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Cognitive Interference Management for Autonomic Femtocell Networks

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ABSTRACT
The femtocell concept is an emerging technology for deploying the next generation of the wireless networks, aiming at indoor coverage enhancement, increasing capacity, and offloading the overlay macrocell traffic. Nevertheless, one of the most critical issues in femtocells deployment is the potential interference, thus mitigating the overall system capacity.
Inspired by the cognitive radio technology which enables a station to cognize and adapt to the communication environment to reach the optimum network performance, this paper presents a joint power control and scheduling algorithm for interference management in femtocell networks. Simulations were conducted under Matlab. Theyshow the efficiency of our proposal and its ability to improve the overall throughputas well asreducing the energy consumption.

General Terms
Wireless Networks

Keywords
Femtocells, Interference, Cognitive approach, Energy efficiency, QoS.

1. INTRODUCTION
Femtocells are single mode, power efficient, backward compatible, low cost and easy to install devices. They can increase the capacity of macrocell as they use the same spectrum as that of macrocell [1][2]. As the radius of Femtocell is much smaller as compared to that of macrocell, that is why it can provide high data rates in any environment such as home or office. Moreover, femtocells can also be a cost effective solution for enterprises because of their self-organizing networks characteristics. Nevertheless, installing femtocells inside enterprise environments, where more than one femtocell may be necessary, and where many guest users may enter the femtocell coverage, leads to major technical challenges.One of the most critical issues in femtocellsdeployment is the potential interference between nearby femtocells.

The available gains from intercell interference awareness in cellular networks have been identified in several papers, see for example, [3-5] and the references therein.

To alleviate interference, one typical solution is to divide the entire available spectrum into several frequency bands. Thus, each femtocell uses different frequency band. This deployment is referred to the "dedicated channel" deployment. However, the performance of this solution is limited by the assigned bandwidth, which makes it infeasible to be applied to the dense femto-networks deployment where each femtocell can only utilize a very limited bandwidth. As a result, a practical solution turns to be the co-channel deployment where femtocells share all available spectrum of the network.

To mitigate interference in the co-channel deployment, dynamically power adapting schemes in femto-networks had been considered effective to alleviate interference when the system adapt wideband code division multiple access (WCDMA) [6]–[7]. However, considering that orthogonal frequency division multiple access (OFDMA) had been endorsed by 3GPP LTE-A and WiMAX, new interference mitigation manners are needed.

Considering that the major cause of interference in OFDMA is that femtocells installed in an ad-hoc manner for large deployment occupy the same radio resources (subcarriers and OFDM symbols), a centralized radio resources allocation scheme had been proposed in [8] to prevent the femto-network from the co-use of radio resources. However, since an enormous number of femto-networks can be expected to overlay a large network, the computational complexity and large among of scheduling related information exchanges are challenges. As a result, a radio resource management scheme for each femtocell shall be able to "autonomously" utilize the radio resources not occupied by others so as to mitigate interference while providing QoS guarantees.

Inspired by the cognitive radio technology which enables a station to cognize and adapt to the communication environment to reach the optimum network performance [9]–[10], this paper presents a joint power control and scheduling algorithm. We propose 'TRIPLET Algorithm' to surmount 3 concepts in a distributed architecture: 'interference mitigation', 'energy efficiency' and 'user's QoS'. Thus, we formulate a multi-objective optimization problem with mixed integer variables for the joint power control, base station assignment, and channel assignment scheme.

2. SYSTEM MODEL

2.1 Network Model
The aim of coverage optimization in residential femtocell deployments is to ensure that leakage of coverage by a single femtocell into public spaces will be minimized while at the same time maximizing indoor coverage [6]. For femtocell deployments in enterprise environments however, a group of femtocells are deployed to work together to jointly provide continuous coverage in a large building or campus to satisfy the QoS requirements, which also increases the technical challenges of interference management, power efficiency and overall system capacity. The requirements for efficient resource partitioning scheme in this case differ significantly from residential femtocell deployments.

The power and resource allocation management in femtocell environment is complex and surcharge the network with overhead and negotiations between the neighboring femtocells. For that purpose, we propose a new architecture "3-ON-3 Femtocell Clustering Architecture", in which, each group of 3 F-BSs will form a cluster that serve 3 types of users. We propose 3 Adaptive Hard Reuse Schemes 'AHRS' as frequency resource partitioning strategy on Cluster to reduce the interference by allowing a frequency reuse factor of 1. Moreover, we consider 3 power Levels to cover users according to their access levels.

Femtocell base stations (F-BSs) communicate together by X2 interfaces or S1 interfaces [12].

The study is done based on LTE-Advanced system specifications from a local area perspective. The considered model is the downlink of an OFDMA/FDD femtocells network which has universal frequency reuse. OFDMA is a multi-carrier technology which allows both FDD and time division duplex (TDD) modes. The available bandwidth B is divided into N orthogonal subcarriers which are then grouped into N_B sub-channels (resource blocks). Furthermore, the time domain is segmented into successive frames of durationT_f, which consist of a given number of time slots (OFDM symbols) of a duration T_s.

