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Load Balancing Based on the Specific Offset of Handover

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Abstract

Load balancing (LB) technology in mobile wireless communication networks has been discussed largely. The current LB algorithms have mainly adjusted the handover parameters without considering the inherent relationship of the handover parameters. In the paper, by considering the internal relationship of specific offset of handover, the constraint of the specific offset of handover was simplified, so the process of mobility load balancing (MLB) algorithm was improved. With the improved MLB algorithm, the number of handover parameters was reduced and the signal process was simplified. Simulation results showed that the congestion rate was reduced, the resource utilization rate was improved and the Qos was improved.

Keywords: *MLB, specific offset of handover, resource utilization, optimization*

1. Introduction

In wireless mobile communication network, the arrivals of mobile users and the resulting traffic load are random, time-varying, and often unbalanced, which make cell load out of balance [1]. With the third generation mobile communication technology (3G) serving the commerce, the network offers more types of service such as Voice, Date, multimedia. Especially, the multimedia has widely been used. The user demands highly for the network. As the 3G cannot make a corresponding adjustment to the dynamic traffic distribution, SON (Self-Organizing Networks) has proposed the framework of MLB Algorithm which makes a dynamic adjustment to the dynamic traffic distribution. The MLB algorithm makes the network reach a higher resource rate, serves the user with a guaranteed Qos and prevents the overload. Moreover, SON has introduced a standard specification to MLB in literature [2].

The current MLB Algorithms almost have focused on adjusting the parameters [3, 4] of handover, which have advantages of controlling the handover parameters simply and flexibly. Moreover, these solutions result on the load balance without affecting the other parameters in system in literature [5-7]. In addition, the current MLB algorithms have proposed the process of adjusting the specific offset of handover, but they have not consider the process of calculating the optimal value of the specific offset of handover. The constraint conditions of the specific offset of handover are proposed to avoid the conflict between MLB and Mobility robust optimization (MRO) in literature [8], but unnecessary parameters and complex conditions are brought without considering the inherent relationship of the handover offsets between the cell and its neighbors. Due to those drawbacks, in this paper, we establish the optimization model of resource utilization rate to simplify the complexity of parameters so as to obtain an optimal value and achieve the expected performance of LB mechanism compared to the current algorithms.

2. The MLB Theory

MLB is an indispensable technology in SON. The purpose of MLB is to balance the load of cell-neighbor-pair by transferring a part of services of overload cell to its neighbor cell.

The current MLB algorithm can flexibly and dynamically adjust the handover parameters to balance the load of cell-neighbor-pair.

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In literature [9], the events A1-A6 can lead to the handover. Specifically, this specification has introduced the condition of handover caused by the event A3.

If received signal power from the source cell s is lower than its neighbor cell, the user handovers from cell s to cell n. And the requirement of handover can be defined as below:

$$M_n + Of_n - OC_n - Hys > M_s + Of_s - Oc_s + Off \quad (1)$$

Inversely, the requirement of handover from cell n to cell s is defined as below:

$$Ms + Ofs - OC_s - Hys > Mn + Ofn - Ocn + Off \quad (2)$$

Where M_n and M_s are the received signal power from cell n and cell s, respectively. Of_n and Of_s are the offset of the special frequency. Oc_n and Oc_s are the specific offset of the special cell. Hys is the lag parameter. Off is the specific offset of the event A3. All the parameters considered are measured in dB.

If we define $Of_n = Of_s = Off = 0$, we could get simplified formula as below:

$$M_n > M_s - Oc_s + Oc_n + Hys \quad (3)$$

Similarly, the requirement of the handover from cell n to cell s is defined as below:

$$M_s > M_n - Oc_n + Oc_n + Hys \quad (4)$$

If we define $Oc_s - Oc_n = Oc_{s,n}, Oc_n - Oc_s = Oc_{n,s}$, the formula (3) is converted as below:

$$M_n > M_s - Oc_{s,n} + Hys \quad (5)$$

Similarly, formula (3) is converted as below:

$$M_s < M_n - Oc_{n,s} + Hys \quad (6)$$

Where $Oc_{s,n}$ represents the offset of handover from cell s to cell n. Similarly, $Oc_{n,s}$ represents the offset of handover from cell n to cell s.

