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ScienceDirect

The Journal of China Universities of Posts and Telecommunications

October 2016, 23(5): 32–39
www.sciencedirect.com/science/journal/10058885

http://jcupt.bupt.edu.cn

Dense small cell clustering based on undirected weighted graph for local mobility management

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Abstract

The concept of dense small cell has been recently emerged as a promising architecture that can significantly improve spectrum efficiency and system capacity. However, it brings frequent handover for user equipment (UE). Furthermore, this will bring a great deal of signaling overhead to the core network. Virtual technology has been received widespread attention for solving this problem. Its essence is to form virtual cells by clustering various terminals properly. The local mobility management proposed recently is based on the virtual technology. Therefore, the formation process of virtual cells is the basis for the research in local mobility management. So clustering scheme for dense small cell network has been studied in this paper, and a maximum benefit merging algorithm based on undirected weighted graph has been proposed. There are X2 interfaces between the cluster head and each of cluster members within the same cluster. The cluster heads manage the handover among cluster members acting as the local anchors. The proposed clustering scheme is useful for local mobility management. The simulation results show that the proposed clustering algorithm can decrease the signaling overhead more than 70% and 20% compared with the non-clustering algorithm and other clustering algorithms respectively.

Keywords mobility management, dense small cell network, handover, clustering, LTE-A

1 Introduction

Cisco published a report on global mobile data traffic forecast in February 2016. It indicates that global mobile data traffic grew 74% in 2015. Global mobile data traffic reached 3.7 EB per month at the end of 2015. Global mobile data traffic will increase nearly eightfold between 2015 and 2020. It will reach 30.6 EB per month at a compound annual growth rate (CAGR) of 53% [1]. However, traditional cellular networks cannot provide high wireless data-rates to meet the demand. The concept of cellular networks overlaid with small base stations has recently emerged as a promising architecture [2], e.g. the dense small cell network in long term evolution-advanced (LTE-A) and in ultra-dense small cell network the 5th-generation (5G) [3]. Nevertheless, the deployment of small cells raises several challenges that need to be addressed, notably at the level of handover management and interference management [4]. The intensive small base stations cause frequent handover and more interference. The frequent handover brings a lot of signaling overhead to the core network.

To solve the problem of handover, many jobs have been done. In Ref. [5], a fast handover scheme is proposed. Nevertheless, this scheme does not save handover costs on core network significantly. In Ref. [6], Wang et al. proposed to move the mobility anchor from the mobility management entity (MME) to the femtocell gateway. Such an approach does not minimize signaling overhead related to handover since the femtocell gateway is still located on the mobile operator's premise. Local mobility management is studied in Ref. [7] to optimize paging and registration updates. In Ref. [8], an X2-based data forwarding scheme is proposed. In Ref. [9], handover management in ultra-dense femtocell network is studied. It puts the local

Received date: 02-06-2016
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DOI: 10.1016/S1005-8885(16)60055-9

mobility management under the premise that the femtocell is formed a static cluster. In this way 50% signaling overhead can be reduced.

Local mobility management is a promising way to achieve overall mobility performance improvement. It makes small cells with smaller coverage form small cellular clusters by collaborating with each other. Managing handover within the cluster by local mobility anchor can reduce the signaling overhead. The basic of local mobility management is to form clusters. At present, the base station clustering scheme includes static clustering scheme and dynamic clustering scheme. Static clustering scheme [10–12] is mainly based on the location of base stations. This method is simple but every cluster formed is with fixed size. For all the users, their collaborative clusters are the same. So for users with different locations, their inter-cell interference cannot be eliminated maximally. The algorithm does not guarantee fairness. Dynamic clustering scheme [13–17] is based on the feedback of the channel state information (CSI) and the formed clusters' scale is real-time. However, this scheme is compute-intensive and it is difficult to obtain the real CSI in real time. In Ref. [17], Huang et al. propose a dynamic clustering method based on benefit-tree for base station cooperation. In Ref. [18], Ng et al. propose a clustering method based on the closest base station to form clusters. In Ref. [19], Tariq et al. propose a new clustering scheme for femtocell networks based on maximizing the minimum distance of the femtocells. This method is very simple, but the actual signal in wireless transmission channel is greatly influenced by environmental factors. Even though the base station geographically closer to UEs may also result in receiving poor signal quality to UEs due to the impact of environmental factors such as terrain.

From the above analysis, we can see that there is no effective clustering scheme for the local mobility management. In order to improve the effectiveness of the new schemes, we study small cell clustering scheme in this paper. The scheme aims to provide an efficient clustering scheme applied to the local mobility management and improve system performance more effectively. A small cell clustering model aiming to minimize core network signaling overhead is proposed in this paper, referring to the existing clustering scheme. According to the general communication process, we get handover statistics used to form clusters within small cells' immediate neighboring cells. Cluster head manages handover among cluster members acting as a local mobility anchor. In order to reduce the complexity of the model, we propose maximum benefit merging algorithm. It calculates the benefits of clustering based on handover statistics and merges selected two clusters with biggest benefit gradually to form the cluster of small cells. Simulation results show that the performance of our proposed algorithm can improve the performance in terms of core network signaling overhead compared with the algorithm proposed in Ref. [19].

The rest of the paper is organized as follows. Sect. 2 describes LTE-A system, models the problem and presents a dense small cell clustering model based on X2 interface. In Sect. 3, we modify the above model as an undirected weighted graph, and propose maximum benefit merging algorithm. In Sect. 4, simulation scenario and mobility models for UEs are introduced. Sect. 5 shows the Matlab simulation results and analyzes the results in detail. Sect. 6 summarizes the study and the contributions of this paper.

2 System model and cluster formation scheme

Consider an LTE-A small cell network composed of n open access femtocells home evolved node B (HeNBs) in the macro-cellular evolved node B, eNB coverage. Let F denotes the set of active HeNBs in the network, f_i denotes the ith HeNB. So it can be expressed as $F = \{f_1, f_2, \dots, f_n\}$. For convenience, let $N = \{1, 2, \dots, n\}$ represents these femtocells subscript. Based on the recent LTE-A enhancement program in the 3rd generation partnership project (3GPP), a network overlaid with femtocells can be deployed as shown in Fig. 1. Evolved packet core (EPC) contains security gateway (S-GW) and MME. HeNB GW denotes gateway of HeNB. A HeNB can normally maintain the X2 interfaces with its immediate neighboring cells (instead of a full Mesh) with overlapping radio coverage [20].

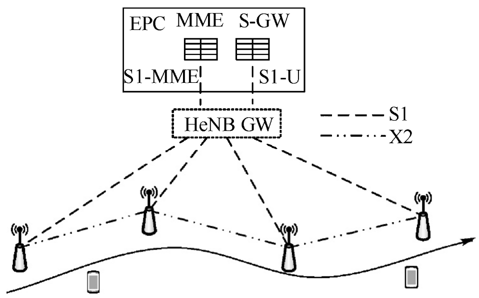

Fig. 1 3GPP LTE-A network architecture

First, we observe the behavior of UEs. In the process of