CELL SELECTION TECHNIQUE FOR INTERFERENCE MITIGATION IN HETEROGENEOUS NETWORKS

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Abstract: *The significant advances in cellular networks and mobile devices have led to a rapidly growing demand for high speed multimedia applications. The co-existence of macro eNodeBs and the additional low power nodes (LPNs) could lead to higher interference in LTE-Advanced Heterogeneous Networks (HetNets). Due to high transmission power emitted by macro cell, very few users will be off-loaded to nearby pico cell which leads to underutilization of pico cells in HetNets. Hence, in practical HetNets scenario, Range Extension (RE) is a promising scheme to utilize the low power node (LPN) resources more effectively and improve the cell edge performance. With the help of CRE, user equipment (UE) will add a bias value to actual signal strength received from pico cell and thereby offload their traffic from macro cell to pico cell. However, if the bias value is not properly set in a way to capture the users' distribution and network density, it may introduce more interference. In this paper, a solution of Intelligent Pico Cell Range Expansion which calculates the optimal and effective bias value for each mobile station independently is been proposed. Simulation results demonstrate that the proposed scheme can reduce the number of outage and increase the number of offloaded UE in HetNet.*

Keywords: *Cell Association, Cell Range Expansion, Heterogeneous, Networks, Inter-Cell Interference, Pico Cell*

Introduction / Background Study

Fast evolution towards IoT, M2M and IoE are motivating the Telecom enterprises and wireless communications enablers to define the architecture, specifications, and requirements of the 5G networks (Ning et al., 2014). Future generation wireless system (such as 5G) was conceptualized due to high demand on network capacity, mobility, high data rate, better end-to-end performance. One of the solutions to support this increasing data traffic is ultra-dense deployment of small cells. Fifth generation wireless network is expected to be a mixture of network tiers of different transmission powers, backhaul connections and different radio access technologies (RAT). For capacity improvement, users will need to be actively pushed onto the more lightly loaded tiers (pico cells, femto cells and remote radio heads (RRHs), even with lower signal to interference and noise ratio (SINR), (Yuan and Liang, 2016). The goal of using low power nodes (LPNs) is to offload the traffic from the macro cells, enhance coverage, and increase the spectral efficiency by spatial reuse of spectrum (Tariq et al., 2013). Moreover, this approach helps to decrease or reduce the distance between transmitter and receiver thereby yielding improved radio link quality. Since data traffic demand is increasing at an exponential rate, further spectral efficiency improvements are needed. Higher transmit power of macro cell leads to underutilization of small cells. This introduces a lot of challenges in the multi-tier network, one of which is Inter-cell Interference (ICI). In 5G, the existing interference management scheme will not be sufficient to mitigate the Inter-Cell Interference problem. Cell Range Expansion (CRE) is a technique to virtually expand the coverage range of pico cell (Cao, et al., 2013). There are some studies on the SINR bias, but have not given any theoretical guidance on the best value. Hence, if the bias value is not appropriately selected, this could lead to overloading and low system performance, which defeats the purpose of deploying pico cells. Apparently, a few numbers of users will be offloaded to pico cell if a small offset value is used because of the difference in the RSRP received from the macro BS, which is stronger than the value received from the pico BS, with the added bias value. Therefore, the performance of macro UEs will decrease because more UEs are served by macro cell. However, for a large offset value, more UEs are offloaded to the pico cell while these UEs are far away from the pico eNBs. As a result, they will suffer significant interference from macro eNB which leads to increased outage probability and decrease of throughput. Several works have been done on range expansion. Tian e al. (2011) suggested a CRE scheme with an adaptive offset value based on throughput and number of UEs using a logarithmic approach. In addition, some papers, (Oh and Han, 2012 ; Lopez-Perez et al., 2012) have proposed CRE approaches based on interference management. By this technique, the best offset value can be calculated such that the required system performance is satisfied. The proposed adaptive bias configuration strategy is introduced in detail in subsequent sections

