Multi-Decision Handover Mechanism over Wireless Relay Networks

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***Abstract*— With the popularity of wireless networks, it needs to support user's mobility cross different base stations, hence, the handover mechanism becomes an important issue. When the user frequently moves between two cells, it will occur the Ping-Pong effect that increases the delay time and reduces the efficiency of system. In this paper, we proposed a new handover mechanism over relay networks to reduce the unnecessary handover. It uses the value of signal to interference and noise ratio (SINR) and the parameter of distance to make handover decision. The simulation results indicate the proposed handover mechanism can reduce more than 8% of the handover number in average in comparison to the competing method in the best case.**

I. INTRODUCTION

With the fast development of wireless network and 3G smart phone in recent years, the need for wireless network increases. In order to provide huge amount of bandwidth and higher efficiency of wireless transmission, the technology develops from 3G to 4G. The possibility of being interrupted by shadowing effect and channel fading that are caused by buildings on the ground can lead to worse coverage range of base station (BS). Multi-hop relay proposed in [1][2] under the standard of IEEE 802.16j in order to improve the worsening situation. The extra relay stations (RS) can upgrade the transmitting speed of wireless network and expand the coverage range of the BS. Even now, both the standard of IEEE 802.16m and 3GPP LTE extend the relay technique.

Handover issues become very important behind joining multiple relay stations in the network system. It will dramatically increase the number of handovers, that some of them are unnecessary ones. The handover of "Ping-Pong effect" is the major reason that deteriorates the performance of the entire system. Ping-Pong effect means that users frequently switch handover between two cells to cause serious delay impact [3]. Fig. 1 shows the traditional handover process. Where mobile station, serving relay station, serving base station, target base station and target relay station are respectively denoted by MS, RS_S, BS_S, BS_T and RS_T. Handover decision mechanism is mainly judged by using the signal strength between two base stations. The process probably can be divided into three stages, such as processing, decision, and execution to be described as follows.

Processing stage: BS not only transmits the data information to the user but also periodically transmits the status information of BS of neighboring cell to the user. When the user receives this status information, they will choose the suitable RS to handover. And then, the user will open an extra connection to receive the signal from the target RS. The signal will be used to make handover decision in the second stage.

Decision stage: This stage uses the handover algorithm to make handover decision. As in [4], when the user receives the signal strength from serving RS is even weaker than the target RS, they will send a handover request to BS. And then, to verify that the handover request of user is correct, BS will exchange messages to mobile management entity (MME) and serving gateway on the backbone network. It will go to the next stage after confirmation.

Execution stage: BS will instruct users and RS to do handover process. At this time, the new target RS will do some process with the user, such as synchronization, ranging, negotiate basic capabilities, authorization and registration. When these processes are completed, the old RS will no longer transmit data to the user. It is replaced by the new target RS to transmit data to the user.

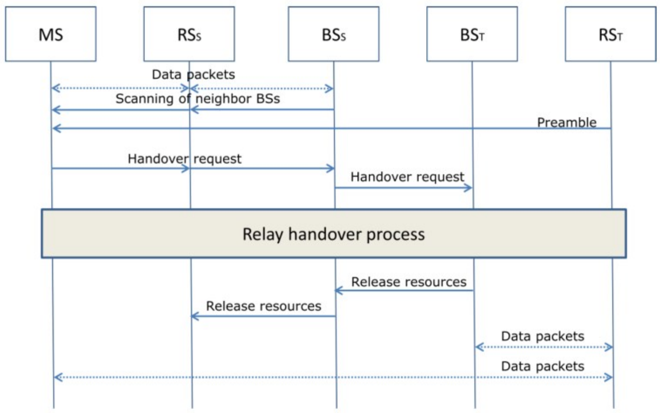

Fig. 1 Process of the traditional relay handover method

In this paper, we proposed a handover method that will reduce the number of handovers. Not only the value of SINR but also the distance will be the parameter of handover judgment to reduce the number of unnecessary handover and the handover probability.

The rest of this paper is organized as follows. Section II introduces the background and related work. The problem description and the proposed methods are given in Section III. Simulations are conducted in Section IV. Finally, conclusions are drawn in Section V.

II. RELATED WORK

There are many kinds of handover methods that have been proposed to solve handover problem, such as received signal strength based TTT window [5], integrator handover algorithm [6] and LTE standard hard handover algorithm [4]. They are described more details in the following.

