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Energy Efficient Design in Heterogeneous Cellular Networks

Sruthi.K.T

MTech Student
Electronics and Communication Engineering
NSS College of Engineering, Palakkad, Kerala, India

***Abstract* - Energy efficiency has a vital role to mitigate increased power consumption and carbon dioxide emissions. Future wireless communication systems should be designed in such a way that energy efficiency as an important design rule. Heterogeneous Networks (HetNets) have recently being considered as an effective approach to provide better cellular network coverage and capacity. In the proposed system energy efficiency optimization problem is formulated with power and density as constraints for two tier HetNets consisting of micro and macro base stations. Deploying more number of micro base station in an energy efficient manner will further increase the energy efficiency . Greedy algorithm which is based on capacity of each user is used for base station deployment, thereby capacity enhanced energy efficient solution is proposed for HetNets.**

***Index Terms* - Heterogeneous cellular networks, energy efficiency, power and density optimization, base station deployment, greedy algorithm.**

I. INTRODUCTION

It has been detected that growing consumption of energy leads to 2% of CO2 emission and 3% of worldwide energy, this figure projected to increase significantly .In order to reduce the energy consumption green wireless communication has arrived, and it is considered as the most promising way for reducing the energy consumption to meet the increasing traffic demands. The demand for higher data rate and ever increasing number of users led to rapid increase in power consumption. One potential solution is to address these issues is to deploy small cells with the macro cell network to provide better coverage and capacity. This new deployment model is based on densifying the current network with complementary low power nodes; that is to say, adding small cells to create a heterogeneous network. HetNet comprise conventional cellular networks overlaid with various lower-power base stations (BSs), and it has been identified as a key method to fulfill the huge future demands on mobile broadband usage as both the number of users and the user demand will increase. A two tier heterogeneous cellular network consisting of micro and macro base station is considered as system model. In the existing system, optimal configuration for energy efficiency is formulated by optimizing the power and density for both micro and macro base station without considering network capacity. This brings an incomplete energy efficiency analysis. So the existing two tier network to be redesigned in order to improve the efficiency with the constraint of network capacity. Greedy algorithm which is based on capacity of each user is used for base station deployment.

II. HETEROGENEOUS CELLULAR NETWORK MODEL

A two tier heterogeneous cellular network consisting of micro and macro base station is considered as system model. HCNs including conventional macro BSs and distributed low power BSs have higher energy efficiency. The location of BSs may have significant role on the throughput and outage performance of a network. However the locations are usually unknown while designing HCNs and its analysis. For modify the location of BSs, spatial stochastic process model is widely used, such as Poisson Point Process (PPP) and Poisson Cluster Process (PCP).A tractable, flexible and accurate model for a downlink HCN consisting of multi tier BSs was recently presented. In order to keep up with increasing traffic growth in cellular networks, the infrastructure becoming increasingly dense; the conventional macro BSs are overlaid with small-cell BSs that act as hotspot inside the macro cells.

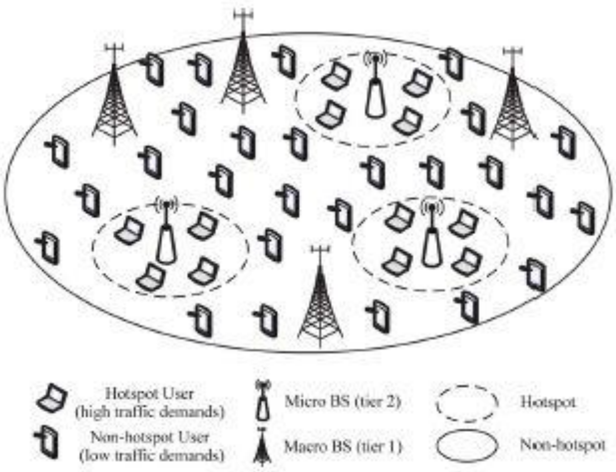

Figure 1 System Model

In wireless networks, the traffic demands vary in both temporal and spatial domains. System model consists of two kinds of regions, they are hotspot regions and non hotspot regions, which are covered by a two tier Heterogeneous Cellular Networks (HCNs) consisting the conventional macro BSs that provide coverage for non hotspot region, and micro BSs that provide coverage for hotspot region. The hotspot regions and the non-hotspot regions are differentiated by either volume or density and size. Hotspots occur due to a difference in the load in different regions of a network. In homogeneous traffic, which does not lead to an imbalance in the overall load and no part of the network is overly loaded compared to other parts and therefore, there is no probability for the occurrence of hotspots. However, in real net-works, traffic is more heterogeneous than homogeneous and there is a finite probability for the occurrence of hotspots. In general, the volume or density of traffic demands in hotspot regions is higher than that in non-hotspot regions and size of hotspot regions is smaller than that of non-hotspot regions. In this system model, the distribution of traffic demands and distribution of user location are considered as different concepts. The user's locations in this two kinds of regions are assumed to follow uniform distribution with the same density but the traffic demands and size of two kinds of regions can be different.

