PERFORMANCE ANALYSIS OF COOPERATIVE NOMA IN 5G SYSTEMS

[1] BURRE TEJASWINI [2] D SRI RAMA MURTHY
[1] M. Tech student, Dept of ECE, DMSSVH College of Engineering, Machilipatnam, AP, India
[2] Associate Professor, Dept of ECE, DMSSVH College of Engineering, Machilipatnam, AP, India.

Abstract:
Today's wireless networks allocate radio resources to users based on the orthogonal multiple access (OMA) principle. However, as the number of users increases, OMA based approaches may not meet the stringent emerging requirements including very high spectral efficiency, very low latency and massive device connectivity. Non orthogonal multiple access (NOMA) principle emerges as a solution to improve the spectral efficiency while allowing some degree of multiple access interference at receivers. The latest member of the multiple access family, (NOMA) has been recently proposed for 3GPP (LTE) and envisioned to be an essential component of 5th generation (5G) mobile networks. The key feature of NOMA is to serve multiple users at the same time /frequency /code, but with different power levels, which yields a significant spectral efficiency gain over conventional orthogonal multiple access. In this paper we providing a unified model for NOMA including uplink and downlink transmissions along with the extensions to cooperative communication.

Keywords:
Cooperative NOMA, Outage Probability, successive interference cancellation, minimum mean square error.

1. Introduction:

Wireless mobile communication systems became an indispensable part of modern lives. However the number and variety of devices increases significantly and same radio spectrum is used several times but in different applications.[1].In particular, NOMA allocates less power to users with higher channel conditions, and these users can decrypt their own info by applying sequent interference cancellation [2]. Consequently such users will know the messages supposed to different users; such previous info can be exploited to boost performance, but this has not been considered in previous forms of NOMA [3] and [4].

In this paper, a NOMA transmission scheme is proposed to completely exploit previous info on the market in ulcer systems. In particular, the use of the successive detection strategy at the receivers means users with higher channel conditions have to be compelled to decrypt the messages for the others, and therefore these users is used as relays to boost the reception dependableness for the users with poor connections to the base station. Local short-range communication techniques, such as Bluetooth and ultra-wideband (UWB), can be used to deliver messages from the users with higher channel conditions to the ones with poor channel conditions. The outage probability and diversity order achieved by this NOMA scheme are analyzed, and these analytical results demonstrate that NOMA can achieve the maximum diversity gain for all the users.

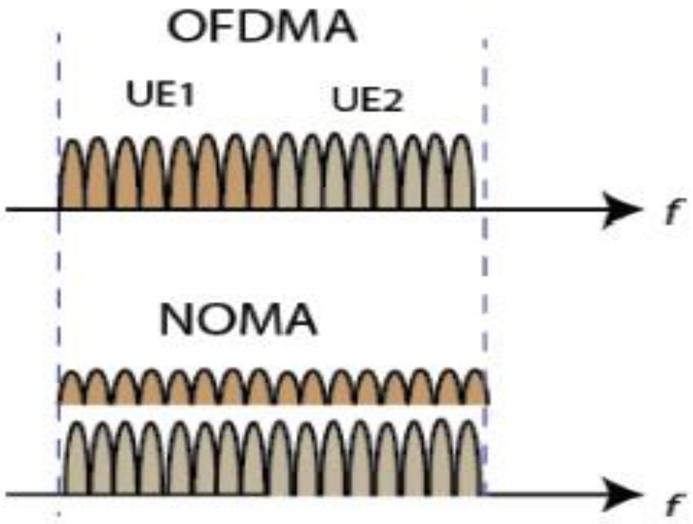

Fig 1. Spectrum Sharing OFDM and NOMA

In practice, inviting all users in the network to participate in ulcer may not be realistic because of the system complexness for coordinating user cooperation. User pairing is a promising solution to reduce system complexity, and we demonstrate that grouping users with high channel quality doesn't essentially yield an outsized performance gain over orthogonal MA. Instead, it is preferable to combine users whose channel gains, absolutely the squares of the channel coefficients, are more distinctive.

