A Survey on Non-orthogonal Multiple Access Schemes

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Abstract
In this paper, we make a survey on non-orthogonal multiple access (NOMA) schemes, which could be a promising candidate as a downlink wireless access scheme for future 5G radio access technology. To enhance the spectrum efficiency, NOMA adopts a successive interference cancellation (SIC) receiver as the baseline receiver scheme for robust multiple access. In order to get a better tradeoff between the system spectrum efficiency measured by the total user throughput and the user fairness measured by cell-edge user throughput, fractional frequency (FFR) and resource management schemes have been applied to NOMA with SIC. Furthermore, multi-antenna/site technologies with a proposed NOMA/MIMO scheme using SIC and an interference rejection combining (IRC) receiver to get a further user capacity is discussed in some related papers. Finally, it is shown that even in relay channel, NOMA is still effective for system throughput enhancement.

I. Introduction
Non-orthogonal access code-division multiple access (CDMA) based on direct sequence-code division multiple access (DS-CDMA) is widely used in the 3rd generation mobile communication system. In the 3.9 and 4th generation (4G) mobile communication systems such as LTE and LTE-Advanced [1] adopt orthogonal multiple access based on orthogonal frequency multiple access (OFDMA) in the downlink and signal carrier (SC)-FDMA in the uplink. It is a reasonable choice for achieving good system-level throughput performance to orthogonal access in packet-domain services.

However, considering the future radio access in the 2020s, further enhancement to achieve significant system throughput and user fairness has become one of the key issues in handling this explosive data traffic increase in 5th generation (5G) mobile communication systems [2] and need for enhanced delay-sensitive high-volume services. Non-orthogonal multiple access (NOMA) with successive interference cancellation (SIC) is considered to be a promising technology that could improve the sum throughput [3]. Because the communication resources (time and frequency) in a NOMA system are shared by all the users, the sum throughput can be enhanced over what is possible, compared with orthogonal multiple access (OMA) [4]-[5]. In addition, a research activity for next generation of mobile and wireless communication has emerged such as the Mobile and wireless communications Enablers for the Twenty-twenty Information Society (METIS) project [6].

This paper is organized as follows. Section II introduces the basic system model of NOMA with SIC. Section III describes the evaluation of NOMA through both link-level and system-level. Section IV describes NOMA in relay channel, and finally, Section V concludes the paper.

II. Basic NOMA with SIC
In this section, we discuss the basic NOMA with SIC. Fig.1 illustrates the basic NOMA issue with SIC for UE receivers in the downlink within a cellular [7]. To make scenario simplicity, assuming a two user-UE case, a signal transmitter, and a signal receiver antenna. The transmit signal for $UE_i$ ($i = 1, 2$) at the base station is $x_i$, with transmission power is $P_i$. The sum of transmit power is restricted to $P$. In the NOMA, $x_1$ and $x_2$ are superposition coded as

$$x = \sqrt{P_1} x_1 + \sqrt{P_2} x_2.$$ (1)
The received signal at $UE_i$ is expressed by

$$y_i = h_i x + w_i,$$  \(2\)

where $h_i$ is the complex channel coefficient between the base station and $UE_i$, $w_i$ represents the receiver Gaussian noise, $N_{0,i}$ denotes the density of $w_i$.

In the downlink, according to the NOMA with SIC process can be implemented at the UE receiver. In a two-UE case, assuming $|h_1|^2/N_{0,1} > |h_2|^2/N_{0,2}$, therefore, $UE_2$ can decode $x_1$ without interference from $x_2$. The capacity of $UE_i$, $R_i$, is expressed as

$$R_i = \log_2 \left(1 + \frac{P_i|h_i|^2}{N_{0,i}}\right), \quad R_2 = \log_2 \left(1 + \frac{P_2|h_2|^2}{P_1|h_1|^2 + N_{0,2}}\right).$$  \(3\)

By adjusting the power radio, $P_i/P_j$, the capacity of each UE can be controlled flexibly by the BS. Obviously, the power allocation scheme affects the total cell throughput, cell-edge throughput deeply. So, a flexible radio interface should be adopted to utilize the potential gain of the NOMA.

