterization effect of the cell's load parameter. The proposed handoff decision scheme can reduce the amount of network congestion by avoiding picking the eNB whose cell load is higher as the target cell. This feature enhances load balancing effect among the cells of the network.

Finally, the normalization of the RSRP parameter of the i^{th} cell is given as in Eq. (9):

$$f_i\left(RSRP\right) = e^{RSRP} \quad (9)$$

The normalization presented in (9) is effective for the cost function algorithm proposed because $RSRP_i$ is a negative quantity which is normally computed from the logarithm of the power ratio. Evaluating the index processing of its value will give an increasing function whose result is bounded between 0 and 1.

This normalized value gives a direct characterization effect of the RSRP. The proposed handoff decision scheme can reduce the amount of UE's battery drain and cell congestion by avoiding picking the eNB whose RSRP is lower. From all the normalization of the parameters, it is obvious that whenever path loss increases, RSRP and network throughput decreases causing network congestion. In the same vein, a decrease in path loss is capable of improving the uplink transmission power which could in turn cause an increase in power usage of the UE. In other to make the cost function to be load and battery efficient, the initial weights for load and uplink transmission parameters are made equal and greater than the initial weight of the RSRP parameter. The initial weights are set as follows: $W_p = 0.4$, $W_{load} = 0.4$ and $W_{rsrp} = 0.2$. The weight with the highest value has the highest priority and the assigned parameter to the weight has a corresponding dominance in the overall cost function value. In all, the weight components of the cost function are set the satisfy Eq. (10):

$$W_p + W_{load} + W_{rsrp} = 1 \quad (10)$$

Each weight uses the initial value from the start of the simulation. As soon as the battery's state of charge (SoC) is at 50% or below of the full charge, an adaptive weight function presented in Eqs. (11) and (12) would be used as the new weight values. The adaptive weight function increases the priority given to the power consumption related parameters in a stepwise fashion as the simulation runs:

$$\text{if } \left(0 < SoC \le Thr_{sos}\right)$$
$$\text{then} \begin{cases} W_{p,k} = \dfrac{W_{p,k-1}}{SoC} \\ W_{load,k} = \left(1 - \dfrac{1}{SoC}\right) + \dfrac{W_{load,k-1}}{SoC} \\ W_{rsrp,k} = \dfrac{W_{rsrp,k-1}}{SoC} \end{cases} \quad (11)$$

$$SoC = \frac{V_{residual}}{V_{full}} \quad (12)$$

where $W_{p,k-1}$, $W_{load,k-1}$ and $W_{rsrp,k-1}$ are the previous values of $W_{p,k}$, $W_{load,k}$ and $W_{rsrp,k}$ respectively. $V_{residual}$ is the residual voltage level of the battery and V_{full} is the full voltage level of the battery.

$SoC = 0$ means the battery is completely exhausted and $SoC = 1$ means the battery is fully charged.

From Eqs. (11) and (12), it can be seen that $W_{p,k}$ and $W_{rsrp,k}$ will have a gradual increment for each time the algorithm being executed given the condition of Eq. (11).

Regardless of how much the addition may be, the algebraic sum of all the weights cannot exceed 1 so that Eq. (10) is always fulfilled. From the discussion and application of Eq. (11) above, Eq. (6) can be rewritten as:

$$C_{i,k} = W_{p,k} \times e^{-\left(\frac{P_{UE}}{P_{max}}\right)} + W_{load,k} \times e^{-\left(\frac{N_{occupied}}{N_{total}}\right)} + \\ + W_{rsrp,k} \times e^{RSRP} \quad (13)$$

Using the information in Eq. (13), we can achieve a handover decision given in Eq. (14) by selecting the eNB whose cost function $C_{i,k}$ gives the maximum value as the target $eNB_{i,k} i^*$.