The network model that we consider, is composed of $N_f$femtocells {$F\text{-}BS_0$, $F\text{-}BS_1$, ..., $F\text{-}BS_{Nf-1}$} and N_u users {UE_1,UE_2, ...,UE_{Nu}} where N_B sub-channels {RB_1,RB_2, ...,RB_{Nb}} are available for transmission. For simplicity, every RB will be assigned for only one UE.

2.2 Assumptions and Definitions

In this subsection, the network assumptions underlying this work are given.

1) In this study, the femto-layer is considered only, i.e., interference between femto and macro layer is neglected.

2) Hybrid access method is considered.

In enterprise scenarios, open access femtocells will lead to a decreased performance of the user's QoS when the number of guest users is too high, due to the sharing of resources and the heavy interference conditions. Furthermore, in CSG mode, it may be that the macrocell coverage will not be sufficient to satisfy the quality of service (QoS) requirements of the guest users. Hence, it is important that femtocells can optimally balance their access control mechanisms.

Thus we consider the case of hybrid mode where users are given priorities:

- The highest one L1 to the femtocell owner; L1-UE.
- L2 the medium priority to other enterprise employers; L2-UE.
- L3, the least one to any guest user; L3-UE.

3) In a single femtocell, a sub-channel can be assigned to only one user at a time slot. This way, no intracell interference will occur.

Therefore, the sharing of femtocell resources between these 3 types of users needs to be finely tuned. We describe here an approach that grants resources to users according to their priorities of access. We reserve for the L1-UE adaptive traffic between 50% to 80% of the total Bandwidth B. This willgarantee that the owner of the F-BS is not penalized by other users. Adaptive rate between 30% and 50% of bandwidth is accorded to the L2-UEs, and 20% to 30% for the L3-UEs.

4) The performance of the system is improved using 3 different frequency reuse schemes so as to mitigate the amount of interference originating by neighboring femtocells. Based on Adaptive Hard Reuse Scheme 'AHRS', each femtocell utilizes the entire bandwidth and transmits with 3 power levels on the frequency resource band as shown in Fig.1.

Thus AHRS scheme is designed such that the entire frequency band is divided into three sub-bands. A reuse factor of three is employed, i.e., each femtocell only associates adaptively each third of the band (or one sub-band) for one user-access Level and neighboring femtocells in the same cluster must use either repartitioning sub-bands. Doing this reduces the amount of interference originating from the femtocells immediately surrounding a cell in question.

According to the frequency resource percentile described above, the entire bandwidth of each $F\text{-}BS_{i=1..3}$ belonging to the same cluster is divided on 3 parts Bi1, Bi2 and Bi3 differently. We associate and allocate adaptively Bii for L1-users, Bij for L2-users and L3-users, as it's described by the Fig.1,

Bij 's bandwidths are dynamically adjusted according to number of connected users and their priorities.

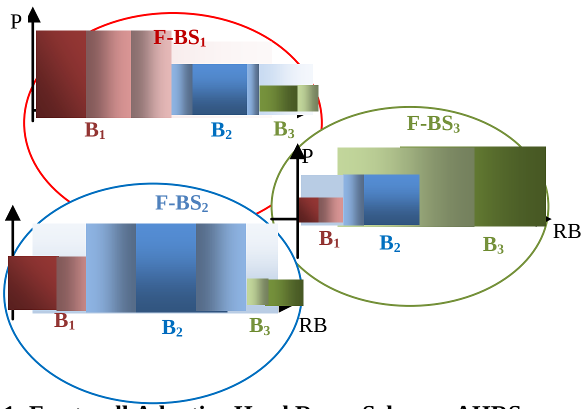

Fig1 :Femtocell Adaptive Hard Reuse Scheme: AHRS.

Thus we formulate the Cluster resource allocation matrix CA that describes the resource repartition factors of every $F\text{-}BS_i$ in a Cluster.

$$CA = \begin{array}{c} \\ F\text{-}BS_1 \\ F\text{-}BS_2 \\ F\text{-}BS_3 \end{array} \begin{array}{c} \begin{array}{ccc} B1 & B2 & B3 \end{array} \\ \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \\ \beta_{31} & \beta_{32} & \beta_{33} \end{bmatrix} \end{array}$$

5) A perfectly synchronized OFDMA network is assumed. This means that crosstalk between between neighboring RBs and time slots is neglected.

6)Furthermore, the users in the system are assumed to be static for the duration of the snapshot, so that the effects due to Doppler spread are neglected.

7) A F-BS restricts access to its network primary for L1-users,then for L2-users and finally for L3-users, which results in a better quality of service (QoS) and higher data bandwidth. Thus, Eachfemtocell defines Power assignment priorities and Levels according to user-access levels, which directly translates to quality of service (QoS) constraints for a given user (fig1).

We denote Li-P, the power that a F-BS transmits to cover Li-user on a RB.

- L1-Pmax to L1-users (femtocell owner),
- L2-Pmax to L2-users (other enterprise employers)
- L3-Pmax to L3-users (guest users).

