A High-efficient Algorithm Of Mobile Load Balancing in LTE System

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***Abstract*—Mobility Load balance(MLB) is an key technology belonging to self-organization networks(SONs) in Long Term Evolution (LTE) system. In the paper, a high-efficient algorithm is proposed to balance the uneven load between neighboring cells in LTE system. The algorithm adjusts the cell-specific offset between neighboring cells(OCN) adaptively depending on the load difference between neighboring cells. If the load difference exceeds the presetting threshold, then the algorithm will be triggered and adjust the OCN by adding or subtracting an adaptive step-size. Also, a power function is proposed to characterize the adaptive step-size and the step-size will be larger as the load difference between neighboring cells increases. This feature of the power function makes the MLB algorithm more efficient to fit the largely uneven load between neighboring cells. Furthermore, a simulation platform with 7 cell is set to evaluate the algorithm with different power of the function. It demonstrates that the adaptive algorithm can get the lower call blocking rates and handover failure rates because of its high-efficiency in load balancing. It also shows with the small appropriate power, we can get better system performances.**

I. Introduction

Over the past decade, the mobile communication system is becoming more and more complex and expensive with the requirement in the quality of service(QoS) of the system and its efficiency. A great deal of strategies and algorithms have been proposed and used to reduce capital expenditures(CAPEX) and operational expenditures(OPEX)[1] including self-organization networks(SONs). The concept of self-organization networks(SONs) is introduced in Long Term Evolution(LTE) system by the international standardization body Third Generation Partnership Project(3GPP) and operators' lobby Next Generation Mobile Networks(NGMN)[1]. Load balancing is one of the technologies belonging to SON which can be used in many scenes. This technology is adopted among heterogeneous wireless networks(HWNs)[2].

However, in the wireless cellular network, the load in different cells is often substantially uneven, and the load in different cells is time-varying due to user mobility. It makes the increase of the call blocking, the call dropping and decrease of the cells throughput in the heavy-loaded cell. In addition, it reduces the radio resource utilization in light-loaded cells. In order to make efficient use of the radio resources in the whole network, many techniques have been proposed to make the load across the network balance[3][4][5][6][7][8][9][10]. Ali, Bejerano proposed a cell breathing technique for load balancing by controlling the coverage range of base station in cellular networks or WLAN cells[3][4]. However, automatic adjustment of cell coverage area runs the risk of creating coverage holes. Another mechanism in [6][8][9][10] was proposed by modifying the handover regions between neighboring cells. The mechanism adjusts the cell-specific offset between neighboring cells(OCN). Then the users in heavy-loaded cells can more probably handover to less heavy-loaded neighbor cells and thereby decreasing the call drop rates and improving call access rate. Based the mechanism, some algorithms for adjusting the OCN were proposed. Kwan proposed an algorithm based on cell load measurements[8]. The algorithm adjusts the OCN by adding or subtracting a constant step-size when the difference load between neighboring cells exceeds a presetting threshold. The simulations in [8] have shown that the algorithm can decrease the call drooping rates and improve the call accessing rates and the cells throughput. However, When the difference load between neighboring cells is large, the efficiency of the constant step-size algorithm in [8] needs to be doubted. So, the more efficient MLB algorithm needs further exploration.

In the paper, a high-efficient algorithm is proposed to make the uneven load between neighboring cells balance in LTE system quickly. The scheme adjusts OCN adaptively based on the load difference between neighboring cells. If the load difference exceeds the presetting threshold, then the algorithm will be triggered and adjust the OCN by adding or subtracting a adaptive step-size. Also, a power function is proposed to characterize the adaptive step-size and the step-size will be larger as the load difference between neighboring cells increases. This feature of the power function makes the MLB algorithm more efficient to fit the largely uneven load between neighboring cells. Furthermore, a simulation platform with 7 cell is set to evaluate the algorithm with different power of the function. It demonstrates that the adaptive algorithm can get the lower call blocking rates and handover failure rates because of its high-efficiency in load balancing. It also shows with the small appropriate power, we can get better system performances.

