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Letter of Acceptance

Dear Author(s)

Based on the results of the reviewer evaluation and the coordination meeting of the editorial board of the Jurnal Ecotipe, your article entitled:

User Capacity Optimization Using the Mobility Load Balancing Algorithm for Downlink Data Long Term Evolution

Written by : Miranti, *Lydia Sari, Muhamad Doris, Syah Alam, Indra Surjati
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User Capacity Optimization Using The Mobility Load Balancing Algorithm For Downlink Data Long Term Evolution

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ABSTRACT

The increasing number of users in a Long Term Evolution (LTE) network often decreases network performance. A cell that has high traffic experiences a decline in network performance due to unavailable resources for certain users, while in cells with low traffic, the use of resources in these cells is inefficient. The mobility load balancing (MLB) algorithm balances the intercellular loads in an LTE network and improves the performance by distributing part of the load in a high traffic cell to neighboring cells that have low loads. An activated MLB will detect the network load and calculate the available resource for each cell to determine which cells are overloaded. The MLB will consider the candidate cell where the load could be distributed. MLB simulation results show that the application of MLB has succeeded in reducing the percentage of unsatisfied users by 9.4% and increasing throughput system to 5.617 Mbps.

Corresponding Author:

1. INTRODUCTION

Long Term Evolution (LTE) is a telecommunication technology that offers a data rate of up to 100 Mbps (downlink) and 50 Mbps (uplink), making it suitable to meet the demands of high data rate transfers [1]. However, as the number of users in an LTE network increase, it becomes difficult to achieve stable performance. Overload conditions on cells (congestion) will affect overall user access for both new users and active users and variations in usage time create an unequal load for each cell resulting in a decrease of the system's Quality of Service (QoS)[2], [3]. This encourages cellular operators to pay attention to resource blocks in cells to accommodate traffic and maintain a balanced network load. One possible scenario to provide the same user experience to all users is to measure QoS performance by utilizing the Mobility Load Balancing (MLB) algorithm at the cell level [4], [5]. The MLB algorithm will detect the load and then calculate the available resources in each cell to determine which cells are overloaded and consider candidate cells that will accept users from overloaded cells [6]. Ideally, optimization will automatically be carried out to balance the load between cells, where the load of cells with excess users will be transferred to cells with fewer users.

In research [2], the decision to move the excess load automatically from the source cell to the neighboring cell is based on the hysteresis value of the MLB simulation analysis on call admission and user throughput. In the proposed work, we analyze the effect of the implementation of the MLB algorithm on network performance on LTE in time division duplex (TDD) access mode. The trigger to activate the MLB algorithm is based on the load and total resources on the cell. The MLB algorithm is expected to increase network capacity and utilization of available resources which in turn will increase the throughput on LTE networks.

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The rest of the paper is organized as follows. The second section discusses the LTE network architecture, mobility load balancing scheme and the simulation setup. The simulations results are discussed in the third section, while the conclusion is given in the last section.

2. RESEARCH METHOD

2.1. LTE Network Architecture

LTE consists of three main components, namely User Equipment (UE), Evolved UMTS Terrestial Radio Access Network (E-UTRAN) and Evolved Packet Core (EPC). An LTE network architecture is depicted in Figure 1 [7]. User Equipment (UE) consists of 3 main parts, namely mobile termination (MT) which serves for communication, Terminal Equipment (TE) which serves for disconnection of communication links and Universal Integrated Circuit Card (UICC) which serves to run the Universal Subscriber Identity Module (USIM). USIM is used for identifying and authenticating subscriber devices and as a movable security key to protect radio transmission interfaces. The UE serves as a communication application platform, which can perform various functions required by the end user, such as signal and network regulation and maintenance, as well as communication link disconnection. The radio access interface from the UE to the core network is handled by E-UTRAN on the LTE architecture system. In the previous technology, node B and RNC were separate elements, in LTE architecture the two elements were only one component. The combination of the two elements is called Evolved Node B (eNode B), and functions to monitor and control signals for carrier delivery and authentication. In LTE technology, the EPC serves for end-to-end IP delivery services.

