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Green Mobile Communication

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Abstract: The world is moving to 5G technology where MIMO, small cell technology places a vital role. There is a linear relationship between generations and total power consumed. The capacities, speed of the data rate are the parameters for the upcoming generations which consume more power. Gupta, A., & Jha, R. K. Stated that, to improve the cellular energy efficiency, network topology must be densified and a combination of two densification approaches namely "massive" multiple-input multiple-output (MIMO) base stations and small cell access points are analysed in this paper[1]. The proposed Network Architecture reduces the traffic to the main base station and improves Quality-of-Service (QoS) to each user thus reducing power consumption. We have also performed simulations which show how the power consumption can be reduced by combining MIMO and small cells.

Keywords: Multiple Input Multiple Output (MIMO); Base Station (BS); Small Cell Access Point (SCA); Direction of Arrival (DOA); Base Transceiver Station (BTS); Quality of Service (QoS)

I. INTRODUCTION

Energy consumption has become a primary concern in the evolution of 5G technology. 5G cellular network aim to provide 1000 times higher system capacity, 10times spectral efficiency and higher energy efficiency compared to present cellular network technology[1]. The below figure shows the structure of performance analysis in 5G.

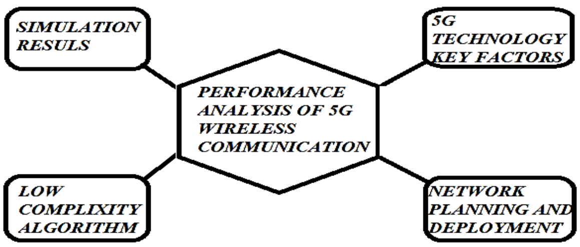

Fig 1. Structure for evolution of 5G technology

Every element that shows its performance in 5G cellular technology is discussed:

A. *5G Technology Key Factors*

The key factors in 5G technology are:

a) *MIMO*

Multiple-Input Multiple-Output (MIMO) is a wireless communication antenna technology in which multiple antennas are used at both the transmitter and the receiver is shown in the Fig 2. The antenna at each end of communication circuit is combined to minimize errors and optimize data speed. MIMO is used for high spectrum efficiency and has been recorded a rate of 145.6 bits/Hz.

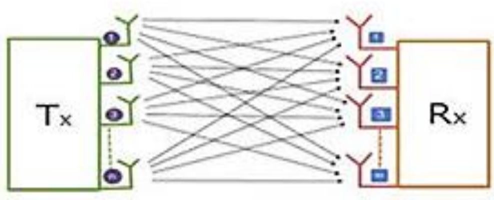

Fig 2. Basic structure of MIMO system

A smart antenna consists of several antenna elements, whose signal is processed adaptively in the spatial domain. In actual, antennas are not smart antennas, systems are smart.

The smart antenna systems are placed within a base station, they combine an antenna array with a digital signal-processing capability to transmit and receive in an adaptive, spatially sensitive manner [1] (i.e. System can automatically change the directionality of the radiation pattern with respect to signal environment).

There are two main parameters: 1. Direction of arrival (DOA). 2. Beam forming. DOA denotes the direction from which a signal arrives. In this paper we have estimated DOA using MUSIC algorithm and the simulation result is shown in Fig5. Beam forming is a method used to create the radiation pattern of the antenna array by adding constructively the phases of the signals in the direction of intended user [1]. We have estimated beam forming using LMS algorithm and the simulation result is shown in Fig6. In recent years the smart antenna systems have been used to reduce power consumption predominantly. Smart antennas have a capability of radiating a beam towards the intended user and nullifying interferers which is not possible in the case of conventional antenna. Hence this shows a promising result of minimization of power consumption at the base station.

b) Small Cells

Small cells are portable miniature base stations that require minimal power to operate and can be placed in every corner [2]. Small cells are used as a solution to allow spatial reuse as an important method of increasing cellular network capacity and quality.

Small cells encompass micro cells, picocells, femto cells.

i. Micro Cell: Micro cell is the low-power cellular base station covering a limited area such as malls hotels etc. The range of micro cell is 2-5 km.

ii. Picocell: A picocell is cellular base station covering a small area such as indoors where signals are difficult to reach indoor. The range of picocell is 200 meters.

iii. Femtocells: Femtocell is small, low power cellular base station, desired for use in a home or small business sectors. Its supports 4-8 simultaneous active mobile phones in residential areas and 8-16 in enterprises setting. HNB is a 3G femtocell and HeNB in an 4G femtocell. The range of femtocell is 10-12 meters.

c) Beamforming

Beamforming is a traffic-signalling system for cellular base stations that identifies the most data-deliver to a particular user[1]. Beamforming can help massive MIMO arrays to use spectrum more efficiently. At massive MIMO base station we use signal processing algorithms to plot the route to a particular user from the base station and can send data packets in different directions avoiding the fading effect.

d) Full Duplex

In 5G, a transceiver will be able to transmit and receive data at the same time, on the same frequency. It could increase the capacity of the cellular network.

