A Survey on Non-Orthogonal Multiple Access (NOMA) For 5G Systems And Beyond

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Abstract- *This paper presents a comprehensive survey on Non-Orthogonal Multiple access for 5G systems and onwards. With the advent of 5G Communications, increasing number of users, increased bandwidth and data requirement yet limited bandwidth availability have become serious challenges. Hence 5G networks would need improved multiple access techniques than their present day counterparts. Non-Orthogonal Multiple access is a technique in which multiple users data is separated in the power domain. The problems addressed by NOMA are low overall bandwidth for multiple users.*

Keywords- 5G, Non-orthogonal multiple access (NOMA, Bit Error Rate (BER), Quality of Service.

I. INTRODUCTION

With increased number of users, higher data traffic due to big data technologies and limited bandwidth; it has become mandatory to offer networking services with high Quality of Service, (QoS). [1] Multi-user scenario has become a commonplace. The challenge which networks face is however the detection of all users with equal accuracy. As we can see the high paced networking of communications globally, this can be seen as one of major progress in technical aspect in our civilization to date. It became possible only with the onset and use of the digital communication framework in the world today. [2] The recent era demands a very high speed networking environment to keep pace with the ongoing technical advancements. With increase in noise and many other reasons and causes for distortion of the signal, it remains a challenge to be able to send the signal correctly. The sole aim of the communication system that is digital is to send transmit signal properly and without any distortion with least errors.

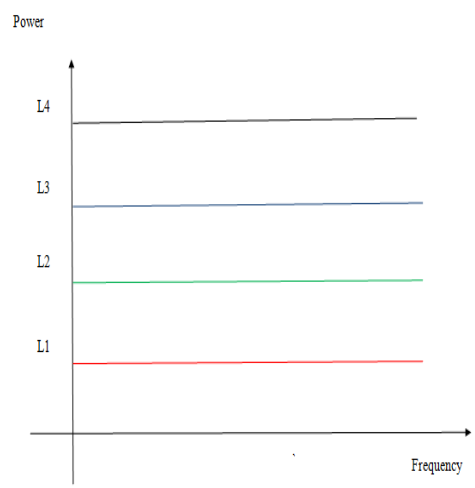

Fig.1 Concept of NOMA

There arises a need for a huge bandwidth for the implementation of the fast digital communication networks. These systems are prepared as such, so that they can send very high speed data over the networks. [5] The medium happens to be the channel incorporating the transmitter and the receiver and the receiver gets the data from sender. At the point of the receiver, the demodulation of signal is done initially to recover the baseband signal. The processing of the demodulated signal is done then by the filter at the receiving end also termed as the demodulating filter at receiver, and this should match with the signal sent by the transmitter.

II. COMPARISON OF FDM, OFDM AND NOMA

A comparative spectral analysis of FDM, OFDM and NOMA is shown in the figure below.

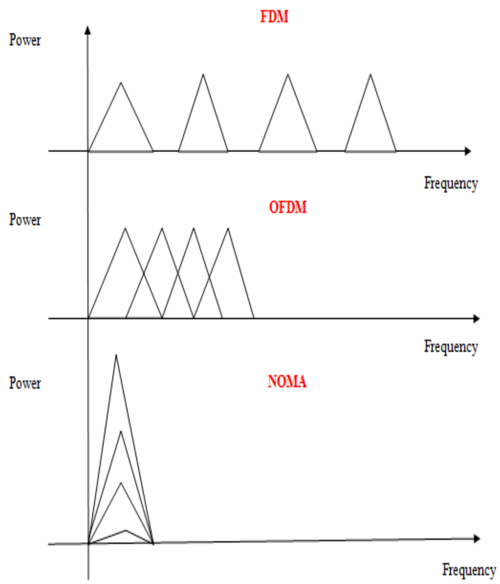

Fig.1 Comparative Spectra of FDM, OFDM and NOMA

It can be seen that NOMA utilizes lesser bandwidth compared to OFDM and FDM. Hence it is preferred for 5G systems.

III. PREVIOUS WORK

The following section presents the previous work in the related field.