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8) Each receiver is assumed to be able to estimate the link gains from nearby transmitters with the help of transmitter specific training sequences.
9) The existence of a separate feedback channel is assumed. This channel enables receivers to send link gain estimations to their respective transmitters nearby.
10) The bandwidth of a sub-channel is assumed to be smaller than the coherence bandwidth of the channel. This way, the fading of the subcarriers within a sub-channel is frequency-flat. Furthermore, the coherence time of the channel is assumed to be larger than the duration of a frame T_f. This results in equal fading for all OFDM symbols within one frame.
11) The opportunistic scheduling is performed at the base stations considering the QoS requirements of the users according to their priority access levels and the whole system throughput performance. Scheduling phase is considered when the transmission attempt to UE on sub-channel is deferred, hence, it will be scheduled dynamically in orthogonal resource.

2.3 Challenges addressed:

The main objectives of this work are:

- To conduct a comprehensive study on inter-cell interference mitigation in a local area network such Femtocells Enterprise.
- Another important objective of this work is to develop a new resource allocation scheme which performs the frequency spectrum efficiency according to user's priority levels.
- Through the proposed interference management scheme, we try to reduce the total transmitted power consumed by the whole network by providing a resource allocation pattern which is conservative at the same time.
- To balance the load amongst the femtocells in the group to prevent overloading or underutilization.
- To satisfy the Workload Office Level, thus employer and user's needs and QoS.

This work aims to develop fully distributed, scalable and autonomous channel allocation schemes with minimal information sharing between F-BSs in a cluster. Since each F-BS takes decisions in an autonomous fashion, there is no need for any centralized control entity.

2.4 Autonomic Architecture survey:

The central idea of the proposed scheme is to consider the capacity gained by a F-BS when a new resource block is attributed which is estimated with the help of data collected by UEs during their normal system operation and their priority Levels. It's then compared with the capacity loss reported by all the neighboring F-BSs using the same resource. The resource is not accorded if the loss exceeds the gain thereby ensuring an efficient scheduling through the resource blocks according to the QoS required, as well as improving the system throughput.

The MAC scheduler in Femtocell base station controls the physical layer segments to assign the suitable resource blocks to incoming UEs, according to their access levels and its frequency resource allocation scheme 'AHRS'. Using the utility function '*fifi*', the F-BS decides whether to allocate the new RB or to differ the transmission for another one according to MAC scheduler. Consequently the interference with neighboring cells is minimized.

3. THE "POWER, INTERFERENCE, QOS" CONTROL ALGORITHM

In this section, the TRIPLET Algorithm is considered. It's a distributed power control and scheduling algorithm which aims to minimize the interference in the whole network. Furthermore, it exploits multiuser diversity when determining power levels on each sub-channel and delivers suboptimal results on response to the QoS requirement. The F-BS go through several iterations of carrier selection until arriving at a stable allocation.

We consider an enterprise network, where F-BSs are located at the center of offices. Both F-BS and user are equipped with an omni-directional antenna. The F-BS creates cell coverage with radius R_f , which is adaptively adjusted by the TRIPLET Algorithm. The proposed algorithm is divided in two steps:

- Startup Self-configuration step.
- Adaptive power control step.

3.1 Startup configuration Step: Distributed Interference Management Scheme

3.1.1. Distributed Graph Coloring femtocells cluster:

Initially, when F-BSs powered on, clusters of 3 femtocells are formed and an adequate frequency spectrum allocation scheme AHRS is associated to each F-BS. We deal with the clustering problem with the help of graph theoretical coloring algorithm, i.e., graph-based method as shown in Fig2. All the active F-BSs can be grouped into different clusters by applying the greedy three-graph coloring algorithm in the interference graph. Accordingly the corresponding spectrum allocation scheme problem for every F-BS can be translated into a graph coloring problem where a node represents a femtocell, a weighted edge connecting two nodes represents the reciprocal of the interference between the nodes, and the color of the node represents an AHRS. The spectrum allocation problem is then transformed into a vertex coloring algorithm based on a modified greedy three-coloring algorithm.

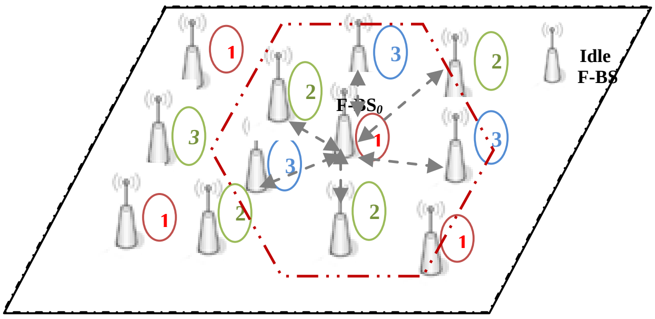

Fig 2: Cluster Architecture (3-Femtocells) per floor in Enterprise Network

3.1.2 Orthogonal frequency partitioning (OFP)

The first channel allocation is very crucial for our studies, since the capacity improvement and loss experienced by the UEs will depend heavily on the optimality of this process.
Firstly, we consider that only one L1-UE is attached to its F-BS. Thus, every F-BS measures the Reference Signal Received Power (RSRP) of the surrounding F-BSs and determines the set

of F-BSs that are likely to have an interfering relationship with it by checking whether the RSRP is above a certain threshold. Then, every F-BS will be assigned a sub-channel that is non-overlapping with its interfering F-BSs. After this step, one sub-channel has been allocated to each femtocell, which provides the communication connection between the F-BS and UE.
Then, more RBs are attempted to be used and assigned by a femtocell according to user-arrivals in the second step.

