Dynamic Traffic Management for Green Open Access Femtocell Networks

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ABSTRACT

***Abstract*—The exponential increase in high rate traffic driven by the new generation of wireless services is expected to overload cellular network capacity in the near future. Femtocell networks have recently been proposed as an efficient and cost-effective solution to enhance cellular network capacity and coverage. However, dense and unplanned deployment of new Base Stations (BSs) and their uncoordinated operation may increase the system power consumption and rise co-channel interference. Thus, efficient schemes are essential for managing femtocell activity and improving the system performance. Classical cell switch off and discontinuous transmission (DTX) algorithms aim at improving the network Energy Efficiency (EE) in lightly loaded scenarios. In this paper, we propose a novel multi-cell architecture for Open Access femtocell networks, which also enables energy saving at medium and high loads without compromising the end-user performance.**

I. INTRODUCTION

Mobile cellular networks are tremendously successful, which results in wide proliferation and demand for ubiquitous heterogeneous broadband mobile wireless services. To take advantage of this usage evolution, cellular networks can integrate *femtocell* access points (FAPs) also known as *Home evolved Node-Bs* (HeNBs) [1]. HeNBs are low power access points that offer radio coverage with a given wireless technology while a broadband wired link connects them to the backhaul network of a cellular operator. Such a technical solution presents several benefits both to operators and end consumers. The latter will obtain a larger coverage, a better support for high data rate services, and a prolonged battery life of their devices. The advantages mainly come from the reduced distance between an end-user terminal and the access point, the mitigation of interference due propagation and penetration losses, and the limited number of users served by a HeNB.

Furthermore, recent economical investigations claim that femtocell deployment might reduce both the Operational Expenditure (OPEX) and Capital Expenditure (CAPEX) for cellular operators [2].

Cellular network energy consumption might be drastically increased by the massive and uncoordinated roll out of additional base stations. The growth of energy consumption will cause an increase in the global carbon dioxide (CO_2) emissions and impose more and more challenging operational costs for operators. Relationships between EE, service constraints, and deployment efficiency (DE) are not straightforward and reducing the overall energy consumption while adapting the target of spectral efficiency to the actual load of the system and QoS emerges as a new challenge in wireless cellular networks.

Cao and Fan [3] investigated the tradeoff between EE and user performance in two-tier networks. However, they only considered irradiated RF power in the analysis. Badic et al. [4] as well as Fehske et al. [5] compared EE in different size cells. Chen et al. studied how the density of small cells affects the system EE [6]. We have recently proposed a *Ghost Femtocell* algorithm that lowers the HeNBs irradiated power and reduces interference trading off transmission energy for frequency resources [7]. Ashraf et al. [8] and 3GPP [9] investigated energy saving procedures that allow a HeNB to dynamically deactivate/activate transmission functionalities according to UEs presence/absence in its coverage area. Due to the static properties of the indoor femtocell deployment scenario, this mechanism operates at a mid-time scale (several minutes or hours). In order to limit the number of underutilized BSs in the cellular network, Son et al. considered BS operation and the related problem of UE association jointly [10]. Frenger et al. proposed Cell DTX [11] to enable BSs to switch off radio in subframes where there are no user data transmissions. Such a fast adaptation mechanism allows a great energy saving especially in low traffic scenarios.

Most of the work in the past has focused on improving the EE of BSs at low load or in the absence of end-users. However, in this paper, we propose a novel architecture that improves system EE even at moderate load scenarios. In particular, we introduce a novel algorithm for multi-cell traffic management that dynamically distributes user data amongst neighboring femtocells and adaptively controls their activity. Such a dynamic activation/deactivation of HeNBs reduces the system power consumption and also limits co-channel interference amongst femtocells. These gains come at the expense of an increasing packet delay, which is acceptable if it stays within the application QoS requirements.