For example:

$$i^* = arg\left(\max_i \left\{C_{i,k}\right\}\right) \quad (14)$$

The last phase of the handover procedure is the handover execution phase. Based on the result obtained from the handover decision phase, the best candidate eNB is selected for the UE to be handed over.

If however, the present serving eNB turns out to remain the best candidate cell, the handover algorithm will proceed to end without making the unnecessary handover. On the contrary, the UE will be switched to the new eNB (target eNB) to start communicating with it.

The flow diagram of the whole procedure is depicted in Fig. 3.

V. Simulation Results and Discussion

The simulation of the proposed cost-based algorithm was implemented with Matlab software. The most relevant parameters considered for the simulation are presented in Table I. The initial parameters were generated from the start of the simulation as measured parameters. The network comprises of a cluster of 7 cells as shown in Fig. 1. The network resources were allocated to every cell with users randomly distributed.

The best target cell is always selected based on the governing equations following the step by step flow of the algorithm.

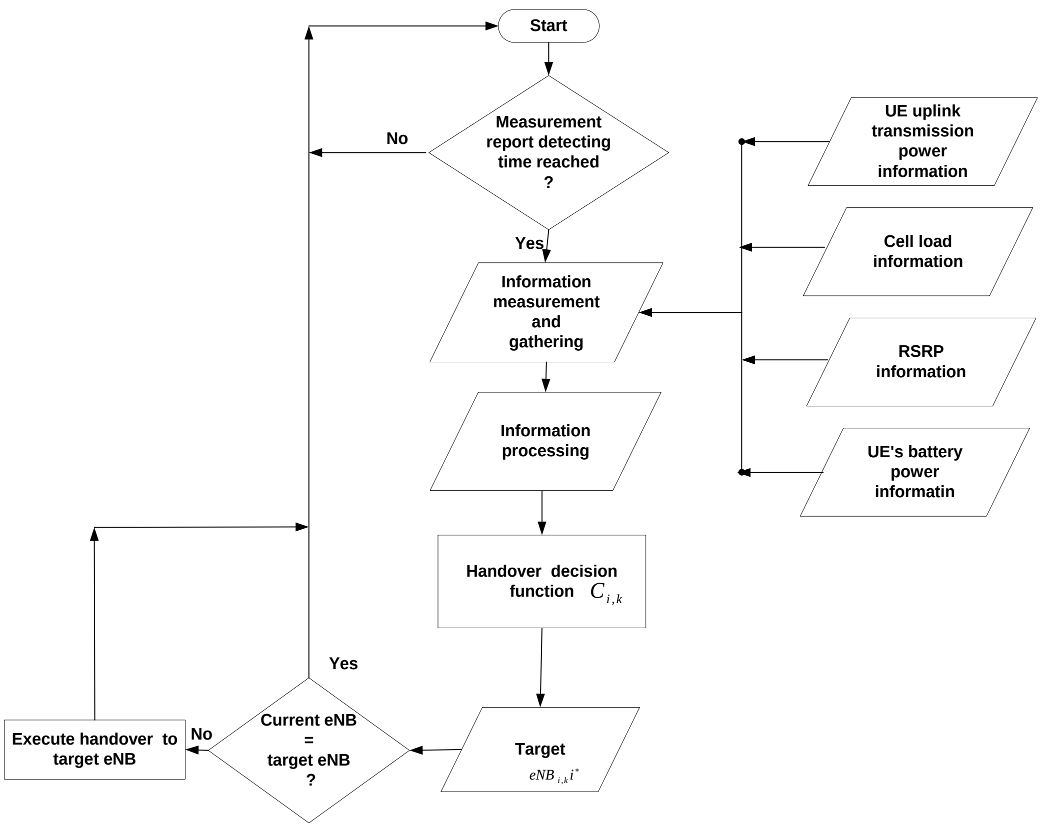

Fig. 3. Flow chart of the proposed algorithm

TABLE I
SIMULATION PARAMETERS

Parameter	Value
Cell radius	500m
Cell bandwidth	5MHz
Cell capacity	25PRBs
Number of cells	7
Number of UE	0 - 250
Transmit power of eNB	46dBm
Maximum uplink transmit power of UE	24dBm
Carrier frequency	2GHz
Path loss compensation factor α	0.8
Thr_{SoS}	0.5
$V_{residual}$	0-5V
V_{full}	5V
Base power P_o	-69dBm
eNodeB antenna height	25m
UE antenna height	1.5m
Shadowing standard deviation	6.5dB
Measurement report period	100ms
Transmission power weight (Initial)	0.4
Load weight (Initial)	0.4
RSRP weight (Initial)	0.2
Simulation time	2000s

The algorithm is periodically called at the laps of each measurement report time. The performance of the proposed algorithm is verified by comparing our results with two other works in literature which are LBA [6] and HMD [5]. The performance metrics tested are new call blocking rate, handover call blocking rate, the number of handovers, and load distribution index.

