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Position-based Fully-Scheduled Precoder Channel Strategy for POMA Structured LTE Network

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***Abstract*—Increasing number of mobile terminals and their services at a constantly rapid growth at high data rate is becoming the Long Term Evolution (LTE) spectrum allocation a major bottleneck for many cellular network operators. Through physical spectrum sharing the scarcity of spectrum can limited, among them are orthogonal and non-orthogonal spectrum sharing. In orthogonal spectrum sharing, user terminals (UEs) are scheduled with different operators, and in non-orthogonal spectrum sharing, UEs are allowed with different operators to allocate the same spectrum frequency simultaneously. These two spectrum strategies potentially interfere with UEs and operators, causing the performance degradation in realistic scenarios at multi-terminals and operators based on spectrum assignment. To overcome these, this paper propose a strategy through numerical assessments, Fully-Scheduled Precoder Channel (FSPC) Strategy, to tackle the problem of primary uplink, which can be obtained through modelling the transmission model with Position-orthogonal multiple access (POMA) system, where the position of UEs are structured with different operators to use the same spectrum frequency and time simultaneously, which in-turn increase the spectrum sharing capability in LTE network. Comparative results shown an improved remarks with the surveyed methods and the proposed work forms the basis for Structured LTE Network deployments in future.**

Keywords-- LTE, spectrum, precoder, signal-to-noise ratio (SNR), throughput.

1. INTRODUCTION

The 4th generation (4G) cellular system, which is known as the LTE system, commercialized in 2010, uses Orthogonal-Frequency-Division-Multiple-Access (OFDMA) scheme to avoid inter-user interference, also enables better utilization of the spectrum frequency usage and improves the peak data rate to 100 Mbps in a 20MHz bandwidth channel. In LTE systems, each base station (BS) serves a large number of users, the data rate of each user increases rapidly, and with the demand of LTE cellular system, the data traffic increases to 1,000 times compared to 2010 in future days compare to the present days.

The LTE system performance is based on the baseband precoders (analog and digital). Using these, the cost-effective algorithms are recently introduced. The hybrid precoder introduced provides a single-user gain allowing single MIMO system. Therefore to support such MIMO system, there is a need of a massive-user transmission system, is made to allow multi-user gain to improve the precoder performance by offering high throughput and is robust against existing LTE problems.

Even, due to the rapid growth in 4G device utilization, the size limit has become a constraint in the mobile equipment / device (ME) i.e., size of the antenna employed through MIMO system has to be tiny. Therefore to support such technology rapid change, a large number of these antennas should be employed on MEs, there is a need of multiple access (MA) technique to improve the peak data rate by employing MIMO system by utilize the current LTE hardware configuration.

In this paper, a FSPC Strategy is proposed to improve the precoder performance and a POMA system is introduced to establish a new MA technique in LTE system through simulation. This paper is organized as follows: Section 2 briefly reviews the related LTE background and Section 3 introduces the proposed work. In Section 4 present experimental results and discussions and Section 5 concludes the paper.

2. RELATED WORKS

In this section, surveyed research work on LTE design is presented. LTE precoding is an emerging technique through hybrid in traditional MIMO systems [1], among them is a fully-connected structure [2] orthogonal matching pursuit (OMP) which improves LTE system performance. It utilises the channel analog precoders and discrete Fourier transform (DFT) beam-formers [3] with a sparse MIMO reconstruction design, causing a degradation problem in performance of LTE system with an overhead on acquiring channel response on MIMO antenna structure. Recent works focus on reducing the degrading complexity of LTE MIMO system through OMP algorithm, by using channel matrix inversion in each MIMO iteration. With an investigation [4] GA-enabled hybrid precoding is included, but they lag in RF domain requirements. Including hybrid precoder, the structures of partially-connected structure [5-10] having less MIMO design parameters.

Channel State Information (CSI) makes use of high diverse antennas structures with low cost in massive MIMO, can improve the channel estimation error [11] [15] [17].

This paper provides a way to POMA, a multiple access technique to increase the MIMO systems to large, by incorporating multi-user massive MIMO in a positioned framework. POMA refers to multi-user SNR and throughput, allowing multi-users to share spectral frequency and time at the same frequency-time access channel block, can lead to multi-user gain to immense rate, making multi-user SNR to improve. Channel capacity also improves through proper iterative process of POMA CSI and with the position orthogonality of uplink offering maximum ratio LTE channel estimation.

FSPC strategy is introduced in this paper and compared with PE-AltMin [12], AE-AltMin [12], OMP Algorithm [13] [14], MO-AltMin [12], EPC [15], SPC [15], MRC-SIC [16], ZF [17] and MRC [17] for analysis, by proposing a fully-scheduled structure, by adopting hybrid precoder design through position minimization as the main design, by two precoder designs: analog and digital. For analog precoder, a variant position orthogonality is employed. For digital precoder, a semi-variant position orthogonality is employed, hybrid precoder optimal solution to optimization is solved. The FSPC strategy can be applied to narrowband and broadband OFDMA systems.

