Resource Allocation and User Associations in Dense Heterogeneous Wireless Networks

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Abstract

The proliferation of novel network access devices and demand for high quality of service by the end users are proving to be insufficient for existing wireless cellular networks. These bandwidth hungry access devices and novel applications are straining the network capacity. Heterogeneous access networks are a promising solution for solving this network capacity issues. This motivates a very dense small cell network. To this end, solving user association and resource allocation will be very challenging. Therefore, we formulate the resource allocation and user association problem as an optimization problem and present a scheme which solves the resource allocation and user association in a dense settings. Simulation results reveal the convergence of our proposal in terms of rate, interference protection and we provide comparison with the currently deployed received signal strength indicator association scheme.

I. Introduction

The explosion of cellular devices and bandwidth hungry modern applications over the cellular network has raised the cellular network requirement. The existing cellular system in order to provide this high data rate requirement installs low power small cells along the currently deployed macro cell. This paradigm also known as Heterogeneous Network (HetNets) is the dominating and promising approach used by the network operators to meet the Quality of Service (QoS) for end users. However, this installation of SC poses some new challenges which needs to be handled in order to maximize the benefit of deploying the SCs in the network.

In dense setting Hetnets user association and resource allocation will play a vital role and are considered as one of the biggest challenge [1]. First we discuss the user association problem in which users receiveing multiple signals for associating to different base-stations (BSs) from different tiers (i.e., macro/pico/femto) as shown in figure 1. It is well known that associating to a heavily loaded tier can cause degradation in the performance and wastage of resources (for lightly loaded tier) from network point of view. Therefore, associating to the optimal tier among the available can significantly improve the overall network utility. In current practice, user are associated based on the received signal strength indicator (RSSI) values from base stations (BS) only which may result in associating to an overloaded BSs. We therefore, We

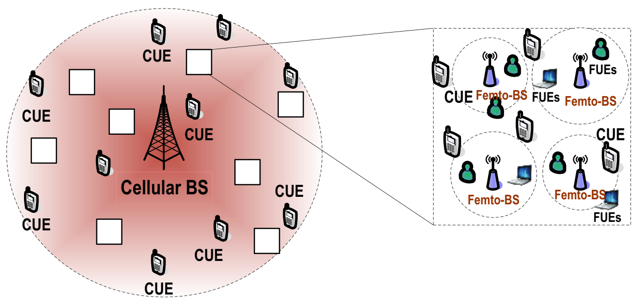

Fig.1. System model

propose a user association scheme in which a user is associated to a cell tier depending on the highest achievable data rate thus maximizing the user throughput and network throughput. The second problem is the interference problem which also can create significant degradation if not handled efficiently. In fact, enabling small cell communication poses significant challenges pertaining to the interference management because of reuse of resources as shown in figure 1[2].

In this paper we address the downlink user association and resource allocation problem for HetNets from an optimization prospective. Our aim is to maximize the utility for the complete network. User equipment (UE) will be associated to the respective macro base station (MBS) or any small cell base station (SC-BS) depending upon the highest achievable data rate instead of currently practiced RSSI values. After users are associated we do the resource allocation. This will give an opportunity to every user to maximize its data rate and will also maximize the overall network throughput without interference.

The rest of the paper is organized as follows: Section II presents the network model and formulation of our problem and Section III presents our solution. Numerical results are illustrated in section IV. Finally, we conclude our work in section V.

II. System model and Optimization Problem

We consider a downlink two-tier heterogeneous network with a MBS, a set P of femto BS (FBS) which belong to set J of BSs (macro and small cell), and K is the set of users randomly placed in the cell. We consider C which represents a set of channels available for communication between the UEs and the BSs. We in this work, suppose slowly changing transmit power (fixed power) from all the BSs during a timeslot. This problem is a combinatorial and intractable and a number of suboptimal solutions are presented in the literature to solve this problem [3].

Let r_{kj}^{c} denote the data rate of user *k* connected to base station *j* on channel *c*. Similarly γ_{kj}^{c} represent the received SINR of channel *c* for user *k* connected to BS *j* and is given as follows:

$$\gamma_{kj}^{c} = \frac{P_j^c g_{k,j}^c}{\sum_{j' \in J \setminus j} P_{j'}^c g_{k,j'}^c + \sigma^2}, \quad (1)$$

$$r_{kj}^{c} = W\log(1+\gamma_{kj}^{c}) \quad (2)$$

Where *W* is the bandwidth available and γ_{kj}^{c} is the received SINR on channel *c* for user *k* connected to base station *j*. Let x_{kj}^{c} be the binary variable to represent the association of user k with base station j. The typical user association optimization problem can be written as:

$$\begin{aligned} \max_{x_{kj}^c}. \quad & \sum_c \sum_k \sum_j x_{kj}^c \log(r_{kj}^c) \\ s.t \quad & \sum_c x_{kj}^c \le 1, \forall k, j, \\ & \sum_j x_{kj}^c \le 1, \forall k, c, \\ & I_k^c \le I_{\max}^c \ , \forall c, \\ & x_{kj}^c \in \{0,1\}, \forall k, \forall c. \end{aligned} \quad (3)$$

Where $I_k^c = x_{k,j}^c P_j^c g_{k,j}^c$.

The first and second constraint guarantees that a user can be associated with one BS, the third constraint is the interference protection constraint. Finally we have the binary allocator. In order to solve this combinatorial problem we use the dual based approach shown in next section.

III. The Resource Allocation Algorithm

In this section we propose a distributed algorithm based on the duality solution to solve the problem P1 based on Duality theory [3].

