A Ripple Form RSRP Based Algorithm for Load Balancing in Downlink LTE Self-Optimizing Network

Fangqin Zhou, Lei Feng, Peng Yu, and Wenjing Li
State Key Laboratory of Networking and Switching Technology,
Beijing University of Posts and Telecommunications,
Beijing, 100876, P. R. China
Email: fqzhou2012@gmail.com

Abstract—In this paper we present an autonomous load balancing algorithm for downlink LTE network, the ripple form reference signal received power based load balancing algorithm (RF-RSRPBLBA), which mainly requires the reference signal received power (RSRP) and cell load information. In RF-RSRPBLBA, overloaded cells distribute their surplus load in a greedy manner. As a general character of the greedy algorithm, its solution is not necessarily the optimum one. However, simulation results show that RF-RSRPBLBA performs better than handover offset based load balancing algorithm (HOOBLBA) [1][2], a typical greedy algorithm for load balancing from use case suggested by EU FP7 SOCRATES project [1], when handling certain types of hotspots. Under normal circumstances both performance close.

Keywords—Load balancing, LTE downlink network, greedy algorithm, hotspots types.

I. INTRODUCTION

In the mobile access network, the randomness of both user location and its state is the reason for uneven distribution of users. In extreme cases, there generate hotspots, where users focus. In this case, the cells in the area of hotspots will experience resource shortage. This not only affects the access of new users, but also impact the quality of service (QoS) of active users. It seriously affects the overall performance of the communication network.

LTE mobile communication system deal with such situation with autonomous function modules constantly monitors the load of the network, in the event of hotspots, by adjusting network parameters or otherwise, the surplus load in overload cells is transferred to neighbor low load cells [4], allowing more rational allocation of network resources, thereby improving network performance.

RF-RSRPBLBA presented in this paper requires cell load and RSRP information, and they are all available in LTE network. When it reaches the condition for load balancing, the algorithm select a certain overloaded cell and transfer the surplus user terminals to its neighbor cells. When deciding which users to be transferred, RF-RSRPBLBA takes those into consideration whose value of RSRP from serving cell as little as possible and the RSRP increment after transfer as big as possible. It makes the decision of users for transfer and their target cells more reasonable.

The remainder of this paper is organized as follows. In section II, we analyze and define four types of hotspots, and the definitions of some metrics used in the paper will also be presented here. In section III, we explain the detail of RF-RSRPBLBA. Simulation results are given in section IV and the whole paper is concluded in section V.

II. ANALYSIS AND DEFINITIONS

A. Hotspot Types

Current communication system in urban area is experiencing urgencies that the number of mobile users increasing rapidly, the density of base stations getting larger, and the area of each cell decreasing. Under this circumstance, the Hotspot [5] is no longer the one covering one or a few cells, but covering much more. This brings new challenges for load balancing in mobile access network. So we analyze different types of hotspots to get a clear view of the properties of them.

1) Tiny Hotspot
This type of hotspot has small range and only affects the exact cell it locates.

2) Medium Hotspot
This type of hotspot has larger range compared with Tiny Hotspot and often involves two to four combining cells.

Existing works on load balancing generally take these two types of hotspots into their consideration [1][2][5][6], thus hotspots in Type 1 and 2 are collectively referred to as Conventional Hot Spots.

3) Super Hotspot
This type of hotspot has much larger range compared with Conventional Hotspot. It involves one or some overloaded cells without low load neighbor cells, in this paper we define them as Hotspot Center. Existing loading balancing algorithms neglect super hotspots and have difficulty in dealing with hotspot center [2].

The above three types of hotspots, whose affecting cells have geometry distribution rules, and we call them Regular Hotspot.

4) Irregular Hotspot
This type of hotspot has no regular geometry distribution rules and always has larger scale than conventional hotspots. Several regular hot-spots can also be treated as an irregular
hotspot, if they are close enough, because they will affect each other in the process of load balancing.

**B. Metric**

Set $U$ denotes user group, each element $i \in U$ represent a user. Set $E$ denotes base station group, each element $j \in E$ represent a base station in mobile network.

