Dwell-time based Cell Association with Carrier Aggregation for Heterogeneous Cellular Networks

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Abstract: In heterogeneous networks (HetNet), it is an important issue to determine a suitable access network for call request to support seamless service and stable connectivity. For moving user equipment (UE), when and how to select a appropriate cell is more challenging. Since relatively long handover (HO) interruption time occurs due to the frequent HO, they experience significantly degraded data rate. Therefore, we propose dwell-time based multi-traffic cell selection method with carrier aggregation (CA) to reduce the effect of HO interruption time. Dwell time means the time UE stays in a cell. Using the dwell-time considered cell selection method, we expect increase average UE throughput by declining the interruption time. Simulation results show that our proposed scheme improve the UE experienced data rate.

1. INTRODUCTION

Over the past few years, introduction of new mobile devices arises an explosive increase in cellular traffic. To meet such a significant demand for wireless data capacity, heterogeneous network (HetNet) has played a central role [Yeh *et al., 2011*]. However, it is still inefficent to satisfy a peak data rate target of 1 Gbps established for IMT-Advanced [Shen *et al., 2012*]. In LTE-Advanced, one promising approach is to extend the transmission bandwidth by carrier aggregation (CA) in order to increase data rate [Parkvall *et al., 2011*].

There have been many studies on CA with the purpose of higher user throughput. In [Li *et al., 2011*], a bias based cell selection method is proposed for efficient usage of small cells. By giving bias to small cells when choosing secondary cells for higher data rate, the increased number of UEs served by small cells can bring significant performance gain. In [Wang *et al., 2012*], a load balance based cell selection method is described. By considering current nodes' traffic conditions, frequency resource will be fully exploited in HetNets.

However, it is still difficult to make full use of those schemes to support UE with high mobility becuase user mobility is not taken into account. To solve such a problem, a new concept of spliting the control and user (C/U) planes of the radio link is proposed [Ishii *et al., 2012*]. According to [Pedersen *et al., 2013*], macro BS(mBS) is selected as a C-plane cell regardless of traffic condition for a high speed UE and U-plane cell is choosed based on expected data rate. However, although UE may have a good connectivity through C-plane, they might not be provided high data rate by U-plane when frequent U-plane cell changing happens. In this paper, a dwell time based cell seletion method is proposed to prevent unnecessary HO and thus improve the average UE throughput.

2. SYSTEM MODEL

In this paper, we focus on the downlink data transmission of HetNet which is macro and small cells are coexisted forming hotspots. Let us assume that macro base station(mBS) and hotspot are randomly located according to a homogeneous Poisson Point Process(PPP) with density λ_M amd λ_H, respectively. Also, small cell base station(sBS) is randombly distributed according to a homogeneous PPP with density λ_S, over a circle with radius R centered at hotspots.

The transmission total power of mBS and sBS are $P_M= 46dBm$ and $P_S= 30dBm$ with the thermal noise $N_0= -104dBm$. There is a set of $\mathcal{M}$ available bands denoted as $\mathcal{M} \in \{800MHz,\ 2.6GHz,\ 60GHz\}$. For mBS, it only uses $800MHz$ band and for sBS, it uses both $2.6GHz$ and $60GHz$ bands. The bandwidth, the path loss coefficient and the number of cell on band m are denoted by B_m ($B_{800MHz} = 10MHz$, $B_{2.4GHz} = 10MHz$ and $B_{60GHz} = 2GHz$), $\alpha_m(\alpha_{800MHz} = 3$, $\alpha_{2.4GHz} = 4$ and $\alpha_{60GHz} = 5)$ and I_m, respectively.

Also, we presume that density of UE is λ_U and the ratio of moving UE to staitionary UE is ρ_{Um} to ρ_{Uf}. Staitionary UE is located according to a homogeneous PPP with density $\lambda_U \times \rho_{Uf}$ and the rest of UE travels over a predefined straight road with a mobility v. Mobility are i.i.d with distribution function $f_u(v)$.

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3. PROPOSED CELL ASSOCIATION WITH CA

For a moving UE with a high speed, to maintain a stable connectivity is important matter for UE to be served. Therfore, we split C/U-plane to last the connection without breaking up as in [Ishii *et al., 2012*]. In the conventional method adopting the 3GPP carrier aggregation terminology, it translates to assuming that UE devices are assumed to have their PCell configureed on the macro layer [Pedersen *et al., 2013*]. In this paper, the proposed scheme also choose a C-plane cell based on connection power and cell coverage. Thus, C-plane cell are selected as follow.

$$C(i_m^*)_{conv} = C(i_m^*)_{pro} = \underset{i_m \in I_m, m=800MHz}{\arg\max} RSRP_{i_m} \quad (1)$$

where $RSRP_{i_m}$ is reference signal received power (RSRP) of ith cell on band m.