NOMA was proposed as a candidate radio access technology for 5G cellular systems [2, 3]. Practical implementation of NOMA in cellular networks requires high computational power to implement real-time power allocation and successive interference cancellation algorithms. By 2020, the time that 5G networks are targeted to be deployed, the computational capacity of both handsets and access points is expected to high enough to run NOMA algorithms.

2. Multiple-Access Techniques

As mentioned before, sophisticated multiple-access (MA) techniques have also been regarded as one of the most fundamental enablers, which have significantly evolved over the consecutive generations in wireless networks [10], [11]. Let us have a deeper looker at the development of MA techniques.

As illustrated in Fig. 1, the past three to four decades have witnessed historic developments in wireless communications and standardization in terms of MA techniques. Looking back to the development of the MA formats as we briefly discussed above, in the first generation (1G), FDMA

was combined with an analog frequency-modulation-based technology, although digital control channel signalling was used. In the 2G GSM communications, TDMA was used [12]. Then, CDMA, which was originally proposed by Qualcomm [13], became the dominant MA in the 3G networks.

In an effort to overcome the inherent limitation of CDMA, namely that the chip rate has to be much higher than the information data rate, OFDMA was adopted for the 4G networks [14]. Based on whether the same time or frequency resource can be occupied by more than one user, the existing MA techniques may be categorized into OMA and NOMA techniques [15]. Among the aforementioned

MA techniques, FDMA, TDMA, and OFDMA allow only a single user to be served within the same time/frequency resource block (RB), which belong to the OMA approach.

By contrast, CDMA allows multiple users to be supported by the same RB with the aid of applying different unique, user-specific spreading sequences for distinguishing them. Fuel by the unprecedented proliferation of new Internet-enabled smart devices and innovative applications, the emerging sophisticated new services expedite the development of 5G networks requiring new MA techniques. NOMA techniques can be primarily classified into a pair of categories, namely, code-domain NOMA and power domain NOMA [16]. The most prominent representative code-domain NOMA techniques include trellis-coded multiple access (TCMA) [18], IDMA [19], and low-density signature (LDS) sequence based CDMA [20]. These solutions are complemented by the more recently proposed multiuser shared access (MUSA) technique [21], pattern-division multiple access (PDMA) [22], and sparse-code multiple access (SCMA).

The power-domain NOMA, which has been recently proposed to 3GPP LTE [23], exhibits a superior capacity region compared to OMA. The key idea of power-domain NOMA is to ensure that multiple users can be served within a given time/frequency RB, with the aid of superposition coding (SC) techniques at the transmitter and successive interference cancellation (SIC) at the receiver, which is fundamentally different from the classic OMA techniques of FDMA/TDMA/OFDMA as well as from the code-domain NOMA techniques. The motivation behind this approach lies in the fact that, again, NOMA is capable of exploiting the available resources more efficiently by opportunistically capitalizing on the users' specific channel conditions [24] and it is capable of serving multiple users at different QOS requirements in the same RB.

