Femtocell Cluster-based Resource Allocation Scheme for OFDMA Networks

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Introduction

- Recently, operators have resorted to femtocell networks in order to enhance indoor coverage and quality of service since macro-antennas fail to reach these objectives. Nevertheless, they are confronted to many challenges to make a success of femtocells deployment.

- In this paper, we address the issue of resources allocation in femtocell networks using OFDMA technology (e.g., WiMAX, LTE)

Objective and Solution

- Our objective is to associate the best spectrum set of frequency/time resources with each FAP in order to deliver the users data, while minimizing the gap between the required and allocated tiles and at the same time minimizing interference between FAPs.
- To achieve this, we formulate the resource allocation as a Min-Max optimization problem and propose a hybrid centralized/distributed scheme, namely FCRA, involving three main phases:

  (i) Cluster formation

  (ii) Cluster-head resource allocation

Literature Review

- In [5], the authors proposed three resource allocation algorithms in OFDMA femtocells. The objective was to avoid interference between femtocells and macrocells in order to maximize the global network throughput.
- The authors in [6] proposed a distributed resource allocation algorithm namely Distributed Random Access (DRA), which is more appropriate for medium-wide networks.
- In [4], the authors proposed a fully distributed and scalable algorithm for interference management in LTE-Advanced environments.
- In [7], the authors propose a decentralized F-ALOHA spectrum allocation strategy for two-tier cellular networks.

Network Model

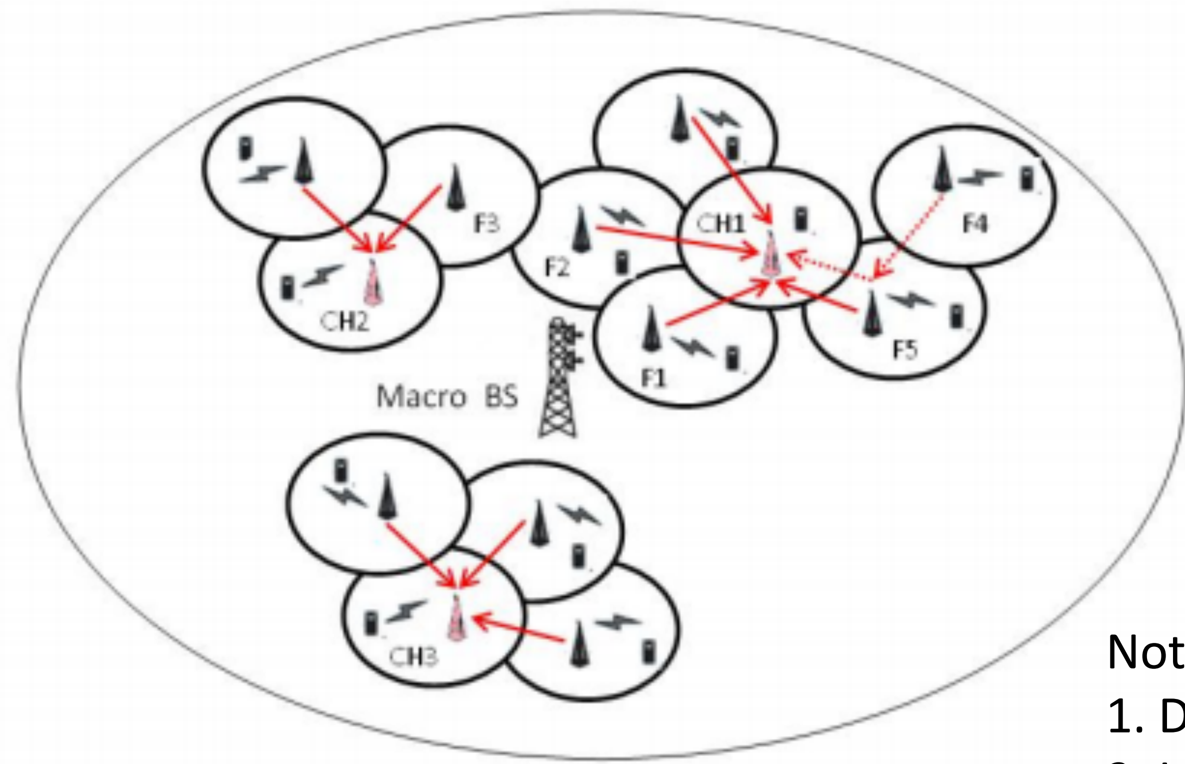


Fig. 1. Network Model

Note:

1. Downlink Communication
2. Interference between mac/femto users.
3. Max. Th within mac/fem
4. Optimal Resource alloc for Femto.

