Design And Implementation of NOMA With Successive Signal Detection And Equalization For 5G Networks

Mr. Abhijeet Srivastava[1], Prof. Vijay Bisen[2]
[1, 2] Dept of Electronics & Communication
[2]Professor, Dept of Electronics & Communication
[1, 2] VITM, Indore (M.P.)

Abstract- *With increasing number of users and increased bandwidth requirement for each user due to multimedia applications, need for more effective multiplexing techniques have arisen. Non orthogonal multiple access of NOMA has emerged as a key contender for the same due to the fact that NOMA doesn't need to adhere to orthogonality among different sub-carriers like OFDM. Moreover, it doesn't need to circumvent the problems of high peak to average power ratio (PAPR). NOMA is based on the separation of signals in the power domain. In this paper, a NOMA based system for a practical wireless scenario is designed. However, due to the enormity in the difference f power levels, the NOMA scheme is prone to high bit error rate (BER). The proposed work uses a successive signal detection mechanism with channel equalization to implement NOMA and attain low BER values.*

Keywords- Non orthogonal multiple access (NOMA) Inter Symbol Interference (ISI), Channel Equalizer, Successive Signal detection, Bit Error Rate (BER).

I. INTRODUCTION

In recent years, fifth generation (5G) wireless networks have attracted extensive research interest. According to the 3rd generation partnership project (3GPP)[1], 5G networks should support three major families of applications, including enhanced mobile broadband (EMBB) [1] massive machine type communications (MMTC) [1], [2]; and ultra-reliable and low-latency communications (URLLC) [1], [2]. On top of this, enhanced vehicle-to-everything (eV2X) communications are also considered as an important service that should be supported by 5G networks [1].

These scenarios require massive connectivity with high system throughput and improved spectral efficiency. In NOMA, the signals are separated in the power domain which is depicted in figure 1.

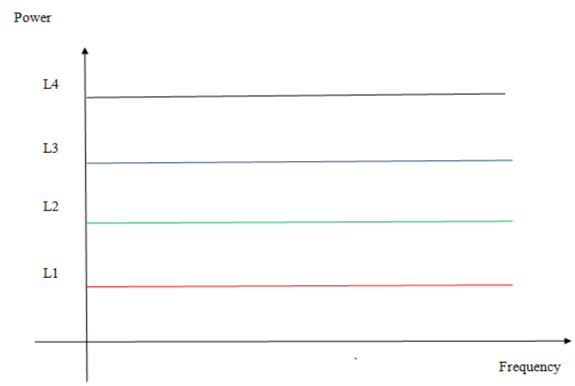

Fig.1 Separation of signals in Power Domain using NOMA

Let u(t) be the transmitted signal. If N co-efficient are represented by A_1, A_2, A_3, A4...A_N and the strength of the reflections is a_1, a_2, a_3,.. ,a_N then the weighted received signal y(t) is given by:

$$y(t) = a1u(t-A1)+ a2u(t-A2)+ \ldots\ldots\ldots+ aNu(t-A_N)+n(t) \quad (1)$$

Where,

n(t) represents additive interferences.

This model of the transmission channel has the form of a finite impulse response filter, and the total length of time AN - A1 over which the impulse response is nonzero is called the delay spread of the physical medium.

This transmission channel is typically modeled digitally assuming a fixed sampling period T_s. The above expression can be approximated as:

$$y(kTs)=a1u(kTs)+a2u((k-1\ )Ts)+\ldots\ldots+aNu((k-n)Ts)+n(kTs) \quad (2)$$

The total time over which the impulse response is nonzero (the time pT_s) must be at least as large as the maximum delay A_N .Since the delay is not a function of the symbol period T_s, smaller T_s require more terms in the filter, i.e., larger n.

The Successive Signal Detection Approach for NOMA

The successive signal detection approach can be understood by the diagram shown below:

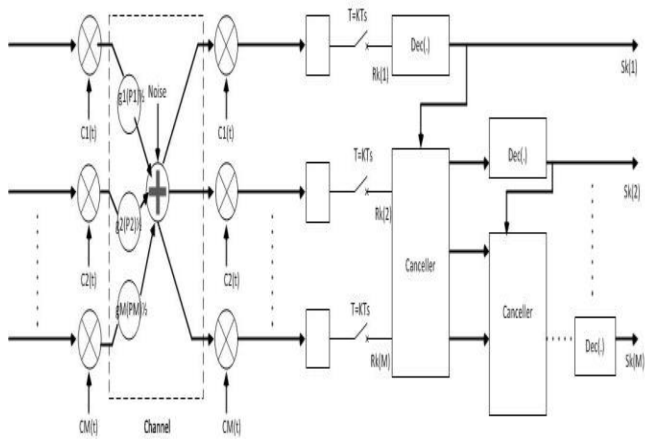

Fig.2 Successive Signal Detection Approach for NOMA

This approach utilizes the fact that it is the easiest to detect the signal with the least run-length or the maximum power compared to all the signals arriving at the receiver. Hence the approach detects the signal with the maximum strength, saves it and cancels it from the composite signal arriving at the receiver. This process is performed iteratively. It tries to emulate a single signal scenario among the multi-path scenario of different MPCs.

II. MATHEMATICAL MODELLING OF PROPOSED APPROACH

In light of the explained approach, it is necessary to derive its mathematical formulation which is given below:

a) Individual signal strength of each MPC be given by:

$$S_i = g_i\sqrt{P_i} \qquad (3)$$

Where S represents i^{th} MPC power,
'g' represents gain of the i^{th} path
P represents the power of the i^{th} MPC

b) The cross correlation of the spreading function applied on the data stream:

$$\text{Spreading Function} = R_i, j(k)$$

c) The noise statistics for the k^{th}sample

i.e. $n_i(k)$

Thus the different MPCscorresponding to paths can be mathematically written as:

$$r_k = R_k.D.S_k + n_k \qquad (4)$$

Where D represents the signal strength matrix corresponding to different MPCs given by:

$$S_i = g_i\sqrt{P_i} \qquad (5)$$

The proposed algorithm can be explained as: Let the various MPC strengths be:

$$S_1.G_1,\ S_2.G_2,\ S_3.G_3 \ldots\ldots\ldots\ldots\ldots\ldots S_n.G_n$$

It can be observed that the signal power of transmitter is multiplied with the corresponding channel gain where the channel gain for different MPCs varies due to frequency selectivity of the channel.Considering that we have the information about the signal strengths given by equation :

$$P_1 g_1{}^2 > P_2 g_2{}^2 > \ldots\ldots\ldots\ldots\ldots\ldots\ldots P_M g_M{}^2 \quad (6)$$

We decide the strongest among all the received user MPCs.

2. Detect the k^{th}strongest MPC among all the signals using the following equation:

$$S_k = dec(P_i G_i)^M$$

3. Cancel the first strongest MPC interference at the receiver end according to the equation:

$$y_{e+1}^{(i)} = y_e^{(i)} - g_e\sqrt{P_e}R_i, e(k)\hat{S}_k^{(e)} \qquad (7)$$

Here we subtract the interference from the strongest interfering signal from each signal received at the receiver using the Decision Feedback actuating Signal $e(k)S_k^{(e)}$

4. let k=1, and repeat the above process for all the received signals up to k=M

Plot the BER performance for the proposed system for the following cases:

a) When there is only one signal travelling from transmitter to receiver

b) When multiple signals with multiple run lengths are travelling from transmitter to receiver.
c) MPC governed BER without proposed system
d) MPC governed BER with proposed system.

The system is said to exhibit equalizing effects only if the MPC governed BER performance matches to a large extent the one without multi path communication and hence no multi path propagation.

Channel Equalization for NOMA

To circumvent the negative effects of the channel on the composite NOMA signal, channel equalization is proposed. The implementation of the equalization is given below:.