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3. PROPOSED LTE MODEL

In this section, the addressed problem solutions through proposed model is illustrated. Fully-scheduled precoder design allows more throughput for multi-users through POMA structure. This paper access the SNR and power errors on the problems stated for different MA and precoders techniques.

A. Contributions

In this paper, investigation of precoder design in MIMO systems is performed. The proposed precoder channel strategy improve the hybrid precoders by adopting POMA design, which helps precoder problems to eliminate. So far the hybrid precoders are in implementation, proposed work through fully-scheduled precoder overcome and replace the MIMO structure with POMA structures offering good performance in link level and system level LTE networks. Proposed work contributions towards the LTE design are summarized below:

a) For fully-scheduled precoder design, the analog and digital precoders are positioned orthogonally through position variant. This design alternatively improve the design problem of hybrid precoder.

b) POMA technique is introduced through orthogonality for precoder design to develop a FSPC strategy. This strategy improves the antenna structure in MIMO systems adopted in this work.

c) For POMA technique, Precoder channel strategy is proposed, to offer solutions to sub-problems of hybrid precoder in each positioned channel. This improves the MIMO antenna structures by optimizing the FSPC strategy.

d) With the proposed strategy, POMA structured LTE network is simulated by taking advantage of MATLAB simulation environment.

Thus, proposed work results establish the effective usage of POMA technique applicable in 4G and 5th generation (5G) LTE cellular system.

B. Problem Formulation

These can put as one problem, i.e., the fully structured coders, formulated as:

$$\underset{F_{RF}F_{BB}}{minimize} \left|\left|P_{opt} - P_{RF}P_{BB}\right|\right|_{P}, \text{Eq.(1)}$$

$$subject\ to \begin{cases} P_{RF} \in A \\ \left|\left|P_{RF}P_{BB}\right|\right|_{P}^{2} = N_{s} \end{cases}, \text{Eq.(2)}$$

which is different for hybrid precoding structures. To maximize the spectral utilization, Eq.(1) is minimized and treat Eq.(2) as unconstrained precoder design through a matrix value decomposition problem, for which precoder minimization is proposed in this paper, involving two variables F_{RF} and F_{BB}.

There are many sophisticated options in MIMO designs, like NOMA as in Eq.(3)

$$R_{sum} = log_2\left(1 + \frac{1}{N_0}\sum_{k=1}^{K} p_k|h_k|^2\right), \text{Eq.(3)}$$

is used to create subspaces orthogonally forming a group of spectrum to improve the performance, but suffers from PC and SIC scheme coincides, and gain is reduced if high complex UEs and mobile terminal (MT)s are allowed. With the principle of precoder minimization, solution to Eq.(1) Eq.(2) and Eq.(3) is presented throughout this paper. Simulation results are provided in this paper to support the above, by demonstrating the efficiency of POMA, compared with other techniques.

C. Fully-scheduled precoder design

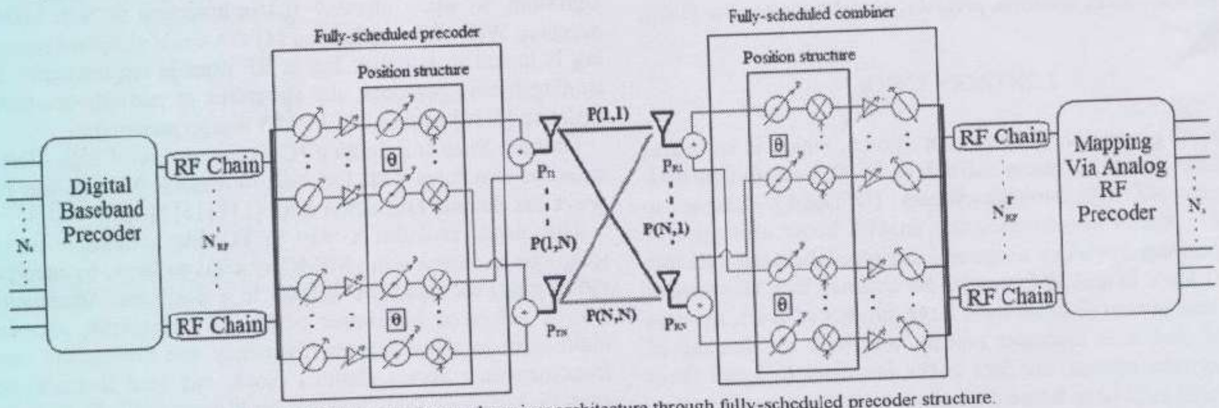

Figure1: POMA transmitter and receiver architecture through fully-scheduled precoder structure.

Consider a multi-user POMA system as shown in figure 1. N^t_{RF} & N^r_{RF} are the RF chains, having $N_s \leq N^t_{RF} \leq N_t$ and $N_s \leq N^r_{RF} \leq N_r$ variations.