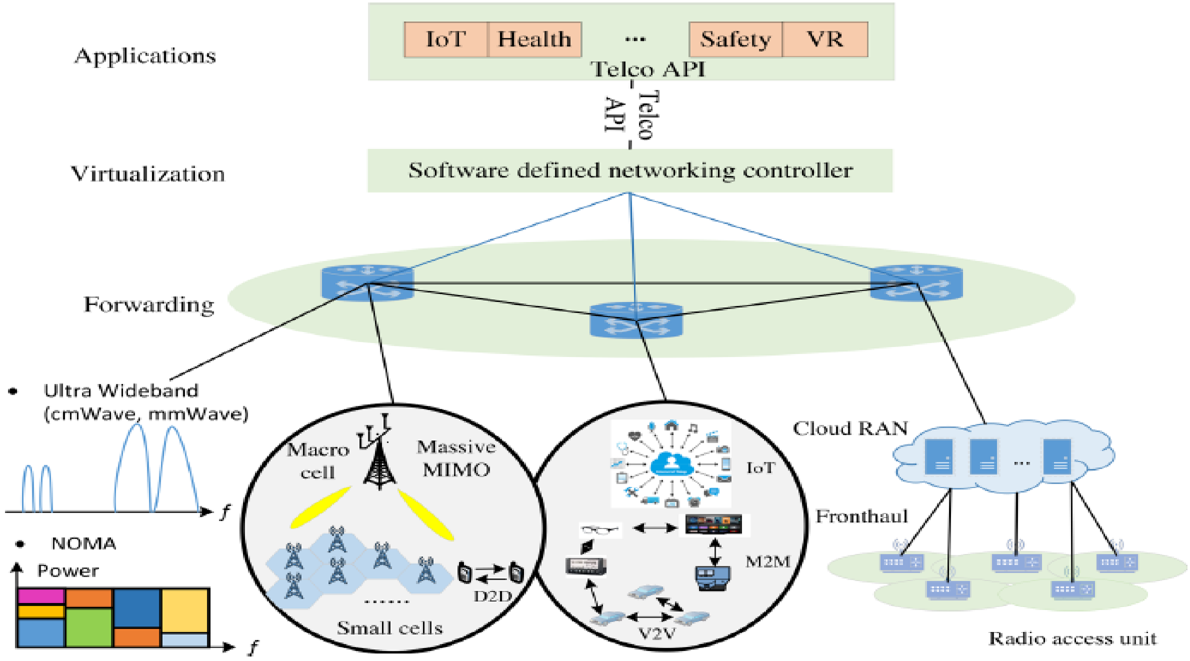

Fig 2. Illustration of the future 5G network architecture

3. NOMA for Downlink and Uplink:

NOMA for downlink

In NOMA downlink, the base station superimposes the information waveforms for its serviced users. Each user equipment (UE) employs SIC to detect their own signals. Figure 3 shows a BS and K number of UEs with SIC receivers. In the network, it is assumed that the UE1 is the closest to the base station (BS), and UEK is the farthest. The challenge for BS is to decide how to allocate the power among the individual information waveforms, which is critical for SIC. In NOMA downlink, more power is allocated to UE located farther from the BS and the least power to the UE closest to the BS. In the network, all UEs receive the same signal that contains the information for all users. Each UE decodes the strongest signal first, and then subtracts the decoded signal from the received signal. SIC receiver iterates the subtraction until it finds its own signal. UE located close to the BS can cancel the signals of the farther UEs. Since the signal of the farthest UE contributes the most to the received signal, it will decode its own signal first.

