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Power Allocation Optimization for Non Orthogonal Multiple Access

Dipa Nitin Kokane[a], Geeta Nijhawan[b], Shruti Vashist[c]

[a] Research Scholar, MRIIRS, Faridabad, dipakokane@gmail.com
[b] Professor, MRIIRS,Faridabad, geeta.fet@mriu.edu.in
[c] Professor, Manavrachna University,Faridabad, shruti.fet@mriu.edu.in

Abstract

Recently researchers are paying more attention to do a work in Non-orthogonal multiple access (NOMA) technique due to its cost effectiveness to enrich the spectral efficiency. This helps in increasing the capacity of advanced wireless systems without expanding the bandwidth. This paper investigate various power allocation schemes which are used in Non Orthogonal multiple access wireless communication and proposed modified power optimization scheme under maximum fairness constraints between users throughput. We also discuss spectral efficiency and Energy efficiency Tradeoff for both NOMA and OMA system and simulation results shows that NOMA has improved results compare to OMA.

Keywords: Power Allocation; FPA; FTPA; OMA; NOMA; Spectral Efficiency; Throughput; Energy efficiency

1. Introduction

The innovative technologies which have come up in the recent years have a more influence on current generation of wireless communication. In future advanced wireless communication is expected to fulfill all the emerging requirements along with enhanced efficiency, throughput, service quality, massive connectivity. However the resource allocation parameters like radio spectrum, transmit power are limited. Researchers are working and proposing various technologies to fulfill the requirements and addressing the challenges for future advanced wireless communication. One important technology which has a great impact on capacity of the system is multiple access schemes in which available resources are shared by multiple users in efficient manner to enhance the performance parameter of the system. To support the above mentioned requirement 3GPP standardized NOMA in LTE and LTE-A named as multiuser superposition Transmission (MUST) [1, 15]. NOMA is different than the traditional access scheme in which users are sharing same time and frequency. NOMA is roughly categorized in two domain 1) code domain 2) power domain. In this paper power domain NOMA is discussed in which users are separated in power domain. NOMA proved as a promising Non-Orthogonal access scheme to achieve massive connectivity, high throughput, efficiency improvement and latency reduction [2, 9, 12].

As stated earlier in this paper power domain NOMA is consider and main objective is to focus on the power allocation techniques to enhance the data rate under fairness constraints of the NOMA compare to orthogonal technique and fractional power allocation. We also discuss the EE and SE relation of NOMA along with the proposed scheme. The selection of the proper power allocation strategy is one of the important resource allocation parameter to increase the effectiveness of the NOMA [3, 13]. In the paper, we propose new power allocation scheme to optimize NOMA performance.

The paper is organized as, section 2 presents System model of downlink NOMA. Section 3 describes the analysis of Signal to Noise Ratio (SNR) and throughput of NOMA Scheme. Sections 4 discuss the various power allocation techniques. Section 5 propose new power allocation scheme for NOMA to enhance the NOMA capacity along with fairness constraint. Section 6 describes the energy and spectral efficiency of NOMA and OMA. Section 7 compares the simulation results of proposed scheme with OMA and FPA NOMA for data rate, Spectral and energy efficiency. Section 8 gives the overall conclusion of the work.

2. System Model

In this section we discuss about the downlink NOMA. As shown in Figure 1 , in a network at transmitter side multiple users are assigned different power coefficient as per channel condition i.e. the users with weak channel, who is away from the Base Station (BS) are assigned the higher power factors and user with stronger channel condition i.e, near to base station are assigned the low power factor. These power factors are basically used to enhance the channel gain of the weak signals of the users. All these power enhanced users signals are combined to form superimposed signal which is emitted by the BS. At the receiver section all users' signals are recovered by performing the Successive Interference cancellation (SIC). At receiver SIC is performing the iterative subtraction until the desired signal is decoded.

