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Power Domain Non-orthogonal Multiple Access (PD-NOMA) Technique For 5G Networks

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Abstract: The possibility of applying non-orthogonal multiple access technology with compound modulation scheme for future 5G networks to improve the overall spectral and spatial efficiency is investigated. Calculation method of channel capacity for Power Division Non-orthogonal Multiple Access (PD-NOMA) with combined spatial modulation (SM) and amplitude phase modulation schemes is developed. Throughputs of PD-NOMA and Frequency Division Multiple Access (FDMA) techniques are compared. Numerical calculations and simulation show that in some scenarios the total capacity in the case of using PD-NOMA is about 1.6 times higher as for FDMA multiplexing technique.

Keywords: Non-orthogonal multiple access, 5G networks, channel capacity, spectral and spatial efficient.

1. Introduction

With the growing demands for high data rate, the use of millimeter-wave bands for next generation wireless communication network such as the fifth generation (5G) mobile systems attracts much attention of researchers. 5G promises a major change in mobility and, although not just 'built' for Internet of Things (IoT), it is heralded as a major driver of the growth of IoT [1]. The number of users in future generation cellular networks (e.g., 5G) is expected to increase dramatically.

One driving force of this increase in users is likely to be the continued deployment of the IoT which will consist of large numbers of connected devices. The rapid growth in connected users necessitates new technologies which improve spectral efficiency (SE) and allow for this additional traffic in the network.

There is an expected explosion in the number of users which will be connected to future wireless networks with the continued expansion of the Internet of Things. New technologies are needed in order to keep up with this connectivity demand. Therefore, the existing OFDM technology may not be well suited for the transmission of the data of some 5G applications. Hence, several alternatives non-orthogonal multiple access (NOMA) have been proposed and will be considered for the 5G physical layer [2].

One of the most promising techniques is power domain non-orthogonal multiple access which takes advantage of users having different received power levels, either through power control or naturally occurring in the network, in order to separate the users. Power domain non-orthogonal multiple access (PD-NOMA) is used with successive interference cancellation (SIC) in order to cancel higher power signals, which are decoded first, before decoding the other users.

The idea is to allow at least one UE to be separated from the other UEs in the power domain at the receiver. This allows for the UEs to completely share the time and frequency resources. Fig. 1 shows working scheme of PD-NOMA and block diagram. One of the attractive features of PD-NOMA is that it can be used in combination with UL multiuser multi-input multi-output (MU-MIMO) schemes in order to further overload resources. This can be achieved in the uplink (UL) by using power control to have one UE transmit at a higher power level than the other UEs using the same resources (see Fig.1. a)). At the base station the UE with much higher received power is then decoded first by treating the other UEs as noise. After being decoded the user's signal is then canceled from the original received signal using SIC. The remaining users are then decoded.

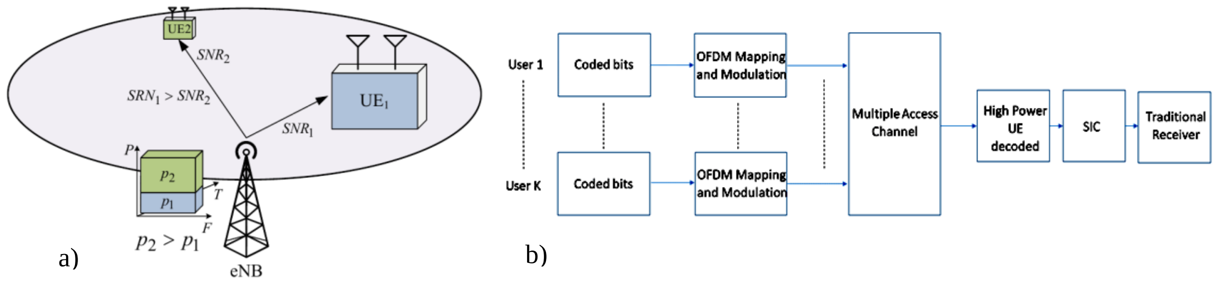

Fig.1. a) Principle of PD-NOMA scheme in the case of two users, b) Block diagram of PD-NOMA.

2. Results and discussion

The calculation of throughput in the case of noisy channel is calculated based on Shannon's law. In the case of frequency division (FD) the total capacity will be the sum of separate channels capacities

$$C_{tot} = \sum_{k}^{K} C_k \tag{1}$$

there the C_k is the k -th channel capacity estimated by

$$C_k^{FD} = F_k \cdot \log_2\left(1+\frac{\alpha_k P_k}{N_k}\right), \qquad 1 \le k \le K \tag{2}$$

In the case of FD the frequency band F is divided into F_k sub-bands. Inter-channel interference is negligible if multiplexing is orthogonal and there are only AWGN noise. However, then multiplexing is non-orthogonal like PD-NOMA the inter-channel interference is arises and with existing AWGN noise decrease the system SNR. Hence, for PD-NOMA the total capacity should be calculated by slightly different relation there the existence and influences of neighboring channel is taken into account (K -is the users/channels quantity):

$$C_k^{PD} = \begin{cases} F \cdot \log_2\left(1+\dfrac{\alpha_k P_k}{\alpha_k \cdot \sum\limits_{i=k+1}^{K} P_i + N_k}\right), & 1 \le \mathrm{k} < \mathrm{K} \\ F \cdot \log_2\left(1+\dfrac{\alpha_k P_k}{N_k}\right), & \mathrm{k}=\mathrm{K} \end{cases} \tag{3}$$

Based on eqs. (1) and (2) the total throughput is calculated for different scenarios. It is interesting to compare total throughputs of FD and PD-NOMA multiplexing techniques in different conditions. Let's consider two scenarios with 2 and 3 users. The users located in different distances from NB, hence according to PD-NOMA principle they have different powers: in the case of two users we choose: $P_2/P_1 = 1/4$, and for three users: $P_3/P_2/P_1 = 1/4/16$ (see Fig.2 a,b)).

