SSR Improvement in OFDMA Femtocell Networks

Sandhya Y. A.
M.Tech Student, KU
Mar Baselios College of Engineering and Technology, Trivandrum-695 015, India
Sandhyaya91@gmail.com

Abstract: **To enhance indoor coverage and capacity of fourth generation cellular networks femtocells are introduced. These are the small cellular base station installed in a home or buildings. Femtocells are deployed in the existing macrocell networks. Both uses same frequency band. Since both femtocell and macrocell uses same frequency band there is a problem of interference between the femtocell and macrocell, which reduces the performance of these networks. Therefore it is necessary to allocate resources to them in such a way that interference is mitigated. In order to improve the performance a distributed Resource allocation using link state propagation algorithm is proposed. Which allocate OFDMA resources to all femtocell in the network. This method gives better Spectral Spatial Reuse (SSR) than the existing methods.**

Key words- **Femtocells, orthogonal frequencydivision multiple access (OFDMA),Spectral Spatial Reuse(SSR), resource allocation.**

I. INTRODUCTION

Wireless cellular technologies are continuously evolving to meet the increasing demands for high data rate mobile services. In order to meet the forecasted growth of cellular subscribers and the need for faster and more reliable data services, orthogonal frequency division multiple access (OFDMA) has been selected as the multiple access scheme for state-of-the-art wireless systems such as LTE and WiMAX. Orthogonal frequency division multiplexing (OFDM) is based on dividing the transmitted bitstream into multiple substreams and sending these over different orthogonal subcarriers. In OFDM, the data rate achieved on each subcarrier is considerably less than the total data rate. In addition, the bandwidth occupied by each subcarrier is much less than the total system bandwidth. The number of subcarriers is selected such that each subcarrier has a bandwidth less than the coherence bandwidth of the channel, in order for the subcarriers to experience relatively flat fading. This allows OFDM to efficiently resist to the effects of frequency selective fading, since the rate and power can be adjusted on each subcarrier individually. It should be noted that the subcarriers in OFDM are not required to be contiguous. Thus, a large continuous block of spectrum is not needed for high rate multicarrier communications, and several contiguous blocks of smaller size can be used instead. This provides flexibility in spectrum allocation and spectrum management.

But in these networks the indoor coverage is very poor. In order to improve the indoor coverage and SSR of these networks femtocells [1] are introduced. Femtocells are small cells that help to share traffic loads from macrocells and improve the coverage and capacity of network in modern cellular networks. In this architecture, two tier network is formed in which the first tier is macrocells and the second tier consists of femtocells. Femtocells are used to provide connectivity where broadband wired networks are locally available. Connecting users to femtocells can reduce the load of macrocells up to about 70-80% [2]. The economic aspect is also very important to use femtocells because energy consumption is reduced for service clients and the coverage of network is also improved.

II. RELATED WORK

Resource allocation in wireless mesh and ad-hoc networks has been widely studied [5], [6]. The nodes in the network are assigned channels, and the number of channels assigned depends on the number of radios in a node. Two nodes are assigned the same channel if they want to communicate with each other. This is different from resource allocation in femtocells, where there is no data transfer between femtocells and a femtocell can be assigned as many AUs as possible. Autonomous component carrier selection (ACCS) is a fully distributed, scalable and robust interference management scheme, where each cell selects the most attractive frequency configuration [7]. The authors in [8] study two classes of interference management techniques: semi-static interference management, where neighboring interfering cells coordinate resources over 100s of ms, and fast dynamic interference management, where resource coordination is done in the order of ms. Fractional Frequency Reuse (FFR) mitigates interference by assigning different portions of the frequency to neighboring cell edge users. A graph-based framework for dynamic FFR in multicell OFDMA networks is described in [9]. A survey on the different resource allocation and interference management techniques is given in [10]. Some of the interference management approaches, like femto-aware spectrum management, and beam subset selection strategy, only deal with cross-tier interference, whereas clustering of femtocells, and fractional frequency reuse (FFR) mitigate both cross-tier and intra-tier interference. The paper compares the different schemes on different parameters like complexity, efficiency, and access mode, and proposes that FFR is the best approach with low complexity and high efficiency.

