Co-Tier Interference Reduction with Intelligent Scheduling in between LTE Femtocells

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Abstract - In wireless networks, there is an ever-increasing demand for higher system throughput along with growing expectation for all users to be available to multimedia and Internet services. This is especially difficult to maintain at the cell-edge. To deal with the increasing demand of high speed data streaming and good quality voice traffic from mobile users at home, Femtocell Networks are deployed in homes that enables an indoor mobile user to achieve high speed downloading from the internet and make good quality voice calls. Femtocell networks suffer from the problem of interference. In this paper, a contribution to the existing research on the avoidance of interference in Femtocell networks is presented. The proposed methodology designs a resource allocation and reuse mechanism combined with allocating different resource blocks and interference-aware reuse. The presented results show that the proposed methodology can efficiently mitigate the Co-tier as well as Cross-tier interference in LTE based cellular networks and outperform the other mechanism.

Keywords*-Femtocell, Macrocell, Interference, Resource Block (RB).*

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I. Introduction

Femtocell is a small base station that can be placed at subscriber's home/office to improve indoor coverage. Cost of Femtocells is reasonably acceptable. Femtocell provides advantage to service subscribers as well as service providers. Femtocells provide indoor coverage to users when Macrocell signals are weak. It increases battery life of mobiles as mobiles do not need to communicate with Macrocell from very high distance. Femtocell can be easily deployed at subscriber home as it provides better features. LTE networks are implemented on cellular structure consisting of Macrocells. When Femtocells are deployed in LTE system frequency interference can occur as Femtocell will share available frequency band with Macrocells. Despite the advantages of Femtocells the deployment of Femtocells in large numbers causes the Femtocells to interfere with each other. This type of interference is called "Co-tier interference". This interference is particularly strong when all Femtocells operate in Co-channel mode meaning that all Femtocells share the same resources. And interference between Macrocell and Femtocell also vice versa is called as "Cross-tier Interference". So frequency reuse schemes are applicable for frequency allocation in LTE Femtocell networks. Many frequency reuse schemes can be used that reviewed in [1]. So in this paper proposed methodologies which help not only reduce Co-tier but also help to minimize Cross-tier interference. Which is the modified part of CASFR scheme [2] and FFR scheme [4].

This paper is composed of V sections they are organized as follow. System Model is described in Section II. Section III presents Methodology help to reduce interference occurs because unplanned deployment of Femtocells. Section IV describes Results and Discussions. Section V presents Conclusion & Future Scope.

II. System Model

This section describe theoretical approach to calculate the path loss, SINR, throughput and user satisfaction factor. We assume that network topology consists of different number of adjacent cells and number of Femtocells place inside Macrocell.

Each cell consists of number of different users place and these are then divided into inner, outer region if interference is present.

A. Mathematical Equations

Consider a system with bandwidth B that is divided into N RBs. The signal power [2] observed by receiver 'r' from transmitter't' on RB n is given by:

$$Y_n^r = P_n^t G_n^{r,t} \quad (1)$$

Where, P_n^t is the transmit power per RB n and $G_n^{r,t}$ is the channel gain between r and t.

1) Coverage Probability

The coverage probability is the probability that a typical mobile user is able [6] to achieve some threshold SINR, mathematically it is given by:

$$\text{Pc}\,(\text{T}, \lambda, \alpha) \equiv \text{P}\,[\text{SINR} > T] \quad (2)$$

Where, T is target threshold for SINR, λ is userequipment intensity and α is path loss component.

2) Path Loss Model

In this section the relevant channel models for the communication paths from the Macrocell base station to the Macrocell user equipment's and the Femtocell user equipment's are discussed [5].

A. Outdoor Path Loss Model

This model is designed specifically for small cells with high user densities in dense urban areas. The path loss for the LoS condition is calculated as $d'_{BP}=\frac{4h'_{eNB}h'_{UE}f_c}{C}$ and receiver isd'_{BP}, the effective breakpoint distance is calculated as where f_c is the Centre frequency in Hz, C is the speed of light in m/s and h'_{eNB}andh'_{UE} are the effective antenna heights for the eNB and UE, respectively.

$$L_{OLOS} = 22log_{10}d + 42 + 20\log_{10}\left(\frac{f_c[GHz]}{5}\right); \quad (3)$$

$$10m < d < d'_{BP}$$

$$L_{OLOS} = 40log_{10}d + 9.2 - 18log_{10}(h'_{eNB}) - 18log_{10}(h'_{UE}) + 2log_{10}\left(\frac{f_c[GHz]}{5}\right); d'_{BP} < d < 5000m \quad (4)$$

$$L_{ONLOS} = 36.7\log_{10} d + 40.9 + 26\log_{10}\left(\frac{f_{c[GHz]}}{5}\right); \quad (5)$$
$$10m < d < 2000m$$