3.2 Adaptive power control step

In this section, we propose a Distributed Multi-Channel Allocation Scheme which selects suitable physical resource blocks RBs for incoming users and employers in their offices.
In this proposed scheme, the average increase in capacity of incoming user is compared with the loss in capacity experienced by the loss-users in the 'K' interfered neighboring femtocells. The central idea here is that when a F-BS considers the possibility of allocating new RBs, all the neighboring femtocells having the same resource currently in use will suffer from interference. Hence, the potential loss which would be experienced by those femtocells are reported to the F-BS trying to add these RBs. Then based on the values reported and the estimated capacity gained by adding these RBs, the F-BS can make a decision whether to add the resource or not. This algorithm is abbreviated as TRIPLET Algorithm. The logic behind the naming is that it aims firstly to provide the QoS required (in terms of capacity and throughput) to the incoming user according to his access level (L1, L2 or L3). Secondly it's a distributed power control algorithm that ensures a specific power level for each user type. Finally, it's based on a MAC scheduler component that controls and adapts the RB assignment to the incoming user in regard to the femtocell AHR scheme.

3.2.1 Algorithm steps:

a) Capacityfunction:

Consider the case when a new user/employer UE_j arrives at an office covered by $F\text{-}BS_i$ and 'K' neighboring loss-users are taken into account. The capacity estimated by this user having 'C' number of RBs is given by the Shannon Fitting formula :

$$\mathrm{Cp_j} = \sum_{n=1}^{C} \mathrm{W} * \log_2\left(1 + \frac{\mathrm{SINR}_{(j,n)}}{\mathrm{SINR_{eff}}}\right)$$

Where:

- W is the transmission bandwidth on sub-channel `n'
- $SINR_{(j,n)}$ is the signal to noise ratio experienced by the user `j' on sub-channel `n'.

$$\mathrm{SINR}_{(j,n)} = \frac{\mathrm{L_j\_P_{f_i}} * \mathrm{G}_{(i,j,n)}}{\sigma^2_{\mathrm{RB_n}} + \sum_k \mathrm{P}_{(f_k,n)} * \mathrm{G}_{(j,k,n)}}$$

Where :

- $L_j\_P_{f_i}$ is the $F\text{-}BS_i$ transmit power according to the access priority level of UE_j
- $P_{(f_k,n)}$ is the $F\text{-}BS_k$ transmit power on RB_n
- $G_{(i,j,n)}$ is the channel Gain between UE_j and $F\text{-}BS_i$ on RB_n
- $G_{(j,k,n)}$ is the channel Gain between UE_j and $F\text{-}BS_k$ on RB_n
- $\sigma^2_{RB_n}$ The constant noise power on RB_n

- $SINR_{eff}$ is the SINR efficiency which adjusts for SINR implementation efficiency of LTE.

b) Capacitydecrease

The capacity decrease is the loss in capacity experienced by neighboring femtocell users when $F\text{-}BS_i$ allocates new RBs. Let the Interfered Neighboring F-BSs be numbered `1',`2', `3', ... , `K'. The algorithm scans through the capacity loss experienced user belonging to neighboring F-BSs which is denoted as the loss-user. The loss by the loss-user is then reported by the corresponding $F\text{-}BS_k$ to $F\text{-}BS_i$.
In fact, it's assumed that $F\text{-}BS_i$ transmits on RB_n (in the illustrated case) for some time during which measurements are taken. As part of normal system operation, UE_j measures and reports the interference experienced by it to the surrounding F-BS at regular intervals (e.g. Every 10s). It is assumed that $F\text{-}BS_k$ keeps track of the interference value reported by the UE over a period of time. Thus, it will assume that the neighboring $F\text{-}BS_j$ is trying to add a new RB. Based on the channel in which interference has increased, with the UE interference reports and with the knowledge of transmitted power, it can estimate the SINR value and using the Shannon-Fitting formula, the capacity loss can be estimated as well.
Let $Cp_{(1,k,n)}$ be the capacity of the loss-user in $F\text{-}BS_k$ having the RB_n before assignment is done and $Cp_{(2,k,n)}$ the capacity after allocation. The loss in capacity can be formulated as:

$$Cp_{(k,n)} = Cp_{(1,k,n)} - Cp_{(2,k,n)}$$

c) Utility function:

$F\text{-}BS_k$ then reports the loss in capacity experienced by the loss-user on RB_n to $F\text{-}BS_i$. Then, after receiving the message from the neighboring F-BSs, $F\text{-}BS_i$ compare the increase in capacity that is experienced by its incoming user with the loss in capacity reported by the neighboring F-BSs. Based on this comparison as described above, the $F\text{-}BS_i$ will decide whether to allocate the resource or not. If the gain is less than the loss, it will be deferred; otherwise it will go ahead with the resource allocation by scheduling in orthogonal resource.

