ICIC Express Letters ICIC International ©2017 ISSN 1881-803X
Volume **11**, Number **11**, November **2017** pp. **1651–1660**

TWO-STEP HANDOVER ALGORITHM BASED ON CLUSTERING IN ULTRA-DENSE NETWORK

Yafei Liu, Deyang Teng and Changwei Ge

Key Lab of New Generation Broadband Mobile Communication Technology
Chongqing University of Posts and Telecommunications
No. 2, Chongwen Road, Nan'an District, Chongqing 400065, P. R. China
853529456@qq.com

Received May 2017; accepted July 2017

Abstract. *Aiming at the problem of cell handover management in ultra-dense networks, considering the speed of user movement and the delay of cell handover, a two-step handover algorithm based on clustering is proposed. In this algorithm, the handover procedure is divided into pre-handover and official handover after clustering small base stations. The pre-handover phase mainly completes the selection of the best target cell, the cell resource reservation and the pre-authentication. During the official handover, hysteresis margin of the handover threshold is adjusted according to the moving speed of the device. The simulation results show that the algorithm can effectively avoid unnecessary handover, reduce the handover delay and handover failure rate, and improve the system throughput.*
Keywords: Ultra-dense network, Hysteresis margin, Cell, Handover

1. **Introduction.** With the rapid development of Internet applications and the explosive increasing in the demand for data services, wireless networks face enormous challenges. Ultra-dense network as an effective means to improve the network throughput and resource utilization efficiency, has become the fifth generation of mobile communication in the key technology [1]. In the face of increasingly complex network structure, multi-cell overlap coverage, in the future of ultra-dense network, the user equipment will bring more frequent mobile handover [2], and how to ensure a good user experience and business stability is the top priority of ultra-dense networks. For this reason, we have done a lot of research on the cell handover algorithm in ultra-dense network.

Three handover algorithms for dense networks based on cross-layer architecture are proposed in [3], which are used to measure, save and release the resources of small base stations by user equipment, and the filtering method and historical information are used to avoid unnecessary handover.

The mobile management technology is studied in [4], in the ultra-dense network, the mobile management technology should improve the prediction accuracy of the mobile state of the user equipment, enhance the anti-interference of the handover algorithm to the dense network environment, simplify the handover process, shorten the handover time, and optimize the handover elements for various network scenarios, making the handover more efficient and accurate.

Small cell handover management algorithm based on ultra-dense network is studied in [5], the algorithm considers the coexistence of macro base stations and femtocell base station, a new call access control scheme is proposed by establishing a more appropriate neighbor list, and a detailed handover process is given. Although the algorithm takes account of the handover between the macro base station and the FAPs dual layer network, it does not take account of the mobile state and the service type of the user equipment.

In [6], the nearest target femtocell is selected by measuring the distance between the UE and the femtocell, most of the femtocells are deployed in the indoor environment and have more obstacles, so it is difficult to select the optimal target cell by only one factor of the distance between the UE and the target femtocell.

A two-step handover concept based on pre-handover and official handover is introduced in [7], combined with the speed of the user equipment and cell location of the two elements a handover algorithm is proposed to avoid unnecessary handover and reduce the call rate. A recent study [8] proposes a flexible cross-zone handover scheme to reduce the impact of HO delay on user movement speed in a dense cell environment that allows the user to skip some of the base stations along the trajectory interval during the handover, and is alternately connected to the next base station.

In this paper, a two-step handover algorithm based on clustering is proposed for the environment of ultra-dense networks, the algorithm divides the small base station according to the geographical position and the signal strength and it can effectively reduce the signaling in the core network. The handover process is divided into pre-handover and official handover. Resource allocation, authentication and other operations would be completed in the pre-handover phase, to speed up the official handover process and reduce the handover delay. When the signal strength of the source base station is less than the set threshold, the device initiates the handover, compared to the traditional handover algorithm (the target base station signal strength is higher than the source base station a lag margin handover criteria), it can effectively reduce the number of unnecessary handover, at the same time, the hysteresis margin is dynamically adjusted according to the speed of the device, so that the handover failure rate can be reduced compared with the conventional method of fixing the hysteresis margin.

