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Detection of Message Signal at Receiver by Spectral Efficiency Analysis in 5G

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Abstract: In wireless communication networks, the main thing is to achieve high data rates and to minimize the noise. As compared to 4G which supports 100 Mbps the 5G supports 1 Gbps data rates. By using multiple users, NOMA can share data on same time and frequency. NOMA has increased the spectral efficiency and user fairness as compared to orthogonal multiple access. In OFDM Users are allocated different subcarriers to convey information. In this paper, four users with non-orthogonal pilot signals are considered by using more pilot signals the channel state information can be improved but it can reduce the spectral efficiency. Four signals are transmitted on two subchannels. In this paper the 5G system transmission and reception is discussed with detail. The technique used for transmission is superposed coding and successive interference cancellation method is used at receiver. The message signal is detected at receiver and all users' information is extracted from superposed signal. The spectral efficiency with energy efficiency is also observed for detected signals.

Keywords: Spectral efficiency, NOMA, SIC, OFDM, Superposed coding, BER, SNR.

1. INTRODUCTION

Fifth generation (5G) wireless communication standard requires higher spectral efficiency (SE), lower latency and massive connectivity. New standard is expected to be deployed in 2020, consequently at this stage a lot of research is being carried out. One application of this technology is the Internet of Things (IoT), which includes Machine-to-Machine and Device-to-Device communication. 5G systems should support 100 billion connections, data rate of several tens of megabits per second for thousands of users and 1 ms latency. Multiple access technology allows multiple users to share the available radio resources in a cost-effective and a spectrum-efficient manner [1]. Non-orthogonal multiple access (NOMA) scheme is solutions to increase the number of users inside a given time-frequency resource [2]. Unlike conventional orthogonal multiple access techniques such as frequency division or time division and code division multiple access,[3]-[6] NOMA uses some controllable interference to implement overloading in the increased receiver complexity. As a result, higher spectral efficiency and massive connectivity can be achieved. NOMA allocates one frequency channel to multiple users at the same time in the same cell and offers a number of advantages, including high cell-edge throughput improved spectral efficiency (SE), relaxed channel feedback low transmission latency and relax channel feedback. NOMA is divided in to two categories, one is code domain and other is power domain [7]. In NOMA one sub channel can be shared by multiple users at the same transmit rate, hence it can increase the spectrum efficiency compare with 4G. The technology used in this paper in NOMA is successive interference cancellation (SIC). Successive interference cancellation is used at receiver side. SIC is done by introducing the interference information in the system, it can achieve high spectrum efficiency but also has the multiple access interference (MAI) problem. To support applications such as the Internet of Things (IoT) [8], a downlink version of NOMA is standardized in the 3GPP LTE Advanced (3GPP-LTE-A) having the name Multi-User Superposition Transmission (MUST) [9]-[11]. IoT applications, where fewer channels are needed to serve large numbers of sensors due to limited throughput, or utilization requirements of the IoT devices [12]-[13].

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2. DETECTION METHOD AT RECIEVER

The detection method in NOMA for multiple users is applied at the receiver [14]-[15]. In SIC technique the interference is canceled by gradual elimination strategy, the user are distinguished one after another. Then multi-path interference cancellation on each user is performed, after that the system total multi-access interference is removed from the received signal. SIC at UE can successfully extract its own signal components from the superimposed signal by canceling the unwanted signal information of other users.

3. POWER ALLOCATION TO USERS

By combining multiple users using the different power domain the spectrum efficiency and hence throughput can be increased [16]. Lets consider four users are assigned same frequency and different power as given in figure 1.

In figure 1 power allocation scheme is in decreasing order. i.e PI>P2>P3>P4. After modulation of each user power is allocated to all users.

P1: Power allocated to user 1

P2: Power allocated to user 2

P3: Power allocated to user 3

P4: Power allocated to user 4

The power allocated to all users is different. The frequency is same for all users and power allocation is assigned in decreasing order. After power allocation all the user information is superimposed and transmitted over channel. As shown in Figure 1 and Figure 2.

