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Noma Based Communication In 5G Scheme on Nonlinear Real Signal SVM OFDM System.

Hemant Iklodiya, Prof. Madhvi Singh Bhanwar
Department of Electronics and Communication Engineering (DC), SAGE University

Abstract

Due to massive connectivity and increasing demands of various services and data hungry applications, a full-scale implementation of the fifth generation (5G) wireless systems requires more effective radio access techniques. In this regard, non-orthogonal multiple access (NOMA) has recently gained ever-growing attention from both academia and industry. Compared to orthogonal multiple access (OMA) techniques, NOMA is superior in terms of spectral efficiency and is thus appropriate for 5G and beyond. In this article, we provide an overview of NOMA principles and applications. Specifically, the article discusses the fundamentals of power-domain NOMA with single and multiple antennas in both uplink and downlink settings. In addition, the basic principles of code-domain NOMA are elaborated. Further, the article explains various resource allocation techniques such as user pairing and power allocation for NOMA systems; discusses the basic form of cooperative NOMA and its variants; and addresses several opportunities and challenges associated with the compatibility of NOMA with other advanced communication paradigms such as heterogeneous networks and millimeter wave communications.

Keywords: Non-orthogonal multiple access (NOMA), 5G and Beyond, mobile cellular communications, and radio access techniques.

I. INTRODUCTION

This chapter offers a fundamental overview of 5G/6G MIMO-OFDM and MIMO-OFDMDBF and its applications. It describes the Embedded Architecture and its importance in Embedded Wireless Communication Systems. It provides the background theory and the generalized process for this thesis. Further, the concise problem statement along with research objectives creates the foundation for the proposed research.

Cellular or mobile communications have evolved from the formative 2G to 3G, culminating in 4G and LTE with a futuristic outlook for 5G/6G. The bandwidth, data rate, and throughput are the main criteria used to evaluate the performance of new communication systems. The advances in algorithms in communications engineering complemented by the progress in the DSP processors, Embedded Processors and FPGA have provided an impetus for an evergrowing demand for increased data rate and throughput in modern communication systems.

II. MIMO CHANNEL FOR WIRELESS COMMUNICATIONS

Communication through wireless channels depends on the channel conditions. There are time-varying multiple paths during the propagation of a signal through a channel. This results in a time-varying fading channel. A satisfactory communication and reception of a signal under such channel conditions can pose difficulties and challenges. There are different types of channel models:

• Additive White Gaussian Noise: It is a basic model of channel impairment by introducing white noise linearly. The noise distribution is Gaussian. It exhibits constant spectral density (Rappaport 1996) [7].

• Rayleigh Flat Fading Channel: It is used to represent channels with multipath fading and the signal or radio wave propagation is under Non-Line of Sight (NLOS) [7].

• Rician Flat Fading Channel represents a multipath fading channel consisting of many multipath components and a prominent LOS component (Rappaport 1996) [7].

• Nakagami Fading Channel depicts a channel condition where the signal reception takes place after maximum ratio diversity combining.

The Rician and the Nakagami models behave similarly, near their mean values. Nakagami fading is more applicable for multipath scattering with relatively large delay-time spreads. The scattering considers different bands of reflected waves (Rappaport 1996) [7].

• Clarke's Flat Fading Channel is a model where the statistical characteristics are used to deduce the scattering of the electromagnetic fields for the received mobile signal. In this model, the direct LOS consideration is based on the equal average amplitude of the scattered components of the electromagnetic wave at the mobile receiver. Due to this assumption, the arriving scattered component experiences similar attenuations (Rappaport 1996) [7]

• Clarke and Gans Fading Channel is a model which is useful to simulate and analyse the multipath fading conditions of channels in both hardware and software. It is one of the popular simulation models utilising the concept of in-phase and quadrature modulation paths to generate a simulation model of the signal with temporal and spectral behaviours (Rappaport 1996) [7].

III. FADING CHANNEL

In a fading channel, signals undergo fading (fluctuations in the amplitude of the signal) as the signal power falls significantly. This increases the BER which leads to the loss of data. Diversity is the solution to overcome fading. This involves performing the transmission by providing copies of the transmitted signal over time, frequency or space [8]. Different types of diversity modes are available to provide several advantages:

• Time diversity: Time diversity helps to transmit a message at different times (Transmission of the signal at different timeslots over the channel) [8].