B. Indoor Path Loss Model

This model is used to model the channel for indoor links [5]. The LoS path loss is calculated as shown in Equation (6) and the non-LoS model is calculated as shown in Equation (7).

$$L_{OLOS} = 16.9log_{10}d + 46.8 + 20\log_{10}\left(\frac{f_c[GHz]}{5}\right); \quad (6)$$
$$3m < d < 10m$$

$$L_{NOLOS} = 43.3log_{10}d + 25.5 + 20\log_{10}\left(\frac{f_c[GHz]}{5}\right); (7)$$
$$10m < d < 150m$$

C. Outdoor-to-Indoor (and vice versa) Path Loss Model.

The Outdoor path loss model is used to model only the indoor to outdoor path loss and vice versa as [5]

$$L_{OI\ or\ IO} = L_b + L_{tw} + L_{in}; 10m < d < 1000m \quad (8)$$

Here, L_b is the basic path loss calculated using the outdoor model as $L_b = L_{ONLOS}(d_{out} + d_{in})$. The parameter d_{out} refers to the distance between the femto-cell wall and the outdoor MBS/UE and d_{in} refers to the indoor distance between the UE/FBS and the femto-cell wall. The parameter L_{tw} is the wall penetration loss and L_{in} dependent on the indoor distance alone, is calculated as $L_{in} = d_{in}/2$.

3) Channel Model

Channel model is given by below equation [2]:

$$G_n^{r,t} = 10^{(-\frac{LS}{10})} \quad (9)$$

Where, *LS* is path loss between the transmitter t and receiver r on RB n.

4) Interference

Since the Macrocells and Femtocells share the sameavailable resources in both time and frequency domain, the interference received at any receiver r is the aggregated interference from both. Thus I_n^r is given by [2]:

$$I_n^r = \sum_{i\in M'} P_n^m G_n^{r,i} + \sum_{j\in F'} P_n^f G_n^{r,j} \quad (10)$$

Where, P_n^m denotes the Macrocell User Equipment (MUE) transmit power in the uplink and Macrocell Base Station (MBS) transmit power in the downlink. Likewise, P_n^f denotes uplink Femtocell User Equipment (FUE) and downlink Femtocell Base Station (FBS) transmit power respectively. The sets of interfering macro and femto base stations are denoted by$M'$and F' respectively. $G_n^{r,i}$isthe channel gain between the FBS and interfering MUE in the uplink and FUE/MUE and interfering MBS in the downlink. Similarly, $G_n^{r,j}$is the channel gain between the FBS and interfering FUE in the uplink and FUE/MUE and interfering FBS in the downlink.

5) Signal to Interference plus Noise Ratio

The Signal-to-Interference-and-Noise-Ratio (SINR) can be determined from Equation (1) and (10) as follows [2]:

$$SINR = \frac{P_n^t G_n^{r,t}}{\sum_{i\in M'} P_n^m G_n^{r,i} + \sum_{j\in F'} P_n^f G_n^{r,j} + \eta} \quad (11)$$

Where, η is the thermal noise per RB_n.

6) Throughput

Throughput is given by Shannon's equation that determines the achievable data rate of a channel [2]:

$$Thp_r = B_{RB}.\log(1 + SINR_n^r) \quad (12)$$

Where, $B_{RB}$is the bandwidth of a RB. From Equation (12) the total throughput of a cell can be expressed as:

$$ThP_{total} = \sum_{u=1}^{U} \sum_{n=1}^{N} Thp_{u,n} \frac{bits}{s} \quad (13)$$

Where, U is the total number of users of a cell and N is the total number of RBs assigned to the users of that cell.

7) Uplink Power Control

Uplink power control is given by[2]:

$$P_n^t = \min\left\{p^{max}, max\left[p^{min}, p^{max}\left(\frac{L}{\alpha}\right)^{\varepsilon}\right]\right\} \quad (14)$$

Where, $p^{max}$and $p^{min}$are the maximum and minimum transmit power per RB. The k-percentile path loss value α determines the critical path loss above which the UE transmits with maximum power. The balancing factor ε determines how steeply the transmit power increases with increasing path loss.

