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A Fair Power Allocation Method For Improving Capacity Of Sc-Noma System

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Abstract- This paper explains the main concepts of the Power Allocation in Non-orthogonal multiple access (NOMA).The, relationship between Bit Error Rate (BER) of NOMA with the values of power allocation coefficients is established.The power allocation coefficients for a dynamic power allocation scheme called fair Power Allocation is derived. Further the outage and sum rate performance of fair Power Allocation is simulated and studied. Finally, the number of users that can be multiplexed on the same user is also studied and the improvement in capacity compared to other traditional orthogonal multiple access (OMA) schemes is demonstrated.

Keywords: Fifth Generation (5G),Non-Orthogonal Multiple Access, Power allocation, Successive interference cancellation

I INTRODUCTION

Non-Orthogonal Multiple Access (NOMA) is a candidate multiple access scheme for 5G, it has the ability to break the limitation of capacity which faced by the other orthogonal multiple access (OMA) schemes, likedivision multiple access (TDMA), frequency division multiple access (FDMA), code division multiple access (CDMA) and orthogonal frequency division multiple access (OFDMA).

In TDMA the bandwidth of channel is separated and divided into many stations depends on time basis. Each one of this station has a time slotwhere the station can send its data during that time slot only. In FDMA the given bandwidth is divided into different frequency bands. Each station can send its data by using specific band which is reserved for particular station for all the time. In CDMA instead of divided the radio frequency channel into sub-channels or time slots, each slot of this has a unique code.So, the transmitted radio frequency is the same in every slot and the slots are transmitted at the same time.Theoretically, Orthogonal Multiple Access based system do not suffer inter user interference due to orthogonal resource allocation and as a result of that lowcomplexity receivers can be employed to detect the signal of the desired user.

Unlike OMA, non-orthogonal multiple access (NOMA) has inter-user interferencein the resource allocation of users and thus NOMA allows multiple users to transmit and receive simultaneously using the same frequency and the same Resource Block (RB).

As a candidate multiple access technology for 5G, non-orthogonal multiple access (NOMA) offers greater transmission capacity than current orthogonal multiple access (OMA) techniques. This increase in achievable rate is possible because NOMA allows simultaneous transmission of multiple user data in the same frequency carrier. It allows users with good channel conditions to have access to users with poor channel conditions [1].There, are two techniques for NOMA, code domain multiplexing where the users are separated at the side of the receiver by using redundancy via coding/spreading, another technique is power domain multiplexing which is able to perform successive interference cancellation (SIC) for users with better channel conditions [2].

In this paper, Section II introduces the basic principles of NOMA techniques.Section III explains the Main Advantages of NOMA. Section IV explains the fundamentals of Power Allocation in NOMA. Section V refers to the power allocation method for multiple user single carrier NOMA. Finally, Section VIconcludes this paper.

II THE BASIC PRINCIPLES OF NOMA TECHNIQUES

The two key operations that make NOMA possible are superposition coding which must be done at the transmitter side and successive interference cancellation (also known as SIC) at the receiver side [3].

1) Superposition Coding(SC)

The main idea of Superposition Coding is considered as one of the fundamental blocks of coding schemes for achieving the capacity of a scalar Gaussian BC [4]. Superposition coding is a fancy term for power domain multiplexing. The main concept of SC is that it has the ability of encoding a message for a user with bad channel conditions at a lower rate and after that superimpose with a signal of a user having a good channel condition.

Researchers became motivated to apply Superposition Coding to different channels, such as relay channels, wiretap channels and interference channels [5]. As a result, further research was required for develop SC technique from theoreticalperspective to practice [6]. Specifically, Vanka et al. designed an experimental platform using a software-defined radio (SDR) system to check out the performance of SC.

2) Successive Interference Cancellation

Successive Interference Cancellation is a promising Interference Cancellation (IC) technique in wireless network. This technique capable to improve the network capacity, it allows the strongest signal to be detected first who has the least interference. Then the strongest user reencodes and remodulates its signal, then subtracted from the composite signal. The same procedure is done by the second strongest signal and so on.When last signals were detected, the weakest user decodes its information without suffering from any interference at all

