On Improving Network Capacity for Downlink and Uplink of Two-Tier LTE-FDD Networks

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***Abstract*—A Long Term Evolution-Frequency Division Duplexing (LTE-FDD) small cell is one of the promising solutions for improving service quality and data rate in both the uplink and downlink of home users. Small cell (e.g., femtocell, picocell, microcell) is short range, low cost and low power base station installed by the indoor consumers. However, the avoidance of interferences is still an issue that needs to be addressed for successful deployment of small base stations (SBS) within existing macro cell networks mainly in co-channel deployment. Moreover, interferences are strongly dependent on the type of access control of small cells. Closed and open access are in conflict interests for macro users and home users in the uplink and downlink. To mitigate this conflict, we propose a fully distributed algorithm based on the shared time access and executed by LTE-FDD small cells, in order to reduce the effect of interferences, improve QoS of users, and maximize the overall capacity of downlink and uplink in two-tier LTE networks when small cells are deployed randomly. Simulation results validate our algorithm and show the improvement attained in offloading macro cell and satisfying QoS requirements of home users compared to the closed and open access mechanisms in both the uplink and downlink.**

***Index Terms*—Small Base Station(SBS), Macro cell networks, Co-channel, Long Term Evolution(LTE), Frequency Division Duplexing(FDD).**

I. Introduction

Nowadays, there is an intense demand for higher data rate. Users expect to attain high data rates in both downlink and uplink to satisfy their increasing traffic demands. This has triggered the design and development of new cellular standards like LTE, a standard developed by the Third Generation Partnership Projects (3GPPs)[1]. Indeed, the Long Term Evolution (LTE) is 4G technology based on Orthogonal Frequency Division Multiple Access (OFDMA) which appears to be the most promising candidate to reach higher data rates and enhance spectral efficiency. LTE-FDD (Frequency Division Duplexing) and LTE-TDD (Time-Division Duplex) are two variant standards of LTE. LTE-TDD does not require a paired spectrum since transmission (uplink) and reception (downlink) occur in the same channel. In LTE-FDD, there is a paired spectrum with different frequencies, one for uplink transmission and the other for downlink reception. [2]. Depending on traffic statistics given by Huawei and Nokia-Siemens [3],[4], 60% of traffic distribution in cellular networks comes from indoor environments like work, home,...etc. The indoor users generally get low data rates due to poor cellular network signal coverage inside buildings. In order to increase the network signal coverage, LTE has developed a small cell for indoor coverage. Small cells are short-range low-cost low-power BSs installed by the consumers who work in the licensed frequency bands and they are connected to broadband Internet backhaul [5],[6]. A small cell gives the opportunity to service providers to extend service coverage indoors, particularly where access would otherwise be limited or unavailable. Consequently, the indoor consumers are satisfied with higher data rates and reliability. Meanwhile, the operator offloads the amount of traffic on macro cell network. By contrast, these advantages are not easy to accomplish. There are still several constraints and challenges that vendors and operators must face so as to deploy a large number of small cells within the existing macro cells. The major challenges that operators have to face are the interferences that emerge in two-tier networks, which degrade the whole network performance [7]. In two-tier networks, interference is classified as follows:

- Cross-tier interference is caused by an element of the small cell tier to the macro cell tier and vice versa.
- Co-tier interference occurs between elements of the same tier, for example, between neighboring small cells.

The techniques used for allocating the spectral resources to the macro cell and small cells have an impact on the strength of interferences as well as on the method used to access the small cells. In an orthogonal deployment of macro cells and small cells where separate carriers are assigned to each tier, cross-tier interference is entirely removed. This happens at the cost of decreasing the spectral efficiency of the network. Oppositely, co-channel deployments where the carriers are shared between both tiers can result in higher spectral efficiency throughout the use of self-organization techniques. To face interferences in co-channel deployments, a smart allocation of the power, frequency and time resources of the small BS must be performed based on an accurate sensing of the radio environment, as well as an optimal tuning of its parameters. This way, cross-tier interference can be efficiently attenuated. Furthermore, the selection of an access control mechanism to small cells has dramatic effects on the performance of the overall network, mainly due to its role on defining the degree of interference. Different approaches have been proposed:

- Closed access: only a subset of the users, which is defined by the small cell owner.
- Open access: all customers of the operator have the right to make use of any small cell.

