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Energy-Efficient User Scheduling and Power Allocation for NOMA Wireless Networks

By

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Abstract

Previous research focuses on increasing the network sum rate, as it is well acknowledged that there will be an explosion on the transformation of data in the next generation, so the spectrum efficiency and energy efficiency is getting more and more important and precious, it is necessary to take energy efficiency into account when constructing our network. This paper is going to compare the merits and drawbacks of OMA and NOMA system, which one is more energy efficient. More importantly, it is aiming to explore the fundamental principles of NOMA system such as superposition coding (SC) and successive interference cancellation (SIC) techniques. Later part of this paper will discuss proposed algorithms to optimize the energy efficiency performance by improving the scheme of user scheduling and power allocation in NOMA system.

Keywords: OMA, NOMA, SC, SIC.

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Contents

Chapter 1

Introduction

With the dramatical growth in the number of mobile subscribers and smartphones, the demand for higher data rate and a more reliable communication channel is becoming increasingly fierce. According to [1], it is going to be 1000 times increase in capacity compared to the current networks, it is predicted that there will be over 100 billion devices which means there will be multiple connections. More than 7.6 billion of mobile subscribers could use their cell phones, smart phones, iPad or laptops download and upload uncountable information and data. Network operators are running at LTE platforms, operating the networks, but it is not able to bear the weight of the explosion of data [2]. The operator is facing the challenge today about how do they deliver the customer experience with all this drivers and technology and how do they drive their ROI profitability . Therefore, there is a need for a new information technology which is more energy efficient to contribute to green communication.

In the fourth generation, OFDM has been widely adopted because it can effectively eliminate the interference between signal waveforms and highly increased the sum rate of the wireless system. OFDM is an advanced technology which has high transmitting rate, the concept of this advanced technology is to transform the serial data into parallel data and multiplexed into relatively low speed and modulated by different carriers. The symbol bandwidth is dramatically enlarged by the parallel channel. The performance of anti-fading and anti- interference will be improved as well. The spectrums of each subcarrier are not mutually overlapping by using multiplexing method in traditional frequency division. An enormous number of filters are required at transmitter and receiver side, this dramatically increases the construction cost of the system and its complexity [4] [5]. Simultaneously, Sufficient frequency intervals must be maintained between the subcarriers to deal with the inter carrier mutual crosstalk, which will reduce the spectrum efficiency of the system. Although The data transmission rate of OFDM could reach to hundreds of megabytes per second or even Gigabit, and it may be able to meet the needs of mobile communications applications to some extent for a period of time. With the popularization of smart terminals and the growing demand for new mobile services, the demand for wireless transmission rate will increase exponentially, and the transmission rate of wireless communications will still be difficult to meet the needs of future mobile communications applications.

To deal with more strict and harsh situation in 5G, manage more and more data, to pursuit higher sum rate and capacity, more spectrum efficiency and energy efficiency. OFDM is not enough to meet those deliverables, Therefore, NOMA is well considered to achieve higher system throughput and keep the low cost at the same time.

In OMA, A single radio resource can only be assigned to one user, such as frequency division or time division, while in NOMA system, a resource can be allocated for multi users. In some scenarios, such as the near-far effect and wide coverage of multi-node access scenarios, especially the uplink intensive scene, non-orthogonal multiple access multiplexing by using power multiplexing has obvious performance advantages compared to traditional OMA access, it is more suitable for the future deployment of the system [2]. The present research [1] has verified the NOMA effect in cellular downlink scenario which can increase the overall throughput of macro cell to a large extent. The non-orthogonal multiple access through a combination of serial interference cancellation or maximum likelihood demodulation to achieve the ultimate capacity limit, so the difficulty of design and implementation is designed a low complexity and effective receiver algorithm. This is one of the hottest research topics worldwide.

From the above information, we can see that NOMA is new technology which incorporates some 3G and 4G techniques and ideas. For example, subchannel and carriers were mentioned in 4G and SIC was initially utilized in 3G. While for 3G, it applies CDMA technology to transmit non-orthogonal signal, all users are sharing one channel, and RAKE receiver is used to receive signal. But there is a serious near-far problem, so power control is adopted in 3G. The technology limits the power to the user near the cell center, guaranteed the arrived signal at the receiving terminal, the power of each user is equal. In the 4G system, it is based on OFDM technology, different users take orthogonal transmission, thus the near-far problem is not influencing so much and power control is not necessary as well. As OFDM applied Adaptive modulation coding (AMC) technology, modulation coding can be automatically adjusted according to link state information, so as to provide the best pass and transmit rate to the user, however, to some extent it has to rely on the link status information of the user feedback [7-12].

