A Self-Organized Resource Allocation Scheme for Heterogeneous Macro-Femto Networks

Abstract—**This paper investigates the Radio Resource Management (RRM) issues in a heterogeneous macro-femto network. The objective of femto deployment is to improve coverage, capacity and experienced Quality of Service of indoor users. The location and density of user-deployed femtos is not known *a-priori*. This makes interference management crucial. In particular, with co-channel allocation (to improve resource utilization efficiency), RRM becomes involved due to both cross-layer and co-layer interference. In this paper, we give an overview of the significant resource allocation strategies available in the literature for heterogeneous macro-femto network. Then, we propose a Self-Organized Resource Allocation (SO-RA) scheme for an Orthogonal Frequency Division Multiple Access based macro-femto network, to mitigate co-layer interference in the downlink transmission. We compare its performance with the existing schemes like Reuse-1, Adaptive Frequency Reuse (AFR) and *AFR with power control (one of our proposed modification to AFR approach)* in terms of 10 percentile user throughput and fairness to femto users. The performance of AFR with power control scheme matches closely with Reuse-1, while the SO-RA scheme achieves improved throughput and fairness performance. It also ensures minimum throughput guarantee to all femto users and exhibits better performance than the existing state of the art resource allocation schemes.**

Index Terms—**o-layer interference; femtocell; macrocell; OFDMA; resource allocation.o-layer interference; femtocell; macrocell; OFDMA; resource allocation.C**

I. Introduction

With the rapid increase in varied wireless applications and the advent of smart-phones, Personal Digital Assistants (PDAs), etc., there is a tremendous proliferation in *indoor* voice and data traffic. It is envisaged that in future, about 50% of voice traffic and 70% of data traffic will originate from indoor wireless users [1]. However, there are large penetration losses and attenuation indoors, due to which the indoor users often suffer from Quality of Service (QoS) degradation [1]. To meet the high data rate requirement, efficient mechanisms for resource allocation and interference mitigation indoors are needed. Femto Base Station (BS) deployment is one such mechanism to meet these objectives. It is a short-range, user-deployed, low-power node operating in the licensed spectrum. It connects mobile devices to a cellular operator's network using residential Digital Subscriber Lines/wired broadband connections [2]. The purpose of femto deployment is to improve capacity (by achieving higher rates due to the proximity to indoor users and increasing reuse of resources) and coverage (by covering the dead zones formed due to insufficient macro signal penetration) in the indoor environment. Due to power-efficient transmission, femtocell network improves battery life and contributes to greener communication. Moreover, femto offloads indoor traffic from the macrocell, which increases capacity of macro BS and reduces CAPital EXpenditure (CAPEX) and OPerational EXpenditure (OPEX) of network operator. Thus, macro-femto networks are beneficial to both operator and subscribers.

Femtocell network is an overlay deployment (Figure 1) by the indoor users and resource allocation is done independently by macro and femto BSs. This makes Radio Resource Management (RRM) in a macro-femto network challenging. As macrocells and femtocells share the available radio resources, it may cause *cross-layer interference* (between femtocell and macrocell) and *co-layer interference* (between neighboring femtocells) [3]. Ideally, orthogonal resource allocation alleviates cross-layer interference, but results in poor resource utilization efficiency. Therefore, co-channel allocation is preferred. Various cross-layer interference reduction schemes are available in the literature [4], [5], [6]. However, limited literature is available to address the problem of co-layer interference. In [7] and [8], authors have proposed schemes which begins with an orthogonal allocation amongst the co-layer femtocells. Then, they apply different variants of adaptive reuse schemes to increase resource utilization efficiency based on either power control or coordination between neighboring femto BSs.

***In general, cross-layer interference mitigation has been addressed sufficiently well in the literature. Therefore, we assume in this paper that the cross-layer interference is mitigated by using one of the well illustrated schemes [9] and focus on co-layer interference mitigation only.* However, our proposed Self-Organized Resource Allocation (SO-RA) scheme reduces cross-layer interference in implicit manner (Section III-B). Reviewing the different schemes available in the literature (Section II), it is realized that coordination between neighboring femto BSs is essential, to adapt**

the resource allocation strategy intelligently (according to the changes in interference levels). With this motivation, we propose a SO-RA scheme for heterogeneous macro-femto network, which mitigates co-layer interference. The distinct feature of our scheme is that in addition to reduced co-layer interference, it ensures fairness and improves 10 percentile throughput performance for femto users. It is to be noted that although we illustrate our proposed scheme in the framework of an Orthogonal Frequency Division Multiple Access (OFDMA)-based Long Term Evolution (LTE) network, it is applicable to any cellular system in general. Also, our proposed scheme provides a generalized framework of self-organized resource allocation, which can be applied to any small-cell network. The only distinction would be the interface used to exchange information between the small cells.

The outline of this paper is as follows: Section II discusses few significant approaches available in the literature for interference management in macro-femto networks. Section III explains the system model and describes our proposed SO-RA scheme. *In addition, we also illustrate one variant of AFR scheme which is our proposed modification to AFR approach.* Section IV discusses the simulation results and inferences. Finally, we conclude in Section V.

II. Related Work

An overview of interference analysis and resource allocation approaches in a macro-femto network is given in [3]. The fundamental trade-off in achieving interference management in macro-femto networks is to ensure two things: 1) interference due to femto BS does not severely affect Macro User Equipments (MUEs) and neighboring femto UEs (FUEs) and 2) the transmit power of femto BS must be sufficiently high to ensure that the rate requirement of FUEs are met.

