Improving Spectral Efficiency of Massive MIMO Network for Next Generation 5G Wireless Network

Seetaiah Kilaru[#1]

#1 BVRIT Hyderabad College of Engineering for Women, JNTU Hyderabad, Telangana, India, +91-9666837310

ABSTRACT

Justify Future wireless standard requires excellent data rates to meet the expectations of users. 5G will come into the reality soon. The operators should be ready to meet the demand from the world. Considerable research is going on this issue and the research is trying to find out the methodology to get the best data rates. This paper proposes a novel method which is just modification to existed FP7 Project METIS. In this paper we focussed on tight bound between small cells without interfere each other. To achieve this, we used the concept of Coordinated Multipoint and initially we explained the channel modelling and then we performed simulations. Our results shown that, CoMP simulation scenario is much better than existed scenario with some assumptions. In future, we are expected to propose optimised model with practical constraints. The current work in this paper is satisfactory with respect to MIMO standards. The analysis in this paper focussed on massive MIMO implementation with cooperation between all existed cells.

Key words: Massive MIMO, Coordinated multi point, Spectral Efficiency, 5G

Corresponding Author: Seetaiah K

INTRODUCTION

There is a need to boost the capacity of wireless networks to meet challenges from next generation smart devices. The next 5G will need high capacity to serve the user with the data rates of more than 100 Mbps. A very well known research project ARTIST4G as explained in [10], if the distance between the inter-cells is more than 500m, then there is a more possibility to face strong inter-cell interference. In other popular project FP 7 Project METIS as described in [8], ultra dense environments with cell size less than 500m will also face inter-cell interference. There is a need to define a tight and prescribed inter cell interference avoiding method is required. To achieve this, this paper recommending Coordinated Multipoint (CoMP) in transmission process between two cells.

The possibility of joint transmission was introduced in EU FP 7 project [9,10]with respect to homogeneous networks and proposed Interference Mitigation Framework (IMF). The proposed IMF-A performance depends on cooperation between user centric served CoMP user equipments. We used traditional Tortoise concept is used to achieve interference floor shaping. This fllor shaping is advantage to the operator in two aspects, they are decouple adjacent cooperation areas and also for cell tilt adaptation. This extends the high level optimization of Multi layer network which confined to single cooperation area.

The joint transmission CoMP in homogeneous network is achieved, but the new trend is all about Heterogeneous Networks (HetNet). This is due to the fact that, the operator is placing much number of small cells to achieve excellent coverage area. This indirectly results high number of backhaul connections. These small cells are placed at the height of 20m to 50m (depending on the terrain structure) with corresponding transmission powers of 37 dBm to 49 dBm. These cells are allowed to have a maximum bandwidth of 20 MHz. HetNet's can also be implemented with the help of pico stations (small base station which can place below rooftop) and they can be operated with the transmission power of 20 dBm to 25 dBm.

The area which has number of small cells with less covering distance will form Ultra Dense Networks (UDN). For these areas, the existed joint transmission CoMP may not give a solution to achieve excellent cell capacity. The problem of tight cooperation between them to reduce inter-cell interference will increase considerably. In [6], for the similar set up, backhaul traffic is generated in the order of 10 Gbps. We should also consider the other complexity to acquire pre-coding for joint transmission CoMP because it requires many matrix inversions (the mathematical analysis is complicated).

One of the basic solutions to avoid these problems is to assign different frequency channel to macro cell and small cell. in this paper, we considered the open frequency 2.6 GHz for macro and 3.5 GHz for small cell. Existed Inter-cell Interference Coordinated (ICIC) techniques are allowing fine coordination between macro cell and small cell depending on the load conditions as discussed in [7]. In many practices, coordination between cells are existed with the help of intentional switch off of small cell or macro cell which can disturb the other layers. To achieve the defined coordination between cells, we cannot switch off either macro cell or small cell completely in the technique further enhanced ICIC (feICIC). Instead of switching off completely, we can send blank frames to achieve the backward compatibility.