As an eNodeB has limit resource to serve users, in this paper, we assume eNodeB can only accommodate a certain number of active users, namely the capacity of a cell, denoted as $C$. The load of a cell is the active users it is serving, denoted as $N$. The load ratio of a cell is the ratio of $N$ to $C$, as the following formulation 2-1 shows.

$$\rho = \frac{N}{C}$$  \hspace{1cm} (2-1)

The signal to noise plus interference ratio (SINR) is defined in formulation 2-2.

$$\text{SINR}_{ij} = \frac{s_{ij}}{\sigma^2 + \sum_{k \in E, k \neq j} s_{ik}}$$  \hspace{1cm} (2-2)

The rate per unit bandwidth of user $i$, denoted as $R_i$ is defined in formulation 2-3.

$$R_i = \log_2 (1 + \text{SINR}_{ij})$$  \hspace{1cm} (2-3)

Assuming that users share the total available bandwidth of eNodeB $j$, denoted as $B_j$, equally [7]. User $i$ gets the bandwidth of $B_{ij}$ in formulation 2-4.

$$B_i = \frac{B}{n}$$  \hspace{1cm} (2-4)

Throughput of a user $i$, $T_i$, can be calculated by formulation 2-5, and sum of $T_i (i \in U)$, as in formulation 2-6, is approximate to the throughput of the whole network, denoted as $T$. In this paper we use it as the throughput of the whole network.

$$T_i = B_i \cdot R_i = \frac{B}{n} \cdot \log_2 (1 + \text{SINR}_{ij})$$  \hspace{1cm} (2-5)

$$T = \sum_{i \in U} T_i$$  \hspace{1cm} (2-6)

**C. Neighbor Cell Types**

RF-RSRPBLBA considers two different types of neighbor cells, Base Station Neighbor Cell (BSNC) and Mobile Terminal Neighbor Cell (MTNC), from the viewpoint of eNodeB and user terminal respectively. Previous works on load balancing only consider BSNCs. However, it is obvious that, to a certain user, the number of MTNCs it can connect to is much less than the number of BSNCs.

**III. LOAD BALANCING ALGORITHM**

The load transfer process of RF-RSRPBLBA is similar to the process of ripple expansion, in which the energy of ripple absorbed by the media it passing by, and the surplus load of a hotspot is transferred from overload area of the network to the lower load area and absorbed by the cells it passing by, until the load of all the cells within the network is balanced.

**A. The Principle of RF-RSRPBLBA**

The main process of RF-RSRPBLBA is to adjust the load of all overloaded cells, until the load beneath a certain threshold. Different to HOOBLBA, RF-RSRPBLBA has special character that it allows the load ratio bigger than 1 temporarily, as long as the final result satisfies the load requirement.

Another character is that RF-RSRPBLBA considers both load status and the number of low load neighbor cells (LLNC) in selecting a specific overload cell to perform load balancing. When cell selection loop starts, it will choose the cell with minimum number of LLNC. If there exists more than one, it choose the cell of highest load ratio. Hotspot center naturally has priority to be chosen, and it can also avoid forming new hotspot centers, because bigger number of LLNC means more space to absorb the transferring load.

When selecting target cell for a user, RF-RSRPBLBA takes the intersection of BSNC and MTNC as the cell set for selection. As a result, it reduces the amount of calculation, and makes the choice of target cell more reasonable.

**B. RF-RSRPBLBA Procedures (in Pseudo-Code)**

**Algorithm Pseudo-Code**

**Pretreatment loop:**
1. Get data of eNodeB such as load ratio (LR), BSNC and data of users such as MTNC, RSRP.
2. If $(\sum_{j \in E} (\rho_j > \eta_i)) = 0$ wait to start a new pretreatment loop.
3. else trigger the main procedures

