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Capacity Enhancement using Game Theory-Based Power Assignment for 5G Cellular Network

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***Abstract**: The increasing demand for high data rate services necessitates technology advancement and adoption of beyond 4G termed as 5G cellular standards. In this paper, game theory-based power assignment for capacity enhancement is investigated for 5G cellular network. Specifically, in this work, we analyze a multiple input and multiple output (MIMO) multi-carrier (MC) code division multiple access (CDMA) scheme as a possible air interface for next generation wireless network with capacity enhancement techniques. A pricing methodology and two non-cooperative MIMO power control games using recreation hypothesis are proposed in this work. The study shows that the proposed pricing scheme and power control games prove to be powerful techniques for attaining an enhanced performance as it results in 10% growth in equilibrium with less power usage in a MIMO MC-CDMA uplink communication.*

***Keywords**: MIMO, Nash equilibrium, MC-CDMA, power-control, MAI*

I. INTRODUCTION

The past decade has seen an upsurge interest in the direction of the capacity enhancement techniques that can support the network operators to provide very high data rates. Multi-carrier (MC) techniques that merge high-quality bandwidth competence with an exemption to medium scattering are being used in the 5G networks [1]. In line with these MC techniques, multi-carrier code division multiple access (MC-CDMA) seems to offer better capacity, provide multiple access interference (MAI), and near-far effect that restricts the capacity being suppressed [2]. In this connection, power management procedure plays a dynamic function in overcoming these effects. Though multiple input and multiple output (MIMO) MC-CDMA exhibits improved performance than CDMA, it has the usual impairment as the single antenna system [3]. Therefore, the success of a MIMO MC-CDMA sooner or later drops in the vicinity of interference and power management in multi-user situation. In recent times, recreation theoretic method is used to manage power in multi-user environment [4–7]. It is a far effective device in displaying exchanges among self-centered customers and calculating the decision of regulations. Every competitor in the sport makes best use of a few characteristics of effectiveness in a disbursed manner. The recreation resolves at Nash equilibrium if one survives. From the time when users act inconsiderately, the stability factor is always not the satisfactory running end as of a social factor of vision. To evade this, cost of the resources seems to be a powerful device for accomplishing a greater result. In the CDMA, increasing one's strength is not simply to raise their signal-to-noise-plus-interference ratio (SINR), however, it will also boost the intrusion manipulated through different users, thereby declining their SINR leading to attaining the stable state of a system [8]. To overwhelm this case, a dispensed interest theoretic power managing set of guidelines offer, proficient usage of the high-fidelity properties in MC-CDMA tool have been considered in this article. A new-fangled service capability using singular value decomposition (SVD) is projected as a remedy to the power management issues for the non-cooperative power control game (NPG) [9,10]. A brand-new application function that checks the spectral and power performance is taken into consideration. The software features additional functions to facilitate the quality of service on the information it receives, wherein convenience is described as ability to communicate signal strength. At that point, power management games in a distinct cell MIMO MC-CDMA system are taken into consideration for measuring the stability of the system and overall efficiency, which appear to be the best solution to make use of the gadget more resourcefully.

The rest of the contents are described subsequently. Details about MIMO MC-CDMA system and the software characteristic of the power manage recreation are described in Section 2. The two non-cooperative multiple input multiple output power control games (NMPCGs) for the MIMO MC-CDMA gadget are explained in Section 3. Sections 4 and 5 give the details about the lifestyles and strong point of the games and the set of rules to reach the stability of the system. Section 6 describes the Simulation results and the conclusion is given in Section 7.

II. MC-DS/CDMA SYSTEM USING MIMO

Upward frequency of a cellular N-users MIMO MC-CDMA device is taken into consideration for this study. Each user is supposed to comprise M_t antennas in addition to the wireless access point with M_r antennas and M_k sub-channel will be transmitted by each antenna.