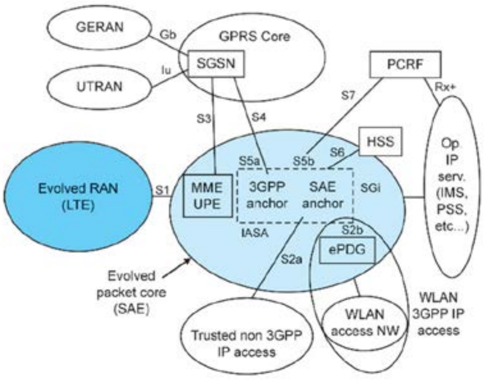

Figure 1. LTE network architecture [7]

The Physical Resource Block (PRB) is illustrated in Figure 2. One resource block consists of 12 subcarriers where the bandwidth of each subcarrier is 15 kHz and there are 7 OFDM symbols or one slot of 0.5 ms. This means in 1 resource block the bandwidth is 15 kHz x 12 subcarriers = 180 kHz. The smallest part of the resource block is the resource element or RE. In one resource block there are 12 subcarriers x 7 OFDM symbols = 84 resource elements. In the LTE system, there are variations in bandwidth, such as 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, and 20 MHz. The choice of bandwidth used by cellular operators will affect the number of resource blocks. The greater the bandwidth used, the greater the number of resource blocks and the maximum throughput generated [8]. Table 1 shows the number of resource block (RB) in accordance to the bandwidth used.

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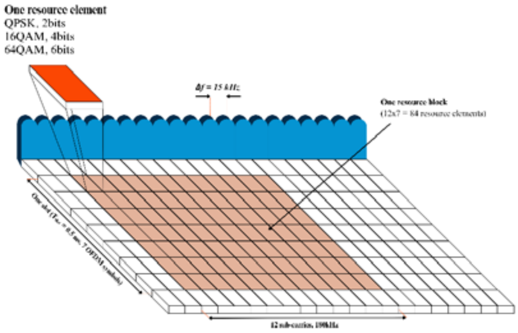

Figure 1. Physical resource block [9]

Table 1. Number of resource block vs channel bandwidth

Number of Resource Blocks	Channel Bandwidth (MHz)
6	1.4
15	3
25	5
50	10
75	15
100	20

In cellular networks, two full duplex techniques are generally used, namely Frequency Division Duplex (FDD) and Time Division Duplex (TDD). FDD allows sending and receiving data simultaneously using different frequencies. This technique requires a guard frequency as a separator between the sending and receiving frequencies and requires an accurate frequency filtering process. TDD uses one frequency for both sender and receiver simultaneously. The multiplexing process for each channel is done on a time basis so that each channel has a different time slot. In the 3GPP Release 8 specifications for TDD and FDD access modes, there is no difference in the basic subframe format and configuration protocol for the OFDMA radio access scheme in the downlink and SC-FDMA in the uplink.

2.2. Mobility Load Balancing (MLB) Algorithm

The MLB algorithm aims to balance the traffic loads between cells to increase system capacity. The algorithm ensures the user equipments (UEs) are distributed optimally across available neighboring cells. By keeping the UEs evenly distributed across the cells, frequent handover process can be avoided and thus drop-calls.

To trigger the start of MLB algorithm, the load of a source cell must exceed a predetermined threshold value, and there must be a neighboring cell which load is low enough to handle the traffic from the source cell. When these two events exist, the source cell will choose several user candidates to be transferred to the neighboring cell [4]. Depending to the types of handover and the handover parameters, MLB can be categorized into three approaches, namely Intra-frequency, Inter-frequency, and Inter-Radio Acces Technologi (Inter-RAT). In Intra-frequency MLB, the handover occurs on systems with the same frequency. On the other hand, in Inter-frequency MLB, the handover process occurs between different frequencies on the LTE network if available. The Inter-RAT MLB is the same as inter-frequency, but the handover occurs between different Radio Access Technologies (RATs).

Load balancing in LTE networks is done in several stages. In the first stage, the eNodeB performs traffic load assessment. If a traffic overload is detected, the source cell and the target cell will exchange

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information using Resource Status Request, Resource Status Response, and Resource Status Update messages. The next stage is the UE selection stage, where the number of UEs to be offloaded is calculated. If the traffic in a source cell exceeds its maximum threshold, an inter-frequency measurement report is triggered and UEs candidates are selected for handover. Finally the UE offloading is done, prioritizing UEs with non-Guarantee Bit Rate (GBR) to be transferred to the neighboring cell as to maintain the Quality of Service (QoS) of the network.