• Frequency diversity: This form of diversity helps to transmit the signal with different frequencies. Techniques such as Spread spectrum or OFDM are used [8].

• Space diversity: This is used in MIMO where the antennas are located at different positions to derive the benefits of multipath in communication systems [8].

The diversity of the propagating signal with data is efficiently achieved by MIMO systems because of multiple antennas which provide better diversity [8].

ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

Emerging multicarrier technology such as OFDM, which is meant for a high data rate, is used in WiMAX, LTE and IEEE802.11a. OFDM provides a higher data rate through a multicarrier transmission along frequency selective sub channels. In OFDM, the frequency selective wideband channel is divided into groups of frequency non-selective narrowband channels using IFFT/FFT. This leads to orthogonality among the adjacent channels operating in the respective sub carriers. The frequency domain orthogonality feature of OFDM facilitates the communication system to be robust against large delay spreads.

Interference between the narrowband channels is reduced with the introduction of the cyclic prefix (CP) at the transmitter. Due to interference and channel noise, the modulated signals are corrupted and weakened. To avoid this, the transmitter needs to transmit by using the guard band providing a space between the two sub-channels.

This guard band helps at the receiver to successfully demodulate the signal symbol with fewer errors. In an OFDM signal, the spacing between the modulated carriers is very narrow. The orthogonality facilitates the reception and recovery of the signals without interference, despite the overlap of the sidebands from each sub-carrier. As shown in Figure 1.7, the orthogonality can be realised with carrier spacing. Carrier spacing is reciprocal to the symbol period [12].

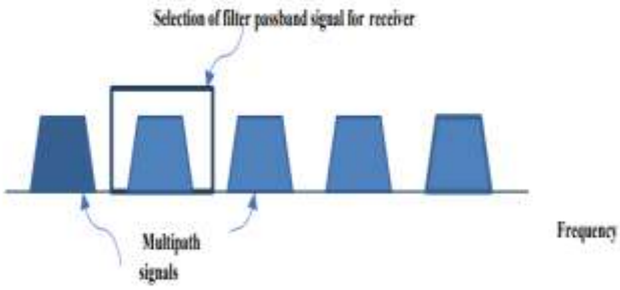

Figure 1 : Conventional view of the Reception of Modulated Signals

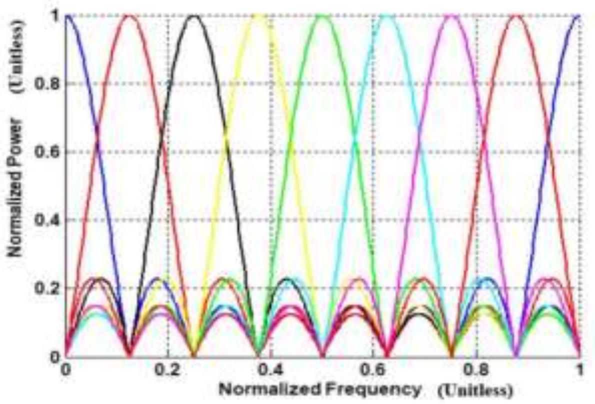

Figure 2: The OFDM Spectrum

The underlying concept of OFDM can be appreciated through the functioning of a receiver. The receiver is comprised of several demodulators to translate an individual carrier through Down Conversion (DC). With the integration of the received signals over a symbol period, recovery or regeneration of the data signal from the OFDM carrier is possible.

The other carrier signals are demodulated by the same demodulator.

There is no contribution of interference in the OFDM spectrum as shown in Figure 1.4 [12]. Transmitting and receiving OFDM systems must satisfy the linearity requirements. Linearity is essential in the sub-systems of the OFDM transmitter and receiver. Non-linearity resulted by inter-modulation distortion leads to interference between the sub-carriers. This interference degrades or impairs the orthogonality feature.

In OFDM, the higher value of Peak to Average Power Ratio (PAPR) introduces distortion of the signal, eventually leading to degradation in its efficiency. To achieve the required efficiency of the OFDM system and lower the PAPR, the RF power amplifier must be operated in a linear range [2].

The Normalized Frequency: In analog the signal frequency is measured in hertz (Hz), or cycle per second. In digital system the digital frequency is the ratio between the analog frequency and the sampling frequency, as shown by the Equation

Digital frequency = analog frequency ÷ sampling frequency

The digital frequency is known as the normalized frequency and is measured in cycle per samples.

IV. 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.

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.