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Along with the subcarriers, processing benefit *G* is taken into consideration. Herein, the user's data stream is de-multiplexed between numerous communicating antennas; all antennas transmit an independent restrained signal in identical pulsation band. These signals are obtained by the base station through an antenna range whose sensor outcomes are evaluated in such a way that the unique statistics can be progressed. If the channel state information (CSI) is entirely recognized by the recipient, then the CSI feedback can be obtained by the transmitter. Consider the Channel matrix as *H* for a user "*i*," it may be decayed using SVD as illustrated in
(1)

$$H_i = U_i \Lambda_i V_i = \sum_{K=1}^{\min\{M_t, M_r\}} U_i^{(K)} \lambda_i^{(K)} V_i^{(K)}, \quad (1)$$

Here, the unitary matrices are $U_i^{(K)}$, $V_i^{(K)}$ and the singular values of H_i are denoted as $\lambda_i^{(K)}$.

The feasible standardized throughput per user of MIMO MC-CDMA device is the amount of the standardized output gain of the min (M_t, M_r) decoupled sub-channels. At that point, the uniform output gain of *i*th customer is specified in (2)

$$T_i = \sum_{k=1}^{\mathrm{MIN}\{M_t, M_r\}} T_{k,i} = \sum_{k=1}^{\mathrm{MIN}\{M_t, M_r\}} \sum_{S=1}^{N-1} \log_2 M_{k,i} \left(1-\mathrm{BER}\left(\gamma_{k,i}\right)\right)^L, \quad (2)$$

where $\gamma_{k,i}$ denotes SINR of *i*th user in *k*th sub-channel, which uses *s*th subcarrier. All aerial can incorporate sub transporters. To resolve the energy control issue in the proposed system, an insignificant application characteristic that is articulated in (3) is attained.

$$um_i = T_i / P_i = \frac{\left(\sum_{K=1}^{\min\{m_t, m_r\}} \sum_{S=1}^{N-1} \log_2 M_{k,i} \left(1-\mathrm{ber}\left(\gamma_{K,i}\right)\right)^L\right)}{\left(\sum_{K=1}^{\min\{m_t, m_r\}} \sum_{S=1}^{N-1} P_{k,i}\right)}. \quad (3)$$

The power rule assessment effectiveness is specified in (4)

$$u_i = \frac{\left(\sum_{k=1}^{\min\{m_t, m_r\}} \sum_{S=1}^{N-1} \log_2 m_{k,i} \left(1-2\,ber\left(\gamma_{K,i}\right)\right)^L\right)}{\left(\sum_{k=1}^{\min\{m_t, m_r\}} \sum_{S=1}^{N-1} P_{k,i}\right)} = \frac{\left(\sum_{k=1}^{\min\{m_t, m_r\}} \sum_{N=1}^{N-1} \log_2 m_{K,i}\, f\left(\gamma_{K,i}\right)\right)}{\left(\sum_{k=1}^{\min\{m_t, m_r\}} \sum_{S=1}^{N-1} P_{K,i}\right)}, \quad (4)$$

$f(\gamma_i)$, the frame successive rate is estimated carefully for the possibility of accurate outcome while developing frame rate equivalent 0 at P_i =0. The strategy is changed and delivered into the MC-CDMA non-cooperative power management recreation. With the pricing strategy, the power recreation becomes well-organized [8,11–13].

The novel utility of proposed system power management is described in (5).

$$u_i^c = \left(\frac{\left(\sum_{k=1}^{\min\{m_t, m_r\}} \sum_{S=1}^{N-1} \log_2 m_{k,i}\, f\left(\gamma_{k,i}\right)\right)}{P_i}\right) - tP_i$$

$$P_i = \sum_{k=1}^{\min\{m_t, m_r\}} \sum_{S=1}^{N-1} P_{k,i}. \quad (5)$$

The cumulative transmitting power of the *i*th user is symbolized as *Pi*. This recommended application feature offers concentration to the spectral performance and power competence of MIMO-MC-CDMA structure.

III. GAME THEORETIC APPROACH USING NMPCG

Consider $G = [N, \{Ai\}, \{Ui(.)\}]$ as NMCPG where the directory set intended for the movable users present in the cell is *N* = {l, 2,...*N*}. The total transmit power strategy P_i is chosen by the *i*th user so that $P_i \in A_i$, the notation A_i represents the system area of *i*th user. The vector *P* represents all of the required energy levels and P_{-i} describes the factors of *P* except *i*th factor [14].

