Media-based modulation aided uplink NOMA for massive machine-type communications

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Abstract

This paper presents a novel media-based modulation (MBM) aided uplink non-orthogonal multiple access (NOMA) technique for massive machine-type communications (mMTC). NOMA supports massive connectivity while MBM as a modulation technique provides high spectral and energy efficiency. In the proposed MBM-NOMA, users are equipped with a single transmit antenna surrounded by multiple radio frequency (RF) mirrors while a base station (BS) is equipped with multiple receive antennas for uplink NOMA communication. Maximum-likelihood (ML) estimation technique with successive interference cancellation (SIC) is used at the receiver to detect the MBM-NOMA signals. Performance of the proposed MBM-NOMA is analyzed in terms of bit error rate (BER) and is compared with the conventional SIC based NOMA technique. It is shown that MBM-NOMA outperforms conventional NOMA in terms of error performance, achievable transmission rate and energy efficiency.

Ⅰ. Introduction and Background Study

Future wireless networks due to increasing number of users require high data rates with high spectral and energy efficiency. Additionally, index modulation (IM) is an spectral and energy efficient technique which uses part of the information bits as indices of the system resources used for transmission. Furthermore, many IM techniques are introduced in combination with the other emerging technologies like massive multiple input multiple output (MIMO), and orthogonal frequency-division multiplexing (OFDM) []. Recently, the combination of NOMA with IM attracted many researchers and the performance of IM is analyzed considering NOMA networks [2]. However, there are several IM techniques that still needs to be analyzed by integrating them with NOMA. Media-based modulation (MBM) is one among the list of IM techniques which uses reconfigurable antennas (RA) with radio-frequency (RF) mirrors and convey ON/OFF status of RF mirrors as an additional information as shown in Table. 1 [3]. Importantly, the main contributions of this work as follow: Unlike the other works, a novel MBM-NOMA scheme is presented for uplink communication. SIC-based ML detection technique is used at the receiver to decode and recover the superimposed signals transmitted by the MBM-NOMA users. For validation compared with the conventional uplink NOMA technique.

Ⅱ. System Model and Proposed Scheme

In this paper, MBM aided uplink NOMA transmission is considered for K-users in a mMTC system. Each user (k) is equipped with a single transmit antenna Nt and n_{rf} mirrors around it for MBM-NOMA signal transmission while at the receiver there are Nr received antennas. A SIC-based MBM-NOMA receiver is designed at the receiver which detects the superimposed signal using ML detection as shown in Fig. 1. For the above considered users the received superimposed signal at the receiver can be written as.

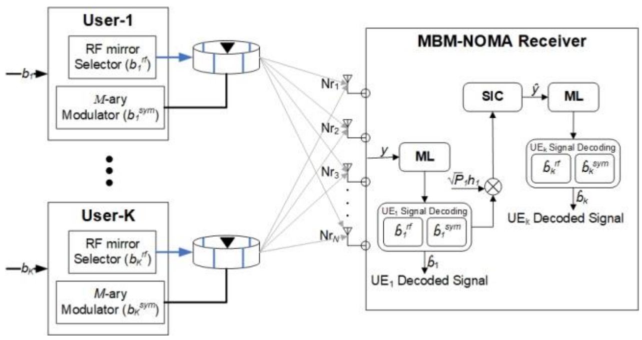

Figure 1: System model of MBM-NOMA with K-users and a SIC-based receiver.

$$y = \sum_{k=1}^{K} \mathrm{H}\sqrt{P_k x_k} + w, \qquad (1)$$

where H is the channel matrix consists of received channel vector hk=[h1,⋯,hN] ^{T} for each user (k), Pk is the transmit power, xk=[x1⋯,xK]^T is the received symbol vector and w is the AWGN noise vector at the receiver. Moreover, it is assumed that channel gain of both users are known at the receiver. For ease of exposition, two users in a pair are considered for an uplink NOMA transmission with channel gains h1 > h2 and power allocation P1>P2.