II. SYSTEM MODEL

In this paper, we consider a mobile wireless cellular network in which mobile terminals and base stations implement an OFDMA air interface based on 3GPP/LTE downlink specifications [12]. OFDM symbols are organized into a number of physical Resource Blocks (RBs) consisting of 12 contiguous sub-carriers for 7 consecutive OFDM symbols. With a bandwidth of 10 MHz, 50 RBs are available for data transmission. Each user is allocated one or several RBs in two consecutive

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slots, i.e., the Transmission Time Interval (TTI) is equal to two slots and its duration is 1 ms. The overall channel gain is composed of a fixed distance dependent path loss, a slowly varying component modeled by lognormal shadowing, and Rayleigh fast fading with unit power. Table I shows key model parameters including shadowing, fast fading, the macrocell antenna gain, and the transmission power.

TABLE I
MAIN SYSTEM MODEL PARAMETERS

Parameter	value
Carrier frequency	2.0 GHz
Carrier bandwidth	10.0 MHz
Inter-site distance	500 m
eNB Tx power	40W
eNB antenna gain after cable loss	13 dB
HeNB maximum Tx power	10 mW
HeNB antenna gain after cable loss	0 dB
Shadowing distribution	Log-normal
Shadowing standard deviation	8 dB
Autocorrelation distance of shadowing	50 m
Fast fading distribution	Rayleigh
Thermal noise density	N_0=-174dBm/Hz

A. Deployment and Path loss Models

We assume that femtocells are deployed according to the 3GPP grid urban deployment model [13] that represents a single floor building with 10 m x 10 m apartments placed next to each other in a 5 x 5 grid. In such a scenario each HeNB can simultaneously serve up to to 4 users ($N_{MAX} = 4$). The block of apartments belongs to the same region of a macro BS (i.e. eNB). Moreover, we assume that 6 additional eNBs surround the central macrocell generating additive interference for both macro and femto users. To consider a realistic case in which some apartments do not have femtocells, we use a system parameter ρ_d called a deployment ratio that indicates the percentage of apartments with a femtocell.

We use two different models to capture the signal propagation effect based on the 3GPP specifications [13]:

1) Transmissions from eNBs to cellular users:

$$PL(dB) = 15.3 + 37.6 \log_{10} d + L_{ow},$$

where d is the distance between the transmitter and the receiver (in meters) and L_{ow} is the penetration losses of an outside wall equal to 20 dB.

2) Transmissions from HeNBs to cellular users:

$$\begin{aligned} PL(dB) =& 38.46 + 20 \log_{10} d + 0.7 d_{2D,indoor} \\ &+ 18.3 n^{((n+2)/(n+1)-0.46)} + q \cdot L_{iw}, \end{aligned}$$

where d is the distance between the transmitter and the receiver (in meters), $d_{2D,indoor}$ is the two dimensional separation between the transmitter and the receiver (in meters), n is the number of penetrated floors, q is the number of walls that separate the user apartments and the transmitting HeNB apartment, L_{iw} is the penetration loss of walls within the grid of apartments equal to 5 dB. The third term in the above expression represents the penetration loss due to walls inside an apartment. This attenuation is modeled as a log-linear value equal to 0.7 dB/m. The fourth term represents the penetration loss through different floors. In the considered single floor building scenario, $d = d_{2D,indoor}$ and $n = 0$.

B. BS Power Consumption Model

Our investigation is based on the power consumption model by Auer et al. [14] that provides an accurate estimation of the BS power consumption considering different radio components such as Antenna Interface, Power Amplifier, Baseband Interface, Cooling, etc. According to this model, the required input power P^* to attain a certain RF output power P_{out} can be computed as:

$$P^* = \begin{cases} P_0 + \Delta_p P_{out}, & 0 < P_{out} \leq P_{max}; \\ P_{sleep}, & P_{out} = 0. \end{cases} \tag{1}$$

where P_{max}, P_0, and P_{sleep} indicate the RF output power at maximum load, minimum load, and in sleep mode, respectively. Δ_p is a coefficient that represents the dependency of the required input power on the traffic load.