The structure of this paper is divided into the following five parts: the first part describes the cell system model, the second part introduces the user movement trajectory and the forecasting model, the third part introduces the main process of the two-step switching algorithm, the fourth part is the simulation of the algorithm, and the fifth part summarizes the whole paper.

2. **Cell Resource Allocation Model.** The clustering of small base stations in ultra-dense networks can effectively improve the management capability of the network and the cluster-based network model is shown in Figure 1. The mobile device adopts the double link mode, the control signaling interacts with the pilot base station, and the service signaling interacts with the specific service base station. The mobile device uses the same pilot base station when moving within the cluster. Small cells in the same cluster have a unified cell cluster ID, the controller pre-hands over according to the movement of the mobile device and the network condition, and the pre-handover phase only needs to be reconfigured within the local cluster of the current cluster, pre-allocating the corresponding resources. When the device is official handover, the mobile device is handed over to the corresponding small base station in the cluster. When the mobile device moves between clusters and reaches the pre-handover threshold, the local controller informs the controller of the target base station of the handover request and completes the pre-handover preparation; the target base station controller receives the official handover request of the mobile device and allocates the corresponding resource to complete the access when the official handover condition is satisfied according to the characteristics of the cell network and the mobile device.

3. **Motion Prediction Model of User Equipment.** In the ultra-dense network, the small base station power is small, the coverage is relatively small, usually take a radius of 10m, and we assume that the user needs to hand over to the target cell for t_i. As shown in Figure 2, the speed at which the user enters the cell is v, and the speed does

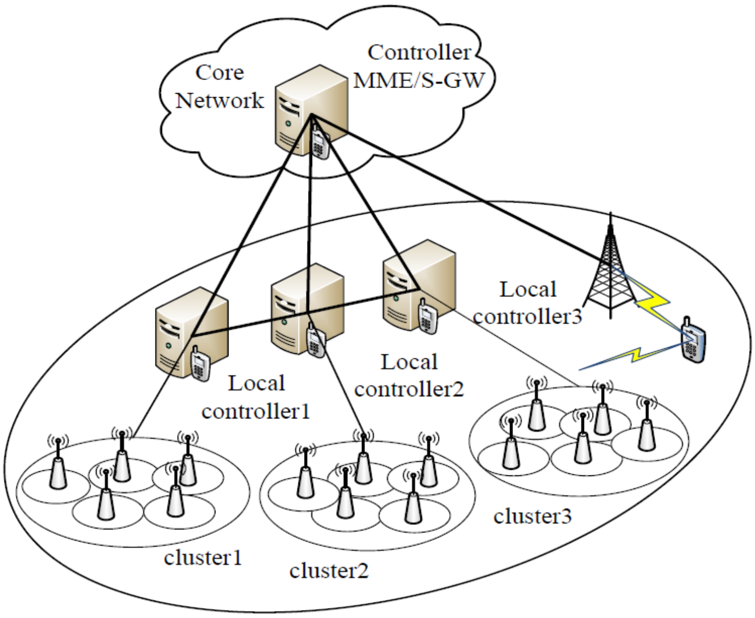

Figure 1. Cell model based on clustering in ultra-dense networks

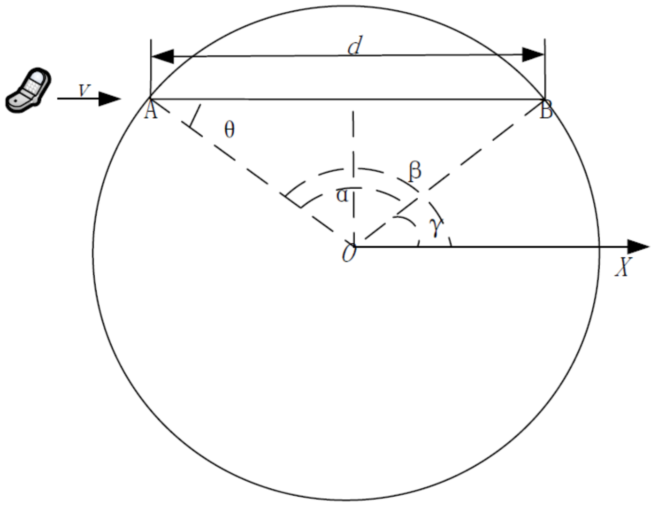

Figure 2. The movement of the user in a single cell

not change significantly during a single measurement cycle. The local controller detects and calculates the speed at which the device is at this time and the angle of the entry into the cell when the user performs a pre-handover.