The remainder of this paper is organized as follows. The system model and some definitions are proposed in Section

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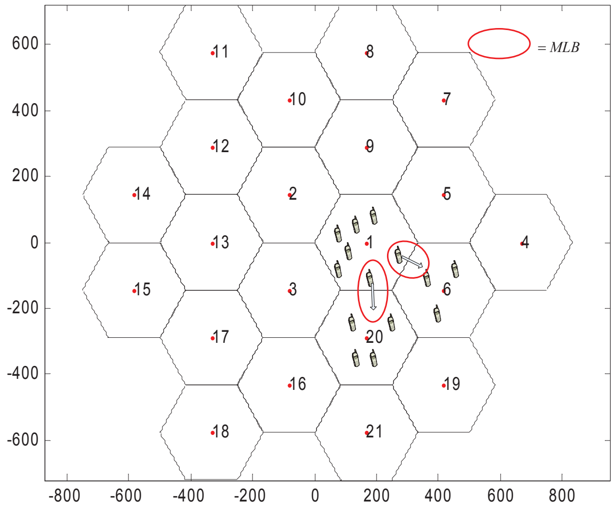

Fig. 1. The basic system model

II. The new algorithm is proposed in Section III and some analysis is made. In Section IV, the performances of the scheme are evaluated, we evaluate the call accessing rates and handover failure rates and take the algorithm in [8] for comparisons. Finally, conclusions are drawn in SectionV.

II. System Model

AS shown in the Fig 1 , cell1 has heavy load but cell6 and 20 is lighted-loaded. Then the cell1 will suffer from high call blocking rates and high handover failure rate when UEs belonging to other cells handover into the cell1. However, the cell6 and 20 is less heavy-loaded and have low radio resource utilization. So, the MLB algorithm bias the handover region between neighboring cells and handover the UEs to the cell6 and cell20. Then the basic scene has been shown, but there are some critical items needed to be detailed described and studied further.

A. Handover Process

The handover can be triggered when a UE u detects that a neighboring cell offers a better signal quality than its currently serving cell. The detail can be expressed as:

$$M_{u,j} - M_{u,i} > HO_{initial} - HO_{ji} \tag{1}$$

where the $M_{u,j}$ and $M_{u,i}$ denote the receive power from cell j and i. The $HO_{initial}$ is the presetting value to prevent handover ping-pong effect. It can be the sum of the hysteresis term and a fixed offset. The HO_{ji} is the cell-specific offset between cell j and cell i and is the key parameter to be adjusted to make load balance between cells.

B. Resource Assignment

In this paper, we focus on the LTE downlink, which is a localized OFDMA system. According to the definition of LTE system, the smallest unit can be allocated which is called physical resource blocks(PRBs). When a UE becomes active, the system will assign resources to it. The resource assignment is just like the scheme in [11] due to the main consideration on MLB algorithm. The number of PRBs assigned to the UE is briefly took into account below.

An active UE has a bit rate requirement which is denoted as D_u and the required number of PRBs to meet D_u can be denoted as $\hat{N}_u$. The required resources $\hat{N}_u$ depends on the $SINR_u$ unfortunately. Given the $SINR_u$, we can get the data rate per PRB using a throughput mapping $R_u = R(SINR_u)$. The most prominent example for such a function R() is Shannons equation. We can express the Shannon formula as:

$$R_u = log_2(1 + SINR_u) \tag{2}$$

$$SINR_u = \frac{P_c \cdot L_{X(u)}}{N + \sum_{c \neq X(u)} \rho_c \cdot P_c \cdot L_c} \tag{3}$$

where N denotes thermal noise and P_c is transmit power for a cell. The $X(u)$, $L_{X(u)}$ and L_c denote the currently serving cell of UE u, the pathloss with shadow fading from the currently serving cell and other interference cell, respectively. The ρ_c denotes the load of the cell c.

With the definition, the amount of required PRBs $\hat{N}_u$ can be obtained as:

$$\hat{N}_u = \frac{D_u}{R(SINR_u)} \tag{4}$$

For reality, the actual amount of PRBs occupied by UE u can be yielded:

$$N_u = \begin{cases} min(\hat{N}_u, K_c) & PRB_{Left} > min(\hat{N}_u, K_c) \\ 0 & else \end{cases} \tag{5}$$

Where K_c is a constant(2 in simulation) to keep PRBs occupied by the users with low channel quality under reasonable level. PRB_{Left} denotes the left PRBs of cells for accessing.

From the equation 5, we can obtain that the users will be blocked when N_u is zero ($PRB_{Left} < min(\hat{N}_u, K_c)$).

C. Load measurement

The cell load ρ_c is an important parameter which influences the MLB algorithm greatly. The MLB algorithm is carried out based on cell load measurement, so the performance lies on it heavily. In general, we define cell load as the mean utilization of the total amount of physical resource blocks across the cell

$$\rho_c = \frac{\sum_{u|X(u)=c} N_u}{M_{PRB}} \tag{6}$$

M_{PRB} is the total number of resources in the cell.

In this paper, we follow the real scenario and will not assign resources when there is no enough PRBs for new coming active UEs. As a result, the cell load ρ_c will not exceed 1.

