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Mobility Management While Integrating Small Cells into the Existing Macro-only Network

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Abstract. Cell selection/reselection and handover (HO) are important mobility features and challenges of wireless cellular system. When network topology transforms from macro-only to heterogeneous network (HetNet) deployment, the imbalance of transmitted power and coverage area of different kinds of cells in HetNet introduce more challenges to those two important processes. In this paper, we investigate and elaborate some new algorithms and strategies to meet those challenges. On cell selection/reselection, there are two directions in associating more UEs with small cells, one is RSRP-based by introducing a empirical bias to expand small cells' coverage area, the other is fairness-based to maximize the system throughput and usage of resources. As to more important and difficult HO process, the proposed methods include optimizing the parameters of event A3, handling time to trigger(TTT), optimizing HO process and utilizing inter-cell interference coordination algorithm(ICIC) etc, to maximize the usage of capability of deployed small cell. The presented new algorithms and strategies promise specific performance improvement with introducing receivable time and computing complexity.

Keywords: Heterogeneous network, HetNet, cell selection, cell reselection, handover, HO, small cell, HF

1 Introduction

The main difference between homogeneous network and Heterogeneous network (HetNet) is that there are low power nodes (LPN) deployments throughout the macro cell layout[1]. Such LPNs include femto cells, pico cells and micro cells etc. Sometimes we call these LPNs small cells. In this paper, LPN and small cell are used interchangeably. One possible HetNet topology scheme is shown in Fig.1. There are many benefits by introducing small cells into macro cell layout. Firstly, small cells can effectively offload the traffic from some overloaded macro cell. Secondly, due to frequency reusing between macro cells and small cells, system capacity will increase remarkably. Thirdly, network coverage will be improved by deploying small cells in the cell edge where UE can access the network through small cells.

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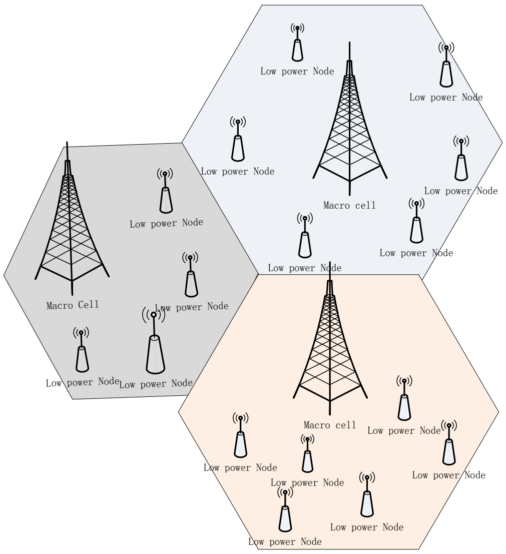

Fig.1. One possible HetNet topology scheme of HetNet

However, although deployment of HetNet brings such advantages to the system, deployment of different types of cells in the same coverage area introduces some problems to the wireless communication network which impact mobile process including cell selection/reselection and handover (HO) process. First of all, the different transmitting power level between macro cells (about 46dBm) and small cells (about 20dBm) means that macro cell will shadow small cell, i.e., the user equipment (UE) of LTE-A does not discover the existence of small cell at all. Such small cell shadowed phenomena will decrease the whole data throughput and increase drop rate of UEs at the cell edge. Moreover, if deployed small cells can't be discovered and selected efficiently, the corresponding resources including device, frequency and power are a kind of waste to some extent. Lastly, due to the low power capability, the coverage radius of small cell is relatively small, which will result in problems to UEs' HO process, especially impacts high speed UEs. HO failure and PingPong HO are the main two problems of HO process in HetNet[2].

Operators would like to utilize these resources to the most degree. So there need some methods and ways to redirect UE to connect with small cell as many as possible.Scientists and practitioners have done many researches to resolve the above-mentioned problems. Meshkati et al[3] and Prasad et al.[4] have proposed some quick and effective small cell discovery algorithms. After discovering the small cell, UE can proceed to corresponding operation, such as cell selection/reselection, call process and HO process etc, according to channel and system condition.

In this paper, we investigate the cell selection/reselection (II) and HO (III) algorithms and strategies used to improve the system performance, cell edge throughput and resource utilization of small cell.

2 Cell selection and reselection process

When UE is initiated or moves to a new cell during IDLE mode, it need to select or reselect suitable cell to camp on to process calling and data transmitting. So-called suitable cell is the cell that satisfies specific criteria for UE's need of communication. Conventional cell selection/reselection criterion is reference signal receiving power (RSRP-based) and reference signal receiving quality (RSRQ-based)[5]. Under HetNet deployment circumstances, the only RSRP-based and RSRQ-based method can't effectively distribute UEs to small cell[6]. Therefore, there needs other strategies to evenly distribute UEs among the cells, biased RSRP[7] and fairness-based methods are two relative new menthod[8].