When the load of cell s has exceeded the threshold of overload, the cell s transfers a part of users to its neighbor cell to balance the load. The process of MLB of the cell-neighbor-pair is shown in Figure 1.

MRO is a requisite optimization mechanism in SON. The function of MRO is to deal with optimization problems of handover while MLB is to solve the unbalanced traffic problem. Although MLB and MRO operate independently, they have an inherent relationship since they optimize the specific offset of handover Oc in opposite direction. When MRO and MLB adjust the parameter simultaneously, they may conflict and bring about some problems such as Too-Early HO, Too-Late HO and Ping-Pong Effect. In the optimization process, MLB decreases the specific offset of handover to balance the load of cell-neighbor-pair while MRO increases the specific offset of handover to optimize the network. So the conflict leads to the endless loop between the two optimization mechanisms. The result is the decline of the network performance.

Too-Early HO, Too-Late HO degrade the Qos which make the user disconnect from the serving cell. Ping-Pong Effect severely wastes the network resource for the frequent handover between the two cells.

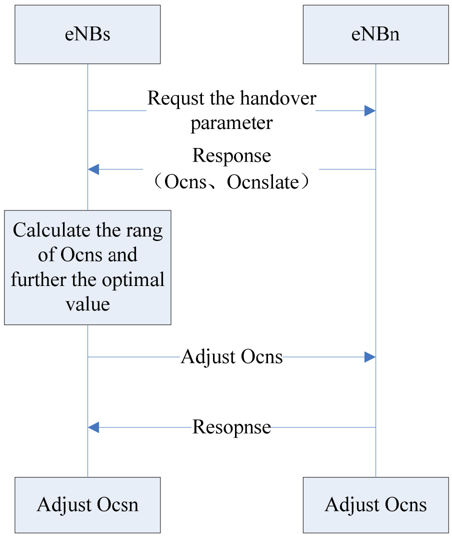

Figure 1. The MLB Process

In literature [8], in order to avoid the conflict, the constraint conditions of the specific offset of handover are defined as below:

$$\begin{cases} Oc_{s,n} < Oc'_{s,n} < Oc_{s,n,early} \\ Oc_{n,s,late} < Oc'_{n,s} < Oc_{n,s} \\ Oc'_{s,n} + Oc'_{n,s} < 2Hys \end{cases} \quad (7)$$

Where $Oc_{s,n,early}$ is the threshold of Too-Early HO from cell s to cell n , $Oc_{n,s,late}$ is the threshold of Too-Late HO from cell n to cell s .

3. The Simplified MLB Model

As introduced in previous section 2, we have defined $Oc_{s,n} = Oc_s - Oc_n$ and $Oc_{n,s} = Oc_n - Oc_s$. The MLB process in[8] independently adjust $Oc_{s,n}$ and $Oc_{n,s}$ without considering Oc_s and Oc_n. The result is the redundancy parameters and the complex constraints. According to the formula (7), we can get the formula as follow:

$$\begin{cases} Oc_s - Oc_n < Oc'_s - Oc'_n < Oc_{s,n,early} \\ Oc_{n,s,late} < Oc'_n - Oc'_s < Oc_n - Oc_s \\ 0 < 2Hys \end{cases} \quad (8)$$

Where $Hys > 0$, so the formula (8) can be further simplified just as the formula (9) express as below:

$$Oc_s - Oc_n < Oc_s' - Oc_n' < \min(Oc_{s,n,early} - Oc_{n,s,late}) \quad (9)$$

Based on the analysis above, the function of the formula (9) with a concise expression is equivalent to the formula 7 which can be regarded as the constraint condition to avoid Too-

Early HO, Too-Late HO, Ping-Pong Effect. One hand, the three constraints decrease to one. The actual calculation contains the process that the form with constraint transforms to the form without constraint. The decrease of the number of constraint condition reduces the complexity of the operation process. On the other hand, before the simplification if the cell s is a regular hexagon, it should set 6 handover parameters $Oc_{s,n1} \leftrightarrow Oc_{s,n6}$ for its neighbor while there are six corresponding handover parameters $Oc_{n1,s} \leftrightarrow Oc_{n6,s}$ to the cell s. After the simplification, the cell s set only one parameter Oc_s, so the number of parameters of each cell and the complexity of the operation process can be significantly reduced by using the simplified MLB algorithm. The signaling process of the simplified MLB algorithm is shown in Figure 2.