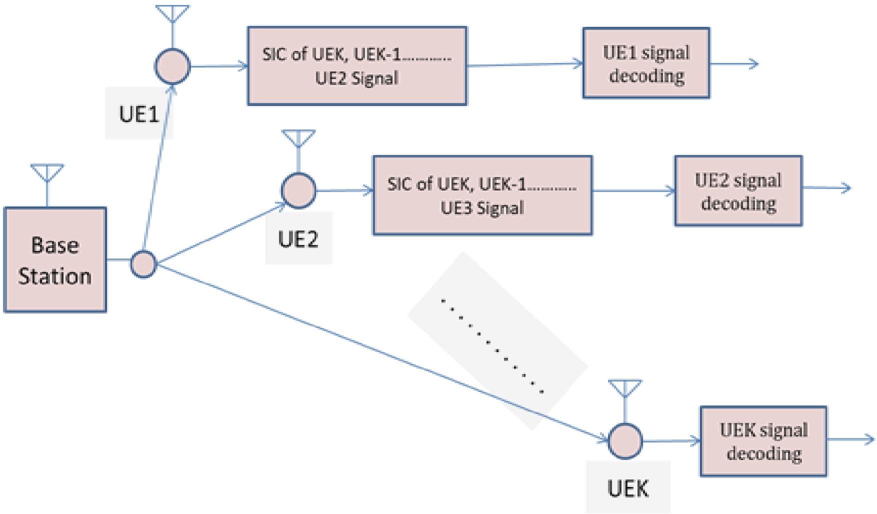

Figure 1. Structure of downlink NOMA

Consider the K users signals are multiplexed using NOMA technique. The superimposed signal emitted by BS is given as

$$x(t) = \sum_{k=1}^{K} \sqrt{\alpha_k P_t}\; x_k(t) \qquad (1)$$

Where $x_k(t)$ is individual user signal, P_t is the total power of BS, α_k is the allocated power factor to kth user. Thus the total power of kth user is $P_k = \alpha_k P_t$, the power allocation to each user is subject to the

$$\sum_{k=1}^{K} P_k = P_t \qquad (2)$$

The channel gain of K users is order as

$$|h_1| \geq |h_2| \ldots\ldots\ldots\ldots |h_{K-1}| \geq |h_K| \qquad (3)$$

The received signal of ith user with white additive Gaussian noise, $n_i(t)$ with zero mean and noise spectral density No (W/Hz) is written as

$$Y_i(t) = x(t)\; h_i + n_i(t)$$

$$Y_i(t) = \sum_{k=1}^{K} \sqrt{\alpha_k P_t}\; x_k(t)\; h_i + n_i(t) \qquad (4)$$

3. SNR and Data Rate Analysis

Let consider the user which is far away from BS first. This signal is detected first since it has higher power coefficient compared to others and the other users signal will be consider as interference. The instantaneous SNR of kth user is given as

$$SNR_k = \frac{P_k |h_k|^2}{N_0 B + \sum_{i=1}^{k-1} P_i |h_k|^2} \qquad (5)$$

Where B is the transmission bandwidth and for the closer user1 the instantaneous SNR becomes

$$SNR_1 = \frac{P_{k1} |h_1|^2}{N_0 B} \qquad (6)$$

Downlink NOMA data rate (bps) is given as

$$R_k = Blog_2\left(1 + \frac{P_k|h_k|^2}{N + \sum_{i=1}^{k-1} P_i|h_k|^2}\right) \quad (7)$$

Where N = NoB

In OMA, both the total power and bandwidth are equally assigned to each user. So the OMA data rate(bps) is given as

$$R_k = B_k log_2\left(1 + \frac{P_k|h_k|^2}{N_k}\right) \quad (8)$$

Where $B_k = B/K$ and $N_k = N_0\, B_k$

The sum rate of OMA and NOMA can be given as

$$\mathrm{R_T} = \sum_{k=1}^{K} \mathrm{R_k} \quad (9)$$

Next the Jain fairness index is calculated as [3], this shows that how the system is fair enough in terms of capacity which is shared among the users.

$$F = \left(\sum_{k=1}^{K} R_k\right)^2 / K \sum_{k=1}^{K} R_k^2 \quad (10)$$

The maximum limit of F is 1, i.e. F closer to 1 indicates that capacity of each user is closer to each other.