D. Non-uniform Traffic model

In this paper, The non-uniform geographical traffic distribution is considered. We assume the the call arrival is Poisson process and λ_s is the arrival rate of the cell $s \in \{1, 2, 3, ...\}$. Also, we assume the min arrival rate and max arrival rate is

λ_{min} and λ_{max} respectively. Then, we can generate a non-uniform geographical traffic distribution as follows:

$$\lambda_1 = \begin{cases} \lambda_{min} + \frac{2n}{N}(\lambda_{max} - \lambda_{min}) & n \le N/2 \\ \lambda_{max} - \frac{2(n-N/2)}{N}(\lambda_{max} - \lambda_{min}) & n > N/2 \end{cases} \quad (7)$$

where λ_1 is the arrival rate of the baseline cell, here we take the arrival rate of the cell 1 as λ_1 as the Fig 1 shows. The n and N is the simulation time index and the total simulation time. Based on the λ_1, the arrival rate of the cell s is the circle shift of the cell 1 and the distant of shift is $(s-1)\frac{N}{C_t}$. Where C_t is the number of the simulation cells.

III. Adaptive OCN updating Algorithm For MLB

In the wireless cellular network, the load in different cells is uneven and time-varying. It proves the necessity of MLB algorithm like constant step-size algorithm in [8]. However, when the load difference between neighbor cells is large, the efficiency of the algorithm is doubted due to the OCN updating period limitation which affects the process complexity and signaling overhead.

In the section, an adaptive cell-specific offset between neighboring cells(OCN) adjusting scheme is proposed to improve the efficiency of the load balancing and a simple analysis is obtained.

A. Adaptive OCN updating Algorithm

The OCN(HO_{ji}) updating over time is as following:

1) Initialization:

$$HO_{ji}^{0} = 0 \quad (8)$$

2) Updating:

$$HO_{ji}^{m+1} = \begin{cases} HO_{ji}^{m} + \Delta & \rho_j^{m+1} - \rho_i^{m+1} > \rho_{th} \\ HO_{ji}^{m} - \Delta & \rho_j^{m+1} - \rho_i^{m+1} < -\rho_{th} \\ HO_{ji}^{m} & |\rho_j^{m+1} - \rho_i^{m+1}| \le \rho_{th} \end{cases} \quad (9)$$

$$HO_{ji}^{m} = min(HO_{ji}^{m}, HO_{max}) \quad (10)$$

$$HO_{ji}^{m} = max(HO_{ji}^{m}, -HO_{max}) \quad (11)$$

Where HO_{ji}^{m} is the OCN between cell j and cell i in the mth simulation time index. where HO_{max} and ρ_{th} is a presetting value of max cell-specific offset and load difference threshold to trigger the algorithm. where Δ is the adaptive step-size for OCN updating that is the power function of load difference between neighboring cells. The function of Δ is as following:

$$\Delta = \left(\frac{|\ \rho_j^{m+1} - \rho_i^{m+1}\ | - \rho_{th}}{1-\rho_{th}} - \epsilon \right)^n (HO_{max} - HO_{ps}) + HO_{ps} \quad (12)$$

where n is the power of the equation(12). HO_{ps} is the presetting value of minimal step-size of OCN updating and ϵ is a small constant to make the adaptive algorithm degrade to the constant algorithm when $n \to \infty$.

3) Updating the HO_{ji} in the next updating time index.

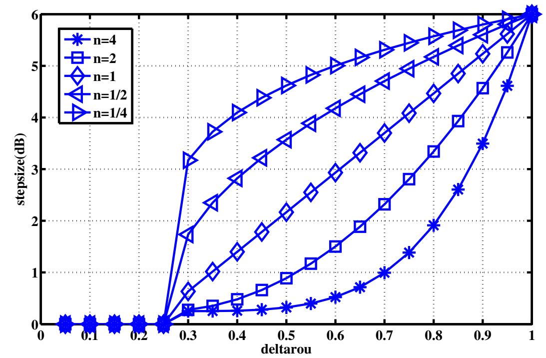

Fig. 2. The Δ VS $\rho_j^{m+1} - \rho_i^{m+1}$ with different n

B. An Simple Analysis

The Figure2 shows the relationship between the step-size Δ and the load difference. Comparing to the algorithm in [8], the bigger step-size is obtained in the proposed adaptive algorithm when the load difference between neighbor cells is large. Then the bigger step-size lead to smaller threshold to trigger handover, and the probability users in server cell j handover to the cell i increases. Otherwise, the users in server cell i are less probably handover to the cell j. Because of the limitation of the OCN updating period, the adaptive algorithm makes the loads of cell i and cell j balance more quickly and the performances of system will be improved.

