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Throughput Maximization for NOMA based Cognitive IOT Systems

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ABSTRACT
Internet of Things (IoT) is an ecosystem of connected physical objects such as sensors, vehicles, electronic equipment's etc. that are accessible through the internet. With increasing number of users, large data being generated and limited bandwidth available for IoT macro-cells, efficient multiplexing techniques are needed that use the available bandwidth efficiently. Non-Orthogonal Multiple access is a technique in which multiple users data is separated in the power domain and it is one of the most effective multiplexing techniques. The major challenges with NOMA based IoT networks are decreasing throughput with increasing path loss factor, increase in throughput with increased power levels but reduced battery life of IoTDs and BER degradation for far or weak users. In the proposed approach NOMA along with successive interference cancellation and zero forcing equalization is proposed. It has been shown that proposed approach attains higher throughput compared to existing techniques and a very low BER value.

General Terms
Internet of Things (IoT), Non-Orthogonal Multiple Access (NOMA), Throughput.

Keywords
Internet of Things (IoT), Non-Orthogonal Multiple Access (NOMA), Successive Interference Cancellation, Equalization, Throughput, Bit Error Rate.

1. INTRODUCTION
With the advent of digital transmission, there has been a continuous search for effective multiplexing techniques. Different multiplexing techniques try to separate signals in different domains. For example, frequency division multiplexing (FDM) separates the signals in the frequency domain [1]-[2]. A more advanced version of the frequency division multiplexing is the orthogonal frequency division multiplexing (OFDM) in which the bandwidth efficiency is higher than FDM due to the condition of orthogonality [2]. However, OFDM has its own challenges such as the inherent high peak to average power ratio (PAPR) and complexity in maintaining orthogonality among user signals. Another alternative is the time division multiplexing technique which as popular in second generation networks, with user signals being separated in the time domain. Off late, Non-Orthogonal Multiple Access (NOMA) has emerged as a promising multiplexing technique for wireless communications in which the bandwidth efficiency is much higher compared to OFDM [3]. In case of NOMA, signals are separated in the power domain. This necessitates the user signals to bear stark difference in power levels so that even while transmitting at the same frequency band and at same time slots, the separation among different signals can be accomplished [4]. The concept of IoT is depicted in figure 1.

Fig 1: Applications of Supply Chain Management

Considering x(t) be thetransmitted signal, If N co-efficients 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 signaly(t) is given by:

$$y(t)=a_1(t)+a_2x(t-A_1)+ \ldots\ldots a_N x(t-A_N)+ (t) \quad (1)$$

Here,
n(t) represents additive interferences or noise effects.
Generally, the transmission channel is typically modeled digitally assuming a fixed sampling period T_S.,thus equation (1) can be approximated as:

$$(kT_S)=a_1(kT_S)+a_2u(k_1T_S) + \cdots a_N u(k-n)T_S+ (kT_S) \quad (2)$$

Equation (2) assumes that the signal is sampled for every $T_S$time slot. The composite signal at the receiver needs to be separated in such away that all users are detected with identical accuracy[5].

2. RECEPTION OF IoT-NOMA
Typically, wireless channels depicts frequency selective nature i.e. they behave differently for different frequencies. Moreover, the frequency selectivity is not fixed by also exhibits temporal variation [8]. This is depicted in figure 2.

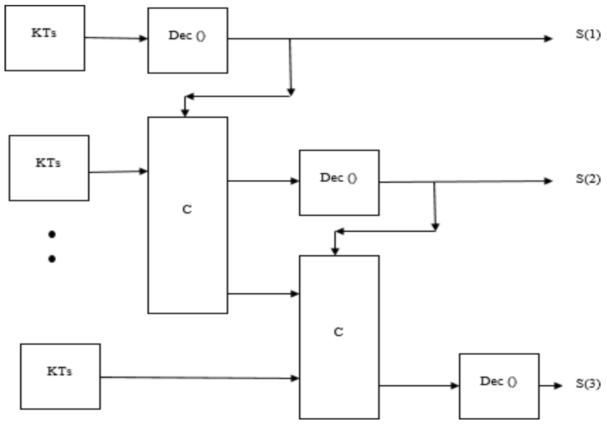

Fig 2: SIC Detection Mechanism

In light of the explained approach, it is necessary to derive its mathematical formulation which is given below [5]:

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

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

Where S represents ith MPC power,
'g' represents gain of the ith path
P represents the power of the ith 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 kth sample
i.e. $n_i(k)$

Thus the different MPCs corresponding to paths can be mathematically written

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

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

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

The proposed algorithm can be explained as: Let the various MPC strengths be:
$S_1.G_1, S_2.G_2, S_3.G_3$.................. $S_n.G_n$
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 [6]. Considering that we have the information about the signal strengths given by equation [7]:

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

We decide the strongest among all the received user MPCs.
2. Detect the kthstrongest MPC among all the signals using the following equation[8]:

$$S_k = dec(P_iG_i)^M \quad - \qquad (7)$$

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

$$y = y_e^i - g_e\sqrt{P_e}R_i, e(k)\hat{S}_k^{(e)} \quad - \qquad (8)$$

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 [9]:

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 [10].

3. PROPOSED METHODOLOGY

To circumvent the negative effects of the channel on the composite NOMA signal, channel equalization is proposed. The above cited approach uses decision feedback to cancel the interference from symbols which have already have been detected [11].