III. SYSTEM MODEL

Consider a macro cell embedded with several femtocells. All the base stations (BSs) use OFDMA technology where the whole frame is divided into time-frequency slots called AUs. The macro and femto BSs have no direct coordination using the wireless medium. Denote the set of femto base stations by *B* and the set of users by *U*. Assume that the users are uniformly distributed within the femtocells and a user is associated with one femto base station. Thus $B(j) = i$ denotes user j is associated with base station i. Assume every femtocell BS has an unique Identifier and the Identifiers can be sorted in some order. The location of the FAPs is not fixed and can change from time to time when the consumer moves the FAP to a different location. The number of UEs associated with a FAP and their QoS requirements can also change; however, the number of UEs associated with a FAP is restricted to a maximum.

III. PROPOSAL:RESOURCE ALLOCATION USING LINK STATE PROPAGATION

RALP is a framework where AUs are allocated to FAPs in a distributed manner, but each femtocell constructs a global view of the network. We represent the femtocells under a macrocell as a graph, where the femtocells form the nodes of the graph, and edges denote connections between the femtocells. If two nodes share an edge, that means they interfere with each other and cannot be assigned the same AU. The graph may have several connected components. Each node then assigns AUs to itself and other nodes so that interfering nodes are not assigned the same AUs. As each node executes the same algorithm that depends on the unique identifiers, the output of each node will be the same and there will not be any conflicts.

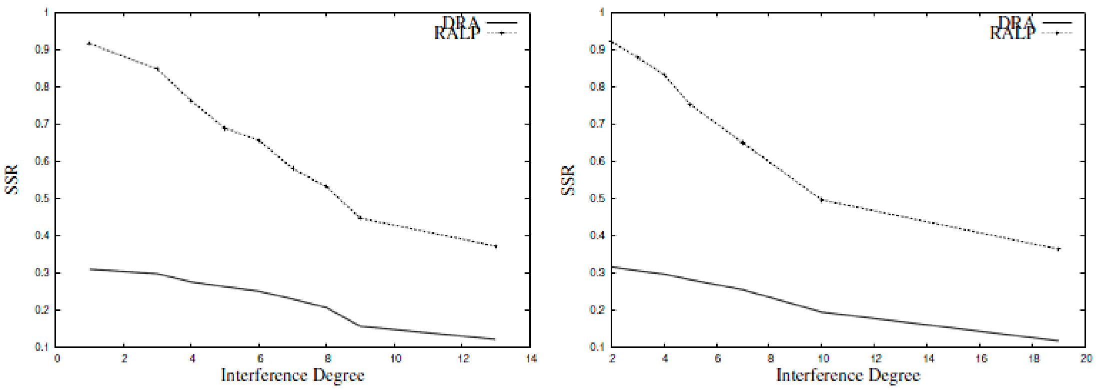
The goals of this algorithm are:

• Assign AUs to femtocells such that interfering femtocells are not assigned the same AU.
• adapt to changes in channel conditions, femtocell additions and removals.
• try to maximize spatial reuse max_*i*,*a* *Xi*,*a* where *Xi*,*a* indicates whether AU *a* is assigned to femtocell *i*.
• try to ensure some amount of fairness in the resources allocated to the femtocells.
• deal with the unreliable nature of wireless networks.

RALP consists of two stages - graph construction stage, and allocation stage. These two stages are described below.

1) Graph Formation Stage: Each UE associated with a FAP senses the wireless medium and finds out the interfering FAPs. This information is conveyed to the serving FAP of the UE. Thus, a FAP gets information from its neighbors in this manner. A FAP broadcasts its own ID and its view of the network at regular intervals. The broadcast message includes information about other FAP IDs, and the distance between this FAP and the other FAP (for example, whether the other FAP is a immediate neighbor, or 2-hop neighbor and so on). This is similar to ”Link State Advertisements” in link state protocol. UEs act as relays and distribute this information across different femtocells. Thus, after some time, all the FAPs get the complete neighborhood information and can build the network graph.

