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A Cost Function Algorithm for Mobility Load Balancing in Long Term Evolution Networks

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Abstract: Recently, different types of service demand by subscribers of Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) Network is continually on the increase and this necessitated the introduction of Self-Organizing Network (SON) functionalities in LTE systems. Load balancing is one of the major issues in self-optimization process of SON that needs adequate research attention due to high demand of scarce network resources, time-varying traffic and economy side consideration. To solve this issue, we proposed a low computational complexity and effective cost function solution to mitigate the problem of load imbalance in an LTE cellular network. Our solution aimed at balancing the network load fairly for optimized performance by automatically handing over cell edge users from an over-loaded cell to under-loaded cell using an estimated weighted value derived from SINR, cell's response time for user's service demand, the number of users in active mode and the number of connections of real time service class. We consider the cell with highest weighted value to be over-loaded and hence, load-shed some of its cell edge users to under-loaded neighbours by triggering a load balance handover process in the system. Performance evaluation of the proposed solution achieved a 98% in terms of network load distribution index with a few numbers of unsatisfied user.

Key words: Long Term Evolution, Self-Organizing Network, Load balancing, cost function, handover.

INTRODUCTION

Long Term Evolution (LTE) is a new cellular radio system introduced in the Third Generation Partnership Project (3GPP) to cope with the rapidly increasing service demands of heterogeneous subscribers (Schmelz, Van Den Berg *et al*. 2009; Yang, Kim *et al*. 2012). 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. 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). RMM (Rapiei, Yusof *et al*. 2012) is used to efficiently utilize and manage the network's air interface resources. With the goal of reducing capital expenditures (CAPEX) and Operational expenditures (OPEX) (Schmelz, Van Den Berg *et al*. 2009; Viering, Dottling *et al*. 2009; Hu, Zhang *et al*. 2010; Wang, Wen *et al*. 2010; Xiao, Zhang *et al*. 2012; Yang, Li *et al*. 2012) in LTE network, Self-Organizing Network (SON) functionalities was introduced by 3GPP to boost RRM capability for better Quality of Service (QoS) provision as perceived by the users.

SON functionalities in LTE include self-configuration, self-optimization, self-diagnosis and self-healing (; Luketić, Šimunić *et al*. 2011) and it is defined as a situation where user equipment (UE) and eNB measurements and performance measurements are used to automatically tune the network for better network QoS performance and service delivery to UE (Yu, Bo *et al*.). Mobility load balancing (MBL) is one of the several challenging features of self-optimizing network and hence, it forms the focus of this paper.

MBL (Yu, Bo *et al*. ; Hu, Zhang *et al*. 2010; Lobinger, Stefanski *et al*. 2010; Suga, Kojima *et al*. 2011; Xu, Chen *et al*. 2011) refers to a situation where cells that are highly loaded called (over-loaded cells) shed their traffics to lower loaded (under-loaded) neighbouring cells so as to provide for effective use of radio resource in the overall network. A load balancing related issues (Yang, Kim *et al*. 2012) happens when a serving cell has

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inadequate resources to service the demands of users while at the same time, its neighbouring cell still have enough unutilized resources to accommodate other users. If this problem is not adequately checked, the over-loaded cell will begin to experience high rate of blocking probabilities of new calls and handovers calls which is not in the best interest of the overall network. Many methods have been used in literatures to solve LTE load imbalance problem (Altrad and Muhaidat ; Nguyen-Vuong and Agoulmine ; Nguyen-Vuong, Agoulmine *et al*. 2008; Zhang, Liu *et al*. 2011; Atayero and Luka 2012; Fotiadis, Polignano *et al*. 2012; Li, Wang *et al*. 2012). Interestingly, most of these works in known literature are yet to solve the MLB problem in LTE from the angle of weighted cost function to reduce computational complexity. We therefore focus this research work in the direction of MLB that has less computational complexity requirement. In this paper, we propose an effective weighted cost function estimator that takes into account the SINR, cell's response time for user's service demand, the number of users in active mode and the number of connections of real time service class. We consider the cell with highest weighted value to be over-loaded and hence, load-shed some of its cell edge users to under-loaded neighbours by triggering a load balance handover process in the system. The result of the weighted cost estimates show which cell is over-loaded and under-loaded before an appropriate handover process is triggered. The rest of the paper organization follows. Section two presents the system model framework where we discuss in details LTE network architecture and handover procedures. We introduced the related work in literature in section three. Section four gives the weighted cost function problem formulation and normalizations. Section five presents our proposed algorithm for the weighted Cost function scheme. In section six, we present our performance evaluation and results. Finally, the paper's conclusion is presented in section seven.