Cluster Formation

$\mathcal{F}_a$ creates the 1-hop neighbouring interfering femtocells list
$\mathcal{F}_a$ sends the associated interfering list to its 1-hop neighbours
if $\mathcal{F}_a$ has the highest degree of interfering neighbours **then**
    $\mathcal{F}_a$ elects itself as a cluster-head
else
    if $\mathcal{F}_a$ is interfering with cluster-heads **then**
        $\mathcal{F}_a$ attaches itself to the cluster administered by its highest interfered neighbour cluster-head
    else
        $\mathcal{F}_a$ selects the highest interfering neighbour femtocell $\mathcal{F}_b$
        $\mathcal{F}_a$ attaches itself to the $\mathcal{F}_b$'s cluster
    end if
end if

Femtocell Resource Allocation

$$\forall \mathcal{F}_a \in \mathcal{F} : \qquad \min \left[\max_a \left(\frac{\mathcal{R}_a - \sum_{i,j} \Delta_a(i,j)}{|\mathcal{F}| \times \mathcal{R}_a} \right) \right]$$

`subject to:`

$$(a) \quad \forall \mathcal{F}_a \in \mathcal{F} : \qquad \sum_{i,j} \Delta_a(i,j) \leq \mathcal{R}_a$$

$$(b) \quad \forall i, j,$$

$$R_a = \sum_{i=1}^{n_a} V_a(i)$$

$$\forall \mathcal{F}_a \in \mathcal{F}, \forall \mathcal{F}_b \in \mathcal{I}_a : \qquad \Delta_a(i,j) + \Delta_b(i,j) \leq 1$$

$$(c) \quad \forall i, j, \quad \forall \mathcal{F}_a \in \mathcal{F} : \qquad \Delta_a(i,j) \in \{0,1\}$$

Note:

F_a – Femtocell

R_a – Number of required resource

$\Delta_a(i,j)$ – Location of allocated resource in allocation matrix.

F – Total number of femtocell

I_a – Interfarence matrix for each F_a

V_a = demand of e ach users belongs to a femtocell

n_a = Total number of user belongs to a femtocell

Experimental Setup

Sl no	Tools	Objective
1	MatLab R2013b	Distribute FAPs, Cluster formation, Result Analysis
2	MatLab Winner Library [4]	Path loss model
3	IBM ILOG Cplex 12.6	Resource Allocation Optimization