III. MBM-NOMA

In the proposed, MBM-NOMA the transmission bits at user (k) are represented as b_k where brf are to select the ON/OFF status of RF mirror while bsym is to select the M-ary modulation symbol. It is considered that both users at same time/frequency RB transmit their data as a superimposed signal using different power levels. At the receiver multiple receive antennas Nr are used to receive the superimposed MBM-NOMA signal (y) and the ML based detection is used to decode the signal of each user. Following NOMA, first the signal of high channel gain user is decoded considering the far user or low channel gain user signal user as interference. The ML detection for near user is performed as

$$\bar{x}_1 = \arg\min_{x_1 \in \chi} \|y - h_1 x_1\|^2 . \qquad (2)$$

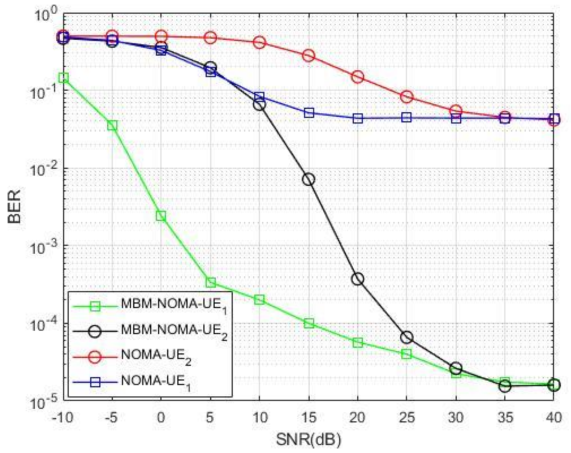

Figure 2: BER performance comparison of MBM-NOMA and conventional NOMA at same bpcu=4.

Similarly, for far user the decoded signal is subtracted from y and similar ML operation will be applied on it. As the ML detection scheme checks all possible combinations therefore, the complexity of MBM-NOMA with ML detection scheme is more than the other estimation techniques. However, the BER performance of ML scheme is better as it performs exhaustive search. Moreover, due to the interference from other users during the SIC process of MBM-NOMA the error floor cannot be avoided at high SNR regime. For the performance analysis, two users (K=2) in a pair are considered with Nt=1 transmit antenna and nrf=2 RF mirrors. In Fig. 2., BER performance comparison of conventional NOMA and the proposed MBM-NOMA is shown at different SNR. The BER of conventional NOMA shows saturation because of the SIC based decoding of the received signal. As during the SIC process the signal of low channel gain user is considered as interference to the high channel gain user. Therefore, the BER at high SNR gets saturated and it is common for NOMA as in [5]. Moreover, the BER of MBM-NOMA is less than the conventional NOMA with same bpcu.

In conventional NOMA, the numbers of bits per transmission are given as log2(M) while for MBM-NOMA it is given as nrf+log2(M). Therefore, the number of achievable bits per transmission in MBM-NOMA are proportional to the number of RF mirrors. It will increase by increasing the number of mirrors. While in conventional NOMA it is depends only on the modulated symbol without conveying any additional information bit. Thus, the achievable transmission rate of MBM-NOMA is better than the conventional NOMA.

The energy efficiency of MBM-NOMA can be calculated based on the successful data recovery i.e., less BER and the rate of the user. It can be given as EE-MBM-NOMA=RTx/P_T where RTx is the achievable transmission rate and PT is the total normalized power of each user which is considered as PT=1. Thus, due to the high achievable rate the MBM-NOMA is energy efficient than the conventional NOMA i.e. EE-MBM-EE-NOMA>NOMA.

IV. Conclusion

In this paper, a novel uplink MBM-NOMA scheme is proposed for mMTC where spectral and energy efficiency are the important requirements. NOMA provides massive connectivity while MBM enables the additional information transmission using the MAPs of RF mirrors with different channel fading realizations of RAs. Results show that MBM-NOMA outperforms the conventional NOMA in terms of BER, achievable transmission rate and energy efficiency.

ACKNOWLEDGMENT

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