System Model Framework:

The system model comprises an LTE cellular network with seven cluster cells as shown in Fig. 1. We consider the centrally place cells as cell number one (1) surrounded by six (6) other neigbouring cells numbered two (2) to seven (7) respectively. Each cell in the network is serviced by an eNB that is centrally placed in the cell. 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 eNB s load status information is exchanged periodically through X2 interface as required in LTE architecture. The mean response time which include service time, is assumed to contribute to cell load of the network.

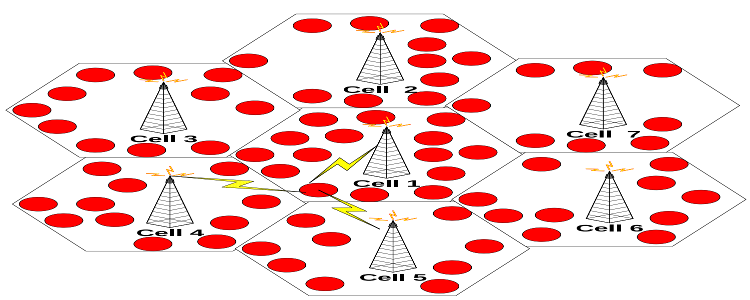


Fig. 1: Proposed Network Model.

LTE System Architecture:

LTE system architecture is a flat IP based architecture. It comprises of eNBs, Mobility Management Entity (MME) and System Architecture Evolution (SAE) gateway (Kim ; Kim, Lee *et al*. 2010). The detailed LTE architecture is presented in Figure 2. The eNBs and MME/SAE gateway are linked together by the S1 interface. The X2 interface connects one eNB to another eNB in the network. The X2 interface takes care of communication exchange between adjacent eNBs and it is also responsible for the User plane when temporary user downlink data is to be sent during handovers handover user from one eNB and another. Handover in LTE (Kim, Lee *et al*. 2010; Rapiei, Yusof *et al*. 2012) is the transfer of user connection from one eNB to another eNB. It can be executed between cells of a single eNB called intra- eNB handover and between eNB s of the same MME/S-GW called inter- eNB or intra- MME handover. The last one is handover between eNBs of different MMEs. Inter- eNB handover which does not involve changing MME is usually performed over X2 interface.

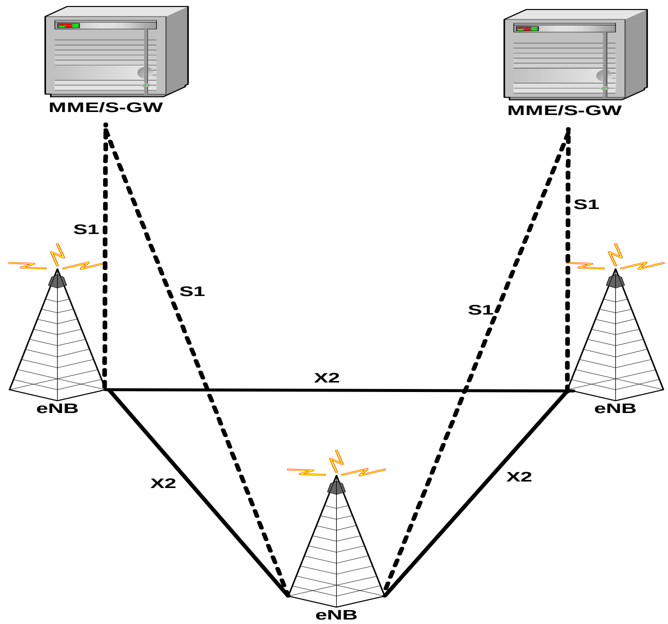


Fig. 2: LTE system architecture.

Handover Procedure in LTE Network:

Handover procedure in an LTE system (Kim) is shown in Figure 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), reference symbols received quality (RSRQ) or load information report. 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 favor of the UE, it sends a corresponding measurement report to trigger 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 the 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.