The remainder of the paper is organized as follows. We discuss the motivation and related work in Section II. We present the system model analysis in Section III and simulation and results in section IV. We present our solution and analysis results in section V. Finally, the paper concludes in Section VI.

II. Motivation and related work

In closed access, only registered home users can communicate with the small cell BS. it seems to be efficient to the home user, however it results in severe cross-tier interference from nearby macro users to home users in the uplink and to nearby macro users from small BS in the downlink. To mitigate this interference in closed access, previous studies have considered power control [8], frequency assignment [9], and a spectrum sensing approach [10]. An alternative is to provide an access to the nearby macro users that cause or experience strong interference to the small cell. This is known as open access. In the case of uplink, open access is generally preferred by home users and macro users[11]. In the case of downlink, the closed access mode is favorable for home users while macro users prefer the open access mode. The downlink capacity of open versus closed access has been studied using simulations for HSPA small cells [12], and OFDMA small cells [13]. To resolve the conflict in the case of downlink, a shared time access has been suggested as a compromise between home users and macro users to maximize the network throughput subject to a network-wide QoS requirement [14]. In this paper, we propose a fully distributed algorithm based on shared time access mode and executed by small cells to improve the overall network throughput system and QoS of macro and home users in both the downlink and uplink of Two-Tier LTE-FDD heterogeneous networks.

III. System model analysis

In our model, we focus the study on LTE-FDD [15] where there are two carrier frequencies, one for uplink transmission (f_{ul}) and one for downlink transmission (f_{dl}). Uplink and downlink transmission can occur simultaneously with the same BS or decoupled among different BSs. We consider a single LTE-FDD macro cell M with radius R_M centred at a Macro Base Station (MBS), and a variable number of LTE-FDD small BS N_s with radius r_s, distributed uniformly within the area covered by macro cell M. Each small BS does not overlap with each other. N_m macro users are randomly distributed within the area of macro cell M and $n_{h,i}$ users are randomly distributed within the serving small cell SBS_i. We consider a co-channel deployment when all small cells and the macro cell use the same band frequency. In our model, we take into consideration the cross-tier interferences between each small cell and macro cell, co-tiers interferences between small cells and a path loss and propagation models in order to estimate the SINR in the downlink and the uplink for each user. for more details and to study different access mechanism, we divide all the users in three categories, home users or small BS owners, macro indoor users and macro outdoor users.

$$N_m = N_{m_{(out)}} + N_{m_{(in)}} \tag{1}$$

N_m represents the total number of macro users, $N_{m_{(in)}}$ represents the number of macro indoor users who are under small BS and macro BS, and $N_{m_{(out)}}$ represents the number of macro outdoor users who are under macro BS service only.

$$N_{m_{(in)}} = \sum_{i=1}^{N_s} n_i \tag{2}$$

n_i represents the number of macro indoor users in the area of small cell SBS_i.

$$N_h = \sum_{i=1}^{N_s} n_{h,i} \tag{3}$$

N_h represents the total number of home users in the area of macro cell, and $n_{h,i}$ represents the number of home users in the area of small cell SBS_i.

A. SINR Estimation

In our analysis, the estimation of the received SINR of a macro outdoor user m_{out} in the downlink on subcarrier k, when the macro user is interfered from all the adjacent small cells, is expressed by the following equation:

$$\gamma^{dl}_{m_{out},k} = \frac{P_{M,k} G_{m,M,k}}{N_0 \triangle f + \sum_{j=1}^{N_s} P_{s_j,k} G_{m,s_j,k}} \tag{4}$$