In this research, the handover number is the number of handover call. Other performance metrics used are defined thus:

$$H_{blocking\_rate} = \frac{N_{blocked\_handover}}{N_{total\_handover}} \quad (15)$$

where $H_{blocking\_rate}$, $N_{blocked\_handover}$, $N_{total\_handover}$ are the handover call blocking rate, number of blocked handover calls and the total number of handover calls respectively:

$$H_{new\_blocking\_rate} = \frac{N_{blocked\_handover}}{N_{new\_handover}} \quad (16)$$

where $H_{new\_blocking\_rate}$, $N_{blocked\_handover}$, $N_{new\_handover}$ are the new call blocking rate, the number of blocked handover calls and the number of new handover calls respectively. The load distribution index of the entire network D_{index} at any time *t* is given as:

$$D_{index} = \frac{\left(\sum L_{load,i}(t)\right)^2}{|M|\sum\left(L_{load,i}(t)\right)^2} \quad (17)$$

where $L_{load,i}(t)$ is the load of the ith cell at time *t* and M is the total number of cells in the network. A larger value of D_{index} gives an indication of a balance load distribution among the cells of the network.

From Fig. 4, it is shown that the handover call blocking rate increases as the number of users are increasing. The reason being that many unnecessary handover calls are prevented by the target cell except the proper handover conditions are met. Furthermore, we are able to achieve a much lower value of handover call blocking rate when compared with other two in literature. Fig. 5 shows the new call blocking rate. The trend is the same with Fig. 4. However, the new call blocking increases rapidly as the number of users are increasing because the network loads are being shared fairly among all the cells are more new calls can be accommodated. Again, our proposal still performs better having the lower rate when compared with the other two works.

The relationship between the number of handover calls against the number of users is given in Fig. 6. It can be seen here the proposed algorithm is better when compared with LBA and HMD. Lower handover means lower network overhead.

