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Co-operative NOMA in 5G Systems

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ABSTRACT: Non Orthogonal Multiple Access (NOMA) is one of the radio access scheme suggested for the performance enhancement in next-generation cellular communications (5G). The key concept of NOMA is to transmit information by using power domain using same frequency/time/code domain. It performs power domain or code domain at the transmitter side and adopts Successive Interference Cancellation (SIC) at the receiver side. In this paper, we mainly focus on the performance of Multi-Input Multi-Output (MIMO) scheme with Zero-Forcing (ZF) and Minimum Mean Square Error (MMSE) SIC schemes. Here, we show that NOMA is more efficient than other OMA schemes such as OFDMA, CDMA and TDMA etc. The simulation results shows that the Bit Error Rate (BER) and Packet Error Rate (PER) are decreased in NOMA schemes after SIC at the receiver side.

KEYWORDS: Non-orthogonal Multiple Access, Successive Interference Cancellation, Zero-forcing, Minimum Mean Square Error

I.INTRODUCTION

The key idea of NOMA is to support more number of users or signals that possess significant differences in power levels**.** Due to enormous increase of mobile traffic now a days , new technology 5G has been introduced so as to meet the requirements of better system performance, better throughput and less error data transmission. All the above can be achieved by NOMA using various methods. As each generation of mobile communications uses one of the multiple access schemes like Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Wideband Code Division Multiple Access (WCDMA) and Orthogonal Frequency Division Multiple Access (OFDMA). The 5G uses the technique called Non-Orthogonal Multiple Access where it performs multiplexing on the user side and adopts Successive Interference Cancellation at the receiver side. The main drawback of NOMA is due to non-orthogonality of signals where interference occurs. The main aim of this paper is to cancel out the interference at the receiver side and to prove that NOMA is better and can meet the requirements of future wireless communication networks. In this paper, we mainly focus on the interference cancellation on the receiver side.

In this paper, we consider a perfect SIC on the receiver side and using Link-Level Simulation of NOMA with the practical SIC schemes such as Zero-Forcing (ZF-SIC) and Minimum Mean Square Error (MMSE-SIC). Mainly, ZF corresponds to bring down Inter symbol interference (ISI) to zero and MMSE scheme is used to estimate the mean squared error in the transmission of signal. In this paper, we used interference predicted MMSE scheme to cancel out the interference at the receiver side. The simulation results show that by using proposed IC schemes the Bit Error Rate (BER) and throughput performance has been increased compared when to other OMA schemes. The rest of paper includes system model, types of NOMA schemes and comparison of the performance using NOMA and without NOMA.

II. RELATED WORK

In future, people are expected to be surrounded by smart objects in smart homes, offices, streets and cities; so in the smart world. The smart world will result in tremendous increase at the number of connected devices, the data traffic demand and variety of supported applications. Examples of interesting applications include; smart monitoring and control, content sharing and always on always up to date data. It is clear that, these applications which require significant information to be conveyed from the users and devices to access the network .Therefore traffic demand in the uplink

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directly will very rapidly increase, as well as the downlink direction. 5G finds its application in medicine field in remote surgeries and to work efficiently the latency in transmission must be very low. It has many applications such as IOT, education, smart cities, vehicle to vehicle communication.

III. SYSTEM MODEL

2.1 NOMA basic

Let us consider a downlink transmission scenario which consists of a base station and two user equipment's. One of the two UEs is located in high SNR region which is nearer to base station. Let us consider this asUE1 and another UE is located far away from the base station, in low SNR region and it is named as UE2. When base station transmits the signals, messages are superposed in power domain and then transmitted. If UE2 is given more power while UE1 is allocated with less power. Due to this superposition scheme, it allows UEs to utilize the entire bandwidth of the channel.

First, let us consider that the message is arrived at UE1. As UE1is allocated with less power, the superior signal here is the message to far UE2. The receiver of UE1 decodes the interference message and subtracts it from the total message. The main message to UE1 is obtained. The method is called as SIC. After that the original signal for UE1 is decoded without any problem.