A centralized approach is one of the ways to achieve this trade-off. In this approach, a centralized controller uses information from femto BSs and FUEs to mitigate cross and co-layer interference. However, due to the random variations in topology and large number of femto BSs, centralized approach may not be scalable. Another approach could be coordination-based, where intelligent decisions for resource allocation and interference mitigation are based on information exchange between macro and femto BSs. We briefly review such coordination-based approaches available in the literature for interference management.

- *Resource Partitioning based methods*:
  In [10], [9], [11], authors suggest Fractional Frequency Reuse (FFR) for OFDMA-based macro-femto network. They deploy hybrid spectrum allocation where orthogonal allocation is deployed for inner femtocells (located close to macro BS) and shared allocation for the outer femtocells (located away from macro BS). These schemes ensure cross layer interference mitigation to the FUEs located near macro BS. Dynamic resource partitioning for cross-layer interference avoidance is proposed in [6], where femto BSs are denied access (via wired backhaul) to those resources that are assigned to nearby macro UEs. In [12], authors propose a low complexity randomized interference avoidance method for femtocells. Each femtocell is allocated a random subset of resources considering the fact that neighboring femtocells are unlikely to consistently use identical resources. In [13], location based resource management algorithm is proposed which allows femtocell to reuse macrocell resources to increase spatial reuse. Authors provide a hashing scheme based resource allocation for femtocells which does not require coordination. In [7], [8], [14], [15] coordination based co-layer interference avoidance and Adaptive Frequency Reuse (AFR) algorithms are proposed. It begins with orthogonal resource allocation to femtocells and then, coordination-based resource reuse is deployed to improve spectrum efficiency. The coordination between femtocells ensures that co-layer interference remains below the acceptable level. Due to the initial orthogonal allocation, such schemes suffer from poor resource utilization in the initial phase of algorithm.
- *Transmit Power Control based methods*:
  In [16] and [17], a power control method is suggested to achieve constant femto BS coverage while ensuring no adverse impact on the macrocell throughput. In [18], a reward (signal to interference ratio) and penalty (interference) based objective function is formulated for femto BSs in which the interfering femto BSs reduce their transmit power to mitigate cross-layer interference. Similar adaptive power control algorithms to mitigate cross-layer interference are discussed in [4] and [5]. In [19], two joint power control and resource allocation schemes are discussed, one is centralized while other is a coordination-based distributed scheme.
- *Cognition based methods*
  Femtocells may determine interference pattern and resource utilization of network cognitively [20]. Authors consider femto BSs as secondary users, determine the available channels cognitively and design autonomous algorithms for cross-layer interference management. The benefits of cognitive approach depend on the spectrum occupancy of primary macrocell UEs.
- *Self-organized and Learning based methods*
  In [21], we have proposed a self-organized resource allocation algorithm to mitigate inter-cell interference in a macro-relay network. Focussing on macro-femto network in [22], resource allocation algorithm to avoid co-layer interference is executed at the backhaul after each femtocell identifies its neighboring

femtocells. Authors in [23] propose sensing and tuning phase to minimize interference and maximize the system performance. One method is based on information exchange between femtocells and other, on measurement reports from users. Both schemes give improved performance compared to random allocation policy. Authors describe a self optimization framework to jointly optimize spectrum assignment and transmission power in [24] and Q-Learning based distributed interference control scheme for self-organized femtocell network in [25] to mitigate cross-layer interference.

In this paper, we propose a scheme which mitigates co-layer interference, while improving the minimum rate (10 percentile throughput) achieved by FUEs and ensuring fairness to them. This issue of improved minimum rate achieved by FUEs and fairness along with interference mitigation has not been addressed in the literature to the best of our knowledge.

III. System Model and Proposed Self-Organized Resource Allocation Scheme

A. System Model

We consider the downlink transmission scenario in an OFDMA-based macro-femto network. Our system model consists of seven macrocells with macro BS located at the center of each macrocell. L femtocells are overlaid in the central macrocell (Figure 2). In an OFDMA-based LTE network [26], the system resources are divided along frequency (sub-carriers) and time slots. These resources are scheduled in units of Physical Resource Blocks (PRBs). Each PRB (bandwidth = 180 kHz) consists of 12 sub-carriers. We assume that N PRBs are available for both macrocells and femtocells. To compute SINR, we use the path loss models for these links: between FUE and femto BS when FUE is in the same/different apartment as femto BS, and between FUE and macro BS when FUE is inside the apartment as specified in [27].

B. Proposed Self-Organized Resource Allocation (SO-RA) Scheme

There is an inevitable trade-off between aggressive resource reuse and co-layer interference. Our proposed self-organized resource allocation scheme meets this trade-off by coordination between femtocells. It is a two-step algorithm to reduce co-layer interference between femtocells, while ensuring rate requirement satisfaction and fairness to FUEs.

In Step-1, interfering neighbor set for each femtocell is identified and Reuse-1 is employed. In Step-2, each femto BS identifies PRB which offers minimum SINR and performs two levels of *a-priori* check to ensure that dropping of that PRB does neither cause any degradation in system performance nor in its own performance. The femto BS drops that identified PRB to reduce co-layer interference. This is done iteratively for all femto BSs. This self-organized resource allocation algorithm mitigates co-layer interference by exchanging information with neighboring femtocells locally and achieves an overall improvement in system performance. Figure 4 gives the flowchart of SO-RA algorithm.