8) User Satisfaction (US)

This shows that how close the user's throughput is to the maximum throughput in the area. While when US approach 0, there are big variations in the throughput achieved by the users in the cell. And when it is approach to 1, then all users in corresponding cell experience same throughput [4]. US give fair allocation of bandwidth in different region of the cell.

$$US = \frac{\sum_{x=1}^{X} T_x}{\max\_user\_T.\ X} \quad (15)$$

III. METHODOLOGY

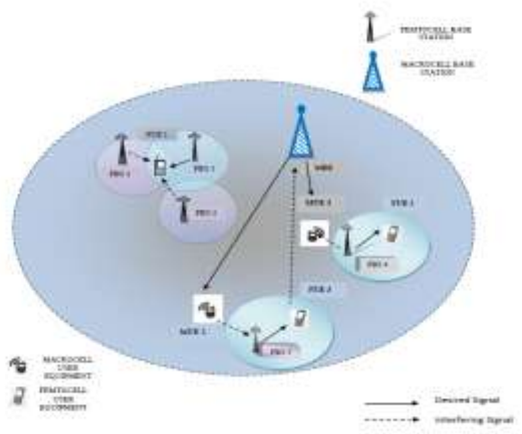

Fig.1. Desired Network

This section outlines the basic network architecture has 5 randomly deployed Femtocells per Macrocell in a suburban area. This model follows the LTE's resource block allocation. Macrocell splits the available 20MHz bandwidth into many resource blocks, where each resource block comprises of 12 subcarriers with a 15 KHz spacing each. Later Macrocell assigns this resource block to the subscribed Femtocells and to the Macrocell users. There is a chance of assigning same resource to a Macrocell user and to a Femtocell that are geographically apart under the same coverage span. This way of frequency reuse introduces the thread for co-channel interference. The basic system model consists of a large density of Femtocells deployed in some area inside the Macrocell. FUE1 suffers strong interference from FBS2 & FBS3 as it is near the edge area of desired FBS1. Also MUE1 suffers interference from FBS4 as it is close proximity of their area. MUE2 also gives interference to FBS5 and FUE3 also gives interference to MBS. So from above scenario it is clear that due to unplanned deployment their might be issue regarding degradation of signal.

A. *Proposed Methodology*

Below explains the necessary steps follow for given proposed methodology which focus on to reduce Co-tier interference with effective scheduling mechanism and tries to minimize Cross-tier interference with dynamic FFR with adaptation process which is modified.

Steps:-

1] Generate network model & define require parameter.

2] Unplanned deployment of Femtocells.

3] Calculate Coverage Probability.

4] Dynamically allocate Resource Blocks (RBs) to the User Equipment (UE)

5] For Co-tier Interference:-

i) FBS Continuously receives periodic information from its FUE & all FBS should synchronize with each other.

ii) Condition check as if Interference > Threshold

iii) If condition is true then make group of interfering FBS & perform cell partitioning: - cell center as well as cell edge area.

iv) Allocating RBs which is not in used by any interfering FBS & serving FBS.

v) Then again check above condition.

vi) If condition is true then exchange RBs with neighboring cell edge.

vii) If condition is false then END process.

6] For Cross-tier Interference:-

i) MBS Continuously receives periodic information from its MUE & all MBS should synchronize with each other.

ii) Condition check as if Interference > Threshold

iii) Perform cell partitioning: - cell center as well as cell edge area.

iv) RBs which is free i.e. not in used by any interfering FBS/MBS & serving MBS/FBS that can be Reuse. Calculate SINR, Throughput, US etc.

v) Then perform adaptation process for above & check Interference is below threshold level then END process.

Every FBS has its unique cell-id. As per methodology initially, every FBS uses all the available RBs and randomly allocates them among its UEs using 1-to-1 matrix mapping. This guarantees complete avoidance of intra-cell interference. According to self-configuring concept, the serving FBS learn about the current interference level of its UE through periodic reports sent by the FUE. FBS compare this interference level with threshold level set. If the interference experienced by any of its FUE is above a certain threshold, the serving FBS exchanges load information messages with its neighbors then identify the cell-ids of the interfering FBSs by measuring reference signal received power (RSRP) by its UE and stores the cell-ids in a neighboring list. This list of interfering FBSs forms the group. Further member of group follows cell partitioning process so as to select different set of RBs to different part of same cell i.e. cell center and cell edge. Then apply different set of RBs. If still interference measured is above threshold level then FBSs can exchange RB from neighbor cell edge cell. If Cross-tier interference present then we can use dynamic FFR methodology that selects the optimal frequency allocation based on the cell total throughput and user satisfaction. As we early discussed about Cross-tier interference scenario there might be chance that given MUE suffers interference to reduce this use adaptation process, the mechanism updates the frequency allocation (FA) and inner cell radius in order to take into account the users' mobility. On the other hand, the case without adaptation assumes that the FA and inner cell radius are calculated once (for the initial user distribution) and remain constant during the scenario. So this helps to reduction of interference with great extent and gives better throughput which shown in section IV.