B. Network Planning and Deployment

There are many techniques for planning and deployment in 5G out of which we use optimal soft cell coordination using massive MIMO base station and small cell access point and is shown in Fig3. This technique is discussed in section III.

C. Low Complexity Algorithm

The equation (7) presented in the paper shows the optimization problem of minimization of power satisfying QOS and power constraints. This equation contains beam forming vectors which are not feasible in polynomial real time. So we propose low complexity algorithm to eliminate the convex optimization problem in section III.

The factor 4 (simulation results) is shown in the section V.

II. BASE STATION AND ITS SOLUTION TO REDUCE POWER CONSUMPTION

A base station (BS) is a fixed point of communication for customer cellular phones for a carrier network. The base station is connected to an antenna that receives and transmits the signal in cellular network to phones and devices; this equipment is connected to a mobile switching station that connects cellular calls to the public switched telephone network (PSTN).The geographic area covered by base station is called a cell. The base station sub-system consists of base transceiver station (BTS) and base station controller (BSC). BTS correspond to transceiver used in each cell of the network usually placed in the centre of the cell. BSC manage the radio resources for BTS it is the connection between mobile and the MSC. A BTS is usually composed of transceiver power amplifier, combiner, multiplexer, base band receiver unit, control function etc. however base station consumes 85% of the network total energy there are two solutions to reduce the power consumption

A. Base Station Based Solution

The solution is to put base station into sleep mode i.e. switching off the base station experiencing low traffic's during the off-peak period can balance the transmitting and circuitry power consumption and the achieve the purpose of energy saving in the base station. In 5G, setting a base station into sleep mode can give 10% of efficiency compared to current network when there are no users. The power amplifier in the base station consumes 57% of energy in the macro base station, while cooling contributes 10%.By upgrading the power amplifiers and RF chains according to technology development can reduce the power dissipation which leads to the minimization of power at base station.

B. *Network Architecture Based Solution*

It can be implemented by doing some changes in the current network architecture. This paper proposes the new idea which is discussed in section III to reduce the power consumption

III. OPTIMAL SOFT CELL CO-ORDINATION METHOD

This paper analyzed the possible improvements to minimize power consumption when the macro cell topology is modified by employing massive MIMO at the BS and/or deploying with Small Cell Access point (SCA). We consider a single cell down link scenario where a macro BS equipped with N antennas to deliver information to M single antenna users. In addition deploy SCA's each equipped with N antennas [2].

The BS and SCA are connected to a backhaul network that enables each user to the served by multiple transmitters but the information symbols are coded and emitted independently.

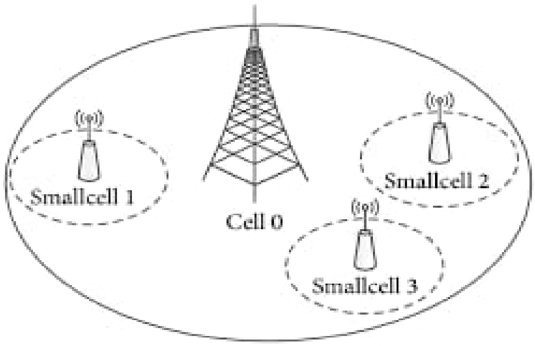

Fig 3. Structure showing network planning and deployment of SCA

The received signal at user M is given by

$$y_m = c_{m,0}^C x_0 + \sum_{i=1}^{s} c_{m,i}^C x_i + n_m \tag{1}$$

where,

X_i: transmitted signal at the SCA

X_0: transmitted signal at base BS

n_m: Gaussian receiver noise

$c_{m,o}$, $c_{m,i}$: Baseband for BS and SCA

We call it spatial multiple flow transmission and it enables users covered by SCA to receive extra signals from the BS or other SCA.