It is known that the user entering the cell angle is arbitrary, assuming that the user enters the cell at point A, the angle between OA and OX is β; the user leaves at point B, and the angle between OX and OB is γ. Thus, the probability density function of β can be obtained:

$$f_\beta = \frac{1}{2\pi}, \quad 0 \le \beta \le 2\pi \tag{1}$$

Likewise, the probability density function f_γ of γ is expressed as:

$$f_\gamma = 1/(2\pi), \quad 0 \le \gamma \le 2\pi \tag{2}$$

From the relationship in Figure 2 it can be obtained:

$$d = 2\gamma \sin\frac{a}{2} = \gamma\sqrt{2(1-\cos a)} \tag{3}$$

$$\alpha = |\beta - \gamma| \tag{4}$$

For β and γ are independent of each other, then their joint probability density function is given by:

$$f_{\beta_\gamma} = 1/(2\pi)^2, \quad 0 \le \beta \le 2\pi, \quad 0 \le \gamma \le 2\pi \tag{5}$$

From Formulas (4) and (5) it can be obtained: when $x < 0$, $F_a(x) = 0$; when $x > 2\pi$, $F_a(x) = 1$. When $0 \le a \le 2\pi$,

$$F_a(x) = 1 - \int_0^{2\pi - x} \frac{1}{4\pi^2} d\gamma \int_{\gamma + x}^{2\pi} d\beta - \int_0^{2\pi} \frac{1}{4\pi^2} d\gamma \int_0^{\gamma - x} d\beta = \frac{x}{\pi} - x^2/(4\pi^2) \tag{6}$$

Therefore,

$$f_a(a) = \frac{1}{\pi} - \frac{a}{2\pi^2}, \quad 0 \le a \le 2\pi \tag{7}$$

From Formula (3) $d = 2r\sin(a/2)$ can be calculated:

$$\begin{aligned} P(d \le D) &= P\left(0 \le a \le 2\arcsin\frac{D}{2r}\right) \cup P\left(\pi - 2\arcsin\frac{D}{2r} \le a \le 2\pi\right) \\ &= \int_0^{2\arcsin\frac{D}{2r}} \left(\frac{1}{\pi} - \frac{a}{2\pi^2}\right) da + \int_{\pi - 2\arcsin\frac{D}{2r}}^{2\pi} \left(\frac{1}{\pi} - \frac{a}{2\pi^2}\right) da \\ &= (2/\pi)\arcsin\frac{D}{2r} \end{aligned} \tag{8}$$

So the probability distribution function of d is:

$$F_d(d) = \begin{cases} 2/(\pi)\arcsin\dfrac{d}{2r}, & 0 \le d \le 2r \\ 1, & 2r < d \end{cases} \tag{9}$$

If the handover completion time required by users is fixed as t_i, then the value of the minimum handover distance $d_{\min i}$ will depend on the user's speed. To successfully hand over to the target cell, the maximum value of $d_{\min i}$ is 2γ. Therefore, the probability of handover failure probability function is expressed as:

$$P_{hf} = \begin{cases} (2/\pi)\arcsin(d_{\min i}/2r), & 0 \le d \le d_{\min i} \\ 1, & d_{\min i} < d \end{cases} \tag{10}$$

And the time when the user hands over out of the cell is set to t_0, $d_{\min i} = vt_i$, $d_{\min 0} = vt_0$. If the user equipment in the target cell retention time $t < t_i + t_0$, even if the user can successfully hand over into the target cell, the user cannot successfully hand over out of the district, indicating that this district is not suitable as a target cell.

According to the path loss model [9], the signal strength RSS of the base station received by the user is expressed as:

$$RSS = E_t - P_L + \varepsilon \tag{11}$$

where E_t is the transmit power of the base station, P_L is the path loss model, and ε is the shadow fading with the mean value of zero and the standard deviation σ. As shown in Figure 3, combined with the above system model, according to Formula (11) the rate of change of RSS in user movement is given by:

$$\Delta RSS = 10\beta\log(l_0/l_1) \tag{12}$$

where β is the constant from the case of different path loss models, l_0 is the distance between the pre-handover position and the center of the cell, and l_1 is the distance from the official handover position to the center of the cell.