Step-1: Interfering Neighbor Set Discovery and Initial Reuse-1 Allocation

In accordance with the LTE standard [28], *Reference Signal Received Power* measurement is performed by UEs for path loss estimation between UE and BS [26]. Based on these measurements made by FUE, femto BS computes path loss from neighboring femto BSs, which are then compared with specific threshold value PL_{th} to determine whether they may cause interference or not. Thus, each femto BS determines a set of neighboring femto BSs that are likely to cause significant interference to its FUEs. The interfering neighbor set of femto BS l is given by,

$$I_l = \{Femto\,BS_j \mid PL_{j,l} - PL_{l,l} > PL_{th}\}, \quad j = 1, 2...L \tag{1}$$

where, $PL_{j,l}$ is pathloss between FUE l and femto BS j and $PL_{l,l}$ is pathloss between FUE l and femto BS l. Note that same index l is used for femto UE and femto BS because we consider only one femto UE per femtocell. *Note that the underlying assumption in determining threshold value PL_{th} is that only those femtocells present in the vicinity cause co-layer interference.*

After interfering neighbor set discovery, resource allocation is to be done. Most of the existing schemes performs orthogonal allocation initially ([7], [14], [15]). However, this increases the signaling overheads required for coordination in the initial stage, while in SO-RA, employing Reuse-1 eliminates the need of coordination between femto BSs at the initial stage and signaling overhead reduces.

Step-2: Coordinated Resource Drop

In this step, each femto BS identifies and drops the PRB with minimum SINR, such that neither femtocell throughput reduces below the threshold nor the overall system performance deteriorates. We assume that messages required for coordination are exchanged between femto BS and its interfering neighbors via backhaul. The SINR for FUE l on PRB n is given by,

$$SINR_l^n = \frac{P_{Ftx}^{l,n} \cdot PL_{l,l}}{I_{femto} + I_{macro} + N_o} \tag{2}$$

where,

$$I_{femto} = \sum_{j=1, j \neq l}^{||I_l||} P_{Ftx}^{j,n} \cdot PL_{j,l} \cdot x_{j,n} \quad (3)$$

and

$$I_{macro} = \sum_{k=1}^{7} P_{Mtx}^{k,n} \cdot PL'_{k,l} \cdot y_{k,n}. \quad (4)$$

$P_{Ftx}^{j,n}$ and $P_{Mtx}^{k,n}$ denote the transmit power of femto BS j and macro BS k on PRB n respectively. $PL'_{k,l}$ is the pathloss between FUE l and macro BS k. $x_{j,n}$ is a variable indicator that denotes whether PRB n is used by femto BS j or not. Similarly, $y_{k,n}$ indicates whether PRB n is used by macro BS k or not. N_o is additive white Gaussian noise.

To determine which PRB to drop, femto BS l calculates the SINR experienced on all PRBs that are used by its FUEs. Then, it chooses a candidate PRB n on which it experiences minimum SINR. It is likely that minimum SINR is due to high amount of interference on that PRB. If such PRB is dropped, it may reduce the interference caused to the neighboring femtocells, at the cost of reduced serving femtocell throughput. To ensure that this penalty is minimal, we select the PRB with minimum SINR so that its dropping results in minimum rate loss and eventually co-layer interference reduces. However, to ensure that the decision of dropping PRB (taken in coordination with the localized neighborhood) does not adversely affect the global system performance, femto BS l performs two levels of *a-priori* checks before actually dropping that PRB.

1) Level-I *a-priori* Check:
Here, we analyze the impact of dropping PRB n on the performance of serving femtocell l. For femto BS l, the achievable throughput on PRB n is given by,

$$R_l^n = B \cdot \log_2(1 + SINR_l^n) \quad (5)$$

and total throughput of femto BS l is given by,

$$R_l = \sum_{n=1}^{N} B \cdot \log_2(1 + SINR_l^n) \cdot x_{n,l}, \quad (6)$$

where B is the PRB bandwidth.
Femto BS l calculates its new throughput value $R_{l,new}$ assuming that it has dropped PRB n as,

$$R_{l,new} = R_l - R_l^n \quad (7)$$

Further, it compares the new throughput $R_{l,new}$ with the specified threshold $thpt_{th}$. If

$$R_{l,new} < thpt_{th}, \quad (8)$$

then femto BS defers the decision to drop PRB n and algorithm repeats for the next femtocell. Otherwise, when (8) is not satisfied, it implies that Level-I *a-priori* Check results in favor of dropping PRB n. Only then, femto BS l initiates Level-II *a-priori* Check, as discussed next.

2) Level-II *a-priori* Check:
Here, we analyze the impact of dropping PRB n on the performance of neighboring femtocells by coordination. Femto BS l requests all its neighboring femto BSs to report the gain in their individual throughputs assuming femto BS $l \in I_l$ has dropped the PRB n. Each femto BS $m \in I_l$ calculates its new SINR and throughput as follows,

$$SINR_{m,new}^n = \frac{P_{Ftx}^{m,n} \cdot PL_{l,l}}{I_{femto} - P_{Ftx}^{l,n} \cdot PL_{m,l} + I_{macro} + N_o} \quad (9)$$

where,

$$I_{femto} = \sum_{j=1, j \neq m}^{||I_m||} P_{Ftx}^{j,n} \cdot PL_{j,m} \cdot x_{j,n}. \quad (10)$$

$$R_{m,new} = \sum_{n=1}^{N} B \cdot \log_2(1 + SINR_{m,new}^n) \cdot x_{n,l} \quad (11)$$

Then, femto BS m computes gain in throughput as,

$$\Delta R_m = \sum_{m \in I_l} (R_{m,new} - R_m) \quad (12)$$

On receiving ΔR_m from all neighboring femto BSs, femto BS l calculates the total throughput gain of its neighbors as,

$$\Delta R = \sum_{m \in I_l} \Delta R_m \quad (13)$$

To observe the impact of dropping PRB n on the overall system throughput, we compare,

$$R_l^n < \Delta R \quad (14)$$

where R_l^n represents the loss in throughput due to dropping PRB n and ΔR represents the net gain in throughput.
If dropping PRB n at femto BS l results in increasing system throughput (14), femto BS l takes a final decision to drop the PRB n. Otherwise, Step-2 is repeated for the next femto BS.