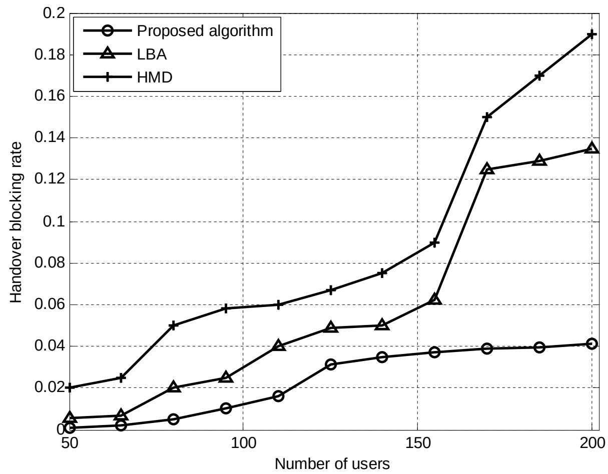

Fig. 4. Handover blocking rate

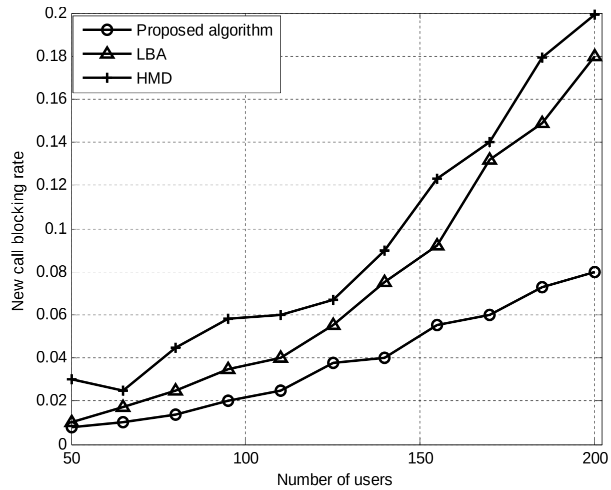

Fig. 5. New call blocking rate

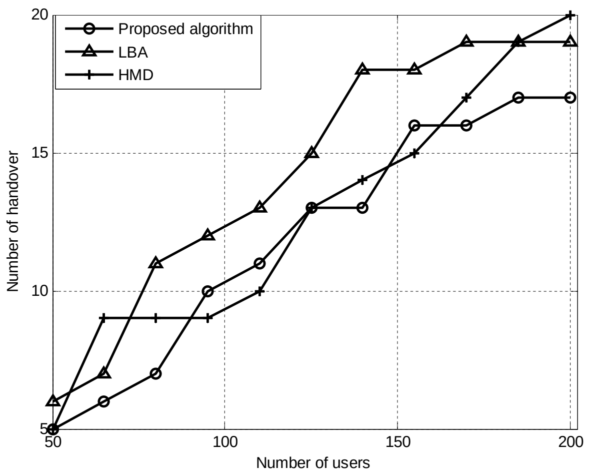

Fig. 6. New call blocking rate

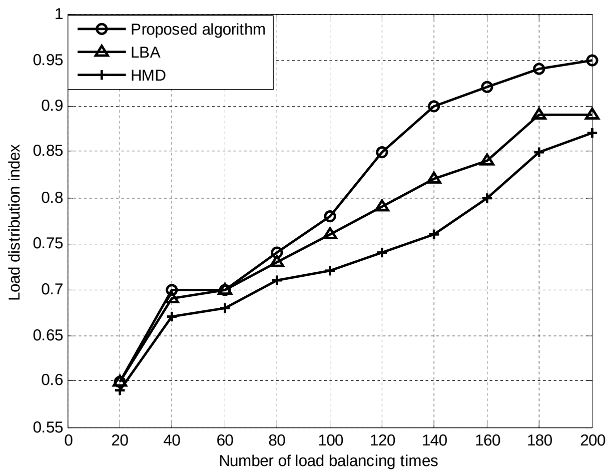

Fig. 7. Load distribution index

Finally, in Fig. 7, the relationship between the load distribution index and the number of load balancing times is shown. A higher number of load balancing times allows for a higher number of load distribution index.

The desire is to make the index as close to 1 as possible. As seen from the figure, the proposed algorithm gives a better performance than LBA and HMD.

VI. Conclusion

In this research, an adaptive cost-based handover decision algorithm for user equipment battery-life aware load balancing in LTE is presented. The cell load, the RSRP and the uplink transmission power were the parameters used for the cost function formulation.

The proposed algorithm is made adaptive by using the battery life information of the user equipment to compute the weights. In summary, more than 90% load distribution index is achieved after many load balancing times. The proposed algorithm was compared with LBA and HMD method and a good improvement over the compared works was obtained. The high value of the load distribution index achieved is an indication of a fair distribution of the network loads among the cells.

For future work, the proposed algorithm could further be optimized to cover Call Admission Control (CAC) and service scheduling for enhanced QoS of the network.

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