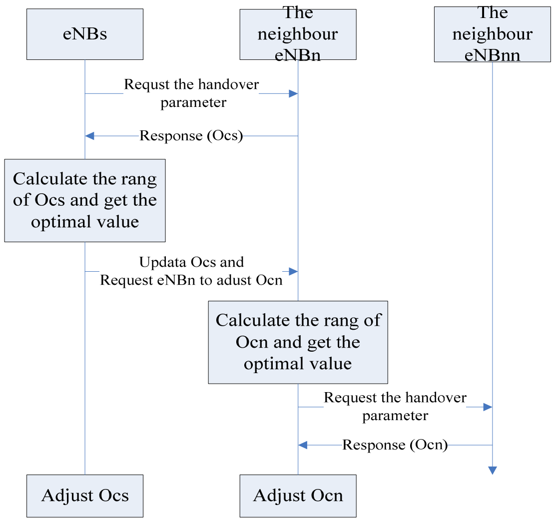

Figure 2. The Simplified MLB Process

We assume that the cell s has K neighbor cells, the detailed steps of LB algorithm are illustrated as followed:

(1) The cell s inquiry the handover parameters of its neighbor, then its neighbor send the relative parameters—$Oc_{n1} \leftrightarrow Oc_{nK}$ and $Oc_{n1,s,late} \leftrightarrow Oc_{nK,s,late}$.

(2) According to the formula (9), the cell s which takes $Oc_{n1} \leftrightarrow Oc_{nK}$ as a constant value can calculate the range of Oc_s and further obtain the optimal value of Oc_s.

(3) The cell s sends the update value of Oc_s to its neighbors to adjust the specific offset of handover Oc_n.

(4) According to the formula(9), each cell calculate the range of Oc_n in condition of considering its specific offset of handover as a constant value and further obtain the optimal solution of Oc_n.

As the thresholds of Too-Early HO and Too-Late HO are only related to the transmitted power of the BS, the thresholds are relatively stable parameters. Each cell constructs a list and installs the parameters including: Too-Early HO, Too-Late HO, the specific offset of handover and so on. When the specific offset of handover has changed, each cell will inform its neighbors to update the specific offset of handover in their list. So MLB algorithm can save the request and response steps to simplify the process of MLB algorithm descried as the Figure 2. And the upgrade process can be shown in Figure 3.

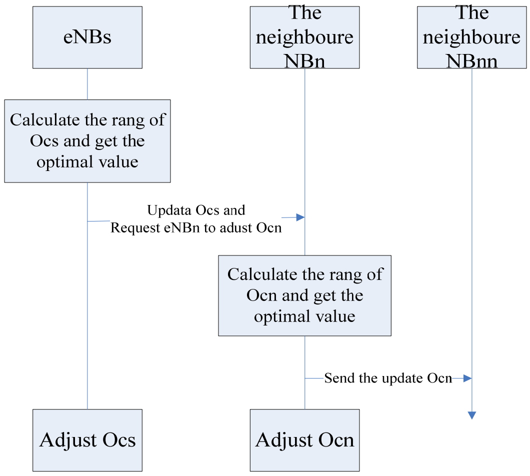

Figure 3. The Upgrade MLB Process

4. The Research on the Resource Utilization Model

4.1. The Optimization Model

According to the optimization model based on the resource utilization rate, we can get the utility function of each cell which can be expressed as below:

$$u_s = \begin{cases} -a(\rho_{th} - \rho_s) + a\rho_{th} & \rho_{th} \ge \rho_s \ge 0 \\ b(\rho_{th} - \rho_s) & \rho_{th} < \rho_s \end{cases} = \begin{cases} a\rho_s & \rho_{th} \ge \rho_s \ge 0 \\ -b\rho_s + b\rho_{th} & \rho_{th} < \rho_s \end{cases} \tag{10}$$