$P_x = P_{RF}P_{BB}Ps$ is the POMA link transmit, x represent transmitter antenna numbers. The fully-scheduled precoders consist of an $N^t_{RF} \times N_s$ digital baseband precoder P_{BB} and an $N_t \times N^t_{RF}$ fully-scheduled precoder P_{RF}. The transmitted signal after position structure processing is given as

$$P_x = \sqrt{R_{avg}}\{P^{P_H}{}_{BB}P^{P_H}{}_{RF}P_H Q^{P_H}{}_{BB}Q^{P_H}{}_{RF} + P_H Q^{P_H}{}_{BB}Q^{P_H}{}_{RF} * n\}, \text{Eq.(4)}$$

where R_{avg} is average power received, P_H is the H matrix, Q_{BB} is the $N^r_{RF} \times Ns$ digital baseband encoder response after position encoding, Q_{RF} is the $N_r \times N^r_{RF}$ fully-scheduled encoder response after position encoding at the POMA link with CSI at transmitter and receiver is given as,

$$R = log_{det}\left\{I_{N_s} + \frac{R_{avg}}{\sigma_n^2 N_s(Q^{P_H}{}_{BB}Q^{P_H}{}_{RF})\dagger P^{P_H}{}_{BB}P^{P_H}{}_{RF}P_H \times Q^{P_H}{}_{BB}Q^{P_H}{}_{RF}}\right\}, \text{Eq.(5)}$$

where I_{Ns} is the information of symbol vector. The fully-scheduled precoders are implemented with position shifters, which can locate the positions of the signals as shown below,

$$P^{P_H}{}_{BB} \times P^{P_H}{}_{RF} = Q^{P_H}{}_{BB} \times Q^{P_H}{}_{RF} = 1, \text{Eq.(6)}$$

$N_t = N^t{}_{RF}$, connected to each RF chain which in turn reduces the physical length of antennas in structure. Thus, the proposed fully-schedule structure provides full beam forming gain. The channel at the POMA uplink is modelled as

$$P_H = \sqrt{\frac{N_t * N_r}{N_{cl} * N_{ray}}} \sum_{i=1}^{N_{ray}} \sum_{l=1}^{N_{ray}} \alpha_{il} a_r(\varphi_{il}^r, \theta_{il}^r) a_t(\varphi_{il}^r, \theta_{il}^r)^H \partial_H, \text{ Eq.(7)}$$

The array response is written as

$$a_r(\varphi_{il}^r, \theta_{il}^r) = \left(\frac{1}{\sqrt{N}}\left[e^{\frac{j2\pi}{\lambda d}}(p\sin(\varphi_{il}^r)\sin(\theta_{il}^r) + q\cos(\theta_{il}^r)\right]\right)^T, \text{ Eq.(8)}$$

The first term in Eq.(8) is the variant position for analog precoder and the second term in Eq.(9) is the semi-variant position for digital precoder.

The POMA downlink the Signal-to-Noise Ratio (SNR)

$$\gamma_k[n] = |h_k[n]|^2 SNR_k, \text{ Eq.(9)}$$

Considering the digital precoder P_{BB} with a positioned fully-structured precoder P_{RF}. Thus, problem (1) and (2) can be restated as

$$\underset{P_{RF}, P_{BB}}{\text{minimize}} \left\|P_{opt} - P_{RF} P_{BB}\right\|_P, \text{ Eq. (10)}$$

fix P_{BB} and seek a digital precoder which optimizes the following problem:

$$\underset{P_{RF}}{\text{minimize}} \|P_{opt} - P_{RF} P_{BB}\|_P^2, \text{ Eq. (11)}$$

$$\text{subject to} \begin{cases} P_{RF} \in A \\ \|P_{RF}\|_{(i,j)} = 1 \end{cases}, \text{ Eq. (12)}$$

The position is given as

$$\underset{P_{RF}\, P_{DD}}{\text{minimize}} \|P_{opt} P_{DD}^H - P_{RF}\|_P^2, \text{ Eq. (13)}$$

$$\text{subject to} \begin{cases} P_{DD}^H \ P_{DD} = I_{N_s} \\ \|P_{RF}\|_{(i,j)} = 1 \end{cases}, \text{ Eq. (14)}$$

The problem formulation (1) implies the following problem

$$\underset{P_{DD}}{\text{minimize}} \|P_{opt} P_{DD}^H - P_{RF}\|_P^2, \text{ Eq. (15)}$$

$$\text{subject to} \begin{cases} P_{DD}^H \ P_{DD} = I_{N_s} \\ \|P_{RF}\|_{(i,j)} = 1 \end{cases}, \text{ Eq. (16)}$$

The equality is established only when $P_{DD}=V_1U^H$, where $P^H_{opt}P_{RF}=U \sum V^H=USV^H_1$, which is the SVD of $P^H_{opt}P_{RF}$, and S is a diagonal matrix whose elements are the first N_s nonzero singular values $\sigma_1,\ldots,\sigma_{Ns}$. the fully-structured is,

$$\underset{P_{RF}, P_{BB} = \sum_{k=0}^{K-1}}{\text{minimize}} \left\| P^k{}_{opt} - P_{RF} P_{BB}^{H\ k} \right\|_P^2, \text{ Eq. (17)}$$

$$\text{subject to} \begin{cases} F_{RF} \in A \\ \left\| P_{RF} P_{BB}^{H\ k} \right\|_P^2 = N_s \end{cases}, \text{ Eq. (18)}$$

D. Position-orthogonal multiple access (POMA)

POMA is shown in figure 2.