The LTE systems, TDD attracts growing interests as it is better suited to data traffic, namely data downloading, video conferences and internet browsing. In the TDD-FDD convergence scenarios, load balancing is an important solution to maximize the radio resource utilization efficiency.
The general algorithm mechanism of MLB is illustrated in Figure 3.

A cell is overloaded if the following condition is satisfied [2] :

$$\frac{V_{AR}(0)}{V_{TR}(0)} < Th_{PreMLB} \qquad (1)$$

where V_{AR} (0) is the number of resources in each cell 0, V_{TR} (0) is the total resource in cell 0, and Th_{PreMLB} is the trigger to activate the MLB algorithm.

The overloaded cell dynamically configures a new hysteresis threshold for different neighbor cells taking into account the relative amount of resources of the two cells available. The update of the hysteresis threshold is calculated according to the following equations [2]:

$$ThHys(0,i) = \alpha_i \, . ThHys(0), \ \ (0 \le \alpha_i \le 1) \qquad (2)$$

$$\alpha_i = \begin{cases} 0 \ \ if \ \dfrac{V_{AR}(i)}{V_{TR}(i)} > Th_{PostMLB} \\ \beta_i \ \ if \ Th_{availMLB} \le \dfrac{V_{AR}(i)}{V_{TR}(i)} \le Th_{PreMLB} \\ 1 \ \ if \ \dfrac{V_{AR}(i)}{V_{TR}(i)} \le Th_{AvailMLB} \end{cases} \qquad (3)$$

$$\beta_i = 1 - \frac{Th_{AvailMLB} - \dfrac{V_{AR}(i)}{V_{TR}(i)}}{Th_{AvailMLB} - Th_{PostMLB}} \qquad (4)$$

where $V_{AR}(i)$ is the available resources in the i^{th} cell, $V_{TR}(i)$ is the total amount of resources in the i^{th} cell, $V_{AR}(i)/ V_{TR}(i)$ is the relative amount of available resources in cell i, Th_{preMLB} is the predefined threshold for triggering MLB, $Th_{postMLB}$ is the threshold for disabling MLB, and $Th_{availMLB}$ is the threshold to accept MLB.

The variable Th_{Hys} (0) is the cell hysteresis threshold before MLB is run and Th_{Hys} (0, i) is the cell hysteresis threshold (with index 0) to neighbor cells with index i. The variable $Th_{availMLB}$ is the effective threshold when MLB is running and $Th_{postMLB}$ is the threshold for disabling MLB [2]. The cell updates the hysteresis threshold Th_{Hys} (0, i) and sends it to active UEs, namely the UEs residing in the cell. The UEs update the new hysteresis threshold until it returns to the default value. After reaching the MLB condition it will be disabled, namely if the following condition is met [2]:

$$\frac{V_{AR}(0)}{V_{TR}(0)} > Th_{PostMLB} \qquad (5)$$

Equation 6 is the effective threshold value when MLB is running [2]

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$$\frac{V_{AR}(i)}{V_{TR}(i)} > Th_{AvailMLB} \tag{6}$$

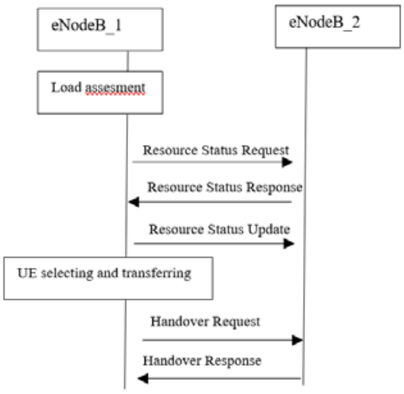

Figure 2. General concept of MLB [10]

The performance of the MLB system is the measurement of the effect of MLB algorithm implementation on the LTE network. The parameters measured as a reference for the performance of the MLB algorithm are the number of unsatisfied user and throughput, which are explained in details in the following:

