Implementation of Successive Power Level Detection and Equalization for NOMA

Nidhi Kumar Sahu[1] Deepak Sharma[2]
[1]M-Tech Scholar [2]Assistant Professor
[1,2]Lord Krishna College of Technology, Indore, India

Abstract— With the rapid increase in the number of cellular users and increase in data size, the bandwidth crunch for 5G systems and onwards has become a serious problem. The need for multiplexing techniques which can accommodate more number of users and yet render satisfactory Quality of Service (QoS) is indispensable. Orthogonal Frequency Division Multiplexing (OFDM) has been used widely for 3G and 4G based systems, however Non-Orthogonal Multiple Access (NOMA) has been the frontrunner for the future based cellular system due to its higher spectral efficiency. It has its associated problems too, which happens to be separation of the signals at the receiving end in power domain. This paper presents a technique which uses successive power level detection and equalization to attain accurate separation of signals at the receiver and achieve satisfactory Quality of Service (QoS). Additionally, channel equalization has been incorporated to nullify the adverse effects in the channel. The performance of the system has been evaluated based on the Bit Error Rate (BER) of the system for different path gains for signals. It has been shown that the proposed system attains better BER performance compared to conventional and existing previous systems.

Keywords: Non-Orthogonal Multiple Access (NOMA), Orthogonal Frequency Division Multiplexing (OFDM), Successive Power Level Detection, Equalization, Bit Error Rate (BER), Quality of Service (QoS)

I. INTRODUCTION

The major challenge which cellular systems are facing today are increase in the number of users, limited bandwidth availability and increase in the data size due to big data applications. This calls for techniques which can utilize the available bandwidth efficiently and yet maintain the required Quality of Service (QoS)[1]. NOMA is the contender for the future generation cellular systems owing to its spectral efficiency. While frequency division multiplexing and time division multiplexing separate signals in the frequency and time domain respectively, NOMA separates the signals in the power domain. This allows simultaneous transmission at the same time and spectral band thereby increasing the spectral efficiency of the system[2]. The difference in the power levels needs to be maintained so as to facilitate the receiver in detecting the different signals arriving at the receiving end with high accuracy. This is a major challenge since channels behave in a frequency selective nature and invariably cause fading effects. The concept of NOMA can be clearly understood by the figure depicted below.

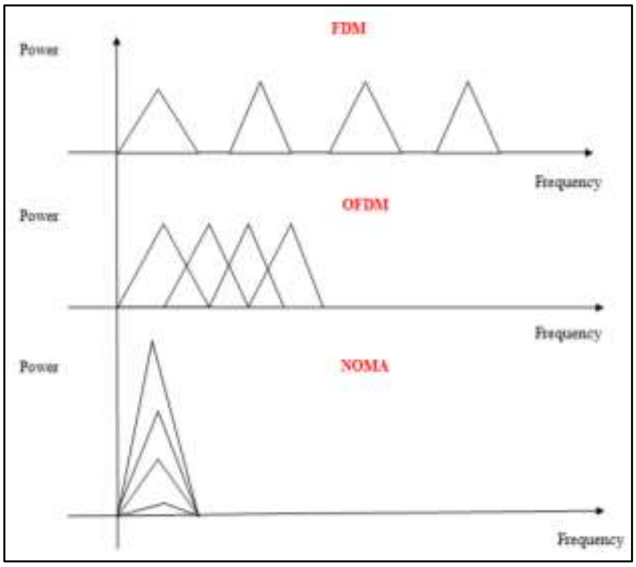

Fig. 1: Spectral of FDM, OFDM and NOMA [3]

It can be clearly seen that the bandwidth saving in case of NOMA is significantly larger compared to FDM and OFDM which leads to the following possibilities:

1) Incorporating more number of users for a given amount of bandwidth
2) Allocation of more bandwidth per user.

II. FREQUENCY SELECTIVE NATURE OF WIRELESS CHANNELS

Most wireless channels are frequency selective in nature. Mathematically,

$$H = f(freq, t) \quad (1)$$

Here,
H represents the channel response of a wireless channel
f represents a function of
freq represents frequency
t represents time.

Thus it can be seen that the channel response not only temporal variations but also frequency selective nature which leads to different path gains. This results in different fading effects and a non-ideal channel impulse response depicted in figure 2.Mathematically, such an impulse response can be modelled as:

$$h(t) = \int_{i=1}^{n} \delta(t - it_0) \quad (2)$$

Here,
h(t) is the impulse response of the wireless channel
n is the number of multiple paths corresponding to the number of delayed versions of the impulse
t_0 is the average time after which the delays occur
δ represents a delta function.

