DOWNLINK CAPACITY IMPROVEMENT FOR A FEMTO-CELL ASSISTED MACRO-NETWORK

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***ABSTRACT** — Providing high capacity to the indoor users in cellular system is a challenge due to the power losses caused by the wall penetration of the signals. A proposed solution is to deploy indoor access points that are connected to the service provider's backhaul and operated on licensed spectrum. In this paper, we evaluate the performance gain achieved by this type of deployment. The performance gains, complexity and applicability have been validated by using system level simulations in Matlab. A novel inter-cell access schemes is also presented and compared with the state of the art scheme. We conclude that there is a potential up to seven-fold increase in the capacity of a cellular system by using Femto-cells using the proposed technique alongside the conventional macro-cells.*

Index Terms — Macrocell, Femtocell, LTE, System level Simulation. Interference.

I. INTRODUCTION

Building interfaces in urban environment causes signal power loss in the present macro network for indoor users. One possible solution is meeting higher data rates is the design of intelligent data-minded mobile networks, paving the path towards the next generation network. Reducing the communication distance between transmitter and receiver is a definite way to boost wireless capacity by improving link capacity on account of higher channel gains and an increased spatial frequency spectrum reuse. This in turn does two things 1) shrinks the cell size and 2) optimally reutilizes the available resources for a fixed area of coverage. Considering cost from the operators' point of view in a dense cell, this is an optimal solution, than increasing the capacity of the same cell by installing large amount of supplemental network infrastructure. The solution lies with both the end user and the operator, is a low transmission power licensed access point (mini base station (BS)) known as femtoBS connected to indoor users. This is further connected to service provider's core network (CN) to attain higher spectral efficiency than with macrocell alone which is hosting them.

As an end-user solution, FemtoBS are generally deployed without network planning which is crucial. Marco-cellular network is formed to provide coverage for huge and open areas including rural areas, whereas femtocells are framed for congested urban areas having some degree of difficulty of signal penetration. Both of the above mentioned cells must allocate their resources properly to avoid interference. BS must be programmed in such a way that it must know out of an array of the resource blocks (RBs) to which of them it will transmit signals.

Spectrum splitting and spectrum sharing are two approaches that are recommended in the literature for spectrum allocation to femtocells. Macro and femto cells are assigned orthogonal frequency bands aiming to ensure no cross tier interference, but this is not a spectrally efficient approach compared to sharing spectrum where both cells use same carrier frequency consequently leading to management challenges for inter carrier interference (ICI) as well as for multiple access interference (MAI).

Femtocell assisted communication system may be a preferred choice in big institutions/plazas or in the buildings like underground rush places to get rid of low signal problem. This heterogeneous system will be more efficient regarding frequency spectrum and bandwidth if we use coordinated femto-BS and macro-BS. Intelligent use of frequency bandwidths will also allow networking companies to provide more services both qualitatively & quantitatively, making it an essential ingredient for upcoming networks, a step towards next generation cellular network being spectrally efficient.

Distributed and cooperative BSs can meet the demands with better resource management system using multicellular processing [1, 2]. All path loss models in literature have their own environments for success, therefore a compromise is made to make femtocell feasible.

Transmission band is limited when macrocell and femtocell do not interfere with each other at all and share totally different spectrum bands. Spectral efficiency is increased when macrocell and femtocell share the complete spectrum. A cell must know in a perfect manner when it should transmit its signals to the resources and at what frequency. For an LTE system [3] has reported recent research advances in inter-cell interference coordination (ICIC) addressing their limitations and advantages. For macro-BS and neighboring femtocells coordination, the transmission distance between BS and femtocells is preferred to be a fraction of BS-BS distance, otherwise resulting in ICI and MAI which requires signal from the strongest femtocells to be in synchronism (same frequency signals) with desired macroBS. Femto-BS has to be configured for its radio parameters that include: switching on femto-BS, connecting to overlaying management system and obtaining the relevant femto gateway. Whenever frequency spectrum is configured by mobile operators, macroBS detects that frequency resources for femtocells are being shared within its coverage.

With the aid of capacity formulations, the authors in [4] investigated the bandwidth constraints on interference in different femtocell network deployments. With system level simulations the authors in [5] and [6] showed a maximum two-fold capacity improvement as a function of indoor user penetration by inserting femtocells with even distribution and varying its modulation order in a macrocell HSDPA network. Marginal throughput improvement is simulated in [7] by rearrangement of femtocell-aware spectrum. Intercell fairness was improved in femtocell networks through cooperative resource allocation, but at the cost of degraded capacity in [8]. Others [9] analyzed the network capacity at system level with LTE technology using femtocells without any quantitative results. Authors in [10] has reported aggregate throughout improvement of the order two on deploying femtocells in open access manner.