Table: Used tools and softwares

Exp. Setup - Cluster Formation

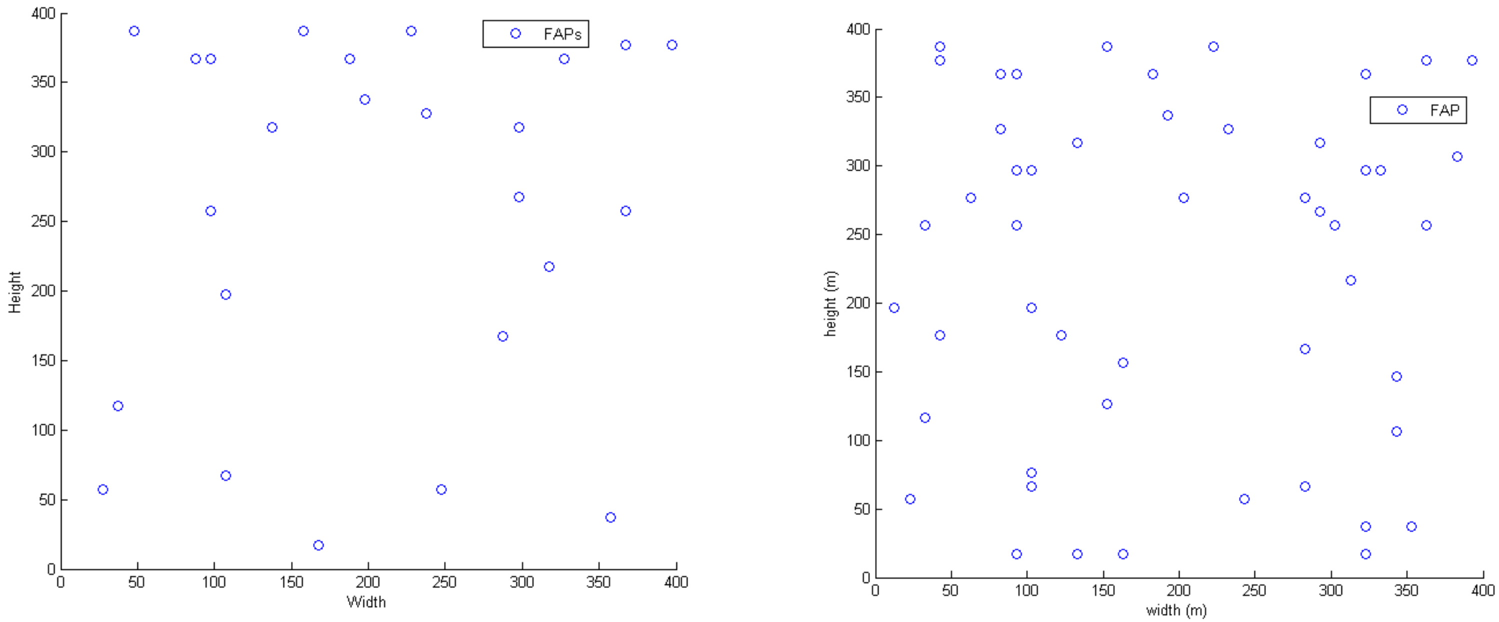


Fig: FAPs Distribution

Note:

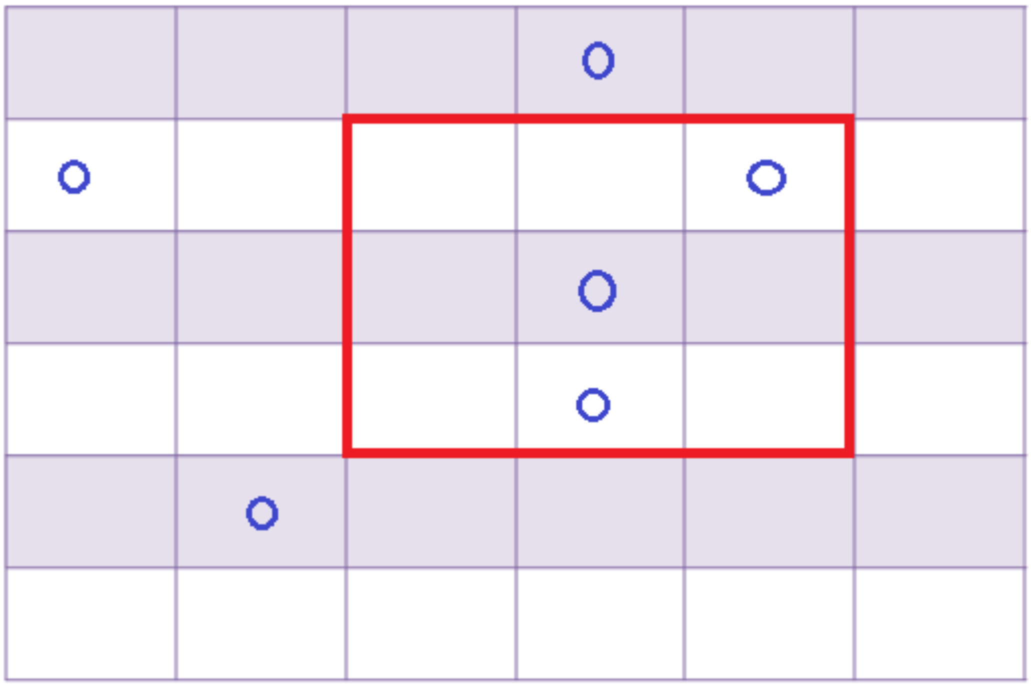
Total Area – 400m × 400m

Each FAPs area – 10m × 10m

Number of FAPs – 25 and 50

Funtions - randperm();