The coverage area of all consumers without the *i*th user is indicated as A_i. Depending on the evaluation, two non-cooperative power games are recognized. These events have the similar strategy space and participant area. *G*1 is represented by

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$$G1 = \max_{P_i \in A_i} \left\{ U_{1i}(P_i, p_{-i}) = \frac{\left(\sum_{k=1}^{\min\{m_t, m_r\}} \sum_{s=1}^{N-1} \log_2 M_{K,i} f(\gamma_{K,i}) \right)}{P_i} \right\}. \quad (6)$$

G2 is illustrated as

$$G2 = \underset{P_i \in A_i}{MAX} \left\{ U_{2i}(P_i, p_{-i}) = \left(\frac{\left(\sum_{k=1}^{\min\{m_t, m_r\}} \sum_{S=1}^{N-1} \log_2 M_{K,i} f(\gamma_{K,i}) \right)}{P_i} \right) - tPi \right\}, \quad (7)$$

for all values of $i \in N$.

Non-cooperative power game has a realistic and self-interest on every user. By choosing the nice transmit power approach users always maximize their individual utilities, which is contingent on the communication strength techniques of every different customers in the scheme. In the game, overall powers can be determined to fulfill the customers.

IV. STABLE STATE OF A SYSTEM

Stability is mainly used as a resolution in NPG. It states that no user can moreover gain with the aid of independently conflicting Nash equilibrium. As a result, Nash stability is a strong operational factor because no client has any inducement to alternate approach. The non-cooperative NCPG, G1, and G2 are fabulous modular game with suitable approach space $Ai = [P-i, \bar{P}_i]$. Correspondingly,

$$\frac{\partial u_{li}}{\partial P_i} = \boldsymbol{P}_i^{-2} \left\{ \sum_{k=1}^{\min\{M_t, M_r\}} \sum_{S=1}^{N-1} \log_2 M_{k,i} \left((\gamma_{k,i}) \frac{\partial f(\gamma_{k,i})}{(\partial \gamma_{k,i})} - f(\gamma_{k,i}) \right) \right\}. \quad (8)$$

$$\frac{\partial^2 u_{li}}{\partial P_i \partial P_j} = \boldsymbol{P}_i^{-2} \left\{ \sum_{K=1}^{\min\{m_t, m_r\}} \sum_{s=1}^{N=1} \log_2 M_{K,i} \left((\gamma_{K,i}) \frac{\partial^2 f(\gamma_{K,i})}{(\partial \gamma^2{}_{K,i})} \frac{\partial \gamma_{K,i}}{\partial p_j} \right) \right\}. \quad (9)$$

If $\frac{\partial^2 f(\gamma_{k,i})}{(\partial \gamma^2{}_{k,i})} \leq 0$, it is possible to conclude that $\frac{\partial^2 u_{li}}{\partial P_i \partial P_j}$ for all values of $j \neq i$. Consider P_{-i} with condition $0 < P_{-i} < P_i$ that is a imitative outline of $\frac{\partial^2 f(\gamma_{k,i})}{(\partial \gamma^2{}_{k,i})} \leq 0$. It can assure $\frac{\partial^2 u_{li}}{\partial P_i \partial P_j} \geq 0$ for all values of $j \neq i$. Consequently, it is concluded that through this approach the game g1 is super modular. The subsequent statements, established in [15–17], ensure the distinctiveness of a Nash stability of super modular game and furnish the set of rules which could come together to the stability. The preeminent response is

$$BR(P_{-i}) = p_i \in A_i : u_i(p_i, P_{-i}) \geq u_i(p'_i, P_{-i}) \forall P' \in A_i. \quad (10)$$

Assume that for all $i = 1, 2, 3, 4, ...N$, A_i's are dense, rounded, inferior semi-unbroken in their state, and grasp scalability property. Additionally, they take for granted that for each $i = 1,2, \ldots N$, $BR(P_{-i}) > 0$ for all $P_j \in A_j$, $j \neq i$. At that point, the Nash stability is exceptional and fashionable in updating set of rules that converges regularly to stability whose union grasps for some preliminary coverage within the strategy space. It is to conclude that each of the non-cooperative power game has exceptional Nash stability factor and then the asynchronous power management algorithm is taken into consideration in this effort, converges to a complete exclusive Nash stability point. In this method, users replace their broadcast powers inside in an identical way as in Refs. [18–20]. Consider user i keep informed its broadcast power at instant of time in the set, the NMCPG produces a sequence of power vector following the iterative procedure as follows. The power vector $P(0)=P$ is set at stint $t = 0$. For all $i \in N$, calculating $r_i(t_k) = \arg\max_{p_{i \in P}} u_i(p_i, p_{-t}(t_{k-t}))$ has given that $p_i(t_k)=\min(r_i(t_k), p_{max})$. If $p(t_k)$ is equivalent to $p(t_{k-1})$, the iterative procedure ends and Nash equilibrium power vector are considered to $bep(t_k)$. If it is not the case, the iterative procedure is repeated predetermined number of times until $p(t_k) = p(t_{k-1})$.