As can be seen in Figure 3, from the pre-handover to the official handover from the beginning of the signal strength it changes:

$$\Delta RSS = 10\beta\log(l_0/(l_1 - l_{AB})) \tag{13}$$

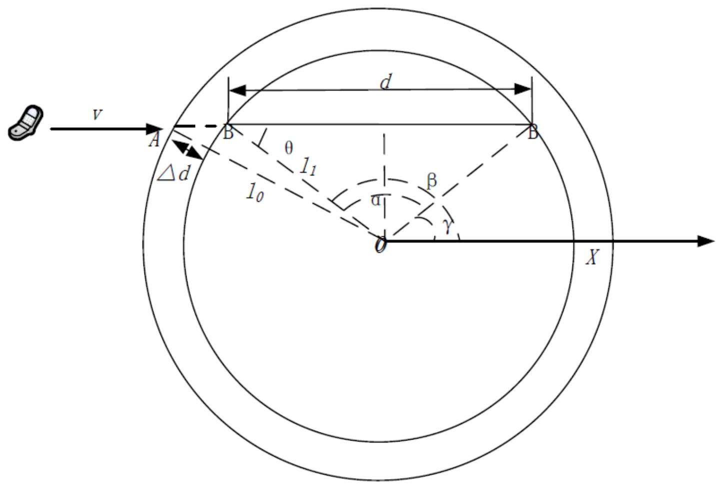

FIGURE 3. Pre-handover phase to the official transition phase of the movement

4. **Two-Step Handover Algorithm Based on Clustering.** Assume that RSS_{th2} is the minimum signal strength to ensure that the device is properly connected, RSS_{th1} is the signal strength of the official handover initiated. The user equipment (UE) continuously receives and measures information such as the wireless signal strength (RSS) of the base station periodically return to the local controller in the network. When the UE moves into the cell, the signal strength received by the UE becomes larger, at this point, the local controller predicts that the device does not have a handover request for a short period of time, and the UE normally uploads the measurement report. When the mobile device moves outward from the cell, the RSS of the source base station received by the UE becomes smaller, which indicates that the UE may perform the handover operation at a certain point in time, and the controller handover operation is triggered by the UE handover request status. The local controller records the change of the RSS of each base station received by the UE and records the value of $k = \Delta RSS/\Delta t$, the UE only reports a candidate base station exceeding the RSS_{th2} to the local controller, assuming that the number of candidate base stations to be removed from the source base station is n, the set of RSS received in turn is $\{RSS_1, RSS_2, \ldots, RSS_n\}$, and the wireless signal strength of the source base station is RSS. The RSS change rate of the candidate base station is $\{k_1, k_2, \ldots, k_n\}$, and the RSS rate of change of the source base station is k_s. Here,

$$RSS_{\text{th}i} \geq RSS_{\text{th2}}, \quad i = 1, 2, \ldots, n \tag{14}$$

$$\begin{cases} k_s < 0, & \text{The user device is leaving the cell} \\ k_s > 0, & \text{The user device is entering the cell} \end{cases} \tag{15}$$

The local controller determines whether the state of the device needs to be handed over according to the information reported by the UE or not. When the source cell RSS reaches the pre-handover threshold RSS_{th0}, the pre-handover event triggers, and the device starts sending its own status information to the base station, the status information includes the location, speed, service information of the device, and the RSS value of the source and peripheral base stations, etc. The local controller receives the uploaded measurement information and analyzes the data uploaded by the device, constantly updating the candidate base station and the local controller monitors the speed v of the device. If the moving speed of the device is greater than the maximum speed v_0 allowed by the small base station, the macro base station controller is informed that the device will hand over to the corresponding macro cell. If the moving speed of the device is less than v_0, the corresponding controller is informed that the device will hand over to the corresponding small cell. The local controller records the information of the device and selects the best target candidate base station by tracking the speed change rate of each candidate base station by the mobile device. At the same time, the controller of the neighboring small cell is informed to inform the device of the optimal target cell for pre-handover, and the specific process is shown in Figure 4.