Level-I check provides minimum throughput guarantee to each Femto cell, while Level-II check allows the femtocell throughput to increase further (above the minimum threshold) to the extent that the neighboring femtocells are not adversely affected.

Step-1 of the algorithm is triggered periodically after a predetermined number of OFDMA frames. This repetition period can be configured based on the system dynamics. Step-2 of the algorithm gets implemented iteratively for each femto BS successively. The algorithm stops when any further dropping of PRB becomes infeasible due to violation of minimum throughput guarantee to the femto BS.

In case any femto BS gets deactivated during Step-2, it will release its PRBs and they will become available for reuse at its neighboring femto BSs immediately. However, Step-2 of our algorithm does not consider re-allocation of resource and therefore, until Step-1 is revoked, resources may remain underutilized. However, due to the periodic repetition of Step-1, underutilization of resources is likely to happen only for a small time duration.

The distinct features of SO-RA scheme are:

- It ensures minimum throughput guarantees to the FUEs by applying Level-I *a-priori* Check.
- In Level-II *a-priori* Check, each femto BS decides to drop PRB by comparing the impact of dropping that PRB on self and neighbors. This distributed decision making, based on localized interaction between neighboring femto BSs makes algorithm self-organized.
- Our algorithm iteratively drops the PRB with minimum SINR such that the throughput requirement of FUEs is ensured and overall gain is not compromised. It also helps in reducing interference to MUEs located either close to femto BS or in the overlapping coverage area. Thus, SO-RA scheme reduces cross-layer interference implicitly.

IV. *Simulation Results*

To evaluate the performance of our proposed schemes, we have performed system level simulations in MATLAB (simulation parameters in Table I). We have carried out performance analysis for the users located in the central cell. For the FUEs, we consider the interference from all seven macro cells and the neighboring femtocells.

We consider dual stripe model for dense urban femtocell deployment where each femtocell block has two stripes of apartments [29]. Each stripe has 2×10 apartments each of size 10m×10m. To ensure sufficient separation between femto BSs from different stripes, there is a 10m wide street in between and a 10 m wide space around the stripe (Figure 3). Each femtocell can have random number of floors F within the range 1 to 10. So each femtocell block has a $40\times$F apartments. Each apartment may not have active femto BS in it. To model this scenario, two ratios are defined: *Deployment Ratio* (β) indicates the fraction of apartments with femto BS and *Active Ratio* (ρ) gives the fraction of active femto BSs.

We assume that each apartment can have at most one active femto BS in it, located at the center of apartment. Both FUEs and MUEs are dropped uniformly in the apartment and macrocell respectively. We assume only one floor per femtocell block, i.e. $F = 1$. We consider only one FUE per femtocell and therefore, use same indices for FUE and femto BS. Also, we assume femto BSs to operate in closed access mode (i.e., only a set of users are allowed association with femto BS). To investigate the impact of increased femtocell density, we consider four femtocell blocks with deployment ratio $\beta = 1$ and active ratio ρ varying from 0.1 to 1. To model the scenario of randomly deployed femtocells, we have done the following. For a given active ratio, simulations are performed for the femtocell blocks located at different locations and the average performance is considered for comparison.

We review the significance of femtocell deployment by comparing the throughput performance of users with and without femtocell deployment in Figure 5. Next, we observe the impact of active ratio on the cell throughput performance of macro and femto cells. We observe from Figure 6 that with an increase in the femto BS density, amount of cross-layer interference caused to macro users increases and therefore, the macrocell throughput decreases. Also, the femtocell throughput decreases significantly because of increased co-layer interference.

Before evaluating the performance of our proposed SO-RA scheme, we illustrate our proposed modification to the existing AFR scheme and we call it Adaptive Frequency Reuse (AFR) with Power Control. The existing AFR scheme [7], [14], [8], [15] achieves coordination based co-layer interference avoidance, where the neighboring femtocells use non-overlapping resources initially. Later, femtocells attempt to reuse the resources by coordinating with neighbors to improve resource utilization efficiency. It is ensured that the co-layer interference does not exceed the tolerable threshold. However, its limitations are: 1) initially, system performance is low due to inefficient resource utilization and 2) reuse of resources at lower power is not considered.

AFR with power control is our proposed modification to the existing AFR scheme. When a femto BS cannot use a particular PRB at full transmit power, it is likely that the same PRB may be used with reduced power level without causing significant interference to its neighboring femtocells. We exploit this concept in *AFR with power control* scheme, which is a two-step interference coordination algorithm. In the first step, resources are shared between interfering femtocells in an orthogonal manner. Then in the second step, reuse of resources is facilitated with power control. When a femto BS is not allowed to use a PRB at full transmit power due to interference concerns, it checks for the feasibility of using the same PRB at half of the transmit power. This feasibility is determined by *a-priori* interference measurement, which may be caused to neighboring femtocells if this PRB was used. If this interference is less than the acceptable threshold, femto BS is allowed to use that PRB at half the transmit power. *Note that the idea behind using half the transmit power is to exploit the possibility of maximizing throughput of femtocells by transmit power variation, which was not explored in the AFR scheme.*