1. Number of unsatisfied User
   Unsatisfied users are those denied an LTE service. This occurs due to limited cell resources in the LTE network. The number of unsatisfied users on the network is the number of unsatisfied users per cell expressed as [6]:

$$z = \sum_{\forall c} max\ (0, |U|.\left(1 - {}^{1}/_{P_i}\right) \tag{7}$$

   where $|U|$ is the number of users in the cell, and P_i is the load of the 0^{th} cell, and z describes the maximum number of users that will be allocated a resource.
2. Throughput
   Throughput is calculated from the number of symbols per second of data that can be transferred between a UE and eNodeB, which is converted into bits per second depending on the number of bits carried in one symbol. The number of bits per symbol depends on the modulation scheme, namely QPSK, 16-QAM, and 64-QAM. For QPSK, each symbol contains 2 bits per symbol, whereas 16QAM and 64QAM carries 4 and 6 bits per symbol, respectively. User throughput is can be stated as [11]

$$Throughput = \frac{number\ of\ bits}{time\ interval} = \frac{number\ of\ Resource\ Block \times 84 \times modulation\ factor}{0.5\ ms} \tag{8}$$

2.3. Simulation Setup

The system simulates 6 hexagonal cells with uniform radius, as illustrated in Figure 4. The total number of users in the simulated system is 140, where the number of users in each cell has been

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determined but the distribution of users in each cell is random. Data services are provided in the cell, with 64 Kbps data rate used by 50% of the users, 1280 Kbps used by 30% of the users and 1000 Kbps used by 20% of the users. In the simulated system, one cell is overloaded, namely the total resource blocks used in the cell is more than 60% of the total resource provided. In the simulated system the bandwidth channel is 15 MHz so that the total resource block is 75.

The overloaded cell will be triggered to shift one or more users to other cells. The MLB algorithm is used to determine target cell, namely the appropriate cell where the users from the overloaded cell can be transferred to. Consequently, the user from the overloaded cell will be moved to the target cell. RSRP value is used to determine the position of the user. The user who is located at the edge of cell will be selected as a candidate user to be moved to the target cell. If none of the users' RSRP values meets the qualification for the move, the MLB cannot be performed.

The flowchart of the MLB algorithm is given in Figure 5. The simulations will be conducted based on the parameters given in Table 2.

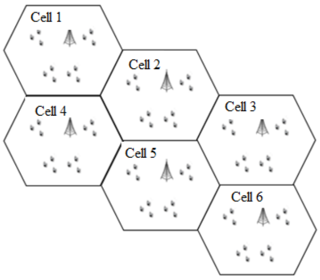

Figure 3. Simulated cells positioning

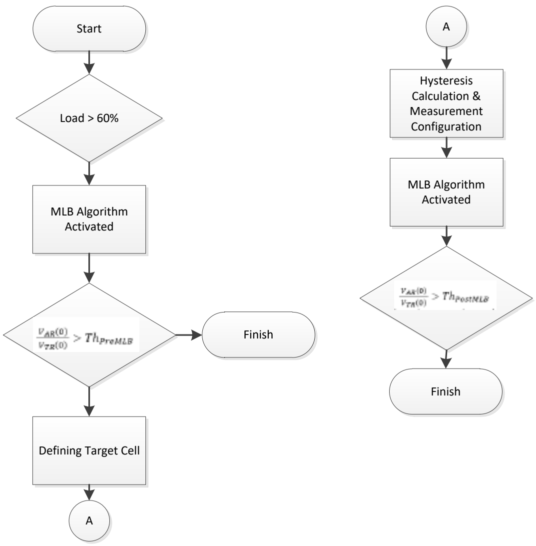

Figure 4. MLB algorithm

Table 2. Simulation Parameters

Parameter	**Value**

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Simulation time	300 s
Number of cell	6
EnodeB distance	500 m
Downlink transmitter power	46 dBm
Downlink bandwidth	15 MHz (72 PRB)
Traffic type	Data
Data Rate	64 Kbps; 1000 Kbps ; 1280 Kbps
SINR	0 ~ 15 dB
RSRP	-120 ~ -75 dBm
Number of user	140
Antenna type	MIMO
Default hysteresis value	3 dB
Default Load	60 % (0.6)
ThPreMLB	40 % (0.4)
ThAvailMLB	30 % (0.3)
ThPost	40 % (0.4)