In the ultra-dense network environment, the inter-cell deployment may overlap, as shown in Figure 5. When the mobile device moves to the S point, since the algorithm uses an official handoff trigger threshold that is below the threshold of a variable ΔRSS threshold of the pre-handover threshold, instead of the target base station signal strength is above the source base station a handover criterion of the hysteresis margin, it will not hand over to the area of C1. When the device continues to move, it will leave the service area of C0, and then reach the pre-handover phase, and the candidate base station has C1 and C2. When the device selects the target base station as C1, the device will soon pass through the C1 service area and re-enter the C2 area of the service area, thus increasing

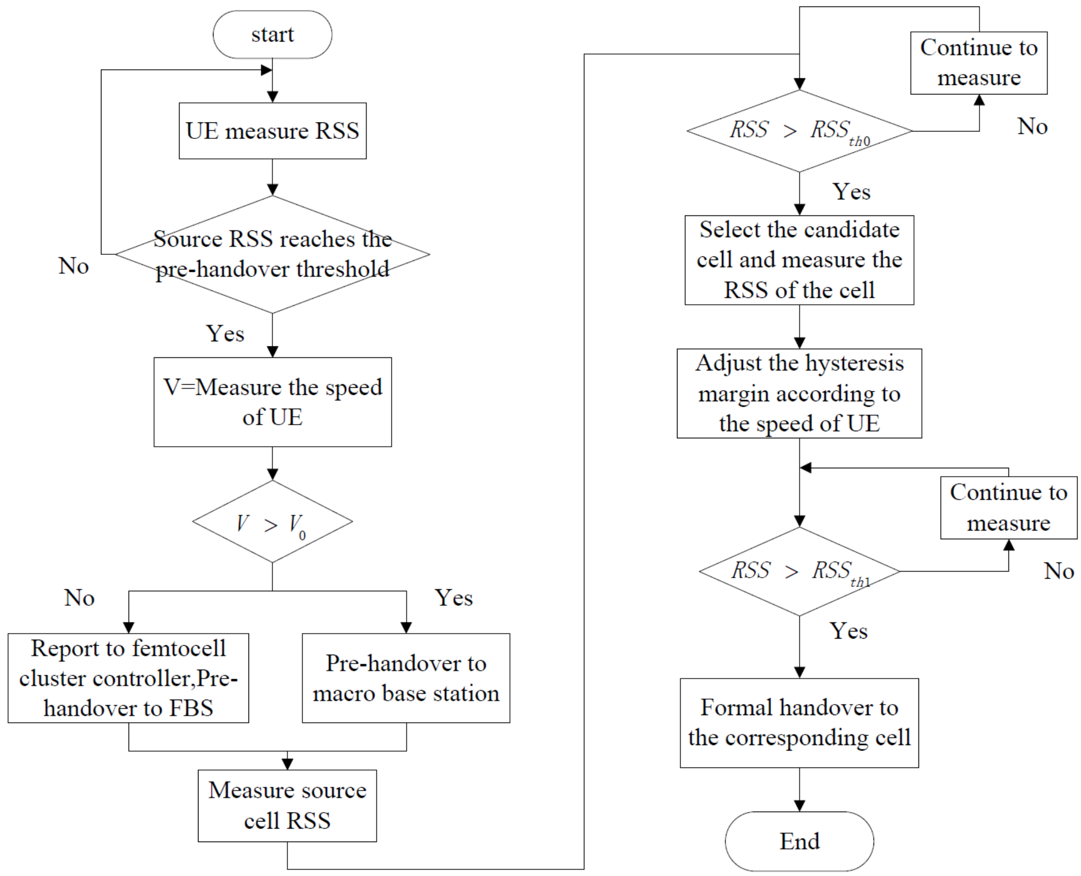

FIGURE 4. Two-step handover algorithm flow chart

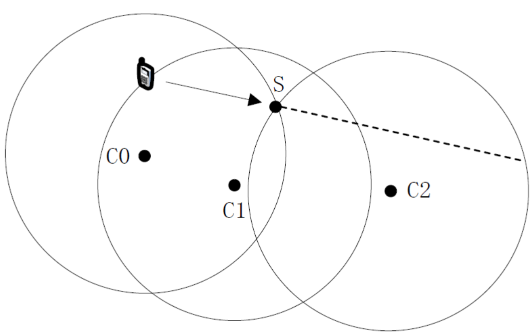

FIGURE 5. Ultra-dense cell overlap distribution scene graph

the number of handover. Therefore, the base station controller predicts that the device enters the cell C2 for a longer duration by predicting the motion trajectory of the device, and selects C2 as the best candidate cell. If the traditional A3 algorithm is used at this time, then the handover order of the device is C0, C1, C2. It can be seen that C1 is an unnecessary handover. In the case of cell overlap deployment, the algorithm reduces the number of unnecessary handoffs compared to traditional algorithms.