NON-ORTHOGONAL MULTIPLE ACCESS (NOMA)

Non-Orthogonal Multiple Access (NOMA) waveform technology stands at the forefront of contemporary wireless communication systems, revolutionizing the way information is transmitted in the era of 5G and beyond. Unlike traditional orthogonal multiple access schemes, NOMA employs a novel approach by allowing multiple users to share the same time-frequency resources simultaneously [1]. This groundbreaking technique enables a more efficient use of the available spectrum, significantly boosting the overall system capacity and spectral efficiency. In NOMA, users are served with different power levels and modulated symbols, creating distinct signal signatures that can be successfully decoded by the receiver. This nonorthogonal approach maximizes the utilization of resources and enhances the overall network throughput [2]. NOMA also plays a pivotal role in supporting diverse communication requirements, catering to a multitude of devices with varying data rates, latency constraints, and connectivity needs. The versatility of NOMA extends its applications across a spectrum of domains, from enhancing the capacity of massive machine-type communication (mMTC) to providing low-latency connectivity for missioncritical applications [4]. As the telecommunications industry continues to advance, NOMA waveform technology stands as a key enabler for meeting the growing demand for high data rates, improved spectral efficiency, and diverse connectivity in the ever-evolving landscape of wireless communication. The detection of signals in NOMA waveforms is a critical aspect that underpins the efficiency and reliability of this advanced communication technology.

NOMA relies on non-orthogonal resource allocation, where multiple users share the same time-frequency resources, each assigned a unique power level and modulated symbols [5].

V. PROPOSED METHODOLOGY

The "5G Scheme on Nonlinear Real Signal SVM OFDM System" combines multiple advanced communication concepts. Here's a step-by-step explanation of the process, integrating Support Vector Machine (SVM), Orthogonal Frequency Division Multiplexing (OFDM), and handling nonlinearities in real-valued signals — all within the context of 5G systems:

1. System Overview

In 5G, OFDM is a core modulation technique. It is highly efficient in handling high data rates and multipath fading. However, real-world components like power amplifiers introduce nonlinear distortions, especially in high Peak-to-Average Power Ratio (PAPR) systems like OFDM. Here, SVM (Support Vector Machine) is used for:

- Signal classification
- Channel estimation
- Nonlinearity compensation or equalization

2. Signal Flow Diagram (Block-wise)

Input Data → Modulation (QPSK/QAM) → OFDM Modulation (IFFT) → Nonlinear Channel (e.g., Power Amplifier) → Receiver with SVM-based Equalizer → OFDM Demodulation (FFT) → Demodulation → Output Data

3. Step-by-Step Process

a. Data Generation & Modulation

- Input binary data is mapped using modulation schemes like QPSK or 16-QAM.
- Resulting symbols are real or complex valued (but real-valued signals are often preferred in simplified models or specific hardware).

b. OFDM Modulation

- Apply IFFT (Inverse Fast Fourier Transform) to modulated data to generate OFDM symbols.
- Add cyclic prefix (CP) to combat Inter-Symbol Interference (ISI).

c. Nonlinear Channel Modeling

- The OFDM signal is passed through a nonlinear system, often modeled using:

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  - Memoryless nonlinearity (e.g., Saleh model)
  - Power amplifier (PA) distortions
- Nonlinear effects distort the OFDM signal and create Inter-Carrier Interference (ICI).

d. Support Vector Machine (SVM) Application

- SVM Regression or Classification is applied to either:
  - Equalize the distorted OFDM signal
  - Estimate the channel with nonlinear effects
  - Detect symbols in a nonlinear and noisy environment

Training phase:

- Known training data is sent through the system.
- The SVM learns the nonlinear mapping from input (received signal) to output (actual transmitted data).

Testing phase:

- The SVM predicts or corrects the received data using the learned model.

e. OFDM Demodulation

- After SVM correction, FFT is applied to convert back from time to frequency domain.
- The cyclic prefix is removed before FFT.

f. Symbol Detection and Demodulation

- Detect original data symbols using standard demodulators.
- Compare with original to calculate Bit Error Rate (BER) and system performance.