In the year 2018, X.Wang et al. proposed that Multi-User Detection (MUD) for uplink grant-free Non-orthogonal Multiple Access (NOMA) has received much attention recently. In this paper, the authors consider the scenario in which a Base Station (BS) is equipped with multiple antennas, and propose a Compressive Sensing-based Hard Fusion Algorithm (CSHFA) to realize multi-user detection. More explicitly, they detect the user activity information by a conventional CS algorithm at each antenna, and then amalgamate the detected user activity information to derive an active user set. [4]Finally, the authors can use the obtained active user set to estimate the active users' data. The proposed CS-HFA with low complexity for uplink grant-free Single-Input Multiple- Output Non-Orthogonal Multiple Access (SIMO-NOMA) systems can achieve better BER performance than traditional CS-based MUD in the NOMA system with single antenna at the BS.[6]

In the year 2016, B. Wang at al. proposed a technique based on compressive sensing of the wireless channel or radio between the transmitting and receiving ends. The approach was rather customized for up-link data transmission form several nodes to a common receiving point or node. The approach was based on the dynamic compressive sensing of the radio wherein the channel state information was sensed using compressive sensing. The channel state information using compressive sensing needs to be continually adapted in order to update the channel matrix. It was shown that the system attained low bit error rate but the downside was the low spectral efficiency.

In the year 2016, J.Choi et al. put forth a mechanism for maximum likelihood detector for channel estimator. In this case, a one bit analog to digital converter was used for detecting the values of the received signal stream and to be adjudged as bit-0 or bit-1. The maximum likelihood approach was rather effective in deciding upon the soft threshold of signal detected based on the soft threshold probability. Moreover a MIMO system was employed upon which multiple transmitters and multiple receivers contributed to the channel estimation information updating log.

In the year 2016, Maha Alodeh et al. proposed a technique for multi user detection which used an energy efficient mechanism based on symbol level pre-coding of data stream prior to transmission. The approach followed interleaved pre-coding so as to avoid burst errors in packet data transmission. The approach was well suited to multi user scenario in with a Multiple Input Single Output (MISO) framework. The detection region was termed as relaxed detection region due to the fact that the proposed technique used large degrees of freedom for the actual signal detection.

In the year 2015, Fabian Monsees et al. proposed a technique based on compressive sensing for sporadic machine type communication. In this approach, the authors used a compressive sensing technique for sensing the channel to find out the channel's frequency response. The approach is rather sporadic wherein the shadowing or noise effects are pre-dominant only in certain frequency ranges. The simulations are run for varying shadowing effects and the performance is evaluated based on the Bit Error Rate of the system corresponding to different parameters.

In the year 2015, Bichai Wang et al. proposed a new system for multi user detection which used Compressive sensing using the energy detector approach. The approach was suited for non-orthogonal access. The technique was intended for spectral widths of users which were separated by large guard bands and hence was used for uplink access. The proposed system did not use cyclo-stationarity as a comparative parameter which is generally considered for multi-user detection in spectrum holes of the available spectra.

IV. PREVIOUS WORK

Different PAPR reduction techniques can be broadly categorized as:

In [1],Gurtej Singh Toor, Harjinder Singh, Amandeep Singh Bhandari have simulated and the explained concept and results prove to be better than previous methods in terms of PAPR reduction and BER improvement. It is observed that PAPR is reduced to 2.8dB by using SLM combined with logarithmic companding. By using suitable parameters BER performance of the system improves. The system is also less complex due to limiting phase sequence in SLM to 16 phase sequences. As conventional SLM is being used in this technique, the limitation here is that SLM requires additional data to be transmitted along with the OFDM data. This additional data is the Phase sequence of the selected SLM output. This reduces the overall data rate of the system.

In [2], Chunjiang Duanmu , Hongtao Chen concluded that For the improvement of the PAPR performance, the clipping technique is simple and effective. However, it can bring out-of-band interferences, and much degradation of the BER performance of the system. The coding technique can obtain a relatively simple and stable system performance. Its shortcoming is that when the number of sub-carriers increases, the throughput of the system will be significantly degraded and the efficiency of the spectrum usage will be lowered. This technique is only suitable for the system with a relatively low number of sub-channels and a high requirement of system stability.