4. Power Allocation Scheme

There are various power allocation techniques for NOMA wireless system. As per [4],[5],[6], we summarized that power allocation algorithm influences the reconstruction of the UEs signal which directly concern to SNR and accuracy of the network. Below we explore various power allocation mechanisms.

a) Arbitrary power allocation

In this technique for NOMA network the users are grouped in two categories i.e. stronger Signal and Weaker signal depending on their location from the BS and weaker signals are assigned more power and stronger signal are assigned less power of the total available power. There is no particular explanation for the division of total power among the users [7], [8].

b) Fixed power allocation (FPA)

In FPA every user is allotted with a different power which is fixed depending on its channel gain condition. The power multiplication factor ranging from 0 to 1 is allocated to every user and accordingly the new power is allocated to the user. Based on the channel condition user with stronger channel is assigned with less power i.e 0.1P, the UE with poor channel condition are assigned with higher power i.e 0.6P and remaining power of the total power is assigned to other user. The main problem to consider is that user's power is not calculated using any defined formula and as it assigns the fixed power to the user so it will not perform according to the fluctuation in the channel gain.

c) Fractional transmit power allocation (FTPA)

FTPA is a modest PA technique without any Specific Objective of optimization [11, 14]. In FTPA every user is assigned with a different power level depending on its channel gain condition [6]. In this the users power level is depend on decay factor α which is ranging from 0 to 1.

5. Proposed Power Allocation Scheme for Downlink NOMA

As per the literature survey [4],[5],[6] we understand that power allocation is one of the important scheme while designing a wireless system using NOMA and to solve the problem of above mentioned power allocation techniques , we have proposed a new formula to calculate a power allocation factor of every user in which channel gain of every user is modified using the choice factor C . The value of choice factor C is lies between 0 and 1 and is selected to optimize the system capacity with consideration of fairness index. In a network if we are multiplexing K users signals the power factor of K-1 users are calculates as

$$\mathrm{P_i} = \sum_{i=1}^{i} \left(|h_i|^2 / NoB\right)^{\mathrm{Ci}} \quad (11)$$

and Kth user power is calculated as

$$\mathrm{P_K} = 1 - \sum_{i=1}^{K-1} \mathrm{P_i} \quad (12)$$

we are having K-1 choice factors lies between 0 and 1 and $\sum_{k=1}^{K-1} C_k = 1$. Thus in a proposed scheme instead of having only one decay factor , there are different choice factors which are varied as per the channel fluctuation to optimize the system capacity.

Algorithm 1: For optimizing network capacity using proposed power allocation scheme

Initialize the choice factor set matrix include all possible values

Set Fairness condition to F"

for k set in choice factor matrix do

Calculate power

Calculate capacity

Calculate fairness index

If fairness index ≤ Fairness condition then

Set capacity (k) to zero

end if

end for

6. Energy Efficiency and Spectral Efficiency of NOMA and OMA

In the above section we have discussed about our proposed power allocation scheme. In continuation to that we analyze the energy efficiency and spectral efficiency of the NOMA network. In this static power is analyzed which is a result of power amplifiers of the BS is also incorporated. So at the transmitter total consumed power is the sum of users signal power and the circuit power of BS (Power amplifiers). Consider the Downlink NOMA , the total power consumption at BS is given as,

$$P_{tot} = P_t + P_{static} \quad (13)$$

Then the energy efficiency (EE) is written as [10],

$$EE = R_T / P_{tot} = SE * B / P_{tot} \text{ (bits/Joule)} \quad (14)$$

$$SE = R_T / B \text{ (bps/Hz)} \quad (15)$$

Where R_T is total rate of the system. The above equations are common for both NOMA and OMA.