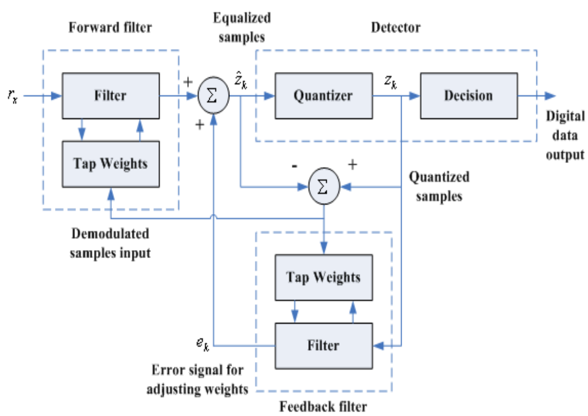

Fig.3 Block Diagram for channel equalization in NOMA

The above cited approach uses decision feedback to cancel the interference from symbols which have already have been detected. The equalized signal is the sum of the outputs of the forward and feedback parts of the equalizer. The forward part is like the linear transversal equalizer. Decisions made on the equalized signal are fed back via a second transversal filter. The basic idea is that if the values of the symbols already detected are known (past decisions are assumed correct), then the ISI contributed by these symbols can be canceled exactly, by subtracting past symbol values with appropriate weighting from the equalizer output.Since the output of the feedback section of the equalizer is a weighted sum of noise- free past decisions, the feedback coefficients play no part in determining the noise power at the equalizer output. However, the equalizer can compensate for amplitude distortion without as much noise enhancement as a linear equalizer. The equalizerperformance is also less sensitive to the sampler phase.

Flowchart of Proposed System

The figure depicts the flowchart of the proposed system.

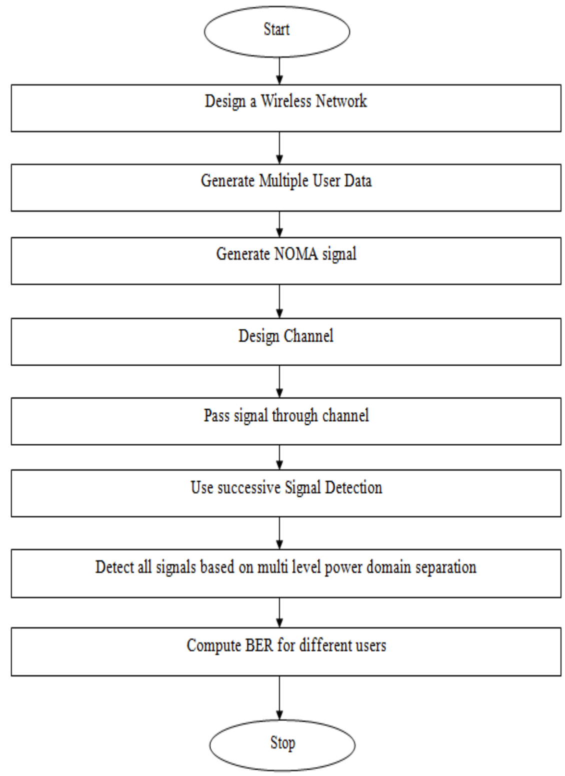

Fig.4 Flowchart of Proposed System

III. RESULTS

The results obtained are shown below. Firstly, the BER performance of MPCs without the proposed mechanism is shown. Subsequently, the results employing the proposed mechanism are shown.