Information symbols multiplied with beam forming vectors to obtain transmitter signal is given by the below equation,

$$x_i = \sum_{m=1}^{M} V_{m,i} x_{M,i}, i = 0 \dots \dots . . s \tag{2}$$

where,

$x_{m,0}$: Information symbols from base station

$x_{m,i}$: information symbols from SCA

$v_{m,0}$: beam forming vectors of BS

$v_{m,i}$: beam forming vector of SCA

A. *Problem Formulation for Power Consumption*

The total power consumption is model with a static part that depends on transceiver hardware and a dynamic part which is proportional to the emitted signal power[2]. Massive MIMO and small cell networks promise great improvements in the dynamic part that require more hardware that is static part[2]. In other words dense network topologies must be properly deployed and optimized to improve overall efficiency the power consumption can be modelled as $P_{dynamic}$ + P_{static} [6-7] which are given by equations.

$$p_{dynamic} = \rho_0 \sum_{m=1}^{M} \|v_{m,0}\|^2 + \sum_{i=1}^{s} \rho_1 \sum_{m=1}^{M} \|v_{m,i}\|^2 \tag{3}$$

$$p_{static} = \frac{\eta_0}{B} N_{BS} + \sum_{i=1}^{s} \frac{\eta_i}{B} N_{SCA} \tag{4}$$

The dynamic power consumption comprehends the emission as $\sum (v_{m,i})^2$, each multiplied with a constant pi ≥1 accounting for the inefficiency of the power amplifiers at this transmitter. Each BS and SCA in prone to L_i power constraints given by the equation

$$\sum_{m=1}^{M} v_{m,i}^C Q_{i,l} v_{m,i} \leq q_{i,l}, l = 1 \dots \dots . . L_i \tag{5}$$

QOS is represented as a data rate [bits/s/Hz] that each user should achieve in parallel. These are defined as $\log_2(1+SINR_m) \geq \alpha_m$ where α_m is the fixed QOS target and where $SINR_m$ is given by

$$SINR_m = \frac{|c_{m,0}^C v_{m,0}|^2 + \sum_{i=1}^{S} |c_{m,i}^C v_{m,i}|^2}{\sum_{j=1,j\neq m}^{M} \left(|c_{m,0}^C v_{j,0}|^2 + \sum_{i=1}^{S} |c_{m,i}^C v_{j,i}|^2\right) + \sigma_m^2} \tag{6}$$

Here $\log_2(1+SINR_m)$ is the depiction of the information rate which is achieved when the interference is successfully cancelled from the own data symbols, whereas the co-user symbols are treated as noise [5].

The goal is to minimize total power consumption why satisfying QOS constraints at the users are power constraints at BS and SCA, the optimization problem is given by the equation

$$minimize_{v_{m,i}\forall_{m,i}} P_{dynamic} + P_{static}, subject\ to$$

$$\log_2(1 + SINR_m) \geq \alpha_m \quad \forall_m, \tag{7}$$

$$\sum_{m=1}^{M} v_{m,i}^{C} Q_{i,l} v_{m,i} \leq q_{i,l}, \quad \forall_{i,l}$$

The optimized solution for power minimizing is self-organizing i.e. only one transmitter will serve each user.

The convex problem obtained in the above equation is optimized and clearly stated in the section III of [1] using the interior point toolbox SeDuMi [15].

The case study paper[1-2] is considered as the standard for low complexity algorithms for non-coherent coordination. To validate this, low complexity non iterative multiflow-RZF beam forming is explained as:

a) each transmitter i=0,………s computes

$$u_{m,i} = \frac{\left(\sum_{j=1}^{M} \frac{1}{\sigma_j^2} c_{j,i} c_{j,i}^{C} + \frac{M}{\alpha_m^{\sim} q_i} I\right)^{-1} c_{m,i}}{\left\| \left(\sum_{j=1}^{M} \frac{1}{\sigma_j^2} c_{j,i} c_{j,i}^{C} + \frac{M}{\alpha_m^{\sim} q_i} I\right)^{-1} c_{m,i} \right\|} \forall m,$$

$$g_{j,m,i} = \left|c_{j,i}^{C} u_{m,i}\right|^2 \forall_{j,m},$$

$$Q_{i,l,m} = u_{m,i}^{C}\, Q_{i,l}\, u_{m,i}\ \forall_{l,m} \tag{8}$$

b) The i^th^ SCA sends the scalars $g_{j,m,i}$, $Q_{i,l,m}$, $\forall_{m,j,l}$ to the BS. The BS solves the convex optimization problem

$$minimize_{\rho_{m,i} \geq 0\ \forall_{m,i}} \sum_{i=0}^{s} i \sum_{m=0}^{M} \rho_{m,i} + P_{static}$$

$$subject\ to \sum_{m=1}^{M} Q_{i,l,m}\, \rho_{m,j} \leq q_{i,l} \quad \forall_{i,l}, \tag{9}$$

$$\sum_{i=1}^{s} \rho_{m,i}\, g_{m,m,i} \left(1 + \frac{1}{\alpha^{\sim} m}\right) - \sum_{j=1}^{M} \rho_{j,i}\, g_{m,j,i} \geq \sigma_m^2 \quad \forall m$$

c) The allotment of energy on $\acute{p}_{m,i}$ $\forall_m$, which gives solution for the above equation is given to the i^th^ SCA, which computes.