The estimation of the received SINR of a macro indoor user m_{in} in the downlink is given by :

$$\gamma^{dl}_{m_{in},k} = \begin{cases} \frac{P_{M,k} G_{m,M,k}}{N_0 \triangle f + \sum_{j=1}^{N_s} P_{s_j,k} G_{m,s_j,k}} & \text{Closed access} \\ \frac{P_{s_i,k} G_{h,s_i,k}}{N_0 \triangle f + P_{M,k} G_{h,M,k} + \sum_{j \neq i}^{N_s} P_{s_j,k} G_{h,s_j,k}} & \text{Open access} \end{cases} \tag{5}$$

where $P_{M,k}$ is the transmit power of serving macro cell M on subcarrier k. $G_{m,M,k}$ is the channel gain between macro user m and serving macro cell M on subcarrier k. Similarly, $P_{s_j,k}$ is the transmit power of neighboring small cell SBS_j on subcarrier k.$G_{m,s_j,k}$ is the channel gain between macro user m and neighboring small cell SBS_j on subcarrier k. N_0 is a white noise power spectral density, and $\triangle f$ subcarrier spacing.

In case of a home user h on subcarrier k interfered by macro cell M and adjacent small cells, the received SINR in the downlink can be given by :

$$\gamma_{h,k}^{dl} = \frac{P_{s_i,k} G_{h,s_i,k}}{N_0 \triangle f + P_{M,k} G_{h,M,k} + \sum_{j \neq i}^{N_s} P_{s_j,k} G_{h,s_j,k}} \quad (6)$$

$P_{s_i,k}$ is the transmit power of small cell SBS_i on subcarrier k. $G_{h,s_i,k}$ is the channel gain between home user h and the small cell SBS_i on subcarrier k.

The estimation of the received SINR of a macro user outdoor m_{out} in the uplink on subcarrier k is given by :

$$\gamma_{m_{out},k}^{ul} = \frac{p_{m,k} G_{M,m,k}}{N_0 \triangle f + \sum_{j=1}^{N_s} \sum_{h=1}^{n_{h,j}} p_{h,k} G_{M,h,k}} \quad (7)$$

The estimation of the received SINR of a macro indoor user m_{in} in the uplink on subcarrier k is expressed by :

$$\gamma_{m_{in},k}^{ul} = \begin{cases} \frac{p_{m,k} G_{M,m,k}}{N_0 \triangle f + \sum_{j=1}^{N_s} \sum_{h=1}^{n_{h,j}} p_{h,k} G_{M,h,k}} \text{Closed access} \\ \frac{p_{h,k} G_{s_i,h,k}}{N_0 \triangle f + \sum_{m=1}^{N_m} p_{m,k} G_{M,m,k} + \sum_{j \neq i}^{N_s} \sum_{h=1}^{n_{h,i}+n_i} p_{h,k} G_{s_j,h,k}} \text{Open access} \end{cases} \quad (8)$$

where $p_{m,k}$ is the transmit power of a macro user on subcarrier k. $G_{M,m,k}$ is the channel gain between macro user m and serving macro cell M on subcarrier k. Similarly, $p_{h,k}$ is the transmit power of a home user on sub-carrier k. $G_{m,s_j,k}$ is the channel gain between macro user m and neighboring small cell SBS_j on subcarrier k.

The estimation of the received SINR of a home user h in the uplink on subcarrier k is given by :

$$\gamma_{h,k}^{ul} = \begin{cases} \frac{p_{h,k} G_{s_i,h,k}}{N_0 \triangle f + \sum_{m=1}^{N_m} p_{m,k} G_{M,m,k} + \sum_{j \neq i}^{N_h} \sum_{h=1}^{n_{h,i}} p_{h,k} G_{s_j,h,k}} \text{Closed access} \\ \frac{p_{h,k} G_{s_i,h,k}}{N_0 \triangle f + \sum_{m=1}^{N_m} p_{m,k} G_{M,m,k} + \sum_{j \neq j}^{N_h} \sum_{h=1}^{n_{h,i}+n_i} p_{h,k} G_{s_j,h,k}} \text{Open access} \end{cases} \quad (9)$$

where $p_{h,k}$ is the transmit power of a home user on subcarrier k. $G_{s_i,h,k}$ is the channel gain between a home user and its serving small cell SBS_i on subcarrier k.