V. PROJECTED GAME THEORETIC POWER MANIPULATE SET OF RULES FOR MC-CDMA

Consider that there are "*N*" customers in a sole cubicle, the SINR is predicted for every "*N*" users included in the game. Assume that if a selected customer utilizes the maximum appreciation level further than the necessary point, then authorization to that precise user could be so as to maintain the intrusion point fine not beyond control. Aforementioned course of action is accompanied for every clients whoever is likely to amplify the power point, thereby focusing on the MAI. Output domino effect proves that by using this design, the general service of a picky user achieves huge statistics by mitigating the MAI.

Figure 1 shows the proposed game with and without pricing scheme. In Figure 1 each and each user is allotted with power level established upon the SINR. In the scheme without pricing, if a user tends to raise the power level beyond the assigned level, access to the network won't be denied. Here every user tends to raise its private utility, thereby subsequent in interference to the other users. But in the altered power control game with pricing, access is denied to the network if a user tends to rise its own utility. Hence the user cannot subsidise to interference. The flow diagram gives perception of the modified game with pricing in Figure 1.

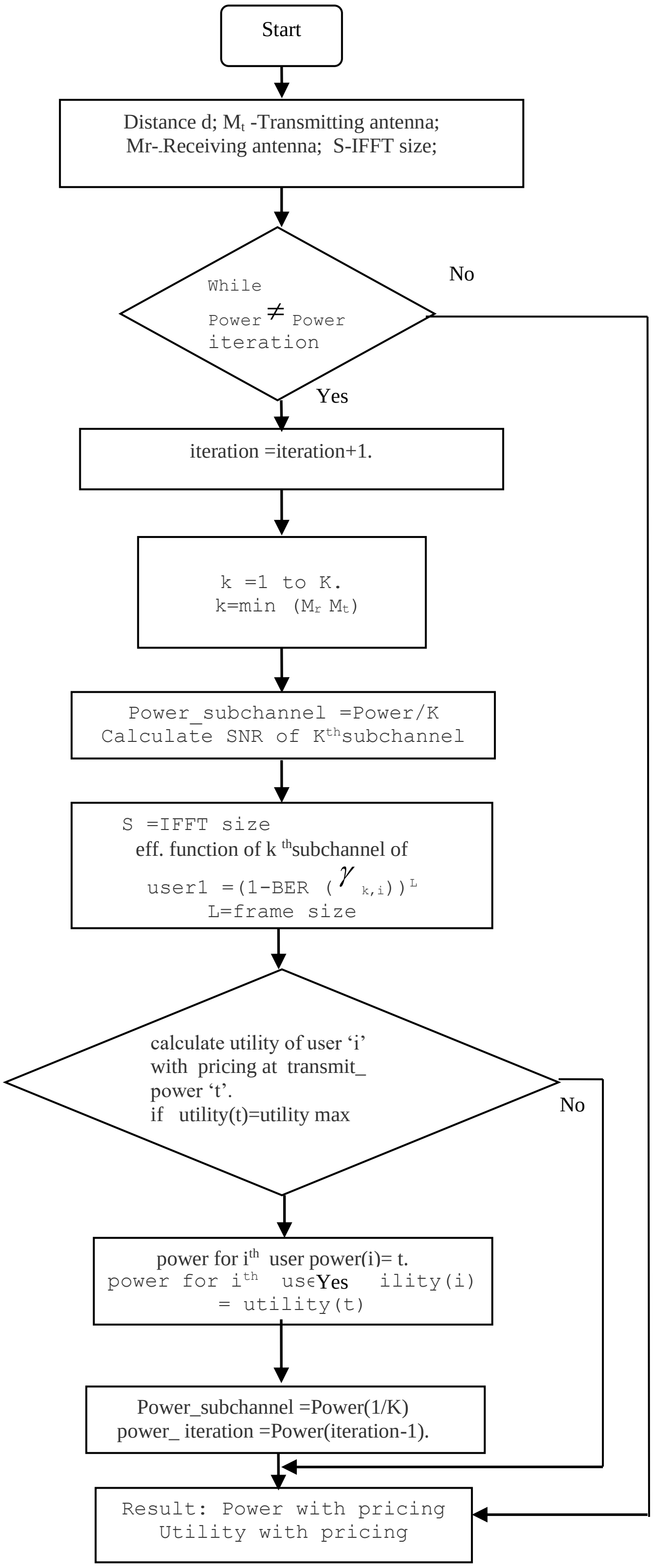

Figure 1Flow diagram of power assignment game with pricing

VI. EXPERIMENTAL OUTCOME