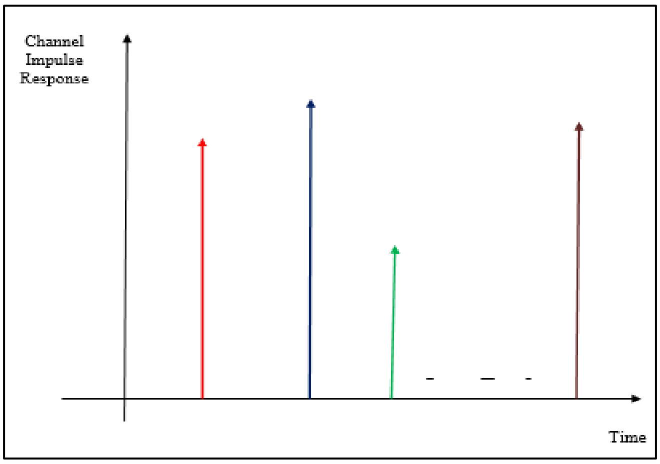

Fig. 2: Temporal Impulse Response of a frequency Selective Channel [4]

Such an impulse response leads to variable fading effects and hence variation of the power level at the receiving end [5]-[6]. The envelope of the signal varies at the receiver and hence makes is challenging to maintain the amount of separation at the receiver among different signals.

III. PROPOSED SYSTEM WITH SUCCESSIVE POWER LEVEL DETECTION AND EQUALIZATION

The proposed system aims at designing a system which can rectify the following effects of the channel:

1) Fading effects resulting in separating the signals in the power domain
2) Degraded BER performance of the system resulting in poor Quality of Service (QoS).

The the power domain. This is given by:

$$s(t) = s1 + s2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots . sn \quad (3)$$

Here,
S1, s2 ….. sn are the different signals corresponding to the different users
s(t) is the composite signal reaching the receiving end.

For this purpose, the successive power level detection and channel equalization is proposed. The proposed algorithm is explained below:

1) Generate the QAM modulated NOMA signal to the transmitted.
2) Design a frequency selective channel. The channel would exhibit temporal as well as frequency selective nature given by equations (1) and (2)
3) Add noise in the channel to emulate a practical Additive White Gaussian Noise (AWGN) condition given mathematically as:

$$Noise_{psd} = \frac{N_0}{2} \; \forall f \quad (4)$$

Here,
psd represents the power spectral density
f represents frequency
$\frac{N_0}{2}$ represents the two sided AWGN psd

4) Transmit signal through channel
5) The equalization is implemented by sounding the channel at every repetitive interval 'T' and estimating the channel response H(f,t). The errors in channel estimation can be minimized by employing the following relation:

$$E_h = mean\{e^2[n]\} \rightarrow 0 \quad (5)$$

Here,
E_h denotes the error in estimation
e denotes current error sample value
n denotes the number of error samples

6) At time ant time 't', for n received signals,

for (i=1:n)
{
Find Max[s(t)],
Where,
s(t) is the composite NOMA signal given by:

$$s(t) = \sum_{i=1}^{n} s_i(t) \quad (6)$$

Detect Max[s(t)],
Cancel Max[s(t)] from s(t)
}
end

7) Compute BER of the system for different signals with varying path gains

Here,
n is the number of user signals in the composite NOMA signal
The iterations are run till all the signals are detected. The comparison of the power levels of such a composite multi-level signal is carried out by a multi-level comparator.