Compared to CDMA and OFDM, NOMA applies orthogonal transmission between subchannels, so the near-far problem is not as much as it in 3G, and multiple access interference problems is not that serious as well. Because it is not depending on the users' feedback CSI, when applying AMC and power multiplexing techniques, it could easily deal with variable links, even under a fast-moving environment, it can still keep good speed performance [22]. More importantly, NOMA allow one subchannel can be shared by multiple users, under the same transmit rate, it can definitely increase the spectrum efficiency compare with 4G. In the light of the research published by some of the world's leading research organizations, the spectrum efficiency will be one of the key points of 5G. From this point of view, NOMA, which can not only satisfy the mobile service speed demand but also enhance the spectrum efficiency, is likely to be adopted as the new multi-access technology in 5G [9].

Figure 1 clearly shows the difference between 3G, 4G and 5G.

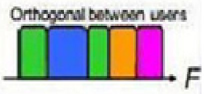
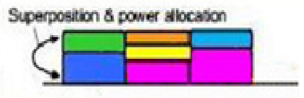
Telecommunication system	3G	4G	5G
Multiple Access	Non-orthogonal (CDMA)	Orthogonal (OFDM)	Non-orthogonal with SIC (NOMA)
Signal	Single carrier	OFDM (or DFT-s-OFDM)	OFDM (or DFT-s-OFDM)
Self-adaption	Fast TPC	AMC	AMC + Power allocation
Spectrum Graph			

Figure 1. The overview of 3G, 4G and 5G.

Considering the importance of NOMA technology, it is necessary to understand the principles and key techniques of NOMA system. Here are several key technologies applied in NOMA system:

A. Successive Interference Cancellation (SIC) [23].

At the transmitter side, similar to the CDMA system, by introducing the interference information to the system, it can acquire higher spectrum efficiency, but also meet the multiple access interference (MAI) problem. To eliminate the multiple access interference problems, many achievements have been made in the process of the third-generation mobile communication system, successive interference cancellation (SIC) is one of them. The detection method used for multiple users is applied at the receiver side in NOMA. SIC technique is used for cancelling the interference by gradual elimination strategy, the user was distinguished one after another. Then by doing amplitude compensation and multi-path interference cancellation on each user, the system total multi-access interference was wiped off from the received signal.

B. Power reuse.

To eliminate the multi-access interference at the receiver side, it is necessary to judge the interference cancellation priory of the different user, and the judgment is based on the signal power of the user [25] [26]. To achieve optimum performance and distinguish the different users at the same time, the base station allocated different power level for transmitting multiple users' signal. Power reuse is not widely used in conventional multi-access schemes. The base station follows the relevant algorithm to do the power allocation rather than just simply control the signal power.

C. Independent of user feedback CSI.

In practice cellar networks, due to the delay of user feedback CSI and dynamic network system. It is hard to provide real effective channel state information in real time. Although many advanced technologies are not relying on this and can acquire stable performance gain, NOMA which is applied SIC technology is more suitable for this kind of situation, which can achieve better performance in high-speed moving scenes and construct better mobile node backhaul [28].

In this paper, we focus on increasing energy efficiency of NOMA system from two different aspects. The first is to find out the optimal user scheduling scheme to maximize the system's energy efficiency [29]. The second approach, based on the proposed scheme in the first part, is to consider and determine the percentage of the power used for each user in the same subchannel, propose a power allocation algorithm for NOMA system and measure the energy efficiency performance of the networks by using the unit of bits per Joule [30].

The later part of the paper is arranged as follows, chapter 2 will provide the system model followed with problem formulation. In chapter 3, I will discuss the proposed user pairing as well as power allocation algorithm for NOMA system. Then, the simulation result will be shown in chapter 4 with discussion. Finally, I will conclude this paper with summary and future work.

Chapter 2

System Model and Problem Formulation

We are trying to establish a downlink of NOMA system network. And users are running SIC technique at their terminals, assume that there are M users and N subchannels in the system and we use m to denote the mobile user and n denote the nth subchannel in this system. There is distance R which denote the radius of the cellular network and M users are randomly distributed in this area. The total bandwidth is B and it is split into N subcarriers. The total power of the system is P_s ($\sum_{n=1}^{N} p_n = p_s$) and the subchannel's total power is P_n ($\sum_{i=1}^{M} p_{i,n} = p_n$). In NOMA system, we assume that a great number of users could be arranged in the same subcarrier and they are randomly paired together, further assume that the users will experience the same Rayleigh fading in the same subchannel.