Now, consider the message is arrived at UE_2, as it is allocated with more power the message that was intended for UE_1 will be attenuated to near noise levels and decoding of message to UE_2 can be done by using the interference occurred byUE_1 as noise. The whole concept can be shown by fig.1

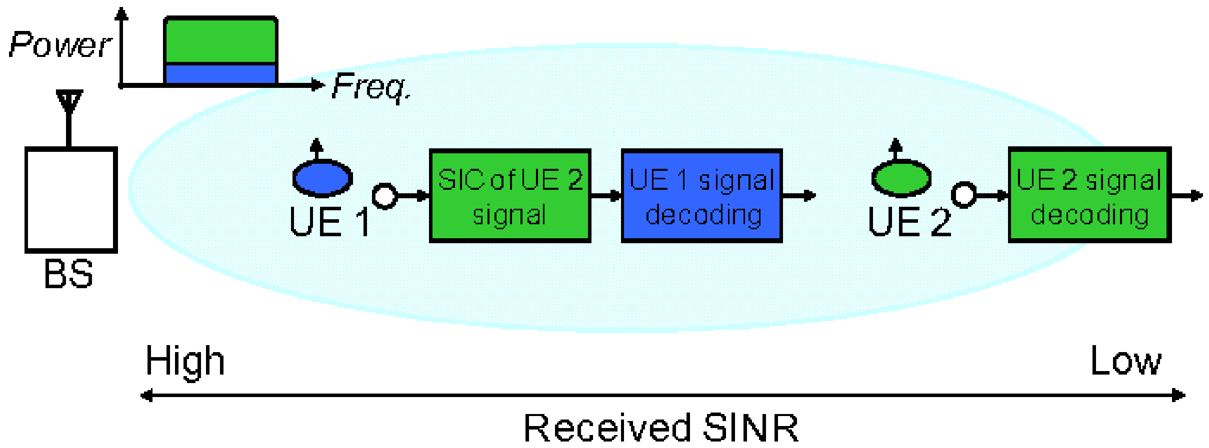

Fig.1 A simple NOMA System

2.2 Analysis

For analysis, we assume that the system has single transmit and receive antenna, the overall transmission bandwidth is assumed to be 1MHz. We will have two user equipment's named UE_i, (i=1,2).
The signal transmitted by BS is called y_i
The superposition of y_1 and y_2 is

$$Y=\sqrt{p_1}x1+\sqrt{p_2}x2 \quad (1)$$

The received signal in UE-i will then be

$$y_i= h_i\, x + n_i \quad (2)$$

Here h_i is the complex channel coefficient between UE_i and BS; n_i is receivers Gaussian noise including intercell interference. The power density of n_i is $N_{0,i}$. In NOMA downlink, decoding will be in the order of the increased channel gain normalized by noise and inter cell interference power,$|h_i|^2/N_{0,i}$, for a 2 UE case as shown in fig.1,we

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assume that $|h_1|^2/N_{0,1} >,|h_2|^2/N_{0,2,}$so UE_1 first decodes x_2 and deletes its component from received signal y_1. And UE_2 decodes x_2 without interference cancellation, because it has he first decoding order. The throughput of UE_i, $R_i$is

$$R_1 = \log_2(1 + \frac{P_1 |h_1|2}{N_{0,1}}),\ R_2 = \log_2(1 + \frac{P_2|h_2|2}{P_1|h_2|2 + N_{0,2}}) \quad (3)$$

III. TYPES OF NOMA

There are two types of NOMA they are NOMA with SIC and NOMA with Spatial Multiplexing. In this paper, we mainly concentrate on NOMA with SIC. NOMA with SIC is an approach used to cancel outinterfering signals and retain the required message waveform when the interference power is greater than the signal power.It is based on principle that if interference power is much greater than the signal power, the interference signal can be demodulated by treating the actual message as noise. The demodulated interference signal can be Re-modulated and subtracted from the received signal to cancel out the interference. Now, we have an interference message signal.

NOMA with spatial multiplexing is used to increase the spatial multiplexing gain using multiple antennas. In this scheme, each transmit antenna sends an independent data stream. Thus, bit rate can be increased by a factor of number of antennas. This requires multiple antennas at the user side.