B. Capacity Calculation

Having estimated the SINR, we can now proceed with the capacity calculation. The practical capacity of macro outdoor user m_{out} on subcarrier k can be given by the following equation :

$$C_{m_{out},k}^{dl,ul} = \begin{cases} \frac{\triangle f . B_{dl,ul} . \log_2(1+\delta \gamma_{m_{out},k}^{dl,ul})}{N_m} \text{Closed access} \\ \frac{\triangle f . B_{dl,ul} . \log_2(1+\delta \gamma_{m_{out},k}^{dl,ul})}{N_m - N_{m_{(in)}}} \text{Open access} \end{cases} \quad (10)$$

B_{dl},B_{ul} : are the bandwidth occupied by the data subcarrier in the downlink and uplink respectively.

$$B_{dl} = B_{ul} = \frac{N_{sc}.N_{symbol}.N_{rb}}{T_{sub}} \quad (11)$$

Where N_{sc} is the number of sub-carriers in one RB, N_{symbol} is the number of OFDM symbols in one frame, N_{rb} is the number of RBs in the selected bandwidth, and T_{sub} is the duration of one sub-frame. δ is a constant for target Bit Error Rate (BER), and defined by $\delta = \frac{-1.5}{\ln(5BER)}$.

The practical capacity of downlink and uplink of macro indoor user m_{in} on subcarrier k can be given by the following equations :

$$C_{m_{in,i},k}^{dl,ul} = \begin{cases} \frac{\triangle f . B_{dl,ul} . \log_2(1+\delta \gamma_{m_{in},k}^{dl,ul})}{N_m} \text{Closed access} \\ \frac{\triangle f . B_{dl,ul} . \log_2(1+\delta \gamma_{m_{in},k}^{dl,ul})}{n_{h,i}+n_i} \text{Open access} \end{cases} \quad (12)$$

The practical capacity of downlink and uplink of home user h on subcarrier k can be given by the following equations :

$$C_{h,i,k}^{dl,ul} = \begin{cases} \frac{\triangle f . B_{dl,ul} . \log_2(1+\delta \gamma_{h,k}^{dl,ul})}{n_{h,i}} \text{Closed access} \\ \frac{\triangle f . B_{dl,ul} . \log_2(1+\delta \gamma_{h,k}^{dl,ul})}{n_{h,i}+n_i} \text{Open access} \end{cases} \quad (13)$$

IV. RESULTS AND SIMULATION

The simulations are event-based and developed according to 3GPP standards. The simulations' scenario is given in Fig.1. The plotted values are an average of 1000 independent simulations. The assumed system parameter for the simulations is given in Table 1. The simulation results are achieved using Matlab.

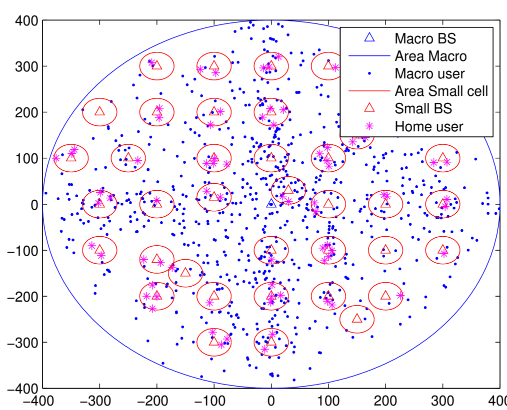

Fig. 1. Simulation Scenario.

As depicted in Fig.2 and Fig.3, The overall throughput capacity reaches its high level when the closed access mode is used in the downlink and open access mode in the uplink. Closed and open access are in conflict interests for macro users and home users in the uplink and downlink. This conflict is due to the cross-tiers interferences caused by nearby macro indoor users to home users in the closed access mode in the uplink and the degradation of QoS requirements of home users