(a) Received signal strength based TTT window:

The handover decision of received signal strength based TTT window proposed in [5] is primarily classified into three stages. The first stage is processing. It needs to prepare necessary information before handover decision. The second stage is decision. In order to determine whether it needs to conduct the handover mechanism, it compares the filtered received signal strength that the user received from the serving cell and from the target cell. The third stage is execution. It determines whether the cell that the user handover to according to the comparison results in the second stage. The following formula is used to calculate the signal strength that each user receives.

$$\overline{\mathrm{RSS}}(\mathrm{nTm}) = \beta \mathrm{RSS}(\mathrm{nTm}) + (1-\beta)\overline{\mathrm{RSS}}((\mathrm{n}-1)\mathrm{Tm}) \quad (1)$$

where $\overline{\mathrm{RSS}}$ denotes the filtered received signal strength. The cycle time of each received signal strength is denoted by Tm. n and n-1 denote the n-th and (n-1)-th time of Tm, respectively. β is used as a "forgetting factor," which can be expressed as follows:

$$\beta = \mathrm{Tu} / \mathrm{Tm}$$

where Tu is several times of Tm and denotes the time of handover from the beginning to the end.

$$\overline{\mathrm{RSS}}(\mathrm{nTu})_{\mathrm{TS}} \geq \overline{\mathrm{RSS}}(\mathrm{nTu})_{\mathrm{SS}} + \mathrm{HOM} \quad (2)$$

The above formula is used to compare the received signal strength between the serving station and the target station. The parameter of threshold is denoted by handover margin (HOM). The handover process starts when the threshold is greater than the value of HOM. Besides, $\overline{\mathrm{RSS}}(\mathrm{nTu})_{\mathrm{TS}}$ denotes the signal strength that the user receives from the target station in the time interval of the n-th Tu after filtered received signal strength. It mainly uses currently received RSS and historical RSS to get the new value of $\overline{\mathrm{RSS}}$. Then, it will use this value to detemine whether it can make handover decision or not. This condition must conform to the formula above within the entire time of Tu, otherwise the handover mechanism will not start.

(b) Integrator handover algorithm:

The concept of the integrator handover algorithm [6] is similar to received signal strength based TTT window algorithm [5]. Both of them use the historical signal strength. The algorithm probably can be divided into three stages, such as the reference signal received power (RSRP) difference of the serving cell and the target cell, the filtered RSRP difference, and triggering threshold. The RSRP difference can be represented as follows:

$$\mathrm{DIF}_{\mathrm{s\_j}}(\mathrm{t}) = \mathrm{RSRP}_{\mathrm{T}}(\mathrm{t}) - \mathrm{RSRP}_{\mathrm{S}}(\mathrm{t}) \quad (3)$$

The value of RSRP that the user receives from the target station in time t is denoted by $\mathrm{RSRP}_{\mathrm{T}}(\mathrm{t})$. $\mathrm{RSRP}_{\mathrm{S}}(\mathrm{t})$ denotes the value of RSRP that the user receives from the serving station in time t. $\mathrm{DIF}_{\mathrm{s\_j}}(\mathrm{t})$ is the downlink RSRP measurement differences between the received signal level of the source cell s and the target cell j at the time t. The formula of the filtered RSRP difference can be represented as follows:

$$\mathrm{FDIF}_{\mathrm{s\_j}}(\mathrm{t}) = (1-\alpha)\mathrm{FDIF}_{\mathrm{s\_j}}(\mathrm{t}-1) + \alpha \mathrm{DIF}_{\mathrm{s\_j}}(\mathrm{t}) \quad (4)$$

The parameter α is the value between zero to one ($0 \leq \alpha \leq 1$). $\mathrm{FDIF}_{\mathrm{s\_j}}(\mathrm{t})$ denotes the filtered RSRP difference between the received signal level of the source cell s and the target cell j at the time t. Accordingly, the filtered RSRP difference ($\mathrm{FDIF}_{\mathrm{s\_j}}(\mathrm{t})$) is calculated by the current RSRP difference ($\mathrm{DIF}_{\mathrm{s\_j}}(\mathrm{t})$) and the historical filtered RSRP difference ($\mathrm{FDIF}_{\mathrm{s\_j}}(\mathrm{t}-1)$). After calculating the filtered RSRP difference, it can be used to make handover decision. Nevertheless, the handover decision must meet the following conditions:

$$\mathrm{FDIF}_{\mathrm{s\_j}}(\mathrm{t}) > FDIFThreshold \quad (5)$$

Similar to HOM, $FDIFThreshold$ is the handover triggering threshold used to make handover decision. If the value of $\mathrm{FDIF}_{\mathrm{s\_j}}(\mathrm{t})$ is larger than that of $FDIFThreshold$, then the handover is triggered immediately. Therefore, the handover decision is made according to the triggering condition between the filtered RSRP differences and triggering threshold.