Now the $F\text{-}BS_i$ is allowed to keep the channel if and only if the **Utility-Function fifi>0:**

$$fifi_n = \eta_0 Cp_j - (\eta_1 Cp_{(1,n)} + \eta_2 Cp_{(2,n)} + \ldots + \eta_K Cp_{(K,n)}) > 0$$

We define $\eta_{i,(i=0..K)}$ as the QoS-coefficient that expresses the gain/loss in capacity according to the priority access level of the i^{th}user.
That is, the increase in capacity experienced by the incoming user is greater than the decrease in capacity experienced by the loss-users in 'K' neighboring femtocells. This automatically also takes care of preventing greedy F-BSs from allocating all channels for itself and thereby creating unfavorable conditions for other femtocells. From a protocol view point, very little signaling is required for this scheme. The loss experienced by

the neighboring interfered femtocells can be exchanged periodically.

d) MAC Schedulingstep:

Ifthe gain is less than the loss *(i.e*$fifi_n$*< 0)* for RB_n, the MAC Scheduler in $F\text{-}BS_i$ will try to associate other $RB_{n'}$ according to the priority level of the incoming user and the available RBs by considering the AHRS allocation scheme. Otherwise the transmission attempt of user UE_jon sub-channel RB_n is deferredto the next frame, i.e., sub-channel RBs can notbe assigned to the user UE_j within the current frame.

4. PRACTICAL IMPLEMENTATION IN LTE SYSTEMS

In order to implement the resource partitioning concept, the interfering femtocell needs to be identified and then be informed of the restricted resources blocks that will be allocated and must not use according to the utility function decision. This involves integrating the proposed resource partitioning concept within the LTE network architecture.

In abstract, femtocell resource partitioning is integrated to the LTE network architecture by the following procedure.

1) An incoming UE determines the cell-ID of surrounding F-BSs, by reading the corresponding broadcast channel (BCH), and stores them in a list containing neighboring cell-IDs.

2) UE identifies the heavily interfering F-BSs in its proximity using reference signal received power (RSRP) measurements.

The necessary UE measurements that identify which femtocells are in close vicinity of the UE are similar to a handover procedure. In LTE, UEs read the broadcast channel (BCH) not only from their serving F-BS, but also from one or several secondary F-BS. As the BCH contains the cell-IDs, a UE can establish a list of neighboring F-BSs. Knowledge of the cell-ID also enables UEs to read the cell-specific reference signals (also known as training symbols or pilots) of neighboring F-BS, that are needed to carry out RSRP measurements. These enable the estimation of the average channel gain between the UE and the surrounding F-BSs

3) The cell-IDs of the corresponding F-BSs are reported to the serving F-BS.

4)In the LTE downlink, a bitmap known as the Relative Narrowband Transmit Power (RNTP) indicator is exchanged over the X2 interface between F-BSs. The RNTP indicator is used by the serving F-BS to signal to neighboring F-BSs on which RBs it intends to transmit with maximum power L1-P in the near future. Each bit of the RNTP indicator corresponds to one RB in the frequency domain and is used to inform the neighboring F-BSs if the F-BS in question is planning to exceed the transmit power for that RB or not [13]. The value of the threshold and the time period for which the indicator is valid are configurable parameters. This bitmap is intended to enable neighboring cells to estimate the amount of interference on each RB in future frames and therefore estimate its capacity loss on the RB. Otherwise (i.e if the transmit power isn't max; L2-P or l3-P), based on reference signal received power (RSRP) and SINR measurements reported by its users UEs and its transmitted power on the sub-channel (in which interference has increased), the neighboring F-BS can estimate the capacity loss.

5) The capacity loss reports are disseminated to the serving F-BS over the X2 or S1 interfaces. Neighboring F-BSs are interconnected via the X2 interface, that conveys control information related to handover and interference coordination. The X2 interface is therefore particularly suited for signaling related to femtocells interference avoidance [11][12]. Therefore, the resource allocation decision report is transmitted over the X2 interface to the interfered F-BSs which will schedule their UEs accordingly.

In this way, detrimental downlink femtocell interference at the vulnerable incoming UEs is avoided.

5. SIMULATION RESULTS

5.1 Simulation Concept

Our simulator continuously simulates the temporal development of cells by evaluating the performance metrics within uniform spaced snapshots. Within each snapshot,the positions of userschange and thetraffic situation is updated. Next, the channels between eachmobile station and each femto base station F-BS are newly calculated and scheduling is performed for eachsnapshot. UMTS-LTE allows different timing granularities [14].In this simulation we use the time interval T = 1 ms.

We consider a densely populated area as an enterprise environment, where there are multi-floor apartment buildings. For simplicity, only hexagonal femtocell block with 100 x 120 (m x m) area is considered as it's shown in fig3., and described above.

The simulated femto scenariosare a 'suburban model'. Until18 users are generated and distributed uniformly within each femtocell.

Each scenario is randomly created 100 times and simulated for within T.