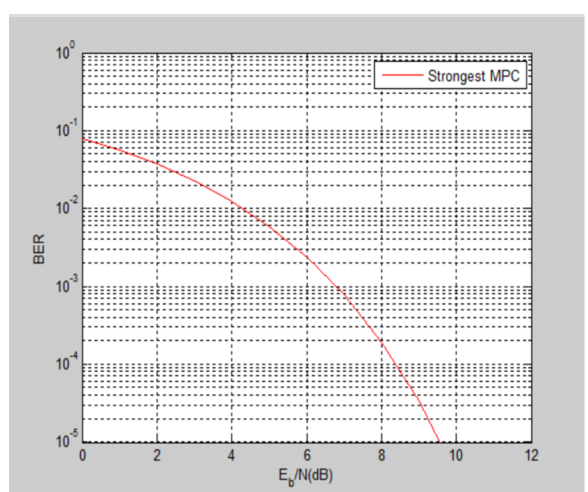

Fig.4 Strongest MPC

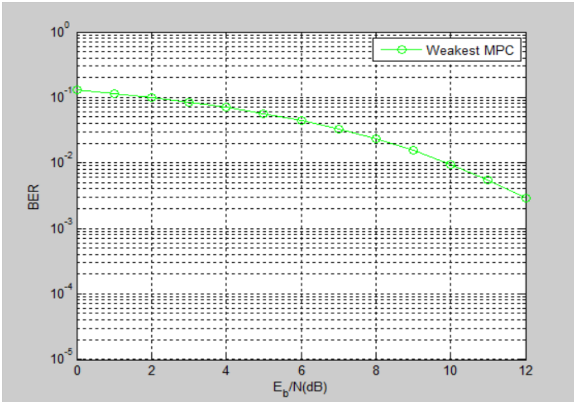

Fig.5 Weakest MPC

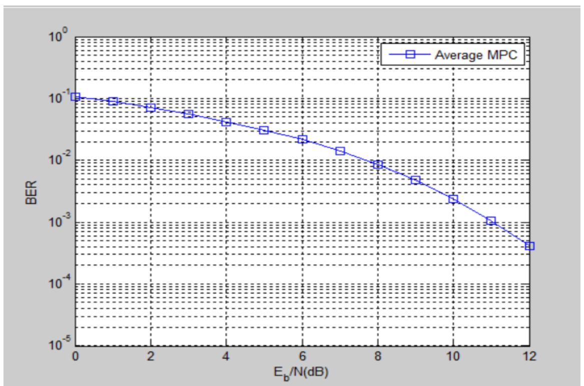

Fig.6 Average MPC

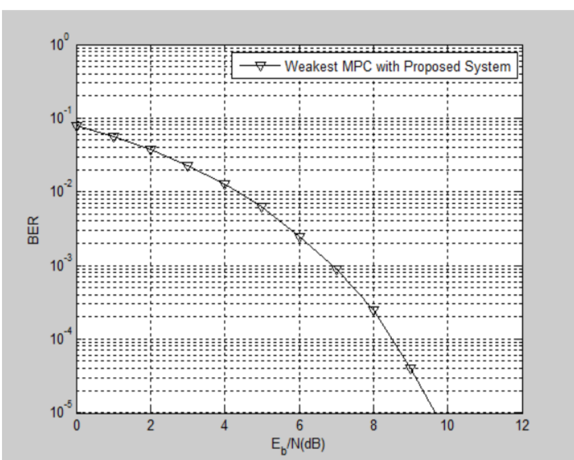

Fig.7 Weakest MPC with proposed system

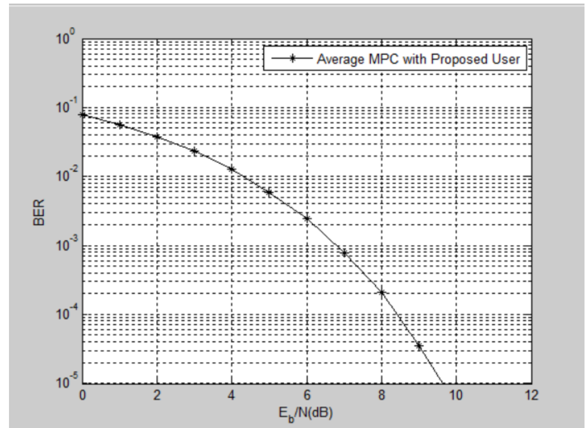

Fig.8 Average MPC with proposed system

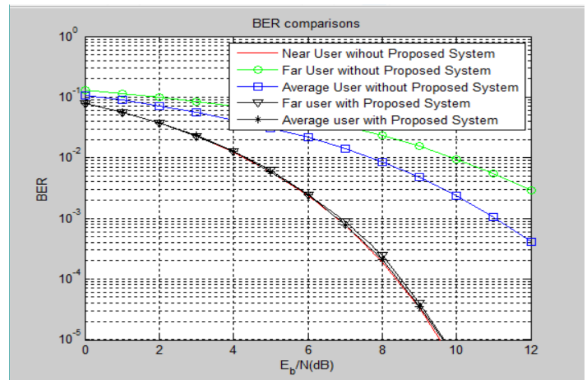

Fig.9 Comparative BER analysis

Table 5.1 Comparative BER tabulation

User Analysis	**BER**	**SNR required**
Weakest MPC with conventional Detection	10^{-2}	10dB
Weakest MPC with Proposed Algorithm	10^{-2}	4dB
Average MPC with conventional Detection	10^{-2}	7dB
Average MPC with Proposed Algorithm	10^{-2}	4dB
Strongest MPC	10^{-2}	4dB

IV. CONCLUSION

It can be clearly seen from the graphs that different received signals users have different BER conditions. Table.1 renders insight into the working of the proposed technique. It can be seen that the BER falls much more steeply for MPCs 1 and 2 in case of the proposed receiver compared to singular detection of the same signals. Therefore the proposed technique would need much less SNR boiling down to lower Signal Power to achieve same BER performance compared to conventional techniques. Conversely, the same SNR would result in much improved BER performance for the proposed technique compared to the conventional technique. Also it can be seen that the proposed technique achieves results almost similar to strongest user scenario. It can also be seen that the outage probability decreases with increasing SNR for the system.

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