IV. RESULTS AND DISCUSSIONS

The results have been simulated on Matlab 2018a

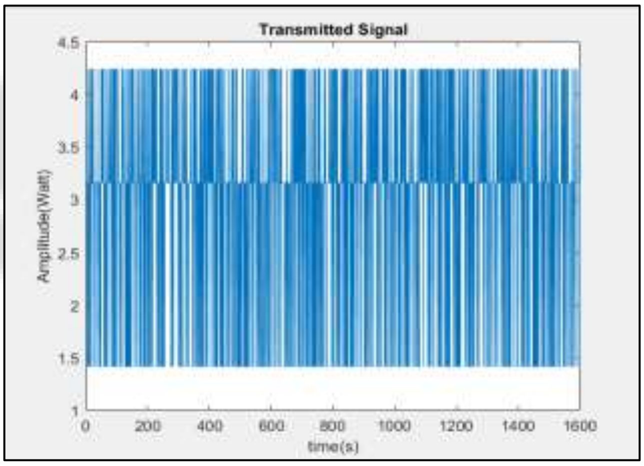

Fig. 3: 16-QAM transmitted

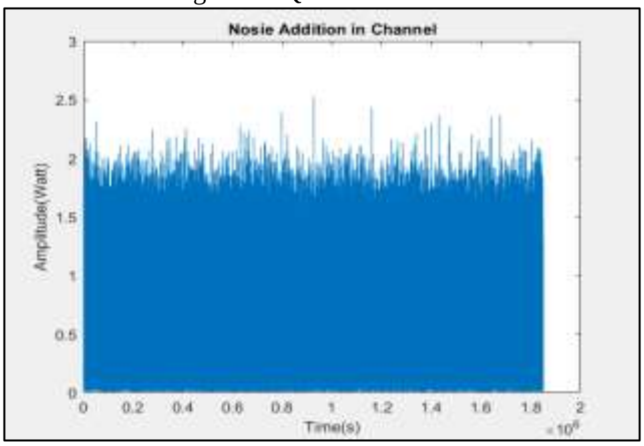

Fig. 4: Addition of Noise in Channel

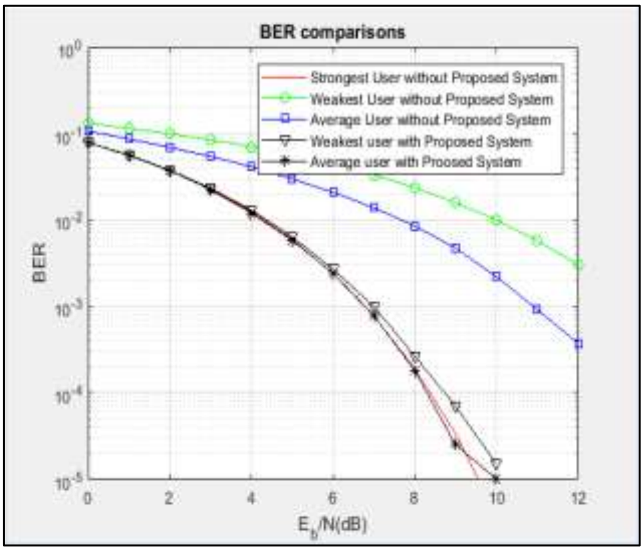

Fig. 5: Obtained BER for the proposed system

- Fig.3 depicts the NOMA signal employing 16 point Quadrature Amplitude Modulation (QAM).
- Fig.4 depicts the random white noise added in the channel governed by (4).
- Fig.5 depicts the comparative BER analysis with and without the proposed system. Three different cases have been considered based on the fading effects in the channel. The signal with the least fading corresponds to the strongest user, the one with the maximum fading corresponds to the weakest user and the one which stands intermediate corresponds to the average user. The BER obtained of the proposed system reaches almost 10^{-5} for an SNR of 10dB which is significantly less compared to the BER of 10^{-3} of conventional and previously existing techniques [7]-[8].

V. Conclusion

It can be concluded from previous discussions that NOMA would become invariable to be used for future generation cellular system due to its high spectral efficiency. However, the difficulty in error free reception lies in the fact that fading effects in the channel along with addition of noise leads to degradation on the power level separation. This paper presents a successive power level separation along with channel equalization for the implementation of NOMA. It has been shown that the proposed system achieves lower BER compared to contemporary and previously existing techniques.

References

[1] https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-450-principles-of-digital-communications-i-fall-2006/video-lectures/lecture-20-introduction-of-wireless-communication.
[2] M.F.Mesiya, "Comtemporary Communcations", 1st Edition, McGraw Hill Publications
[3] Andreas F.Molisch, "Wireless Communcation", 4th Edition, WileyPublications.
[4] J Choi, J Mo, RW Heath, "Near maximum-likelihood detector and channel estimator for uplink multiuser massive MIMO systems with one-bit ADCs", Vol-64, Issue-5, IEEE Xplore- 2016
[5] Maha Alodeh ; Symeon Chatzinotas ; Björn Ottersten, "Energy-Efficient Symbol-Level Precoding in Multiuser MISO Based on Relaxed Detection Region", Vol-15, Issue-5, IEEE Xplore- 2016
[6] Bichai Wang ; Linglong Dai ; Yifei Yuan ; Zhaocheng Wang, "Compressive Sensing Based Multi-User Detection for Uplink Grant-Free Non-Orthogonal Multiple Access", IEEE-Xplore 2015
[7] B Wang, L Dai, Y Zhang, T Mir, "Dynamic compressive sensing-based multi-user detection for uplink grant-free NOMA", Vol-20, Issue-11, IEEE 2017
[8] Xiaojuan Zhao, Shouyi Yang, Aihua Zhang, Xiaoyu Li, "A Compressive Sensing Based Multi-user Detection Algorithm for SIMO-NOMA Systems",15th International Symposium on Wireless Communication Systems (ISWCS) IEEE 2018