These proposed methods will only support the high frequency of operation, i.e. about above GHz. But, the RF signals with below few GHz has the excellent coverage and there is a much availability of bandwidth. For mobile network operators, Base station (macro-cell) is a huge asset where they can place at greater heights with strong power radiation, whereas small cells are placed on particular region with height 30m to 50m and it will consume less power too.

The two main issues which are difficult to implement the methodology in [10] are

- Noise: In HetNet small cells are deployed in indoor region, due to the penetration loss and atmospheric losses, the signal can be corrupted with noise.

- Rank limitation: In homogeneous scenario, the preparation of channel matrix is easy. It will assign ranks to each channel available at the base station. In HetNet, the channel matrix modeling is very difficult as it has several small cells.

In [4], the authors proposed the possibility of implementation of Massive MIMO. This technology will use very narrow beam-widths to increase Signal to Noise Ratio. Due to the frequency of implementation and dense circumstances, this Massive MIMO will always use small cells. Small cells will get high SNR due to the fact that the distance between small cell and user equipment is very less; hence there is a considerable low path loss. The designer should be careful to not assign same band of frequency to both macro and small cells. If there is a same set of frequency is distributed among them, then the channel correlation is high what the operator does not expect to happen.

In this model, we implemented two operating bands for small cell, one band is exclusively used for conventional data offloading. This primary band will use high frequency carrier. The other band will focus on selection of subset of macro layer in an opportunistic way. This dual band operation of small cell will increase the efficiency of the system.

PERFORMANCE EVOLUTION OF COMP

A. *Channel model*

Many people around the world are in serious research on MIMO and CoMP. For the better understanding of each contribution to others with respect to FP7 project METIS, the people agreed to use basic simulation assumptions and to use QUADRIGA channel model as described in [5]. This channel is proposed by Heinrich Hertz institute in Berlin (HHI). This channel model is the extension of existed Spatial Channel Model extended (SCMe) which are used in 3GPP. The required channel model can be characterized with the simulation parameters as given in [4] which are tabled in table 1..

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B. *General Simulation Scenario*

The general simulation scenario is shown in figure 1. From this figure 1, the 70 small- cells are dropped randomly into homogeneous set of 57 macro cells. The red part shown in figure 1 represents dropped portion and we trying to form single co-operation area of three/nine macro sites/cells. To this red selected area, we are applying interference floor shaping is applied with the help of tortoise concept. Using this concept we can decouple the adjacent cooperation areas by strong/low tilting values. For the assessment, we considered first order to ignore inter-cell interference. To decrease the system level simulation time, only 9 out of 57 cells are taken into consideration.

TABLE I
SIMULATION PARAMETERS

Parameter	Specifications
Distance between base station to user equipment	35m
Centre frequency	2.6 GHz
Number of taps	20
drops	300
Distance between small cell to small cell	40m
Correlation between macro cell to macro cell	0.5
Macro base station sectors	57
Correlation between small cell to small cell	0
Distance between small cell to user equipment	10m
Observed time	100ms
Users per sector	110
Small cells per sector	10
Channel model	QUADRIGA
Correlation between macro cell to small cell	0
Number of samples per λ/2	4
Simulation type	Monte-Carlo
Distance between base station to small cell	75m

COMP SCENARIO

The following figure 2 explains about the proposed Opportunistic CoMP set up for over all multi layer system. Three sites with 9 cells are considered as cooperation area. The initial 70 cells are to be dropped into cooperation area randomly. In each base station, we formed Uniform linear array with 16-elements or 32 standard 16 elements Catherine antennas. This setup converted MIMO set up to Massive MIMO with 16×16 antenna elements. The total number of antennas participating in this process is 256. This resultant array will produce 8 narrow beams with equally spaced main-lobe steering angles within 120^0 sector. To avoid complexity of this set up, we are not introduced Vertical beam steering phenomenon till now.

To avoid the effect of flash light, Grid of Beams (GoB) is used to generate constant and expected interference conditions.