2.1 NOMA System with Two Users in One Subchannel.

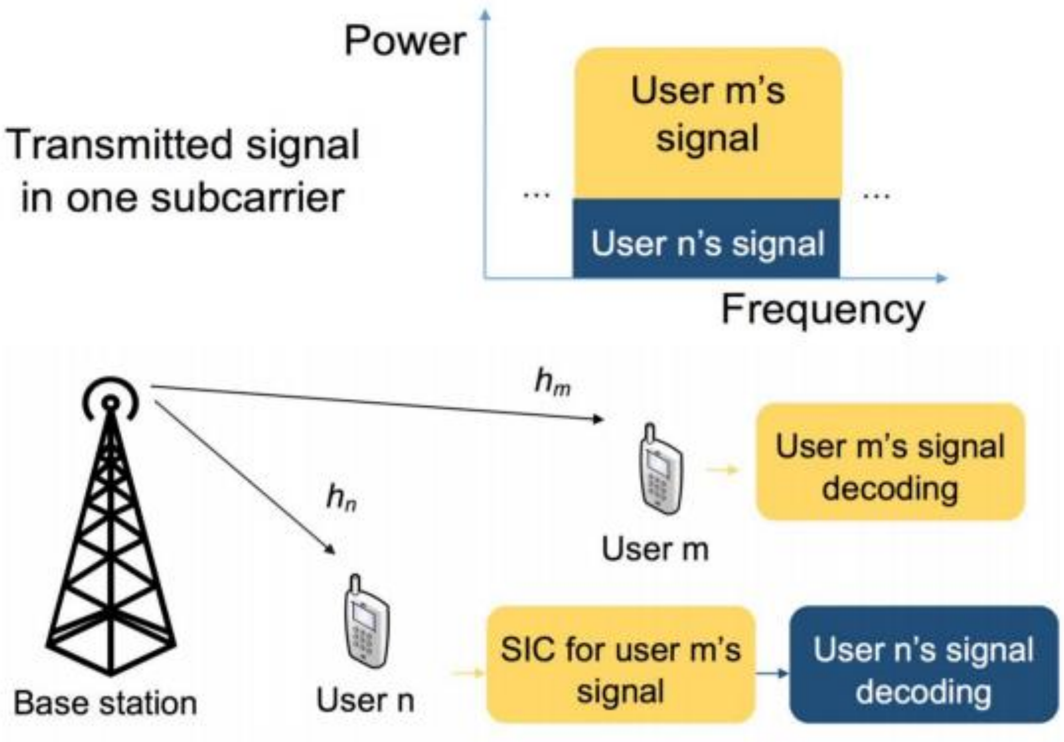


Figure 2. The system model of two users paired in one subchannel.

In this model, the received signal in this system is expressed as:

$$y_i = \sqrt{p_m} h_i s_m + \sqrt{p_n} h_i s_n + N, \quad i=m;n$$

Where h_i is the channel gain of user m or n. N is AWGN.

In figure 2, it is clearly shown that users are multiplexed in BS by power domain, and more power is allocated to the user with poorer channel condition user m, which can be understood as the cell-edge user. For example, there are two users are allocated in one subchannel. When receiving signals, both of user m and user n should receive the same signal which combined both of their signals together and have their messages. User n in near the base station and has a good channel condition, so the user n can apply SIC at receiver side to eliminate the interference from user m, which means that user n decode the user m signal and then remove it from the combined signal, therefore, there is only user n's signal and noise left. So, compared to the previous signal user can achieve better performance with the higher rate. While for user m, it is farther from the base station than user n, and its channel condition must worse than user n, so it can not apply SIC to cancel the interference from user n, so it decodes its own messages by treating the user n's signal as noise. Because the base station allocated more power to user m, so it can still able to decode its signal and acquire some rate. [31][32]

Therefore, the principle of NOMA transmitting process can be regarded as the paired users are allocated with different levels of power according to their channel condition, and all users are applying SIC algorithm in their own receivers.

2.2 NOMA System with Multiple Users in Multiple Subchannels.

Consider M users are arranged in N subchannels, the received signal of user m on subchannel n can be shown as:

$$\mathrm{y}_{m,n} = \sqrt{p_{m,n}} h_{m,n} s_m + \sum_{i=1, i \neq m}^{M} \sqrt{p_{i,n}} h_{m,n} s_i + Z_{m,n}$$

