Parameter Control Scheme Among Multi-cell for Mobility Load Balancing in Ultra-dense Network

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Abstract. Ultra-Dense Network (UDN) can improve the system capacity and satisfy the increasing data traffic demands, and is considered as a candidate technology in the fifth generation (5G) networks. UDN has a smaller cell radius and a new network structure, so it needs some more efficient resource management methods. The characteristic of the smaller cell radius makes the mobility management more difficult. This paper creatively proposes a novel scheme with concurrent Mobility Load Balancing (MLB) among multi-cell in UDN. Simulation results show that our proposed method is more balanced than the traditional method.

Keywords: Ultra-dense network · Mobility load balancing · Quality of service

1 Introduction

In order to meet the 1000x data traffic demands in 2020, some advanced technologies are needed [1]. There are three widely accepted candidate technologies, those are Ultra-Dense Network (UDN), massive multiple-in-multiple-out (MIMO), and new multiple access (NMA) [2]. In recent years, UDN attracts many researches in colleges and in industries. The common goal of the academia and the industry is to satisfy the great data traffic demand of the 5G systems [3, 4].

UDN has a smaller cell radius and a new network structure. It is different from the current LTE network. In urban area, there exist many potential hot spots, such as conference halls, hospitals, and schools. In these areas, users are more easily to aggregate in a small place. At the same time, many users require high data transmission rate to support kinds of multimedia business. So it becomes an overloaded cell easily, and it needs to

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offload some users to the light cells. But the offloading procedure will cause a very high overhead at the processing procedure with an unsuitable scheme. Therefore, UDN needs an efficient resource management [5]. TOTal Expenditures (TOTEX) [5] will be a main problem due to the UDN. Next Generation Mobile Networks (NGMN) [6] and 3rd Generation Partnership Project (3GPP) [7] have proposed Self-Organizing Network (SON) to decrease TOTEX in UDN, and 3GPP has detailed some SON use cases in [6].

MLB can balance the loads among ultra-dense cells. In [8], MLB is automatically adjusting the Cell Individual Offset (CIO) value which could optimally take advantage of overall network resources. Also, MLB is implemented between an overloaded cell and an appropriate neighbor cell by altering CIO. HandOvers (HOs) can be triggered by several kinds of events [9]. We consider the A3 event [8] as the trigger of the HO event in the paper.

This paper describes an offloading mechanism from the overloaded cells to the light loaded neighbor cells, its main idea is to adjust CIO and the number of the target cells i more than one, i.e. one overloaded may offload to more than one target cells at the same time. The remainder of this paper is organized as follows: The system model is shown in Sect. 2. Then the proposed MLB method is illustrated in Sect. 3. Section 4 sets up the simulation and gives the corresponding analysis. Finally, Sect. 5 concludes the whole paper.

2 System Model

In this section, we present the radio environment, cell load computation and the detailed HO procedure.

2.1 Radio Environment and Cell Load

Assume that cell i is the serving cell of User Equipment (UE) u. Let $L_{u,i}$ denote the path loss from UE u to cell i. For cell i, the transmitted power is P_i. The power received by UE u from cell i is $R_{u,i}$, which is given by Eq. (1). We assume White Gaussian Noise (WGN) Power Spectral Density (PSD) is n_o, with B_{cell} is the cell bandwidth. Here, we assume all the cells are allocated with the same bandwidth. UE u's Signal to Interference plus Noise Ratio (SINR) is given by Eq. (2).

$$R_{u,i} = P_i \cdot L_{u,i}. \tag{1}$$

$$S_{u,i} = \frac{P_i \cdot L_{u,i}}{n_0 \cdot B_{cell} + \sum_{j \neq i} R_{u,j}}. \tag{2}$$

Let the number of Physical Resource Block (PRB) as the load metric. We calculate the number of PRBs that UE u requires by Eq. (3).

$$N_u = \left\lceil \frac{D_u}{C(x_u) \cdot BW_{PRB}} \right\rceil. \tag{3}$$

where D_u represents the desired data rate of UE u, $C(x_u)$ represents the spectral efficiency (SE), which is connected with u's SINR in the served cell, given by Eq. (4) and BW_{PRB} denotes the bandwidth of each PRB in Hz.