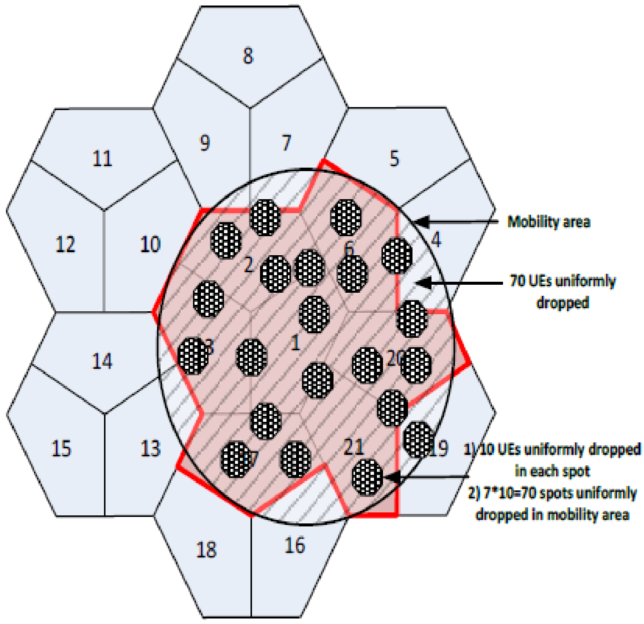

Fig.1.Simulation Environment

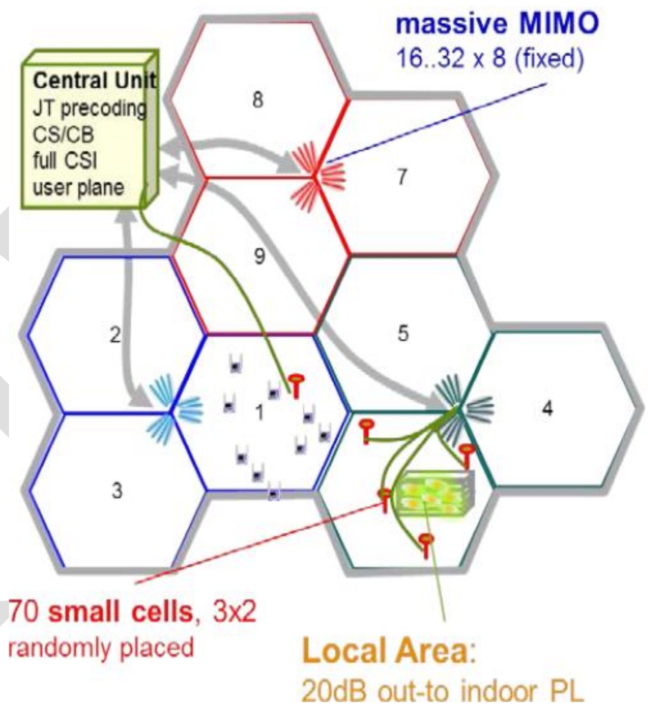

Fig.2. Details of overall multi layer system set up

This reduces the required number of antennas and only limited antenna ports are required to serve to CoMP. Reduction in number of ports will increase the efficiency of Frequency Division Duplex (FDD) systems. In FDD, the channel estimation could be done with the help of orthogonal Channel State Information Reference (CSIR) signals [16, 17, 18, 19].

For an ideal assessment we are considering the macro cell and 70 small cells will form cooperation area and all are connected to a central unit. This connection should be more specific with zero latency and other propagation characteristics. We are expecting that, currently 60% indoor users are creating traffic and it may increase to 75% in the next coming years. Hence, we are proposing this method by considering all users are in indoor region. We also assumed that the knowledge of Channel State Information (CSI) is known to both small cell and macro cell users.
The small cells are in this model has 3 120^0 sectors and each sector has 2 antennas. This policy of sectorization may increase the hardware complexity of the system but it will help to control small cell interference considerably. That means for each cell we have 2 antennas and we have 70 cells.
Total available number of channels= (Number of cells)(number of antennas per cell)
= (70)(6) =420 channels.
From figure 2, after considering the enlarged cooperation, we have 3 sites and each site serving for 3 cells. Hence, we have 3 cells and each cell has 8 virtual beams per cell. Then the total number of beams per cell = (9)(8)=72 channels.
Total number of channels = 72+420 = 492 channels. These 492 channels are available for 90 user equipment (Assumptions).
The following figure 3 shows the receiver power for various channels.