5. Benefits of Using SVM in 5G Nonlinear OFDM

- Handles nonlinearities effectively without exact channel modeling
- Improves BER and SNR performance
- Suitable for non-Gaussian, impulsive noise environments
- Adaptable to real-time systems with proper training

6. Applications

- 5G uplink where UE transmits over nonlinear PA
- Smart receivers for low-cost or IoT 5G devices
- AI-powered SDR (Software Defined Radio) systems

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VI. RESULT AND SIMULATION

MATLAB provides a powerful environment for simulating 5G communication systems through its specialized toolboxes, particularly the 5G Toolbox and Communications Toolbox. These toolboxes enable researchers and engineers to model, simulate, and analyze the physical layer and radio access technologies of 5G New Radio (NR). Using built-in functions and standard-compliant waveforms, users can simulate key features such as OFDM modulation, MIMO transmission, beamforming, channel estimation, and link-level performance under varying conditions. The toolbox supports 3GPP Release 15 and beyond, making it ideal for testing advanced techniques like massive MIMO, mmWave propagation, and carrier aggregation. Overall, MATLAB's integrated simulation capabilities accelerate the design, prototyping, and validation of 5G systems in both academic and industrial settings.

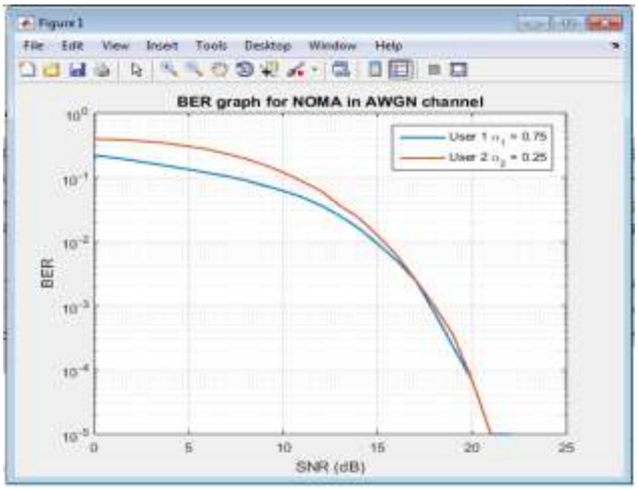

Figure 3 BER and SNR curve.

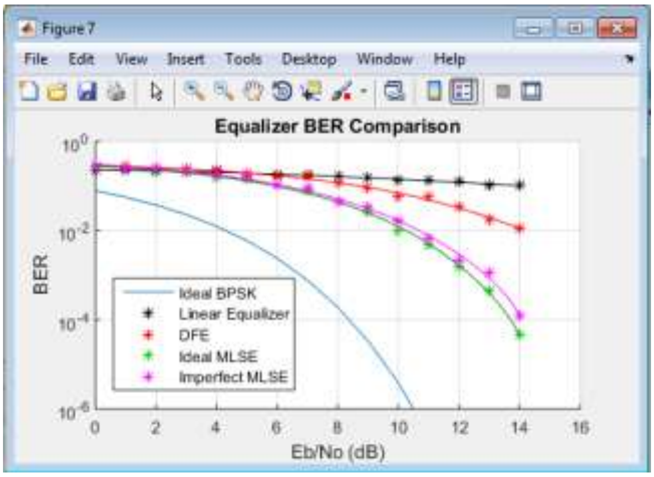

Figure 4 Comparison curve.

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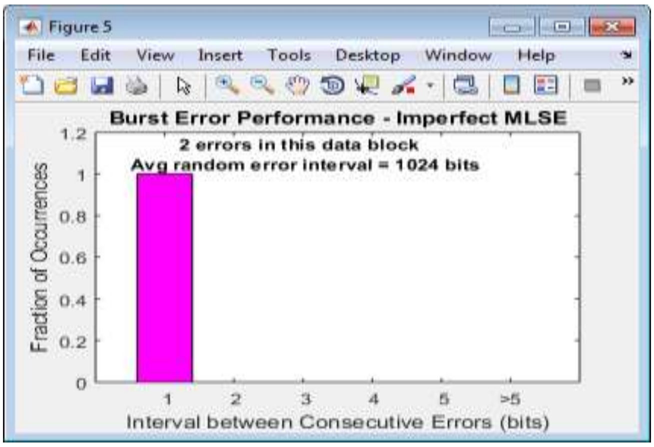

Figure 5 SVM Error.