Our simulation tests are based on the following models:

- *Mobility Model*

The locationsli(t), direction of movement di(t)users and their velocities Vi(t)are updated every snapshotaccording to:

$l_i(Kt + T) = l_i(Kt) . V_i(T). T(1)$

$d_i(Kt + T) = d_i(Kt) + A . \Delta d_i(KT)$ (2)

The direction of movement $d_i(t)$of each user at the(k+1)-th snapshot is obtained by updating its direction at thek-th snapshot by multiplying a uniformly distributed randomvariable Δd_i(with $f_{\Delta d_i}(\Delta d_i) = \frac{1}{\Delta d} rect(\frac{\Delta d_i}{\Delta d})$)with anotherrandom variable Agenerated from a discrete probabilitydensity function :

$$f_A(A) = p_{dc} . \delta(A - 1) + (1 - p_{dc}). \delta(A)$$

Thus the maximum change in direction, also called maximum swing angle is limited to ΔAmax. The probability of direction change p_{dc} is used to make a decision whether or not a user changes its direction. Obviously, the random variable Acan take values of either zero or one. If the mobile station does not change its direction (A = 0), the direction calculated at the previous snapshot remains unchanged.

- *Traffic Model*

The communication traffic in the network is also updated on a snapshot. The traffic model that we consider in this work is 'best effort packet transmission'. The best effort packet service type includes FTP and HTTP.

- *Propagation Model*

An alternative simplified model based on the LTE-A evaluation methodology which avoids modelling any walls is used for the simulated scenario. Here the pathloss is calculated as follows:

$$PL = 127 \text{ dB} + 30 \log10(R/1000 \text{ m}).$$

- *Multipath Model*

The LTE system exploits instantaneous channel conditions for the performance enhancement such as channel dependent scheduling, adaptive modulation and coding (AMC) and different transmission modes for uplink and downlink [15]. For a realistic system performance evaluation, short-term time varying channel characteristics are considered during simulation as well as geometric path loss and long-term shadow fading.
Time-varying short-term fading effects are described by power delay profiles. Modified power delay profiles with 24 taps proposed in [16] were used. Byconsidering user mobility, the channel mixed model for small office scenario [17] is used (Ped-B for femto mobile stations, at the velocity of 3 km/h). The multipath channels between the mobile stations and the base stations were generated once per snapshot for each subcarrier. The resulting channel frequency response is calculated afterwards and averaged over each set of 12 subcarriers to achieve an averaged gain per resource block.

- *SINR and ThroughputCalculation*

The link performance can be evaluated using block error ratio (BLER) or throughput. In this work we focus on the throughput performance. A mapping method 'attenuated andtruncated Shannon bound' could be used for link to systemmapping (3GPP TR 36.942 V8.1.0 A.1). The principle of this method is to map the obtained SINR at each snapshot to the throughput. First of all, the post-processing SINR is calculated for each user and each subcarrier n as it's described above.

- *Link LevelQuality Estimation*

Link adaptation techniques significantly increase user throughput by providing efficient ways to maximize spectral efficiency In case of multi-carrier transmission as in LTE, the set of subcarrier SINRs are mapped with the help of MIESM: Mutual Information Effective Signal to Interference and Noise Ratio Mapping (MIESM).

- *Scheduling*

The scheduler of a femtocell has an essential functionality at the BS. It manages and allocates network resources considering boundary conditions and optimization criteria.
Our simulated scenarios will be able to compare scheduling algorithms which are:

- Triplet Algorithm as it's described above. (a)
- The well known scheduling algorithm 'Round-Robin'[18], which does not require any power control. (b)
- Proportional Fair Scheduler[19]: a proportional-rate scheduler intended to improve fairness among users(c).

The basic parameters used for the simulations are summarized in Table 1.

Table 1. Simulations parameters

Parameter	Value
Femto_Block Size	100x120 (m x m)
Simulation length	100 subframes
subframe duration	1 ms
Number femtocells	7
Frequency reuse factor	1
Carrier Frequency	2140 Mhz
Shadowing standard deviation	8 dB
Shadowing correlation	Between femtocells: 0.5 fixed
Antenna pattern (fixed)	For 3-sector cell sites $A(\Theta) = -\min[12(\Theta/\Theta_{3dB})^2 dB, Am]$ where $\Theta_{3dB} = 70°$, Am = 20dB
femto MS noise figure	9 dB
Number of Tx, Rx antennas for femtocells	2 x 2 MIMO
Femto BS TX power per RB	P_L1: 0.3, P_L2:0.2 , P_L3: 0.12 dBm
System bandwidth	20 Mhz
Subcarrier spacing	15 kHz
Channel profile	AWGN
CQI values	1-15
MIMO transmission mode 4	4 (MIMO),
UE velocity	3 km/h
η : QoS-coefficient	η=0.8 (L1-level) η=0.5 (L2-level) η=0.3 (L3-level)

5.2 Simulation Results

In this section, simulation results are presented to evaluate the performances of the proposed interference coordination scheme in LTE-Advanced networks with femtocells.
For comparison purpose, the performances of the network with all the carriers fully reused between F-BS are also given.
The simulation results of the *Throughput* TP of each femtocell F-BS according to the simulated scenarios are shown in Fig. 4. It's clear that the observed TP of the majority of F-BSs with our proposed channel allocation method is two times higher than using the Round-Robin Algorithm.

