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Procedia Computer Science 52 (2015) 270 – 277

Procedia Computer Science

The 6th International Conference on Ambient Systems, Networks and Technologies (ANT 2015)

An Enhanced Mobility State Estimation Based Handover Optimization Algorithm in LTE-A Self-organizing Network

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Abstract

Heterogeneous network (HetNet) is considered as a prime way to solve the limits of system capacity and broadband service coverage in traditional network. However, the deployments of small cells with varied sizes make the network topology more complicated. Self-organizing network (SON) technology, aiming to reduce the operational costs, is a significant technology in HetNet. One of the common use cases is to improve handover performance. In this paper, a handover optimization algorithm based on enhanced mobility state estimation (EMSE) is proposed. Considering both user equipment (UE) speed and handover types, the optimization algorithm based on EMSE combines selective Time-to-Trigger (TTT) and dynamic handover margin (HM)-adjusting in SON. Furthermore, the algorithm performance is compared with two different reference cases. Simulation results show that total handover failure has an obvious decline with our self-optimizing algorithm. Therefore, handover performance gets improved and UEs have better mobility robustness in HetNet through our algorithm.

Peer-review under responsibility of the Conference Program Chairs

Keywords: EMSE; self-organizing network; handover margin; handover optimization; HetNet;

1. Introduction

As explosive growth in mobile broadband services has stimulated great demands on wireless radio networks, Heterogeneous network (HetNet) is considered as a prime candidate to meet increasing demand for mobile broadband service coverage and capacity[1]. However, since various cell types and cell sizes are deployed in HetNet, it causes more complex mobility management and more serious interference. In addition, after small cells are

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Peer-review under responsibility of the Conference Program Chairs
doi:10.1016/j.procs.2015.05.078

deployed, handover performance gets degradation obviously, and overall handover failure (HOF) gets increased. There are two main reasons, firstly, the conventional mobility state estimation (MSE) proposed in 3rd Generation Partnership Project (3GPP) Release-8 is no longer accurate as in the macro-only deployments, which results in improper mobility parameters for handover process; secondly, as the optimal handover parameters are different for different handover types, same handover parameters setting for different handover types will lead to more HOF in HetNet.

To improve handover performance in HetNet, recent interest has focused on Self-organizing network (SON), which is able to achieve automatic optimization decisions and procedure executions. SON has been introduced in 3GPP Rel-8 standard for Long Term Evolution (LTE) and gained acceleration with increasing support in further releases[2]. As SON can adapt automatically network parameters to improve network performance, it has significant meaning for HetNet implementation. In[3], a comprehensive algorithm for handover among macro and femto applications on LTE-A networks is proposed by using SON instructions.

Handover optimization algorithm has gained more and more attention in the recent research. Several techniques for handover optimization algorithm have been discussed in these literatures. Studies on handover optimization with mobility robustness were presented in[4], which presented optimizing parameters related to handover in homogeneous networks. A hybrid system model of handover algorithm was presented in[5] firstly, and then three optimization strategies were proposed to take handover decision based on such a modeling. In a study conducted by[6], the proposed method optimized mobility robustness based on UE speed. Although it was conducted in homogeneous networks as well, it was confirmed that UE speeds had a great influence on the success rate of handover. Some performance analyses for LTE handovers were described in[7], but no SON algorithms were applied to find an optimal setting of handover parameters in paper[8]. Dynamic hysteresis-adjusting was considered in[9, 10]. In[11, 12], techniques for adjusting both handover margin (HM) and Time-to-Trigger (TTT) were proposed, but it was not analyzed in HetNet and no further impact on user speed was explained.

In this paper, an enhanced mobility state estimation (EMSE) based handover algorithm in SON is proposed. The most advantage of this paper is that both user equipment (UE) speed and handover types are considered in HetNet. The optimization algorithm will select effective TTT according to handover type and adjust dynamically HM through SON. In addition, an EMSE algorithm proposed in[13] is adopt to obtain more accurate UE speed estimation so as to get proper TTT factor in handover process.

The rest of the paper is organized as follows: Section II introduces the existing MSE and the handover mechanisms, and analyzes the HOF in HetNet. In Section III, the proposed EMSE based handover algorithm is presented. System model and the analysis of performance are presented in Section IV. Finally, the conclusions are given in the Section V.