Signal to Noise Interference Ratio(SINR) of the typical user associated with the BS located at a point in the k^{th} tier calculated by considering distance between BS located at a point and the typical user, channel fading power, path loss, received power of the typical user and path loss exponent. Typical user is associated with the BS that offers maximum SINR.

Energy efficiency metrics will provide the information that can be used to assess and compare the energy consumption of various components of a cellular network. These metrics also helps to set research goals for reducing energy consumption. The power consumption of the BS belonging to k^{th} tier is depending on the static power consumption and the transmit power depends on the traffic demands. Thus the Energy Efficiency (EE) of HetNet can be defined as:

EE=Average Spatial Rate/Average Spatial Power Consumption

There are two optimization problems for energy efficiency with fixed micro BS density and fixed macro BS density. The optimal BS transmit power and optimal BS density are derived. In the first scenario, by fixing the micro BS density, optimal density for macro, optimal transmits power of micro and macro can be obtained. Here optimal EE is achieved when received SINR at the macro cell edge equals SINR threshold. In the second scenario, by fixing the macro BS density, optimal density for micro, optimal transmit power of macro and micro can be obtained. Optimal EE in terms of area ratio and traffic rate ratio is formulated.

Energy Efficient BS Deployment

Energy Efficiency depends on the throughput and the consumed power in a network. Traditionally, macro BSs will provide coverage over large areas without any energy efficiency concerns and the consumed power in the network increases as the coverage area becomes larger. Micro BSs will cover relatively smaller areas and thereby consume less power compared to the macro BSs. Energy efficiency can be effectively improved by deploying additional number of base stations which increases the total capacity of the system. Again EE is formulated by considering the capacity and the power consumption for both micro and macro BSs. Greedy BS deployment algorithm is used for deploying more number of micro BSs in order to improve the energy efficiency. At the first iteration, the algorithm selects the micro BS which provides the highest improvement based on the weighted summation of energy efficiency gain over all scenarios. At the second iteration, the algorithm recalculates the capacity of every user, including the selected microcell BS and the existing macro cell. Again, the micro BS which provides the highest improvement based on the weighted summation of energy efficiency gain over all scenarios is selected, but now the micro base station which is previously selected is discarded. The proposed algorithm continues until the desired network capacity is achieved for all scenarios.

III. SIMULATION RESULTS

A two tier heterogeneous cellular network is designed with micro and macro base stations. Figure2 depicts the network scenario for simulation. In figure macro cell and microcell users are randomly distributed inside the cell of radius 500m and 50m respectively. Transmit power of macro and micro are having the value of 43dBm and 30dBm respectively. Path loss exponent is 4. Energy efficiency is a major concern while designing a system. In the existing system, optimal configuration for energy efficiency is formulated by optimizing power and density for both micro and macro base stations without considering network capacity. Deploying additional number of micro BSs in an energy efficient manner will further increase the energy efficiency of the existing system. Greedy algorithm is used for deploying additional number of BSs. The algorithm starts with number of micro BSs in the existing system and iteratively increases the number of BSs in the network.