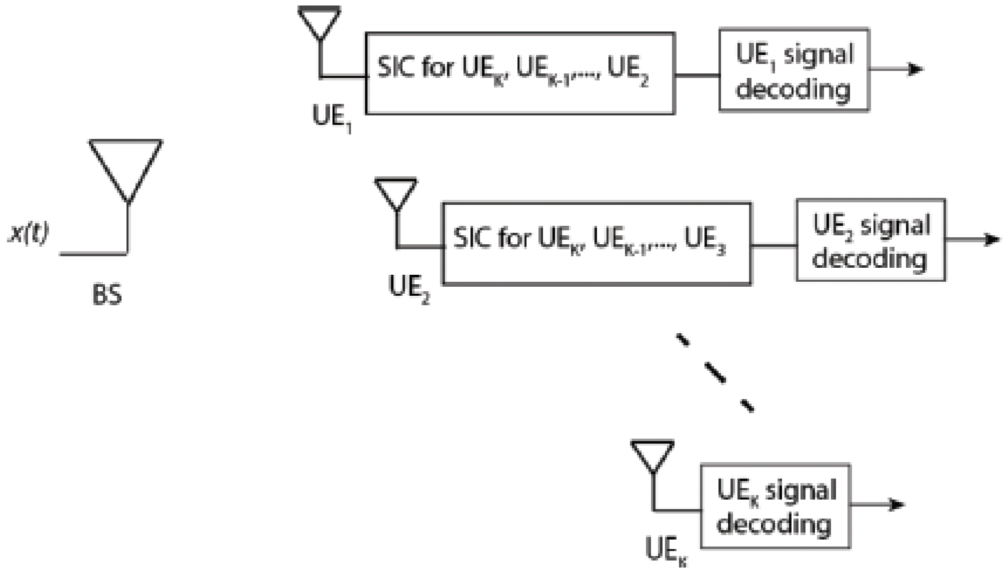

Fig 3.Downlink NOMA for K users

The transmitted signal by the BS can be written as

$$x(t) = \sum_{k=1}^{K} \sqrt{\alpha_k P_T}\, x_k(t)$$

where $x_k(t)$ is the individual information conveying OFDM waveform, α_k is the power allocation coefficient for the UEk, and P_T is the total available power at the BS. The power allocated to each UEk then becomes $P_k = \alpha_k P_T$. The power is allocated according to the distance of UEs to the BS: UE1 is the closest to the BS, so it is allocated the least power, whereas UEK is the farthest one, therefore it has the highest power.

The received signal at the UEk is

$$y_k(t) = x(t) g_k + w_k(t)$$

where g_k is the channel attenuation factor for the link between the BS and the UEk, and $w_k(t)$ is the additive white Gaussian noise at the UEk with mean zero and density N_0 (W/Hz).

Let us consider the farthest user first. The signal it decodes first will be its own signal since it is allocated the most power as compared the others. The signals for other users will be seen as interference. Therefore, the signal-to-noise ratio (SNR) for UEK can be written as

$$SNR_K = \frac{P_K g_K^2}{N_0 W + \sum_{i=1}^{K-1} P_i g_K^2}$$

where W is the transmission bandwidth.

NOMA for uplink

Uplink implementation of NOMA is slightly different than the downlink. Fig 4 depicts a network that multiplexes K UEs in the uplink using NOMA. This time, BS employs SIC in order to distinguish the user signals.

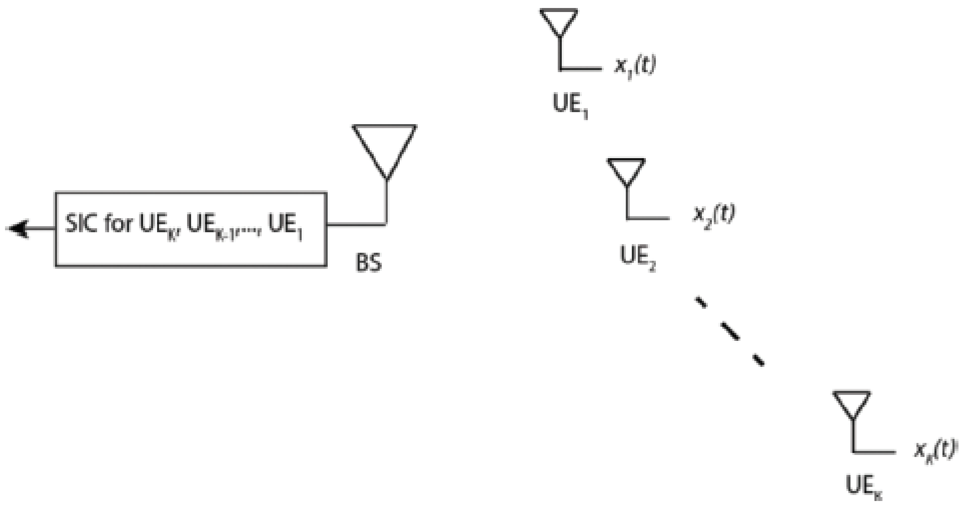

Fig 4. Uplink NOMA for K users.

In the uplink, the received signal by the BS that includes all the user signals is written as

$$y(t)=\sum_{k=1}^{K}x_k(t)g_k+w(t)$$

where g_k is the channel attenuation gain for the link between the BS and the UEk, $x_k(t)$ is the information waveform for the kth UE, and w(t) is the additive white Gaussian noise at the BS with mean zero and density N_0 (W/Hz). In the uplink, the UEs may again optimize their transmit powers according to their locations as in the downlink. However, here we assume that the users are well distributed in the cell coverage, and the received power levels from different users are already well separated. This assumption is more natural from practical point of view, since power optimization requires connection between all the UEs which may be difficult to implement.