Exp. Setup - Cluster Formation(2)



Boundary Condition for calculating list of one hop neighbor –
xLower = {floor(x/10) × 10} – 10
xUpper = {Ceil(x/10) × 10} + 10
Similarly yLower and yUpper.
A FAPs is one hop neighbor, those satisfy following condition
(x>=xLower && x<=xUpper && y>=yLower && y<= yUpper)

Exp. Setup - Cluster Formation(3)

FAPSs Id	Number of Interfering Femtocell	Distance
8	1	10
14	1	10
17	1	10
38	1	10
42	1	10
45	1	10
All	0	0

Table (2) : List of one hop neighbor

$$Path\ loss = 20 \log_{10}(d) + 46.4 + 20 \log_{10}(f_c/5.0)$$

d – distance
fc – frequency

Threshold SINR = 10dB

Exp. Setup – Resource Allocation

- PC Configuration
  Core i3 2.4GHz, 4GB RAM, 64bit OS(Win7)
- Max. number of user per FAP = 4
- Resource demand per femto V_a, *(0<=V_a <= 25)*
- Input –
  Number of femtocells = 25;
  Number of Resources = 36; (6x6)
  Demand[femtocell] = [10 9 3 2 16 4 5 6 7 8 9 11 13 4 5 2 3 12 14 10 9 8 7 6 5];

Exp. Setup – Resource Allocation (2)

- Out put
- Allocation[femtocell][tiles] =

[[0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0]
[0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0]
[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0]
[1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0]
[0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
[0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
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[0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0]
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[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0]

];

Result & Analysis - Formula

- *Throughput Satisfaction Rate (TSR)*

$$\forall \mathcal{F}_a \in \mathcal{F}: \qquad TSR(\mathcal{F}_a) = \Big(\sum_{i,j} \Delta_a(i,j)\Big)/\mathcal{R}_a$$

$$TSR = \sum_{\mathcal{F}_a \in \mathcal{F}} TSR(\mathcal{F}_a)/|\mathcal{F}|$$

- *Spectrum Spatial Reuse (SSR)*

$$SSR = \frac{1}{M \times |F|} \sum_{i,j} \sum_{\mathcal{F}_a \in \mathcal{F}} \Delta_a(i,j)$$

