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A Non-cooperative Uplink Power Control for CDMA Wireless Communication System

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Abstract

In this project, the main focus is to enhance the existing power control algorithm that is applied in a single cell of CDMA network. Nash algorithm is selected and is further improved with modification of its cost function with a value as power of target SINR, which to reduce the SINR error at first iteration, so as to increase the rate of convergence effectively. Decision of a value is important to ensure the SINR error is reduced at first iteration. The uniqueness and algorithm convergence of enhanced cost function is proven with certain conditions requirements. Therefore, enhanced Nash algorithm (ENA) is proposed which only applicable in first iteration of power control method. The rest of iterations are applied by Nash algorithm due to its better convergence to target SINR. After simulations, with consideration of Rayleigh and Rician fading channels, a significant increase in rate of convergence while maintaining the SINR with error less than 0.01 is shown. The transmitted power is lower in some scenarios, or with very slight reduction less than 0.5%. The SINR error at first iteration is reduced about 20% more by using ENA. In overall, ENA has better performance than the existing Nash algorithm in terms of transmitted power and rate of convergence, without compromising SINR.

Keywords Index power control · CDMA · Transmitted power · Rate of convergence · SINR · Nash algorithm · ENA

1 Introduction

In this era of competing wireless communication, demand for advanced mobile services is increasing and leads to the importance of network resources efficiency. Power control refers to the techniques or methods needed in order to manage, adjust and correct the power from

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the mobile station (MS) and the base station (BS) in an adequate manner. Generally, the high speed quality and low power consumption are major goals in wireless communication systems [1]. In designing a code division multiple access (CDMA) system, power control is one of the most important consideration because it has a momentous impact on performance. It is important to consider transmitted power required by mobile users to transmit signal to base station, as well as their signal-to-interference-plus-noise ratio (SINR). Besides, power control also crucial to reduce the overall interference that exists in the system by regulating the transmitted power level.

In a single cell CDMA system, the transmitted power from MS to BS is increased when the signal pass through the medium with high scattering environment, which caused by slow SINR recovery [2]. On the uplink, users' signals are exposed to different path losses defined by the distance from mobile station to base station, and the variations in radio propagation path. The signal transmitted by MS will be attenuated and this lead to severe interference from other users and causes slow convergence to target SINR for CDMA system as the signal power may drop. The MS will then start compensating by increasing the transmitted power, which may lead to power escalation or positive feedback, and this will result the whole system to be unstable. Since the power consumption for mobile is aim to be as low as possible, high transmitted power is not encouraged in communication systems. Currently, various power control algorithms and techniques are available to improve the performance of wireless communication system in terms of transmitted power and rate of convergence, without sacrificing SINR. The priority is given to SINR and then save the power or system rate.

A non-cooperative power control method has the equilibrium solution but it is not necessarily optimal in all cases [3]. Therefore, cost function and non-linear cost function are the research target in recent years. This is due to its decision making process to maximize the interests of users. Without a proper power control algorithm or method to model different channel conditions, the performance of a communication system will be affected. Therefore, this research work aims to have a power control method that reduce power consumption to the minimum with the consideration of convergence speed, without compromising SINR.

2 Literature Review

Power control is a way to reduce transmitter power when SINR is set to a minimum protection ratio, to balance the co-channel interference and to minimize the near-far effect in a network system. The performance of power control is rely on power control algorithm, which consider the system and channel condition, so as to keep power level variations at low enough [4], with quicker SINR recovery to target SINR, or known as rate of convergence. In 1990s, the pioneering work of Zander [5], Grandhi and Zander [6], Foschini and Miljanic [7] and Yates [8] paved the way for the introduction of efficient power control algorithms (both closed- and open-loop) in third generation CDMA-based cellular networks.

2.1 Power Balancing Algorithm (PBA)

Power balancing algorithm is one of the most common power algorithms to closed-loop power control in wireless communication. In early stage, it was designed for satellite communications by Aein [9] and Meyerhoff [10]. After that, Grandhi and Zander [6] applied this in wireless communications. (1) It is simple and can be implemented distributely, because of the variations on the Power Balancing algorithm have replaced the target SINR by functions incorporating minimum allowable SINR [11], SINRs of other mobiles [12], and maximum allowable power among others [6]. However, Power Balancing algorithm has the drawbacks that convergence can be slow and is guaranteed only if every mobile's target SINR is achievable.

2.2 Nash Algorithm

Nash algorithm is a method proposed by Alpcan et al. [13] that a Nash game formulation of SINR-based power control problem in which each mobile user uses a cost function that is linear in power and logarithmically dependent on SINR. Every mobile user has to decide its own transmission power so as to maximize an appropriate profit that enhance the performance [14], and this is known as utility function in power control [15]. This kind of algorithm attracts researchers as it offers a good insight into the strategic interactions between users and obtains results according to users' preferences. PBA is the fundamentals for Nash algorithm. Nash algorithm proposed a cost function with weights constant in transmitted power and SINR that tends to reduce the transmitted power more than PBA, while maintaining SINR [16]. Based on methods in [16–21], a modification on cost function has high potential to improve the effectiveness of the algorithm. The modification cost function should take the system model into considerations, as well as the transmitted power and SINR.