The proposed model confirms that

- HeNB power consumption is slightly related to the load, thus, power control algorithms have practically no impact on the system power consumption of femtocells. EE can be improved by dynamically switching off the femtocells that are not serving active users;
- eNB power consumption is strongly related to the load, thus, macrocell offloading via femtocell deployment can greatly enhance the overall cellular network EE.

Table II shows the classic values of P_{max}, P_0, and Δ_p for eNBs and HeNBs. Note that the value of P_{sleep} depends on the hardware components that are deactivated during sleep intervals. However, more deactivated hardware components result in a slower reactivation process.

TABLE II
BS POWER MODEL PARAMETERS

BS type	P_{max} [W]	P_0 [W]	Δ_p
eNB	40	712	14.5
HeNB	0.01	10.1	15

III. CLASSIC AND EXTENDED DTX SCHEMES

We now briefly introduce the classical cell DTX and an extended version of this scheme, which we refer as cell E-DTX (cf. Figure 1). Cell DTX allows (H)eNBs to avoid radio operations whenever there is no user data transmitted in the cell. While in the classic approach the (H)eNB tries to serve its UEs within the shortest delay, in E-DTX, it buffers the received data and transmits as much as possible during the *transmit intervals*. Therefore, the (H)eNB efficiently exploits available frequency resources and introduces longer *silent intervals* at the cost of a higher delay experienced by the application layer. Due to the limited number of UEs that can be simultaneously served by a HeNB and the short distance between the access point and the user terminal, the spectrum resource is often under-utilized at femtocells. Hence, E-DTX is a very promising approach in femtocell deployment, however, it is important to limit the additional delay due to buffering to satisfy the application QoS constraints.

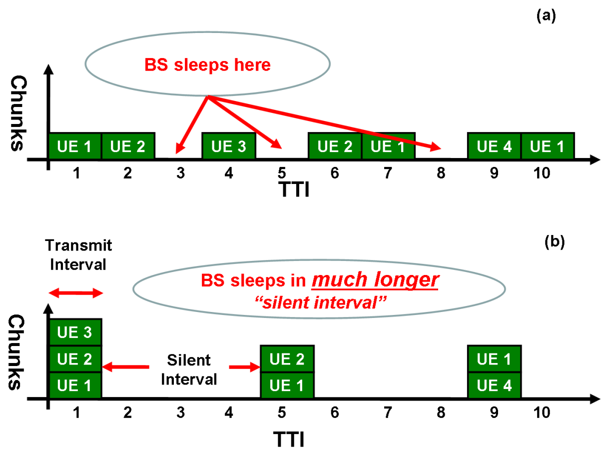

Fig. 1. (a) Classic DTX and (b) E-DTX schemes.

IV. Problem Statement

A. Notation

In the following, matrices and vectors are denoted by boldface symbols, respectively. For instance, the entry corresponding to the *i-th* row and *j-th* column of matrix $\mathbf{X}$ at *k-th* TTI is denoted by $X_{i,j}(k)$. The null matrix of size $[N \times M]$ is represented by $0_{N,M}$. Finally, $\mathcal{A} = \{1, ..., N\}$ denotes a set composed of N elements.

Consider a macrocell region overlaid by a set of femtocells $\mathcal{F} = \{1, ..., N_F\}$ deployed in a block of apartments as described in Section II-A. The eNB serves outdoor UEs and indoor UEs that cannot be served by active HeNBs. Femtocells operate in the same bandwidth of the macrocell and offer service to indoor UEs ($\mathcal{UE} = \{1, ..., N_{UE}\}$) located in their coverage areas. Each UE j identifies the set of closest femtocells (i.e. $\mathcal{F}_j$) by comparing the strength of the Reference Signal Received Power (RSRP) with a predefined threshold.