$$v_{m,i} = \sqrt{\rho_{m,i}^{\star}}\, u_{m,i}\ \forall_m \tag{10}$$

The heuristic RZF beam forming as shown in [2,3] is applied in this algorithm which transforms the power minimization problem into power allocation problem. Relaxed zero forcing beam forming is clearly explained in [4].

IV. NUMERICAL EVALUATIONS

This section illustrates the analytic results and algorithms of this paper in the scenario shown below.

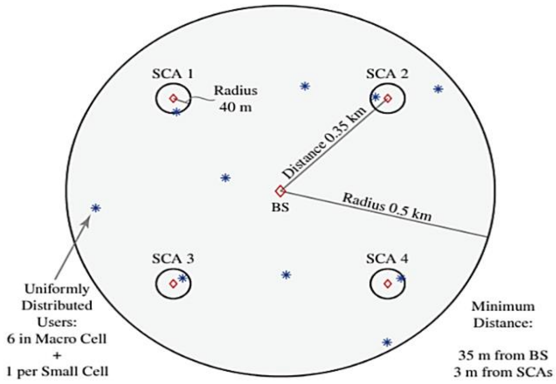

Fig 4. Figure showing optimal soft cell coordination

This figure shows circular macro cell overlaid by 4 small cells. They are 10 active users, where of 6 user distributed in the whole cell and each user in each SCA with in 40m radius the below table shows the hardware parameters that characterize the power consumption.

A. Hardware Parameters in the Numerical Evaluation

Parameters	Values
Efficiency of power amplifiers	$1/p_o$=0.388, $1/p_i$=0.052∀m
Circuit power per antenna	n_o=189mW, n_i=5.6mW ∀m
Per-antenna constraints	$q_{0,l}$=66, $q_{i,l}$=0.08mW ∀m

Table 1. Hardware parameters in the numerical evaluation

B. Channel Parameters in Numerical

Parameters	Values
Macro cell radius	0.5 km
Carrier frequency /number of subcarrier	F=2GHz /B=600
Total bandwidth/subcarrier bandwidth	10MHz / 15MHz
Small-scale fading distribution	$c_{m,I}$ ~CN(0,Rm,i)
Standard deviation of log-normal shadowing	7db
Path and penetration loss at distance d (km)	148.1+37.6 $\log_{10}$(d) db
Special case: Within 40 m from SCA	127+30$\log_{10}$(d) db
Noise variance (5 db noise figure)	-127 dBm

Table 2. Channel parameters in numerical evaluation

C. Evaluation

Figure 7 shows the average total power consumption (per subcarrier) where the users have QoS of 2 bits/s/Hz. It demonstrates that adding more hardware i.e. SCA can substantially decrease the total power consumption.

Fig 8 considers N_{BS}=50 and N_{SCA}=2 for different QOS constraints. Three beamforming algorithms are compared:

1. Optimal beamforming using only the BS
2. Multiflow RZF beam forming.
3. Optimal spatial soft cell coordination.

We consider the RZF beamforming approach instead of optimal beamforming for spatial soft-cell because the algorithm becomes infeasible for real time implementation when NBS and number of small cells (s) grow large.