Related Works:

Mobility load balancing in LTE systems has not been widely researched into in recent times. Hence, more research into load balancing is required to meet the RRM requirements of the LTE system that will later translate into one of the 4G candidate networks. It is therefore necessary to present some of the few works in literature that have been done in this area. Authors in (R. Nasri Z. Altman 2007) 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 (Lv, Li *et al*. 2010). The authors achieved by dynamically adjusting RRM parameters based on the source cell load and its neighbouring cell condition. This work however, has a price to pay in terms of network signalling. In (Lobinger, Stefanski *et al*. 2010), an algorithm evaluation of load balancing in downlink LTE self-optimizing networks was presented. The work evaluated the network performance of the algorithm using loads of a cell as the input with its associated handover parameters used as controls. Different network scenarios where simulated for their research for performance evaluation. Authors in (Awada, Wegmann *et al*. 2010) presented a game theoretic approach for load balancing in cellular radio networks. In their work, the 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 a 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. One of the major problems begging for attention as seen from literatures presented is computational complexity and scalability of load balancing solutions. We therefore, used a weighted cost function idea in this research to reduce complex computations and to enhance network scalability.

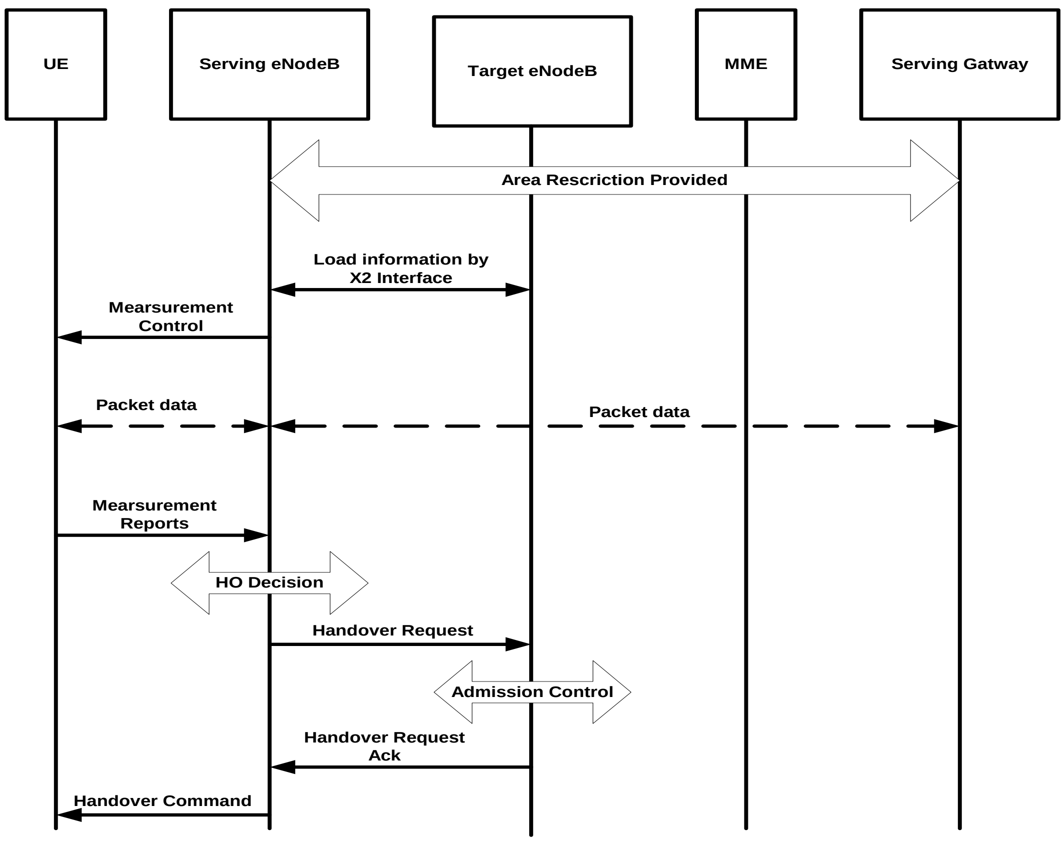


Fig. 3: Handover procedure in LTE.