3 Methodology

A SINR-based power control problem in a single cell CDMA wireless communication is formulated. Existing power control algorithms are compared in terms of rate of convergence and transmitted power. The most potential algorithm among the selected power control algorithms is further enhanced. The performance is mainly based on transmitted power and rate of convergence.

3.1 System Model

Consider the uplink for a single cell CDMA system in which N users are distributed uniformly inside the cell as shown in Fig. 1.

For each link i, which the link that is in ith mobile user to base station, there is a lower SINR threshold limit γ_{min} and upper SINR threshold limit γ_{max}, which has to be same for all links, showing a certain quality of service (QoS) the link has to maintain, so as the transmitted power is adjusted until the least possible power is consumed.

$$\gamma_{min} \leq \gamma_i \leq \gamma_{max} \tag{1}$$

According to Koskie and Gajic [16], this SINR threshold is calculated for the individual mobile to keep a satisfactory frame-error rate (FER). The framework is considered as non-cooperative method because the QoS requirements for other users are not relevant to the current mobile user. Therefore, non-cooperative method is well suited for

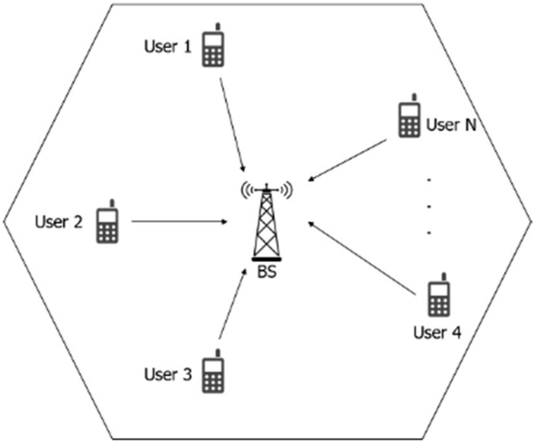

Fig. 1 Single CDMA system with N users

analyzing and solving the power control problem [13]. The transmitted power and SINR for the ith user is denoted as p_i and γ_i, while background (receiver) noise power within the user's bandwidth is n_i. Noise power n_i is treated as constant for problem formulation of power control in wireless networks. Therefore, the SINR of the ith mobile user can be defined as

$$\gamma_i = \frac{h_i p_i}{\sum_{j \neq i} h_j p_j c_{ij} + n_i}, \quad i,j = 1,2,\ldots,n. \tag{2}$$

where $h_i = A/r_i^\alpha$ is the attenuation from ith mobile to base station calculated from the distance r_i without shadowing and fast fading, A is constant gain whereas path loss exponent α is in between 3 and 6. c_{ij} is the correlation coefficient [16]. The interference to the ith user's signal will be $\sum_{j \neq i} g_{ij} p_j$ where p_i is the transmission power corresponding to the ith user and the g_{ij} are link gains. p_j is the received power. The sum of interference including noise in the denominator in Eq. (2) can be denoted as $I_i(p_{-i})$. The SINR for ith user is thus

$$\gamma_i = \frac{g_{ii} p_i}{I_i(p_{-i})} = \frac{g_{ii} p_i}{\sum_{j \neq i} g_{ij} p_j + n_i}, \quad i,j = 1,2,\ldots,n. \tag{3}$$

The subscript $-i$ shows the interference that depends on the power of all users except ith user. The link gains are assumed to be constant over time and noise power should be larger than 0, $n_i > 0$. By comparing Eqs. (2) and (3), it can denoted as following equation

$$g_{ij} = \begin{cases} h_i & j = i \\ h_j c_{ij} & otherwise \end{cases} \tag{4}$$

The g_{ij} denotes an effective link gain from transmitter jth user to base station, which cause interference and affecting the signal of ith user [16].

3.2 Power Balancing Algorithm (PBA)

The PBA [11] iteratively updates power according to

$$p_i(k+1) = \frac{\gamma p_i(k)}{\gamma_i(k)} \tag{5}$$

where k is iteration number.

3.3 Nash Algorithm

The Nash algorithm [16] will run in real time with measurements potentially updated every step of the algorithm

$$p_i(k+1) = \begin{cases} \frac{\gamma}{g_{ii}} I_i(k) - \frac{b_i}{2c_i}\left(\frac{p_i(k)}{\gamma_i(k)}\right)^2 & \textit{if positive} \\ 0 & \textit{otherwise} \end{cases} \tag{6}$$

where $p_i(k)$ is the power of ith mobile user and $I_i(k)$ is the measured interference experienced by the ith user at the kth step of the algorithm. b_i and c_i represent the weights of transmit power p_i and SINR offset respectively.