Before describe U-plane cell selection, we discuss the procedure and set several assumption on the conventional and proposed scheme. U-plane cell selction goes through the procedure as follow. UE calcualtes achievable data rate averaged on whole bandwidth B_m and reports the results to a central eNB directly. In the case of the conventional method, the central eNB determines association results based on information of current number of UE associated to each nodes, n_{i_m}. However, in the proposed scheme, we suppose that the central eNB is informed additionally about dwell time of UE according to a specific mobility range. In this paper, we set 5 different mobility ranges $v_{q=1,..,5}$, $v_1 = 10\ km/h$, $v_2 = 20\ km/h$, $v_3 = 40\ km/h$, $v_4 = 80\ km/h$ and $v_5 = 150\ km/h$. This is because dwell time is rapidly declined below velocity 100 km/h. Therefore we subdivided the velocity more finely within the range. Then, the central eNB can classify dwell time t_{i_m,v_q} according to the mobility set v_q and cell coverage on band m.

For a data transmission, in the conventional method, UE calculates achievable data rate averaged on whole bandwidth, R_{i_m} to select U-plane cell as follow.

$$R_{i_m} = B_m \times \log(1 + \gamma_{i_m}) \quad (2)$$

where γ_{i_m} is Signal to Interference plus Noise Ratio (SINR) of ith cell on m

And UE reports the information to a central eNB directly and the eNB determines association results based on the information as well as the current number of UE associated to each nodes. Thus, U-plane cells selection criteria can be described as follow.

$$U(i_m^*)_{conv} = \underset{i_m \in I_m, m \in \mathcal{M}}{\arg\max} \frac{R_{i_m}}{n_{i_m}} \quad (3)$$

where n_{i_m} is the number of UEs associated to ith cell on band m.

Even though the scheme takes the channel condition and load balance into account to fully exploit small cells, it overlooks the fact that the criteria based on instantaneous information can occur a rapid transition. With regard to appropriate U-plan cells, we should avoid a sudden change by considering quantized dwell time information.

As mentioned above, in the proposed scheme, eNB is informed not only current nodes' traffic load but dwell time of UE. Based on the information, we define effective load coefficient E_{i_m,v_q}.

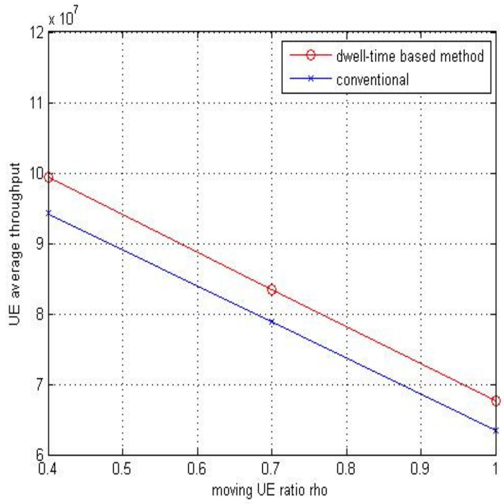

Fig. 1. Proposed SCell selection method

$$E_{i_m,v_q} = \frac{(t_{i_m,v_q} - t_{HO})}{n_{i_m}} \quad (4)$$

where t_{i_m,v_q} is dwell time of UE with the mobility v_q in ith cell on band m. t_{HO} is set up time that UE measures RSRP, reports the information to a central eNB, and receives the association results from the central eNB.

Among candidates, we choose U-plane cell which has the largest obtainable data rate multiplied by effective load E_{i_m,v_q} as follow.

$$U(i_m^*)_{pro} = \underset{i_m \in I_m, m \in \mathcal{M}}{\arg\max} R_{i_m} \times E_{i_m,v_q} \quad (5)$$

4. PERFORMANCE EVALUATION

In this section, system-level simulation results are presented to verify our proposed scheme improve UE average throughput.

We compare the UE average throughput between the proposed scheme and the conventional scheme. In $Fig.1$, the average throughput of total UEs according to increase of moving UE ratio ρ_{Um} is plotted. As the moving UE ratio increases, both schemes show declined average UE data rate. However, the proposed schemes reduces degree of decrease compare to the conventional method. It proves that dwell-time based cell selection method is useful for moving UE.

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