Proposed Load Balancing Cost Function Formulation:

The cost function approach has not been widely used in the literature to solve load balancing problem in LTE. Most authors use single factor when considering network load balancing. In (Lv, Li *et al*. 2010) 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 (R. Nasri Z. Altman 2007) presented adaptive hysteresis scheme where only the load differences between the target and the serving cells were considered. In their work, cell load balancing is based on load information of via the X2 interface. In (Han and Wu 2010), handover signalling was considered for load balancing of IEEE 802.16 network. The algorithm enables load balancing via relay stations through the estimation of handover signalling in the network.

From known literature, the weighted cost function method has not been used for LTE load balancing. In this work therefore, a weighted cost function that considers more than one parameter to bring about an enhanced load balancing scheme was used. The research considers some other factors in determining the cell load weighted cost for better performance. The parameters taken into account in our scheme include: SINR of each user in a cell, cell's response time for user's service demand, the number of users' ratio in active mode in a cell and monetary cost of application demanded. We adopt the general cost function (Kim, Lee *et al*. 2010) to formulate the problem as presented in equation (1)

$$L_i = \sum_{1}^{m} W_m N_m \quad (1)$$

Where L_i is the cost function estimate of the cell load (serving cell), W_m is the weight assigned to *m*th parameter of the cell, N_m is the *m*th normalized parameter value of the cell and *m* gives the maximum number of normalized parameters to be considered. In this paper, we considered four parameters. It is important to note that the sum of all the weights must be equal to 1. The normalized value of N_m is also bounded between 0 and 1. This is important because our goal is to set the estimated load value of each cell between 0 and 1. For further simplification, equation (1) can be broken down as seen in equation (2):

$$L_i = W_{i(SINR)} * N_{i(SINR)} + W_{i(RT)} * N_{i(RT)} + W_{i(K)} * N_{i(K)} + W_{i(CS)} * N_{i(CS)} \quad (2)$$

Where $W_{i(SINR)}$ is the weighted value associated with SINR of serving cell, $N_{i(SINR)}$ is the normalized function of SINR of serving cell, $W_{i(RT)}$ is the weighted value associated with response time of serving cell, $N_{i(RT)}$ is the normalized function of response time of serving cell, $W_{i(K)}$ is the weighted value associated with the ratio of users in active mode (K_a) in the cell to the total number of users (*K*) camped in the cell, $N_{i(K)}$ is the normalized value obtained due to the ratio of users in active mode (K_a) in the cell to the total number of users (*K*) camped in the cell, $W_{i(CS)}$ is the weight associated with the number of connections of real time service class and $N_{i(CS)}$ is the normalized function associated with the number of connections of real time service class. In this paper, we have four service types (VoIP, Video streaming, web browsing and Peer-to-peer (P2P)) (Kim ; Kim, Lee *et al*. 2010). All the service types are classified into two major classes of real time and non real time. VoIP and video streaming are real time services while web browsing and P2P are non-real time services.

In order to determine the serving cell and target cell pair respectively, a weighted cost function is evaluated for each cell in the network. It is assumed that eNB and cell are interchangeable throughout the paper. Therefore, the formulation of the SINR is needed for each user as adapted from (Wang, Ding *et al*. 2011) given in equation (3).

$$SINR_{i,l,k(t)} = \frac{P_{i,l(t)} * G_{i,l,k(t)}}{N + \sum_{j \in N, i \neq i} P_{j,l(t)} G_{j,l,k(t)}} \quad (3)$$

Where *N* gives the power of Additive White Gaussian Noise (AWGN) on a Physical Resource Block (PRB), $P_{i,l(t)}$ is the transmit power of eNB *i* (serving cell) on PRB *l* at time *t*, $G_{i,l,k(t)}$ is the channel gain between eNB *i* and user *k* at time *t*, $P_{j,l(t)}$ is the transmit power of eNB *j* (target or neighbour cell) on PRB *l* at time *t*, $G_{i,l,k(t)}$ is the channel gain between eNB *j* (target cell or neighbour cell of cell *i*) and user *k* in cell *i* at time *t*. The signal strength received by user *k* from serving cell and the target cell at time *t* is given as $P_{i,l(t)}G_{i,l,k(t)}$ and $P_{j,l(t)}G_{i,l,k(t)}$ respectively. Let the SINR information ratio of the serving cell and the target cell be given as seen in the equations (4) and (5) respectively

$$SINR_{i(t)} = \frac{SINR_{i,l,k\max(t)}}{\sum_{k=1}^{K_i} SINR_{i,l,k(t)}} \quad (4)$$

$$SINR_{j(t)} = \frac{SINR_{j,l,k\max(t)}}{\sum_{k=1}^{K_j} SINR_{j,l,k(t)}} \quad (5)$$