3.4 Enhanced Cost Function and Nash Equilibrium

Nash algorithm, which proposed by Koskie and Gajic [16] is used as the fundamental for enhancement power control method. An enhanced cost function is proposed with the consideration of power consumption and deviation from target SINR levels. The main goal is to determine the Nash equilibrium point in game theoretic approach, where no user can get benefit over the others by changing his/her strategy unilaterally [22]. The cost function by Koskie and Gajic [16] is the fundamental for the proposed cost function. Generally, the cost function must be convex and non-negative so as to allow existence of at least one non-negative minimum. This lead to the power is designed always positive in this application. However, difference in SINR may be either positive or negative. To combat the issue, the difference in SINR is squared so as to ensure positivity and convexity of cost function. The Koskie's cost function is denoted as follow

$$J_i\left(p_i, \gamma_i\right) = b_i p_i + c_i\left(\gamma_i^{tar} - \gamma_i\right)^2 \tag{7}$$

where b_i and c_i represent weights of transmit power p_i and SINR offset respectively. Since the sensitivity in SINR error is more significant [16], a cost function is proposed with additional value a added as the power of target SINR. a represents the weights to reduce the SINR error for target SINR and actual SINR, which only applicable for the first iteration in the power control method, so as to improve the overall convergence rate of the system by using Koskie's Nash algorithm for the following iterations. a value is in between 0 and 2, the decision of a value is important as it might worsen the performance if improper a value is chosen. Therefore, we consider the following equation as the enhanced cost function

$$J_i\left(p_i, \gamma_i\right) = b_i p_i + c_i\left[\left(\gamma_i^{tar}\right)^a - \gamma_i\right]^2. \tag{8}$$

3.5 Enhanced Nash Algorithm (ENA)

The power update formula is obtained by differentiating the cost function in Eq. (8) with respect to power and equating it with zero.

$$\frac{\partial J_i}{\partial p_i} = b_i - 2c_i\left[\left(\gamma_i^{tar}\right)^a - \gamma_i\right]\frac{\partial \gamma_i}{\partial p_i} \tag{9}$$

By substitute Eq. (3) into Eq. (9), each mobile user can update its power transmission with the knowledge of its own interference level. The algorithm is updated every step and dependent on the measured interference, which the proposed power update formula can be written as

$$p_i^{(k+1)} = \frac{\left(\gamma_i^{tar}\right)^a}{g_{ii}} I_i^{(k)} - \frac{b_i}{2c_i}\left(\frac{I_i^{(k)}}{g_{ii}}\right)^2 \tag{10}$$

where $p_i^{(k+1)}$ is the power transmission for *i*th user at $(k+1)$th step and the measured interference $I_i^{(k)}$ is at the *k*th step of the algorithm. Similarly, the proposed power update formula can be written in the knowledge of previous power transmission value $p_i^{(k)}$ and current actual SINR measurement $\gamma_i^{(k)}$, in the form of $p_i^{(k+1)} = f_i^{(k)} p_i^{(k)}$. The power update formula in terms of previous power value and SINR is rewritten as

$$p_i^{(k+1)} = \frac{\left(\gamma_i^{tar}\right)^a}{\gamma_i^{(k)}} p_i^{(k)} - \frac{b_i}{2c_i}\left(\frac{p_i^{(k)}}{\gamma_i^{(k)}}\right)^2 \tag{11}$$

From Eqs. (10) and (11), these two formulations require only single measurement in each power update step. If interference measurement is available, Eq. (10) is used. In contrast, if previous power measurement is available, Eq. (11) is used. The minor difference is the initial power for Eq. (11) cannot be zero power, however, Eq. (10) does not require an initial non-zero power because interference will never be zero with existence of noise power. According to Yates [8], in order for the algorithm converges to the fixed point and unique, the algorithm $p_i^{(k+1)} = f_i^{(k)} p_i^{(k)}$ should exist and the function f should satisfy three conditions: positivity $f(p) \geq 0$, monotonicity $p \geq p' \Rightarrow f(p) \geq f\left(p'\right)$, and scalability $\alpha f(p) \geq f(\alpha p);\ \forall \alpha \geq 1$.

Table 1 describes the pseudo code of realization method for enhanced Nash algorithm (ENA). ENA power control algorithm is only applicable on the first iteration of the algorithm process, which is line 9, and the remaining iterations are continued with Nash algorithm. When the SINR error is less than 0.01, the final transmitted power is decided and iteration number is recorded.

4 Results and Discussion

In order for easier comparison of power control algorithms performance in the system model, the initial parameters are tabulated in Table 2.