(c) LTE standard hard handover algorithm(LTESHHO):

Mainly composed by HOM and time to trigger timer (TTT), the LTESHHO algorithm is widely used in LTE. It can also be referred as "the power budget handover algorithm." The TTT parameter is applied to control the whole handover process. Handover will start only when the parameter of TTT is satisfied. In addition, different from the above two algorithms that rely on the parameter of historical signal strength, the LTESHHO algorithm uses the real-time signal strength.

$$\mathrm{RSRP}_{\mathrm{T}} > \mathrm{RSRP}_{\mathrm{S}} + \mathrm{HOM} \quad (6)$$

This algorithm is mainly based on the current signal strength that the user has received from the target station and serving station for handover decision that is conducted by importing the HOM and TTT parameters. When the signal strength that the user has received from the serving station is larger than HOM, the user will send a handover request to the serving BS through RS. Then, BS will keep on monitoring the user to see whether (6) is satisfied or not. When it keeps on satisfying the parameter of TTT, the serving BS will permit the user to conduct handover. Afterwards, the serving BS will send the user related information to target BS to make preparations for handover.

The advantage of this algorithm is that it proposes the concept of TTT time to reduce unnecessary handover and allows the user not to repeat handover in some cases that lead to the Ping-Pong effect.

III. The Proposed Scheme

A. Problem Definition

In the relay system, the user at the cell-edge receives poor signal strength and interference caused by shelter and building. The user will conduct more unnecessary handovers that leads to the Ping-Pong effect. Besides, it will increase the delay time and reduce performance of the system. What follows provides three examples. As shown in Fig. 2, if the user simply moves along the blue line in Fig. 2 from the left cell to the right one, the number of handovers from both the traditional and our proposed handover methods will be one.

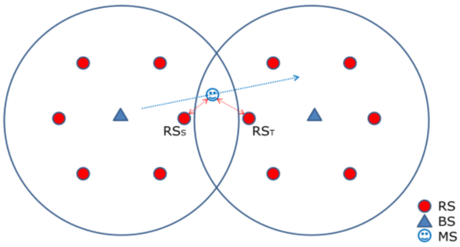

Fig. 2 Linear movement of user.

However, movement of the user is not so simple in real life. As shown in Fig. 3, the user moves and turns randomly. With the traditional handover method, signal strength that the user receives from RS_S will become weaker and weaker when the user moves along the blue line in Fig. 3. In other words, signal strength that the user receives from RS_T will become stronger and stronger. As a result, the user sends a handover request, and the first handover behavior takes place. Then, the serving station is RS_T. When the user keeps moving along the blue line to the blue arrow, signal strength that the user receives from RS_T will become weaker and weaker again. Then, the user sends handover request again and the second handover behavior occurs. Up to now, the total number of handovers is two. However, in the same situation with the proposed handover method, the user will send the same handover request. When BS receives this request, it will not do handover instantly; rather, it will request RS_S and RS_T to calculate the distances from RS_S to the user and from RS_T to the user. It will be found that the ratio of these two distances is not conformed to the proposed ratio. The user will not do handover process, so the total number of handover will be zero.

In this paper, we proposed a handover multi-decision mechanism. The mechanism can reduce unnecessary handover caused by the extra interference that may increase the number of handovers and reduce unnecessary handovers. As a result, time and signaling overhead caused by the frequent handover requests will both be reduced.

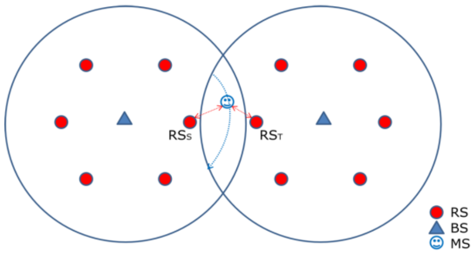

Fig. 3 Random movement of a user.

