International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
doi : https://doi.org/10.32628/IJSRST218558

Optimal Resource Allocation for Multicarrier NOMA in Short Packet Communications

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Article Info
Volume 8, Issue 5
Page Number : 469-475

Publication Issue
September-October-2021

Article History
Accepted : 10 Oct 2021
Published : 20 Oct 2021

ABSTRACT

Wireless communication system needs a spectrum efficient, a power efficient and a cost efficient communication with high throughput to provide communication for ubiquities applications such as voice, data, picture, video, movies, multimedia services, Global Positional System (GPS), navigational system, telemedicine and other value added communication. Non-Orthogonal Frequency Division Multiplexing (NOMA) has become a popular technique for transmission of signals over wireless channels. In the first phase, MIMO system which uses NOMA is used. User signals are divided into parallel streams, using NOMA and are transmitted by the antenna array which propagates through the fading channel. signals are weighted using the Minimum Variance Distortionless Response (MVDR) where the weights are such that the output signal has minimum variance and the desired signal is not distorted. The parallel weighting scheme for interference cancellation leads to a faster, reliable and higher capacity system and results in parallel interference cancellation. Iterative process is also presented in this work, where the approximate weights are found out based on the minimum error value. Both the MVDR weighting and the approximate weighting are evaluated with the help of Bit Error Rate (BER) curves. The curves are plotted for both the Rayleigh and Rician channels. Various plots are obtained by varying the number of antennas in the array and also by varying the length of the user signal. All the BER curves achieved good results and from the analysis it is found that system performs better when Rayleigh channel was considered.

Keywords : NOMA, Resource Allocation, Sub Carrier, Power Reduction

I. INTRODUCTION

Modern society is continuously demanding high data broadband communication services. The mobile telephone services in association with additional services like Short Message Service (SMS), e-mail, fax and multimedia transmission are being requested by a large cross section of people. This necessitates considerable research efforts to be undertaken for providing more efficient techniques to facilitate the

high data communication in mobile network. The communication systems are needed to send a high data rate at different type of conditions. For example, the wired data transmission over internet protocol compared to closed circuit television is delayed. The wireless access transmission delay is increased by using a serial data transmission. The data rate can be increased by using parallel data transmission. It is a challenging task to interface the parallel data lines into the backbone network by using Wavelength Division Multiplexing (WDM). It can enhance the data rate by n times for n parallel data transmission path.

Interferences occur due to high frequency overlap with actual low frequency, multipath fading, frequency re-use, multiple accesses, and adjacent cell. These interferences can be minimized by anti-aliasing filters, matched filters besides serial interference cancellation techniques, parallel interference cancellation techniques, partial parallel interference cancellation techniques and linear partial parallel interference cancellation techniques. With Minimum Variance Distortionless Response (MVDR) algorithm applied with NOMA in order to reduce the interference in serial data transmission, the download data rate is up to one Giga bits, available in Long Term Evolution (LTE) systems.

It can be increased by n times by using n data transmission lines in parallel.

This multistandard functionality imposes several challenges for network and mobile terminal implementations. The main challenge is to provide seamless user mobility between networks with same/different air interface standards. So users have to be equipped with mobile handsets that can inter-work with multiple wireless technologies.

Designing various architectures for each of the multiple standards in the same mobile equipment would result in an intolerable increase in physical size, weight, and power consumption. Therefore area and power consumption become another two challenges in the design of multistandard mobile equipment's. The continuous evolution of wireless standards forces manufacturers to release new products at shorter time and with lower prices. So developing low price devices at shorter time is another design challenge. To support this seamless user mobility across different wireless access technologies, it is important to design reconfigurable multistandard receiver architectures which meet the above design challenges. The idea of the reconfigurable architecture is that it should be possible to alter the functionality of a mobile device at run-time by simply reusing the same hardware for different wireless technologies and ultimately for users to connect to any system that happens to be available at any given time and place. This means that the same hardware should be able to handle many different modulation types as well as different demands on data rate and mobility.

Computationally efficient loading algorithm for NOMA systems in a time varying wireless channel has been proposed by Jiho Jang et al (2003). It is aimed at the maximization of data rate under the constraint of total transmit power and target BER. The algorithm which is based on the waterfilling approach is known as an optimal solution to maximize data rate under the constraint of total transmit power. In this algorithm, the water-filling power allocation is not fully performed. Instead, by adjusting only the waterfilling level needed in the water-filling power allocation, transmit power and number of bits for each subchannel is adapted with low computational complexity.

The total number of loaded bits in an NOMA symbol can be maximized.