Where s_m and s_i are modulated signals, is the subchannel channel gain which in this case, as I mentioned before, is Rayleigh fading channel gain. $Z_{m,n}$ is AWGN noise whose mean is zero and variance is σ_{n}^2. In NOMA system, it is allowed multiple users to share one subchannel at the same time and frequency, so it will create a large amount of interference, if we not using SIC technology at the receiver side, the received SINR is written as:

$$\begin{aligned} SINR_{m,n} &= \frac{\mathrm{p}_{m,n} \left| h_{m,n} \right|^2}{\sigma_n^2 + \sum_{i=1, i \neq m}^{M} p_{i,n} \left| h_{m,n} \right|^2} \\ &= \frac{\mathrm{p}_{m,n} H_{m,n}}{1 + \sum_{i=1, i \neq m}^{M} p_{i,n} H_{m,n}} \end{aligned}$$

Where $H_{\mathrm{m,n}} = \left| h_{m,n} \right|^2 / \sigma_n^2$ represent the channel gain normalized by noise of user m on subchannel n.

Before we move on to the SIC decoding, one of the important procedure is to determine the SIC decoding order. In order to increase the sum rate of the system, we always set higher power level to those users with bad channel conditions, for example, for any two users m_i and m_j in the same subchannel with channel condition $\mathrm{h}_{i,n}$ better than $\mathrm{h}_{j,n}$, we always set $\mathrm{p}_{i,n} \le p_{j,n}$. Therefore, we can rank the users' priority based on the channel condition. And the ranked order can be expressed as:

$$\left|\mathrm{h}_{1,n}\right| \ge \left|\mathrm{h}_{2,n}\right| \ge \cdots \ge \left|\mathrm{h}_{m,n}\right| \ge \left|\mathrm{h}_{m+1,n}\right| \ge \cdots \left|\mathrm{h}_{M,n}\right|$$

When we apply SIC at the receiver side, according to the channel condition order, we can cancel those interferences from the user with the channel condition worse than you, and then we treat those users' signal which channel condition better than you as noise. Therefore, we can achieve a better SINR with SIC.

The received signal to interference plus noise ratio with SIC at the receiver side is written as:

$$SINR_{m,n} = \frac{\mathrm{p}_{m,n} H_{\mathrm{m},n}}{1 + \sum_{i=1}^{m-1} p_{i,n} H_{m,n}}$$

Therefore, the sum rate of one subchannel is:

$$\mathrm{R}_{m,n} = \mathrm{B}\log_2\left(1 + \frac{\mathrm{p}_{m,n} H_{\mathrm{m},n}}{1 + \sum_{i=1}^{m-1} p_{i,n} H_{m,n}}\right)$$

As there are M users in subchannel n, and there are N subchannels in the system, so the total system sum rate can be express as:

$$\mathrm{R} = \sum_{n=1}^{N} R_n = \sum_{n=1}^{N}\sum_{m=1}^{M} \mathrm{R}_{m,n} = \sum_{n=1}^{N}\sum_{m=1}^{M} \mathrm{B}\log_2\left(1 + \frac{\mathrm{p}_{m,n} H_{\mathrm{m},n}}{1 + \sum_{i=1}^{m-1} p_{i,n} H_{m,n}}\right)$$

2.3 Problem Formulation.

We are exploring the energy efficiency of the system and use bits per Joule as its unit. We need to find out both the system rate and the energy consumption. The system sum rate has described in part B, so we need to define energy consumption next. There are two parts energy consumption in this system, one is signal transmit power consumption and the other one is circuit power consumption such as decoding. Therefore, the total energy efficiency of the system can be given by:

$$E = \frac{\sum_{n=1}^{N} R_n}{p_c + \sum_{n=1}^{N} p_n}$$

$$\text{Subject to } \sum_{n=1}^{N} p_n = p_s, \; p_n \geq 0$$

Where R_n is one subchannel sum rate and p_n is its subchannel power, p_c is circuit power consumption. Our task is to increase the energy efficiency of the NOMA system as much as possible which is to maximize E.

$$\max \quad E \quad .$$

$$\max_{\beta_n \in (0,1),\, p_n \geq 0} \frac{\sum_{n=1}^{N} R_n}{p_c + \sum_{n=1}^{N} p_n}$$

$$\text{Subject to } \sum_{n=1}^{N} p_n \leq p_s$$

Where β_n is the optimal power proportional factor of each user and it needs to be determined in the algorithm of power allocation. However, this optimization problem is a non-convex problem, there are no systematic approaches for solving the problem efficiently. The following research will analysis it on user scheduling and power allocation separately.

Chapter 3

Proposed User Pairing and Power Allocation Algorithm

3.1 User pairing Algorithm.

It is important to pair the users at the transmitter because it can make sure the bandwidth can be fully utilized, the users are allocated into each suncarrier symmetrically as well as enhancing user fairness. The following algorithm are assuming $N_{\text{users}} = 2N_{\text{subchannel}}$ which mean that each sunchannel are assigned with two users.