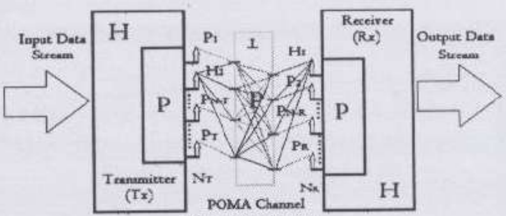

Figure 2: POMA.

To improve the throughput, consider N_T x N_R POMA system with N_T transmit and N_R receive antennas, as shown in figure 2. From a system level viewpoint, a linear time-variant POMA channel is represented by an N_T x N_R channel matrix,

$$H(t,\tau) = \begin{pmatrix} p_{11}(t,\tau) & h_{12}(t,\tau) & h_{13}(t,\tau) \\ h_{21}(t,\tau) & p_{22}(t,\tau) & h_{23}(t,\tau) \\ h_{31}(t,\tau) & h_{32}(t,\tau) & p_{33}(t,\tau) \end{pmatrix}, \text{ Eq. (19)}$$

here $h_{ij}(t,\tau)$ is the time-variant impulse response and $p_{ij}(t,\tau)$ is the time variant position response between the j_{th} transmit and i_{th} receive antenna.

The POMA as illustrated in figure 3: POMA structured LTE network.

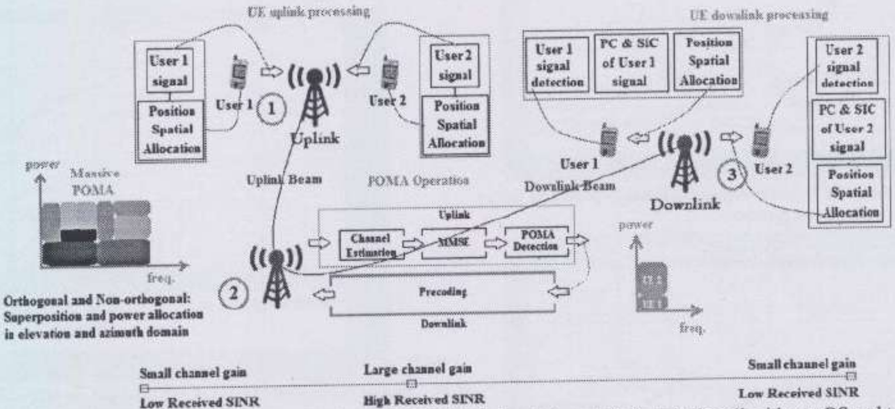

Figure 3:Principle of proposed POMA scheme, applying PC & SIC Uplink and Downlink in a single cell with one BS and two users.

4. SIMULATION RESULTS AND COMPARISON

In this section, simulation results are presented to verify the precoder design. With the precoder position, the average capacity is analysed. With N_t=288, N_r=72, the channel parameters N_{cl}=10 clusters, number of rays N_{ray}=20 rays, the average power of each cluster is 1, the azimuth and elevation angles of departure and arrival is 5 degrees, the antenna spacing is 0.5 wavelength, and the distribution is [0, 2π).

The simulation was developed using the MatLab in order to implement POMA technique, applying calculations of throughput, the services to users in the area under study.

4.1. Numerical Comparisons

This work investigates the following evaluations comparatively i.e., $N^t_{RF}=N^r_{RF}=N_s$.

A. Efficiency evaluation

In this case, as shown in figure 4 (at 0 dB) and figure 6 (at 10 dB), the proposed fully-scheduled precoder achieves significant higher spectral efficiency than the existing precoders PE-AltMin [12], AE-AltMin [12], OMP Algorithm [13] [14] and MO-AltMin [12]. On the performance, proposed precoder achieves good performance over the SNR range considered.

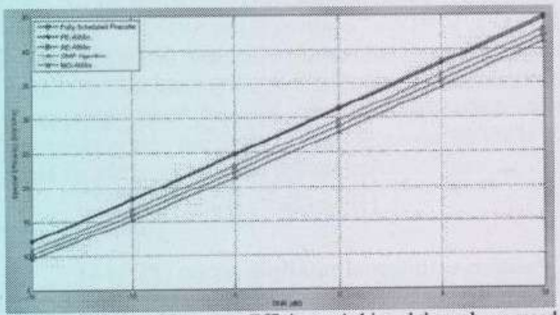

Figure 4: SNR based Spectrum Efficiency Achieved through proposed fully-scheduled precoder.