The work presented by authors so far have; simulated the distributed downlinking algorithms on macro network, studied the bandwidth constraint, improved the capacity of femtocellular networks by varying its key parameters. But none of them have explored the downlink performance with cooperative base stations in a femtocellular environment for the whole heterogeneous network and for its various components especially for cell edge UEs. Therefore, extending the useful work done by [1, 3, 9,10], the authors in this paper investigate and implement the novel cooperative base station technique on femtocell assisted macro network. Capabilities of the proposed scheme are explored through extensive simulations carried out in Matlab environment for practical scenarios and a business model is presented for future networks.

A novel cooperative base station technique is presented where the macrocell is desisted from utilizing available DL resources allocated to femtocell UEs and vice versa. Performance analysis of Femto/Macro overlaid system utilizing this method reveals that the DL capacity of macroBS can largely be increased. This paper primarily focuses on assessing the impact of femto-cell deployment on cellular networks and addressing the various issues associated with femto-cell deployment. A femtocellular layer is incorporated in MATLAB based simulator which further is used for the evaluations and the results indicate availability of a considerable amount of cluster capacity. The SINR and throughput of the user distribution in the network are derived. After defining femtocell parameters for next generation, we estimate and evaluate the throughput for the total network and its various components. A multifold gain and improvement over the existing macro-cellular benchmark network on the downlink performance for the femtocellular and macrocellular users together will be explored using system level simulations. Relevant techniques and state of the art employed will be discussed in the next section in detail.

The next sections describe the model and analyze the interference coordination simulation testbed and results.

II. MODELING & ANALYSIS

A. Framework

Consider a scenario where there are huge buildings and apartments closely spaced to one another and the indoor users are arranged in a specified manner to be served by low power femtocells, in which case interference between macrocell and femtocell will be limited. Under such a scenario the possibility of interference between the two types of cells is quite small as signals have difficulty to penetrate the walls. However if there is high density of femtoells then every macrocell as well as femtocell is affected by the nearby femtocell(s). In case of closed access, the indoor UE within femtocell coverage but connected with macroBS receives an attenuated signal due to wall penetration loss as well as a high level interference originating from the deployed femtoBS. Under this scenario, macro UEs experiences excessive interference from the nearby femtoBSs. It is of paramount importance to ensure that such a femtoBS deployment is not at the cost of degradation in benchmark network due to severe interference. This tolerable interference level puts an upper bound on the capacity of such systems. Both macro and femto-cells reuse the available bandwidth following the universal frequency reuse pattern. This greatly boosts the system capacity but negatively influence the DL performance of wandering macro-UEs near cell edges. A solution to this problem is to reserve a portion of the spectrum only for femtocell, in order not to affect macrocell performances at the expense of cellular capacity. This is not considered as a viable solution. The service provider therefore requires the femtocells to sense the occurring intervals of these bad situations and accordingly reduce their spectrum coverage, intelligently making decisions based on threshold levels of measured interferences at femtocells. Intercell fairness are supported in a cooperative resource allocation manner among femtocells maintaining the same cell capacity and complexity and making traffic load based power allocations. The essence of bringing femtoBS in place is to offload the macroBS based network by allowing alternate access points.

According to the standard, FemtoBS are usually controlled by the service provider, so the operating frequency is assigned from the control station in order to avoid interference with the macroBS in the neighborhood. A femtoBS operates in licensed spectrum and it is linked with the service provider's network by means of a broadband connection (wireless or wired). It may operate on the same or different frequency assignment as macro base stations. Typically its coverage overlaps with that of a macroBS. In our simulation set up, we have assumed femtoBS to be operating on the same frequency assignment as that of macroBS. This potentially increases the capacity utilization and the spectral efficiency by spatial frequency reuse, especially for high data rate scenarios where most users have high bandwidth demands.

B. System Model and Simulation Setup

System modeling: We consider an intercell full reuse cooperative communication DL system build around N cells (two macrocells and one femtocell placed at the boundaries of two sectors of macrocells). Further, within this an orthogonal intracell model (where within a cell, mobile stations do not interfere with each other) as shown in figure 1, in line with the system level model of seven macrocell as shown in figure 2. The BS and the mobile station (MS) in nth cell are referred as BS n and MS n respectively. A free of interference and dedicated communication link between BS's is assumed which is capable of sharing information between them cooperatively. Mathematically, we can express as

$$y_n = h_{n,n}x_n + \sum_{k\epsilon I(n)} h_{n,k}x_n + \mathrm{w}_n\,, \quad n = 1, \dots, N \quad (1)$$