B. The Proposed Handover Process

Fig. 4 illustrates the handover process. The handover process is divided into three stages as the traditional handover method. However, we proposed a method of double-decision mechanism using the parameter of SINR and distance in the second stage. It is more accurate than that in the traditional handover method with only one parameter.

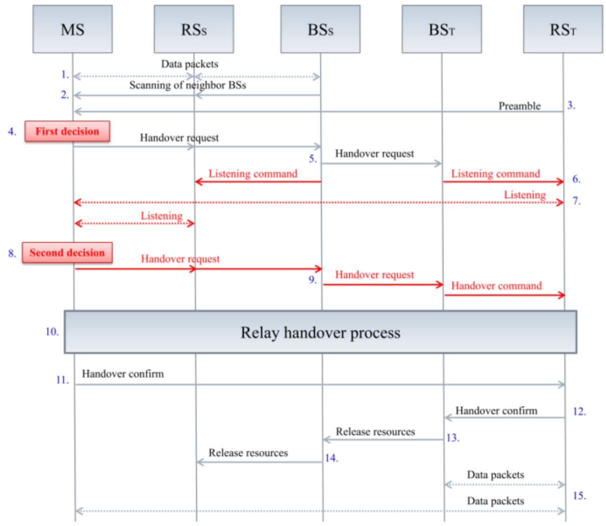

Fig. 4 The proposed handover process

The BS not only transmits the data that the user needs, but also sends the information of the neighboring BSs to the user periodically. When the user receives the signal and recognizes what RSs are around, he will choose a suitable RS as RS_T to handover. Then, it will open an extra channel for the user to receive the signals from RS_T. As soon as the user is aware that the value of SINR received from RS_S is lower than that from RS_T, the first handover request will be sent to BS. Upon BS_S and BS_T receiving the handover request, instead of immediately requesting the user to do handover process, they command the RS_S and RS_T to calculate the distances from the user to RS_S and from the user to RS_T. As soon as the difference of the distance conforms to the formula in Section III.C, the user will send the second handover request to BS. When BS_S and BS_T receive and confirm the second handover request, the handover process starts. The handover process includes ranging, synchronization, DHCP addressing, UL allocation and DL allocation. After the process, the user will send a handover confirmation message to RS_T for confirming the establishment of connection. RS_T will also send a handover confirmation message to BS_T to ask BS_S to cancel the original connection between the user and RS_S, so that RS_S will not transmit the data to the user. It will continue to transfer the remaining data to the user by RS_T, and the handover process is complete. The flowchart of the proposed method is shown in Fig. 5.

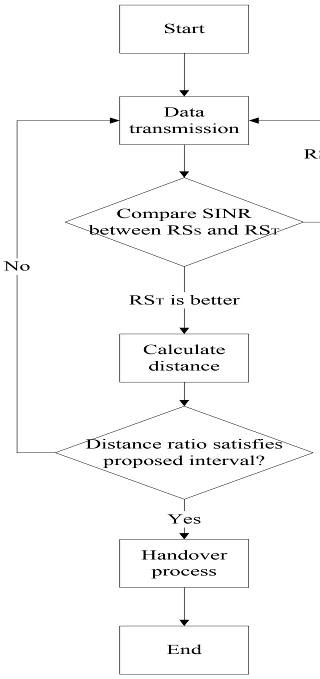

Fig. 5 Flowchart of the proposed method

C. Formulation of the Proposed Scheme

In the first stage of the handover mechanism, we use the value of SINR to make handover decision, which is different from the traditional one. If only the parameter of RSRP is used for the handover decision mechanism, the judgment of the handover decision time-point will not be accurate. Therefore, this paper uses the COST-231 Hata Model and the mechanism of the LTESHHO method without TTT to calculate the value of SINR, it is applied as follows:

$$\mathrm{SINR_T} > \mathrm{SINR_S} + \mathrm{HOM} \quad (7)$$

$SINR_T$ denotes the value of SINR that the user receives from the target BS or RS. SINRS denotes the value of SINR that the user receives from serving BS or RS. HOM is the value of threshold. In the first stage of handover decision, when the difference between the user receiving the value of SINR from target BS or RS and from serving BS or RS is greater than the value of HOM, the user will send the first handover request to BS. In the second stage of handover decision, serving RS_S and target RS_T will continue calculating the distance from the user to the serving RS and from the user to the target RS. In order to calculate the value of the distance, we use the difference of the received and the transmitting signal strengths to obtain the value of the path loss. Then, COST-231 Hata model is applied to get an inversion formula to compute the value of the distance:

$$d_{i,k} = 10^{\left(\frac{PL_{ik,c} - 46.3 - 33.9\times\log(f) + 13.82\times\log(h_{te}) + \alpha(\log(h_{re})) - C_m}{44.9 - 6.55\times\log(h_{te})}\right)} \quad (8)$$