2. Related work

2.1. The existing MSE and EMSE

The existing MSE defined in the 3GPP specifications counts the number of handover within a specific time interval, and then compares the count to predefined threshold to decide UE mobility state. UE mobility state generally is classified into three ranges: normal, medium and high. The existing MSE could perform well in homogeneous network. However, in HetNet, where varied sized small cells are deployed, the configuration parameters are not suitable and the estimated speed will be inaccurate since the MSE does not take cell sizes into account. Thus such estimation method will cause inaccurate mobility state estimation in HetNet, which directly leads to improper mobility parameters setting for handover process. To improve mobility robustness and handover performance, some enhancements are explored. An effective enhancements proposed in[13] is to weight different handover types with scales differently when counting them for MSE estimation. This paper considers the effective radiate coverage for the serving and target cell characteristic, and the pico-related handover will be given less scale due to the smaller coverage area of the small cells.

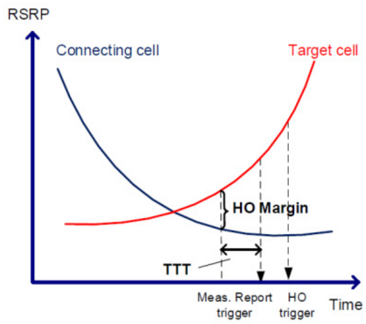

Fig. 1. Handover process

2.2. Handover schemes and parameters

In 3GPP systems, when a UE is in connected mode, the network is responsible for deciding when a handover must be performed to maintain the connection quality[8]. Typical handover process involves three stages: handover measurement, handover trigger and handover execution. The handover procedure in 3GPP LTE-Advanced (LTE-A) is shown in Fig. 1. Handover initiates with a handover message transaction between the serving eNB and the target eNB, and UE begins to transmit measurement report to the serving eNB when triggering event remains satisfied for a duration identified by the timer named TTT. In this paper, A3 event is used as the triggering condition in which target cell becomes offset better than serving cell. The values of TTT specified by 3GPP are 0s, 0.04s, 0.064s, 0.08s, 0.1s, 0.128s, 0.16s, 0.256s, 0.32s, 0.48s, 0.512s, 0.64s, 1.024s, 1.280s, 2.560s and 5.120s. In handover process, TTT is influenced by UE speed *v*. When UE is in high speed, it will experience longer distance and more severe degradation of signal quality during TTT' which is the original value configured in cell, causing too late handover. Thus it is reasonable to set a lower TTT value for high speed UEs according to 3GPP TS 36.331. We apply a scaling factor μ whose value refers to Table 2.

$$\mathrm{TTT} = \mathrm{TTT}' * \mu\,,\quad \mu = \begin{cases} 1; v = \text{normal} \\ 0.5; v = \text{medium} \\ 0.25; v = \text{high} \end{cases} \tag{1}$$

2.3. Analysis of handover failure

There are four handover types in HetNet: macro to macro (M2M), macro to pico (M2P), pico to macro（P2M） and pico to pico (P2P). In this paper, HOF in different HetNet conditions are simulated when UEs are in different speeds. As shown in Fig. 2, two deployment scenarios are considered: 4 picos per macor cell (the upper 3 diagrams in Fig.2) and 10 picos per macro cell (the lower 3 diagrams in Fig. 2). In both scenarios, it can be observed that HOF is different when UEs are in different speed. UE speed has a direct impact on handover parameters. Thus EMSE is expected to give more accurate UE speed estimation and improve HOF.