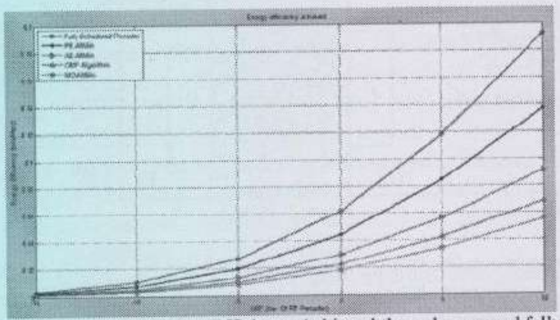

Figure 5: N_{RF} based Energy Efficiency Achieved through proposed fully-scheduled precoder.

Through the RF chains, as shown in figure 5 (at 0 dB) and figure 7 (at 10 dB), the proposed fully-scheduled precoder can more accurately approximate than the existing methods [12], [13], [16] and [17].

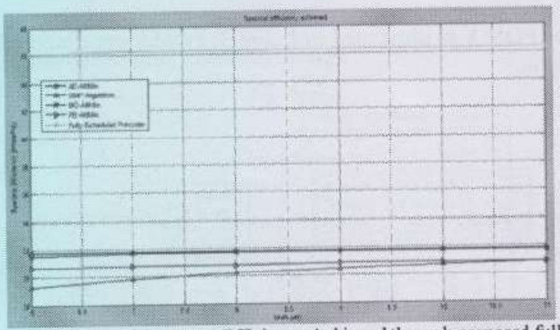

Figure 6: SNR based Spectrum Efficiency Achieved through proposed fully-scheduled precoder.

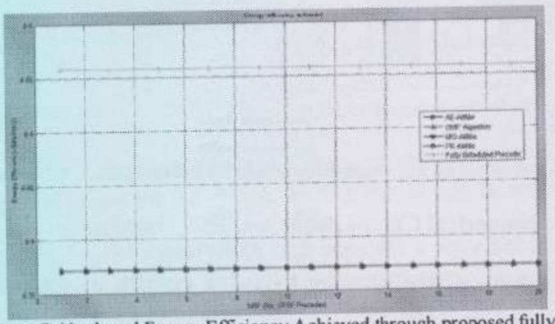

Figure 7: N_{RF} based Energy Efficiency Achieved through proposed fully-scheduled precoder.

B. Power evaluation

With the transmission power set to 8W, the threshold for switching from dedicated to common resources is around 14 UEs per cell, the threshold is 10 UEs. The analysis has taken for total power required and consumed for transmission of the multicast data in the UEs and BS case. Figure 8 shows the simulation of BS total power with number of UEs, Figure 9 shows the simulation of BS total power with different Bit Rates and Figure 10 shows the simulation of BS total power with different E_b/N_o.

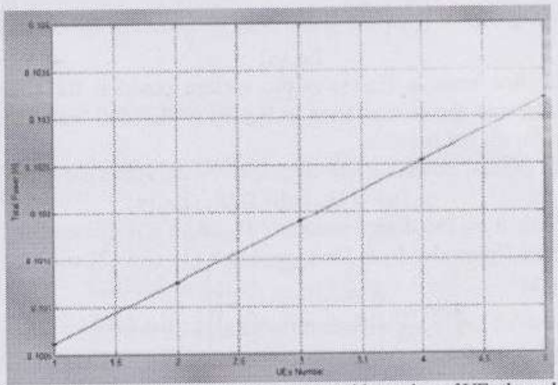

Figure 8: The simulation of BS total power with number of UEs through proposed fully-scheduled precoder.

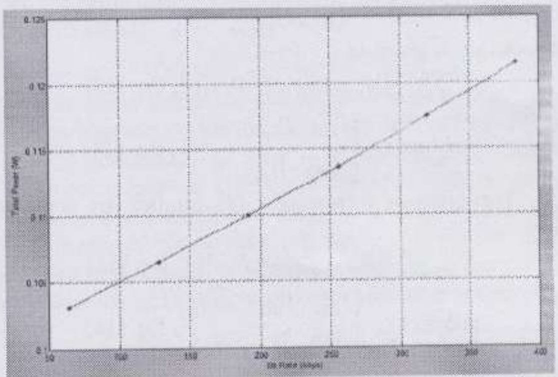

Figure 9: The simulation of BS total power with different Bit Rates through proposed fully-scheduled precoder.

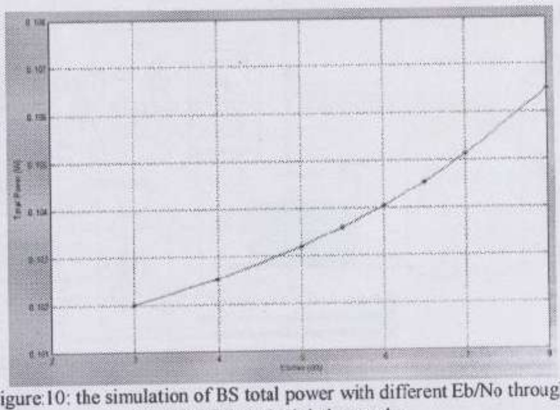

Figure:10: the simulation of BS total power with different Eb/No through proposed fully-scheduled precoder.