Where $SINR_{i(t)}$ and $SINR_{j(t)}$ are the SINR information ratio of the serving and the target cell respectively, $SINR_{i,l,k\max(t)}$ is the maximum SINR value among the users of serving cell, $SINR_{j,l,k\max(t)}$ is the maximum SINR value among the users of the target cell. K_i and K_j are the total number of users camped in serving and target cell respective. Thus, we formulate the normalised function $N_{i(SINR)}$ of the serving cell in relation to target cell as given in equation (6)

$$N_{i(SINR)} = SINR_{i(t)} - SINR_{j(t)} \quad (6)$$

For the mean response time of the call, we formulated it as adopted from (Xue, Luo *et al*. 2009). The formulation assumed that a serving cell contains an M/M/1 queue due to service demanded by users. Users are however serviced based on a first come, first serve fashion. It naturally follows therefore that, the mean response time is the total time to service the user and this includes service time given in equation (7) as:

$$T_{r,i} = T_{w,i} + T_{s,i} \quad (7)$$

Where $T_{r,i}$ the mean response time of cell *i*, $T_{w,i}$ is the mean waiting time of users in cell *i* and $T_{s,i}$ is the mean service time of cell *i*. Let the queue length of users in the cell be denoted as α and the arrival rate of the users be denoted by *λ*. Then, $T_{w,i} = \frac{\alpha}{\lambda}$, and equation (7) becomes:

$$T_{r,i} = \frac{\alpha}{\lambda} + T_{s,i} \quad (8)$$

The cell occupancy which is directly proportional to the cell load and it is given as:

$$\rho = \frac{\lambda}{\mu} \quad (9)$$

Where μ is the service rate.
Number of users in the cell can be obtained using equation (10):

$$K_i = \frac{\rho}{1-\rho} \quad (10)$$

But

$$\alpha = K_i - \rho = \frac{\rho^2}{1-\rho} \quad (11)$$

From little's theorem,

$$\lambda = \frac{\rho}{T_{s,i}} \quad (12)$$

By combining equations (8), (11) and (12) we have equation (13):

$$T_{r,i} = \frac{T_{s,i}}{1-\rho} \tag{13}$$

Let the mean response time information function of serving cell and target cell be given as seen in equations (14) and (15) respectively

$$T_{r,i(\text{inf})} = \frac{T_{r,i}}{\sum_{i}^{j} T_{r(i-j)}} \tag{14}$$

$$T_{r,j(\text{inf})} = \frac{T_{r,j}}{\sum_{i}^{j} T_{r(i-j)}} \tag{15}$$

Where $T_{r,i(\text{inf})}$ and $T_{r,j(\text{inf})}$ are the mean response time information ratio of the serving and the target cell respectively, $T_{r,i}$ is the mean response time of the serving cell, $T_{r,j}$ is the mean response time of the target cell and $\sum_{i}^{j} T_{r(i-j)}$ is the sum total of all mean response time for serving and target cells. Thus, we formulate the normalised function $N_{i(RT)}$ of the serving cell in relation to target cell as given in equation (16)

$$N_{i(RT)} = T_{r,i(\text{inf})} - T_{r,j(\text{inf})} \tag{16}$$

Let the number of users in active mode in the serving cell be denoted as $K_{i,a}$ and K_i be the total number of users camped in the cell. Then, the ratio of the active cell users to the total users in the cell denoted as $K_{i,r}$ is given in equation (17) as:

$$K_{i,r} = \frac{K_{i,a}}{K_i} \tag{17}$$

We also solve for the target cell in similar ways as given in equation (18):

$$K_{j,r} = \frac{K_{j,a}}{K_j} \tag{18}$$

Where $K_{j,r}$ is the ratio of the active cell users to the total users in the target cell, $K_{j,a}$ is the number of users in an active mode of the target cell and K_j is the total number of users camped in the target cell. Thus, we formulate the normalised function $N_{i(K)}$ of the serving cell in relation to target cell as given in equation (19)