Where $\{\mathrm{w}_n\}$ are i.i.d. Gaussian noise variables, with variance $\sigma^2$and zero mean, $\mathrm{h}_{n,k}$ the path gain from BS k to MS n, $I(\mathrm{n})$ the set of indexes of the adjacent cells for cell n, x_n the transmitted signal from BS n and y_n is the received signal at MS n and. At moment we consider the system to be a discrete real-valued with $I(n)$ of same cardinality. In vector form the above model can be expressed as

$$\boldsymbol{y} = \boldsymbol{Hx} + \mathbf{w}\,, \quad (2)$$

where received signal y ϵ R^{N}, w ϵ R^{N} is the noise vector, x ϵ R^{N} transmitted signal and H ϵ $\mathrm{R}^{\mathrm{N\times N}}$ is the downlink channel matrix. Let {dn} be i.i.d. random variables having mean zero and variance unity and these are initially available at BS n that corresponds to the data symbol intended for MS n, where N scalar data symbols $d \epsilon R^N$. In addition, the data vector d is mapped into x the vector of transmitted symbols by the network mapper. A MIMO system is formed if we enable BS cooperation among the N BSs and N MSs. And the system will become

$$\boldsymbol{y} = \boldsymbol{HTd} + \mathbf{w}\,, \tag{3}$$

where $\boldsymbol{T} \epsilon R^{N\times N}$ is the linear precoder. On most of the occasions $\boldsymbol{H}$ is considered to be a full matrix, whereas it may have many zero elements in our model with localized intercell interference. $\boldsymbol{T}$ has two free scalar parameters K with $\beta \epsilon R$ the general form for an optimal linear precoder as:

$$\mathrm{T} = \mathrm{K}\mathrm{H}^{\mathrm{T}}(\mathrm{H}\mathrm{H}^{\mathrm{T}} + \beta I)^{-1}\,, \tag{4}$$

Generically K, the normalization constant is used to meet the constraint of total transmit power P_T (mean power of the data symbols). The second typical tunable parameter is the regularization parameter β.

Fairness across mobiles can be provided if SINR characterizes the performance of each MS. The worst SINR optimization problem, subject to a sum power constraint, can be stated as

$$\max_{\boldsymbol{T}} \min_{n} SINR_n\,, \qquad s.t.\ \|\boldsymbol{T}\|^2 \leq P_T\,. \tag{5}$$

This is a generalized consideration of weighted SINR, reflecting different priorities amongst the MS's.

As shown in figure 1, the entities involved in the proposed solutions are mobility management entity (MME), serving gateway (S-GW), evolved packet core (EPC), and interfaces S1, X2. The cooperation among three cells is enabled through ICIC in frequency domain by passing messages on a standardized backhaul interface X2 [11, 12]. S1 is used for

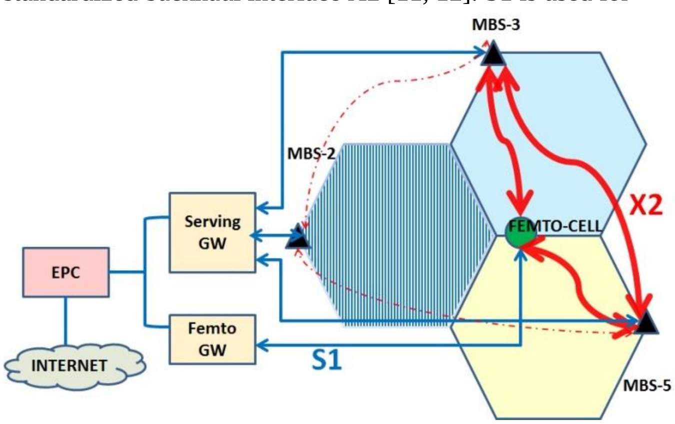

Figure 1. Access via LTE Macrocell nodes and Femtocell nodes in a full reuse intercell cooperative downlink system

connection between S-GW/MME and macroBSs as on neighboring list. Signaling between the EPC and the UE is stored in MME. Interconnections between MacroBSs and femtoBSs is provided via the interface X2 that carry handover information besides ICIC. The wired interfaces between macroBSs and femtoBSs, and the corresponding processing times at both transmission ends are not instantaneous. Rather, they pose delays to this message passing technique, therefore it is further assumed that ICIC messages are occasional (of the order of seconds) as compared to X2 latency which has a characteristic of a few radio frames (tens of milli-seconds). Since higher accuracy of information is received at the destination with X2 as well as mutiple information can be sent to various groups of macro and femto BSs [13], this makes X2 interface a suitable candidate for conveying signals pertaining to interference avoidance among macro and femto components. Relative narrowband transmit power (RNTP) indicator may be utilized for advance decision among a set of cooperating BS but we will use event triggered messages like Overload Indicator (OI) and High Interference Indicator (HII). These messages and their respective framework as used for uplinking are employed for DL-ICIC with exchange rate of the order of tens of milli-seconds. For scheduling cell-edge UEs, the proactive indicator HII is sent as a bitmap with one bit per physical RB(/subband). Any BS (macro/femto) can exchange cell specific HII with adjacent neighboring cell. The mobile station specific information, thus reported comprises the measured neighboring cells downlink interference level. Whereas BS originated interference plus noise level signals are exchanged through a reactive indicator OI. Based on OI benchmark values, a handover or power control may take place.