We compare the performance of our proposed SO-RA scheme with Reuse-1, AFR and AFR with power control scheme [7]. Figure 7 compares the cumulative distribution functions of average throughput of FUEs. For better understanding, Table II gives the average and 10 percentile throughput comparison of all four schemes. There is a slight improvement in the average throughput performance of SO-RA scheme compared to all other schemes. It is observed that SO-RA achieves 30% improvement in the 10 percentile throughput performance of FUEs compared to AFR scheme. This happens due to the following reason - in SO-RA scheme, the femto BS experiencing severe interference does not drop PRBs simply if it deteriorates its own performance (ensured by Level-I *a-priori* Check). Rather, SO-RA strategy ensures that the loss in throughput performance of femto BS is lesser than the net gain in throughput performance of neighboring femto BSs. Thus, global system performance improvement in SO-RA scheme is ensured. On the contrary, to increase the system throughput performance, the severely interfered femto BS in AFR scheme may allow neighboring femto BSs to reuse PRBs, thereby increasing co-layer interference. In AFR with power control scheme, reuse efficiency improves at the cost of reduced throughput. However, the average throughput performance of AFR with power control is close to that of AFR without power control, but the 10 percentile throughput performance shows an improvement of about 24% relatively.

Figure 8 shows the impact of increased femtocell density on the 10 percentile throughput of FUEs for different schemes. SO-RA scheme offers the best 10 percentile throughput, even with increased femtocell density. The performance of AFR with power control is close to Reuse-1 with marginal improvement when the femtocell density increases.

Further, we investigate the fairness performance (Figure 9) by using Gini fairness index. It is given by,

$$I = \frac{1}{2L^2\overline{R}} \sum_{l=1}^{L} \sum_{m=1}^{L} |R_l - R_m| \tag{15}$$

where, $\overline{R} = \frac{\sum_{l=1}^{L} R_l}{L}$. Gini fairness index lies between 0 and 1. A scheme is perfectly fair if Gini index is 0 and unfair if 1. We observe that SO-RA scheme outperforms in terms of fairness to FUEs. AFR with power control exhibits similar performance behavior as for the 10 percentile throughput (Figure 8).

Finally, we compare the schemes based on the resource utilization efficiency metric (Table III). We define resource utilization efficiency (η_{ru}) as the ratio of used PRBs to the available PRBs and is given by,

$$\eta_{ru} = \frac{\sum_{j=1}^{F_{num}} PRB_j}{PRB_{tot} \times F_{num}} \tag{16}$$

where, F_{num} gives the count of active femtocells in the network. PRB_j and PRB_{tot} denotes the number of used PRBs in j^{th} femtocell and total number of PRBs available in the system respectively.

The resource utilization efficiency is the lowest for AFR. η_{ru} in AFR with power control scheme is close to Reuse-1. However, an important observation is that only 41.3% of resources are used with full transmit power and remaining 47.7% resources are used at half of the transmit power. In SO-RA scheme, η_{ru} gets almost doubled compared to AFR, with all resources being used at full transmit power.

In a nutshell, our results indicate improved 10 percentile throughput and fairness performance in SO-RA scheme compared to AFR with power control, AFR and Reuse-1 schemes. Thus, SO-RA scheme offers a reasonable trade-off in achieving improved throughput performance of severely affected FUEs, fairness to all FUEs and improved resource utilization efficiency.

V. Conclusions

Femtocell deployment provides capacity and coverage improvement to indoor users. However, intelligent and self-organized resource allocation is required to ensure improved performance with minimal interference and QoS guarantees. In this paper, we have proposed a self-organized resource allocation algorithm which reduces co-layer interference in the DL scenario, while ensuring throughput performance improvement to the severely affected FUEs, improvement in resource utilization and fairness to all FUEs simultaneously. Thus, SO-RA scheme achieves feasible trade-off between 10 percentile throughput, fairness and resource utilization efficiency, compared to other schemes available in the literature. The two levels of *a-priori* check in SO-RA operate in a self-organized manner to ensure that the emphasis is not on the localized performance improvement of an individual femtocell, but on the global system performance improvement.

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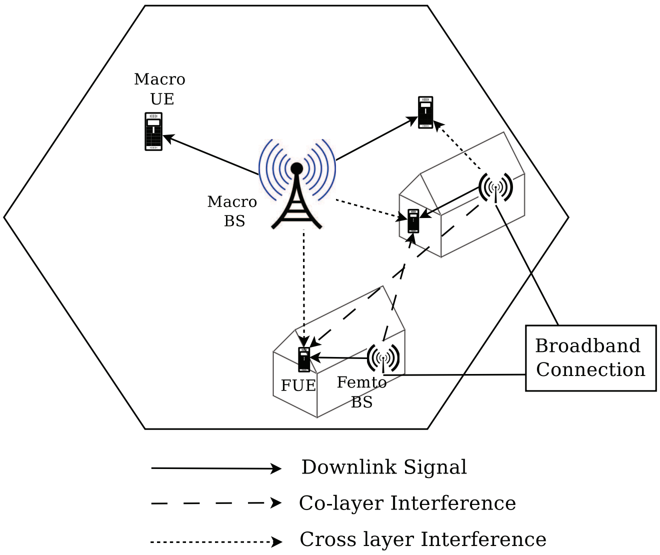