$$N_{i(K)} = K_{i,r} - K_{j,r} \tag{19}$$

Let the number of real time service connections of the serving cell be denoted as X_i and Y_i be the number of non-real time service connections. Then, the ratio of the number of real time service connections to the total number of all service connections Z_i is given in equation (20) as:

$$Z_i = \frac{X_i}{X_i + Y_i} \tag{20}$$

We also solve for the target cell in similar ways as given in equation (21):

$$Z_j = \frac{X_j}{X_j + Y_j} \tag{21}$$

Where Z_j is the ratio of the number of real time service connections to the total number of all service connections of the target cell, X_j is the number of real time service connections of the target cell and Y_j be the number of non-real time service connections in the target cell. Thus, we formulate the normalised function $N_{i(CS)}$ of the serving cell in relation to target cell as given in equation (22)

$$N_{i(CS)} = Z_i - Z_j \tag{22}$$

To determine the appropriate weights to asign to *m*th parameter that will give a good effect, we conducted several analyses and we arrived the following values in order of priorities: $W_{i(SINR)} = 0.4$, $W_{i(RT)} = 0.3$, $W_{i(K)} = 0.2$ and $W_{i(CS)} = 0.1$. The sum total of the weight is 1.

Load Balancing Algorithm:

The load balancing mechanism of the RRM is presented in the flow chart as seen in figure 4. The load balancing controller resides in the eNB to monitor load of each cell in the network. Once the system is initialised, the load balancing controller in the eNB detects all associated cost function parameters for the weight computation. The serving cell in the algorithm is denoted as LS while that of the target cell is denoted as LT. The load information estimation is done periodically as determined by the service provider. The load balancing procedure is initiated once the following is satisfied:

1. When there are edge users receiving adequate communicating signals from both serving and neighbouring cells and,
2. When there is load difference between the target cell and serving cell.

Load balancing handover of cell edge uses is the next issue to handle after cost function evaluation of each cells load. We adapt event A3 proposal given in (Zhang, Liu *et al*. 2011) formulated in equation (23).

$$M_j + O_{fj} + O_{cj} - Hys > M_i + O_{fi} + O_{ci} + Off \tag{23}$$

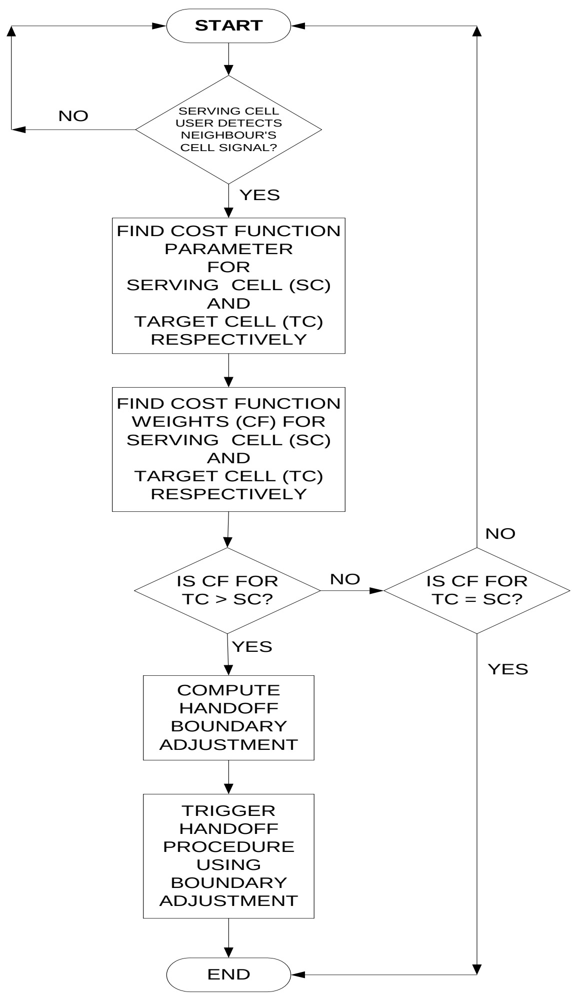
Where M_j is the evaluated result of the target cell without considering any offset, O_{fj} is the frequency specific offset of the frequency of the target cell, O_{cj} is the cell specific offset of the target cell which is normally set to zero if not configured for the target cell. M_i is the evaluated result of the serving cell without considering any offset, O_{fi} is the frequency specific offset of the frequency of the serving cell, O_{ci} is the cell specific offset of the serving cell which is normally set to zero if not configured for the target cell. Hys and Off are the hysteresis parameter for the event and offset parameter for the event respectively. We considered intra-cell or intra-frequency handoff for easy manipulation in this paper and we set $M_i = P_{i,l(t)}$, $M_j = P_{j,l(t)}$ and $O_{fi} = O_{fj} = O_{ci} = Off = 0$ to transform equation (24) into:

$$P_{j,l(t)} G_{i,l,k(t)} - (O_{cj} + Hys) > P_{i,l(t)} G_{i,l,k(t)} \tag{24}$$

From equation (24), it is clear that the value of O_{cj} determines how edge users are moved from over-loaded cell to under-loaded cell. Therefore, the larger the value of O_{cj} value, the easier we can move these edge users to load balance the network cells. We defined O_{cj} as given in equation (25):

$$O_{cj} \leftarrow \min(O_{cj} + \phi \frac{L_i}{L_j}, O_{cj}^{\max}) \, , L_i - L_j \geq L_{threshold} \quad (25).$$

where ϕ is the offset step size, L_i and L_j are the cost function estimate of serving and target cell respectively and $L_{threshold}$ is the predefine threshold to trigger load balancing procedure



Flow Chart Legend: CF = Cost Function Weight, TC = Target Cell, SC = Serving Cell

Fig. 4: Load balancing algorithm.

Performance Evaluation and Results:

Performance evaluation of this research was done in terms of number of unsatisfied users and load distribution index of the network. The number of unsatisfied users in the cell is an indicator that relates the number of users in the cell that can achieve the needed bit rate due to resource scarcity. This parameter is always maximized when we can transfer the load from heavily loaded cell to under loaded cell. From (Atayero and Luka 2012), the number of unsatisfied users is given as:

$$Z_C = N_T\left(1 - \frac{1}{p_c}\right) \quad (26)$$

Where N_T is the total number of users in the cell and P_c is the load of the cell after each load balancing cycle. P_c is given as the ratio of the cell's occupied PRB to the cell's total PRB. When we consider the whole network, we have:

$$Z_{net} = \sum Max[0, N_T\left(\frac{1}{p_c}\right) \quad (27)$$

For load distribution index, we can adopt fairness distribution index given as:

$$\mu(t) = \frac{\left(\sum_c p_c(t)\right)^2}{|k|\sum_c (p_c(t))^2} \quad (28)$$

Where $|k|$ is the total number of cells in the network and t is load balancing cycles. The load balancing index is normally between the interval $1/|k|$ and 1. A larger value of this indicates a more load distribution among cells in the network. The value of 1 is attained when the load is completely balanced among the cells and it desired to always maximise this load balancing index within any given load balance cycle.

The simulations were performed using MATLAB software. We assumed various initial conditions conforming to LTE scenario. There are seven eNB s and several users as shown in our network model in Figure 1. On initialisation, it is assumed that each user arrives randomly on any cell according to a Poisson process with an arrival rate and service rate. Details of other parameters used for simulations are given in Table 1. Each load balancing cycle is performed according to the algorithm in Figure 4 for each iteration.

Table I: Simulation Parameters.

Simulation parameters	Settings
System bandwidth	10MHz
Cell layout	Macro cells, Hexagonal
Transmit power of eNB	46dBm
Antenna type	Omni directional
Distance dependent path loss	128.1+37.6log10R(km)
Cell capacity	20 UE
Log-normal Shadowing standard deviation	8.9dB
ϕ	1dB
Hys	3dB

The results obtained from this research are shown in Figure 5 and Figure 6. We compared the proposed Cost Function Mobility Load Balancing (CFMLB) results with that of A Two-layer Mobility Load Balancing (TL-MLB) proposed by (Zhang, Liu *et al*. 2011) in literature. We achieved upto 98% in terms of network distribution index (figure 5). The number of unsatisfied users also reduces considerably as shown in figure 6.