The following procedure is adopted to integrate the femto-cell and macrocell cooperation into the existing network architecture: Besides DL-HII and X2, the additional entities that take part to complete the procedure include broadcast channel (BCH), physical cell identity (PCI) and reference signal received power (RSRP). A macro-user within femtocell reads the corresponding BCH, then determines and stores the corresponding PCI of femtoBS in a neighboring list of PCIs. Then it compares the interfering femto signal with a configurable threshold value using RSRP measurement value for a fixed time period. Then its PCI is shared among the three neighboring BS as shown in figure 1. Corresponding macroBS then prepares a DL-HII bitmap with information of a particular RB above threshold power value. This message is passed on to the three neighboring BS over X2 interface. A set of cooperating BSs are then desisted from utilizing the specific RBs as marked in the DL-HII bitmap, hence cooperatively sharing DL resources allocated to macroUEs by avoiding femtocell interference. In case femtocell DL resources are full, a handover may take place to serve further femtoUEs by macroBS without going into the outage.

The proposed method is designed to solve the problem for a cellular system with a large number of base stations. Mathematical models and framework is developed and extended to enable simulation of this complex system using appropriate simulation tools. These models are designed to strike a right balance between mathematical tractability and realism in terms of capturing all key physical phenomena affecting the problem (base station cooperation). More detailed mathematical models will hinder the tractability of the solutions and the possibility of realistically simulating and testing the performance of the system. To verify the convergence of the algorithm and quantify the improvement of the state of the art methods, we use extensive system level simulations. This renders our faith in this pedantic way of producing transmit symbols. Since precise results are obtained merely in a few steps on average, this results in favorably smaller delays.

Capacity Calculation: For calculating the capacity of LTE system with bandwidth W, we consider an LTE system based on OFDMA frequency domain duplex (FDD) with universal frequency reuse. It has a number of resource blocks (RBs) each representing the fundamental time-frequency unit where W is apportioned into N_{RB}, each having bandwidth W_{RB} according to $W = W_{RB}N_{RB}$. Each RB carries same transmission power for all the scenarios considered. One LTE frame is made up of ten subframes where each subframe is composed of two RBs where various resource elements (REs) comprise one RB. The simulation is run for the duration of one entire frame. RBs with cardinality $|N| = N_{RB}$, are allocated uniformly by macroBS and femtoBS to the respective connected femto and macro UEs, for the DL and UL.

Now we denote u to recognize femto or macro UE served by femtoBS v_u assuming multiple antennas for signal reception. Maximum ratio combining (MRC) is used to combine these signal streams as $\mathrm{M_{ant}}$. Its estimated output is obtained by simulating these uncorrelated, individual signal streams and combining the SINR thus obtained [14], since it is assumed that the receive antennas at the UE and macroBS are sufficiently separated spatially. The received UL or DL signal power associated with UE u,on RB n, Y_n^u, is given by

$$\mathrm{Y_n^u = P_n^u \sum_m^{M_{ant}} G_{m,n}^{u,v_u} + I_n^u + \eta_{RB}}, \quad (6)$$

where the channel gain $G_{m,n}^{u,v_u}$ between femtoBS or macroBS v_u and in connected UE u, is perceived for RB n with antenna m. η_{RB} denotes the thermal noise/RB with its value fixed for the whole set of RBs in both directions of communication. In the DL, the transmit power is considered to be $P_n^u = P_{\mathrm{macroBS}}$ or $P_n^u = P_{\mathrm{femtoBS}}$ if UE u is served by correspondingly macroBS or femtoBS. In the UL, $P_n^u = P_{\mathrm{FUE}}$ or $P_n^u = \mathrm{P_{MUE}}$, provided the considered UE is served by corresponding femtoBS or macroBS. The values P_{femtoBS}, P_{macroBS}, $\mathrm{P_{MUE}}$ and P_{FUE} are constant across all RBs. Furthermore I_n^u is the aggregate interference comprised of femto and macro-cell interference:

$$I_n^u = \sum_m^{M_{ant}} \left\{ \sum_{i\in\mathcal{F}_{int}} G_{m,n}^{u,i} P_{\mathrm{f}} + \sum_{i\in\mathcal{M}_{int}} G_{m,n}^{u,i} P_{\mathrm{m}} \right\}, \quad (7)$$