The channel link gains are simulated through MATLAB using two different fading channel distribution, namely Rayleigh and Rician. The scaling factor for these distributions is 1. In

Table 1 Pseudo code of realization method for enhanced Nash algorithm (ENA)

```
INITIALIZATION
Initialize transmitted power and noise power
    FOR
    Calculate user numbers
    Generate link gains for different fading channels
    END FOR
Calculate SINR
MEASUREMENT AND UPDATE:
Calculate power using ENA
Recalculate SINR
    FOR
    Calculate power using Nash algorithm
    Recalculate SINR
        IF SINR error < 0.01
        Final transmitted power
        END IF
    END FOR
```

Table 2 Initial parameters for a single cell CDMA network

Number of users	5
Constant gain, A	1×10^{-11}
Path loss exponent, α	4
Correlation coefficient, c_{ij}	1/255
Initial transmitted power	0.001 mW
Noise power, n_i	0.00002 mW
Maximal power, p^{max}	600 mW
Target SINR	5

both Rayleigh and Rician fading channels, g_{ij} is normalized to 1. The channel gains between BS and respective MS are in diagonal matrix, which have included the considerations of distance between BS and MS, the higher gain indicates closer distance whereas lower gain represents the farther distance. Refer to Eq. (4), the attenuation gain of each fading distribution is as follow

$$g_{ij,Rayleigh} = \begin{bmatrix} 0.3561 & 0.0322 & 0.0160 & 0.0051 & 0.0219 \\ 0.0264 & 0.8026 & 0.0045 & 0.0374 & 0.0259 \\ 0.0279 & 0.0198 & 0.6950 & 0.0049 & 0.0252 \\ 0.0111 & 0.0286 & 0.0313 & 0.6469 & 0.0251 \\ 0.0202 & 0.0320 & 0.0167 & 0.0362 & 0.3021 \end{bmatrix} \quad (12)$$

$$g_{ij,Rician} = \begin{bmatrix} 0.3981 & 0.0309 & 0.0351 & 0.0355 & 0.0177 \\ 0.0366 & 0.8469 & 0.0330 & 0.0397 & 0.0220 \\ 0.0373 & 0.0353 & 0.8912 & 0.0140 & 0.0344 \\ 0.0190 & 0.0112 & 0.0315 & 0.7414 & 0.0314 \\ 0.0365 & 0.0174 & 0.0287 & 0.0349 & 0.9296 \end{bmatrix} \quad (13)$$

Based on literature reviews, Nash algorithm has the best performance in terms of transmitted power and rate of convergence in both Rayleigh and Rician fading channel. Therefore, Nash algorithm has the potential to be improved in terms of transmitted power or rate of convergence. ENA and an improved power control method are proposed and compared with existing Nash algorithm. Equation (11) is used as ENA transmitted power at first iteration, followed by Eq. (6) for next iterations, which is the Nash algorithm transmitted power. For SINR, Eq. (3) is used. The results are simulated with the same initial parameters and link gains as previous comparison. For ENA, $a = 1.4$ is used for Rayleigh channel while for Rician channel, $a = 0.9$ is used instead.

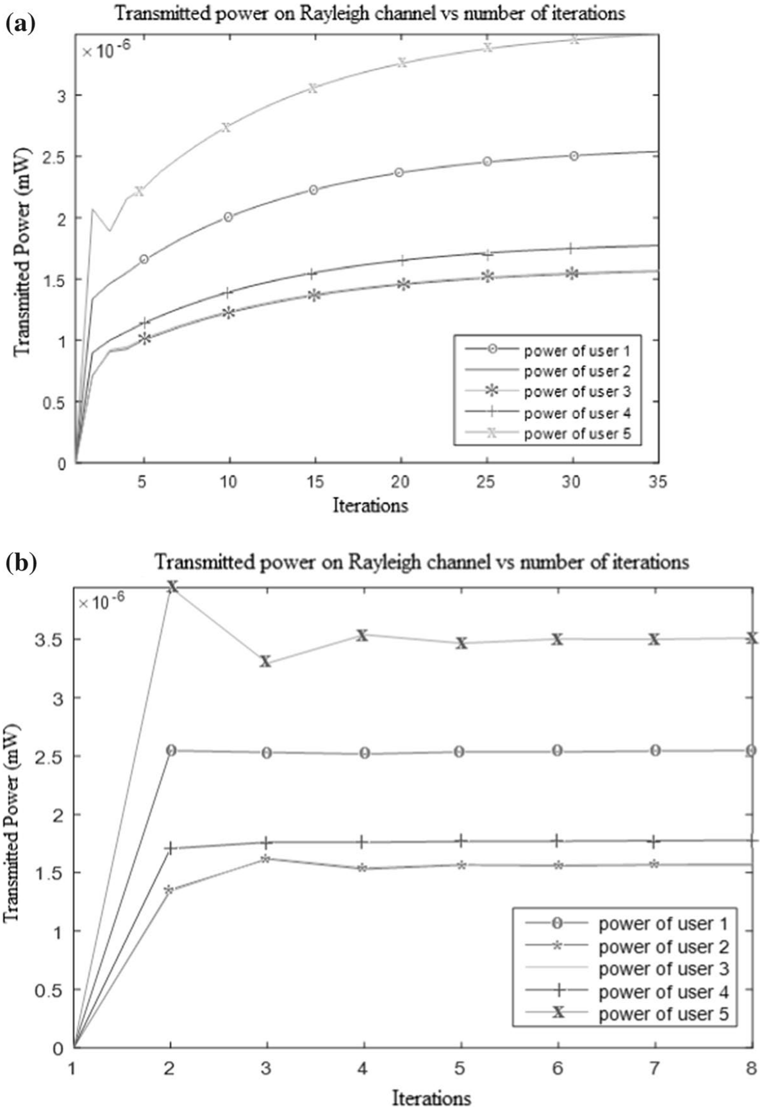

Fig. 2 Transmitted power versus number of iterations in Rayleigh channel **a** Nash **b** ENA