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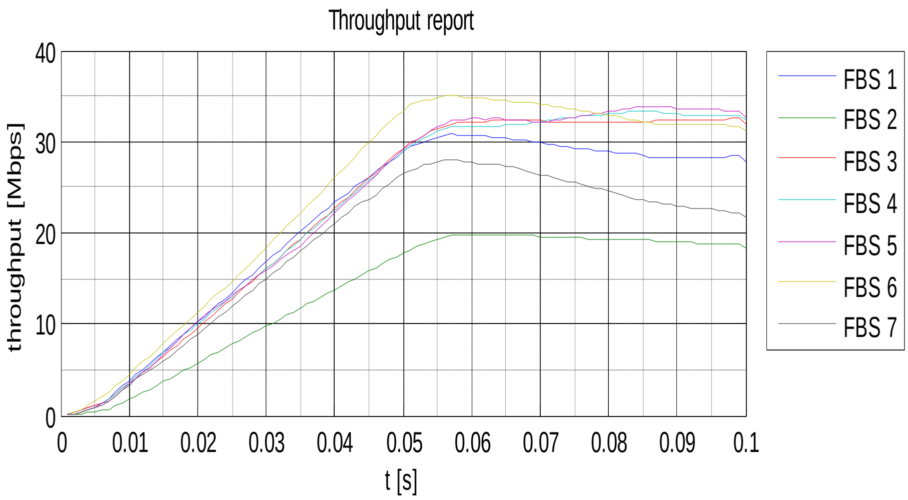
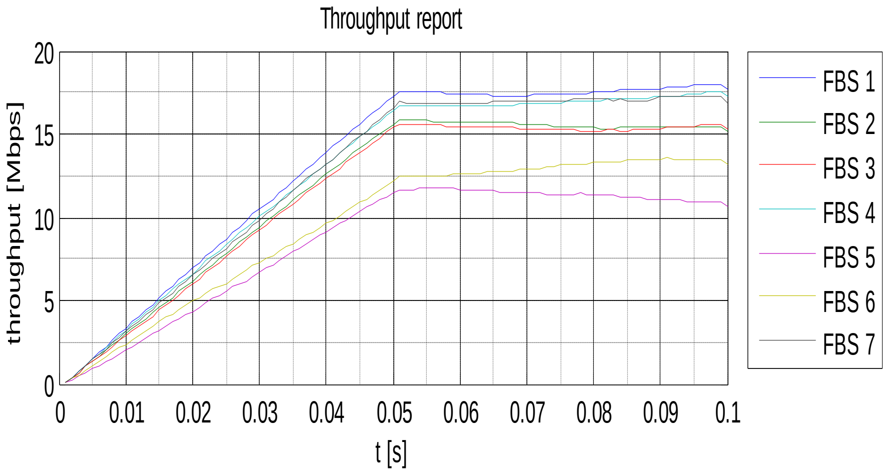
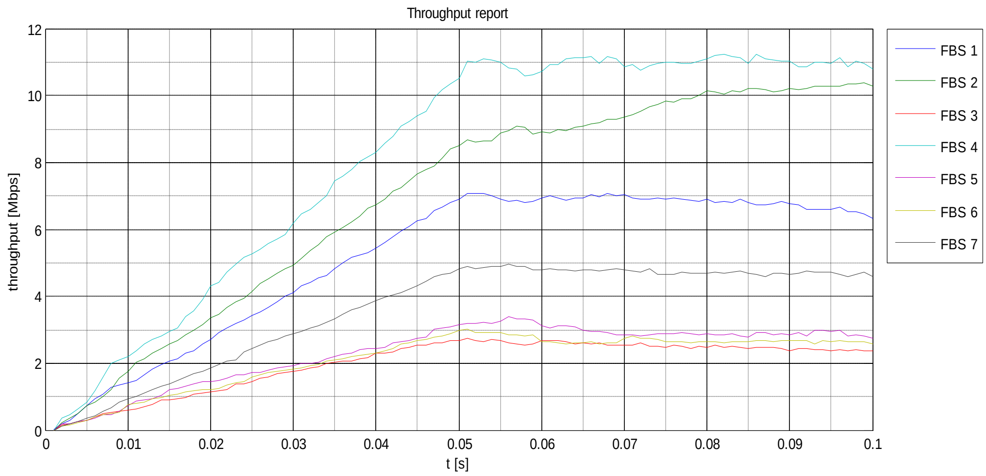


(a)



(b)



(c)

Fig4 : Throughput comparison: (a) TRIPLET Algorithm, (b) Round-Robin scheduling Algorithm, (c) Proportional Fair Scheduling Algorithm

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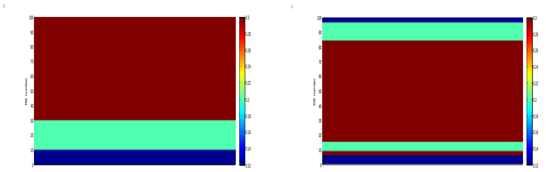
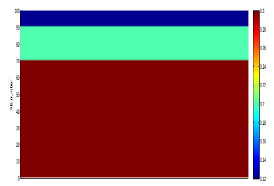
The following figure illustrates the femtocell power allocation within the RBs of (F-BS5, F-BS1, F-BS2) according to AHRS Scheme. It shows that the majority of the RBs are allocated to L1-users with 0.3dBm per RB (red zone), then to L2-users with 0.2dBm (green zone) and finally for L3-users with 0.12dBm (blue zone).