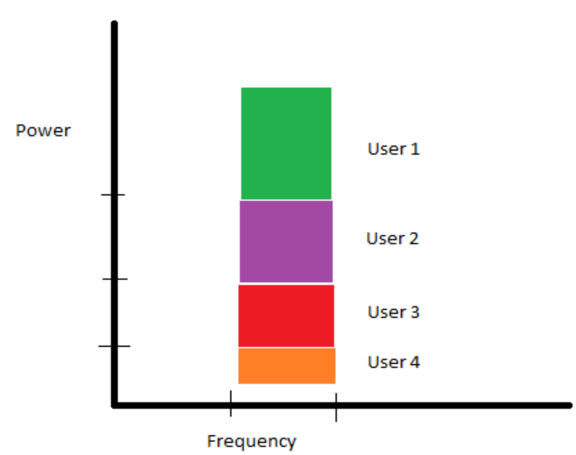

Figure 1: NOMA with four users

At receiver side the low-density parity check code is used to separate the superposed users. The modulation method used is 64-QAM.

4. NOMA SYSTEM MODEL

The system model can be as given in figure 2.

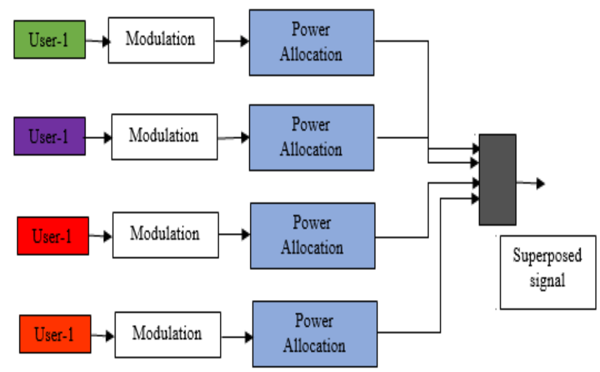

Figure 2: NOMA system model

In figure 2 all the four users are modulated separately. Then after modulation power is allocated to all users and then the users are superposed. Since the users are ordered by their signal strength, the SIC detector [16] first decodes the strongest signal and then subtracts it from the superposed received signal and then the second strongest signal can be detected and subtracted from the composite signal, and this process continues until all the signals are detected [17].

If P_1 is the power of user 1 and S1 is the signal type of user 1 then the user 1 transmitted throughput T is:

$$T1 = S1 * \sqrt{P1}$$

Similarly the throughput for user 2 is:

$$T2 = S2 * \sqrt{P2}$$

For user 3

$$T3 = S3 * \sqrt{P3}$$

For user 4

$$T4 = S4 * \sqrt{P4}$$

The channel total power is P

$$P = \sum_{n=1}^{n=4} \mathrm{Pn} \tag{1}$$

The transmitted signal is the superposed signal ST that is combination of all four signals:

$$S(T) = \sum_{n=1}^{4} (\mathrm{Sn}) \tag{2}$$

A.TRANSMITTING THE SUPERPOSSED SIGNAL

The total throughput TT at transmitter is

$$TT = \mathrm{S1} * \sqrt{P1} + \mathrm{S2} * \sqrt{P2} + \mathrm{S3} * \sqrt{P3} + \mathrm{S4} * \sqrt{P4} \tag{3}$$

At transmitter by adding noise information achieves higher spectral efficiency but introduce multiple access interference. To remove multiple access interference the successive interference cancellation (SIC) is used at receiver [18]. The SIC gradually cancels the interference [7] and then users are distinguished after one another. The formula for all package with noise is as,

$$TT = \mathrm{S1} * \sqrt{P1} + \mathrm{S2} * \sqrt{P2} + \mathrm{S3} * \sqrt{P3} + \mathrm{S4} * \sqrt{P4} + \mathrm{N} \tag{4}$$

Suppose we have 4 users in two sub channels Cm and Cn the received signal R can be expressed as,

$$R = \sum_{m=1}^{2} \mathrm{Sm} * \sqrt{Pm} + \sum_{n=3}^{4} \mathrm{Sn} * \sqrt{Pn} + N \tag{5}$$

B. SIGNAL TO NOISE RATIO

It is ratio of signal power in sub channel to the noise power in overall channel. As given in equation 6. Sub channel noise is removed by successive interference cancellation between users.