Based on Fig. 2, the difference between Nash algorithm and ENA is in the first iteration. Nash algorithm uses the technique to increase the transmitted power gradually until the SINR is in the acceptable range. However, an improved power control method is applied, which ENA uses the method to boost the transmitted power at first iteration and then uses Nash algorithm to approach the desired transmitted power gradually. The method of increase transmitted power at first iteration will not affect the power usage of mobile user, as the transmitted power required for the mobile user to transmit signal is based on the power value at last iteration. From Table 3, under Rayleigh fading channel, the simulation results show that Nash algorithm is outperformed ENA with lesser power requirements. All users with ENA required slightly higher transmitted power. The difference in both Nash algorithm and ENA is in between 0.000003 and 0.000008 mW, or an increase of 0.28–0.37%. This shows that ENA is not performed well in terms of transmitted power for this scenario.

Figure 3 shows the transmited power between Nash algorithm and ENA in the Rician chennel. It can be seen Nash requires higher transmitted power compared to ENA method. Therefore, in Rician fading channel, based on the numerical results in Table 4, ENA has better performance with lesser transmitted power required by all users compared to Nash algorithm. The reduction is range from 0.000002 to 0.000004 mW, or a decrease of 0.23–0.51%. This indicates ENA is potentially an alternative power control algorithm.

ENA with improved power control method is proven applicable in both Rayleigh and Rician fading channels as the SINR of all users converged to target SINR at certain iterations. Based on Figs. 4 and 5, using ENA able to reduce SINR difference very quickly in very less iterations compared to Nash algorithm, which speed up the users' SINR converge to target SINR.

The highlight of ENA compared to Nash algorithm is the rate of convergence. The rate of convergence using ENA is increased significantly with fewer iterations. By referring to Table 5, in Rayleigh fading channel, using ENA is 4.4 times faster than Nash algorithm to determine the final transmitted power. While in Rician fading channel, using ENA can speed up 2.67 times faster than Nash algorithm. The speed of the system is significantly improved without compromising the condition of signal transmission. From previous analysis, ENA is proven that it can increase the rate of convergence significantly. This is mainly because the Nash algorithm is modified by propose a at the power of target SINR, to reduce the SINR difference or known as SINR error. The SINR error for both Nash algorithm and ENA power control method at first iteration is tabulated at Table 6.

From Table 6, by using ENA, it can reduce the SINR error distinctly. For example, User 4 has only SINR error of 0.1528 compared to 0.5086, reduced at 73.14% compared to only 10.58%, a significant improvement of 62.56%. Similarly, Users 1, 2, and 3 also have more SINR error reduction with ENA compared to Nash. However, it may not ideal

Table 3 Final transmitted power using Nash algorithm and ENA under Rayleigh channel

Rayleigh	Transmitted power (mW)	
	Nash	ENA
User 1	0.002539	0.002547
User 2	0.001561	0.001566
User 3	0.001570	0.001575
User 4	0.001774	0.001779
User 5	0.003497	0.003510