$$C(x) = \begin{cases} 0, x < -7.04 \\ -0.0001x^3 + 0.0074x^2 \\ +0.1397x + 0.6218, -7.04 \leq x \leq 20.2 \\ C(20.2).x > 20.2 \end{cases} \tag{4}$$

Let $\sum N_{u,i}$ denote the number of occupied PRBs of cell i. The load of cell i can be denoted as follows:

$$\rho_i(t_k) = \frac{\sum N_{u,i}}{B_{cell}/BW_{PRB}}. \tag{5}$$

2.2 HO Procedure

Assume cell 1 and cell 2 are the source cell and the target cell, respectively. HO event can be succinctly denoted as follows [10]:

$$R_2 > R_1 + Hys + O_{1,2} - O_{2,1}. \tag{6}$$

where R1 and R2 denote the Reference Signal Received Power (RSRP) from the serving cell 1 and from the target cell 2, $O_{i,j}$ denotes the cell CIO of cell i towards cell j, and Hys is the HO Margin.

Set $CIO_{1,2} = O_{1,2} - O_{2,1}$ and $CIO_{2,1} = O_{2,1} - O_{1,2}$, Eq. (6) can be rewritten as follows:

$$R_2 > R_1 + Hys + CIO_{1,2} \tag{7}$$

Equation (7) indicates that UEs in cell 1 will be more easily to be offloaded to cell 2 with the decreasing of $CIO_{1,2}$. Thus we can adjust $CIO_{1,2}$ to offload from cell 1 to cell 2.

3 The Proposed MLB Method

We categorize the load into three categories: passive, neutral and active. Through X2 interface, the adjacent cells in the network could know the load information with each other. Based on the ρ_i and the two load thresholds Th_{Low} and Th_{High}, expressed in Eq. (8), we can judge a cell is seen as passive, neutral or active (Table 1). ρ_{Target} and ρ_{hyst} are fixed values. We can get them from Table 2.

$$Th_c = \begin{cases} \rho_{Target} + \rho_{hyst}, c = High \\ \rho_{Target} - \rho_{hyst}, c = Low \end{cases}. \tag{8}$$

Table 1. Cell categories in MLB.

Cell status	Condition	Action
Passive	$\rho_i < Th_{Low}$	Receive UEs from overloaded cell
Neutral	$Th_{Low} \le \rho_i \le Th_{High}$	Do not participate in MLB
Active	$\rho_i > Th_{High}$	Request removing UEs to light loaded cell

Table 2. Basic Parameters of Simulation scenario.

Parameter	Value
Carrier frequency	2 GHz
Bandwidth	5 MHz
Cell layout	19 regular hexagonal cells (wrap-around)
ISD	35 m
Initial cell individual offset	0 dB
BS transmitting power	33 dBm
ρ_{Target}	0.75 (normalization load)
ρ_{hyst}	0.15 (normalization load)
Th_{High}	0.9 (normalization load)
Th_{Low}	0.6 (normalization load)
Hys	0 dB
Number of UEs	95 (random distribution)
Density of noise	−174 dBm/Hz

After classification work, only passive cells and active cells can take part in MLB parameter adjustment. By this way, the active cell, i.e. overloaded cell, will offload to the passive cell, i.e. lighted cell. The UEs in active cell will gain higher QoS. At the same time, neutral cells do not take part in MLB. The load of a neutral cell itself is high, if UEs are unloaded to a neutral cell, it will be easy to make the neutral cell overloaded. So this can avoid ping-pong effect [11].

Figure 1 presents the proposed MLB method. First, the active cells individually select the neighbor passive cells in ascending order of cell IDs, i.e. cell 1 will determine its MLB region at first, then cell 4 and finally cell 7; Next, there exits only one active cell in the specific area. As shown in Fig. 1, cell 1, cell 4 and cell 7 take part in different MLB procedures. Finally, one passive cell only takes part in only one MLB process.