5. **Performance Simulation and Analysis.** By simulation to analyze the performance of the algorithm, specific parameters of the simulation are shown in Table 1.

Table 1. Simulation parameters

Parameter settings	Parameter value
Small cell radius	10m
The initial value of the hysteresis margin	3dB
β	3
Shadow fading (kafang)	With mean 0 and variance for a Gaussian distribution 8dB
Handover time	0.04s
Path loss (Ps)	$127 + 30 * \log 10(R) + kafang$
Noise spectral density	-174dBm/Hz
Bandwidth	10MHz
The small base station pilot power	10dBm

Figure 6 shows the change in the handover failure rate when the device speed changes from 0 to 5m/s. It can be seen that with the increasing speed of the device, the handover failure rate is rising. Compared with the traditional algorithm using a fixed delay margin, the algorithm used in the method is based on the speed of the device dynamic adjustment. The value of the ΔRSS. When the speed of the device is faster, the hysteresis margin is reduced, increasing the range that can be handed over compared to the original immutable hysteresis margin, can effectively reduce the equipment handover failure rate. Meanwhile, the greater the amount of change in the hysteresis margin at the same speed is, the smaller the failure rate of the handover is. When the speed of the device is greater, the handover failure rate decreased significantly, but is also close to the minimum hysteresis margin.

Figure 7 shows the relationship between the different hysteresis margins and the unnecessary handoff rate. When the device movement speed increases, the device in the cell

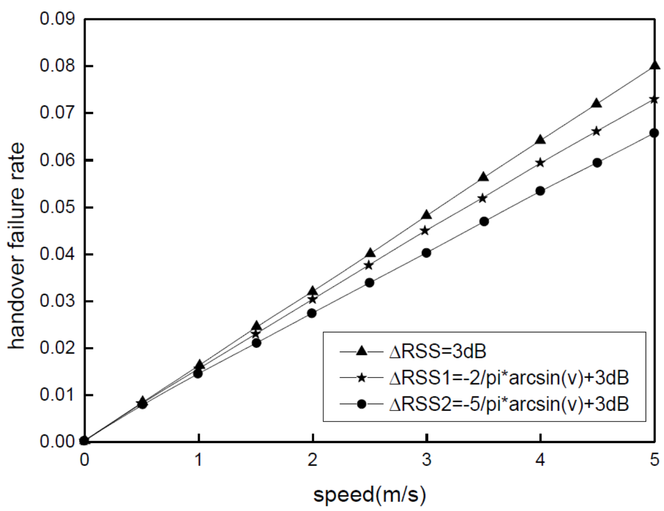

Figure 6. Relationship between handover failure rate and RSS amount of adjustment

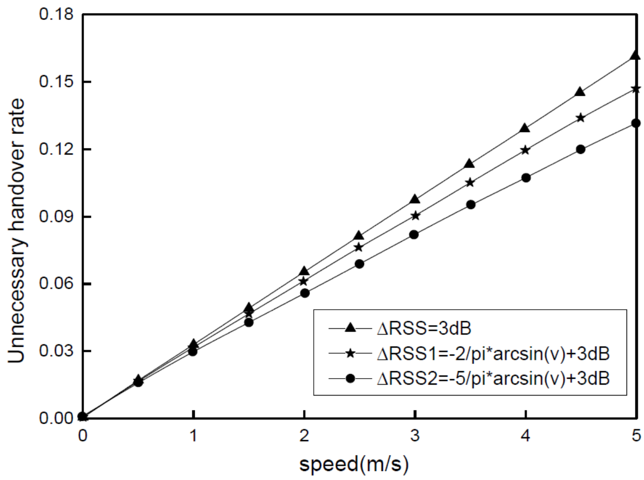

Figure 7. Relationship between unnecessary handoff rate and RSS amount of adjustment