where the first term stands for the femto-cell interfer ence and second term stands for macro-cell interference. Here, P_{m} is set corresponding to P_{macroBS} and $\mathrm{P_{MUE}}$ in the DL and UL. Similarly, P_{f} is set respective to P_{femtoBS} and P_{FUE} in the DL and UL. $\mathcal{M}_{int}$ represents the set of interfering macro UEs in the UL and the set of interfering macroBSs in the DL. Similarly, $\mathcal{F}_{int}$ denotes the set of interfering femto UEs in the UL and the set of interfering femtoBSs in the DL. In case UE u is served by macroBS, $\mathrm{v_u}$, in the DL, $\mathcal{M}_{\mathrm{int}}$ is composed of all macroBSs except for v_u, *i.e.*, $v_u \notin \mathcal{M}_{int}$ and $\mathcal{F}_{int}$ is the complete set of femtoBSs in the network. In this case, for the UL, $u \notin \mathcal{M}_{int}$ and again, $\mathcal{F}_{int}$ is the complete set of network femto-UEs. Similarly, if UE u is served by a femtoBS $\mathrm{v_u}$, then $\mathrm{v_u} \notin \mathcal{F}_{\mathrm{int}}$ and $\mathcal{M}_{\mathrm{int}}$ contains the whole set of macroBSs for the DL. In the UL, $u \notin \mathcal{F}_{int}$ and $\mathcal{M}_{int}$ comprises all macro UEs present in the network. The SINR observed in the UL or DL with regards to UE u on RB n equals to

$$\gamma_n^u = \frac{P_n^u \sum_m^{M_{ant}} G_{m,n}^{u,v_u}}{I_n^u + \eta_{RB}}, \quad (8)$$

where, once again, P_n^u holds the appropriate transmit power value depending on the direction of communication and type of link. Based on receiver side MRC, the channel gains $G_{m,n}^{u,v_u}$ has a constructive contribution, such that the mean SINR is raised by M_{ant} factor simultaneously with a diversity gain of M_{ant}-fold. Given the SINR and the number of served RBs, $|N_U|$, assigned to UE u, the Shannon bound capacity C_u, is calculated as

$$C_u = \sum_{n\in\mathcal{N}_u} W_{RB}\log_2(1+\gamma_n^u), \quad (9)$$

To meet the conditions of interference avoidance among neighboring blocks, a perfect time and frequency synchronization is assumed. The aggregate throughput for user j is [10]

$$T^j = \sum_{i\in R^j} W_{RB}\ log_2\left(1 + \gamma_i^j\right), \quad (10)$$

where γ_i^j is the achieved SINR on the ith RB of user j, $\mathrm{R^j}$ is the set of RBs allocated to user j and $\mathrm{W_{RB}}$ is the bandwidth per RB.

The multi-path effect caused by the dynamic propagation environment, is countered enormously by looking into the benefits of OFDMA systems. This effect results in a delay spread which is the reason for inter symbol interference (ISI). By keeping the OFDM symbol duration longer than the channel delay spread ISI is largely suppressed. Capacity is maximized by allocating the available resource smartly in multiuser diversity.

Channel Model:

Path loss relying on transmission distance, channel variations on account of frequency-selective fading and log-normal shadowing comprises the channel gain as described in equation 8, $G_{m,n}^{u,v}$,:

$$G_{m,n}^{u,v} = \left|H_{m,n}^{u,v}\right|^2 10^{\frac{-L+X_\sigma}{10}}, \quad (11)$$

where $\mathrm{H_{m,n}^{u,v}}$ denotes the channel transfer function between receiver u and transmitter v, perceived for RB n measured with antenna m, L (in dBs) denotes the path loss, and X_σ symbolizes the log normal shadowing (dBs) with standard deviation σ [15]. Channel variations are assumed to be mutually independent on different receive antennas. However, the path loss plus shadowing, L, is assumed to be same due to slow fading for the complete set of receive antennas m and RBs n since this parameter depends on the spatial separation between transmitter and receiver.

Time and frequency dispersions are mostly observed in the channel response. Since the dimensions of RB are considerably smaller than the coherence time and the channel coherence bandwidth, these channel fluctuations within these RBs dimensions can be ignored [16]. For generating the frequency-selective fading Channel, the required delay profiles are fetched from the appropriate propagation scenarios of [15, 17, 18].