1) Random pairing. [35]

Random pairing is the most easier way for user pairing, which means that the base station chooses users randomly and allocated into a random empty sunchannel. This method presents poor performance because the user channel state information does not used. Some users with similar channel condition may have large interference due to the power allocated to each of them may be same level, both of them cannot apply SIC and both of them may have to treat the other one as noise. Therefore, the random pairing is definitely unsuitable.

2) Channel state sorting-pairing algorithm. [35-41]

To increase the system sum rate, decrease the interference between two users in the same subchannel and enhance the user fairness, the sorting- pairing algorithm are implemented in this paper, which is pair the best channel-condition user with the worst channel-condition user for each subchannel. However, the last pair may have large interference between these two users because their channel conditions may have no much difference. But the other channels are performing very good, therefore, this pairing method can minimize the total system interference between two users in the same subchannel.

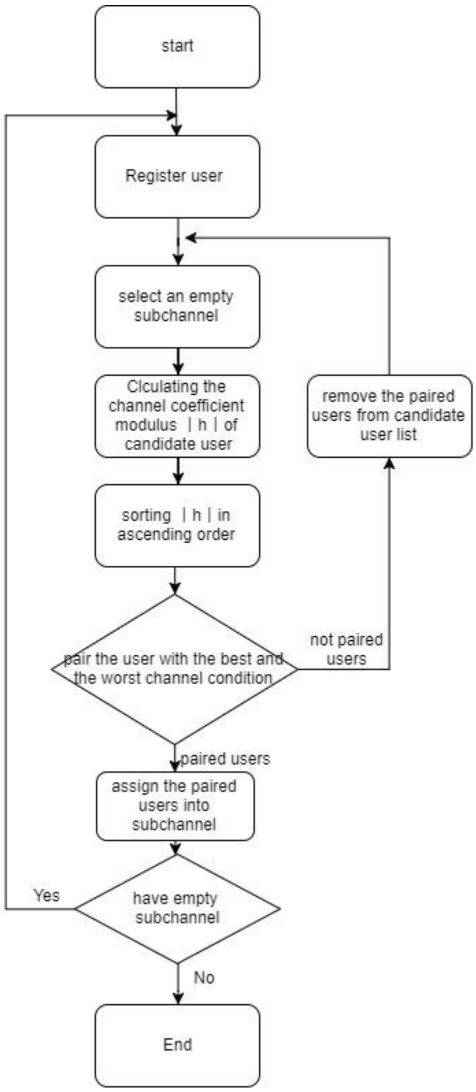


Figure 3. Process of Channel state sorting-pairing algorithm.

The pairing process is shown in figure 3. Firstly, it will register users into the system and then randomly select an empty subchannel, then place the candidate user in ascending order according to their channel condition. Pair the users with the best and worst channel condition and assign them into the channel. The rest of users will then select another empty subchannel and sorting again according to the new channel condition in the new subchannel, another paired user will come out from the new ascending order. This loop will stop when all the users are all paired and assigned into subchannels. If there is subchannel left and it is empty, the system will register users and go through all the procedure again to make sure all subchannels are fully used and the system maximized rate is achieved.

3.2 Power allocation algorithm.

After user pairing, Base station need to allocate different levels of power to different sub channels, and in each sub channel, it is also required to determine the power proportional factors for those two users assigned in the same sub channel. Therefore, there are two parts of power allocation problems in this algorithm.

1) Power allocation for each user in the same sub channel. [39-46]

According to the Shannon's channel capacity theory, the transmit power allocates to one user affect the achievable sum rate of the sub channel. Assume there are two users U_1 and U_2 that are to be multiplexed over a subchannel with the channel condition $H_1 > H_2$. The principle of SIC decoding sequences makes that U_1 can cancel the interfering power term of U_2, whereas U_2 treats the signal power of U_1 as noise. In this section, the problem of finding the appropriate power for U_1 and U_2 to maximize the subchannel transmit rate can be formulated as:

$$\max_{p_1, p_2} R = u_1 \log_2\left(1+\frac{h_1 p_1}{1+h_1 p_2}\right)+u_2 \log_2\left(1+h_2 p_2\right)$$

$$\text{Subject to } \begin{array}{l} C_1 : p_1 + p_2 \le P_{\max}, \\ C_2 : p_1 \ge 0, p_2 \ge 0 \end{array}$$