B. Optimization Problem

We aim at dynamically associating UEs and HeNBs to minimize the femtocell network energy consumption (within observed TTIs $\mathcal{T} = \{1, ..., N_{TTI}\}$) while meeting QoS (latency and throughput) constraints. This optimization problem can be expressed as

$$\min \sum_{k\in\mathcal{T}} \sum_{i\in\mathcal{F}} P_i^*(k)$$

s.t.

$$n_i(k) \leq N_{MAX} \quad \forall\, i \in \mathcal{F} \quad \forall\, k \in \mathcal{T} \tag{2}$$

$$\sum_{i\in\mathcal{F}_j} a_i(k) X_{ji}(k) \leq 1 \quad \forall\, j \in \mathcal{UE} \quad \forall\, k \in \mathcal{T} \tag{3}$$

$$\sum_{p=k}^{k+d} \sum_{i\in\mathcal{F}_j} R_{ji}(p) a_i(p) X_{ji}(p) \geq PQ_{jd}(k) \;\; \forall\, j \in \mathcal{UE} \;\; \forall\, k \in \mathcal{T} \tag{4}$$

$$a_i(k) \in \{0, 1\} \quad \forall\, i \in \mathcal{F} \;\; \forall\, k \in \mathcal{T}$$

$$X_{ji}(k) \in \{0, 1\} \quad \forall\, (i, j) \in \mathbf{X} \;\; \forall\, k \in \mathcal{T}$$

where the parameters used in the problem statement are presented in Table III. Eq. (2) indicates that the maximum number of UEs that can be contemporarily served by a HeNB is limited by N_{MAX}. Eq. (3) underlines that the *j-th* UE can be served only by one of the HeNBs that belong to the set F_j. Finally, Eq. (4) points out that each packet arriving in the queue of the *j-th* UE at TTI n has to be scheduled within its delay tolerance d. This ensures that QoS constraints of femtocell users are satisfied.

TABLE III
System Parameters

Set of femtocells in the macrocell region	$\mathcal{F}$
Set of UEs in femtocells coverage area	$\mathcal{UE}$
Set of neighboring femtocells of *j-th* UE	$\mathcal{F}_j$
Set of observed TTIs	$\mathcal{T}$
i-th HeNB power consumption (see eq. 1)	P_i^*
Number of UEs associated with *i-th* HeNB	n_i
Active HeNB vector	$\mathbf{a}$
UE/HeNB service matrix	$\mathbf{X}$
Number of UEs that can be simultaneously served by a HeNB	N_{MAX}
Useful data allocated to *j-th* UE by the *i-th* HeNB	R_{ji}
Packet size for user j and delay tolerance d	PQ_{jd}
Delay threshold for low and high priority traffic	D_{th}
Set of activated femtocells	$\hat{\mathcal{F}}$
Set of UEs with high priority traffic	$\mathcal{UE}^H$
Average CQI	$\mathbf{CQI}^\star$
Set of low priority UEs that can be served by $\hat{\mathcal{F}}$	$\mathcal{UE}^L$
Maximum delay tolerance of a packet	D_{Max}
Packet queue for low priority users $\mathcal{UE}^L$	$\mathbf{PQ}^L$
Metric to associate low priority UEs and activate HeNBs	$\mathbf{M}$

The above formulation corresponds to a combinatorial problem with high computational complexity especially in dense urban scenarios. Hence, to find a near-optimal solution, we propose a heuristic algorithm that can be implemented in networked femtocell deployment scenarios with a limited amount of signalling overhead.

V. Multi-cell Architecture for Dynamic Cell DTX and Traffic Management

Figure 2 presents the proposed architecture for implementing multi-cell DTX in a femtocell network. In such an architecture, the femtocell network is characterized by a local gateway called a Femtocell Coordinator (FC). The FC dynamically manages the activity of HeNBs in order to limit the network power consumption while meeting traffic constraints. We should note here that the FC is connected to HeNBs via a high speed low latency backhaul, which allows the implementation of fast adaptation mechanisms without affecting communication reliability. The FC is responsible for three main functionalities:

- traffic management,
- dynamic UE/HeNB association,
- HeNB activation.