IV. RESULTS AND DISCUSSIONS

Here the simulation environment has been designed in MATLAB. LTE-based Femtocell network is generated for analysis purpose where Femtocells are placed randomly within the Macrocell. The distribution of users are randomly scattered across the cell by using random distribution function in MATLAB and they are stationary over the plane. Femtocell operates on licensed band. As mention in simulation table numbers of user assigned to Femtocells vary in between 1 to 8

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which is assigned to every Femtocell whereas each MBS can serve multiple MUEs at a time. Users of Femtocells are also the users of Macrocell. Here dense Femtocells environment is generated so as to form an overlapping Femtocells region and all parameters taken for design of network and simulation are as per mentioned in Table I. For the Macrocell deployment with randomly place MUE in MATLAB coding.

I. DESIGN AND SIMULATION PARAMETER

Parameters	Specifications
Macrocell Layout	3 sectors per MBS
Femtocell Layout	1 sectors per FBS
Channel Bandwidth	20 MHz
Max FUE per Femtocell	6
Macrocell Radius	500 Meter
Femtocell Radius	20 Meter
Operating Frequency	2.5GHz
MBS Transmission Power	38dbm
FBS Transmission Power	20dbm
Max. MUE Transmission Power	24dbm
Max. FUE Transmission Power	20dbm
Min. MUE/FUE TX power	-30dbm

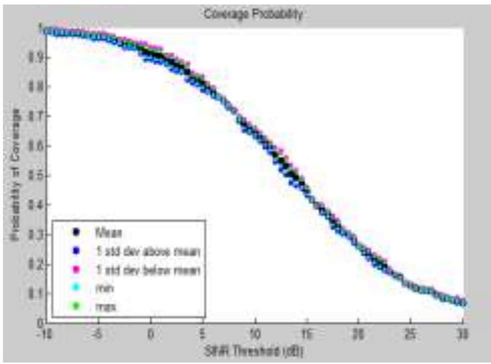

Fig. 2 Coverage Probability.

Here Coverage probability is analyzed for Macrocell network model. Assumption is that all the BSs transmit with equal power which for convenience we set to unity. Also the standard Outdoor path loss model is used. Here main focus is on the downlink performance. Mainly the coverage probability will be helpful to do spectrum allocation within the cell by knowing where coverage is more out of entire region it also gives idea about the high user density within the cell.

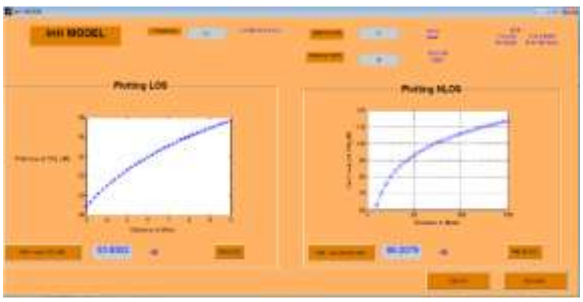

Fig. 3 Indoor Path Loss Model

Path loss is important as its show that as we increase operating frequency then path loss also increases in figure 3. Cost of having more number of sites operating at higher frequencies is compensated by getting an increase in capacity so high frequency operating network use basically. So with the path loss we can get idea signal degradation as it moves away from base station.

The simulation results are as shown below which are analyses the downlink interference, SINR and throughput of the femto users as well as uplink interference, SINR and throughput of FBS.