The simulation steps are as follows:

1. Initialize according to Table 2, where all data are constant except for user position, data rate, RSRP and SINR
2. Generate user positions and distribute the positions randomly within each cells, in accordance with the number of users in each cells
3. Generate data rate
4. Measure SINR and RSRP of each user, considering the user's distance from eNodeB. The farther a user is from eNodeB, the lower its SINR and RSRP value
5. Calculate resource block of each user
6. Calculate the cell load, resource, and number of unsatisfied users
7. Calculate the network throughput before MLB algorithm is implemented
8. Run the MLB algorithm. The simulation time is 300 seconds
9. Measure the SINR until the allocated user resource is transferred to a neighboring cell
10. Calculate the load percentage and the resource of each cell after the MLB algorithm is implemented
11. Calculate the number of unsatisfied users and the network throughput after the MLB algorithm is implemented
12. Create the comparison graph for the conditions before and after the MLB algorithm is implemented

MLB scenarios are applied to analyze network performance with and without the implementation of MLB algorithm. The throughput and number of unsatisfied users are analyzed. In this scenario, the number of cells is 6, and one of the cells is overloaded. The testing scenario is done based on the increase of the number of users in the overloaded cell, with the details as follows:

a. Unsatisfied users

The number of unsatisfied users is calculated based on (7) only for the overloaded cell

b. Throughput

The throughput depends on the number of resources allocated for each user, and the type of modulation used. QPSK modulation is used when a user's SINR is between 0-5 dB. If the SINR is between 5-10 dB, the modulation is 16-QAM. The 64-QAM scheme is used for user's which SINR is between 10-15 dB. The throughput is calculated using (8).

The simulation is carried out by increasing the number of users in cell 3 gradually with the scenario as in Table 3. Before the MLB algorithm is run, the number of users, load and available resources is calculated in each cell. Table 4 shows the calculation results for the parameters.

Table 1. Simulation scenario

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Number of users in observed cell	**Number of users in neighboring cells**				
Cell 3	Cell 1	Cell 2	Cell 4	Cell 5	Cell 6
35	20	10	15	20	15
40	20	10	15	20	15
45	20	10	15	20	15
50	20	10	15	20	15
55	20	10	15	20	15
60	20	10	15	20	15

Table 2. System Parameters

Cell ID	**Number of *users***	**Traffic Load**	**Available Resource**
Cell 1	20	0.426667	0.573333
Cell 2	10	0.226667	0.773333
Cell 3	60	0.986667	0.013333
Cell 4	15	0.32	0.68
Cell 5	20	0.266667	0.733333
Cell 6	15	0.333333	0.666667

3. RESULTS AND DISCUSSION

As shown in Table 4, Cell 3 has a load of 0.9867 which means that the resources in Cell 3 are used up to 99% of the total resources provided. Therefore, the user load in Cell 3 has passed the threshold specified in this simulation, which is 60%.

The selection of target cell is done based on (1), the shortest distance between users in the overloaded cell and the target cell, and whether the target cell has available resources. The cell target candidates are listed from one with the greatest number of available resources, to one with the least number of available resources. As seen in Table 4, the first candidate for cell target is Cell 2. The algorithm will try to find a user in Cell 3 to be moved to Cell 2. If no suitable candidate is found in Cell 3, and the traffic condition in Cell 3 still satisfies (1), the algorithm will choose the next target cell, namely Cell 5. The user which is moved to the target cell will affect the hysteresis calculation for the next user. Hysteresis is calculated repeatedly each time signal quality is measured by the available resource in the target cell.

The simulation is done to analyze the network performance with and without MLB algorithm. During the simulation, the number of users in one of the cells is increased until the cell is overloaded. Some users do not obtain a resource block allocation, and therefore deemed as "unsatisfied users". Unsatisfied users are only found in an overloaded cell. The percentage of unsatisfied users before and after MLB algorithm is activated is given in Table 5.