3.1 NOMA-MIMO with practical SIC schemes

Till now the sets of achievable rates have been found by Bergmans. The capacity region of the uplink fading channel with the receiver channel state information was derived by Gallager. Here, the application of Multiple-Input Multiple-Output (MIMO) NOMA is important since the use of MIMO provides additional degrees of freedom for further performance improvement. The transceiver design for MIMO-NOMA downlink transmission in which each user has single antenna and base station has multiple antennas was studied but a problem of throughput maximization was given. So to solve them two algorithms were proposed. In this paper, we mainly focus on MIMO-NOMA with practical SIC instead of perfect SIC.

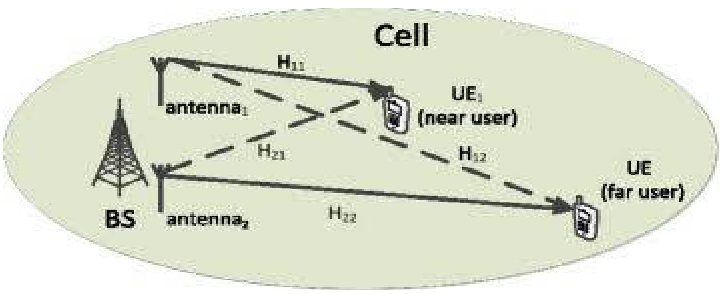

Fig.2 Transmission scenario for downlink MIMO-NOMA

We assume orthogonal frequency division modulation signaling, even if we consider NOMA user multiplexing. Fig.2 indicates the transmission outline for downlink MIMO-NOMA for 2-UE case, where UE1 is the cell center user and UE2 is the cell edge user. Fig.3 shows the block diagram of transmitter and receiver for downlink antennas at BS, each antenna transmits signal to one UE. The transmit signal xi for UEi is

$$x_i = \sqrt{p_i}\, s_i,(i=1,2) \quad (4)$$

Where p is allocated power and s_i is transmitted data for UE_i, after transmitting through 2X2 channel H, as shown in Fig.2, the two UE systems are represented as

$$Y = [x1 \quad x2]\begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} + [n1 \quad n2] \quad (5)$$

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Where, n_i (i =1,2) is the receivers Gaussian noise for UE_i . The received signal y_i for UE_i is represented as

$$y_i = H_{ii}x_i + \sum_{j=i} H_{ji}\, x_j + n_i \tag{6}$$

Where, Hji denotes the channel between jth antenna at the BS and the ith receiver, x_j is the transmit signal for UE_j, which is the interference for UE_i and n_i is the Gaussian noise. After reception the signals are ranked in decreasing order by power. Channel Estimation is performed for the interference signal y_i with the power $p_j > p_i$. Then, SIC is employed until all interference signals are cancelled. The estimated received signal s_1 is obtained for UE_i. For the 2-UE case from EQ1, the received signals for UE_1 and UE_2 are

$$y_1 = H_{11}x_1 + H_{12}x_2 + n_1$$
$$y_2 = H_{12}x_1 + H_{22}x_2 + n_2$$

Since NOMA allows UEs to share the same resources, and differentiates UE by power to cancel he inter-user interference. Because UE2 is a far user with greater power,the element H12x2 is cancelled by the IC from y_1, whereas y2 can be demodulated directly without IC.

In this paper, we consider practical SIC schemes based on the Zero-Forcing (ZF) and he MMSE criteria. As described in the system model, by assuming power $p_2 >> p_1$, he UE_2 can directly detect he signal without cancellation of interference. For UE1, he received signal $y_1$is

$$y_1 = H_{11}\sqrt{p_1 s_1} + H_{21}\sqrt{p_2 s_2} + n_1 \tag{7}$$

Where, interference is $H_{21}\sqrt{p_2 s_2}$, We can get the weigh factor of channel H_{21}, i.e., H_{21}|ZF or H_{21}|MMSE criteria after getting he estimated channel H_{21}

$$\hat{H}_{21}|_{ZF} = (\tilde{H}_{21}^H \tilde{H}_{21})^{-1}\tilde{H}_{21}^H ,$$
$$\hat{H}_{21}|_{MMSE} = (\tilde{H}_{21}^H \tilde{H}_{21} + \sigma^2{}_{n_1} I)^{-1}\hat{H}_{21}^H \tag{8}$$