Path Loss Models: The following channel models are used in our simulations (with corresponding delay profiles) as described in [15, 17, 18]. Macroscopic model TS-36942 with urban environment, for femtocell channel: the indoor model according to LTE-A evaluation methodology and for modeling the channel between network components lying outdoors and indoors: the indoor-to-outdoor model. The line-of sight (LoS) probability is estimated for the respective path loss model used for each link in the network. To define the outdoor-to-indoor and indoor-to-outdoor link environment, an additional wall penetration loss of 20-dB is modeled. Frequency-selective fading is incorporated in the model by using the respective delay profiles of these path loss models. The LTE-A evaluation methodology based simplified femto-cell model is used for modeling the inside channel links. This model avoids modeling any indoor walls for a femtocell.

$$L = 127 + 30\,Log_{10}(\frac{R}{1000}),\ dB \qquad (12)$$

where R is the distance (km).

Simulation Setup: System-level simulations are performed for state-of-the-art cellular networks on Matlab platform and they indicate availability of a considerable amount of cluster capacity attributable to shorter communication distance among cluster of users compared with cell dimensions. For indoor clusters, it is also assumed that there are no wall penetration losses. For hybrid access systems with femtocell deployment, the accumulative macro and femto UE capacity is contrasted with the benchmark system of macroBS serving all UEs. It will be demonstrated with the help of simulation results that by deploying femto-cell in indoor environment has considerable system capacity gains, in any mode of the access schemes.

The major sources of co-channel interference (CCI) in the said environment are channels pertaining macroBS to femtoBS and femtoBS to macroBS, all other channels contribute negligibly due to low power transmission compared

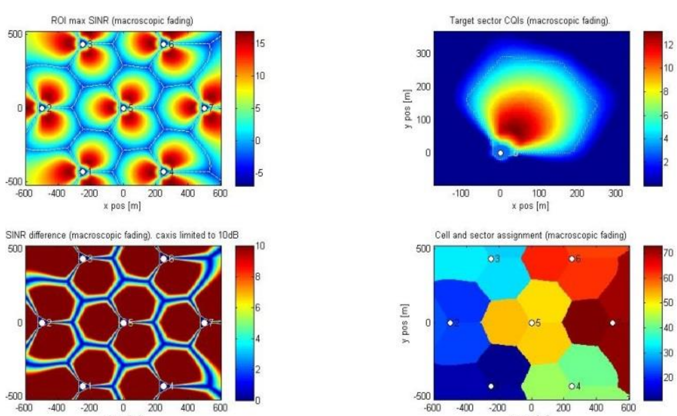

Figure 2. Grid layout, a) SINR, b) Sector CQI, c) SINR difference, d) Sector and Cell assignment

to first two which attract designer attention. This further depends on the inter-site distance and the density of the cellular network, which is verified in the next section. Similarly, on deploying a large number of femtocells, macroUE faces significant CCI compared to femtoUE due to a shorter transmission distance with its relevant femtoBS. To control CCI, frequency planning is a potential solution but in view of the fact that femtocells are user deployed, this becomes a complicated task.

In case all the base stations cooperate among each other as a group which is listed at the core network. An UE connected with a femtoBS enables transmission and all other remaining femtoBSs and macroBS out of the group aid this transmission. These BSs simultaneously put a null in the direction of the UEs connected with macroBS thereby effectively improving the femtocell performance to the extent that the principle interference is originated from the macroBS.

UEs Distribution: One ring comprising of 07 macroBS is considered in a hexagonal grid where each macroBS carries 3 sectors and uniformly distributed 10 UEs per sector as shown in figure 2. Femto-cells have a fixed radius of 10 m in a circular coverage area.

III. SIMULATION TESTS AND RESULTS

A. Assumptions and Key Parameters:

Various parameters for the DL system level simulations are configured according to [19, 20, 21] for the base network and the overlaying femtocell assisted network. First layer is the marco layer only that references as a benchmarked system and second is macro+femto layer. Layer wise implementation helps in the comparative estimation of SINR and throughput for the individual sector. Testbed is simulated in MATLAB using LTE System level simulator [22] for macro layer and the femtocell layer is constructed according to [9] and [23]. The simulator evaluates the spatial user positions development for a defined number of indoor users in a continuous loop fashion [23]. The position of each user and traffic model is updated for each scenario followed by the scheduling.

Due to the inherent issues related to a joint transmission scheme like the iterative multistage numerical power allocation and per-base power constraint make it quite complex and impractical; we keep our model simple where the diversity signals purely interfere with each other. In our simulations, these femtocells are considered to have a boundary of 10m with wall loss of 20 dB. Therefore the interference among these femtocells is low. Although the macroBS carries huge power (40 dB for macro versus 0.1 dB for femto) and it constitutes the main source of interference, whereas the wall loss boundary condition brings the interference levels 20 dB lower.