To solve this problem, for fixed p_2, R is monotonically increasing with p_1. Then p_1 should meet $p_1 = P_{\max} - p_2$ to maximize $R(p_2)$. Then we have:

$$\begin{aligned} R(p_2) &= u_1 \log_2\left(1+\frac{h_1\left(P_{\max}-p_2\right)}{1+h_1 p_2}\right)+u_2 \log_2\left(1+h_2 p_2\right) \\ &= u_1 \log_2\left(1+h_1 p_{\max}\right)-u_1 \log_2\left(1+h_1 p_2\right)+u_2 \log_2\left(1+h_2 p_2\right) \end{aligned}$$

Then

$$\begin{aligned} \frac{dR(p_2)}{dp_2} &= -\frac{u_1 h_1}{\left(1+h_1 p_2\right)\ln 2}+\frac{u_2 h_2}{\left(1+h_2 p_2\right)\ln 2} \\ &= \frac{\left(u_2 h_2 - u_1 h_1\right) - \left(u_1 - u_2\right) h_1 h_2 p_2}{\left(1+h_1 p_2\right)\left(1+h_2 p_2\right)\ln 2} \end{aligned}$$

Since $p_1 \ge 0, p_2 \ge 0$, and $u_1 \ge u_2$ to perform NOMA operation, the zero point of $\frac{dR(p_2)}{dp_2}$ is

$$p_2 = \frac{\left(u_2 h_2 - u_1 h_1\right)}{\left(u_1 - u_2\right) h_1 h_2}$$

Thus, the maximum value of R is obtained when $p_2 = \frac{\left(u_2 h_2 - u_1 h_1\right)}{\left(u_1 - u_2\right) h_1 h_2}$, $p_1 = P_{\max} - p_2$. As $P_{\max}$ is the total power for a subchannel. When considering a single subchannel, it is a fixed value which is assigned by the BS, I will discuss the allocation scheme among subchannels in the next part. P_c is the circuit power which is also a constant value, therefore, as we get the maximum R of a subchannel, the maximum energy efficiency for this subchannel which is $E_{n\_\max} = \frac{R_{n\_\max}}{p_c + p_{\max}}$ can be obtained.

2) **Power allocation among subchannel based on Dinkelbach method.** [43-67]

In our previous work, user pairing algorithm and power allocation solution for two users in the same sub channel have been discussed. The pairing structure and power allocation scheme allows the use of the solution in allocating power for users within a pair (in one sub channel). However, the power allocation across the pairs (across different sub channels) have to be determined.

To maximize the system performance, the BS delivers different levels of power among those subchannels and the problem of maximizing energy efficiency for the whole system is formulated as

$$\max_{p_n \geq 0, \sum_{n=1}^{N} p_n = p_s} \quad \frac{\sum_{n=1}^{N} R_n}{p_c + \sum_{n=1}^{N} p_n}$$

$$\max_{p_n \geq 0, \sum_{n=1}^{N} p_n = p_s} \quad \frac{\sum_{n=1}^{N}\left[u_{1,\mathrm{n}} \log_2\left(1+h_{1,\mathrm{n}} p_n\right) - u_{1,n} \log_2\left(1+h_{1,n} p_{2,n}\right) + u_{2,n} \log_2\left(1+h_{2,n} p_{2,n}\right)\right]}{p_c + \sum_{n=1}^{N} p_n}$$

$$\textit{Subject to} \quad \sum_{n=1}^{N} p_n \leq p_s, \, p_n \geq 0$$

Due to the complexity of this convex problem, it is very hard to find the optimal point of it, therefore, in order to solve the problem efficiently, we convert (13) to Dinkelbach representation that can be simply written by

$$\max_{p_n \geq 0, \sum_{n=1}^{N} p_n = p_s} \quad \left(\mathrm{F}(q) = N\left(p_n\right) - qD\left(p_n\right)\right)$$

Where

$$N\left(p_n\right) = \sum_{n=1}^{N} R(n) = \sum_{n=1}^{N}\left[u_{1,\mathrm{n}} \log_2\left(1+h_{1,\mathrm{n}} p_n\right) - u_{1,n} \log_2\left(1+h_{1,n} p_{2,n}\right) + u_{2,n} \log_2\left(1+h_{2,n} p_{2,n}\right)\right]$$

, $D(p_n) = p_c + \sum_{n=1}^{N}(p_n)$ and $q = \frac{N(p_n)}{D(p_n)}$ which can represent our system energy efficiency. If there is a solution p_n makes $F(q) > 0$, which means

$$N(p_n) - qD(p_n) > 0$$
$$\frac{N(p_n)}{D(p_n)} > q$$
[69-71]

That means that if there is a p_n makes $F(q) > 0$, this testified that this set of solution can obtain a better q. therefore, we replace q by $q_{new} = \frac{N(p_n)}{D(p_n)}$, and redo the calculation. There must be a solution $p_{optimal}$ which makes $F(p_n) = 0$ and other solution will all make $F(p_n) < 0$, then we get the maximum q when $F(p_n) = 0$ with the solution $p_n = p_{optimal}$, which also means that we get the maximum energy efficient point.