Material and Methods

Range Expansion Strategy in HetNets

Range expansion in HetNets increases the downlink coverage footprint of low-power nodes such as pico cells by adding a positive bias to their measured signal strengths during cell association, in order to address the problem of load imbalance in the downlink, (Guvenc, 2011 and Li, 2015). Such base stations are referred to as biased BSs. With a larger range expansion bias (REB), more macro cell user equipments (MUEs) are off-loaded to pico cells, at the cost of increased co-channel interference for range-expanded pico cell user equipments (PUEs) in the downlink. In LTE systems, a UE must detect and monitor the presence of multiple cells and perform cell selection or reselection to ensure that it is "camped" on the most suitable cell. A UE "camped" on a particular cell will monitor the System Information and Paging (SIP) of that cell, but it must continue to monitor the quality and strength of other cells to be determined if handover or the cell reselection is required. Hence, two types of cell selection methods are specified (Sangiamwong et al., 2011). In Rel-8/9, the cell selection criterion is based on the UE's received signal power or quality, i.e. Reference Signal Received Power (RSRP) (Bhuvaneswari et al. 2015).

$$CellID_{serving} = \arg\max_{j}\{RSRP_j\} \quad (1)$$

However, this approach when applied to HetNets will lead to underutilization of the small cells due to the low transmission power of the low coverage cells. Also, the macro cell will be overloaded compared with the small cells, because only a few users would connect to the small cells. Consequently, the available resources of the small cells would not be fully exploited while at the same time the competition for the available resources would remain high in the macro cell. To address this problem, a new cell selection scheme that adds a bias value to the reference signal level (shown in Fig. 1), to attract more UEs towards selecting Pico BS as their serving cell is given by Sasikumar et al. (2016).

$$CellID_{serving} = \arg\max_{j}\{RSRP_j + b_j\} \quad (2)$$

where b_j is the bias value added to the pico BS. Bias b_j is zero for the macro cell and has a non-negative value for the small cells, resulting in more users being transferred to the small cells.

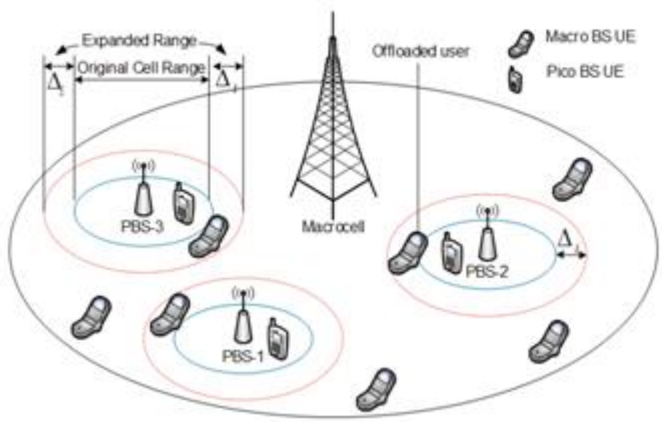

Fig. 1: Cell selection with range expansion in HetNet

Nevertheless, the bias value should be chosen properly in order to profit from the range expansions efficiency, since an excessive value of b_j will considerably increase the resulting interference for users within the pico cells expanded range. On the other hand, a low value of b_j will not have any impact on the global performance, such as load balancing or fairness, hence the purpose of deployment is defeated. Hence, the BS with the highest DL SINR plus a positive value of CRE with the following setting is selected;

$$CRE_j = \begin{cases} CRE & ; \ if \ j \ is \ a \ Picocell \\ 0 & ; \ if \ j \ is \ a \ Macrocell \end{cases} \quad (3)$$

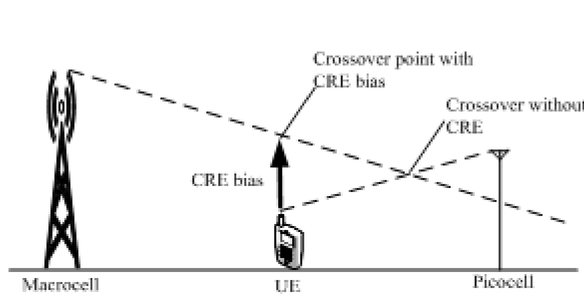

Fig. 2: CRE bias for Pico cell expansion

Interestingly, the bias value for RE strategy mainly affects the HetNet system performance by changing pico cells' coverage. As illustrated in Fig. 2, the lager the bias value is, the bigger coverage pico cells will get. Obviously, the bias value cannot be unlimited, which will cause "empty" macro cells because all users may access into pico cells. Therefore, there should be an optimal bias value in a certain scenario. However, since the bias value is usually fixed in a given scenario (Moon et al., 2014), it will not adapt to the change of the user distribution, which will lead to unbalanced traffic load between macro and pico cells, scheduling outage and bad cell edge performance due to introduced interference.