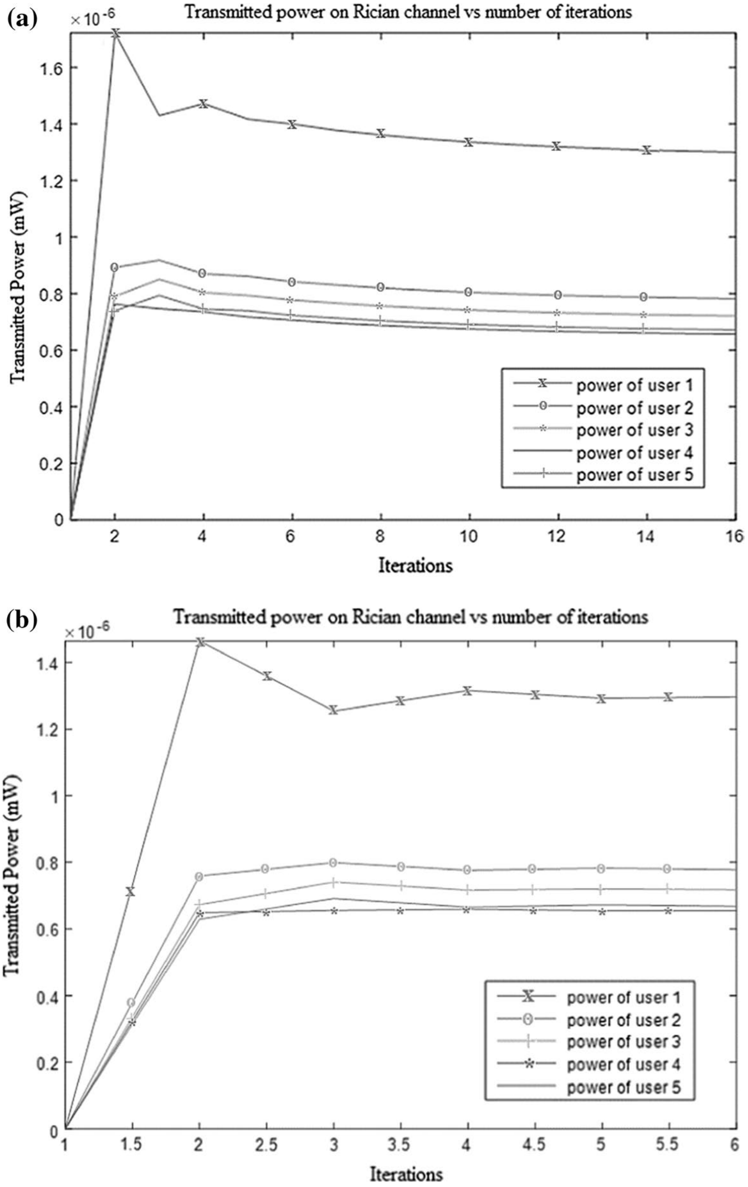

Fig. 3 Transmitted power versus number of iterations in Rician channel **a** Nash **b** ENA

for every user to reduce its SINR error by using ENA. User 5 has lesser SINR error reduction by using ENA compared to Nash algorithm, by 19.27%. In overall, majority users are able to reduce SINR error at first iteration with the use of ENA. The proper *a* value is vital for ENA which is working together with improved power control method. A proper chosen *a* value can increase the rate of convergence significantly. A wrong decision of *a* value may lead to worst performance as the system speed is slower. *a* value

Table 4 Final transmitted power using Nash algorithm and ENA under Rician channel

Rician	Transmitted power (mW)	
	Nash	ENA
User 1	0.001299	0.001296
User 2	0.000782	0.000778
User 3	0.000721	0.000718
User 4	0.000657	0.000655
User 5	0.000671	0.000668

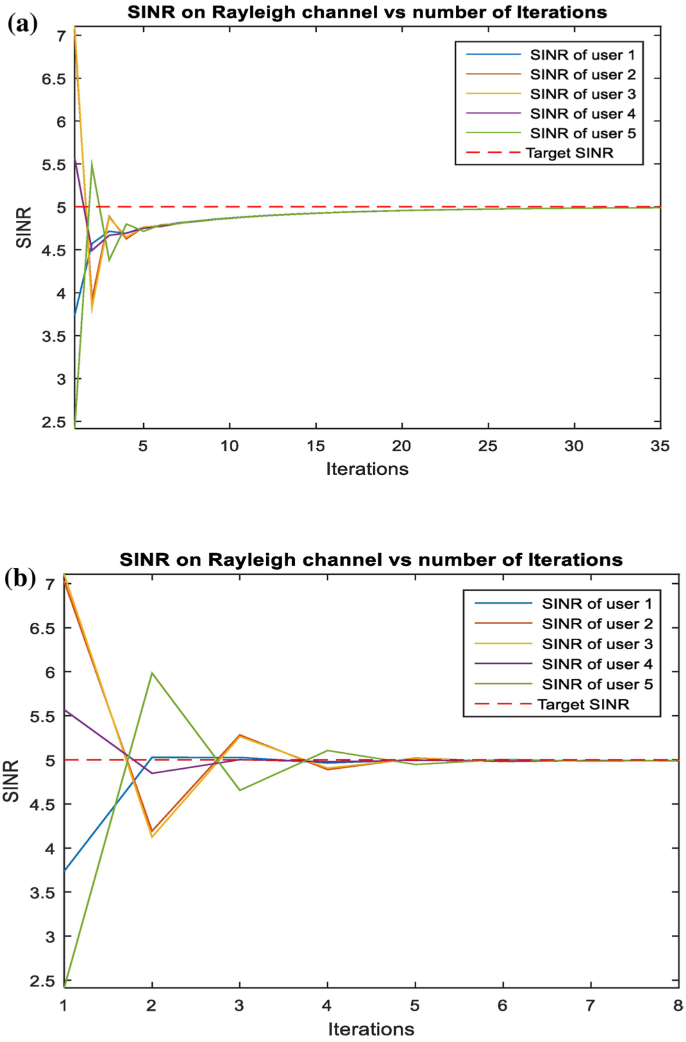

Fig. 4 Convergence to target SINR versus number of iterations in Rayleigh channel **a** Nash **b** ENA