The algorithm of this Dinkelbach Method is shown below. [51] [52]

Initialize q_k, set the iteration number $k = 0$.
while the objective function $F(q) = N(p_n) - q_k D(p_n) > 0$ **do**
    $N(p_n) = 0$
    For subcarrier index =1 to N **do**
    $N(p_n) = \mathrm{N}(p_n) + u_{1,n} \log_2(1 + h_{1,n} p_n) - u_{1,n} \log_2(1 + h_{1,n} p_{2,n}) + u_{2,n} \log_2(1 + h_{2,n} p_{2,n})$
    end for
    If $|F(q)| \le 0.001$
        Break
    else
    $q_k = q_{k+1} = \frac{N(p_n)}{p_c + \sum_{n=1}^{N} (p_n)}$.
    end if
end while

This algorithm describes the proposed scheme of Dinkelbach method to maximize the system energy efficiency. It shows a simple way for solving the optimization problem with two users as a pair multiplex in one subcarrier. To clarify the improvement of the system energy efficiency, the approach of equal power allocated on each subchannel will be used in the comparison in the simulation part.

Chapter 4

Simulation Result

In this section, simulation results are presented to evaluate the performance of the proposed user pairing and power allocation algorithms for NOMA system. In the simulation, we consider one base station, and there are 6 users are uniformly distributed in the cell range of 500m with the random locations. The minimum distance between a user and BS is 30 meters, the bandwidth and carrier frequency for the system are 0.2Mhz and 2.0Ghz respectively. To reduce the demodulating complexity of the SIC receiver, we set 64 subchannels in this simulation and each subchannel can be allocated by one matched pair with two users in this NOMA system. And the OFDM scheme as the comparation can only be allocated by one user in a subchannel. For the subchannel power allocation, we compare the proposed optimal algorithm with equal power allocation scheme. For further analysis the relationship between energy efficiency, we set the circuit power consumption we vary the from 0.5W to 1W and 1.5W to see the different performance of our proposed algorithm.

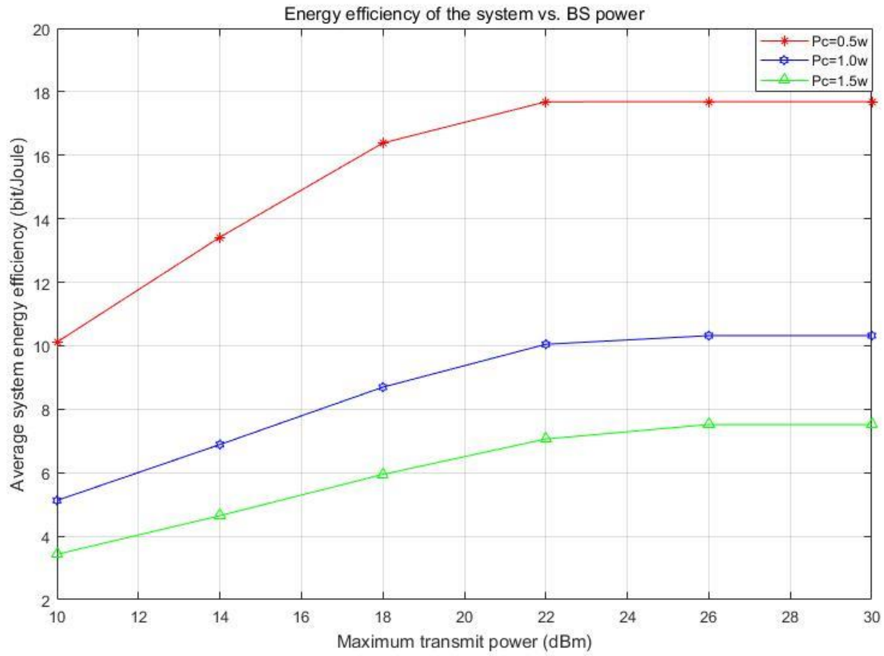


Figure 4. Energy efficiency of the system vs. BS power.