As shown in Fig. 1, cell 1 is an active cell and is overloaded. It firstly chooses cell 2 to offload. This can be easily achieved by adjusting $CIO_{1,2}$. Equation (7) indicates that the smaller the value of $CIO_{1,2}$ is, the earlier UEs will hand over from cell 1 to cell 2. Thus, the minimum $CIO_{1,2}$ can be obtained as follows:

$$CIO_{1,2min} = M_{TH} - M_{1high} - Hys. \tag{9}$$

where M_{TH} denotes the minimum RSRP, when the RSRP which the UE receives from cell 2 is M_{TH}, the RSRP it receives from cell 1 is denoted as M_{1high}. To avoid that cell 1

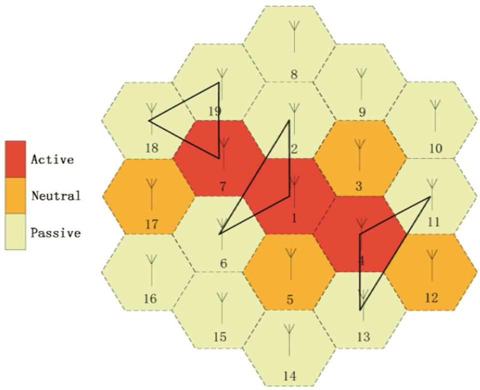

Fig. 1. Cell 1, cell 4 and cell 7 are active cells, so they need unload to other cells. Each cell chooses their own MLB region. Formation of MLB region is described in the figure.

handover to cell 2 too early, $CIO_{1,2}$ should be adjusted to be $CIO'_{1,2}$, which is between the value of the current $CIO_{1,2}$ and $CIO_{1,2min}$. The following two equations express the adjusting rules:

$$\Delta_{1,2} = (CIO_{1,2} - CIO_{1,2min}) \cdot (1 - \frac{\rho_2}{\rho_1}). \quad (10)$$

and

$$CIO'_{1,2} = CIO_{1,2} - \Delta_{1,2}. \quad (11)$$

where $\Delta_{1,2}$ is the step size, and is proportional to ρ_1 inversely proportional to ρ_2. By adjusting the value of $\Delta_{1,2}$, some UEs in cell 1 can be offloaded to cell 2 (Fig. 2).

MLB is triggered by active cells, and the MLB procedure is activated by the active cell and consist of the steps as follows:

(1) MLB functions in overloaded cells are triggered, and sort the load value of all cells;
(2) Sort the active cells ID list in ascending order;
(3) Every active cell decides its MLB region according the list order of active cells;
(4) Sort the passive cells ID list for each active cell in ascending order;
(5) The active cell adjusts the CIO parameter to a special passive cell according to the list order of its passive cells by Eq. (11). If the source cell is not an active cell, i.e. $\rho_i < Th_{High}$, the source cell does not change the CIO parameter to the latter passive cells in the list;
(6) The source cells transfer the parameters to its corresponding target cell, and these cells update the new parameters synchronically.

In the proposed MLB method, the target cells of the active cell is more than one. And several MLB procedures can be employed together. Also, Fig. 3 presents the flow chart of MLB procedure.

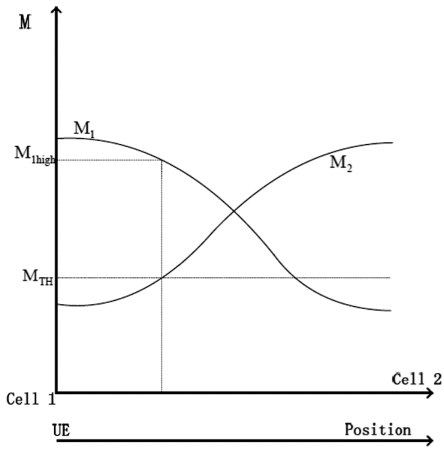

Fig. 2. UEs in the active cell (cell 1) need to be offload to the passive cell (cell 2).