Based on the UEs topology structure, the random user and moving UE is analysed here. Figure 11 shows the simulation of total transmission power of the Examined Node B changes with time and Figure 12 shows the simulation of transmission power of the Moving UE's Active BS total power changes with time.

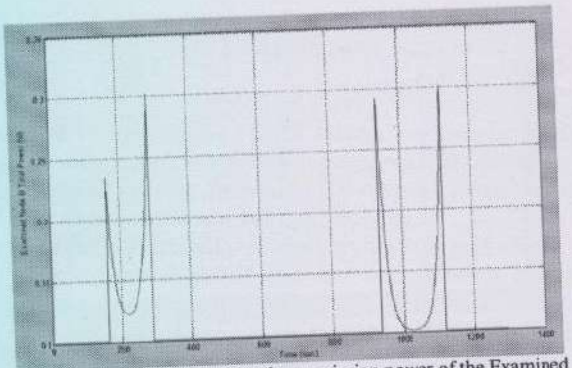

Figure:11 : The simulation of total transmission power of the Examined Node B changes with time through proposed fully-scheduled precoder.

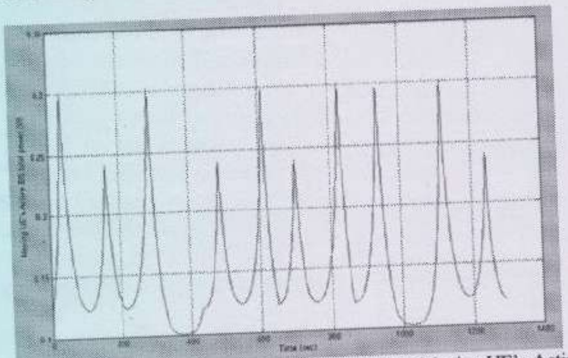

Figure:12: the simulation of transmission power of the Moving UE's Active BS total power changes with time through proposed fully-scheduled precoder.

C. Capacity evaluation

To evaluate the capacity of proposed POMA system, [15] and [16] are considered It is observed from the figures 13 and 14 that the potential gain is more in proposed POMA system compare to [15] and [15].

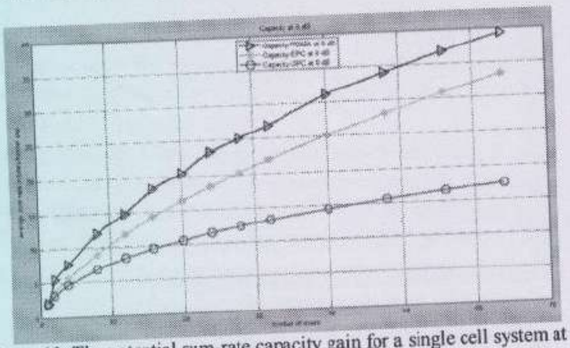

Figure:13: The potential sum-rate capacity gain for a single cell system at 0 dB

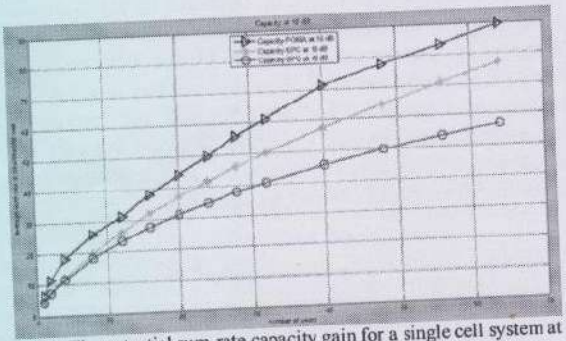

Figure:14: The potential sum-rate capacity gain for a single cell system at 10 dB

D. Rate evaluation

As comparison, POMA under resource allocation, ATDMA [15] and FTDMA [15] is adopted. It is shown in figure 15, figure 16, figure 17 and figure 18, POMA is capacity achieving under maximum sum rate and have achieved performance in transmission durations.