Signal to noise ratio in subchannel is equal to signal power in that subchannel divided by total noise.

$$SNR = \frac{\sum_{m=1}^{2} \mathrm{Sm} * \sqrt{Pm}}{\mathrm{N} + \sum_{n=3}^{4} Sn * \sqrt{\mathrm{Pn}}} \tag{6}$$

At reciver side the noise is removed and then the power allocated to user is used to separate the users information.

C. RECEIVED SIGNAL

The received superposed signals are decoded at receiver using successive interference cancellation. SIC is performed by signal strength difference. In SIC user signals are decoded successively by signal strength.In SIC each user is decoded by taking other user as noise and remove the other users.We have received signal as given:

$$TT = \mathrm{S1} * \sqrt{P1} + \mathrm{S2} * \sqrt{P2} + \mathrm{S3} * \sqrt{P3} + \mathrm{S4} * \sqrt{P4} + \mathrm{N} \tag{7}$$

If we want to recover the user S1 then the S2, S3, and S4 are treated as noise and N is already a noise. Hence user 1 is extracted from superposed signal. Noise is associated with every signal so total noise is summation of all noise associated with each signal.

$$N = N_1 + N_2 + N_3 + N_4$$

The channel matrix for two subcarriers is H_1 and H_2.

At receiver the received signal due to channel matrix H_1 is:

$$R1 = H_1 * S1 * \sqrt{P1} + H_1 * S2 * \sqrt{P2} + H_1 * S3 * \sqrt{P3} + H_1 * S4 * \sqrt{P4} + N \tag{8}$$

$H_1 * S2 * \sqrt{P2} + H_1 * S3 * \sqrt{P3} + H_1 * S4 * \sqrt{P4}$ are removed by SIC and then signal S1 is recovered. Similarly for channel matrix H2.

$$R2 = H_2 * S1 * \sqrt{P1} + H_2 * S2 * \sqrt{P2} + H_2 * S3 * \sqrt{P3} + H_2 * S4 * \sqrt{P4} + N \tag{9}$$

$H_2 * S2 * \sqrt{P2}$ is recovered and $+ H_2 * S1 * \sqrt{P1} + H_2 * S3 * \sqrt{P3} + H_2 * S4 * \sqrt{P4} + N$ is removed by SIC.

To retrieve the signal the SNR must be high that can be achieved by using the high power. So power allocated to each signal must be enough high that SNR should be high.

5. SIMULATION RESULT

Then the superpostion coding is

$$U1 * \sqrt{PU1} + U2 * \sqrt{PU2} + U3 * \sqrt{PU3} + U4 * \sqrt{PU4} \quad (10)$$

As user power increases this increases the SNR, which enhance the throughput. The superposed signal is shown in Figure 3 the signal has no proper format but contains four users information with power allocated to each user. The superposed signal has random shape because it has summation of noise plus four users information.