Furthermore, it is also showed that different handover types occupy different proportion in total HOF, and HOF of P2M shows the worst performance. This is because the different coverage areas and signal attenuation in HetNet, Taking an example of the path loss in macro eNB LOS model (the unit of R is km)：

$$PL_{LOS}(R) = 103.4 + 24.2\lg(R) \tag{2}$$

Then the change of path loss $F(x)$ after UE move *d* km is:

$$F(x) = PL_{LOS}(x+b) - PL_{LOS}(x) \\ = 37.5\lg(1+b/x) \quad (3)$$

The derivative and second derivative of $F(x)$ are:

$$F^{'}(x) = 37.5 \times \frac{1}{\ln 10} \times \left(1+\frac{b}{x}\right)^{-1} \times (-\frac{b}{x^2}) \quad (4)$$

$$F^{''}(x) = 37.5 \times \frac{1}{\ln 10} \times \left(\left(1+\frac{b}{x}\right)^{-2} \times (\frac{b}{x^4}) + \left(1+\frac{b}{x}\right)^{-1} \times \frac{1}{x^3}\right) \quad (5)$$

As the derivative of $F(x)$ is less than 0 and the second derivative of $F(x)$ is greater than 0, $F(x)$ is decreasing convex function. That meanings the farther away from base station, the smaller signal attention is when UEs move the same distance. In another scenery, UEs move the same distance in different serving cell:

When UEs move from 10m to 20m (the distance between UEs and pico eNB), the attention considered in LOS is:

$$103.8 + 20.9 \times \log10(20/1000) - [103.8 + 20.9 \times \log10(10/1000)] = 6.29 \quad (6)$$

When UEs move from 240m to 250m (the distance between UEs and macro eNB), the attention considered in LOS is:

$$103.4 + 37.6 \times \log10(250/1000) - [103.4 + 37.6 \times \log10(240/1000)] = 0.66 \quad (7)$$

It can be observed that the relative attenuation in pico is larger than that in macro. UE will likely experience a severe degradation of signal quality during same TTT when crossing a pico cell and HOF will increase if handover parameters are still the same as in M2M. Thus the optimal handover parameters should be adapted to handover type. Handover type has nontrivial impact on handover performance and should be considered when performing parameters scaling. Hence improving the handover performance according to handover type, especially in P2M, has significant importance to the overall HOF improvement.

Consequently, the main reasons of high HOF in HetNet can be concluded in two aspects: firstly, it is the inaccuracy of UE speed estimation; secondly, there is no handover type taken into account.

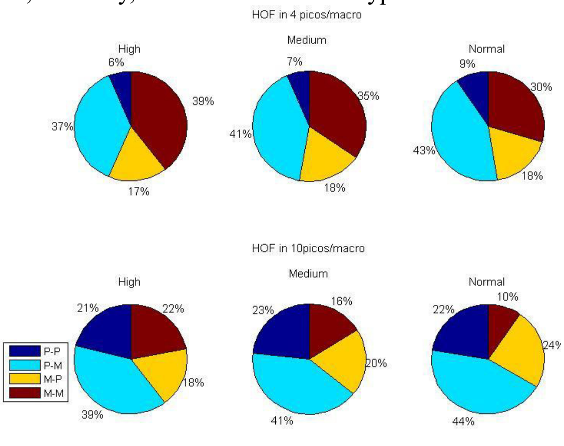

Fig. 2. HOF of different handover types

3. EMSE based handover optimization algorithm

As analyses above, we proposed an optimization algorithm which improves handover performance from two aspects. On the one hand, EMSE is introduced to improve the accuracy of UE speed estimation; on the other hand, we propose adjusting TTT and HM according to handover type. More specifically, according to[14], the values of TTT are cell-pair specific and selective TTT values are determined by handover type. In addition, to further improve handover system, HM is tuned through SON to fit network environment when handover type is P2M. A detailed algorithm description is presented in this section. Fig.3 presents a flowchart of the EMSE based handover algorithm.

Before the optimization algorithm, the initialization in the network is needed. The initial point with a HM value of 2dB and TTT of 160ms turns out to be a good starting point for the optimization, since it showed good handover performance. Subsequently, handover parameters (TTT and HM) are adjusted according to handover type. TTT value depends on the handover type. All handover types in this simulation include P2M, M2P and M2M. If serving cell is macro, the initial TTT is not changed, otherwise the TTT is changed, which is set 120ms for M2P and 80ms for P2M[14]. Then judge the type of serving cell, if it is pico, HM is adjusted dynamically through SON. HM is decreased at one step which is the value at each time for iterative adjusting of HM.