4. COOPERATIVE NOMA:

A cooperative NOMA transmission scheme is proposed to fully exploit prior information available in NOMA systems. In particular, the use of successive detection strategy at the receivers means that users with better channel conditions need to decode the messages of the others and therefore this users can be used as relays to improve the reception reliability for users with poor connections to the base station. Local short-range communication techniques, such as blue tooth and ultra-wide band (UWB), can be used to deliver messages from the users with better channel conditions to those with poor channel conditions. The outage probability and diversity order achieved by this cooperative NOMA can achieve the maximum diversity gain for all the users. In practise, inviting all users in the network to participating in cooperative NOMA might not be realistic due to the system complexity for coordinating user cooperation. User pairing is a promising solution to reduce system complexity, and we demonstrate that grouping users with high channel quality does not necessarily yield a large performance gain over orthogonal multiple access.

5. Results and Discussion:

In Information theory, outage probability of a communication channel is the probability that a given information rate is not supported, because of variable channel capacity. Outage probability is defined as the probability that information rate is less than the required threshold information rate. It is the probability that an outage will occur within a specified time period. In Fig 5, Comparison of MIMO systems with various multiple-access techniques using a two-user case. M = N = 3, where M is the number of antennas at transmitters, and N is the number of antennas at receivers. As such, each user is to receive three data streams from the Base Station.

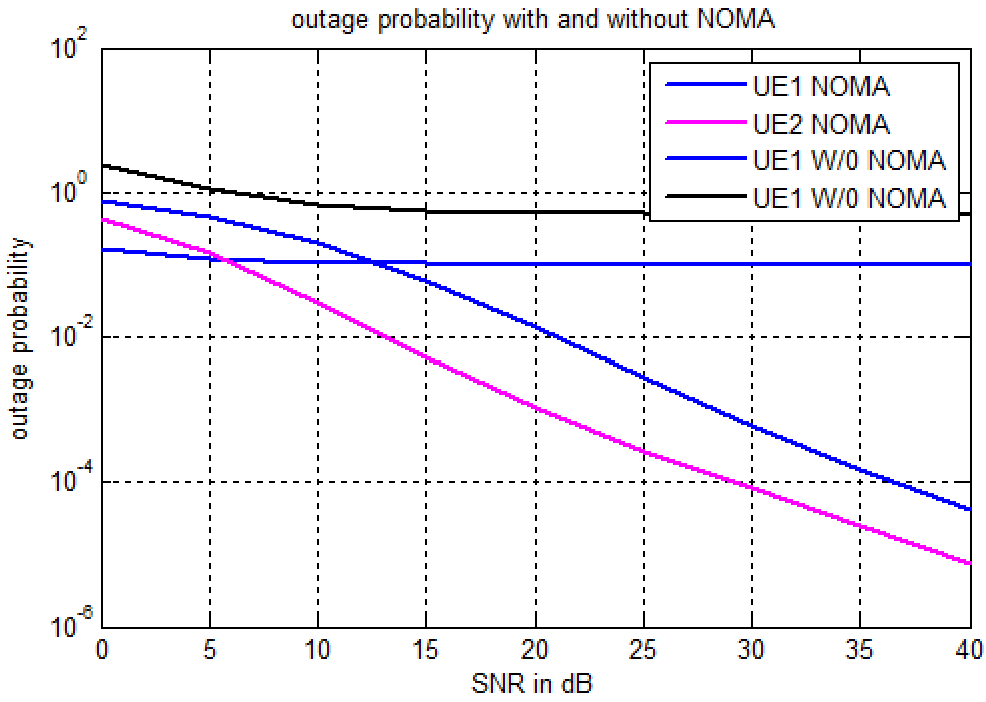

Fig 5. Outrage Probability vs SNR

Fig. 5 illustrates the outage probability defined as the probability of erroneously detecting the message intended for user m in the i th data stream, i = 1, 2, 3 at user n , where the QR decomposition is used to augmenting the differences between the users' effective channel conditions according to the associated QOS requirements. As shown in Fig. 5, the QR-based MIMO-NOMA scheme is capable of outperforming both ZF-NOMA and SA-NOMA as well as MIMO-OMA, since it exploits the heterogeneous Quality of Service (QOS) requirements of different users and applications.