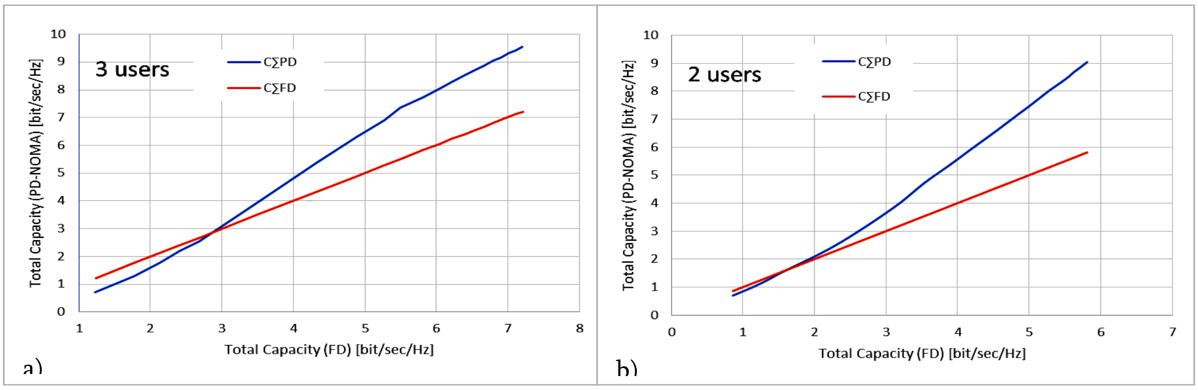

Fig.2. a, b) The total capacities of PD-NOMA vs. total capacities of FDMA in the case of 3 and 2 users correspondingly.

As the modulations have been chosen: QPSK for the farthest user from NB (according to PD-NOMA technique with the highest power), 16QAM for the second one, and 32QAM for the nearest user. As can see from Fig.2. the gain in total capacity of PD-NOMA compared to FD is different for different number of users. For instance, in the case of 3 users the gain is started from $2.8 bit/\sec/Hz$ while for 2 users -$1.6 bit/\sec/Hz$. It is worth to mention, the gain is higher for higher capacities which is expectable, but to obtain a higher channel capacity the higher order of modulation must be applied which brings to the more sensitivity to the noise level and complexity of SIC receiver. The comparison of Fig.2 a) and b) shows that with increasing the quantity of users capacity gain decreases. It should be also noticed that the bigger differences between powers of users the higher gain is expectable, but it brings to the high Peak-to-Average Power Ratio (PAPR) especially if users number is high. This fact is the main drawback of PD-NOMA technique.

It is also interesting to clarify how total throughput depends on total power (the sum of powers for different users) of users in both multiplexing scenarios (see Fig.3).

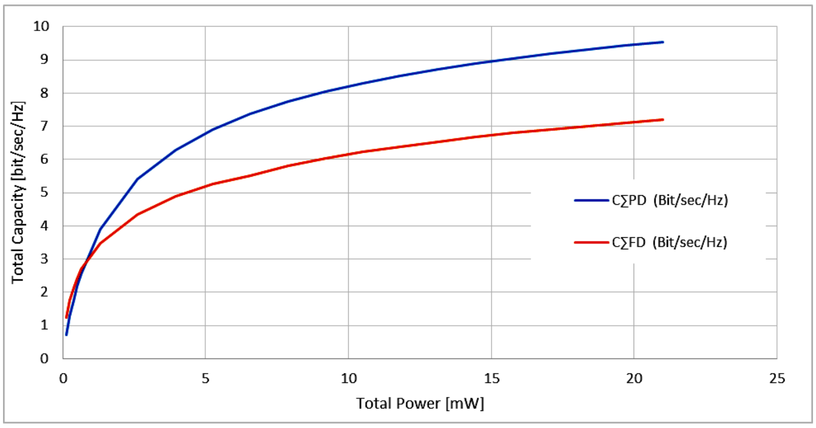

Fig.3 Total capacity dependence on total power for PD-NOMA and FDMA techniques.

As follows from Fig.3 the gain in total capacity if PD-NOMA as higer as bigger total power. But it is also clear that the total power increasing is not so profitable from point of view energy efficiency.

3. Conclusion

Non-orthogonal power division multiple access technology is studied and compared with traditional orthogonal frequency division multiple access technique. The advantages of PD-NOMA with introducing self-interference cancellation (SIC) algorithm in the receiver side in the case of 2 and 3 users is demonstrated. The total throughput of PD-NOMA in some scenarios is higher in comparison with traditional orthogonal multiplexing. It is turned out that with increasing the quantity of users' capacity gain decreases. It is also important that the higher gain is expectable if differences between powers of users are bigger, meanwhile it brings to the high Peak-to-Average Power Ratio (PAPR) especially if users' number is high. This fact from our point of view the main drawback of PD-NOMA technique.

Acknowledgments

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