$d_{i,k}$ denotes the distance between the user k and the transmitting station i. $PL_{ik,c}$ denotes the path loss between the user k and station i in the COST-231 Hata model. The frequency is denoted by f. The height of the transmitting station is represented as h_{te}. The height of the receiving station is denoted by h_{re}. α is the correction factor in the urban scene about 3 dB in the COST-231 Hata model.

Then, we calculated the value of the distances from the user to serving RS (denoted by d_S) and from the user to target RS (denoted by d_T) by the formula above. To compare the relationship of distance, we use the parameter of the distance and d_S to d_T ratio. The relationship of the distance can be divided into the following three conditions:

$$\begin{cases} \text{if } \frac{d_S}{d_T} > 1.1 & \text{, send handover request} \\ \text{if } 0 < \frac{d_S}{d_T} < 1 & \text{, normal case and do not handover} \\ \text{if } 1 \le \frac{d_S}{d_T} \le 1.1 & \text{, with interference and do not handover} \end{cases}$$

Subject to $0<d_S<r$, $0<d_T<r$

The distance between the user and serving RS is denoted by d_S, and d_T represents the distance between the user and target RS. The radius of RS is denoted by r. $\frac{d_S}{d_T}$ denotes the distance ratio that indicates the difference of distance. As the definition above, the handover process will start when both the value of SINR and the distance is all conform to the formula above. The value of 1.1 is derived according the simulation result. When the distance ratio is smaller than 1.1, we will observe the number of handovers is similar to the traditional handover method. On the other hand, when the distance ratio is larger than 1.1, we will observe difference of that becomes large.

Case 1: $\frac{d_S}{d_T} > 1.1$: When the value of distance ratio is larger than one, it indicates that the target RS is closer to the user than the serving RS, and the value of SINR that the user received from the serving RS is worse than the target RS. In order to prevent the user from conducting too many unnecessary handovers caused by the interference of neighboring cell, we use not only the value of SINR but also the distance for handover decision. Then, we set three intervals by the distance ratio to prevent the user from losing signals from RS, such as $1.1 < \frac{d_S}{d_T} < 1.2$, $1.2 < \frac{d_S}{d_T} < 1.3$

and $1.3 < \frac{d_S}{d_T} < 1.35$. When the value of the distance ratio conforms to the three intervals above, the handover process will start. What kind of intervals makes the performance of system perform the best will be analyzed in the next section.

Case 2: $0 < \frac{d_S}{d_T} < 1$: Different from the scenario above, target RS is farther from the user than serving RS is. The value of SINR that the user received from target RS is worse than that from serving RS, which is a normal phenomenon, so it is not necessary to do any handover decision in this case.

Case 3: $1 \leq \frac{d_S}{d_T} \leq 1.1$: It indicates that the target RS is closer to the user than the serving RS, and the user is nearby the middle of them. Although the user is suffered the interference of neighboring cell, it has been reduced the most number of unnecessary handovers restricted by the value of HOM, and the number of handovers is similar compared to the traditional handover method when the distance ratio is lower than 1.1. Therefore, in this paper, we do not handover when the distance ratio is lower than 1.1.

After finishing the two stages of handover decision above, BS will command the user to conduct the handover process, and the total number of handovers (NH) is accumulated to one. In the next section, we will compare and analyze the proposed handover method, the traditional handover method and the LTESHHO method. The objective function is to obtain the minimum number of handovers (NH):

$$\mathrm{NH} = \min\left\{\sum_{\mathrm{cell}\epsilon\omega} \sum_{k=1}^{n} \left\lfloor \mathrm{NH}_{\mathrm{i\_cell}}(k) \right\rfloor\right\} \quad (9)$$

$\mathrm{NH}_{\mathrm{i\_cell}}(k)$ denotes the total number of handovers that the user k in the station i. $\mathrm{cell}\epsilon\omega$ represents as the total cells.