Where ρ_{th}, ρ_s are the threshold of overload and the current load of the cell s, respectively. u_s is the utility function of cell s. a, b are the positive coefficient. If $\rho_s > \rho_{th}$, u_s decreases with the value of $\rho_{th} - \rho_s$ increasing. And if $\rho_s = 0$, $u_s = 0$. If $\rho_s < \rho_{th}$, u_s is in direct proportion to the value of $\rho_{th} - \rho_s$, and u_s is negative. As we can see from the utility function, each cell prefers a higher resource utilization rate rather than an overflowing traffic.

The system utility function of the cell s and its neighbors can be defined below:

$$utility_s = u_s + \sum_{i=1}^{K} u_{ni} \tag{11}$$

Where u_s, u_{ni}, K are the utility function of the cell s, the utility function of its neighbor cell n_i and the number of its neighbor. For the hexagonal cellular cell, K=6.

The optimization model is shown as below:

$$\underset{OC_s}{Max} : utility_s \tag{12}$$

Although the optimization model has not the direct expression of Oc_s, Oc_s can change u_s as the parameter ρ_s of the utility function u_s vary with Oc_s.

The parameter ρ_s of the utility function u_s changes as the value of Oc_s changes, so the ρ_s is considered as an intermediate between Oc_s and u_s.

4.2. The Inherent Relationship between ρ_s and Oc_s

We assume the load of cell s can be defined as below:

$$\rho_s = \frac{\sum_{u|X(u)=s} N_u}{N_{tot}} \tag{13}$$

Where N_u and N_{tot} are the actual amount of resources occupied by user u and total number of resources, respectively. $X(u)$ is the user connection function. If $s = X(u)$, it means the user u has connected the cell s. And the amount of required resources can be written as below:

$$N_u = \frac{D_u}{R(SINR_u)} \tag{14}$$

Where D_u is the UE required rate. $R(SINR_u)$ is the throughput mapping function which expresses the data rate per PRB given $SINR_u$. So we can write the SINR for UE u of the cell s as below:

$$SINR_{u,s} = \frac{P_{s=X(u)} \cdot L_{u,s=X(u)}(\vec{q}_u, \Theta_s)}{N + \sum_{c \neq X(u)} \rho_c \cdot P_c \cdot L_c(\vec{q}_u, \Theta_c)} \tag{15}$$

Where $\vec{q}_u$ and Θ_s are the coordinate of User Equipment(UE) u and the down tilt of cell s, respectively. All users are located on the ground (height zero). $P_{s=X(u)}$ is the transmitted power of the cell s serving UE . $L_{u,s=X(u)}$ is the path loss between UE u and the cell s. N is the additive Gaussian White Noise.

The result of the handover between the cell and its neighbor can be expressed as below:

$$\begin{aligned} X(u) = \arg\max(& P_n \cdot L_n(\vec{q}_u, \Theta_n) \\ & \cdot T_n \cdot Hys \cdot P_s \cdot L_s(\vec{q}_u, \Theta_s) \cdot T_s) \end{aligned} \tag{16}$$

Meanwhile, we can express the parameters of the formula (16) in dB unit as follow:

$$-20\log_{10}[P_n \cdot L_n(\vec{q}_u, \Theta_n)] = M_n$$
$$-20\log_{10}[P_s \cdot L_s(\vec{q}_u, \Theta_s)] = M_s$$
$$-20\log_{10}[T_s] = Oc_s \quad -20\log_{10}[T_n] = Oc_n$$

So we can get the converted expression which is given as below:

$$X(u) = \arg\max_{s,n}(M_n - Oc_n - Hys, M_s - Oc_s) \tag{17}$$

4.3. Convergence Analysis

As introduced in previous section 4.1, with the specific offset of handover Oc_s increasing, the edger user who satisfies the A3 event handovers to its neighbor cell. So we can conclude that ρ_s vary inversely with Oc_s, but $\rho_{n1} \leftrightarrow \rho_{nK}$ are on the contrary.