Result & Analysis – Cluster

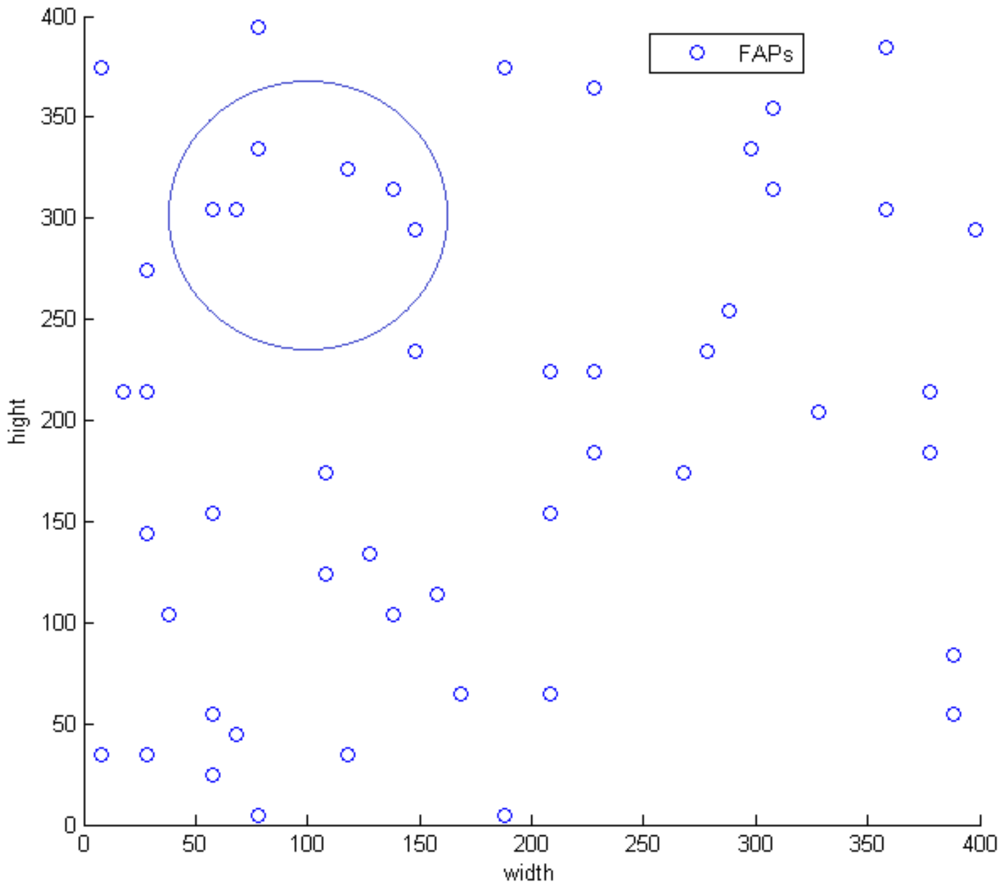
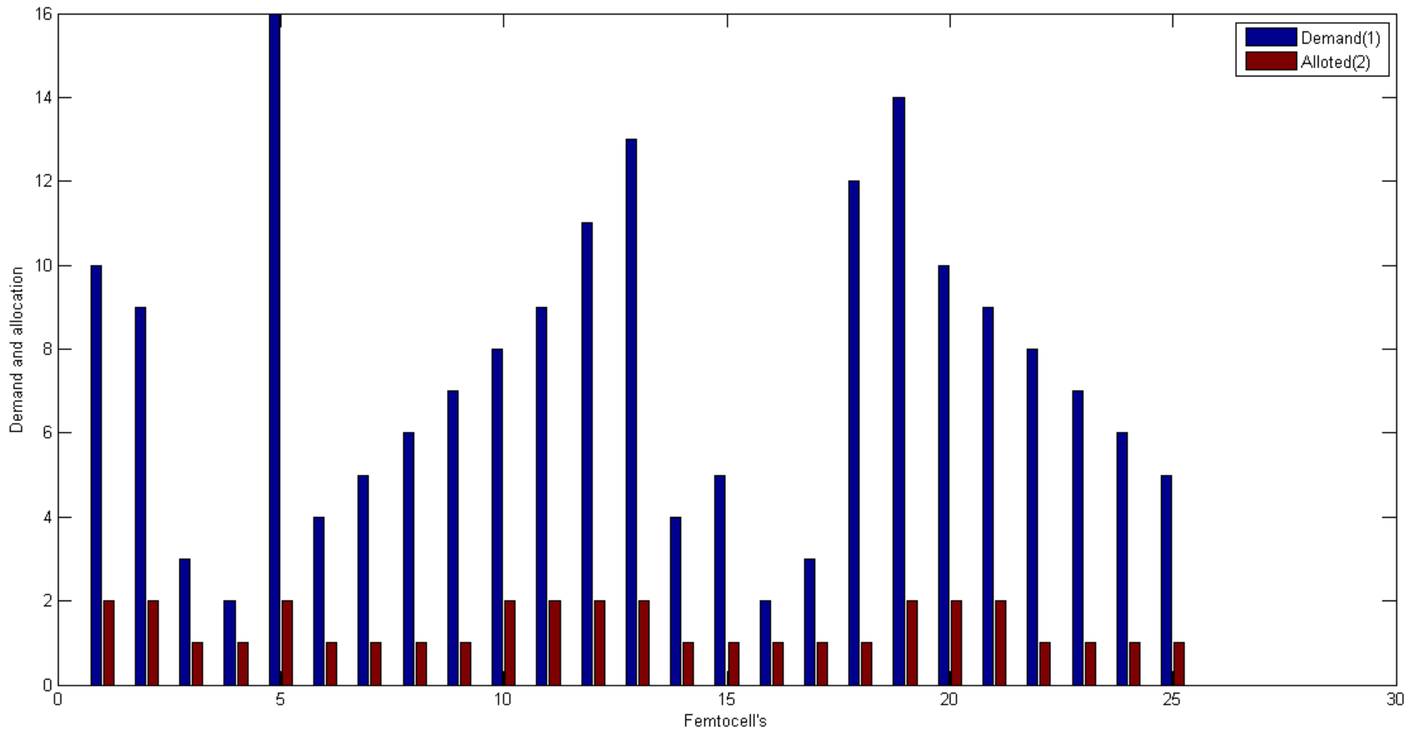