III. Evaluation of NOMA with SIC

A. Link-level Evaluation of NOMA

Kim [8] proposes a non-orthogonal multiple access based multiuser beamforming (NOMA-BF) system design to enhance the sum capacity. In addition, in this paper, Kim recommends a clustering and power allocation algorithm to reduce interference and improve the throughput performance. Through the numerical results, the proposed NOMA-BF system increases the total throughput, compared to the conventional multi-user BF system.

Osada [9] proposes non-orthogonal over multiple channels with iterative interference cancellation (IIC) and fractional sampling (FS), in this scheme duplicate signal is regenerated from the received signal for each desired signal. Through the approach, the BER performance can be improved when the power difference between the desired and imaging components is large. The link-level performance indicates that the power of the imaging components should be large enough for diversity in the meantime as keeping errors on the trial decision small for the purpose of avoiding the error floors.

B. System-level Evaluation of NOMA

Considering the expected evolution of device processing capabilities in the future, Saito [7] adopts a SIC technique for robust non-orthogonal multiple access. Based on system-level evaluations, at the base station side, no matter how the availability of the frequency-selective channel quality indicator (CQI) was, Saito demonstrates that the downlink NOMA with SIC improves both the capacity and cell-edge user throughput performance. Furthermore, Saito also illustrates that multi-antenna/site techniques with the proposed NOMA/MIMO scheme using the SIC and IRC at the UE receiver is an effective to get further user capacity.

Otao [10] employs proportional fairness (PF) based radio resource (bandwidth and transmission power) allocation to enhance both system performance and cell-edge user throughput. The simulation results indicate that NOMA with SIC schemes can increase the system-level throughput performance compared to the conventional orthogonal multiple access (OMA) issues. In order to get a better tradeoff between the system frequency efficiency and the user fairness, Umehara [11] proposes applying fractional frequency reuse (FFR) and weighted proportional fairness (PF) based multiuser scheduling to NOMA with the SIC in the cellular downlink. In addition, a frequency block access policy for cell-interior and cell-edge user groups in FFR is also proposed. The simulation results indicate that NOMA with the SIC along with FFR and weighted PF issues can notably increase the system-level throughput performance compared to the orthogonal multiple access (OMA) schemes.

IV. NOMA in Relay Channel

The multiple-access relay channel (MARC) [12] is the simplest multi-terminal network for physical layer coding. It consists of M sources that want to communicate with a
destination in the presence of a relay. Based on this, Hatefi [13] recommends a new class of MARC of Joint Network Coding (JNCC), refer to as Non-orthogonal MARC (NOMARC), numerical results indicate that NOMARC/JNCC behave significant gains over OMARC/JNCC in different communication scenarios. In [14], Mohamad derives from an information theoretic perspective, an M-user multiple access channel (MAC) assisted by L relay cooperation scheme (see figure 2) defined as follows. \( S_i \) represents the transmission resource, \( R_i \) denotes the relay, \( D \) represents the destination of a transmission resource. Each relay is half-duplex and implements the Selective Decode and Forward (SDF) strategy. In this paper, Mohamad has compared the individual and common outage event for the delay assisted cooperative communication issue NOMAMRC. The simulation results illustrate that the NOMAMRC always get a better performance than the no-cooperation case even under the noisy slow fading source-to-relay links which is a quite perfectly desirable feature.

V. Conclusions

This paper presents a survey on NOMA for future radio access (FRA), which could be a promising candidate as a downlink wireless access scheme for 5G radio access technology. In addition, the NOMA with a SIC scheme is adopted to enhance the multiple access. Furthermore, fractional frequency and resource management schemes have been applied to the NOMA with SIC to get a tradeoff between the system spectrum efficiency and the user fairness. Then, it is illustrated that multi-antenna/site techniques with the proposed NOMA/MIMO scheme using the SIC and IRC at the UE receiver is effective to get increased user capacity. Finally, it is proved that NOMA can also improve system throughput even in relay channel.

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![Fig. 2. A multiple-access multiple-relay channel.](image-url)

References