Fig. 1. Femtocell Overlaid on Existing Macro-Cell Network

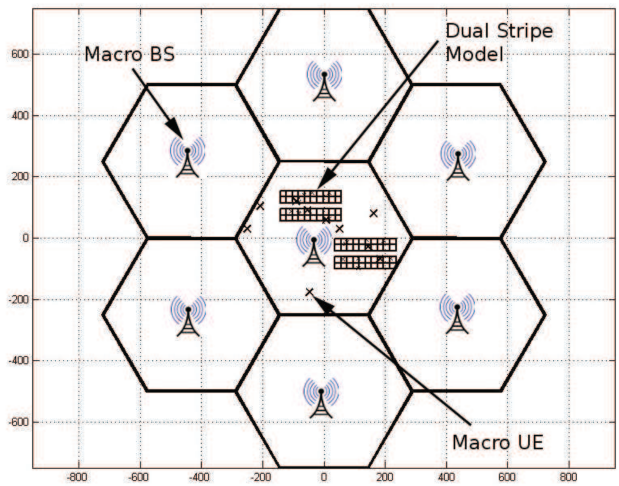

Fig. 2. Network Layout

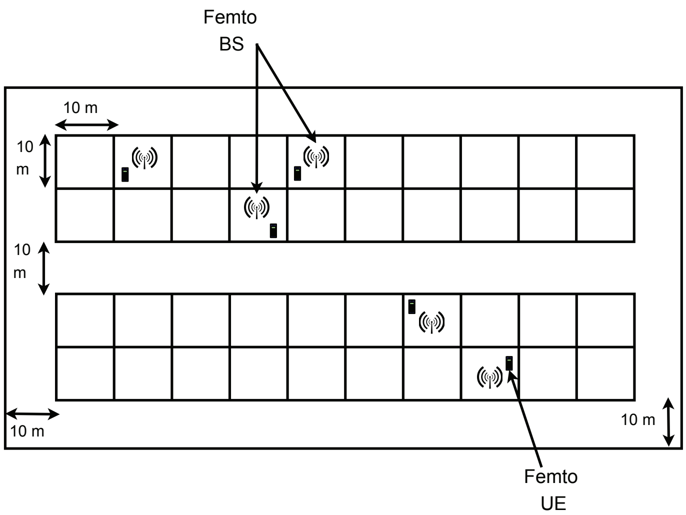

Fig. 3. Dual Stripe Model for Femtocell Deployment

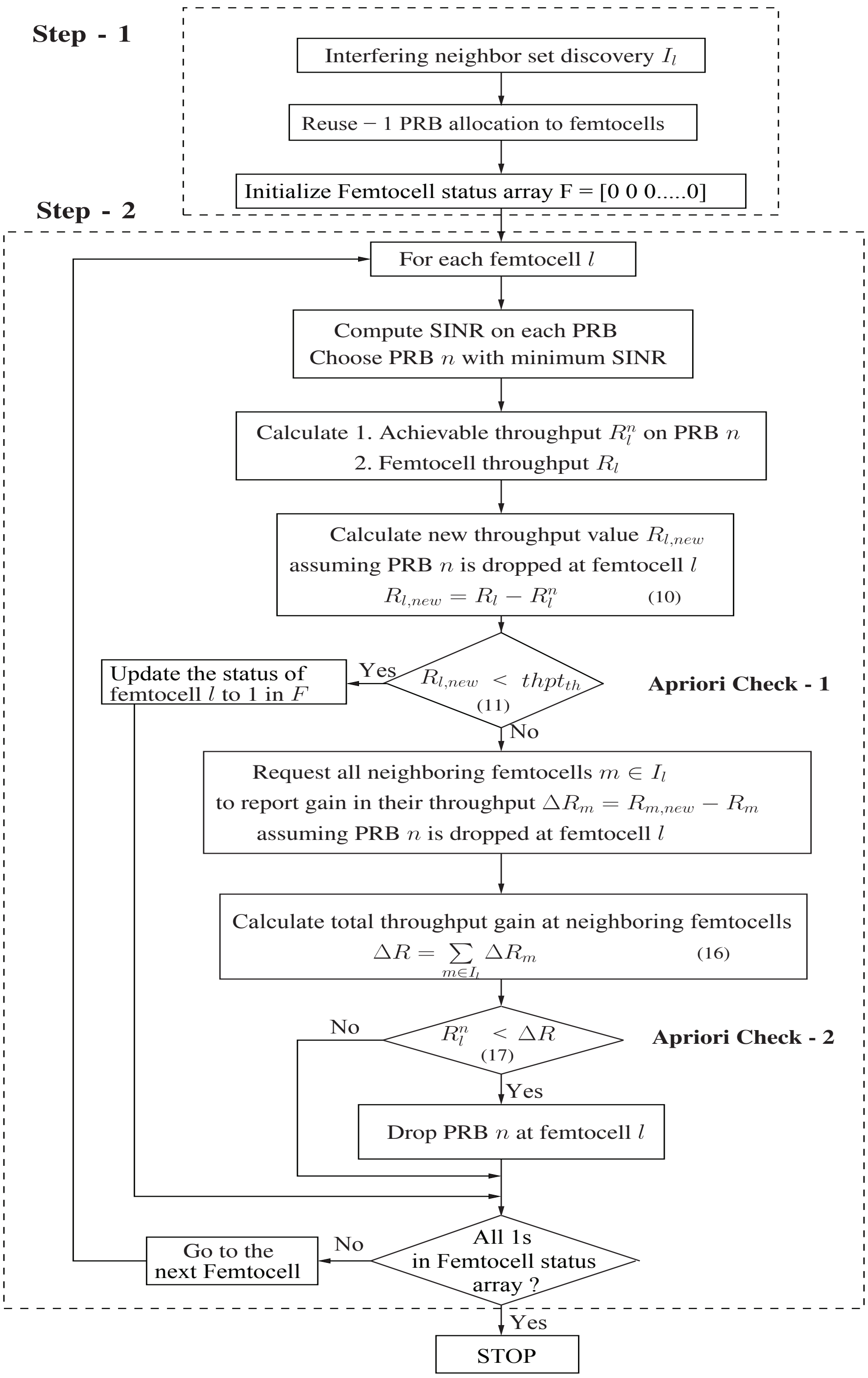

Fig. 4. Self Organized Resource Allocation Algorithm

TABLE I
SIMULATION PARAMETERS

Parameter	*Value*
Inter site distance	500 m
Total bandwidth	10 MHz with 50 PRBs
PRB bandwidth	180 KHz
Macro users per macrocell	10
Number of femtocell blocks	3
Deployment ratio β	0.2
Active ratio ρ	1
Macro BS TX power	46 dBm