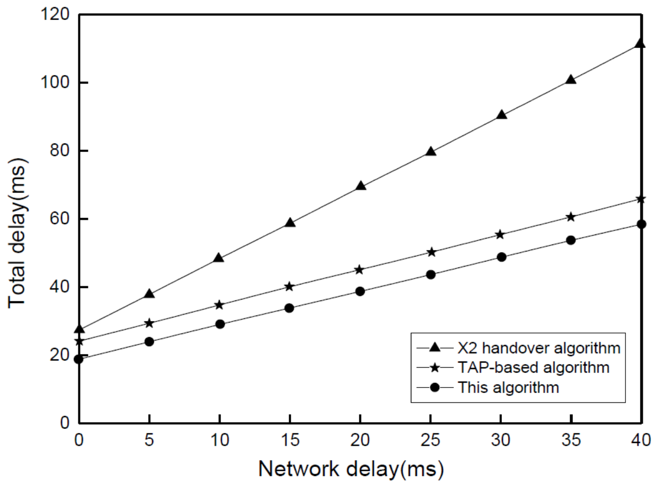

Figure 8. The performance of the three algorithms on the total delay

dwell time is reduced, resulting in the device cannot successfully complete the handover into and out of the area coverage, so the increase in the speed of the device will lead to an increase in the unnecessary handover rate. It can also be seen that when using this algorithm, if the hysteresis margin changes more, you can effectively reduce the unnecessary handover rate.

Figure 8 shows the traditional X2 handover algorithm [10], TAP-based algorithm [11] and the algorithm in the implementation of the total delay in the implementation of the performance comparison. It can be seen that the total delay in the case of different network delays (the delay of the mobility management entity (MME) to the source base station). This algorithm adopts the two processes of pre-handover and official handover, the pre-handover phase completes the operation of the resource reservation and reduces the execution steps during the official handover, thereby reducing the overall delay of the handover execution process, with less total delay than the other two algorithms.

Figure 9 shows the comparison of the throughput of different distances in the case of cell clustering and non-clustering. It can be seen that the throughput decreases as the distance between the device and the cell increases without regard to interference from other cells, and the throughput in the case of clustering is higher than that in the case of no clustering. Because in the case of non-clustering of the cell, each cell is not only used as a base station but also as a service base station, all the power of the network cannot