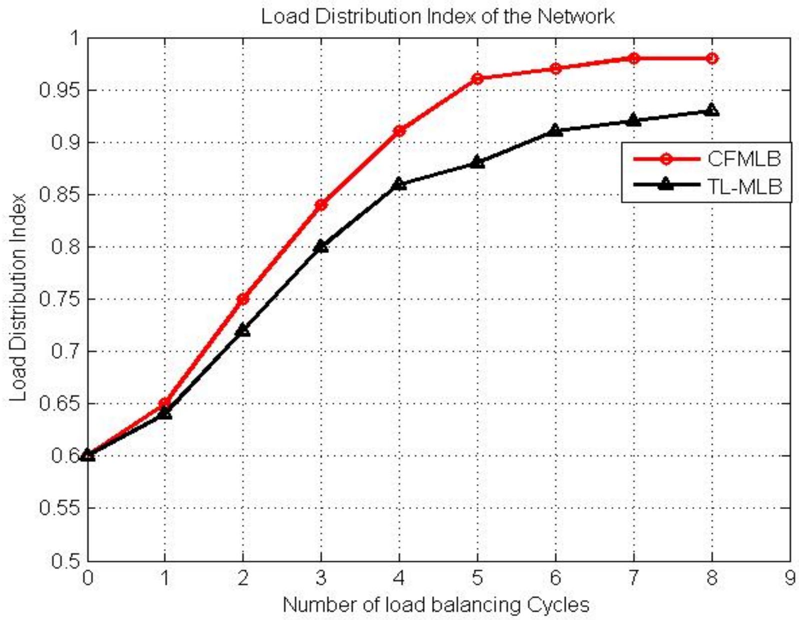


Fig. 5: Load distribution index of the Network.

Figure 5 shows the variation of the load distribution index against the number of load balancing cycles. The load distribution index gives the idea how close the cell load is balanced in the network. The more the value gets close to 1 the more the cell loads are balanced. However, if the cell loads are not balanced, the value tends to 0 depending on the degree of load imbalance of the cells in the network. It can be observed from figure 5 that at the end of 8th load balancing cycles, our CFMLB achieved much more than the TL-MLB due to the strategy we adopted in formulating our cost function.

Figure 6 presented the number of unsatisfied users against the number of load balancing cycles. It is seen that our CFMLB also gives a better result than that of TL-MLB after the 8th load balancing cycles. This is an indication that more users were satisfied with very few users unsatisfied using our proposal as compared with the TL-MLB as the load balancing cycle increases.

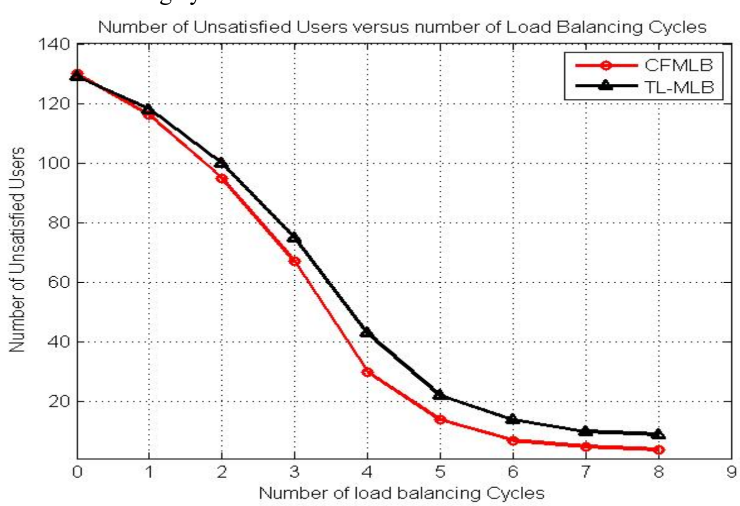


Fig. 6: Number of unsatisfied users of the network.

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Conclusion:

In this paper, a new cost function for LTE mobility load balancing (CFMLB) 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 are SNIR of each user in a cell, cell's response time for user's service demand, the number of users' ratio in active mode in a cell and the class of service demanded. Furthermore, we presented an algorithm that will aid the use of the cost function. Research evaluation based on network load distribution index and the number of unsatisfied users was done. The results show 98% attainment of network load distribution index and a very few number of unsatisfied users for the simulations done. From the results achieved, the proposed solution outperformed that of TL-MLB method in the literature in terms of network load distribution index and the number of unsatisfied users. The future work is to research into ways of mitigating the problem of ping-pong of users due to load balancing procedure in the network.

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