Problem Formulation

In this work, the downlink of an Orthogonal Frequency Division Multiple Access (OFDMA) network was considered. The network topology is composed of a macro BS and a set of pico BSs which are distributed within a single cell. Moreover, both macro BS and pico BSs operate in open access mode which enables all UEs to access them. In addition, a well-defined area was used for our simulation where all UEs are deployed in the coverage of macro and pico BSs, which communicate using the X2 interface. Let $\mathcal{U}$ denote the set of users, and let $\mathcal{M}$ and $\mathcal{P}$ denote the set of macro and pico BSs, respectively, so that the set of BSs $\mathcal{B} = \mathcal{M} \cup P$. In heterogeneous networks, it is usually difficult to coordinate among different BSs. This approach results in great computational complexity of the formulated optimization problem hence, a low complexity distributed solution without central coordination and computation is more desirable. In this proposed user association algorithm, the bias value based on (1) - (3) was computed, where b could assume an arbitrary value within certain range, usually 0~25dB.

User Association Algorithm

Each user $i \in U$ measures the RSRP based on pilot signals received from all available BSs, and receives the value of biasing factors announced by each pico BS $j \in P$, starting with the initial state where $b_j = 0, \forall j \in \mathcal{M} \cup P$.

Each user $i \in U$ connects to BS $j*$, which satisfies the following formula:

$$j* = \arg\max_{j \in B} \{RSRP_{ij} + b_j\} \quad (4)$$

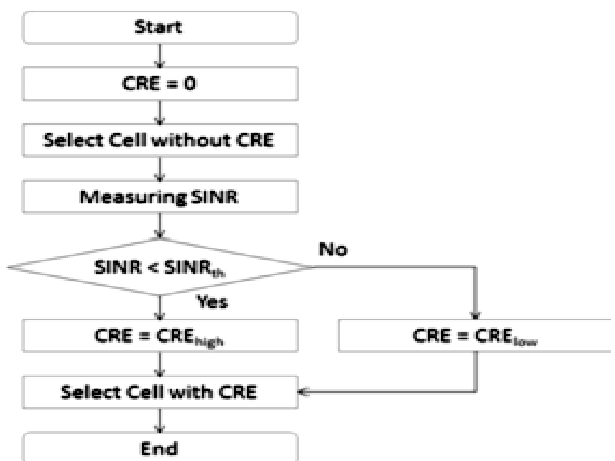

Fig. 3: Flowchart of user association technique

If there are more than one optimum association at the same time, user i can choose any of them as shown in the flowchart of the steps involved in selecting a BS with or without CRE in Fig. 3

Simulation Results and Discussions

Simulation setup comprises a 1-cell topology with a single macro BS overlaid with 4 pico BSs. In this paper, it is assumed that the pico BSs and 20 users are uniformly and independently distributed within the macro cell area for simplicity. Each BS operates with a 20 MHz bandwidth and the rate requirement of each user is set to be 1 Mbps according to 3GPPP specification (3GPP Release 13, 2012). Furthermore, the noise power level is assumed to be -174 dBm/Hz, while the path loss for macro and pico BSs are respectively calculated using L(d) = 128.1 + 37.6 log(d) and L(d) = 130.7 + 36.7 log(d), where d is the distance from a user to its associated BS in km. Figure 4 represents the percentage of UEs connected to both macro and pico BSs. It is shown that users are classified based on their mode of connection to pico cells. In this case, the bias values (in steps of 6dB) range from 0dB, when majority of users are connected to macro cell to 18dB when more users are pushed to pico cells. There is an optimum bias value, which occurs at 12dB bias value as shown in Fig. 4, and has high probability to minimize the number of outage UEs, thus providing load balancing and a much better spatial reuse. It can also be seen that the higher the Bias value, the larger the number of UEs that connect to pico BS.