The FC receives from the core network the data related to the set of UEs attached to its femtocell network (cf. Figure 3), so it can classify the received traffic according to the

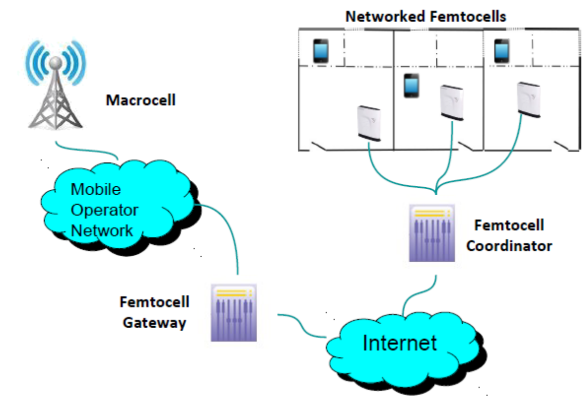

Fig. 2. Proposed architecture for green femtocell networks.

delay constraint [15]. High priority traffic needs to be sent within the next few TTIs, before the packet will be dropped by the user application. On the contrary, low priority traffic is characterized by less stringent constraints. This classification is realized by comparing the packet delay tolerance with the delay threshold (D_{th}). D_{th} is a system parameter that depends on the time necessary to activate idle HeNBs and permits these femtocells to acquire channel quality information (CQI) for data transmissions.

Algorithm 1 describes the selection of the HeNBs set ($\hat{\mathcal{F}} \subseteq \mathcal{F}$) in charge of serving high priority UEs ($\mathcal{UE}^H \subseteq \mathcal{UE}$). The coordinator activates serving femtocells by exploiting the stored average CQI ($\mathbf{CQI}^\star$) that indicates the status of links between femtocells $\mathcal{F}$ and neighboring users $\mathcal{UE}$. We recall that such an assignment is represented by service matrix $\mathbf{X}$ that indicates whether UE j is served by HeNB i (i.e X_{ji}=1).

Algorithm 1 Algorithm to select the set of priority users $\mathcal{UE}_H$ and serving HeNBs $\hat{\mathcal{F}}$

1: $\mathcal{UE}^H \Leftarrow \{j\} \in \mathcal{UE}\;\; s.t.\;\; PQ_{jd} > 0,\;\; d \leq D_{th}$
2: $\mathbf{X} = 0_{\|\mathcal{UE}\|,\|F\|}$
3: $\hat{\mathcal{F}} = \{\emptyset\}$
4: **for all** $j \in \mathcal{UE}^H$ **do**
5: $\quad i^\star = \underset{i}{\text{argmax}}\;\; CQI^\star_{ji}$
6: $\quad \hat{\mathcal{F}} = \hat{\mathcal{F}} \bigcup \;\{i^\star\}$
7: $\quad X_{ji^\star} = 1$
8: **end for**
9: $\mathbf{n} = 0_{1,\|\hat{\mathcal{F}}\|}$
10: $n_i = \sum_{j\in\mathcal{UE}_H} X_{ji}\;\; \forall\, i \in \hat{\mathcal{F}}$

Then, the FC uses $\mathbf{CQI}^\star$ to define connectivity set $\mathcal{UE}^L \subseteq \mathcal{UE}$ composed of by the UEs characterized by only low priority traffic. Therefore, FC assigns a part of these UEs to set $\hat{F}$ such that available frequency resources can be used to transmit additional data packets.

Spectrum resource is often underutilized at femtocells, however, we improve the femtocell EE by increasing the load of active HeNBs. Furthermore, the more data is transmitted during the *activated* TTIs, the higher the possibility of introducing sleep modes in future TTIs. Finally, the FC routes the traffic of selected UEs to their associated HeNBs and subsequently buffers the traffic that will not be scheduled in following TTIs. It should be noted that the FC is not in charge of the Radio Resource Management (RRM) scheduling, which is independently implemented at activated femtocells.

Algorithm 2 describes the approach that assigns low priority users to set $\hat{F}$. Note that the rational behind using metric $\mathbf{M}$ is to ensure that the maximum amount of low priority traffic is allocated to the remaining resources of each HeNB.