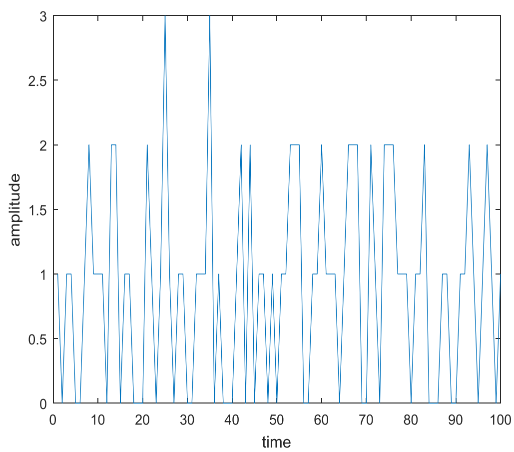

Figure 3: Superposed signal

The figure 4 shows the graph between signal to noise ratio and bit error rate of non-orthogonal multiple access subcarriers. As SNR increases the BER decreases for each user.

U1=sin $2\pi 10t$

U2=random(1,n)

U3=random(1,n)

U4=random(1,n)

The figure 5 shows the relation between energy efficiency and spectral efficiency. As energy decreases the spectral efficiency increases. Therefore, to achieve better spectral efficiency the BER should be low and hence SNR should be high.

For simulation we consider one primary user sine wave and other three users are generated by random data bits.

The power allocated to each user is

PU1=0.92

PU2=0.82

PU3=0.72

PU4=0.62

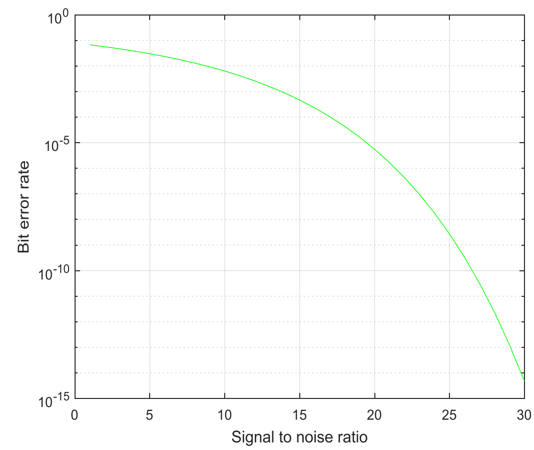

Figure 4 SNR vs BER

Throughput is increased by using SIC method at receiver which increases the spectral efficiency, And SNR are improved by allocating high power and superposition of user at transmitter. So BER is decreased to 10^{-5} and spectral efficiency increases to 40 bits/sec/Hz as shown in figure 5.

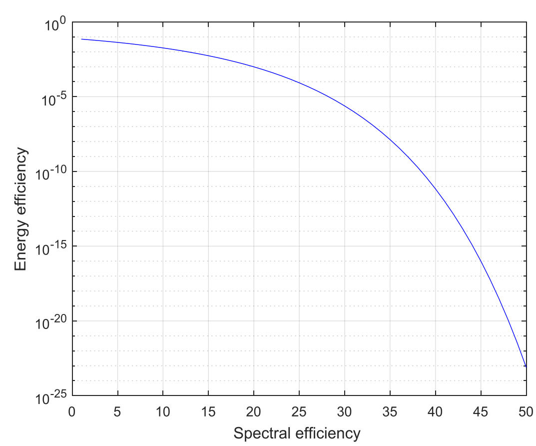

Figure 5: Spectral efficiency

6. CONCLUSION

This paper provides emerging power-domain SC-based NOMA research into 5G, and discusses NOMA transmission and reception performance with numerical results. It is clear that NOMA is multiple access technology for next-generation radio access. Its superposed the gain of transmission by power allocation. In addition to perfect SC at the transmitter and error-free SIC at the receiver, optimum power allocation is done at transmitter. In this paper we have discussed the comparison between BER and SNR of NOMA transmission. When BER decreases the SNR increases. BER is reduced because the noise becomes less due to more users. When noise for each user is extracted treating all other users as noise, it is less for all users. When noise is removed by successive interference cancellation then spectral efficiency increases due to more number of sub channels. Spectral efficiency has been improved upto 40 bits/sec/Hz at energy efficiency at 10^{-5}. Spectral efficiency can be improved by superposing users at transmitter, and SNR are improved by SIC at receiver.

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