C. Performance Evaluation

The following two scenarios are considered as a case study for the evaluation and comparative analysis of the throughput and the gains will be observed in each. In benchmark scenario one receiver and one transmitter antenna is used modeling Single input single output (SISO). Whereas in second scenario, similar configuration but with the addition of femtocells layers alongside proposed access scheme. Now we compare the performance of the two scenarios and summarize the gains of the results obtained. The augmented system capacity with a varying number of indoor UEs and femto-cells are shown in figure 3. Since femtocells are connected to the core network (CN) via cable, hence they transfer indoor UEs from the macrocell. This possibly increases the outdoor in addition to the indoor system capacity. The outcomes of these simulation results emphasize the gains accomplished by deploying femtocells. For the DL systems, the throughput (or sum capacity) is approximately 7 fold than that for the benchmark system as a consequence of offloading indoor UEs from respective macroBS and serving with femtoBS and managing the interference. Inasmuch the available RBs are fixed for a system, RBs per UE are in abundance with femtocells than with the benchmark system for the reason that indoor UEs connected with macroBS releases the respective RBs after connecting to the femtoBS. Thus acculturated indoor macro UEs connected with femtoBS set macrocell resources free. Similarly in majority of circumstances, the benchmark system lives through the minimal interference due to the absence of femtocells in the coverage area. These results further elucidate the effective reutilization of macro network resources to boost up the system capacity.

A number out of set A={6,11,16,21,27,32,37,42,48,53} were used sequentially in ten steps adding 21 indoor users in each step for 100% served and subset of A for seven different steps

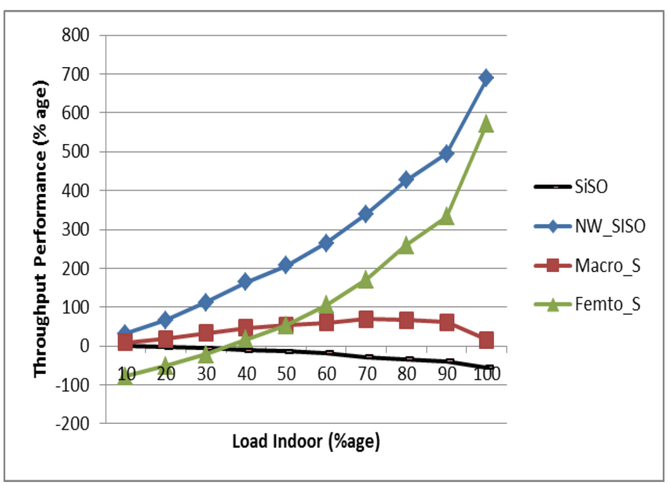

Figure 3. Throughput Performance (% age)

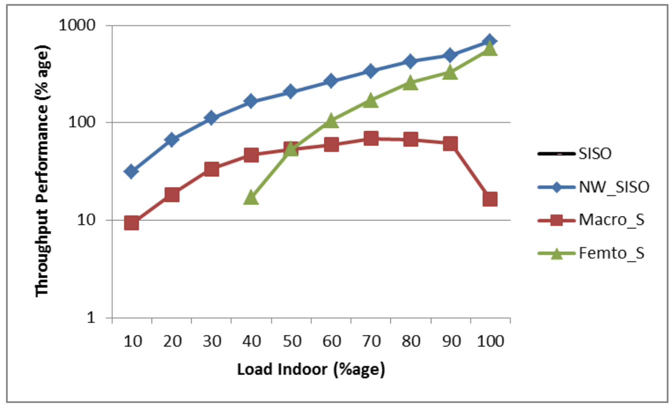

Figure 4. Throughput Performance (logarithmic scale)

TABLE 1
Performance Comparison

	Benchmark System	Proposed System
Network Throughput	55% Degradation w.r.t peak	07-fold improvement
MacroBS Throughput (30-80)% Gbps	0.733	1.63 (2.22 times)
FemtoBS Throughput Indoor UEs	-	2.5 times improvement
Range of UEs served	-	++

of indoor served. This number is kept unchanged for the second scenarios for a comparative statement at each increment of load step. The position of indoor environment is hard coded as it models the fixed infrastructure inside the buildings.

Compared to benchmark system, there was a 55% throughput improvement for 30% to 70% indoor UEs using second layer. The graph of femtoBS throughputs is a linear function of the indoor load penetration with the constraint that below 22% indoor UEs there were no appreciable contribution in the overall network throughput. The reason for this less fruitfulness is the under-loading of femtocells defining a minimum threshold for their effective operation. For the overall system network throughput for 100% edged indoor UEs in a hexagonal layout cell, we observed 7-fold improvement compared to benchmark system. For a hybrid business model, i.e. UEs 70% indoor served by femtoBS and 30% outdoor served by macroBS, the improvement in throughput is 6-fold.