**main procedures:**
1. while $(\sum_{j \in E} (\rho_j > \eta_i)) > 0)$ do
2. $L_{OLBS}$ (list of the overloaded cells)
3. foreach $j \in L_{OLBS}$
4. $n_j$ (number of LLNC of cell $j$)
5. $M_j = \text{map}(n_j, j)$ key $\eta_j$
6. $n_{LLNC} = \text{set}(\eta_j)$
7. end foreach
8. $n = \text{min}(n_{LLNC})$
9. if $(\text{size}(M_j(n)) > 1)$
10. $L_1 = M_j(n)$ (list of cells have fewest LLNC)
11. $j = \text{argmax}_{k \in L_1} \text{LR of } k \in L_1$
12. else $j = M_j(n)$
13. end if
14. $N_{ij} = N_j - N_o \times \eta_{LR}$
15. $N_{ij} = \text{size}(\text{RSRP} < \eta_{RSRP})$ (users can be transferred. $\eta_{RSRP}$ for RSRP threshold)
16. $E_{NJ} = \text{BSNC}_j \cap \text{MTNC}_j$
17. foreach $i \in U_j$
18. $m_{RSRP} = \text{max}(\text{RSRP}_k + \text{DRSRP}_k), k \in E_{NJ}$
19. $t = \text{argmax}_{k \in E_{NJ}} (\text{RSRP}_k + \text{DRSRP}_k)$
20. $M = \text{map}(m_{RSRP}, t)$ key $m_{RSRP}$
21. $M_{RSRP} = \text{set}(m_{RSRP})$
22. end foreach
23. $U_{ij} = \text{sort}(U_{ij})$ on $\max(m_{RSRP})$
24. $U_{ij} = U_{ij}(1: N_j)$
25. foreach $i \in U_{ij}$

27. \( t = M(M_{\text{RSRP}}) \)
28. update \( U_{ti} \) association, RSRP, MTNC data;
29. update \( LR \) of every cell
30. end for each
31. end while
32. perform handover
33. exit main procedure and enter pretreatment

### IV. SIMULATION AND RESULTS

Simulation scenarios are set as follows. In a network of 27 cells, a total of 1350 active users (hotspot and background users) randomly scattered. Due to space limit, only two scenarios are presented. Every simulation scenario has two group of figures. One group presents the connections established by Max-RSRP, RF-RSRPBLBA and HOOBLBA. Max-RSRP gives the initial connection of users and their serving cells giving best RSRP. The other one presents CDF figures for SINR and throughput respectively. Some numeric results are recorded in the table.

#### A. Super hotspot

Typical super hotspot contains entire two tiers of cells and the cell in first tier is a hotspot center, as is shown below.

![Image](image1.png)

**Fig.1 (a) shows the initial connection, (b) and (c) shows the connection of RF-RSRPBLBA and HOOBLBA respectively.**

![Image](image2.png)

**Fig.2 (a) and (b) shows the CDF of user SINR and throughput respectively.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>RSRPBLBA</th>
<th>HOOBLBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total throughput (bps)</td>
<td>1855.5M</td>
<td>1755.5M</td>
</tr>
<tr>
<td>5% throughput (bps)</td>
<td>1.1436M</td>
<td>0.3251M</td>
</tr>
<tr>
<td>User SINR&lt;-10dB</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>Number of Handover</td>
<td>268</td>
<td>235</td>
</tr>
</tbody>
</table>

#### B. Irregular hotspot

Figure 3 shows an irregular hotspot scenario, there are 5 overloaded cells and no hotspot center.

![Image](image3.png)

**Fig.3 (a) shows the initial connection, (b) and (c) shows the connection of RF-RSRPBLBA and HOOBLBA respectively.**

![Image](image4.png)

**Fig.4 (a) and (b) shows the CDF of user SINR and throughput respectively.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>RSRPBLBA</th>
<th>HOOBLBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total throughput (bps)</td>
<td>1899.2M</td>
<td>1895.6M</td>
</tr>
<tr>
<td>5% throughput (bps)</td>
<td>9.3855M</td>
<td>7.8108M</td>
</tr>
<tr>
<td>Users SINR&lt;-10dB</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Number of Handover</td>
<td>90</td>
<td>70</td>
</tr>
</tbody>
</table>

Above results show, RF-RSRPBLBA, compared with HOOBLBA, slightly improves total throughput; however, 5% throughput increases greatly by from 20% to 400%.

### V. CONCLUSION

RF-RSRPBLBA proposed in this paper overcomes the shortage of previous works on load balancing that they cannot handle hotspot center, and load transferred through a ripple expansion way enhance ability in adjusting the unbalanced load. In addition, in the process of selecting users to be transferred, RF-RSRPBLBA considers two different types of neighbor cells and takes their intersection as the cells for chosen. As a result, the amount of computation is reduced, and the selecting of users to be transferred and their target cells more reasonable.

In scenario of super hotspots and irregular hotspots, the joint work of all constrains above makes RF-RSRPBLBA more efficient than HOOBLBA. The 5% throughput increases significantly, and total throughput rises too. Thus, we can see the advantage of RF-RSRPBLBA in load balancing.

### REFERENCES