Zero-forcing beam forming (ZFBF) is preferable especially for a large channel angle. ZFBF can be implemented within each user cluster. ZFBF was adopted based on the user's channel with a larger norm (termed as the strong user) in each cluster. ZFBF and decoding scaling approach to reduce inter-cluster interference. ZFBF-like inter-cluster beam forming in [7]–[9], where only a single beam is available for each cluster. At the second stage, the intra-cluster beam forming is optimized over the effective channel in each cluster, but the obtained result is not guaranteed to be optimal.

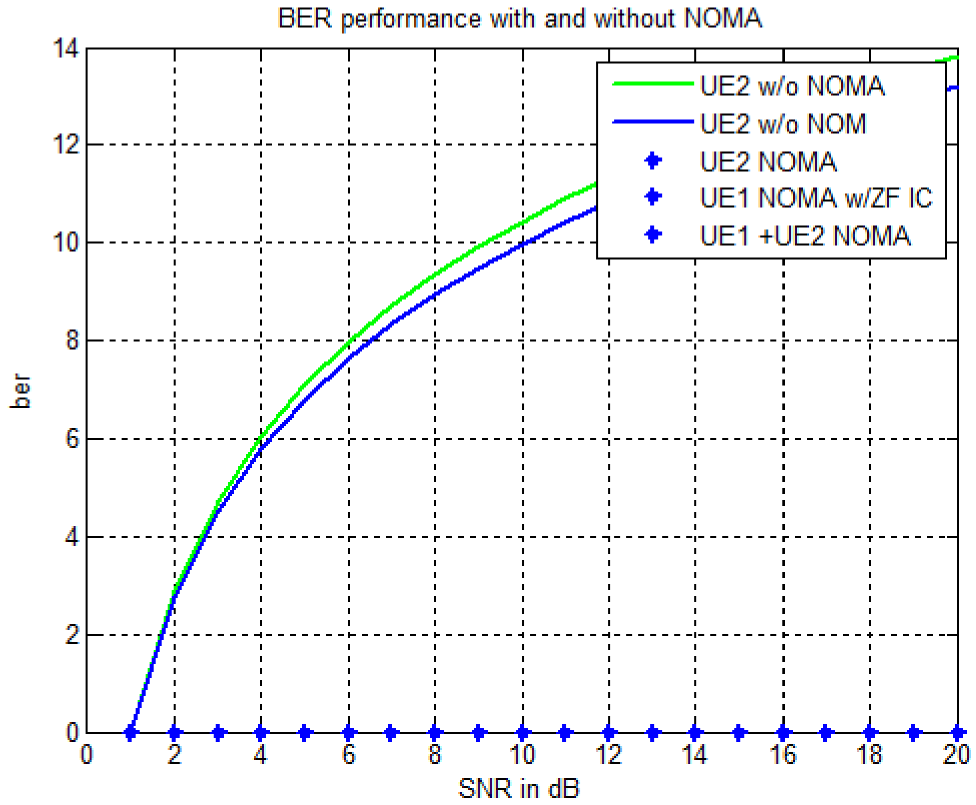

Fig 6. BER vs SNR

Fig 6 shows the efficient transfer of bit performance in MIMO systems. The BER is calculated for different NOMA conditions such QR NOMA and ZF NOMA.

6. Conclusion:

NOMA schemes are proposed to improve the efficient usage of limited network sources. OMA based approaches that use time, frequency, or code domain in an orthogonal manner cannot effectively utilize radio resources, limiting the number of users that can be served simultaneously. In order to overcome such drawbacks and to increase the multiple access efficiency, NOMA technique has been recently proposed. Accordingly, users are separated in the power domain. In OMA, difference between channels and conditions of users cannot be effectively exploited. Furthermore the performance of NOMA can be significantly improved using cooperative communication tecchniques.

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