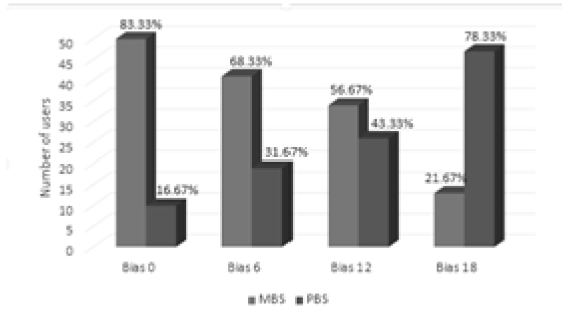

Fig. 4: Cell association connection statistics

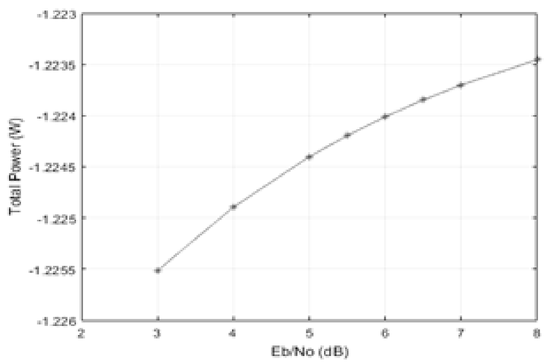

Fig. 5: BS power against Eb/No

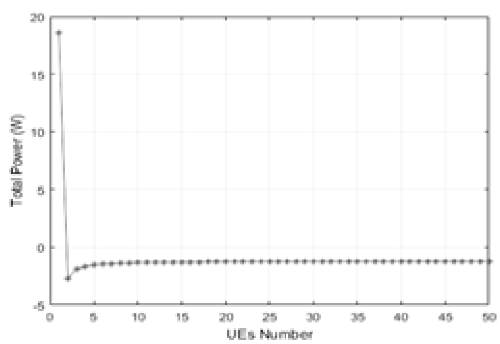

Fig. 6: BS power against No. of UEs

This is because the number of UEs in the expanded region increases as the bias value increases. However, a very large bias value will invariably overload the Pico BSs by making more users access the limited resources from the pico BSs. This is noticed, in this case, when the bias value is 18dB. The range expanded UE's throughput reduces at this point because UEs far away from the pico BSs are connected to the pico BSs while they receive high interference from macro BS. Thus, it is obvious that if the offset value is not precisely selected, the increase of macro/pico UEs throughput sacrifices the throughput of pico/macro UEs. Furthermore, Figure 4 illustrates that the outage probability is an increasing function of bias value. The reason is when the bias value increases, in the case of bias value 18db (21.67% / 78.33%), UEs far away from pico BSs are offloaded to pico cells while they experience lower SINR value. Therefore, with the optimal biasing factor (12dB), the network nearly achieves the optimal cell selection technique. These results demonstrated that biased-based cell association significantly improves resource utilization, and considerably balances the traffic load, leading to increased gain to the overall rate for most users. Comparing with the previous works, (Sun et al., 2014; Lopez-Perez and Chu, 2011), it was discovered that the results achieved about (35-40%) rate for UEs to select pico BS as serving cell. Fig. 5 depicts the BS power plotted against the signal energy per bit divided by noise spectral density (Eb/No). Expectedly, the total transmission power of the macro BS increases when the Eb/No increases. This results in unnecessary battery drain as the macro BS attempts to satisfy users with good and bad radio conditions. Figure 6 shows the plot of the total power expended by the BSs and the number of UEs. Initially when the majority of UE are connected to the macro BS, the macro BS utilizes high power in other to satisfy both cell edge and cell centre users. However, as some users are offloaded to the pico BSs, there is a considerable reduction in the amount of power usage by the macro BS. This approach, therefore, helps to conserve battery life thereby resulting in green energy transmission.

Conclusion

In this paper, the concept of range expansion technique for reducing the number of outage and increasing the number of offloaded UE in HetNet has been investigated. In Macro-Pico scenario, RE strategy is applied to fully utilize the low power node (LPN) resources and improve the cell edge performance. Simulation results have shown that expanded region pico cells supported by the proposed cell association algorithm are able to avoid UE outages and significantly enhance spatial reuse in HetNets.

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