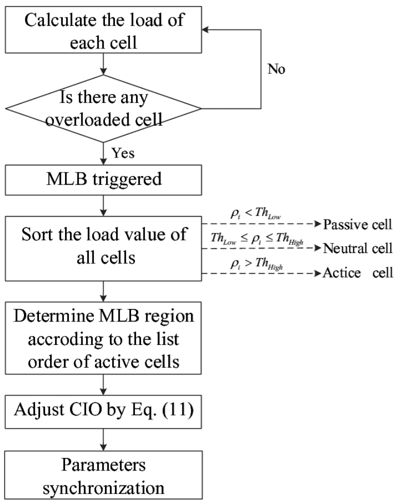

Fig. 3. The flow chart of MLB procedure.

4 Simulation Results and Analysis

This part evaluates our proposed method with simulations. In our simulation, 19 cells are mapped to be 61 cells with wrap-around, to accurately calculate the interference. In one simulation, 95 users are randomly dropped in the specific area [12]. More detailed parameters are listed in Table 2.

In traditional MLB, CIO values change in a pair of cells, that is, the overloaded cell always choose the lightest neighbor cell to offload by adjusting the parameter. Following simulation, we compared the proposed scheme with the traditional MLB.

Figure 4 displays the load histogram before doing MLB procedure, after implementing our proposed MLB procedure and after employing the traditional MLB procedure when the number of the cells is 19. The balanced load distribution among 19 cells is depicted by using MLB procedure. In specific, MLB decreases the load of active cells, and increases the load of passive cells. As shown in Fig. 4, cell 17 is overloaded before MLB, and it becomes light-loaded after employing our proposed MLB method, while with the traditional MLB method, cell 17 is still overloaded since its neighbor cell is not the most light-loaded. On the contrary, the cell 11 is light-loaded before MLB, and our proposed MLB method increases its load and makes full use of its resources. But with the traditional MLB method, the resources of cell 11 can't be fully utilized.

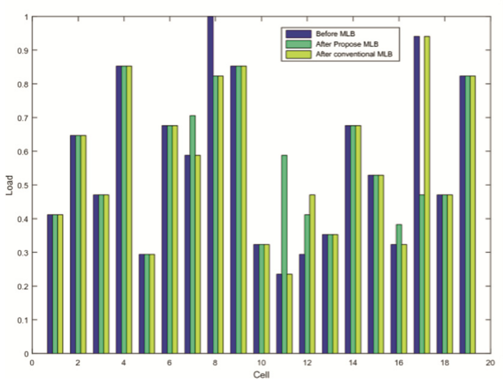

Fig. 4. The load of each cell in three conditions: before MLB, after our proposed MLB and after the traditional MLB when the number of cells is 19.

Figure 5 shows the variance of our proposed MLB method and the traditional MLB method, we can see that the red line is always under the blue one. It means our proposed MLB method can better balance the load of cells than the traditional MLB method

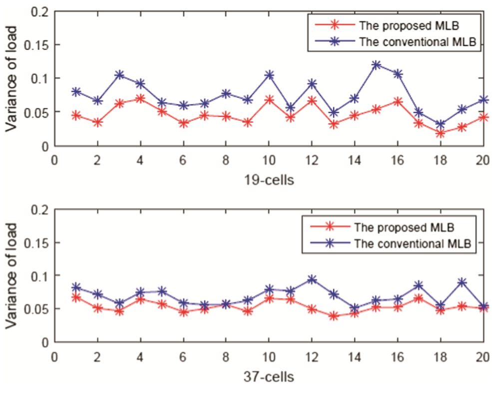

Fig. 5. The variance of load of the above two MLB methods with 19 cells and 37 cells. (Color figure online)

whatever in 19 cells or 37 cells. This is because the traditional MLB method chooses only one target cell to unload, but the proposed MLB scheme chooses more than one cell to unload. From Fig. 5, we can see that the proposed scheme has great malleability. And this scheme can be improved in subsequent research.

5 Conclusions

This paper has proposed a novel MLB method aiming to balance the loads among multi-cells in UDN. In addition, the multi-cell assistance is needed to acquire much more gains. The proposed method was based on multi-cell and decreasing too early HO times. Simulation results have shown that our proposed MLB method could better balance the load than the traditional MLB method, and could be better applied into UDN.

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