IV. Simulation

In this section, we will set up an environment to compare the performance of the three methods, including the traditional handover method, the LTESHHO method and our proposed method, for further analysis. To observe the influence of mobility in different scenarios, we use two different speeds for the users, which are movements by foot and vehicle. This simulation is built using the LTE simulator [7]. To enhance frequency utilization efficiency, we used multicast model to transmit data, so many mobile stations can take part in the same video multicast group and share the same radio resource. We build the simulation that many users move within the range of the seven cells in the wireless relay networks. The following metric is used to evaluate the proposed method. Number of handovers (NH): the metric of number of handovers is used to evaluate these methods.

A. System Topology

In this simulation, there are totally seven cells in the system topology, and six relay stations in each cell. The transmission of every cell can be divided into two stages. In the first step, the BS uses the inner band to transmit data to inner users and RSs. In the second step, all RSs use the outer band to transmit data to outer users simultaneously. If any neighboring cell uses the same frequency to transmit data, it becomes interference against the users.

As a result, the scenario that we want to simulate is one that many users move under the system topology, and the movement is divided into two categories, walking (3 km/h) and movement of vehicle (30 km/h). In order to approximate to the real movement of the user in the urban environment, we limit some conditions to these movements. In the case of 3 km/h, the user can randomly move and turn around in any direction, which is called "random walk." In the case of 30 km/h, the user must move at least 100 meter, before he can make a turn with a 90° direction, which is called "random move."

B. Simulation Parameters

The simulation is based on LTE, and the proposed method can be extended to other relay networks. Parameters of simulation are used by LTE (Release 9) forum in [7]. The parameters of OFDMA and MCSs are used according to [8]. The path loss model that we used in this simulation is the COST 231 Hata model in [8]. We set the speed of walking of the user as 3 km per hour according to the parameter of low-mobility in LTE (Release 9). The speed of vehicle is 30 km per hour according to the parameter of vehicle-mobility in LTE (Release 9).

C. Performance Evaluation

There are 29 users in each cell averagely, and the total number of users is 203 (7*29=203). The movement of users is divided into two categories: random walk and random move. Then, we will compare the result of handover in two different scenarios as follows: (a) The movement is random walk (3 km/h). (b) The movement is random move (30 km/h).

In the first evaluation, the movement is random walk (3 km/h), and time of simulation is 1000 second. When the time of simulation is 500s, the number of handovers is similar in that in the traditional handover method, the LTESHHO method and the proposed handover mechanism. Many users have not yet moved across another cell, because the speed of users is only 3 km/h, time of simulation is 500s, and users are distributed into seven cells that the cell radius is 1000 meters. As shown in Fig. 6 and Fig. 7, we observe that number of handovers is similar in the LTESHHO method and the proposed handover mechanism. Fig. 7 illustrates the probability of handover, which divided by the number of the traditional handover method. Number of handovers in the LTESHHO method is less than 18% in average compared to that in the traditional handover method. As for the proposed handover mechanism, the number of handovers is less than 15% to 35% here in average in comparison to the traditional handover method. By increasing the parameter of the distance ratio, the total number of handovers is obviously reduced. In the condition of $1.3 < \frac{d_S}{d_T} < 1.35$, the proposed handover mechanism can reduce more than 17% of the handover number in average compared to the LTESHHO method.

Next, we change the movement to random move (30 km/h). Because of the speed is 30 km/h, the user will frequently move around under the system topology. As shown in Fig. 8 and Fig. 9, when time of simulation is 1000s, we can observe the number of handovers is similar in the LTESHHO method and the proposed handover mechanism. The LTESHHO method can reduce more than 7% of the handover number in average in comparison to the traditional handover method. The proposed handover mechanism can reduce more than 4% to 12% of the handover number in average in comparison to the traditional handover method.

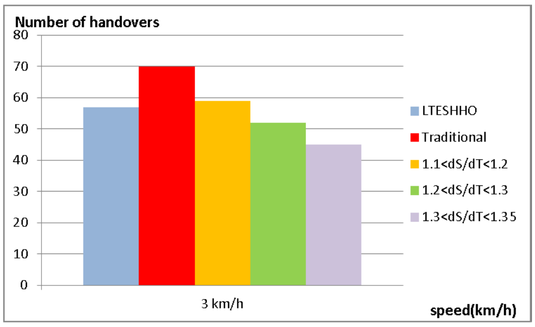

Fig. 6 The movement of users is random walk (3 km/h).