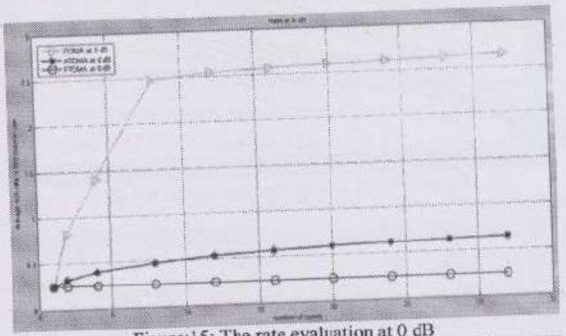

Figure:15: The rate evaluation at 0 dB

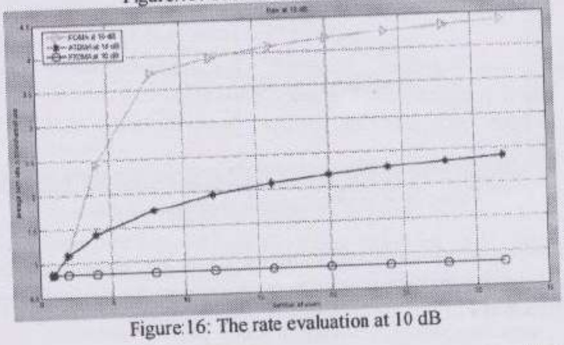

Figure:16: The rate evaluation at 10 dB

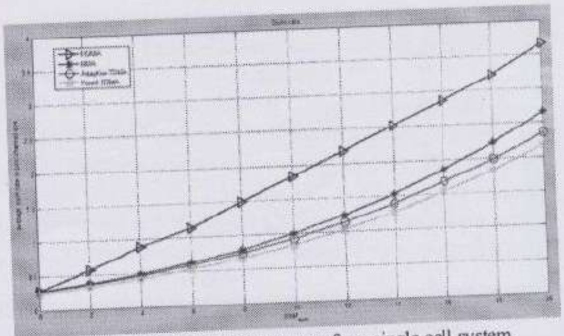

Figure:17: The SNR with sum-rate for a single cell system.

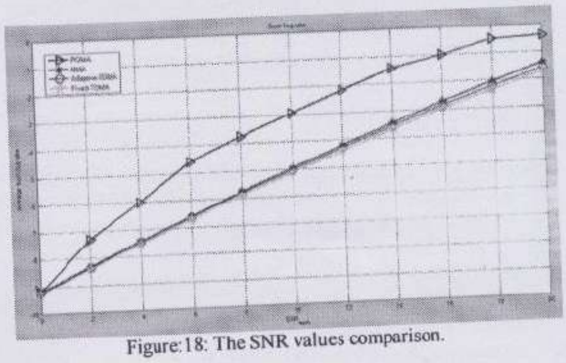

Figure:18: The SNR values comparison.

Figure 19 (at 5 dB) and figure 20 (at 10 dB) compares different parameters under perfect POMA system with the same channel parameters as those in the figures. Compared POMA with MRC-SIC [16], ZF [17] and MRC [17], through the same SPC and PC levels, capacity analysis with unequal rate allocation applicable to both uplink and downlink. From the results, the POMA performs close to maximum value, avoiding noise cancellation, perform well for both EPC and SPC and increase in gain and resource allocation.

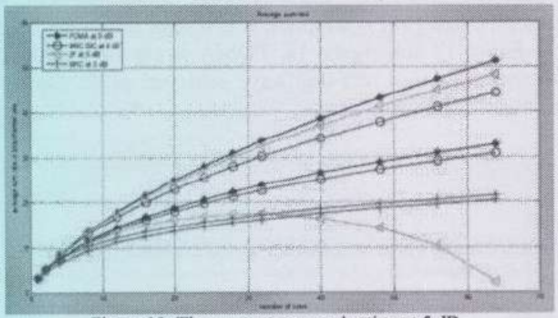

Figure:19: The average rate evaluation at 5 dB

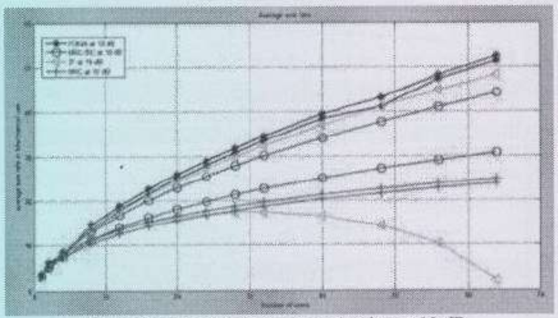

Figure: 20: The average rate evaluation at 10 dB

Based on the channel type, Figure 21 to 26, the simulation results give the performance of proposed precoder performance in different environment scenario.