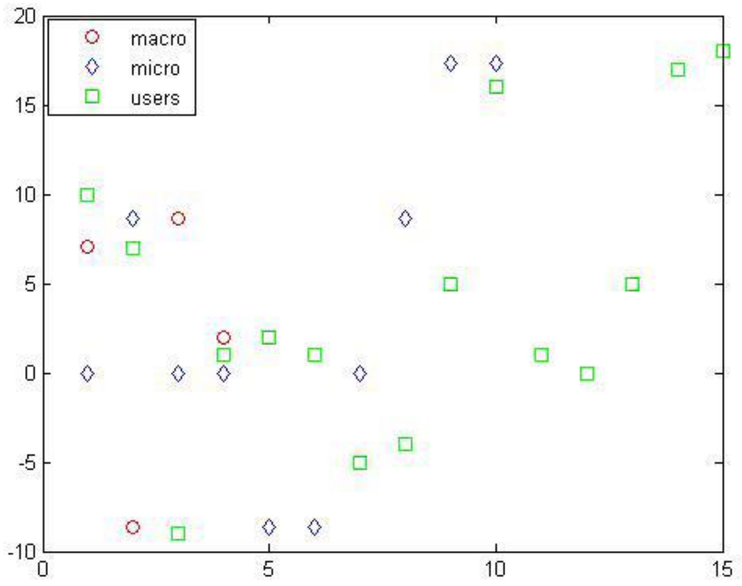

Figure 2 Network Topology

The proposed system modifies the energy efficiency optimization problem by considering the network capacity as a constraint with the transmit power and base station density. The proposed algorithm deploys micro BSs iteratively as shown in Figure 3.

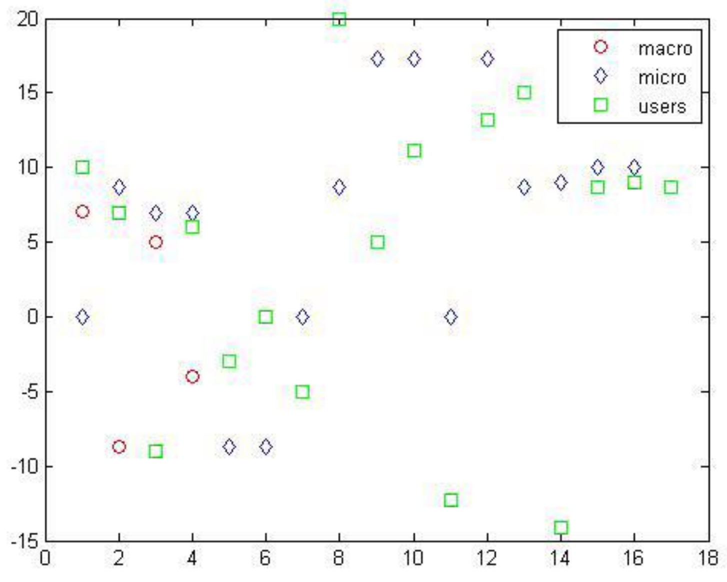

Figure 3 Base Station Deployment

The proposed heuristic method significantly decreases the complexity of the BS deployment problem. As the number of micro BSs increases, it can be observed that the energy efficiency increases monotonically. Through simulation results, it is shown that the proposed algorithm significantly improves the energy efficiency than in the existing system as shown in Figure 4.

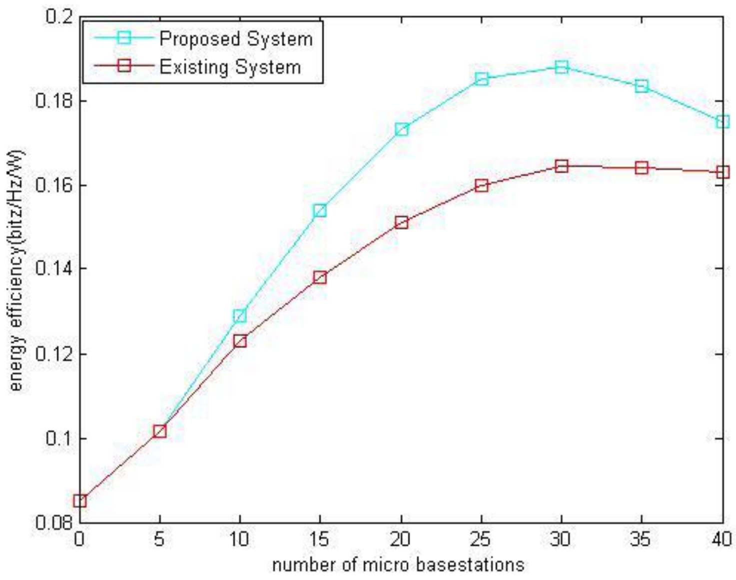

Figure 4 Comparison of Energy Efficiency

IV. CONCLUSION

This paper presents the energy efficiency analysis for two tier heterogeneous cellular networks. Optimal configuration for energy efficiency is formulated by optimizing power and density for both micro and macro base stations. Existing system doesn't consider capacity as a constraint. Here, in the proposed system, energy efficiency is improved by a greedy base station deployment framework for HetNets. Through simulation results it is clear that the proposed method maximizes the energy efficiency of the network.

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