2.1 RSRP-based method

According to [5], the cell selections algorithm is:

$$S_{rxlev} = Q_{rxlevmeas} - (Q_{rxlevmin} + Q_{rxlevminoffset}) - P_{compensat} \quad (1)$$

$$S_{qual} = Q_{qualmeas} - (Q_{qualmin} + Q_{qualminoffs} \quad (2)$$

Where S_{rx} and S_q are cell selection RX level and quality value (dB) respectively, Q_{rxlevm} is measured cell RX level value (RSRP), Q_{qualm} is measured cell quality value (RSRQ), Q_{rxlevm} and Q_{qualm} are minimum required RX level (dBm)and quality level (dB) in the cell, $Q_{rxlevminoff}$ and $Q_{qualminoff}$ are offset to Q_{rxlevm} and Q_{qualm} in S_{rx} and S_q evaluation. $P_{compensation} = max(P_{EMAX} - P_{PowerClass}, 0)$ (d , P_{EM} and $P_{PowerCl}$ are maximum TX power level a UE may use and maximum RF output power of the UE (dBm) respectively.

UE only camps on cell that satisfy conditions where $S_{rxlev} >$ and $S_{qual} >$. In nature, such algorithm is Max RSRP strategy, namely, UE chooses the cell which DL receive power is the strongest as serving cell[7]:

$$Cell_{serving} = arg\,max_{\{i\}}\{RSRP_{meas}(i)\} \quad (3)$$

The Max RSRP strategy is useful and efficient when network are homogeneous cell deployments, e.g., cells are all similar transmitting powers as macro cells or small cells.

When LTE-A introduced HetNet concept, it introduced different types of cells including macro cell and small cell, where the difference of transmitting power maybe as large as 30dB. Moreover, although small cells such as metrocell, microcell and pico-cell etc are deployed by operators, operators have all the information about location and relevant parameters of those cells, femtocells are deployed by users themselves and at users' will, the operators can't control locations and powers of them. Under small cell deployment environment, if the traditional Max RSRP strategy is used, the small cells maybe not chosen for their low transmit power and don't meet the cell selection algorithm. We don't want to waste the scarce spectra and other resources by leaving deployed small cell long time unused. So we need to improve the conventional Max RSRP cell selection algorithm to direct more UE associating with small cell.

Intuitively, we can expand the Max RSRP strategy by introducing a bias[7], which is Max RSRP+bias algorithm, i.e., if DL RSRP received from a cell plus a bias is the strongest, it's chose as serving cell:

$$\text{Cell}_{serving} = \text{argmax}_{\{i\}} \{\text{RSRP}_{meas}(i) + \text{Bi}$$

(4)

Where bias is offset for cell selection, 0 for macro cell, an empiric value greater than 0 for small cell. The Max RSRP+bias strategy sounds well and it can solve the small cell not chosen problem due to low DL RSRP to some extent[7, 9], which can effectively expand the small cell's coverage and offload from macro cell and increase the usage of resources of small cell.

But there is a new problem introduced by the choice of bias. Firstly, now the value of bias is decided by simulation or chosen by empirical experience of practitioners, it's difficult to decided whether the chosen value is optimal or not for specific small cell. Secondly, the cell range expansion (CRE) of small cell indeed results in offloading from the macro cell, but the offload performance, i.e. the UE number and traffic etc associating with small cell, is difficult to justify and predict. Therefore, there need more efficient strategies or methods to balance the number of UE and traffic distribution among macro cells and small cells.

2.2 Fairness-based method

Except traditional RSRP(RSRQ)-based cell selection/reselection algorithms, recently fairness-based scheduling methods including max-min and proportional fair[7, 10, 11] are introduced into cell selection/reselection algorithm. In their inspiring work[11], Fallgren M. et al. integrates Max-min algorithm into joint cell selection and power allocation. And Chen et al. [10] focus their research on proportional fair scheduling algorithm, which is

(5)

where I is the user set and R and R are the average rates of user i allocated by scheduler P and S respectively. Scheduler P is proportional fairness if it satisfies eq. (5).

According to Shannon's theory [12],

$$R = B\ log_2(1 + \frac{RSRP_{serving}}{N_0 + \sum_i RSRP_{ni}}) \quad (6)$$

where B is the allocated bandwidth, $RSRP_{servi}$ is the received serving cell DL RSRP, $RSRi$ is the received DL RSRP of the ith neighbor cell, $\sum_i RSRi$ is the sum of all the received neighbor DL signal, is background noise.

3 Conclusion and Future Work

The transformation from macro-only to HetNet deployment puts forward new challenges that demand many more innovations to take advantage of the full potential of deployed small cells. Among those, mobility management about cell selection/reselection when UEs are in idle mode and HO processing when UEs are in RRC-connected mode is high on the list to secure traffic offloading and small cell associating rates. This paper presents some new ideas about mobility management after integrating small cells into the existing macro-only network on cell selection/reselection and HO respectively after extensive investigation. These presented innovations promise to associating as many UEs as possible with small cell without compromising related performance such HF rates, PP rates and call drop rates etc.

Although there are many innovations on algorithms and/or procedures on mobility management in HetNet, there still need more works on mobility enhancements as of HetNet deployments. About cell selection/reselection, the research objective maybe optimize selecting parameters to direct more UEs into small cells' service without introducing time and computing complexity. As to HO process, emphasis may be put on inventing more effective algorithms or finding optimal procedures to reduce HO responding time, to optimize HO parameters and to validate HO performance etc., by taking UEs' moving speed and small cells' coverage area into account.

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