EMSE mechanism is introduced to adjust TTT further according to UE speed. The handover total number N in EMSE is shown by Eq. (8), in which the numbers of different handover types, including N_{M2M}, N_{M2P} and N_{P2M} is scaled by weights w_1,w_2 and w_3. The weights depend on the effective radiated power for the considered types[13] and the value of w_1, w_2 and w_3 are 1, 0.45 and 0.25, which relate the cells type coverage. Then TTT is scaled according to Eq. (1) and UEs execute handover.

$$N = w_1 \bullet N_{M2M} + w_2 \bullet N_{M2P} + w_3 \bullet N_{P2M} \quad (8)$$

In every time step the handover performance indicators are collected, the allowed HOF rate is set to 9% in the simulation. Until the HOF rate under the allowed HOF rate, the optimization algorithm will not stop and system will keep monitoring HOF.

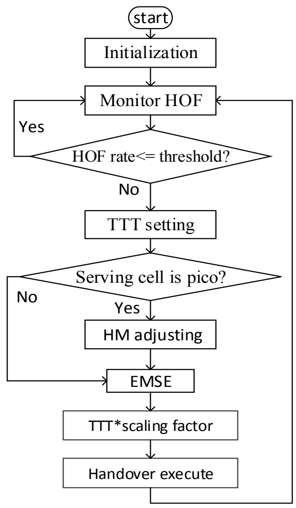

Fig. 3. Flowchart of the EMSE based handover algorithm

4. Simulation and performance evaluation

4.1. Simulation topology and parameters

The network topology is made up of a regular hexagonal grid of three-sector macro cells with pico cells where macro and pico eNBs share the same bandwidth. The simulation methodology is according to the 3GPP guidelines with default parameters as summarized in Table 1 and the simulation topology is shown in Fig. 4, where the red circles are pico deployments and black points are UEs. In the initial, UEs start at random locations, and move in random directions at constant speed along straight lines.

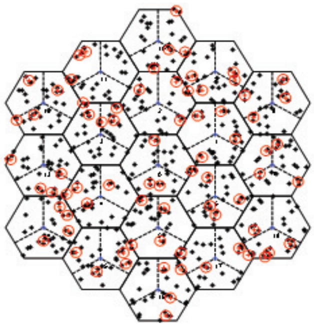

Fig. 4. Simulation topology

Table 1. System simulation parameters.

Parameter	value
Inter-Site Distance(ISD)	500m
Bandwidth and Frequency	10MHz,2GHz
Macro Cells Path-Loss	LOS:103.4+37.6lg(R), R in km NLOS:131.1+42.8lg(R),R in km
Pico Cells Path-Loss	LOS:103.8+20.9lg(R), R in km NLOS:145.4+37.5lgR, R in km
Base Station TX Power	46dBm Macro,30dBm Pico
Cellular layout	Macro:19 cell sites;Pico:4\10 picos per cell

4.2. Performance evaluation

To evaluate the performance, we choose two traditional handover processes as reference cases. The result shows that our algorithm is feasible in HetNet scenario and HOF can be reduced through the proposed solution.

For the purpose of examining the effect of our proposed optimization algorithm, this part presents a comparison among EMSE based handover optimization algorithm, handover without MSE (as reference case1) and handover with existing MSE (as reference case2). In reference case1, without consideration UE speed, handover process executes once the A3 event is satisfied in default TTT interval. TTT value is constant here. In reference case2, considering UE speed by using the existing MSE, TTT will be multiplied by different scaling factors in different mobility states. Moreover, a combination of more accurate TTT value based on handover type and dynamic HM-adjusting will be used. The mobility parameters are shown in Table 2[14].

Table 2. EMSE based handover optimization algorithm mobility parameter

Parameters	Value
UE mobility speed	3km/h,30km/h,60km/h,120km/h
TTT	160ms(default)
	M2P:120ms
	P2M:80ms
TTT scaling factors μ	sf_normal =1, sf_medium =0.5, sf_high =0.25
MSE thresholds	T_{HOmax}=100s; N_{HO_H}=6, N_{HO_M} =3
Step	0.5dB
Intial HM	2dB
HOF rate threshold	9%

Fig.5 and 6 show the overall HOF for reference case1 and reference case2 where UEs move at different speeds in network with 4 pico cells per macro and 10 pico cells per macro.