Algorithm 2 Algorithm to allocate low priority users to activated femtocells $\hat{\mathcal{F}}$

1: $\mathbf{PQ^L} \Leftarrow PQ_{jd}\;\; s.t.\;\; j \in \mathcal{UE}^L,\;\; d \leq D_{Max}$
2: $\mathbf{CQI^L} \Leftarrow CQI^\star_{ji}\;\; s.t.\;\; j \in \mathcal{UE}^L,\;\; i \in \hat{\mathcal{F}}$
{line 1,2: extract data and CQI related to the set $\mathcal{UE}^L$}
3: $\mathbf{M} = 0_{\|\mathcal{UE}^L\|,\|\hat{F}\|}$
4: $M_{ji} = (\sum_{d=1}^{D_{max}} PQ^L_{jd}) \cdot CQI^L_{ji}$
5: **while** $\mathbf{ANY}(\mathbf{M})\;\; \&\;\; \mathbf{ANY}(\mathbf{n} < N_{Max})$ **do**
6: $\quad (j^\star, i^\star) = \underset{j,i}{\text{argmax}}\;\; M$
7: $\quad X_{j^\star i^\star} = 1$
8: $\quad n_{i^\star} = n_{i^\star} + 1$
9: $\quad M_{j^\star i} = 0\;\; \forall\, i \in \hat{\mathcal{F}}$
10: **end while**
{line 5: $\mathbf{ANY}(\mathbf{v}) = 1$ **IF** $\exists\; 0 < i \leq \|\mathbf{v}\|\;\; s.t.\;\; v_i \neq 0$; **ELSE** $\mathbf{ANY}(\mathbf{v}) = 0$}

We foresee that the proposed coordination scheme can be realized within COMP framework in which user data is available at multiple (H)eNBs and the transmitting BS may change from one subframe to another [16]. The main difference is due to the introduction of the FC in the femtocell network architecture, which enables dynamic cell selection and HeNB activity management without direct cooperation between neighboring HeNBs. Furthermore, in our approach, FC routes user data only towards HeNBs that are in charge of transmissions, which results in limited network overhead. The proposed scheme has also an impact on the LTE standard from the control signalling point of view. For example implementing cell DTX without losing UE/(H)eNB connectivity is currently a topic of investigation in the telecommunication community [11], however, it is beyond the scope of this paper.

VI. Simulation Results

In this section, we assess the effectiveness of the proposed Multi-Cell DTX (MC-DTX) scheme by comparing its performance with the reference E-DTX approach. MC-DTX is based on Open Access femtocells while E-DTX can be implemented in both Closed Access and Open Access schemes. Thus, with respect to the E-DTX scheme:

- in the Closed Access Femtocells deployment, a UE can be served by a HeNB only if the access point is placed in the user apartment;

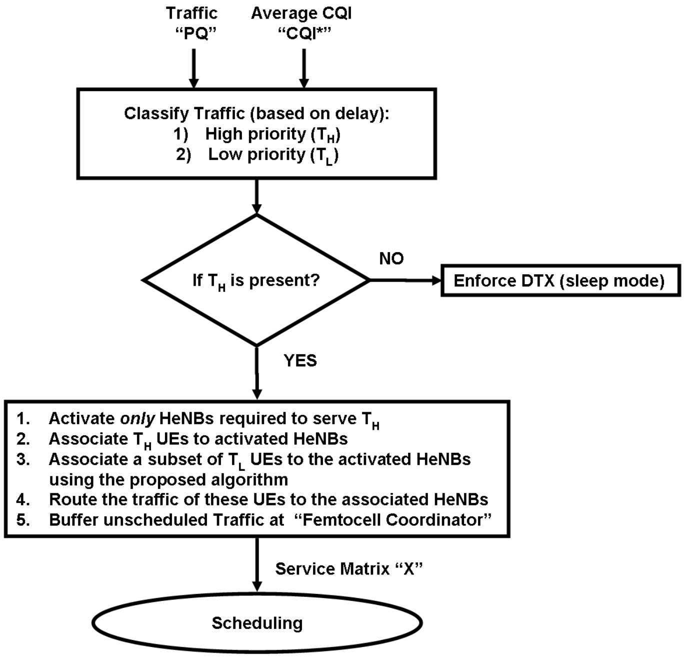

Fig. 3. Proposed algorithm to dynamically associate traffic and HeNBs at femtocell networks.