TABLE I
SIMULATION PARAMETERS

Parameter	**Value**
Macro cell Radius (R_m)	400 m
Small cell Radius (r_s)	30 m
Number of Macro users (N_m)	800
Number of home users ($n_{h,i}$)	1-3
Frequency	2 Ghz
Macro BS Power (P_M)	25 W
Small BS Power (P_s)	100 mW
Home UE Power (p_h)	1 mW
Macro UE Power (p_m)	0.2 W
Path loss (PL) between MBS and outdoor UE	$15.3 + 37.6\log_{10}(d)$ where d is the distance between the transmitter and the receiver in meters
Path loss (PL) between MBS and indoor UE	$15.3 + 37.6\log_{10}(d) + L_{ow}$ where L_{ow} is the penetration loss of an outdoor wall
Path loss (PL) between small BS and an indoor UE	$18.46 + 20\log_{10}(d) + 0.7.d_{2D,indoor} + 18.3n^{((n+2)/(n+1)-0.46)} + q.L_{iw}$ where n is the number of penetrated floors, q is the number of walls separating apartments between the small BS and the UE, and L_{iw} is the penetration loss of the wall separating apartments and the term $(d_{2D,indoor})$ takes account of penetration loss due to walls inside an apartment and is expressed in meter.
Path loss (PL) between small BS and an outdoor UE	$max(15.3 + 37.6\log_{10}(d), 38.46 + 20\log_{10}(d)) + 0.7.d_{2D,indoor} + 18.3n^{((n+2)/(n+1)-0.46)} + q.L_{iw} + L_{ow}$.
Indoor Walls Loss (L_{iw})	5 dB
Outdoor Walls Loss (L_{ow})	20 dB
Channel gain G	$10^{-PL/10}$
Bandwidth of downlink (B_{dl})	20 MHz
Bandwidth of uplink (B_{ul})	20 MHz
Number of sub-carriers in one RB (N_{sc})	12
Number of OFDM symbols of downlink (N_{symbol})	6
Number of OFDM symbols of uplink (N_{symbol})	4
N_{rb}	100
Modulation Scheme	64 QAM
Subcarrier Spacing (Δf)	15 KHz
Bit Error Rate (BER)	10^{-6}
White noise power density (N_0)	-174 dBm/Hz
Ω_h^{dl}	0.5 Mbps
Ω_h^{ul}	0.5 Mbps

in the open access mode in the downlink. To resolve this conflict, a shared time access is proposed in the next section as a compromise between macro users and home users in the uplink and downlink.

V. SHARED TIME ACCESS

We consider the shared time access where a small BS allocates α fraction of time-slots to home users and the remaining $(1-\alpha)$ fraction of time-slots to macro indoor users in the downlink. β fraction of time-slots to home users and the remaining $(1-\beta)$ fraction of time-slots to macro indoor users in the uplink. Due to the absence of coordination among Small BSs and difficulty to implement centralized schemes, each small BS tries to maximize selfishly its throughput capacity of downlink and uplink and satisfies the QoS requirements of home users. the time-slot allocation problem to maximize the network capacity throughput of downlink and uplink of each small cell SBS_i is formulated as :

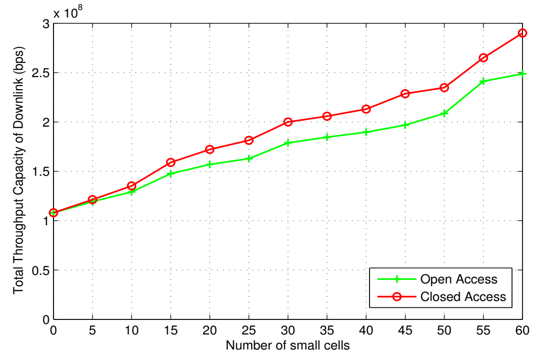

Fig. 2. Total throughput capacity of downlink.

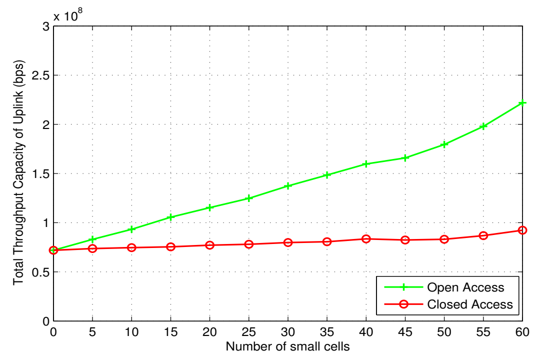

Fig. 3. Total throughput capacity of uplink.