In [3], Houshou Chen and Hsinying Liang have proposed a modified SLM algorithm by decomposing a cyclic code into a direct sum of a correction subcode for encoding information bits and a scrambling subcode for encoding PAPR control bits. Consequently, we can use any decoding technique of cyclic codes and the modified algorithm provides error correction and PAPR control simultaneously.

In [4], Haris P. A, Sen Jose proposed an alternative PAPR reduction technique based on combination of a selected mapping method with the clipping method. We have used selected mapping technique followed by the clipping operation. The simulation results show that the hybrid scheme brings higher PAPR reduction than the component methods. And we got an affordable BER performance for the proposed design compared with the conventional OFDM system

In [5], A. D. S. Jayalath and C. Tellambura proposed a novel blind detection algorithm is proposed to decode SLM-OFDM signals without side information. This algorithm performs equally well in both AWGN and fading channels without any BER degradation. It offers reliable performance in conjunction with trellis based forward error correction codes such as TCM. The proposed BSLM algorithm can decode coded OFDM symbols completely in both AWGN and fading channels even in the presence of a non-linear amplifier. The proposed suboptimal metric can be used to decode uncoded SLM-OFDM signals completely in AWGN channels and with a slight BER degradation in fading channels.

In [6], Marco Breiling, Stefan H. Müller-Weinfurtner, and Johannes B. Huber proposed a powerful extension for SLM PAR reduction and demonstrated its operability for the special case of convolutionally-coded OFDM transmission. The scheme refrains from explicit transmission of side information by a label insertion and scrambling approach where only little redundancy needs to be introduced into the signal. On the other hand, the transmit signal statistics and the spectral properties in presence of transmitter nonlinearities are decisively improved such that a saving of 1 to 2 dB in backoff can easily be achieved.We emphasize again that SLM is also suitable for other modulation schemes, e.g., single carrier modulation.

In [7], K. Kasiri and M. J. Dehghani presented a distortion-less technique for reducing the PAPR of the OFDM system. The method introduced here for Blind SLM is the same as conventional SLM algorithm, in terms of PAPR reduction and Bit Error Rate performance. In other words, 5 subcarriers among the total of 64 subcarriers do not affect the system performance. In return, these reserved subcarriers will help the receiver to detect the symbol transmitted through the channel. As a result the drawback of the SLM technique in sending extra information will be eliminated.

In [8], Ms. V. B. Malode1, Dr. B. P. Patil proposed a modified selective mapping technique is proposed in the paper to improve the performance of the OFDM system with respective PAPR[8]. This scheme requires only one IFFT block at the transmitter. Results of simulation of modified SLM technique show that the PAPR reduction of OFDM system, which further results in high performance of wireless communication.

V. MATHEMATICAL MODELLING FOR NOMA BASED SIGNAL DETECTION

Considering signals of different users travelling through different paths {R}, then the received signal would be:

R(n), R(n-1), R(n-2)… are the delayed version of the received bits(1)

e(n) is the actuating error signal

F(n) is the weight adapting function corresponding to different paths(2)

S(n) is the final signal at the receiving end (at demodulator) (3)

The approach focuses on detecting the strongest among a set of composites and then iterating the process i.e.

$$Find: \max(Sn)\, to\ evaluate\ x1 = max \quad (4)$$

Here,
x1 is the strongest in search of iteration 1.
The iteration is carried out till the last of the composite NOMA signal is not decoded.
The composite signal at a distance d can be statistically expressed as:

$$\bar{L}(d) = \bar{L}(d_0) + 10n\ log_1 \quad (5)$$

d_o=reference distance

n= constant value which is 2for LOS link but mostly uses higher than 2 for Multi path channel in NOMA based system

$$L(d) = \bar{L}(d_0) + 10n\ log_{10}\left(\frac{d}{d_0}\right) + \quad (6)$$

VI. CONCLUSION

It can be concluded from previous discussions that NOMA is an effective prospect for 5G systems and onwards due to its extremely high spectral efficiency. However, challenges remain in attaining low Bit Error Rate (BER) and system complexity. Since future generation networks would be hard pressed for bandwidth and high data rates, NOMA can serve as the multiplexing technique. The paper presents contemporary work on NOMA which may pave the path for future researchers.

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