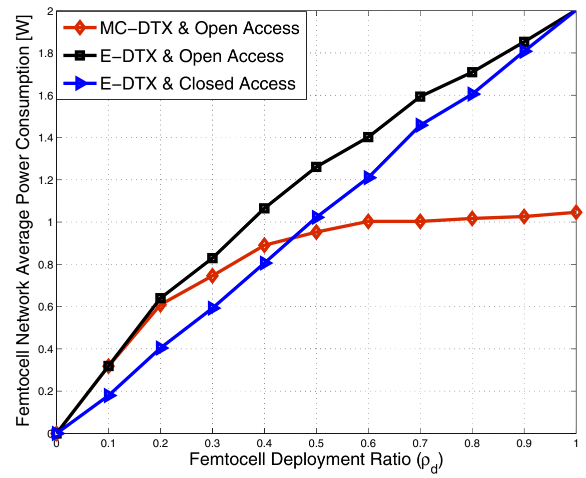

Fig. 4. Femtocell Network Average Power Consumption with respect to the femtocell deployment ratio ρ_d.

- in the Open Access Femtocells deployment, UEs can be in the coverage area of several femtocells. Hence, each user selects the available HeNB associated with the best RSRP.

In both E-DTX and MC-DTX, the system buffers UE data to allow as longer as possible *silent intervals* at serving HeNBs. However, MC-DTX exploits dynamic cell selection amongst neighboring HeNBs to increase the amount of traffic sent by activated HeNBs within their *transmit interval*. We consider that the HeNB power consumption during sleep mode satisfies $P_{sleep} \ll P_0$ and we do not investigate its impact on both E-DTX and MC-DTX schemes. In fact, we expect that in near future the research progress on agile hardware will permit dynamic and energy efficient HeNBs activation/deactivation.

We consider a scenario in which 30 cellular users are deployed in the macrocell area. In line with recent studies [17], we assume that 70% of the traffic is generated by indoor UEs. The results are averaged over 60 independent runs. We simulate $15 \cdot 10^3$ independent TTIs during each run and update channel fading instances at each TTI. At the beginning of each run, HeNBs and indoor UEs are randomly deployed in a block of apartments placed at the macrocell edge. Outdoor UEs are randomly deployed in the macrocell region. The traffic generated by cellular users is modeled as a near real time video (NRTV) traffic [18]. A proportional fair (PF) [19] scheduler is used at both the macrocell and neighboring femtocells. Finally, link adaptation is implemented in downlink transmissions for which modulation and coding schemes are selected according to momentary feedback transmitted by the served UE. In our simulations, triangle marked lines, squared marked lines, and diamond marked lines, respectively correspond to the E-DTX with Closed Access, E-DTX with Open Access, and MC-DTX with Open Access.

First, we want to discuss the impact of the proposed schemes in terms of the femtocell power consumption. Figure 4 shows the average power consumption in the femtocell network with respect to femtocell deployment ratio ρ_d. The difference between the Open Access and Closed Access schemes is related to the number of UEs served by HeNBs (i.e. the load of the femtocell network): in the Open Access deployment, the probability that a UE can be served by a HeNB is higher than in the Closed Access deployment. Therefore, Closed Access results in longer *silent intervals* and lower power consumption at the femtocell network. Note that the gap between Open Access and Closed Access schemes is maximum for medium values of deployment ratio and decreases in very dense deployment scenarios. In particular, when $\rho_d = 1$, all the apartments in the block are equipped with a femtocell and the performance of these two strategies are coincident. However, while in E-DTX schemes the power consumption fairly increases with the femtocell deployment ratio, the MC-DTX power consumption slightly changes in medium/high femtocell density ($\rho_d \geq 0.4$) scenarios. In fact, in such a range of values, the capacity of the femtocell network may exceed the service request and the MC-DTX avoids energy wastage by adapting the femtocells activity to the network topology and load through the implementation of a dynamic UE-cell association. Simulation result shows that our proposal outperforms the reference approaches achieving up to the 50% of power saving.