Also, the complexity of the scheme can be constituted as the process complexity and the signaling overhead. Because the OCN(HO_{ji}) is calculated in base station, the process complexity can be ignored. Moreover, the signaling overhead is the same as the constant scheme in [8] due to the same OCN updating period.

It's interesting to point that for the practicality, the adaptive scheme may need to map the continuous OCN value to the discrete values. It's the further research because we mainly focus on the efficiency and performances of the adaptive algorithm.

IV. Performance Evaluation

In order to evaluate the performance of the proposed scheme, simulations are carried out in two traffic model, Constant bit rate traffic model whose call duration is geometric distribution(CBR-GD)and VOIP model in [12]. The detail parameters can be seen in TABLE 1. In the following simulation,we take the algorithm in [8] for comparison and rename the algorithm as "constant algorithm". Also, we name the proposed algorithm as "adaptive algorithm" for simplification.

A. Performance Indicators

In the paper, we use the call blocking rate and the handover failure rate as the performance indicators.

The handover failure ratio(PI_{HOF}) is the ratio of the number of failed handovers(N_{HOfail}) to the number of handover attempts which is the sum of the number of successful handovers(N_{HOsucc}) and the number of failed handovers:

$$PI_{HOF} = \frac{N_{HOfail}}{N_{HOfail} + N_{HOsucc}} \quad (13)$$

The call blocking ratio(PI_{BC}) is the probability that an new call is blocked. It is calculated as the ratio of the number of blocked calls($N_{blocked}$) to the number of access attempts which is the sum of the number of calls accepted by the network($N_{accepted}$)and the number of calls blocked:

$$PI_{BC} = \frac{N_{blocked}}{N_{blocked} + N_{accepted}} \quad (14)$$

TABLE 1: SIMULATION PARAMETERS

Cell layout	Regular hexagonal grid, 7 cell sites, 3 sectors per site with wrap-around
System bandwidth	5 MHz(25 PRBs)
Inter-Site Distance	500 m
Pathloss	$128.1 + 37.6\log_{10}(R)$
Shadowing Fading(SF)	Log-normal with standard deviation 8 dB
Decorrelation Distance Of SF	100m
Antenna pattern	$A(\theta) = -\min(12(\frac{\theta}{\theta_{3db}})^2, A_m)$, where $\theta_{3db} = 70$deg and $A_m = 20dB$.
UE speed	10m/s random walk
$HO_{initial}$	3dB
HO_{max}	6dB
HO_{ps}	0.5dB
HO_{ji} Updating rate	60 Seconds
ρ_{th}	0.25
AC load threshold	0.7 for new UEs, 0.8 for handover UEs[13][14]
Traffic Model 1(TM1)	Constant Bit Rate(64kbps)
TM1 Call duration	Geometric with mean 180 seconds
Traffic Model 2(TM1)	VOIP Model
TM2	$a = 0.004; c = 0.006; D_u = 32kbps$[12]

B. CBR-GD Model

In the Fig.3 and Fig.4 , the call blocking rate and the handover failure rate are simulated using CBR-GD model.

The proposed adaptive algorithm have the improvement in CBR-GD traffic model comparing to constant algorithm. With the smaller power of adaptive function, the call blocking rate and the handover failure rate can be further reduced. However, when the power of adaptive function is too small, the handover failure rate of the adaptive algorithm is too close to distinguish.

As shown in the Fig.5 and Fig.6 , When the power of adaptive algorithm is as small as $1/2$, the call blocking rate can be reduced almost 15% and the handover failure rate can be minimized almost 10% comparing to the constant algorithm.

C. VOIP Model

The Fig.7 and Fig.8 point that the proposed adaptive algorithm also have the improvement in VOIP traffic model.

When the power of adaptive algorithm is as small as $1/2$, the call blocking rate can be reduced almost 20% and the handover failure rate can be minimized almost 33%.