7. Results and discussion

In this section, we provide the NOMA simulation results of data rate which are achieved by our proposed scheme and compare with the OMA. We have considered the downlink NOMA network with 4 UEs. The simulation parameters are listed in table 1.

Table 1. Parameters

Radio Access scheme	NOMA
Total No. of users	4
Antenna used	BS. 1 Tx and UE : 4 Rx
Bandwidth	1GHz
Channel Gain in dB of 4 UEs (Obtained by Okumura –Hata prapogation model)	-23.20, -26.23 -27.98, -39.24
Noise Power Spectral Density No (W/Hz)	10^{-20}
Power Allocation Choice factor (C_1,C_2,C_3)	0.6, 0.3,0.1

Figure.2 shows the data rate of 4 users in OMA network where power and bandwidth are equally shared among the user. Figure.3 shows data rate of 4 users in FPA NOMA network. Figure.4 shows that the data rate achieved by 4 users in NOMA network when proposed optimization scheme is applied. The numeric comparison of throughput of OMA and NOMA network (FPA and Proposed) is given in Table 2. It shows that the proposed scheme improves the data rate as well fairness index compare to OMA and FTPA NOMA system.

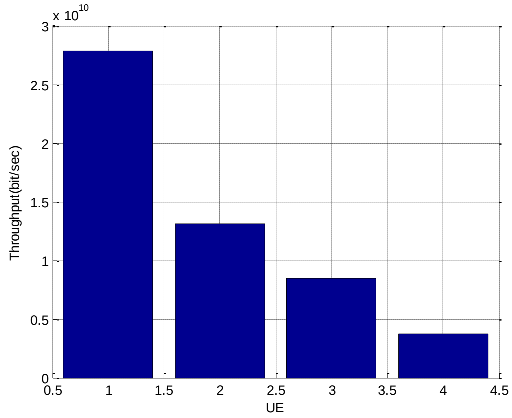

Figure 2. Throughput of 4 Users in OMA network

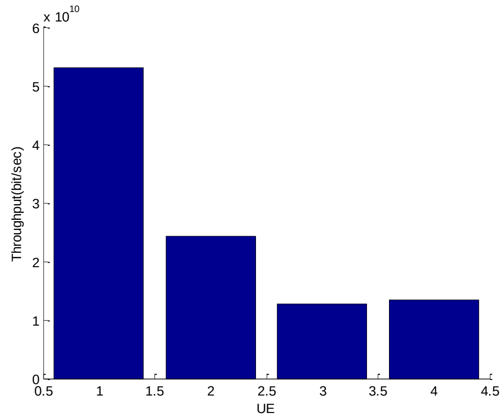

Figure 3. Throughput of 4 Users in FPA NOMA network

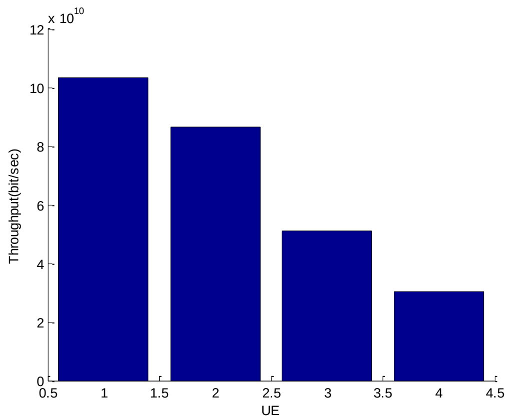

Figure 4. Throughput of 4 Users in proposed NOMA network

Table 2. Data rate/ Throughput Comparison of NOMA and OMA system as per simulation