III MAIN ADVANTAGES OF NOMA

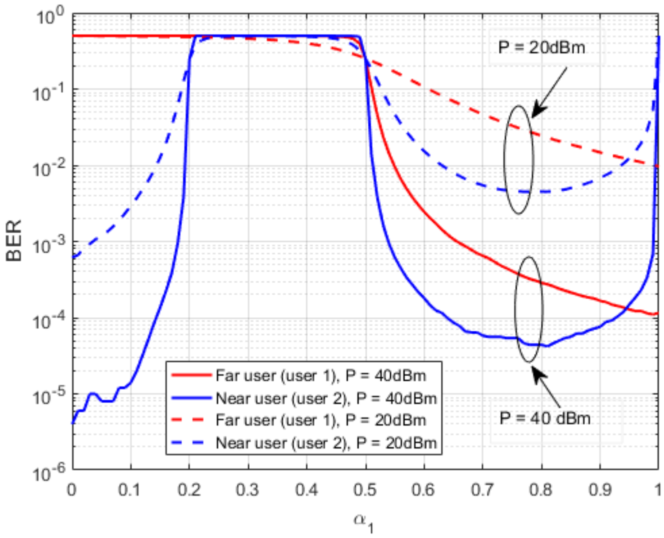
In comparison to OMA, NOMA has more privileges over OMAwhich can be summarized as follows:
1) HIGHER SPECTRAL EFFICIENCY: Since multiple users can share the same frequency resource in NOMA technique. NOMAoffers higher spectral efficiency.
2)MASSIVE CONNECTIVITY: NOMA capable to serve many users simultaneously at the same time.So, it offers massive connectivity.
3)LOWER LATENCY : That is because that NOMA can simulate transmission all the time rather than dedicated scheduled time slot.
4)BETTER QOS (QUALITY OF SERVICE):NOMAintroduces better Quality of Service to all the users using flexible power control algorithms. By using it we can increase the cell-edge throughput and have better user experience at cell-edges [7].

IV POWER ALLOCATION IN NOMA

Power allocation is very important in non-orthogonal multiple access (NOMA). The users are multiplexed in the power domain [8].It improves the system performance, such as interference management, maximizing the sum rate, maximizing the energy efficiency,or a balanced fairness under minimum power consumption.

In our example for fixed power allocation, and regardless of the channel condition, we set α1=0.75 (for far user) and α2=0.25 (for near user). In this way we allocate the power. The advantages of using fixed power allocation method are that there is no need for computation and no need for any information about the channel state information (CSI).

The user 1 is considered to be the far user and user 2 to be the near user. Also, we have used fixed power allocation method. That is, we did not alter the coefficients based on channel conditions. We have just plotted the BERs when we fix different values of power allocation coefficients.In Figure 1we see that some values of power allocation coefficients are better than others, so the BER is low for some values of α1 and high for other values. The near user experiences low BER (< 10^{-4}) at two regions of this plot. i.e., around α_1 <0.1 and around $\alpha_1 \approx 0.8$. The BER for near user (user 2) is lower when α_1<0.1 than when $\alpha_1 \approx 0.8$. So, we cannot we choose α_1< 0.1 and α_2> 0.9) because the far user (user 1) has very high BER in this regime.



1 **Figure 1:**The BER as a function of power allocation coefficients

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The ideal regime to operate is $\alpha_1 \in [0.5,1]$, $\alpha_2 \in [0,0.5]$. Towards the left end of the plot, $\alpha_1 \approx 0$ and $\alpha_2 \approx 1$. This means a very large power is allocated to the near user (user 2). Therefore, he has a very low BER.As $\alpha_1 \approx 0$ and $\alpha_2 \approx 1$, the near user's (user 2) data is dominating and hence, the far user (user 1) will not be able to directly decode his signal. This explains his high BER.

Towards the right end of the plot, $\alpha_1 \approx 1$ and $\alpha_2 \approx 0$. This means a very large power is allocated to the far user (user 1). Therefore, he has a decreasing BER trend.As $\alpha_1 \approx 1$, the interference from the high-power far user (user 1) data is so large that the near user (user 2) suffers high BER.

There are better ways to optimize α_1 and α_2 dynamically based on the values of channel state information (CSI). By using fair power allocation scheme, we gave the priority to the weak(far) user.

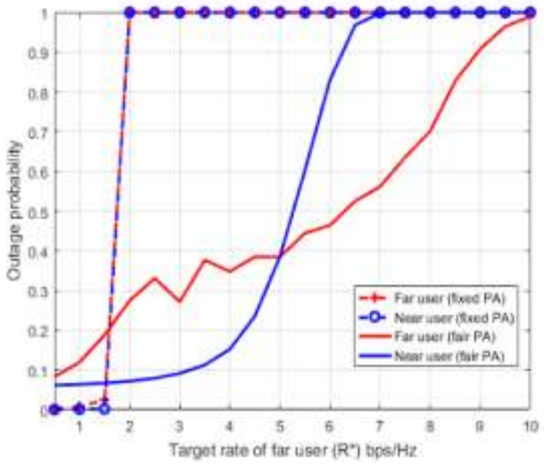
The capacity equations for NOMA far user and near user can be written

$$R_f = \log_2(1 + \frac{|h_f|^2 P \alpha_f}{|h_f|^2 P \alpha_n + \sigma^2}) \quad (1)$$

$$R_n = \log_2(1 + \frac{|h_n|^2 P \alpha_n}{\sigma^2}) \quad (2)$$

$R_n$is obtained after removing the interference from far user transmission by successive interference cancellation (SIC).