2) Allocation Phase: The goal of the allocation stage is to assign AUs to femtocells such that the same AU is not assigned to interfering femtocells and two non-interfering femtocells can use the same AU. After every FAP builds the graph, it executes the allocation algorithm independently as each FAP has the complete view of the connected component of the graph it belongs to. If an algorithm only tries to maximize spatial reuse, it might assign the AUs to only some nodes, and starve other nodes. The goal of RALP is to maximize throughput while ensuring some degree of fairness. One way to do this is to use proportionally fair scheduling algorithm. However, as the AUs can have different rates depending on which UE the AUs are assigned to, and as the AUs are assigned to specific UEs,by the femtocell’s local scheduler, we assume all AUs have the least possible rate in this phase of the algorithm. At each AU allocation step *i*, that is, when AU *i* is being allocated, the scheduler looks at the FAP with the minimum assigned number of AUs and then allocates AU *i* to this FAP. The algorithm then considers all the other FAPs and checks whether this AU can be assigned to these other FAPs. The allocation algorithm loops through all the AUs and all the FAPs; hence, the time complexity is $O(NT)$, where N is the number of FAPs, and T is the number of AUs.



(a) Network size = 50 FAPs (b) Network size = 200 FAPs

Figure 1. SSR v/s Interference Degree

V. NUMERICAL ANALYSIS

For evaluating the algorithm, use the simulation framework similar to what is described in [4]. Consider an OFDMA frame with 100 AUs (time-frequency slots). Consider two network sizes with 50 and 200 femtocells, which are representative of small and large networks respectively. The femtocells are distributed in a rectangular area of 400m by 400m, with each femtocell randomly placed in a 10m by 10m grid. Users are uniformly distributed throughout the rectangular grid, with a maximum of 4 users attached to one femtocell. The user generates traffic demands, which is translated into a number of AUs varying from 0 to 25. Assume all the AUs have the same rates for all the FAPs in our simulations. Model the path loss based on Winner II channel model [12]. The algorithm is compared with the DRA algorithm proposed in [3] and the FCRA algorithm proposed in [4]. The Spectrum Spatial Reuse (SSR) suggested in [4] is used to compare the different algorithms. The parameter is described below.

Spectrum Spatial Reuse (SSR)

Spectrum Spatial Reuse (SSR) denotes the average portion of femtocells using the same AU within the network.

$$SSR = \frac{1}{T|F|} \sum_{i} \sum_{F_a \in F} X_a(i)$$

In the above expressions, *Fa* denotes FAP *a* and *F* is the set of all FAPs, *Ra* is the number of AUs requested by *Fa*, *Xa*(*i*) is an indicator variable denoting whether AU *i* is assigned to FAP *a* and *T* is the number of AUs in the frame. Assume that all AUs can be indexed by a single variable *i*.

Figure 1 shows the results for spectrum spatial reuse (SSR) for small sized and large sized networks. The results for DRA and RALP are shown. RALP performs much better than DRA in all the cases. As it expect, SSR decreases with increasing interference degree in both the cases. The decrease in SSR is much more gradual in DRA than in RALP. In both kinds of networks the SSR for RALP is about 0.9 for small interference degree of 1 or 2 and the SSR falls to 0.4 for larger interference degree. For DRA, the SSR is about 0.3 for small interference degree and then decreases to 0.1 for large interference degree. The results for RALP are as expected, as RALP tries to allocate all the AUs to a femtocell as long as it is not assigned to any interfering femtocell. Thus, the spatial reuse is very good if the interference degree is small.

VI. CONCLUSION

In this paper, resource allocation problem in OFDMA-based femtocell networks is studied. Resource Allocation using Link State Propagation (RALP) algorithm for allocating OFDMA AUs to femtocells is proposed. Algorithm is evaluated by comparing with the existing femtocell resource allocation algorithms, DRA. The simulation shows RALP performs better than DRA with respect to spectrum spatial reuse. One possible improvement in spatial reuse is to use same AUs in the cell center UEs in all the femtocells.

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