Where the sign H in the superscript in the equation represents the Hermitian transpose and is the variance of noise,n_1. Then, the estimated interference signal can be obtained as

$$\tilde{s}_2 = \sqrt{P_2}^{-1}\hat{H}_{21}y_1 = s_2 + \sqrt{p_3}^{-1}\hat{H}_{21}\left(H_{11}\sqrt{p_1 s_1} + n_1\right) \tag{9}$$

The received signal is updated by subtracting the estimated interference signal:

$$y_1 = y_1 - \tilde{H}_{21}\sqrt{p_2}s_2 \approx H_{11}\sqrt{p_1}s_1 + n_1 \tag{10}$$

After the cancelling the interference signal with high power, UE1 can detect the desired information, s1, from the updated received signal.

3.2 Performance evaluation for signals with and without NOMA:

In this section, we compare the Packet Error Rate (PER) and throughput performances of conventional MA and NOMA by LLS. We still use the system model mentioned above for 2-UE. In conventional MA (without NOMA), the power for UE1 (near user), p1, is assigned as 0.8, and for UE2 (far user), p2 is 0.2, which follows the water filling(WF) algorithm. For NOMA, e.g., p1=0.2, p2=0.8 which is power control (PC). We imitate System-Level Simulation (SLS) by LLS, where power allocation is used instead of path loss for cases with and without NOMA. According to the LTE specifications, simulation parameters are shown in Fig.4 shows the PER performance cases with and without NOMA, where the practical ZF IC is applied for UE1 in case-2. According to PER, the throughput C can be calculated by

$$C = \frac{(1-PER) \times n_{bit/packet}}{T_{packet}(s)} \tag{11}$$

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Therefore, the throughput performance for case-1 and case-2 is shown in fig5. In LLS, the path loss is not considered, and if we compare the performance between case-1(p1=0.2,p2=0.8) and case-2(p1=0.8 and p2 = 0.2) under the scenario without NOMA, the performance of UE1 in case-1 is same as UE2 in case-2.

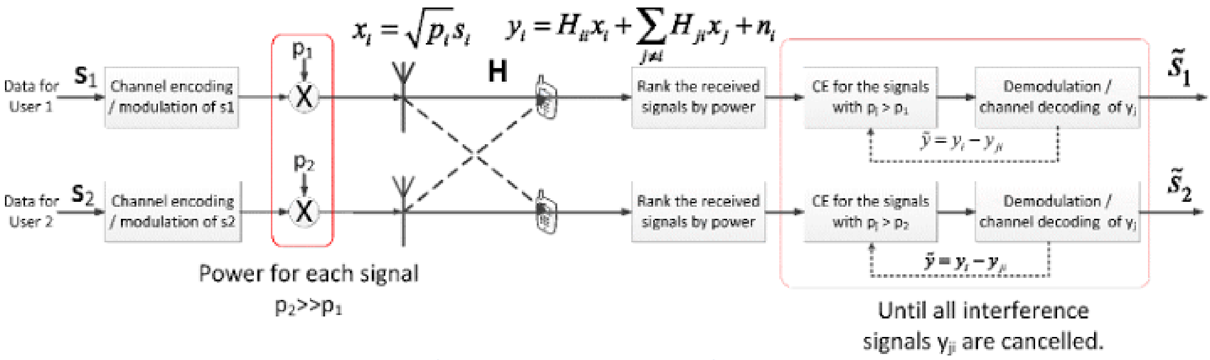

Fig.3 Block diagram of transmitter and receiver for downlink MIMO-NOMA

From the simulation results shown in fig.4, we determine that in NOMA, UE2 can detect information with greater power than the interference from UE1. Without NOMA, UE2 cannot detect information owing to the lower power compared to the interference signal from UE1. On the other hand, UE1 with NOMA can benefit from IC, even though the power of interference signal is much higher than the target signal. Without NOMA, UE1 has performance similar to UE2 with NOMA, owing to the existing interference from the lower power user. From this result we conclude that the error rate is decreased after using SIC- NOMA at receiver side.