Assume a single-cell MIMO MC-CDMA structure with fixed multi-user, no error correction, constant frame size, with $M_t = M_r = 2$ and 4. The MIMO systems channel matrix is set by

$$H_i = \left\{h_{mn}^{(i)}\right\} \quad ; 1 \le m \le M_r, 1 \le n \le M_r. \tag{11}$$

The complex signal path gain is denoted by h_{mn} from nth transmitter to mth user, receiver. The throughput is given by

$$h_{mn}^{(i)} = \sqrt{c/d_i^{\alpha}}\sqrt{s}Z_{mn}. \tag{12}$$

The base-cell remoteness is denoted by d_i of ith user, the exponent path loss as α, the mean path gain median is denoted as c, fading variable as s, Z_{mn} denotes the phasor amount of the multi-lane spread out mechanism [21]. Table 1 shows the parameters that are measured for Matlab simulation.

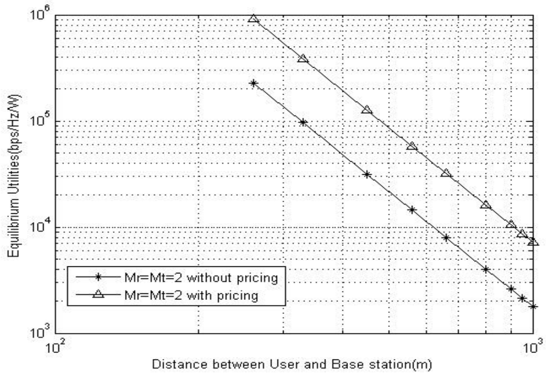

Fig. 2 Efficiency plot of MIMO MC-CDMA.

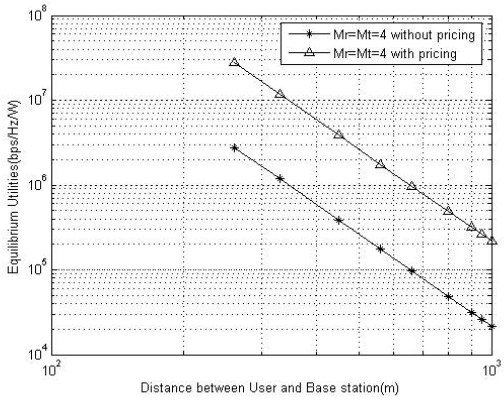

Fig. 3 Efficiency plot of MIMO MC-CDMA.

Figures 2 and 3 elucidate symmetry effectiveness for a task of remoteness among a user and the base station. It is discerned that, as the number of antennas increases, the equilibrium utility designed for a particular customer by some remoteness away from the position decreases. By introducing the concept of pricing, the equilibrium utility increases. Thus, the equilibrium utility without pricing for a user with two antennas is lesser than that with pricing. With pricing, a user with four antennas has higher utility, when compared with the users with two antennas. Thus, users with four antennas have more utility than that of a user with two antennas.