Figure 4 presents the performance of energy efficiency versus the maximum total transmit power of BS. The maximum transmit power of BS is from 10dBm to 30 dBm and there are 6 users assigned in the system. Fig. 4 shows that the energy efficiency grows with the increasing of maximum BS power, and it stabilized when it gets the optimal point, which means that whatever how much more power you add on the system, the redundant power cannot be utilized to increase the system energy efficiency. When considering the system performance with different levels of circuit power consumption, it is noticeable that when circuit consumption is small, the performance of energy efficiency will be better. Moreover, as the circuit power increase, the optimal point will move a little bit to right hand side which means that the BS needs more power to get to the optimal energy efficiency point when increase the circuit power consumption.

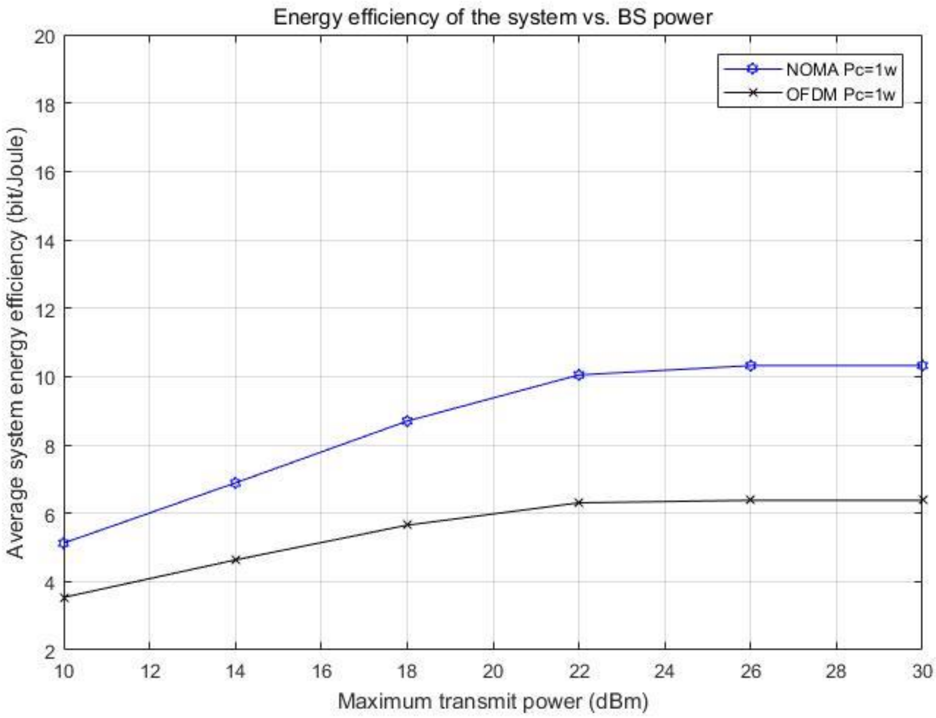


Figure 5. Energy efficiency of OFDM and NOMA with same circuit power.

In order to further compare the energy efficiency performance of OMA and NOMA. We plot the energy efficiency for OFDM and NOMA under the same conditions, with 6 users and 64 subcarriers in the system, the circuit power consumption are all 1w. From figure 5, we can clearly see that for 2 users as a pair in a subcarrier, the NOMA system is always energy efficient than OFDM.

Chapter 5

Conclusion

In this paper, I have provided the reasons that our wireless network need to focus on energy efficiency in the next generation, and also examined the merit and demerit of OMA and NOMA system, basically and technically. There are three key technologies applied in NOMA system, SIC, power reuse and implementing full CSI. They are the main contributors to the better performance of NOMA system in energy efficiency competition. In section two, we have set a system model and try to propose an energy-efficient user scheduling scheme and power allocation algorithm. While these are not easy because it is a non-convex optimization problem and there are no systematic approaches for solving the problem efficiently. Therefore, in the rest of this paper, we proposed energy-efficient resource allocation algorithms for 2-user NOMA system, including channel state sorting-pairing algorithm which is proposed to achieve maximum energy efficiency under the known subchannel power. For power allocation, there are two parts of power allocation task, one is power assignment among multiplexed users in the same subcarrier and the other one is power allocation among different subcarriers. Since the objective function is non-convex, Dinkelbach Method was utilized to simplify the equation and find the optimal solution. Thus, the optimal energy efficiency point could be obtained.

5.1 Future work

For multiple users pairing and power allocation problems, it is much more complex. For example, when applying SIC, user with good channel condition need to decode several other user signals and remove them from the original signal to achieve high data rate. While, it will consume more circuit on decoding, as the simulation result shows the circuit power consumption is a big influence against energy efficiency. Therefore, there is a tradeoff between reducing the circuit power consumption and maximizing data rate at the same time, which need to do further analysis.

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