V. SIMULATION RESULTS

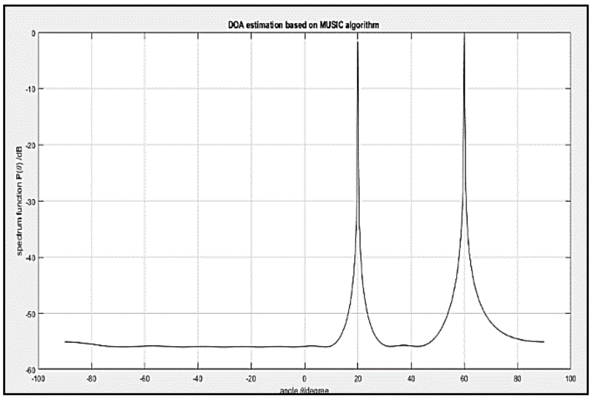

Fig 5. Simulation result of DOA using MUSIC algorithm in MATLAB

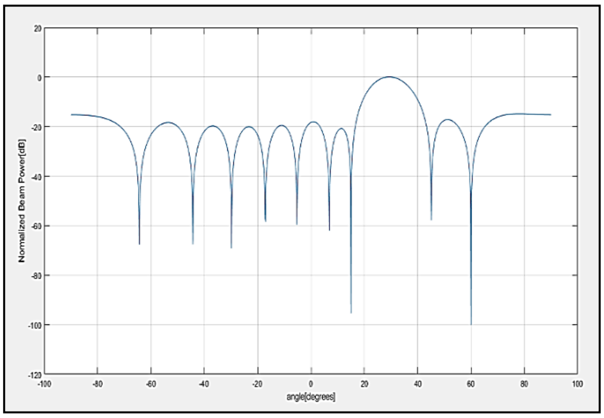

Fig 6. Simulation result of Beam forming using LMS algorithm in MATLAB

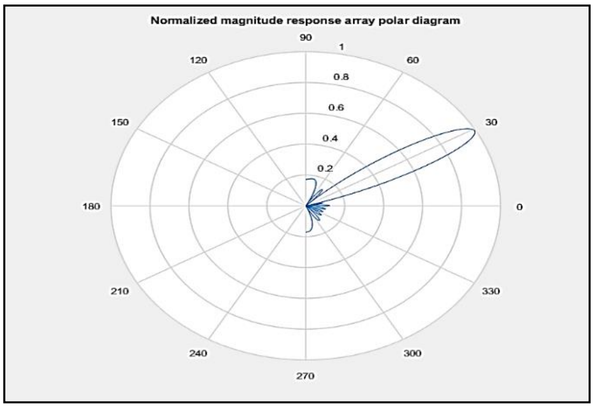

Fig 7. Simulation result of beamforming using LMS algorithm in MATLAB

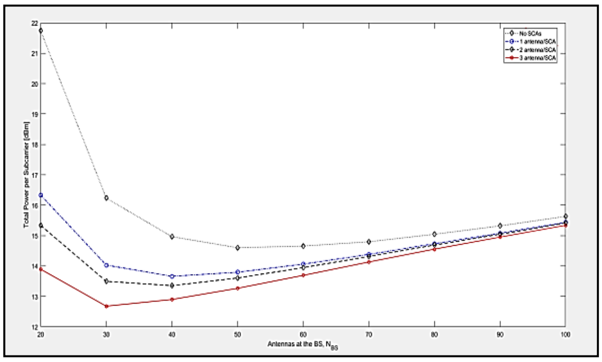

Fig 8. Simulation result showing total power consumption considering different N_{BS} and N_{SCA}.

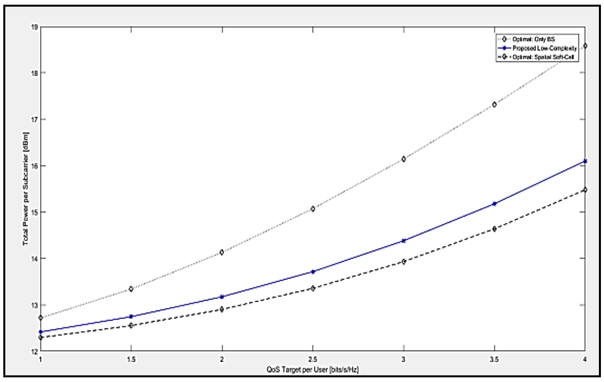

Fig 9. Simulation result with NBS=50, NSCA=2 with different QoS constraints and beam forming

VI. CONCLUSION

The energy efficiency of cellular network can be improved by employing massive MIMO at the BS or overlaying current infrastructure by a layer of SCA's. This paper analyzed a combination of the concept provided the optimal solution dynamically assigns users to optimal transmitters, which usually is only BS or one of the SCA's. If user is in the vicinity of the SCA it is served by the SCA, if not the base station serves the user which reduces most of the traffic to the base station. The smart antenna system placed in base station as well SCA can minimize power consumption compared to present scenario conventional antenna system.

The analysis considers both dynamic emitted power and static hardware consumption. We provided promising results showing that total power consumption can be greatly minimized by combining massive MIMO and small cells.

Fig 7 clearly says that as the number of SCA's increases the total power consumption decreases exponentially.

Fig 8 clearly says that multiflow RZF beamforming gives promising result for practical applications.

VII. FUTURE WORK

The improvement of spectral efficiency can be achieved using OFDM .Improvement in energy efficiency are achieved by having mutli-antenna SCA's; combining SCA's can be done by satellite backhaul networking which can be useful in remote areas and can be an important development in telecommunication industry for the evolution of 5G which is known as New Radio.

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