$\boldsymbol{\alpha_n}$ *is power allocation coefficient for near user*
α_f is power allocation coefficient for far user
h_n *is* Rayleigh fading coefficient for near user
h_f is Rayleigh fading coefficient for far user



[1] Figure2.Outage vs Target rate for fixed and fair PA

The fixed PA is performing very poorly and its outage probability saturates to 1 when R>1.5 bps/Hz. This is because, fixed PA neither exploits the instantaneous CSI, nor takes the target rate requirements into account. Thus, fixed PA, although simple to implement, is not so good after all.The fair PA has lower outage probability because $\boldsymbol{\alpha_n}$ and $\boldsymbol{\alpha_f}$ and dynamically adjusted based on target rate requirement and CSI.

Also, that the outage of far user increases gradually as his target rate requirement increases. This is expected because, as the target rate becomes higher and higher, the chances of far user achieving that target rate becomes lower and lower. This would lead to increase in its outage probability.

The outage of near user shows quite a sharp transition around R values of 4 to 7 bps/Hz. And beyond that, the near user is always in outage.

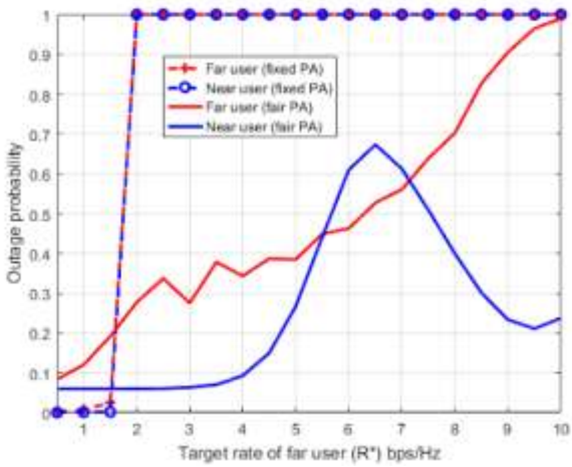


Figure 3: Outage vs Target rate for fixed and improved

In Figure3we add a simple tweak to the previous fair PA. We set $\boldsymbol{\alpha_f} = \mathbf{0}$. Which automatically sets $\boldsymbol{\alpha_n}$=1.Outage of far user follows the trend that we saw in Figure 2. This indicates that our tweak of setting $\boldsymbol{\alpha_f} = \mathbf{0}$, when required, did not affect the outage of far user at all.

Here The outage probability increases, peaks and then starts to decrease. WhenR^*lies in the range of 0 to 6.5 bps/Hz, it looks like we are favoring the far user by allocating more and more power to him, at the cost of sacrificing the performance of near user. But beyond 6.5 bps/Hz, any value of αf may not fully satisfy R^*. When this happens, we favor the near user, instead of wasting all our power on the far user.

This leads to a decrease in the outage of near user, for R^* >6.5 bps/Hz, without affecting the outage of far user, which is a good thing.

In Figure 4we compare the sum rate of our improved fair PA with fixed PA that we have been using so far. By sum rate, we mean $\boldsymbol{R_n} + \boldsymbol{R_f}$.We can clearly see that our fair PA outperforms fixed PA in terms of achievable capacity.

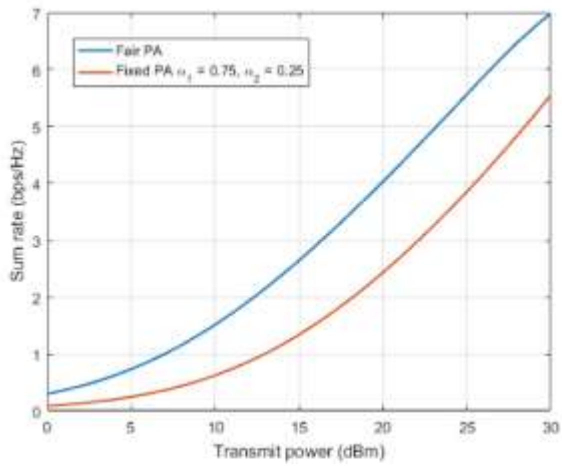


Figure 4: Sum rate vs transmit power of fixed and fair PA

V POWER ALLOCATION METHOD FOR MULTIPLE USER SINGLE CARRIER NOMA

NOMA breaks capacity bottleneck by allowing simultaneous transmission of multiple users in the same frequency carrier. ButHow many users can I multiplex in the same carrier.