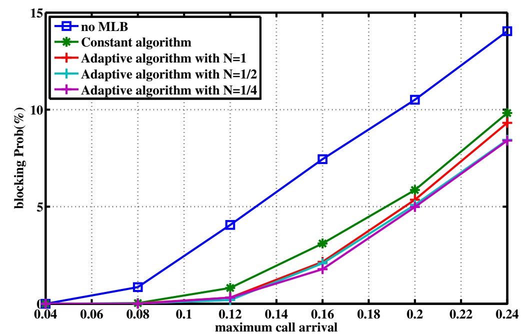

Fig. 3. The call blocking rate vs maximum call arrival rate in CBR-GD model

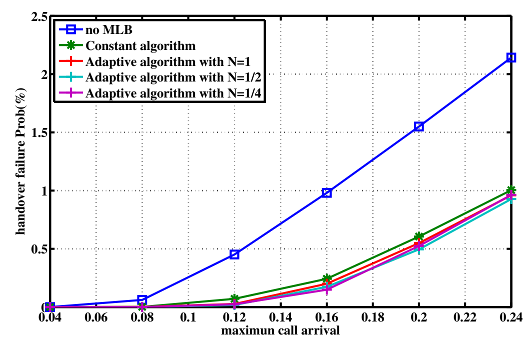

Fig. 4. The handover failure rate vs maximum call arrival rate in CBR-GD model

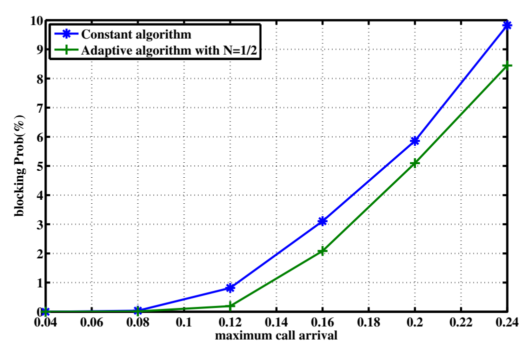

Fig. 5. The call blocking rate vs maximum call arrival rate in CBR-GD model

V. Conclusion

In this paper, a novel high-efficient algorithm is proposed to make the uneven load between neighboring cells balance

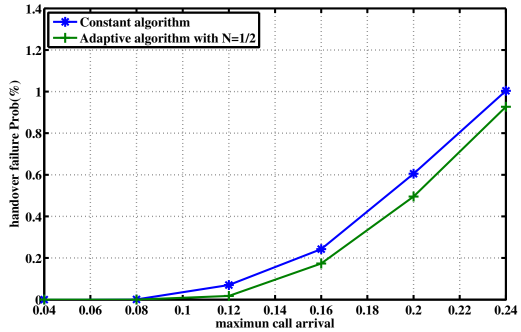

Fig. 6. The handover failure rate vs maximum call arrival rate in CBR-GD model

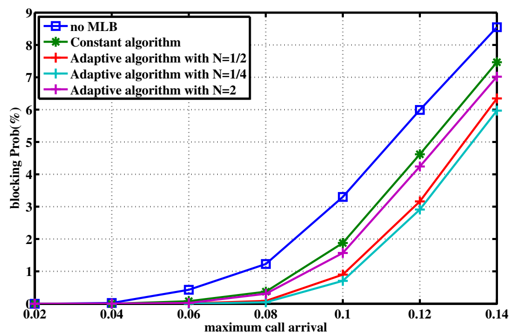

Fig. 7. The call blocking rate vs maximum call arrival rate in VOIP model

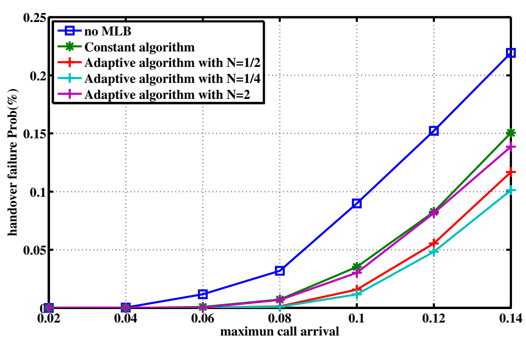

Fig. 8. The handover failure rate vs maximum call arrival rate in VOIP model

in LTE system quickly. The scheme adjusts OCN adaptively based on the load difference between neighboring cells. If the load difference exceeds the presetting threshold, then the algorithm will be triggered and adjust the OCN by adding or subtracting a adaptive step-size. Also, a power function is proposed to characterize the adaptive step-size and the step-size will be larger as the load difference between neighboring cells increases. This feature of the power function makes the MLB algorithm more efficient to fit the largely uneven load between neighboring cells. Furthermore, we set up the 7 cells cellular network simulation platform with 3 sectors in every cell. In the platform, We evaluate the algorithm with different power function. It demonstrates that the adaptive algorithm can get the lower call blocking rates and handover failure rates because of its high efficiency. It also shows with an appropriate small power, we can get the best system performances. When the power of adaptive algorithm is as small as $1/2$, the call blocking rate can be reduced almost 15% and the handover failure rate can be minimized almost 10% in Constant bit rate traffic with geometric distribution call duration. Moreover, in VOIP traffic model, the call blocking rate can be reduced almost 20% and the handover failure rate can be minimized almost 33%.

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