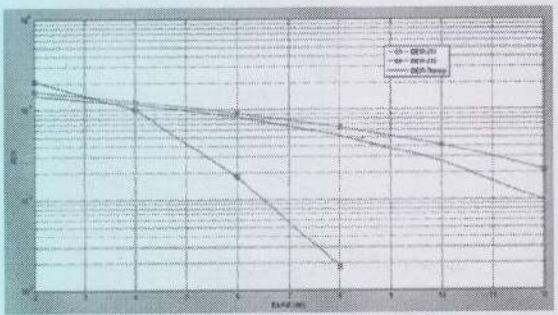

Figure:21:In indoor environment scenario

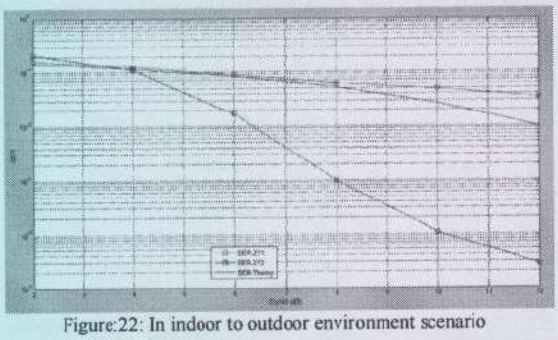

Figure:22: In indoor to outdoor environment scenario

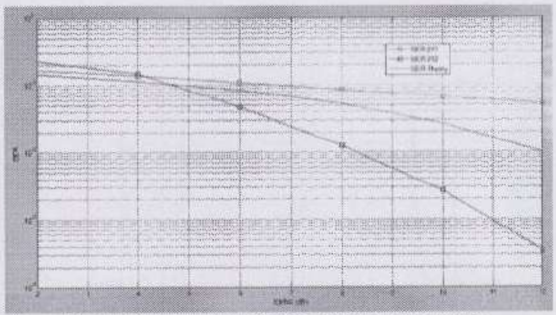

Figure:23 In outdoor to indoor environment scenario

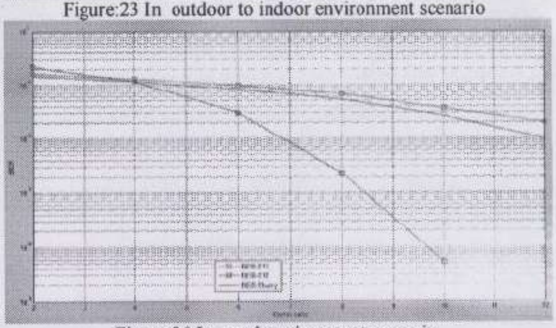

Figure:24 In rural environment scenario

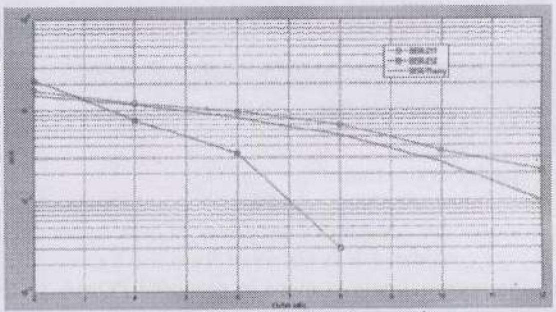

Figure:25: In moving networks scenario

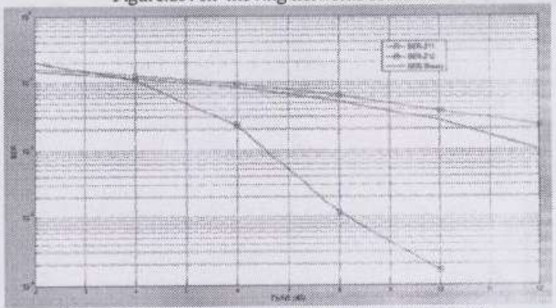

Figure:26: In outdoor to outdoor environment scenario

The values of spectral efficiency are presented in table 1, the average and maximum throughput, obtained by the simulations. For a data centric distribution, the values of spectral efficiency are observed in four scenarios, caused by the difference of the number of BSs in the network, thereby creating a better use of bandwidth used by BSs. In what regards the average and maximum throughput values, these are obtained from the lower radius coverage, available on scenarios, which have influence on maximum throughput offered by each BS.

Table 1 - Throughput and Spectral efficiency results in four scenarios

Scenario	Indoor	Indoor-to-outdoor	Outdoor-to-indoor	Rural
Distribution	Data Centric	Data Centric	Data Centric	Data Centric
Average Throughput	0.39 Mbps	0.41 Mbps	0.41 Mbps	0.74 Mbps
Maximum Throughput	1.02 Mbps	1.07 Mbps	2.09 Mbps	2.17 Mbps

5. CONCLUSIONS

On the LTE system, the POMA system has been made, in this paper fully-scheduled precoder is designed for hybrid precoder in MIMO systems. Proposed LTE system has well simulated in Matlab environment and concludes as:

a) The fully-structured precoders approach is performed
b) The increase in power and cost doesn't affect the increase in number of RF chains.
c) Providing maximum gain and sum rate over beam forming.
d) Demonstrated effective E_b/N_o values for BER comparisons in the designed POMA system.
e) The data rate is improved and with this high data rate, massive users can be allocated in spectrum.
f) Performance degradation is reduced through POMA technique, uplink problem of channel estimation is resolved in the proposed work through structuring the UEs with different operators simultaneously.

Finally, architecture results of LTE network can demonstrate an effective 4G communication system in real-time environment for the extension of this work through proposed spectrum sharing among UEs using POMA system.

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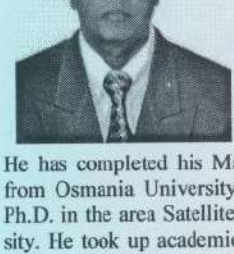

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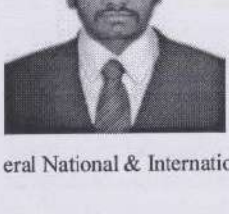

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