II. RELATED WORK

NOMA systems are very sensitive to nonlinear effects due to the high PAPR. In this thesis, different PAPR reduction techniques are analyzed. NOMA transforms a frequency-selective fading channel into large number of flat-fading sub channels (subcarriers) which leads to effortless subchannel equalization and symbol decoding. Due to the large number of subcarriers, NOMA systems have a large dynamic signal range with a very high PAPR. As a result, the NOMA signal will be clipped when passed through a nonlinear power amplifier at the transmitter end. Clipping degrades the BER performance and causes spectral spreading (Li and Cimini 1997, Ren et al 2003). Unfortunately, this clipping technique is not power efficient. Power efficiency is necessary in wireless communication as it provides adequate area coverage. Several proposals (Muller and Huber 1997, Li and Ritcey 1997, Tellado and Cioffi 1998, May and Rohling 1999, Wang et al 1999, Nikookar and Lidsheim 2002, Sezginer and Sari 2006, Jeong Sang Park et al 2007) have been suggested to reduce PAPR of the NOMA system, such as clipping with filtering, block coding, optimization with tone reservation (TR), and selected mapping. However, reduction in PAPR achieved by these techniques is relatively data dependent. Also, the PAPR reduction is obtained at the expense of either an additional complexity to the NOMA transceiver or the need for some kind of transmitter/receiver symbol handshake. In this thesis, some recent important techniques to reduce the PAPR are considered and their results are analyzed. During the analysis, certain techniques provide better PAPR reduction, but fail to maintain the required BER performance.

ARA Algorithms for MIMO-NOMA Systems

The use of multiple antennas to communicate with many users simultaneously is especially charming in WLAN environments such as IEEE 802.11 n. MIMO technology constitutes a breakthrough in wireless communication system design. It offers a number of benefits that help meet the challenges posed by both the impairments in the wireless channel, as well as resource constraints. In addition to the time and frequency dimension that are exploited in conventional SISO

(Single-Input Single-Output) wireless system, the spatial dimension is also exploited. Also Guoliang Shen (2004) presents that MIMO-NOMA provides spatial diversity, combat multipath environment, increases link reliability and reduces receiver complexity in wireless multiuser broadband systems. So MIMO-NOMA is the competitive choice for future broadband wireless communication systems. Jian Xu et al (2006) have dealt with the problem of ARA in multiuser MIMO-NOMA systems under various constraints. In this algorithm, MIMO channel matrix is converted into SISO channel matrix using Frobenious norm criteria. Due to equal power and subchannel distribution

2.1 Precoding with ARA Algorithms for MIMO-NOMA Systems The primary objective of the coding technique is to maximize the system capacity with zero multiuser interference for the downlink multiuser NOMA systems. This coding technique is mainly used where a base station with multiple antennas, communicate simultaneously with many users. Dirtypaper coding technique (DPC) is the first described coding technique for the Gaussian interference channel by Costa (1983). The key idea of DPC is to pre-cancel the interference at the transmitter using perfect CSI and complete knowledge of the transmitted signals. Costa identified the interference as dirt and his signal as ink; his idea is not to oppose the dirt, but to use a code that aligns itself as much as possible with the dirt. It has been shown that the sum capacity is also maximized using DPC (Caire et al 2003). But it is difficult to implement in practice. Consequently, several practical near-DPC

techniques (Hassen Karaa et al 2007, Samardzija and Mandayam 2003, Peel et al 2005) based on the concept of precoding have been proposed to maximize the system capacity. These techniques offer tradeoffs between complexity and performance. Both optimal and suboptimal ARAsuch as subchannel allocation, power allocation, bit loading and adaptive modulation techniques for MIMONOMA systems have been discussed (Cheong Yui Wong and Roger 1999, Suodong Zhang 2004, Zhenping Hu et al 2004 and Peerapong Uthansakul 2006). But in all these papers, the sharing of a subchannel by more than one user haven't been considered i.e. MAI is not into consideration.

In Chengkang Pan et al (2005), a different resource allocation method is considered, but for the removal of MAI, DPC technique is used.

III. METHODOLOGY

In this thesis, five different techniques have been proposed to improve the system performances of the NOMA systems, which are given below

- A novel efficient PAPR reduction technique has been proposed with low complexity to achieve the good PAPR reduction and acceptable BER performance.
- Adaptive modulation with CFO correction for NOMA systems has been proposed to maximize the spectral efficiency.
- A Novel ARA algorithm for multiuser NOMA has been proposed to maximize system capacity and to achieve good QoS. This proposed algorithm jointly achieves guaranteed performance to GP users with good QoS and also maximizes the sum capacity for BE users.
- An efficient ARA algorithm for multiuser MIMO-NOMA systems has been proposed to improve the system capacity.
- A novel BD with ARA for multi user MIMO-NOMA systems has been proposed to maximize the system capacity with zero MAI.

3.1 Proposed PAPR Reduction Technique

To achieve both the PAPR reduction and acceptable BER, a novel efficient PAPR reduction technique has been proposed in this thesis. In this proposed technique, a better reduction in PAPR is achieved by combining precoding technique with non linear companding transform technique. The PAPR reduction is done in both time (companding) and frequency (precoding) domain. Since the precoding matrix is Non Non-Orthogonal, it can maximize the BER performance better than the companding transform techniques. Also the side information is not required in this proposed technique. Hence the complexity is considerably reduced. This proposed technique provides significant PAPR reduction with low overhead of 10%. Simulation results show that the PAPR reduction of the proposed technique is better than the precoding and companding techniques. Also it provides better BER performance than the existing techniques.