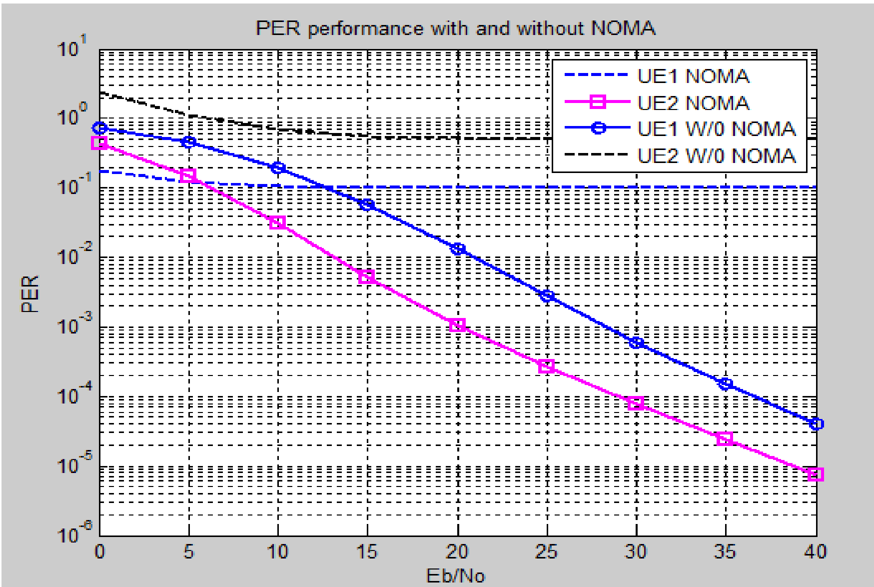

Fig.4

From the simulation results shown in fig.5, NOMA can increase the sum throughput and improve the fairness between the near users and far users compared with the situation without NOMA. Here throughput defines the number of deliverable outputs and E_b/No defines the ratio of Energy per Bit to the Spectral Noise Density. Here in this figure we conclude that NOMA with two users is more efficient than the users without using NOMA schemes.

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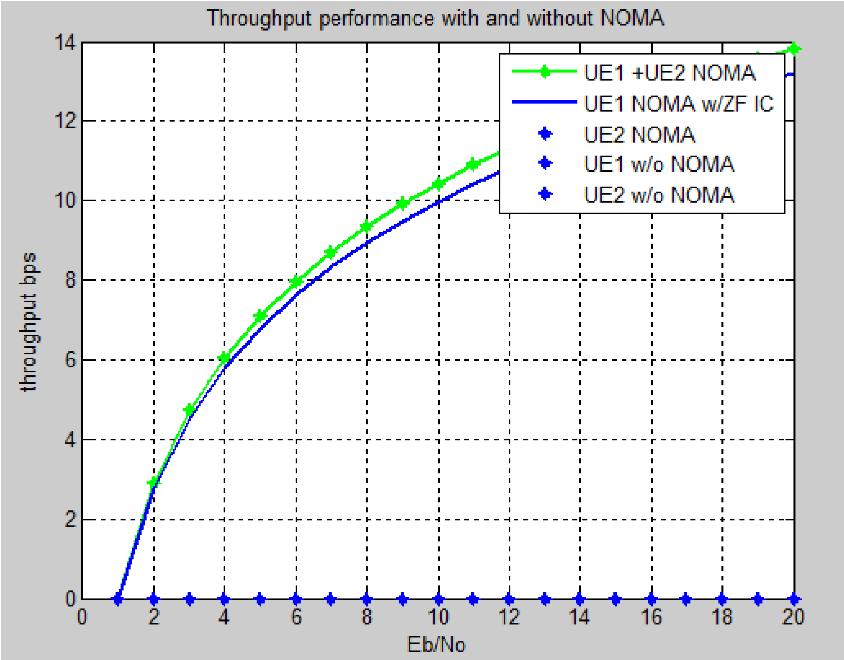

Fig. 5

IV. CONCLUSION

In this paper, we exploit the performance of various signals with and without NOMA schemes, which proves that there is a necessity of performing investigation into IC schemes for NOMA. Because of many previous works and some of research topics, such as implementing SIC and the error effect due to IC are still in early stages but not fully developed. By considering ZF-SIC and MMSE-SIC we here conclude that the BER and PER are greatly reduced and can perform more efficiently than the schemes of NOMA after the application of SIC on receiver side.

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