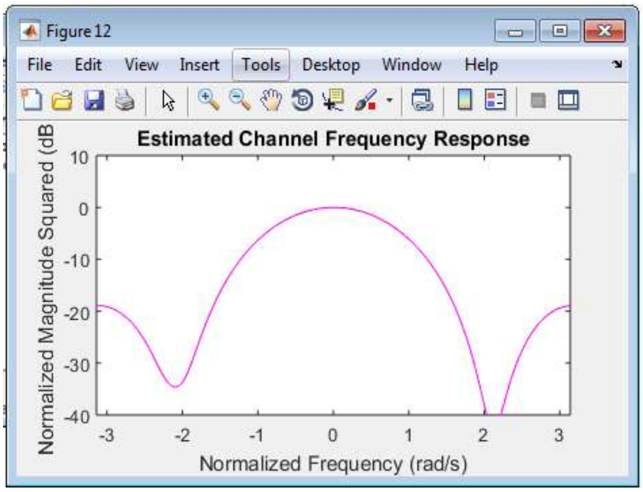

Figure 6 Channel Frequency response.

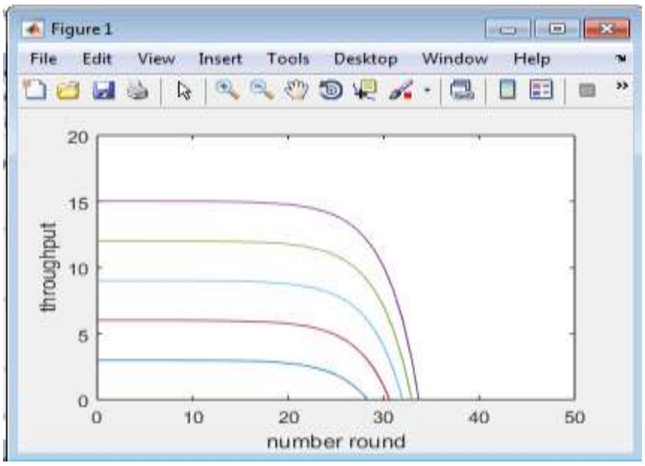

Figure 7 Throughput.

VII. CONCLUSION AND FUTURE SCOPE

CONCLUSION

This study has demonstrated the effectiveness of using SVM for NOMA signal detection in wireless communication systems. The SVM-based method showed better performance in reliably classifying and demodulating NOMA signals, even when interference was present. This was a major problem that had to be solved in NOMA enabled communication networks. The SVM is a good way to deal with the problems that come up with NOMA signal identification because it is good at classifying things and finding the best hyperplanes in environments with a lot of dimensions. During the testing and training phases, the SVM model showed that it could learn and generalize patterns from characterized datasets very well. This made it possible to detect signals in real time in a wide range of dynamic settings. The encouraging results of this study not only develop NOMA communication systems but also demonstrate how machine learning methods, especially SVM, may be used to maximize wireless network performance. The results show that using SVM-based detection methods can make NOMA's communication systems much more reliable and efficient, which will help the development of next-generation wireless technologies. There are other directions to pursue in this area in the future. First, the SVM model can be further improved to maximize its parameters and increase its flexibility in response to changing signal conditions. Furthermore, for practical applications, it will be essential to examine how well Sambaed NOMA signal recognition performs in the presence of real-world impairments and channel uncertainty. To improve detection even more, the use of sophisticated machine learning methods, including deep learning algorithms, might be investigated. Because they automatically pull-out hierarchical characteristics, deep learning models might be able to help us learn more about and improve NOMA signal detection, which is a very complicated field. Additionally, it is necessary to look into how well the suggested SVM-based technique scales and applies to large-scale, multi-user NOMA scenarios. It will be crucial for NOMA's continuous success to modify and expand the suggested SVM-based detection approach in order to handle the complexity of changing communication networks as it becomes more and more prominent in future communication standards.

FUTURE SCOPE

The integration of Support Vector Machine (SVM) techniques with Orthogonal Frequency Division Multiplexing (OFDM) in nonlinear real signal environments presents a promising direction for enhancing 5G communication systems. As wireless networks encounter increasing complexity due to nonlinear distortions from power amplifiers, channel noise, and hardware impairments, the use of SVM-based learning algorithms can significantly improve signal detection and classification accuracy. Future research can focus on optimizing SVM models for real-time processing in massive MIMO and mmWave systems, reducing computational complexity, and adapting to time-varying channels. Additionally, the combination of machine learning with advanced error correction and adaptive modulation schemes could further improve spectral efficiency and reliability. This approach also opens avenues for 6G technologies, where intelligent signal processing and AI-driven communication will be critical.

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