Table 3 Percentage of Unsatisfied Users

Number of Users	**Percentage of Unsatisfied Users (%)**	
	Before MLB Activation	**After MLB Activation**
35	0	0
40	0	0
45	0,8	0
50	10	1,3
55	17	6,1
60	24,6	15,2

From Table 5, it is seen that when the number of users are 35 and 40, the percentage of unsatisfied users are 0, both before and after MLB algorithm is activated. This means all users are allocated resource blocks. When the number of users increases, the percentage of unsatisfied users also increases before the MLB is activated. However, the percentage decreases after MLB is activated. For instance, when

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the number of users is 60, the unsatisfied users before MLB is activated is 24,6%. The percentage lowers to 15,2% when MLB is activated. This means the activation of MLB algorithm will decrease the percentage of unsatisfied users by 9,4%.

Figure 6 shows the comparison of unsatisfied users percentage measured before and after the MLB algorithm is activated. The throughput measured in the simulations is the total throughput in the network. Throughput is affected by several factors, namely the number of users, the type of services used and the users' signal quality (SINR).

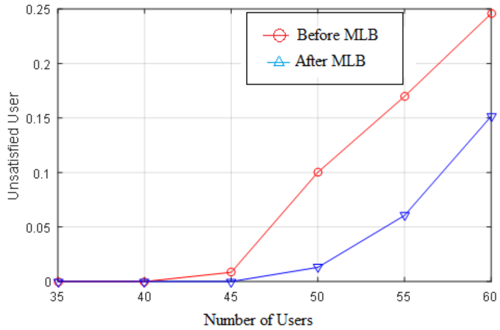

Figure 5. Percentage of Unsatisfied Users Before and After Activation of MLB

The throughput will increase when more of the allocated resource blocks are used in the network, as shown in Table 6. In Table 6, it is seen that when the number of users is 35 and 40, the total throughput decreases as the MLB algorithm is activated. This decrease is because several users are moved to a target cell, which subsequently decreases the signal quality in the target cell. The transfer of users is done to balance the network load. When the number of users is between 45-60, the throughput increases after the MLB algorithm is activated. For instance, when the number of users is 60, the throughput increases from 165.137 Mbps to 170.7552 Mbps. The increase of 5.617 Mbps is because the unsatisfied users in Cell 3 are moved to target cell. This consequently increases the number of users in the target cells and the number of allocated resources being used. The throughput comparison before and after the MLB algorithm is activated is given in Figure 7.

Table 4. Total throughput

Number of Users	**Total Throughput (Mbps)**	
	Before MLB Activation	After MLB Activation
35	150.43392	150.23904
40	158.31648	157.8864
45	163.7664	164.32416
50	163.35104	168.34432
55	164.620	171.4272
60	165.13728	170.7552

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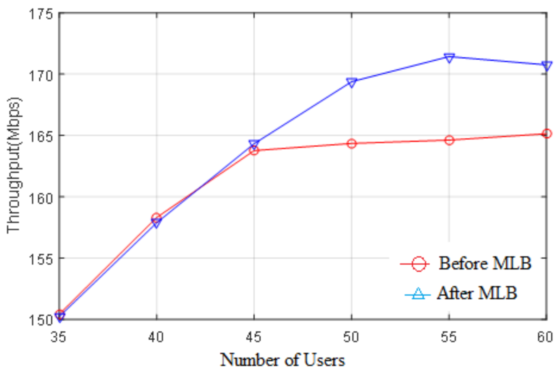

Figure 6. Throughput comparison before and after MLB activation

4. CONCLUSION

Simulations have been done to analyze the impact of MLB algorithm in optimizing the user capacity for downlink data in LTE network. Based on the simulations, it is shown that the use of MLB algorithm can decrease the percentage of unsatisfied users by 9.4%. This means several users which are denied service prior to the activation of MLB algorithm, can obtain resource block after the MLB algorithm is activated. The network throughput increases by 5.617 Mbps after the activation of MLB algorithm, because the resource blocks available in cells with low traffic loads can be utilized by incoming users from the cells with high traffic loads.

The simulations have been done with a limited number of cells and users. Therefore, further researches should be conducted to consider more realistic challenges typically found in real situations. These challenges include dynamic traffic fluctuations, as well radio interferences and channel fading effects. Further research should focus on integrating the LTE network planning and handover mechanism with MLB algorithm, and ideally also consider adaptive MLB based on machine-learning to improve the decision-making process during the MLB algorithm execution.

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