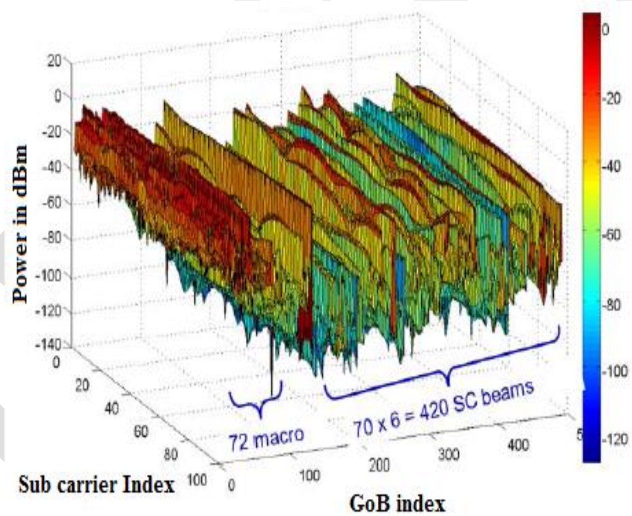

Fig.3. received power w.r.t Sub carrier and GoB index

If we limit all channels within a predefined power window, we can reduce the overall system complexity, the base station frequencies are more selective than the small cell. This is due to the reason that macro cell will experience the reflection often than small cell. Small cell covers less distance and there is a possibility to have more LoS paths and less reflections and it is contrary to macro cell.

MASSIVE MIMO BEAMFORMING GAINS

The following figure 4 shows the SNR of various users either from single transmits antenna and also including massive MIMO.

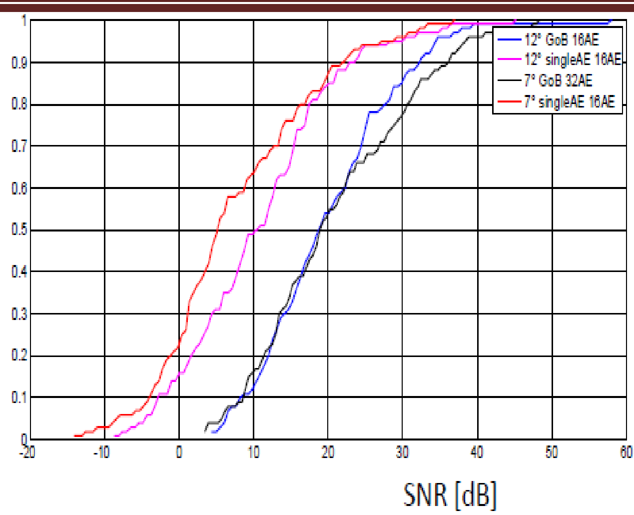

Fig.4. SNR for 90 users in single cooperation network

Here, we used two tilting angles, i.e. 7^0 and 12^0. From the figure 4, we can conclude that the geometry with Inter Site Distance of 500m with 12^0 shown improvised performance than 7^0. SNR gain is about 10 dB due to this massive MIMO beam forming.

Conclusion

In this paper cooperative transmission scheme was analyzed with respect to massive MIMO environment. The opportunistic environment is implemented between base station (Macro cell) and small cells. Spectral efficiency is achieved with this method by activating 20% of the small cells instantly depending on the traffic load. Assumption assumed in this paper is somewhat ideal in nature. Much detailed evolutions are required for further analysis. To achieve this efficiency, designer should not sacrifice the quality of service and also the data rates.

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