At the beginning of adjusting the parameter Oc_s, if the neighbor cells' load is under the threshold, the system utility function of the cell s and its neighbors can be expressed as below:

$$utility_s = u_s + \sum_{i=1}^{K} u_{ni} = b(\rho_{th} - \rho_s) + \sum_{i=1}^{K} a\rho_{ni} \tag{18}$$

Where u_s vary inversely with ρ_s and $u_{n1} \leftrightarrow u_{nK}$ is in proportion to $\rho_{ni} \leftrightarrow \rho_{nK}$, according to the formula (18), $utility_s$ tend to increase. As ρ_s decreases and $\rho_{n1} \leftrightarrow \rho_{nK}$ increase, the calculation of $utility_s$ can be divided into the following conditions.

The condition 1: The load of the cell s and its neighbor $S_i(1 \le i \le k)$ exceed the threshold of overload, but the load of the other neighbor $S_{i+1}(k \le i \le K-1)$ are under the threshold, we can write the utility function as below:

$$\begin{aligned} utility_s &= u_s + \sum_{i=1}^{K} u_{ni} \\ &= b(\rho_{th} - \rho_s) + \sum_{j=s+1}^{K} a\rho_{nj} + \sum_{i=1}^{s} b(\rho_{th} - \rho_{ni}) \end{aligned} \tag{19}$$

As ρ_s decrease to $\rho_s \le \rho_{th}$, the calculation of $utility_s$ in condition 1 is converted to the condition 3.

The condition 2: The load of the cell s and its neighbor cells are below the threshold of overload, the system utility function can be defined as below:

$$utility_s = u_s + \sum_{i=1}^{K} u_{ni} = a\rho_s + \sum_{i=1}^{K} a\rho_{ni} \tag{20}$$

If the load of any neighbor of the cell s exceeds the threshold of overload with their load ($\rho_{n1} \leftrightarrow \rho_{nK}$) increasing, the calculation of $utility_s$ in condition 1 is converted to the condition 3.

The condition 3: The load of the cell s is under the threshold, and a part of its neighbors $S_i(1 \le i \le k)$ exceed the threshold while another part cells $S_{i+1}(k \le i \le K-1)$ do not exceed the threshold, so we can write the system utility function as below:

$$utility_s = u_s + \sum_{i=1}^{K} u_{ni} = a\rho_s + \sum_{i=1}^{s} b(\rho_{th} - \rho_{ni}) + \sum_{j=s+1}^{K} a\rho_{nj} \tag{21}$$

Based on the analysis above, we conclude that u_s and $u_{n1} \leftrightarrow u_{nK}$ increase first and then decrease with Oc_s increasing. We can prove that the curve of the utility function u_s is concave, so the optimal model is convergent and exists the optimal value.

5. Simulations Parameters and Results

The paper uses VC++6.0 and MATLAB software to simulate. Table 1 shows the configuration of the simulation parameter. Under the 9 cases with users ranging from 400 to 1200, the results which contain the congestion rate, the QoS and the resource utilization rate calculated by the MLB algorithm are described in Figure 4-6.

Table 1. The Simulation Parameters

Description	Values
Cell Number	23
Cell to Cell Distance	500m
BandWidth	5MHz
Power of eNB	29dBm
Path loss	$128.1+37.6\log_{10}(R)$ st. R(km)
shadowing standard deviation	10dB
Correlation distance of the shadow	10m
Antenna pattern	$A(\theta) = -\min[12(\frac{\theta}{\theta_{3dB}})^2, A_m]$ st. $\theta_{3dB} = 70\deg, A_m = 20dB$
User Number	400-1200
Hysteresis	3dB
Initial offset of handover	0dB
Threshold of Too-Early HO	10dB
Threshold of Too-Late HO	-10dB
Threshold of Overload	0.9