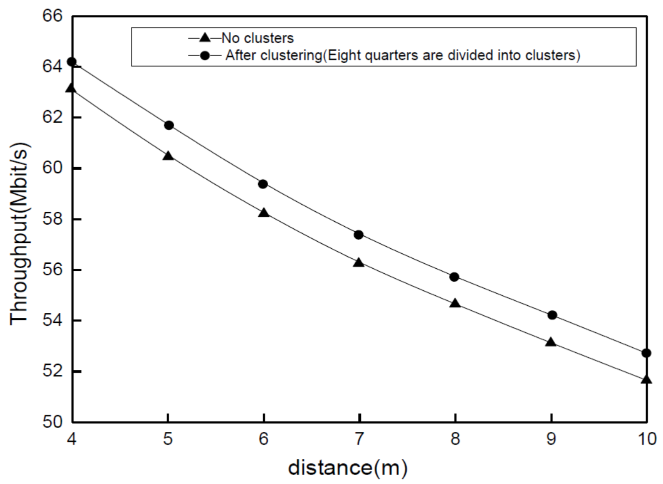

FIGURE 9. Comparison of throughput in cluster clustering and non-clustering

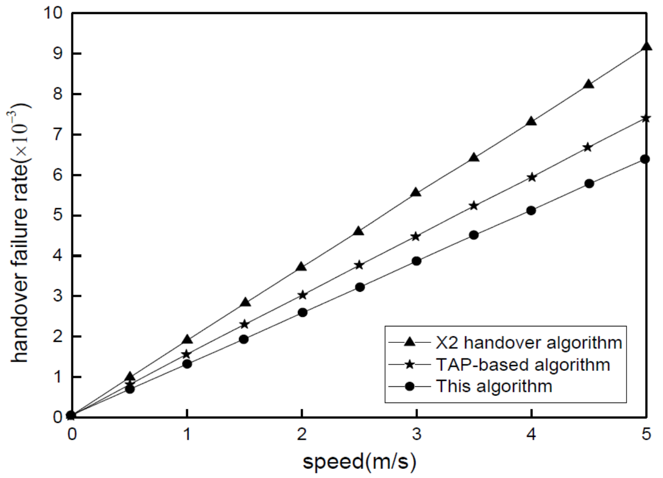

FIGURE 10. Comparison of handover failure rate of three algorithms

be used to transmit traffic. After the cluster is clustered, the intra-cluster cell uses the same cluster pilot, and the cell will only be the service cell. In the case of the total power fixed, the base station can allocate more power to the traffic channel, thus improving the throughput.

Figure 10 shows the handover failure rate comparison of the three algorithms, and it can be seen that this algorithm has a lower handover failure rate compared with the previous two algorithms. In this algorithm, the two processes of pre-handover and official handover are adopted. The operation of resource reservation in the traditional algorithm is completed in the pre-handover phase, the handover process is accelerated, the handover delay is reduced, and the handover failure is reduced.

6. **Conclusions.** This paper studies a two-step handover algorithm based on cell clustering. The algorithm consists of two phases: the pre-handover phase and the official handover phase. The selection of the target base station and ready for operation before the official handover is completed in the cell pre-handover phase, triggering an official handover when the source base station signal strength reaches the handover threshold; at the beginning of the official handover, the hysteresis margin of the official handover is adjusted by the judgment of the condition of the device in the pre-handover phase reduced handover failure rate and unnecessary handover. At the same time, in the case of clustering, centralized management of small clusters, a cluster uses a unified pilot base station,

and the controller centrally controls the small base station, and the algorithm avoids the frequent handover between small cells in the cluster, reduces the signaling of the core network, and increases the throughput of the small cell. In the future of ultra-dense network, energy consumption is an important research direction, the next step in this research work will combine switch and energy to meet the needs of green communications.

Acknowledgment. This paper is supported by the National Science and Technology Major Projects (2016ZX03002010-003).

REFERENCES

[1] H. Peng, Y. Xiao, Y. N. Ruyue et al., Ultra dense network: Challenges, enabling technologies and new trends, *China Communications*, vol.13, no.2, pp.30-40, 2016.
[2] S. Chen, F. Qin, B. Hu et al., User-centric ultra-dense networks for 5G: Challenges, methodologies, and directions, *IEEE Wireless Communications*, vol.23, no.2, pp.78-85, 2016.
[3] S. Park, Y. Shin and P. Song, LTE-advanced mobility performance enhancement in dense small cell environment, *2013 IEEE International Conference on ICT Convergence (ICTC)*, Jeju, Korea, pp.262-267, 2013.
[4] S. Zhao, T. Zhang and X. Zhu, A handover algorithm based on prediction of adjustable threshold hysteresis margin in ultra-dense network, *Journal of Electronics & Information Technology*, 2016.
[5] M. Z. Chowdhury and Y. M. Jang, Handover management in high-dense femtocellular networks, *EURASIP Journal on Wireless Communications & Networking*, vol.6, no.1, pp.104-122, 2015.
[6] A. D. Antoro, I. W. Mustika and S. B. Wibowo, Downlink cross-tier interference mitigation for macrocell user in open access femtocell using handover scenario, *International Conference on Electrical Engineering and Informatics*, pp.656-660, 2015.
[7] W. Khalid and K. S. Kwak, Handover optimization in femtocell networks, *International Conference on ICT Convergence*, pp.122-127, 2013.
[8] R. Arshad, H. Elsawy, S. Sorour et al., Cooperative handover management in dense cellular networks, *Global Communications Conference*, pp.1-6, 2017.
[9] X. Zhang and J. G. Andrews, Downlink cellular network analysis with a dual-slope path loss model, *IEEE International Conference on Communications*, pp.3975-3980, 2015.
[10] S. Oh, B. Ryu and Y. Shin, EPC signaling load impact over S1 and X2 handover on LTE-advanced system, *Information and Communication Technologies*, pp.183-188, 2015.
[11] R. S. Rajpoot, A. Srivastava and R. Jain, Femtocell handover technology with TAP-based technique: A review, *IUP Journal of Telecommunications*, 2016.