Algorithm 1: The Resource Allocation Algorithm:

1: Initialization: $t=0,\ \alpha_{kj}^c(0) \ge 0$, step size $\kappa_{kj}^c(0) > 0$

2: Each SBS associates to users which satisfy

$$x_{kj}^c = \begin{cases} 1, & \text{if } c = c^*, k = k^*, \\ 0, & \text{otherwise} \end{cases}$$

$$c^* = \arg\max_c(\log(r_{kj}^c)), \quad k^* = \arg\max_k(\log(r_{kj}^c)),$$

3: Repeat

4: $t \leftarrow t+1$

5: Each SBS reallocates channels to its associated user to guarantee the interference constraint

$$x_{kj}^{c\,(t)} = \begin{cases} 1, & \text{if } c = c^* \\ 0, & \text{otherwise} \end{cases}$$

$$c^* = \arg\max_c(\log(r_{kj}^c) - \alpha_k^{r(t)} P_j^c g_{k,j}^c),$$

$$\alpha_{kj}^{c\,(t+1)} = \alpha_{kj}^{c\,(t)} - \kappa_{kj}^{c\,(t)}(x_{kj}^{c\,(t)} P_j^c g_{kj}^c - I_{\max}^c),$$

6: Until $\alpha_{kj}^{c\,(t+1)} - \alpha_{kj}^{c\,(t)} \le \epsilon$

IV. Numerical Results

In order to validate our proposed scheme we compare our proposal with currently used RSSI scheme for user association and then show the interference achieved on each channel for a fixed interference threshold. The network topology for our simulations contains BSs and UEs which are randomly located inside a square area of 1 km × 1 km with the MBS at the center as shown in figure 2. Furthermore, we consider a total of eight FBSs distributed randomly and have a limited quota per BS, in our simulation we consider the quota of 10 UEs. We assume that the channel experience Rayleigh fading with propagation loss. The transmit power of the MBS and the SCBSs are assumed to be 40dBm and 25dBm, respectively. It is to ne noted that the results presented here are averaged over a large number of independent runs for different locations and channel gains.

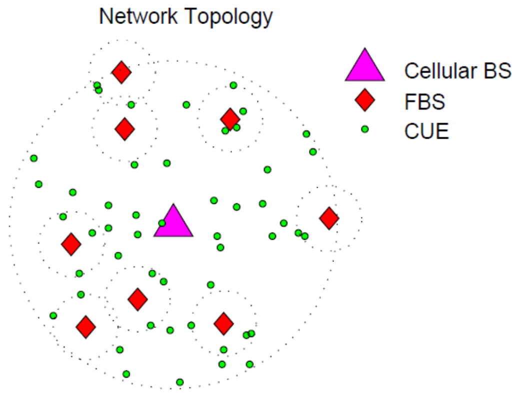

Fig.2. Simulation topology

Figure 3 shows the performance of the proposed scheme when compared to the RSSI in terms of average utility with varying number of users in the system. It can be inferred from the figure that the utility decreases as the number of users increase in the system. This is because of sharing of resources and quota limitation for each BS. Furthermore, it can be observed that a significant gain in average utility per user can be observed when compared to RSSI scheme, i.e. especially when users increase in the system.

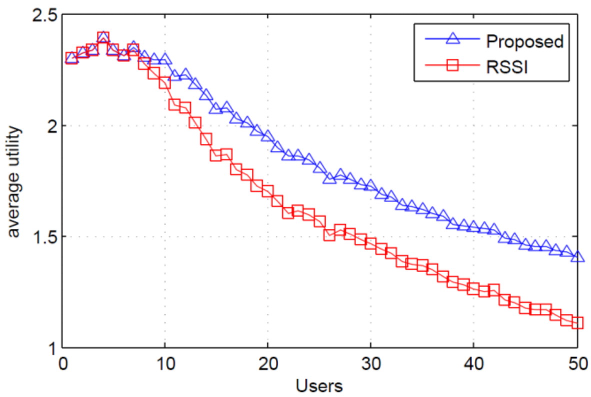

Fig.3. Average Utility per Users

Fig.4 presents cumulative distribution of the interference produced on RBs by FBS transmission by reuse under maximum interference tolerance (i.e. -108dB) threshold scenarios. It can be seen that in all the cases, the interfering power is always less than the predetermined maximum threshold for cellular tier protection.

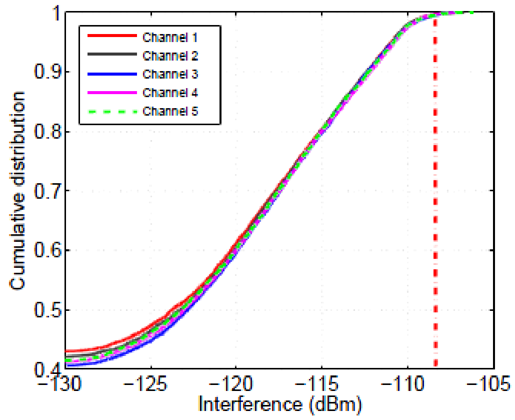

Fig.4. Interference threshold guarantee

V. Conclusions

The deployment of small cells in the current cellular architecture leads to a higher network capacity. We in this work, propose a joint user association and rate control problem for hetnets which is solved using convex optimization techniques under fixed power received from all BSs. Our proposal will allow users to associate to the BS which will allow the maximum throughput for the user and providing interference guarantees over all resources. Simulation results reveal our preposition. In future, we intend to keep variable power levels for different BSs.

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