The performance evaluation for both scenarios are summarized in table 1 as well as in figure 3 that depicts the various network components in terms of their average throughputs compared to the existing macrocellular benchmark system. Here SISO model in black solid color shows performance degradation with increasing number of indoor UEs. Curves for scenario 2 are shown in green, brown and blue lines where the contribution of femtoBS is a linear function of indoor load. And macroBS performs better than without femtocells. The overall network has considerable gain of the order of 07 fold over existing macro network defined in scenario 1. These gains are credited with the following reasons. The indoor improvement is mainly due to shorter transmit-receive distance within femtocell and better interference management due to cooperation of respective BSs. Since all former UEs connected to femtoBS now were served by the macroBS placed outdoor with high wall penetration losses, this resulted in attenuated signals for the benchmark system. Similarly all connected users share the same available macro resources in the benchmark system which results in less RBs/UE in contrast with the new scenario of femto-cell deployment that frees macro resources. Consequently the spatial reuse gain delivered through femto-cell deployment is lost in the benchmark system. Since we are following an existing procedure for signaling between BSs and UEs in the proposed method, meaning there would be no extra overhead.

Throughput performance curve of macroBS with femtocell incorporated is almost identical but slightly higher than the original network for the reason that now the resources freed by femtoUEs are available to take care of the rest of the UEs connected to it. In other words, it provides the maximum throughput for a range of UEs connected to it. When all UEs are indoor, the femtoBS curve outperforms the benchmark curve for whole served range. On the other hand the performance for original network is greatly degraded as it can't provide sufficient service to both rich indoor and depleted outdoor users simultaneously. The throughput performance curve of macroBS with femtocells now crosses banchmark curve for larger number of femtocells deployed indoor that underperforms the macroBS. The macroBS is being inefficient to the large number of its freed resources because there are not enough degrees of freedom and all the resources undermine network performance. For mid-range indoor users, there is 2.17-fold improvement in the macroBS.

Since the pockets of poor or nearly no coverage region within the ring (comprising of 7 macroBS) is sensed inhabited with buildings and an assumed exterior 20 dBs wall loss, therefore, macroBS signals largely contribute among the sources of interferences. Interference between femtocell signals is minimized by installing the femto-device inside the building encapsulated by its respective wall loss. The inclusion of femto-cell layer is dynamically founded without the need for any supplemental installation of infrastructure and its cost is mutually shared between the service provider and the subscriber. Computational complexity is reduced by using cooperative scenario for each base station. It is assumed that additional overhead, delay and complexity does not contribute towards the battery drainage problem. In real world, this amount of gain can be of paramount significance especially for cell edge users or users in areas of no coverage. The practical hindrance will arise mainly from the availability of back haul connectivity with core network in that particular region. More number of buildings will aid to realize this gain by reducing the interference signal between the macroBS and femtoBS. The proposed algorithm functions well in terms of computation and communication cost in case of obtaining the globally optimal transmitted signals.

The network component trends are reproduced in figure 4 with logarithmic scale to explain the dynamic range and effective contribution of each curve in the overall network performance. The two curves for femtoBS follow linear slope and effectively contribute only when there are significant indoor users roughly around 30 % for the same argument explained earlier. The macroBSs contribute effectively throughout the range of UEs except when all the users are indoor. These two arguments define the lower and upper bounds of the effectiveness of the said architecture and in lines with the proposed business model for providing higher data rate indoor services. Hence the overall network throughput curves consequentially outperform the already existing network for the complete range of UEs whether indoor or outdoor. Since the scenario is simulated in an interference limited environment by mitigating the SINR degradation, any noise increment will not affect achieved SINRs notably and consequently system capacity experienced physically will be unaffected.

IV. CONCLUSION

In this paper, we have presented femto-cell assisted cellular network with cooperative base stations. We have shown a marked improvement around seven fold in the performance both in terms of throughput and quality of service by improving spectral efficiency. This gain in capacity is realized by shorter transmit-receive distance with higher achieved SINRs and smart spatial reutilization of available macrocell radio frequency resources. Peak macroBS throughput was delivered for a range of outdoor users as well. The results can be applied to large scale deployment of femtocells in a dense urban environment and may serve as a basis for a realistic future business model to meet higher bandwidth requirement at higher data rates for indoor applications and devices. It is further concluded that the benefits of femtocells deployment with cooperative base stations by far outweigh their impact on the existing system capacity. Since we are following an existing procedure for signaling between BSs and UEs in the proposed method, meaning there would be no extra overhead.

V. ACKNOWLEDGMENT AND FUTURE WORK

The authors gracefully acknowledge advanced studies and research board (ASRB) UET Lahore for funding the project. We further intend to work with setting the priority scenario lies either with the macro-cell femtocell for nomadic macro UEs or multimedia femto UEs for resource allocation.

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