Femto BS TX power	20 dBm
Macro BS antenna gain	14 dBi
Femto BS antenna gain	0 dBi
UE noise figure	9 dB
Wall losses L_{ow}, $L_{ow,1}$	20 dB, 5 dB
Pathloss threshold PL_{th}	30 dB
Femto BS throughput threshold $thpt_{th}$	7 Mbps

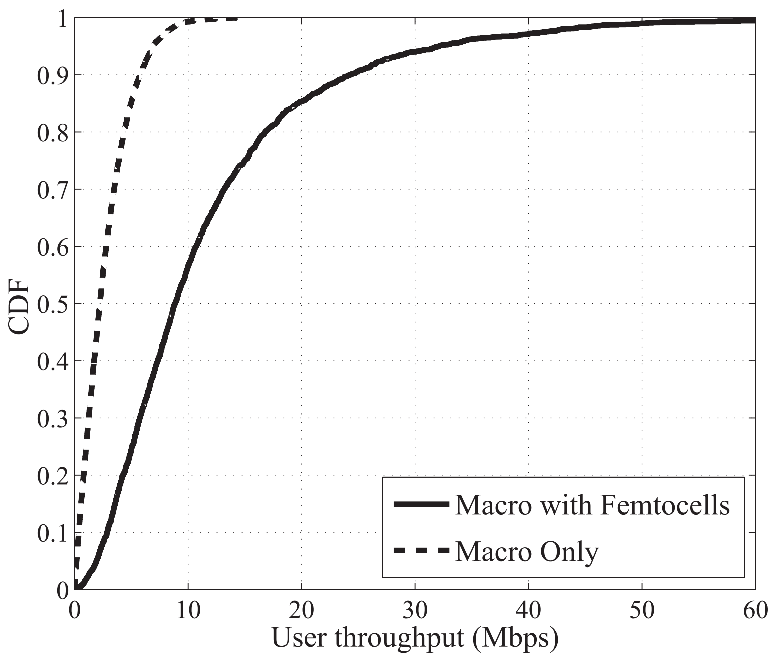

Fig. 5. Performance Comparison - with and without Femtocell

TABLE II
THROUGHPUT COMPARISON OF DIFFERENT SCHEMES

Frequency Allocation Scheme	*FUE Throughput (Mbps)*	
	Avg. Throughput	10 percentile Throughput
Reuse-1	28.83	13.05
AFR	29.57	10.6
Proposed AFR with Power control	29.21	13.18
Proposed SO-RA Scheme	29.92	13.79