$$C^{dl}_{total-SBS_i} = \alpha. \sum_{h=1}^{n_{h,i}} C^{dl}_{h,i,k} + (1-\alpha). \sum_{m=1}^{n_i} C^{dl}_{m_{in},i,k} \quad (14)$$

$$C^{ul}_{total-SBS_i} = \beta. \sum_{h=1}^{n_{h,i}} C^{ul}_{h,i,k} + (1-\beta). \sum_{m=1}^{n_i} C^{ul}_{m_{in},i,k} \quad (15)$$

$\alpha, \beta \in [0, 1]$
In the shared time access, $\alpha, \beta \in [0, 1[$, we have :

$$C^{dl}_{h,i,k} = \frac{\triangle f.B_{dl}.\log_2(1+\delta\gamma^{dl}_{h,k})}{n_{h,i}} \quad (16)$$

$$C^{ul}_{h,i,k} = \frac{\triangle f.B_{ul}.\log_2(1+\delta\gamma^{ul}_{h,k})}{n_{h,i}} \quad (17)$$

$$C^{dl}_{m_{in},i,k} = \frac{\triangle f.B_{dl}.\log_2(1+\delta\gamma^{dl}_{h,k})}{n_i} \quad (18)$$

$$C^{ul}_{m_{in},i,k} = \frac{\triangle f.B_{ul}.\log_2(1+\delta\gamma^{ul}_{h,k})}{n_i} \quad (19)$$

- If $\alpha = \beta = 1$ it will act as a closed access in the downlink and the uplink.
The solutions of the time allocation α^* and β^* is determined by two conditions :

Max $(C^{dl}_{SBS_i}) = \alpha^*.\sum_{h=1}^{n_{h,i}} C^{dl}_{h,i,k} + (1-\alpha^*).\sum_{m=1}^{n_i} C^{dl}_{m_{in},i,k}$ subject to $C^{dl}_{h,i,k} \geq \Omega^{dl}_h$

Max $(C^{ul}_{SBS_i}) = \beta^*.\sum_{h=1}^{n_{h,i}} C^{ul}_{h,i,k} + (1-\beta^*).\sum_{m=1}^{n_i} C^{ul}_{m_{in},i,k}$ subject to $C^{ul}_{h,i,k} \geq \Omega^{ul}_h$

-Ω^{dl}_h, Ω^{ul}_h : represent respectively the required minimum downlink and uplink throughput of a home user h.

A. Our shared time access Algorithm

The algorithm we have proposed is based on an iterative procedure and executed by each small BS to search the solutions of sharing time access α^* and β^*. In order to maximize the throughput capacity of each Small BS and to satisfy the QoS requirements of home users within existing macro users in the coverage of small cells.

Algorithm 1: Distributed Access Sharing for Small cells

α=1, β=1; (Closed mode is activated by default in downlink and uplink in each small cell)
- each small cell sensing periodically for macro users in the area of its coverage
if $(n_i \geq 1)$
 Input parameters:n_i,$n_{h,i}$,Ω^{dl}_h,Ω^{ul}_h,$C^{dl}_{m_{in},i,k}$,$C^{ul}_{m_{in},i,k}$;
 $T^{dl}_{SBS_i} = \sum_{h=1}^{n_{h,i}} C^{dl}_{h,i,k} + \sum_{m=1}^{n_i} C^{dl}_{m_{in},i,k}$ total capacity of downlink in the closed access mode.
 $T^{ul}_{SBS_i} = \sum_{h=1}^{n_{h,i}} C^{ul}_{h,i,k} + \sum_{m=1}^{n_i} C^{ul}_{m_{in},i,k}$ total capacity of uplink in the closed access mode.
 For α=0 to 0.99 (step=0.01)
  search α^* to get :
  Max$(C^{dl}_{SBS_i}) = \alpha^*.\sum_{h=1}^{n_{h,i}} C^{dl}_{h,i,k} + (1-\alpha^*).\sum_{m=1}^{n_i} C^{dl}_{m_{in},i,k}$
  and $C^{dl}_{h,i,k} \geq \Omega^{dl}_h$
 end For
 For β=0 to 0.99 (step=0.01)
  search β^* to get :
  Max $(C^{ul}_{SBS_i}) = \beta^*.\sum_{h=1}^{n_{h,i}} C^{ul}_{h,i,k} + (1-\beta^*).\sum_{m=1}^{n_i} C^{ul}_{m_{in},i,k}$
  and $C^{ul}_{h,i,k} \geq \Omega^{ul}_h$
 end For
 If(Max $(C^{dl}_{SBS_i}) \geq T^{dl}_{SBS_i}$)
  switch to the shared time access in the downlink;
  $\alpha = \alpha^*$;
 end If
 If $(C^{ul}_{SBS_i}) \geq T^{ul}_{SBS_i}$)
  switch to the shared time access in the uplink;
  $\beta = \beta^*$;
 end If
end If