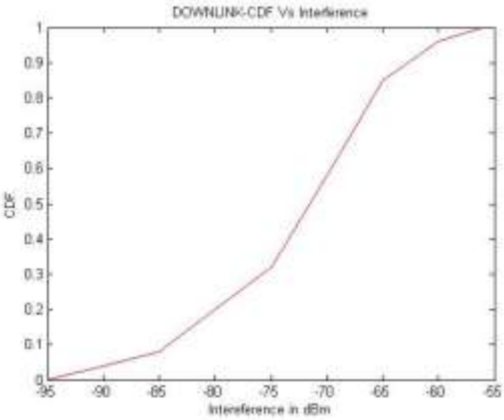

Fig. 4 Downlink User Interference

All plots are plotted versus Cumulative Distributive Function (CDF) as this function is useful to study and understand random signal also its behavior. Figure.4 is CDF of Downlink Interference of proposed methodology for FUEs. The graph clearly shows that proposed methodology can efficiently reduce the interference. The threshold interference level set is -45dBm, proposed methodology managed to reduce the interference up to -56dBm. Somewhat Similar results are obtained for Uplink Femtocell Base Station.

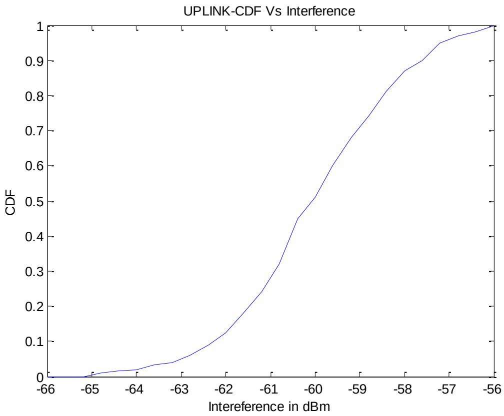

Fig. 5 Uplink FBS Interference

Figure.5 show graph uplink interference of proposed methodology for FBSs. For Uplink proposed methodology is able to reduce Interference up to -56 dBm.

Figure.6 shows graph of CDF vs. SINR of proposed methodology for downlink FUEs. As interference decreases received signal strength increases which improve the system performance.

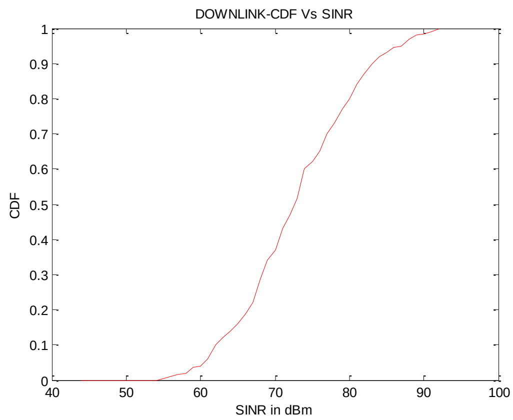

Fig. 6 Downlink User SINR

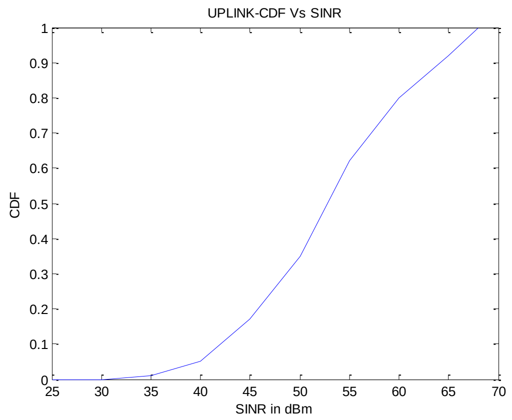

Fig. 7 Uplink FBS SINR

Figure.7 shows graph of SINR for uplink FBSs increases due to proposed methodology. As SINR plays very important role in any communication. System which gives better SINR is always preferable for communication. Interference decreases then SINR increases so main purpose of system methodology is to reduced interference.

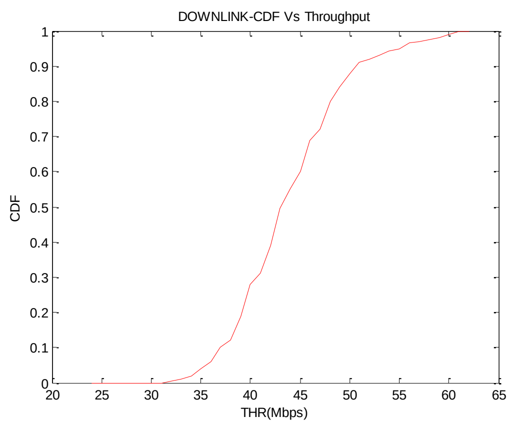

Fig. 8 Downlink User Throughput

Figure.8 shows graph throughput result for proposed methodology. The throughput obtained for the downlink by proposed methodology is around 62 Mbps. So proposed methodology gives greater throughput, which can prove proposed methodology is excellent method for Inter-cell-Interference reduction between Femtocells located in dense environment. As system working on 20MHz so require throughput is nothing but 100 mbps ideally.