User Equipment	Data Rate NOMA (proposed)	Data Rate NOMA (FPA)	Data Rate OMA
UE1	$1.03*10^{11}$	$5.315*10^{10}$	$2.78*10^{10}$
UE2	$8.66*10^{10}$	$2.42*10^{10}$	$1.31*10^{10}$
UE3	$5.10*10^{10}$	$1.28*10^{10}$	$8.47*10^{9}$
UE4	$3.04*10^{10}$	$1.34*10^{10}$	$3.70*10^{9}$
Fairness Index	0.85	0.71	0.68
Sum Rate	$2.71*10^{11}$	$1.03*10^{11}$	$5.31*10^{10}$

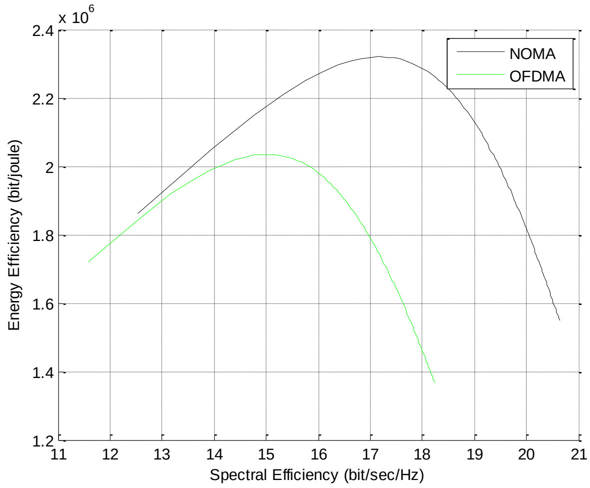

Figure 5. EE-SE relation of NOMA FPA and OMA

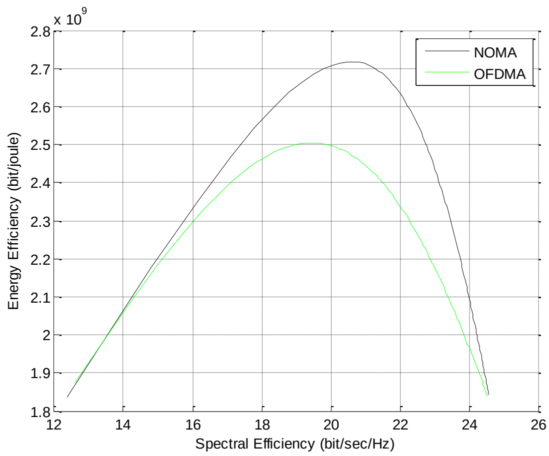

Figure 6. EE-SE relation of NOMA proposed scheme and OMA.

Figure 6 shows that higher EE and SE is achieved in proposed NOMA network compared to OMA network. It also shows that there is improvement in peak values of EE as well as SE compare to EE-SE trade off using FPA technique as shown in Figure 5. The achieved peak values of EE and SE are summarized in table 3 and 4.

Table 3. Peak EE and SE Comparison of Proposed NOMA and OMA system as per simulation

Efficiency	NOMA (proposed)	OMA
EE (bit/Joule)	$2.74*10^{9}$	$2.50*10^{9}$
SE (bit/Sec/Hz)	21	19

Table 4. Peak EE and SE Comparison of NOMA FPA and OMA system as per simulation

Efficiency	NOMA (FPA)	OMA
EE (bit/Joule)	$2.30*10^6$	$2.05*10^6$
SE (bit/Sec/Hz)	17.2	15

8. Conclusion

Power allocation schemes required to be fruitfully identified for the NOMA network which in turn improves the efficiency of the system. In this article, a novel power allocation scheme is proposed under fairness constraint to maximize the system capacity. Further the EE and SE trade of the NOMA network is also discussed. Simulation results of proposed scheme along with the numeric values are compared with the orthogonal and FPA NOMA network which shows the improvement in throughput, fairness index, sum rate, EE and SE..

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