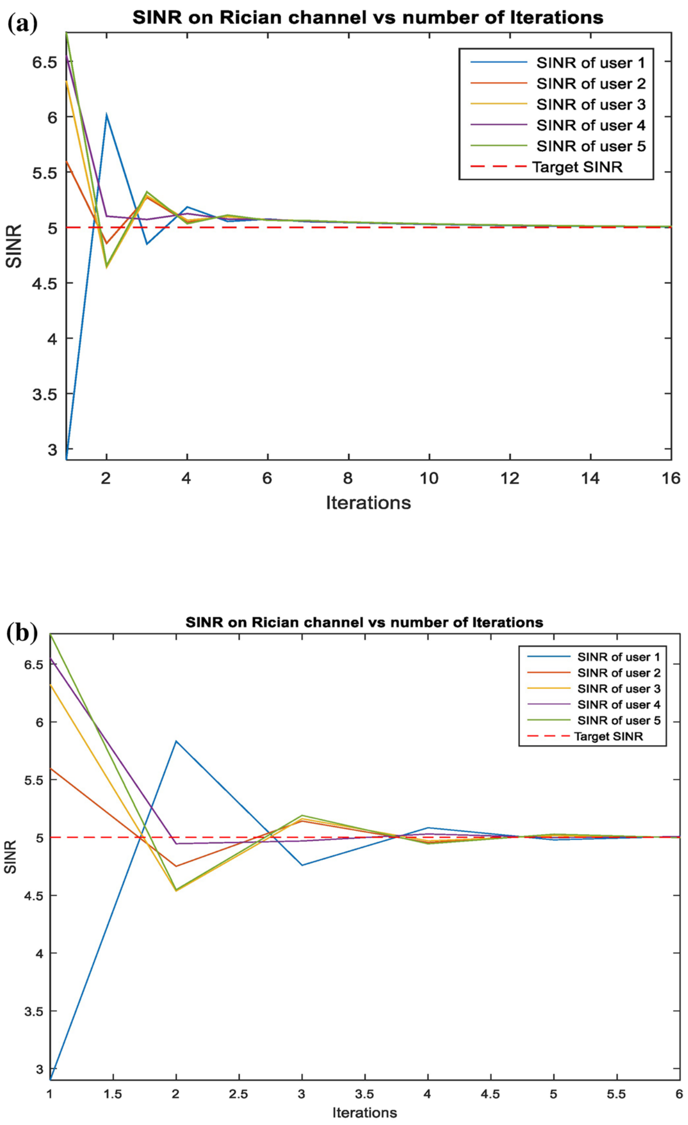

Fig. 5 Convergence to target SINR versus number of iterations in Rician channel **a** Nash **b** ENA

Table 5 Iterations of SINR convergence using Nash algorithm and ENA under Rayleigh and Rician fading channel

	Iterations	
	Nash	ENA
Rayleigh	35	8
Rician	16	6

Table 6 SINR error of Nash algorithm and SINR error of ENA algorithm at first iteration under Rayleigh channel

	Initial SINR error	Nash		ENA	
		SINR error	Reduction (%)	SINR error	Reduction (%)
User 1	1.2620	0.4296	65.96	0.0285	97.74
User 2	2.0265	1.0809	46.66	0.8072	60.17
User 3	2.1048	1.1807	43.90	0.8750	58.43
User 4	0.5688	0.5086	10.58	0.1528	73.14
User 5	2.5862	0.4860	81.21	0.9842	61.94

is in between 0 and 2 as the range is sufficient for ENA to perform. If $a=1.0$, ENA is identical to Nash algorithm. In order to prove the effectiveness of ENA, a values in between 0 and 2 are simulated in both Rayleigh and Rician fading channel by using the same system model previously. The rate of convergence and average transmitted power, are tabulated in Table 7. Figure 6 shows the iterations and average transmitted power versus λ value using ENA in Rayleigh channel, whereas for Rician channel is shown in Fig. 7.

Table 7 Rate of convergence and average transmitted power with different a values using ENA under Rayleigh and Rician fading channel

a	Rayleigh		Rician	
	Iterations	Average transmitted power (mW)	Iterations	Average transmitted power (mW)
0	42	0.002192	29	0.0008126
0.1	41	0.002189	29	0.0008128
0.2	41	0.002190	29	0.0008130
0.3	41	0.002191	28	0.0008127
0.4	40	0.002188	27	0.0008124
0.5	40	0.002190	27	0.0008130
0.6	39	0.002188	26	0.0008130
0.7	39	0.002191	24	0.0008129
0.8	38	0.002191	20	0.0008126
0.9	37	0.002191	6	0.0008230
1.0	35	0.002189	16	0.0008261
1.1	33	0.002190	19	0.0008276
1.2	30	0.002190	22	0.0008263
1.3	25	0.002192	24	0.0008260
1.4	8	0.002195	25	0.0008272
1.5	22	0.002281	27	0.0008259
1.6	31	0.002282	28	0.0008264
1.7	36	0.002285	29	0.0008267
1.8	41	0.002281	30	0.0008269
1.9	44	0.002282	31	0.0008270
2.0	47	0.002282	32	0.0008269