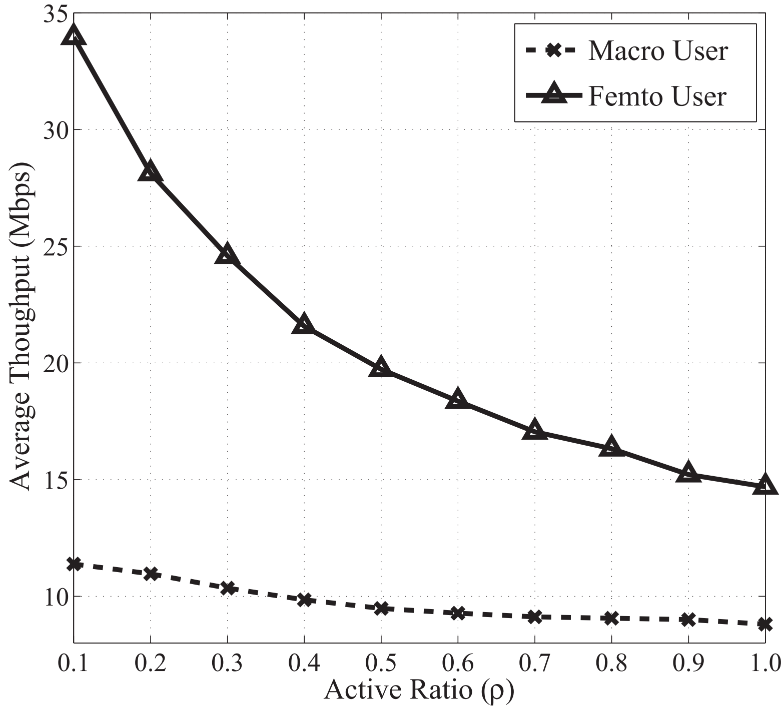

Fig. 6. Impact of Active Ratio on Throughput

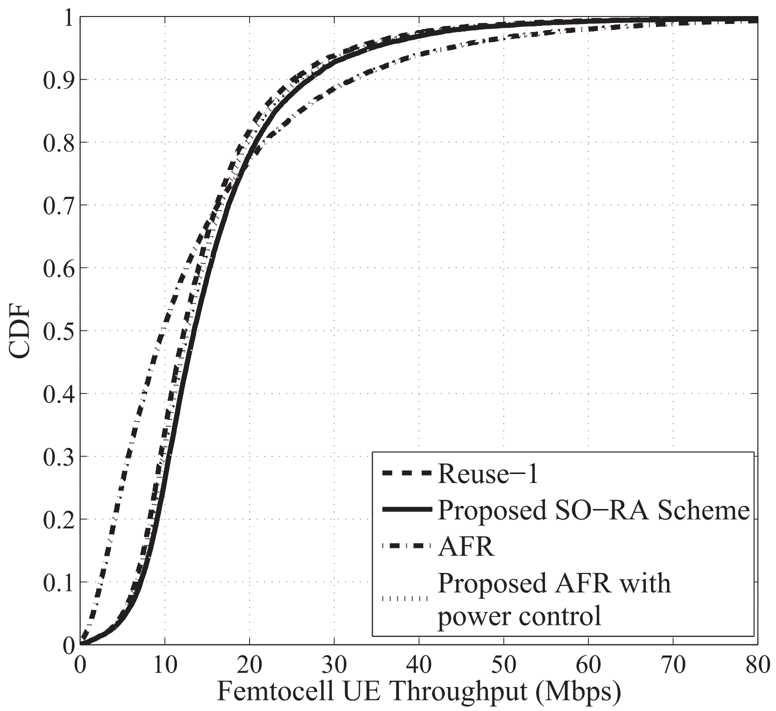

Fig. 7. CDF of Femtocell UE Throughput.

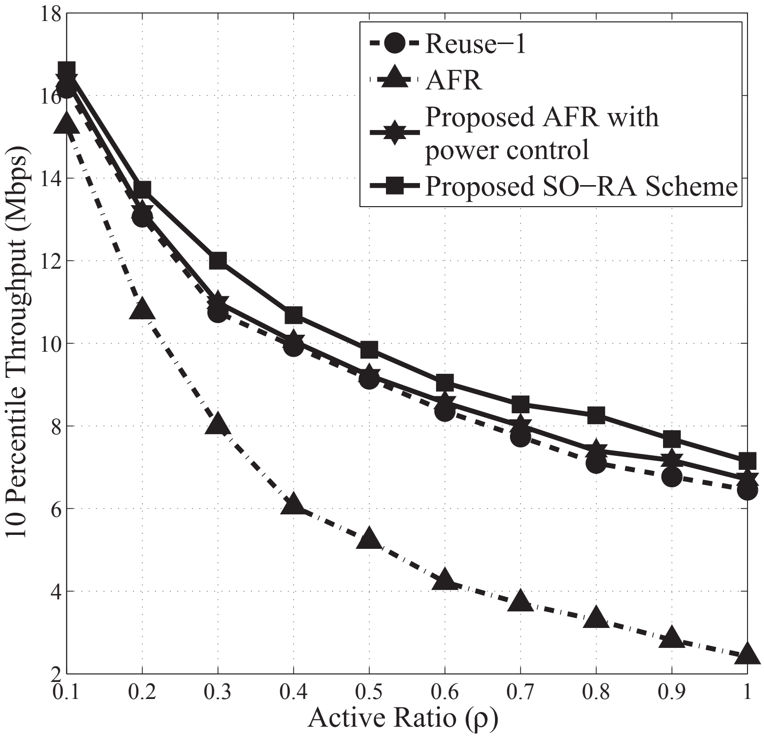

Fig. 8. 10 percentile Throughput Comparison of Different Schemes

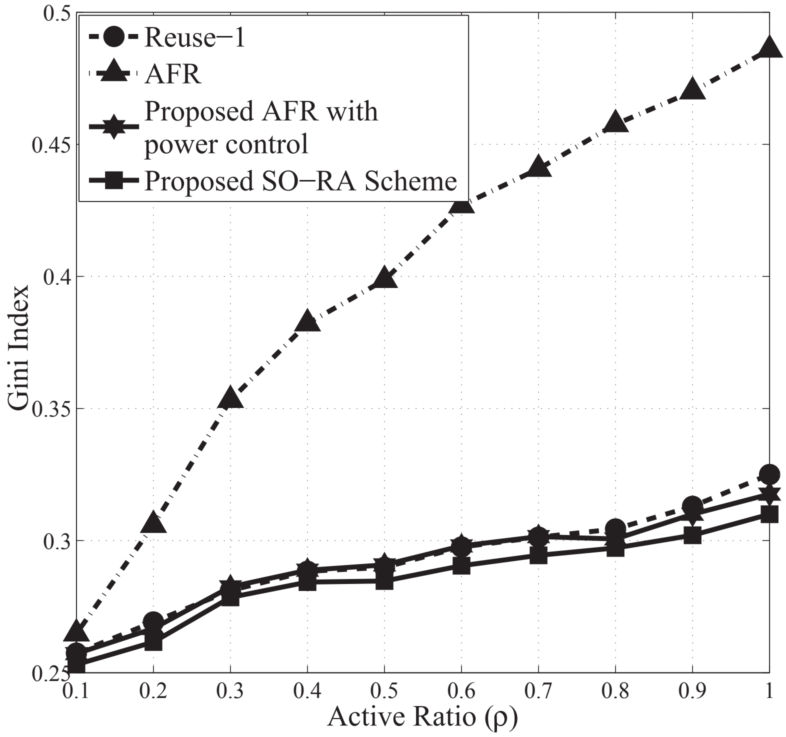

Fig. 9. Comparison of Gini Fairness Index

TABLE III
RESOURCE UTILIZATION EFFICIENCY OF DIFFERENT SCHEMES

Frequency Allocation Scheme	*Resource Utilization Efficiency*
Reuse-1	100%
AFR	41.3%
Proposed AFR with Power control	89% (41.3% resources with full power and 47.7% resources at half power)
Proposed SO-RA Scheme	83.7%