B. Simulation and Results Analysis

The simulations are based on the same scenario (Fig.1) and simulation parameters (Table 1) in section III.

As depicted in Fig.4, The overall throughput capacity of downlink reaches its high level when the shared access mode is used. Shared access mitigates the cross-tiers interferences caused by small BS to macro indoor users in closed mode. Furthermore, it keeps the QoS parameters of home users degraded in the open mode.

In Fig.5, the total throughput capacity of uplink reaches its best in the shared access mode. This is due to the fact that the shared access mitigates the interferences caused by macro indoor users to small BS in the closed mode. And it keeps the QoS parameters of home users degraded in the open mode.

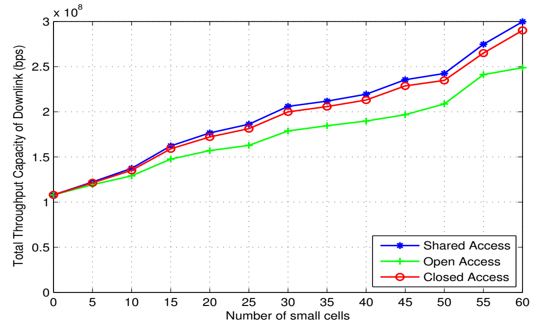

Fig. 4. Total throughput capacity of downlink.

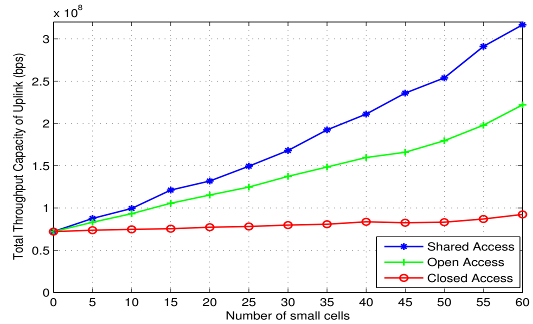

Fig. 5. Total throughput capacity of uplink.

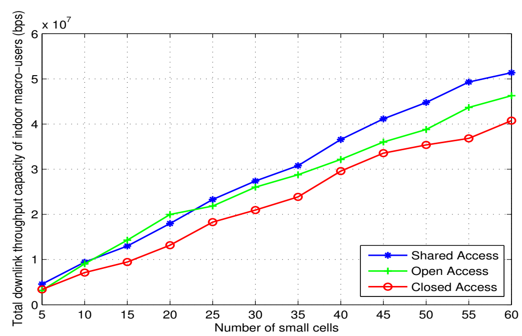

Fig. 6. Total downlink throughput capacity of indoor macro-users.

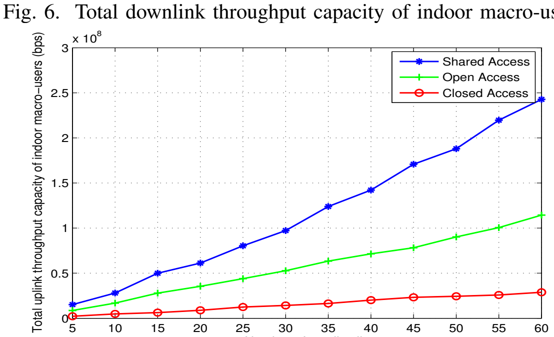

Fig. 7. Total uplink throughput capacity of indoor macro-users.

Fig.6 and Fig.7 shows the total throughput capacity of macro indoor users in the downlink and uplink respectively. Shared mode is the suitable mode for both uplink and downlink because it gives a good compromise by mitigating the interferences caused by small BS(s) to macro indoor users in the downlink and the interferences caused by Macro indoor users to small BSs in the uplink. This will increase the throughput capacity of macro indoor users.