Our proposed algorithm does not permit UEs to select the HeNB associated with the best RSRP. Hence, we may expect that user performance decreases when using MC-DTX. Figure 5 presents the impact of the proposed scheme on the performance perceived by femto users. We show the average throughput of the femtocell network with respect to the femtocell deployment ratio for the compared schemes.

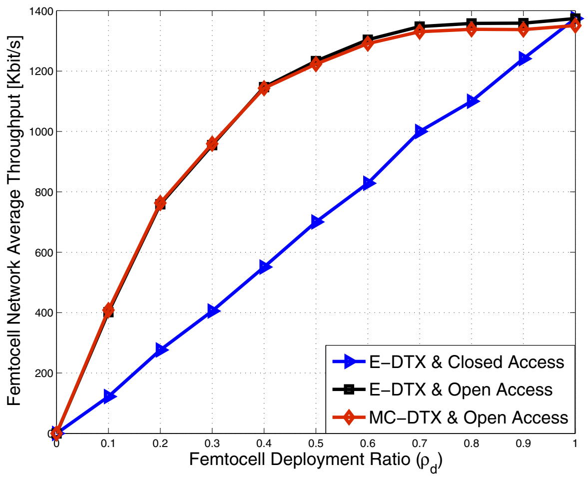

Fig. 5. Femtocell Network Average Aggregate Throughput with respect to femtocell deployment ratio ρ_d.

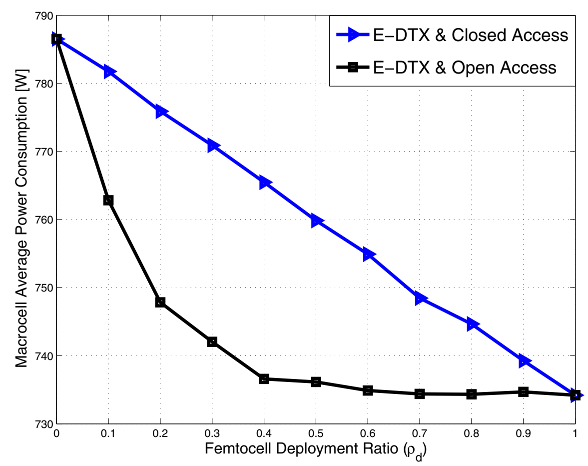

Fig. 6. Macrocell Average Power Consumption with respect to femtocell deployment ratio ρ_d.

As previously mentioned, the Closed Access scheme limits the macrocell offloading due to femtocell deployment, which results in a higher power consumption at the eNB (cf. Figure 6) and a lower throughput of the femtocell network. Simulation results show that the Open access schemes lead to up to 136% throughput improvement in the femtocell network. However, MC-DTX and E-DTX with Open Access femtocells perform roughly in the same way.

VII. Conclusions

The future 3GPP/LTE femtocells deployment is expected to be dense: the deployment of new BSs and their uncoordinated operation may raise both the level of interference and the aggregate power consumption of the cellular network. Cost-effective strategies are essential to manage this novel scenario and to guarantee the QoS of cellular users. We have proposed MC-DTX that permits femtocell networks to cooperatively adapt their activity to traffic scenarios dynamically limiting the network power consumption. Simulation results confirm that the proposed strategy strongly enhances the system EE while meeting QoS constraints. Future studies will consider more heterogeneous cellular networks in which different size cells are deployed in the same geographic area to enhance cellular network capacity and coverage.

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