3.2 Proposed Adaptive Modulation with CFO Correction Technique

Adaptive modulation with CFO correction algorithm has been proposed to maximize the spectral efficiency of the NOMA system. In this proposed algorithm, the CFO is estimated and corrected before the CSI estimation. CFO is estimated using the ML estimator and the direct correction method has been employed to cancel the estimated CFO. This algorithm selects the modulation technique (constellation size M) adaptively based on the new CSI. Hence this proposed algorithm provides better spectral efficiency than the fixed modulation techniques and conventional adaptive modulation techniques

3.3 Proposed ARA Algorithm for MIMO-NOMA

System In this thesis, the algorithm proposed by Shen et al (2003) is modified for MIMO environment. This algorithm maintains proportional rates among users. Since this method maintains strict proportionality there are some unallocated subchannels which decrease the sum capacity. The algorithm proposed by Wong et al (2004) is also modified suitably for MIMO environment. Even though this approach utilizes the unallocated subchannels efficiently it fails to maintain the proportionality among the users. This may affect the users who require strict QoS. The algorithm proposed by Mohmmad Anas et al (2004) for SISO NOMA system is modified to MIMONOMA system using Frobenious norm criteria. Since the equal power allocation is performed for BE users, this algorithm provides less sum capacity. Hence the proposed algorithm for SISO NOMA system has been modified suitably for the multiuser MIMO-NOMA systems. The performance of this proposed algorithm is analyzed with existing resource allocation algorithm for multiuser MIMO-NOMA systems. This algorithm provides better minimum user and sum capacity than the existing and modified algorithms. Since this method utilizes the low complexity power allocation algorithm, it provides less complexity than the existing algorithms.

Two algorithms have been proposed in this thesis to increase the system capacity and BER performance with zero MAI. BD with optimal power and subcarrier allocation is performed with the constraint of total power to maximize the minimum user capacity and sum capacity. BD with adaptive bit loading and power allocation has been done to achieve the target BER with the constraint of data rate and BER performance. These proposed algorithms provide better system capacity and BER performance than the existing algorithms.

IV. CONCLUSIONANDFUTUREWORK

In this thesis, certain investigations on PAPR reduction techniques, adaptive modulation techniques and different adaptive resource allocation algorithms for SISO and MIMO NOMA systems are carried out and their performance have been analyzed. Subsequently five algorithms have been proposed to improve the system performance of NOMA systems and comparative analyses have been made with the existing algorithms. First, for reducing the PAPR and getting better BER performance than the existing algorithms, a novel PAPR reduction technique is proposed for NOMA systems. This proposed method reduces the PAPR about 4dB than the companding technique and 3 dB than that of precoding technique at a CCDF of 10-3 . The proposed technique gives relative power gains of 5 dB for a BER of 10-4 than that of the companding technique. This proposed PAPR reduction technique is data independent and thus avoids the block based optimization. Since the precoding matrix and companding function are well defined and fixed in the transmitter and receiver, the side information is not required. Though, the proposed technique reduces the PAPR, it is not efficient enough to maximize the spectral efficiency. So, to maximize the spectral efficiency of the NOMA system, an adaptive modulation with CFO correction algorithm has been proposed.

Here, the influences of the CFO on adaptive modulation in NOMA transmission over AWGN and fading channels have been investigated. The presence of CFO will degrade the performance of adaptive modulation in NOMA system significantly. Simulation results show that the adaptive modulation with CFO=0.05 achieves average spectral efficiency of 4 bps/Hz and with CFO=0.1, it gives the maximum spectral efficiency of 3 bps/Hz for the target BER of 10-3 . Whereas, the proposed adaptive modulation technique maximizes the average spectral efficiency

up to 8 bps/Hz for the target BER (Ptarget) of 10-3 . The proposed adaptive modulation technique is manifested by computer simulations and the simulation results exhibits better performance than the conventional adaptive and non adaptive modulation techniques. Even though it maximizes the spectral efficiency, system capacity is not improved significantly. So, an efficient adaptive resource allocation algorithm for multiuser NOMA has been proposed to maximize system capacity and to achieve good QoS. In this proposed adaptive resource allocation algorithm, the resources such as subcarrier, bit and power are efficiently optimized to increase the system capacity of the multiuser NOMA systems. The existing ARA algorithms are not significant enough to meet the near future requirements. Also the existing algorithms provide tradeoff between fairness among the users, system capacity and complexity. Whereas, the proposed resource allocation algorithm jointly achieves guaranteed performance to GP users with good QoS and also maximizes the sum capacity for BE users. The minimum user capacity improvement of the proposed method is around 2.5 bps/Hz compared to existing algorithm and around 5 bps/Hz compared to TDMA when two users share the resources. Also the proposed algorithm achieves the sum capacity of 2.5 bps/Hz greater than the existing method. Similarly this proposed algorithm requires less SNR to achieve the same system capacity of the existing algorithm. Since the bit loading algorithm is

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Cite this article as :

K. Archana, B. Shoba, "Optimal Resource Allocation for Multicarrier NOMA in Short Packet Communications", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 8 Issue 5, pp. 469-475, September-October 2021. Available at doi : https://doi.org/10.32628/IJSRST218558
Journal URL : https://ijsrst.com/IJSRST218558