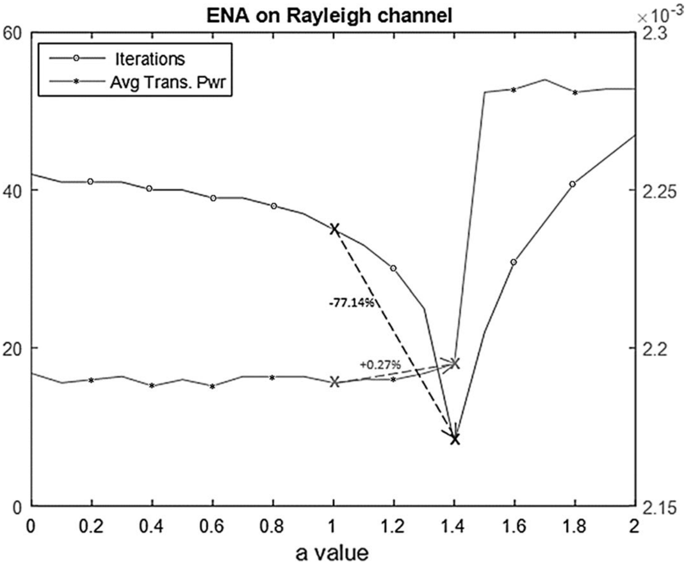

Fig. 6 Iterations and average transmitted power versus a value using ENA in Rayleigh channel

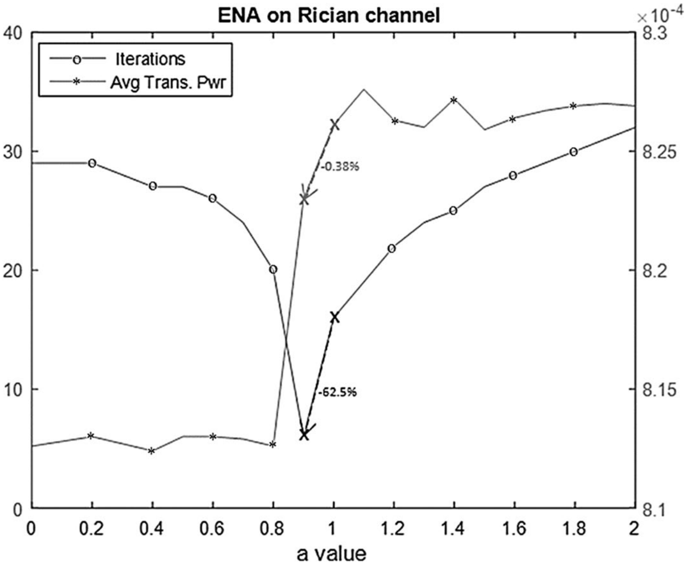

Fig. 7 Iterations and average transmitted power versus a value using ENA in Rician channel

The aim of ENA is to have fewer iterations than the Nash algorithm. From Table 7, in Rayleigh channel, any a value that is lesser than 35 iterations is considered as an improvement in terms of rate of convergence. The $a = 1.4$ has the most significant improvement in system speed as it requires only 8 iterations, compared to Nash algorithm that requires 35 iterations, with lesser 27 iterations and about 4.4 times increase in rate of convergence, or a reduction in iterations of 77.14%. The high rate of convergence can be compromised by slightly increase the average transmitted power by 0.000006 mW or 0.27%, where ENA requires 0.002195 mW while Nash algorithm uses 0.002189 mW. Based on Fig. 6, the a value that is between 1.1 and 1.6 also can be chosen as it has better performance compared to Nash algorithm in system speed. However, if transmitted power is considered, a value that is between 1.1 and 1.4 is more encouraged as the increase in rate of convergence is compromised with slim increase in transmitted power.

From Table 7, in Rician channel, the only a value that is outperformed the Nash algorithm is $a = 0.9$. With $a = 0.9$, the system required only 6 iterations instead of 16 iterations, which is fewer 10 iterations, an increase of speed 2.67 times or a reduction in iterations of 62.5%. Other than that, lower average transmitted power is required for $a = 0.9$ if compared to Nash algorithm, with a decrease of 0.0000031 mW or 0.38%. Based on Fig. 7, the average transmitter power is lower if $a < 0.9$. However, the decrease in average transmitted power is compromised with significant decrease in rate of convergence, which is not encouraged. Even with saving power, the system becomes slower.

5 Conclusion

This project presented the enhanced version of Nash algorithm, namely enhanced Nash algorithm (ENA), which only applied in the first iteration of power control method. The cost function of original cost function from Nash algorithm is modified with consider a value as the power form in target SINR, the weights to reduce the SINR difference between target SINR and actual SINR at first iteration. The purpose is to increase the rate of convergence or reduce the iterations to decide the transmitted power required by mobile users. Simulation results have shown that rate of convergence is significant improved in both Rayleigh and Rician channel, 77.14% and 62.5% respectively. The improvement on transmitted power is less significant compared to rate of convergence as limited by SINR error in cost function, so as to ensure the SINR is maintained at target SINR without the loss of QoS, at most 0.01 SINR error. Other than that, a value in ENA is crucial to improve the overall performance of the system. The proposed ENA can be further improved by introducing ways to decide a value from time to time, so as to tackle the limitation of this algorithm that applicable in first iteration only. a value must to ensure that the SINR is converging to target SINR. It is also recommended to improve transmitted power more than 1% without compromising the decrease of SINR. Moreover, it is encouraged to apply ENA in other communication networks such as cognitive radio network or OFDM to test the effectiveness of ENA.

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