We know that, while performing superposition coding at the transmitter side, the users are ordered according to their channel conditions and the weakest user is allocated the most power. For example, if we have K users, and if they are ordered such that, $|h_1|^2<|h_2|^2 < \cdots < |h_k|^2$ then their corresponding power allocation coefficients will be ordered as $\alpha_1>\alpha_2>...>\alpha_k$.

While doing this power allocation, we should ensure that, $\alpha_1>\alpha_2+\alpha_3+...\alpha_k$ and $\alpha_2>\alpha_3+\alpha_4+...\alpha_k$, and so on.

When we have K users, we have even more conditions to satisfy.

$$\alpha_1>\alpha_2>\alpha_3>...>\alpha_k$$
$$\alpha_1>\alpha_2+\alpha_3+...+\alpha_k$$
$$\alpha_2>\alpha_3+\alpha_4+...+\alpha_k$$
$$\ldots\ldots$$
$$\alpha_m>\alpha_{m+1}+\alpha_{m+2}+...+\alpha_k \text{ and}$$
$$\alpha_1+\alpha_2+\alpha_3+...+\alpha_k= 1.$$

we pick $\alpha_1,\alpha_2,\alpha_3,....\alpha_k$ to satisfy all these conditions by the following
we pick fraction less than 1. For example, $\frac{3}{4}$.
Start with the weakest user. For U1, set $\alpha_1=\frac{3}{4}$.
If K=2,set $\alpha_2=1-\alpha_1$. Otherwise, set $\alpha_2=\frac{3}{4}(1-\alpha_1)$.
If K=3, set $\alpha_3=1-(\alpha_1 + \alpha_2)$. Otherwise, set $\alpha_3=\frac{3}{4}(1-(\alpha_1 + \alpha_2))$.
……
If K=m, set $\alpha_m=1-(\alpha_1 + \alpha_2 + \cdots . +\alpha_m)$. Otherwise, set $\alpha_m=\frac{3}{4}(1-(\alpha_1 + \alpha_2 + \cdots . +\alpha_m))$.

By following this heuristic repeatedly to all the users, we will arrive at a power allocation solution which satisfies all the conditions mentioned in the previous section.

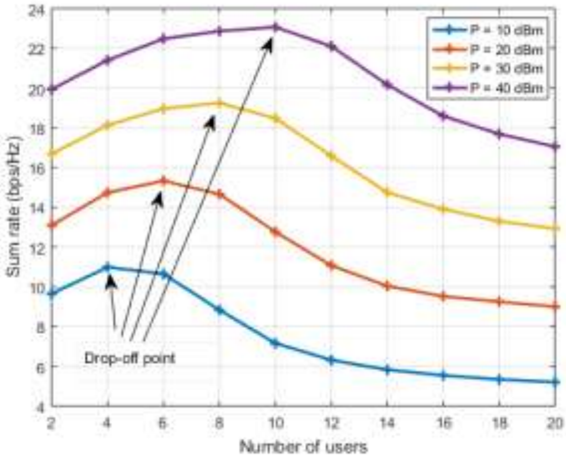


Figure 5: Sum rate of an SC-NOMA network by varying the number of multiplexed users.

In Figure5As the number of users of SC-NOMA is increased, the sum capacity of the network initially increases and then drops and saturates.We can observe a drop off point beyond which the capacity falls. This drop off point can be regarded as the maximum limit on the number of users who can be admitted into the network without any performance degradation.

The drop off point moves towards the right as the transmit power is increased. That is, when 10dBm transmit power was used, the sum rate started to decrease beyond 4 users. But when 40dBm transmit power was used, the drop off point was beyond 10 users. This behaviour is mainly due to the power allocation strategy that we adopted. The weakest user will be assigned the least fraction of power and a small fraction of 40 dBm is greater than a small fraction of 10 dBm.Thus, to accommodate more users without performance degradation, we must increase the transmit power.

VI Conclusion

In this paper, Power allocation is introduced asa very important concept in Non-OrthogonalMultiple Access (NOMA).We saw that the Bit Error Rate (BER) of NOMA has a strong relationship with the values of power allocation coefficients.Fixed Power Allocation does not worry about the instantaneous channel conditions of users. Whatever be channel condition, the power allocation coefficient is fixed. The Fair power allocation is a dynamic scheme. That is, whenever the channel changes, the values of power allocation coefficient are updated to meet the specification. That is why fair power allocation is able to achieve higher sum rate and lower outage than fixed power allocation. Also, non-orthogonal multiple access (NOMA) can break the capacity limitation faced by the other traditional orthogonal multiple access (OMA) schemes. OMA schemes like TDMA, FDMA, CDMA, OFDMA separates the users in time, frequency, code, subcarrier domains respectively.

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