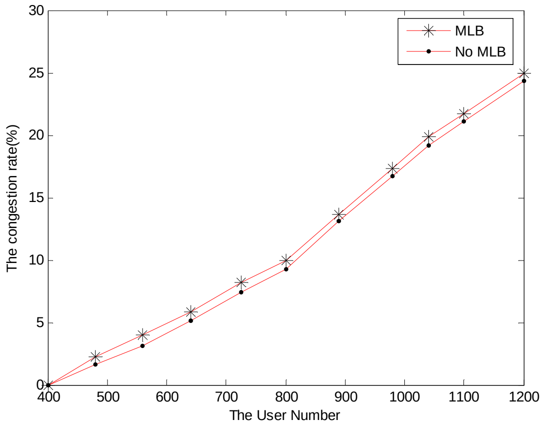

Figure 4. The Congestion Rate

It can be seen from Figure 4, the congestion rate tends to rise with the increase of users whether the MLB algorithm is implemented or not. Apparently, the curve of the congestion rate with MLB algorithm is under the curve without MLB algorithm. It shows that the MLB algorithm reduces the congestion rate. The maximum of decrease is up to 1.1% compared to the case without utilizing MLB and the minimum of decrease is also up to 0.44%. It can be concluded that: the MLB algorithm can effectively improve the network congestion performance.

Figure 5 shows the resource utilization rate of the system with the increasing of the users. The curve with asterisks and solid dots represent the case with and without utilizing MLB algorithm, respectively. The system resource utilization rates of the both case increase with the increasing of the users. However, the curve of the resource utilization rates with the MLB is always above the case without using MLB and result shows that the MLB can improve the system resource utilization rate with the maximum increase achieving 5.35% and the minimum increasing 1.9%. It can be concluded that: the MLB algorithm can effectively improve resource utilization rate.

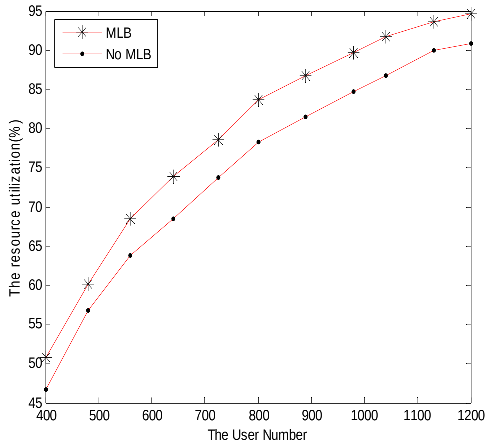

Figure 5. The Resource Utilization Rate

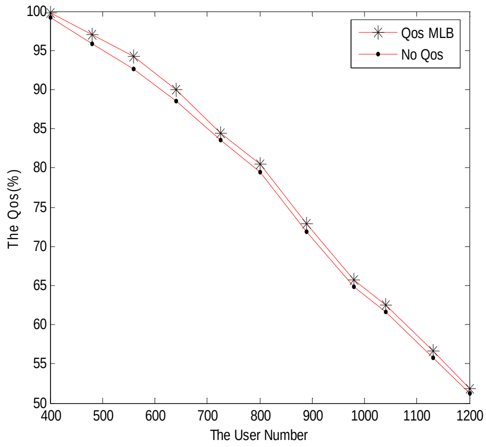

Figure 6.The Qos

It can be seen from Figure 6, the QoS tends to go down with the number of user increasing regardless of the use of MLB algorithm or not. Apparently, the curve of the QoS with MLB algorithm is above the curve without MLB algorithm. It shows that the MLB algorithm improves the QoS. And the maximum of increase is up to 1.6% while the minimum value is up to 0.3%. It can be concluded that: MLB algorithm can effectively improve the performance of the Qos.

6. Conclusion

This paper focus on the MLB technology of the wireless mobile communication network. According to the A3 event (the signal strength of neighbor cell is higher than that of the source cell), we can get the inherent relationship of the specific offset of handover and simplify the constraint of handover. The algorithm improves the current processes and simplifies the signaling procedure.

Duo to the MLB algorithms do not consider the optimization of the specific offset of handover, the utility function was established to calculate the optimal value of the specific offset of handover by the optimization theory in this paper. The utility function has the optimal target to maximize the resource utilization rate and has been proved to be convergent.

The simulation results show that the MLB algorithm had reduced the congestion rate about 1.1 percentage points and had improved the resource utilization rate about 5.35 percentage points and had improved the QoS guarantee rate about 1.6 percentage points.

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