As can be seen from Fig. 5, the HOF rate increases as the UE speed increases in both two network environments. This is because UE with different speed will travel different distance in the same TTT, causing different signal attenuation. Higher speed has more contributions to signal attenuation, which is easier to lead to HOF.

Compared to reference case1, handover performance in reference case2 gets improved as shown Fig. 6.The HOF for UE in medium and high speed get clear decline while not for UE in normal. This is because when taking MSE into account, TTT will get shorter as UEs are in high and medium speed, which results in faster handover to target cell and avoids too late handover causing by longer TTT.

In Fig. 7, it shows the dynamic optimization of the overall HOF rate with the proposed algorithm. We verify the optimization algorithm in simulation platform with 10 pico cells per macro. As can be seen in Fig. 7, HOF rate gets decreased in optimization process and HOF rate for UEs in high speed decline more than that in normal speed.

From above analysis, it can obtain that the handover rate of optimization algorithm and reference case2 are lower than that of the reference case1, which does not use any MSE method. A comparison among these handover mechanisms is shown in Fig. 8. It is obvious that the HOF rate of optimization algorithm is significantly lower than that of reference case2 in different speeds. HOF rate gets improved from 10% to 8.9% compared to reference case2 in normal speed, from 11.55% to 8.91% in medium speed and when in high speed, the HOF rate declines from 12% to 8.95%.

In general, the numerical results validate the effectiveness of handover optimization algorithm and show that EMSE based handover optimization algorithm outperforms the handover with MSE and the handover without MSE. The HOF improves significantly with our optimization algorithm.

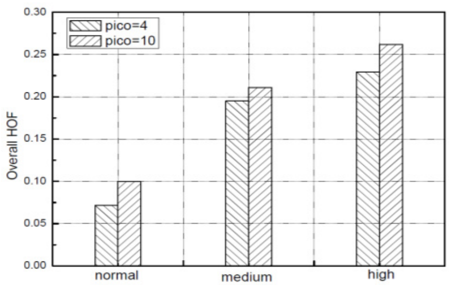

Fig.5.HOF in reference 1

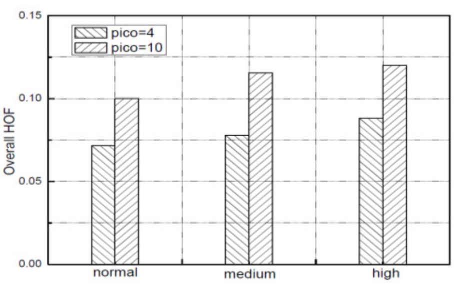

Fig.6. HOF in reference 2

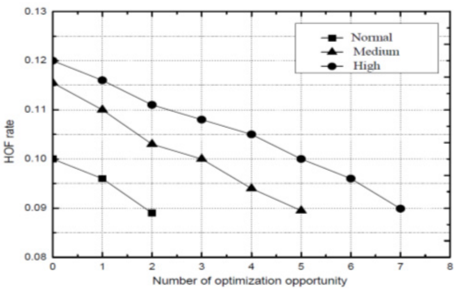

Fig.7.HOF in optimization algorithm

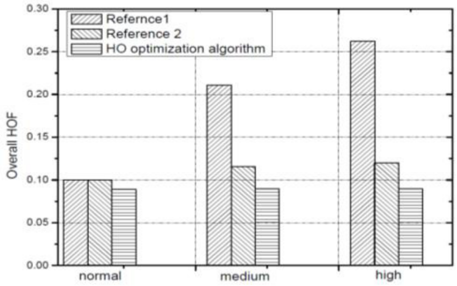

Fig. 8. Comparison with reference cases

5. Conclusion

A dynamic method called EMSE based handover optimization algorithm is proposed in this paper to improve handover performance. The difference between our work and the existing methods is that both UE speed and handover types are considered, and a combination of EMSE and dynamic handover parameters adjusting according to the handover types is presented in this paper. The simulation results validate that EMSE based handover optimization algorithm improves the system performance in terms of handover.

Acknowledgements

This work was supported by the State Major Science and Technology Special Projects (Grant no. 2013ZX03001026-001) and the Fundamental Research Funds for the Central Universities (Grant no. 2014RC0107).

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