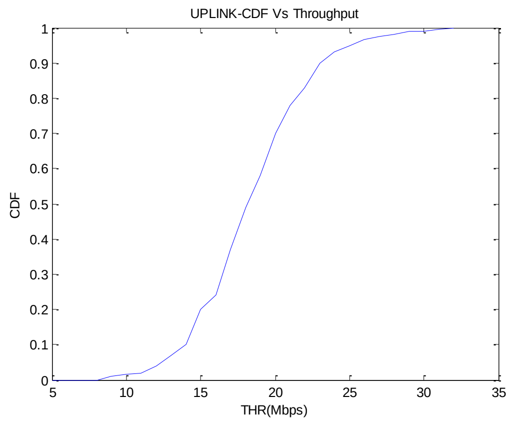

Fig. 9 Uplink FBS Throughput

Figure.9 shows that as ideally 50 Mbps throughput require for 20MHz channel bandwidth. But due to interference ideal throughput is difficult to get. With proposed methodology it can be possible to achieve throughput as 32 Mbps which can be maximum throughput.

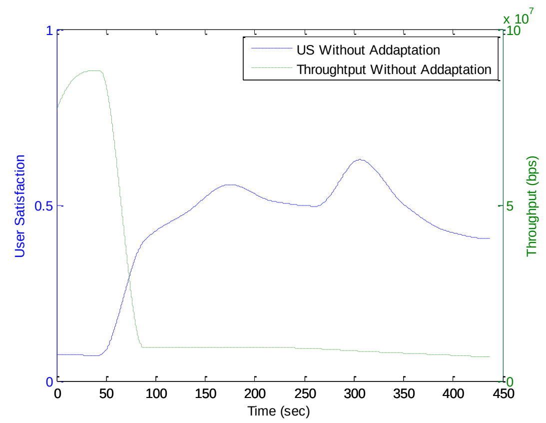

Fig. 10 Throughput without adaptation

From figure no. 10 can show that if cross-tier interference is present that we can use dynamic FFR methodology from which we can achieve better throughput after dividing cell into inner region and outer region. After applying adaptation process which periodically repeats methodology in order to achieve better performance.

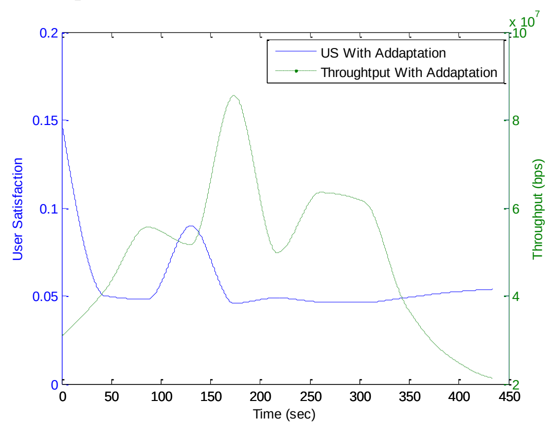

Fig. 11 Throughput with adaptation

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Figure 11 show result after applying adaptation process we can get proper frequency allocation and inner cell radius in order to get maximum throughput. As channel bandwidth is 20 MHz from above without adaptation throughput decreases and with adaptation throughput gives better performance. Adaptation helps to select proper allocation of frequency so this will help for throughput increment.

V. Conclusion and Future Scope

LTE Femtocell really helps to provide efficient solution for indoor coverage with better performance. Choosing an interference mitigation technique is very difficult question in LTE Femtocell network. Main aspect to consider here is to reduce Cross-tier & Co-tier interference but the parameters like user capacity per cell, system complexity should also be taken into consideration. Results shows that the mechanism which helps to reduce the Cross-tier interference that maximizes the cell total throughput as well as the US metric. With effective scheduling mechanism it is possible to reduce Co-tier interference help to improve overall throughput. In practical way there might be difficult for proper scheduling but this help to improve throughput which is main focus of any given communication. The main objective should be to provide best services to users. It is difficult to predict exact number of users or traffic in a specific region of cell. In that way we can say that technique which gives better SINR ratio is effective for implementing in LTE network.

For future work, Handover from Macrocell to Femtocell and vice versa can be possible with some timer in that base station continuously measures RSS which help to direct communication channel with desired base station. Also Macrocell users can reuse RB which will be located far away from desired base station which might probably require an effective as well as best switching mechanism.

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