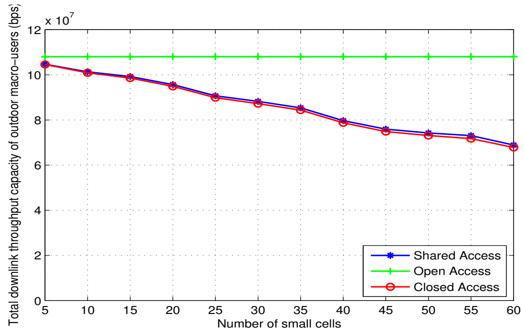

Fig. 8. Total downlink throughput capacity of outdoor macro-users.

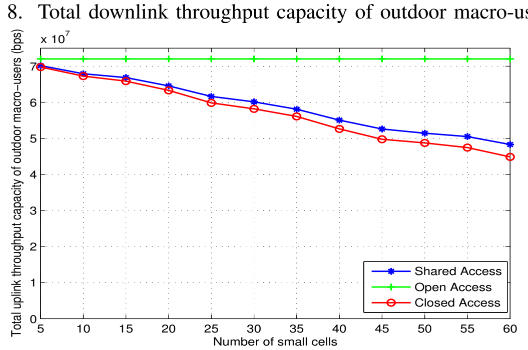

Fig. 9. Total uplink throughput capacity of outdoor macro-users.

As depicted in Fig.8 and Fig.9, the open access is the suitable mode for macro outdoor users in both downlink and uplink because it offloads the macro cell by decreasing the number of macro users using the service of macro cell and increasing the throughput capacity of macro outdoor users. But, this will be at the expense of QoS requirement of home cellular users that will be degraded in this access mode. In shared and closed mode the total throughput capacity decreases. This is due to the increase of macro indoor users at the expense of macro outdoor users by increasing the number of small cell within macro cell, even that the shared access mode gives best results compared to the closed access.

As shown in Fig.10 and Fig.11 the preferred access mode for home users in the uplink and downlink are in contradiction(open access mode in the uplink and closed mode in the downlink. Shared access mode is the suitable mode for home users because it reaches approximately the performance of closed mode in the downlink and it gives better performance compared to the closed access in the uplink. Furthermore, shared access takes into consideration the QoS requirements of home users especially in the case of uplink.

VI. Conclusion

Our distributed algorithm, based on the shared time access and executed by LTE-FDD small cells, is one of the promising solutions for improving the overall capacity of both downlink and uplink in a two tier heterogeneous networks compared to LTE-TDD. Our solution is suitable for recent interactive applications that have symmetric traffic like gaming network and videophone calls, because traffic in both directions is always substantially improving.

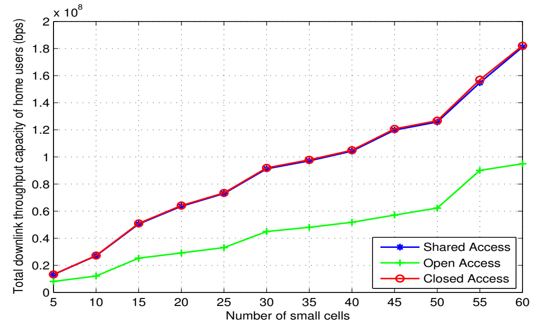

Fig. 10. Total downlink throughput capacity of home users.

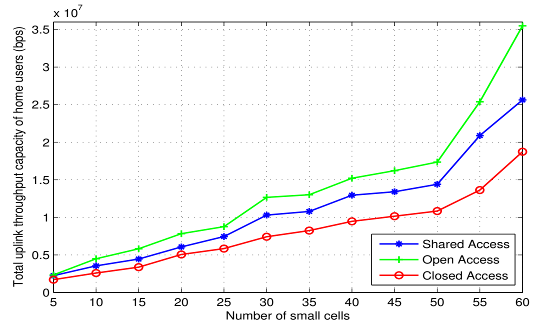

Fig. 11. Total uplink throughput capacity of home users.

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