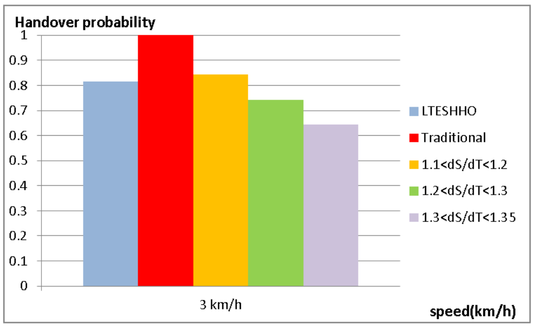

Fig. 7 The probability of handover with 3 km/h.

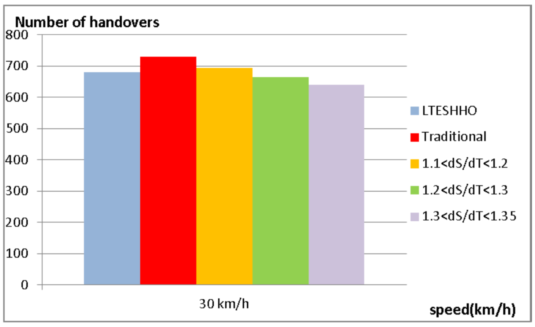

Fig. 8 The movement of users is random move (30 km/h).

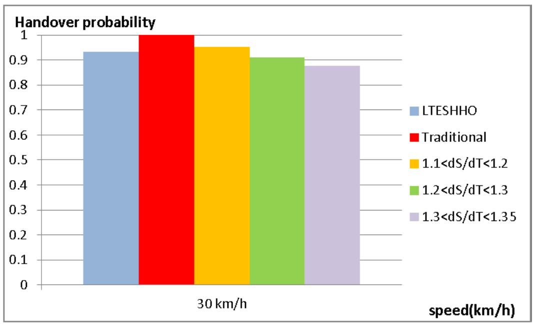

Fig. 9 The probability of handover with 30 km/h.

As the results of four simulations shown above, our proposed handover method can effectively reduce the number of unnecessary handovers. However, the simulation results are under the ideal situation, which the parameter of distance is between 1.1 and 1.35. When the parameter of distance is larger than 1.35, the handover will be disconnected for users. As shown in Fig. 10 and 11, the users do not occur disconnecting in the LTESHHO method, and so as that in our proposed handover method with the parameter of distance between 1.1 and 1.35. The handover blocking probability increases, when the parameter of distance is larger than 1.35. The handover blocking probability with 3 km/h is about 5%, and that with 30 km/h is about 1.5%.

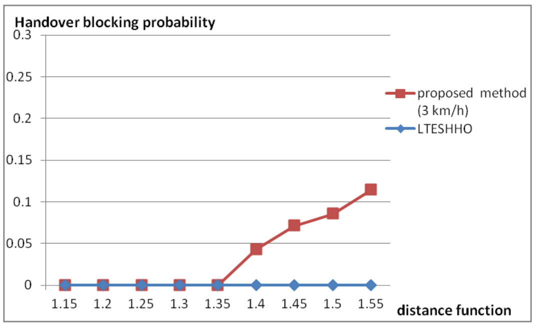

Fig. 10. The handover blocking probability with 3 km/h.

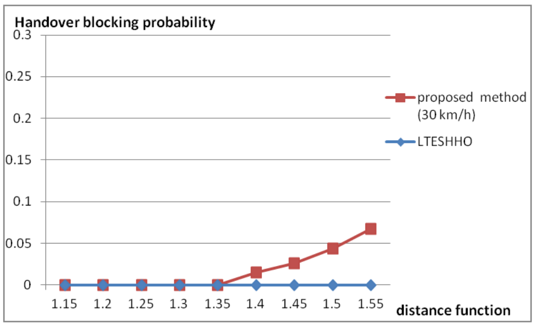

Fig. 11. The handover blocking probability with 30 km/h.

V. CONCLUSIONS

In this paper, we have proposed a multi-decision handover mechanism to reduce the ping-pong effect in handover process. We use the value of SINR and the parameter of distance to make handover decision. Based on the simulation result, the proposed mechanism can effectively reduce the number of unnecessary handovers.

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