Fig (3): FAPs Cluster

Result & Analysis – Resource Allocation



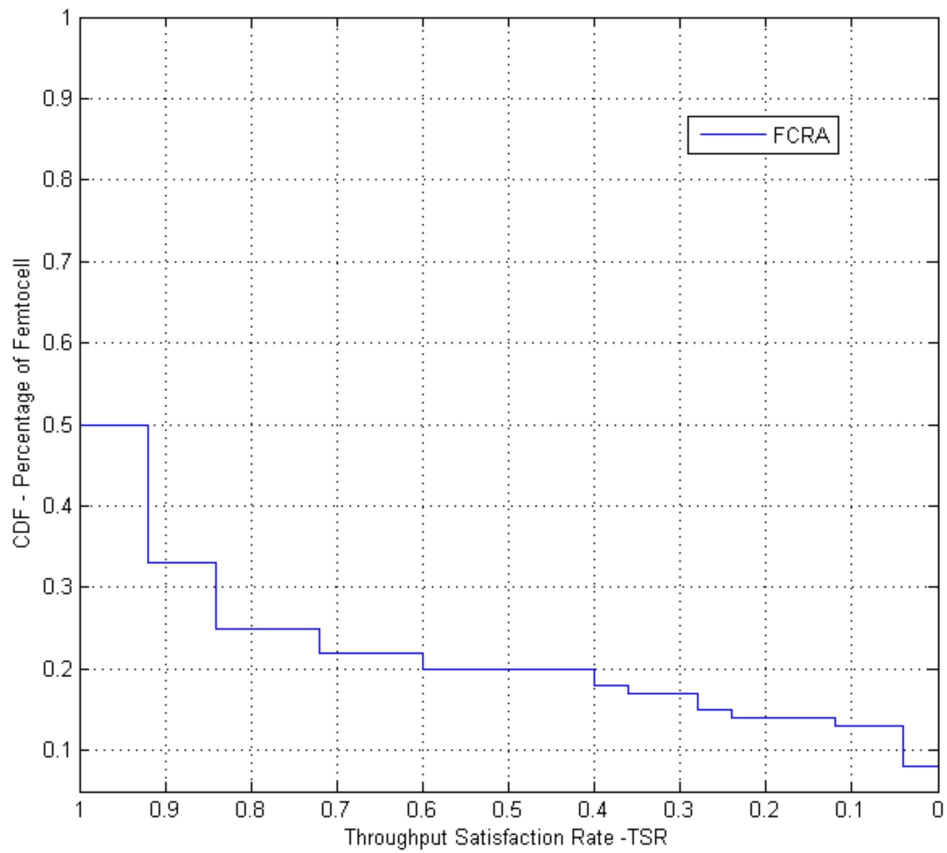
Fig(4): Demand Vs Allocation

Result & Analysis – Resource Allocation (2)

Title	Value
Total Demand	188
Total Allocation (36)	35
TSR	22%
SSR	3.8%
Computational Time	280 ms
Best Bound	0.8623

Table (3) : Result of optimized resource allocation

Result & Analysis – Resource Allocation (2)



Fig(4): TSR when SINR = 10dB

Conclusion and Future work

- In this paper, we studied the resource allocation problem in OFDMA-based femtocell networks and proposed a new allocation scheme called Femtocell Cluster-based Resource Allocation (FCRA). FCRA is based on a hybrid centralized/distributed approach and involves three main phases: (i) Construction of disjoint clusters; (ii) Optimal cluster-head resource allocation by resolving a Min-Max optimization problem; The results concern the throughput satisfaction rate, the spectrum spatial reuse.
- In the future, we plan to compare results with Centralized Optimal (C-DFA) and Distributed resource allocation (DRA) methods.

Acknowledgement & References

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