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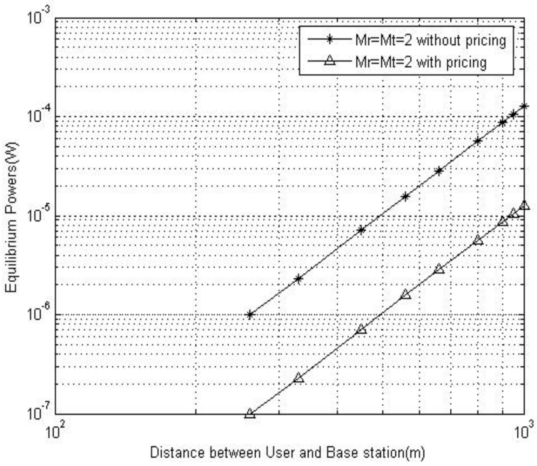

Fig. 4 Efficiency plot of MIMO MC-CDMA

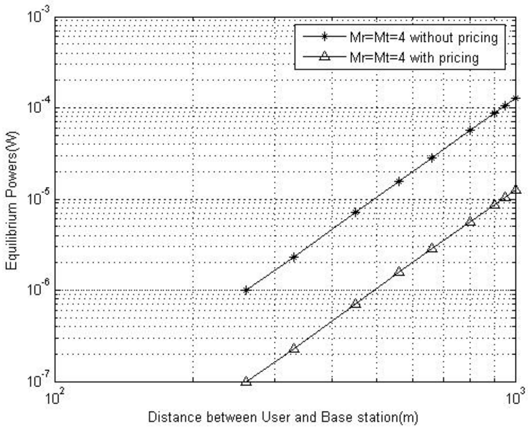

Fig. 5 Efficiency plot of MIMO MC-CDMA

Figures 4 and 5 elucidate the MIMO MC-CDMA performance for both with and without pricing to the overall utilization. It can be discerned that utilization of power with pricing is less in comparison to the scheme without pricing. This represents the performance bound for power allocation in a MC-CDMA system, which is mostly controlled through the pricing scheme with the aid of Nash equilibrium. Thus, the performance bound derived can be generally used for the overall system to retain the interference level as low as conceivable to achieve better overall performance. Here, in MIMO the number of transmitting and receiving antenna is assumed to be 2 and 4. In place of a particular customer at some remoteness away from the position, the equilibrium power increases. By introducing the concept of pricing, the equilibrium power decreases. Thus, the equilibrium power with pricing for four antennas is lower than that without pricing and it is also comparatively lower with the equilibrium power of the user with two antennas. Comparison and performance of MC-CDMA system are given in Tables 2 and 3.

Table 1 Simulation parameter

Parameters	**Value**
Distance, *d* (m)	270, 340, 460, 570, 670, 800, 900, 950, 1000
Block size, *L*	80 bits
Maximum transmit power constraint, $\bar{P}_i$	2 W for each user
Path loss exponent, α	3.6
Mean path gain median, *c*	0.097
Receiver AWGN power^2	5×10^{-5}
Spreading gain, *G*	100
Users	9
IFFT size	512

Table 2 Performance of MC-CDMA system

Number of antenna	**Distance (m)**	**Without pricing (bits/s/Hz/W)**	**With pricing (bits/s/Hz/W)**
TX=2 and RX=2	270	$10^{5.2}$	10^{6}
	380	10^{5}	$10^{5.7}$
	460	$10^{4.2}$	10^{5}
TX=4 and RX=4	270	$10^{6.2}$	$10^{7.4}$
	340	10^{6}	10^{7}
	460	$10^{5.4}$	$10^{6.4}$

Iterations: 2000.

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Table 3 Performance comparison of MC-CDMA system

Number of antenna	Distance (m)	Without pricing (power in watts)	With pricing (power in watts)
TX=2 and RX=2	270	10^{-6}	10^{-7}
	380	$10^{-5.8}$	$10^{-6.8}$
	460	$10^{-5.2}$	$10^{-6.2}$
TX=4 and RX=4	270	10^{-6}	10^{-7}
	380	$10^{-5.8}$	$10^{-6.8}$
	460	$10^{-5.2}$	$10^{-6.2}$

Iterations: 2000.

VII. CONCLUSION

Work done in this paper is on MIMO MC-CDMA with a pricing methodology and power management algorithm using recreation hypothesis. To manage the power during upward frequency, an efficient pricing scheme was proposed. Toward the attainment of stability power, usage of stability is taken into considerations in terms of various bits to analyze the efficiency of proposed scheme with that of the conventional scheme. Experimental results show that from our scheme, a 10% growth is seen in equilibrium utilities with less power usage. Additionally, results show that pricing scheme proves to be a powerful technique for attaining an enhanced performance.

VIII. CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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