Consequently the User-Throughput vary considerably according to the User-Levels as it's shown in Fig.6 (a), while maintaining the same SINR (Fig6. (b)).

To satisfy the enterprise aims, F- BS has to serve in priority L1 users and satisfy their requested QoS first. Then if enough resources exist, it can serve L2 users and so on for users from L3 priority.



(a) F-BS1 (b) F-BS2



(c) F-BS5

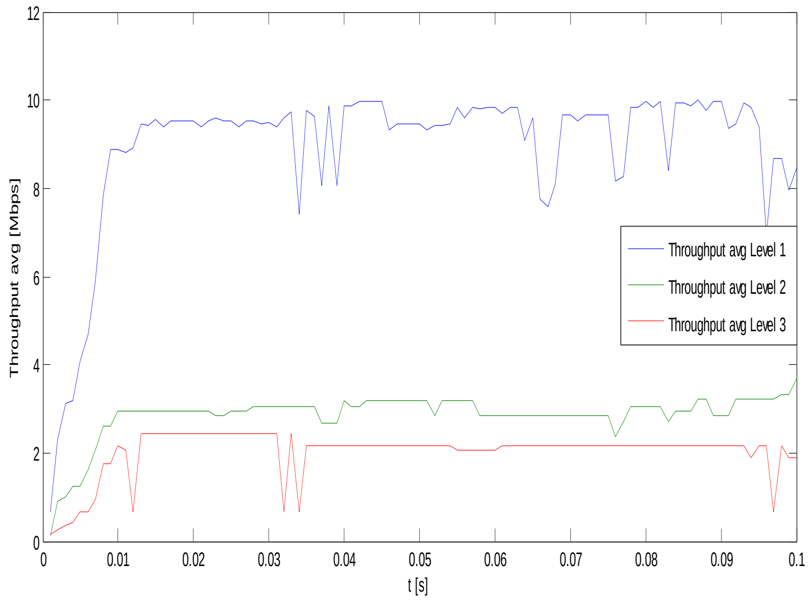
Fig5: FemtocellPower allocation in RB-Grid

6. CONCLUSION

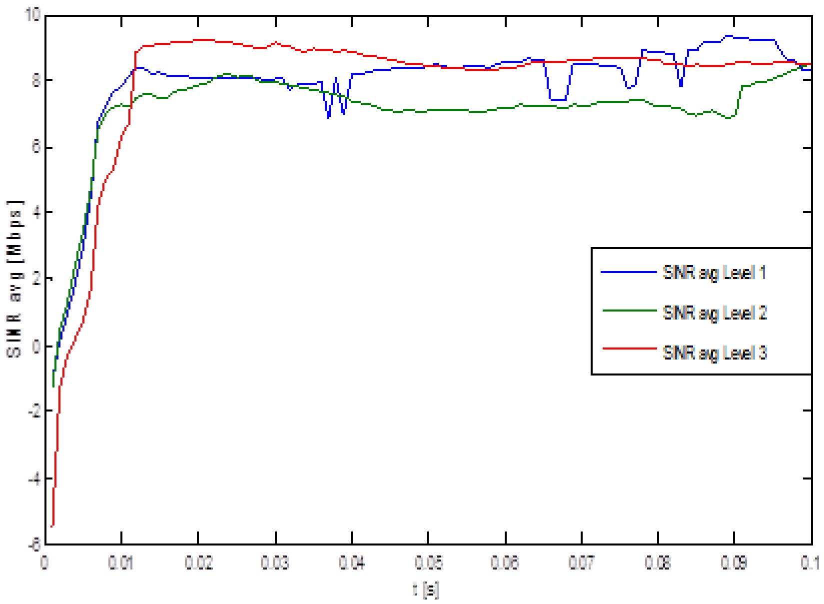
In this work, firstly, we have shed light on the interference management and energy consumption profile of femtocell deployments. Then we proposed an autonomic cognitive femtocell architecture that aims to efficiently utilize the radio frequency spectrum while meeting the service requirements of the clients. A joint power control, base station assignment, and channel assignment scheme is derived to efficiently maximize the overall throughput according to the number of users per femtocell and their access Level.

In this paper, we present a preliminary version of a Autonomic system level simulator for Femtocells networks.

In future works we will also focus on the uplink transmission and investigate the effect of uplink transmission upon the overall system capacity.



(a) Averaged Throughput Report of $L_{i=1..3}$ –Users in F-BS5



(b) Averaged SINR Report of $L_{i=1..3}$ –Users in F-BS5

Fig 6. Performance Parameters Reports in F-BS5

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