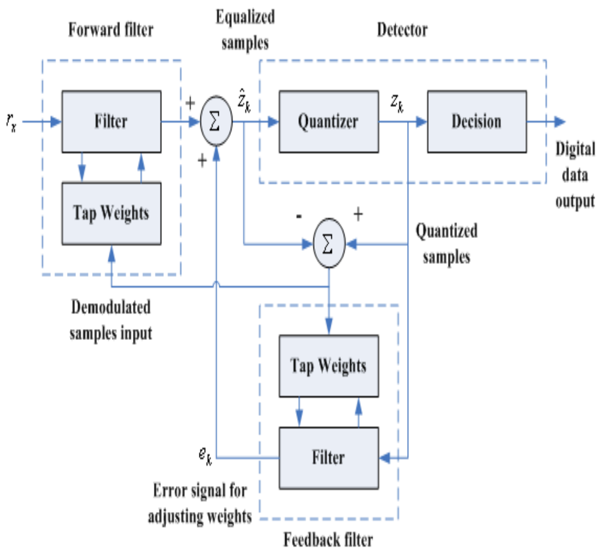

Fig 3: Proposed SIC-Equalization Approach

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 [12]-[13]. However, the equalizer can compensate for amplitude distortion without as much noise enhancement as a linear equalizer. The equalizer performance is also less sensitive to the sampler phase [14].

The proposed approach uses the iterative signal detection an cancellation. In this approach the following points are critica [15]]:

1) NOMA relies on separating the signals in the power domain [16].
2) It is difficult to detect weak signals in the presence of strong signals.
3) It is difficult to maintain the exact power level difference among the different signals due to the non-ideal nature of the channel and multi path propagation and fading [17].
4) It is necessary to detect the signals with all signal

strengths with equal error performance to maintain satisfactory quality of service [18].

To detect the signals in the power domain (for NOMA), the successive signal detectio0n needs to be applied. In this case the signal which is the strongest is to be detected first, then cancelled after detection. The process is to be followed from the strongest to the weakest signals. The BER is then computed for the different users with varying signal strengths arriving at the receiver.

4. RESULTS AND DISCUSSIONS

The simulation has been run for 10 million bits with packet size of 32 bits for the IoT system, on MATLAB 2020a.

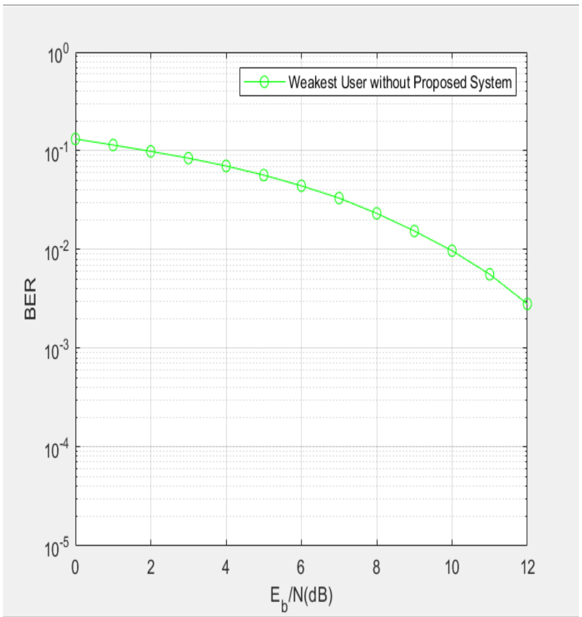

Fig 3: BER analysis of weakest user without proposed System

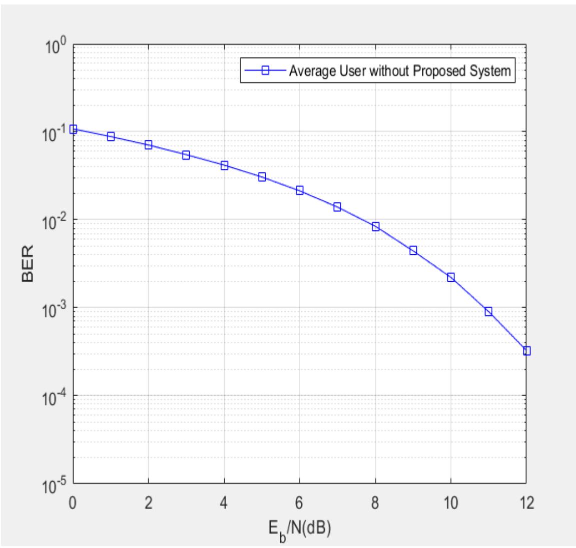

Fig 4: BER analysis of average user without proposed System

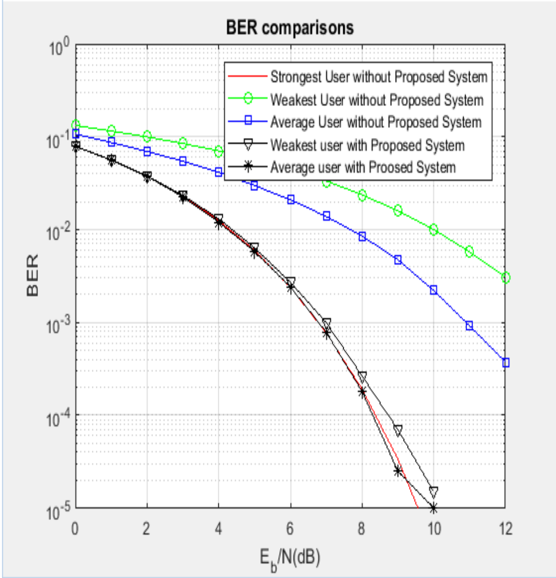

Fig 5: Comparative BER analysis for the proposed system

A comparative analysis of the system BER is depicted in table 1.

Table 1: Comparative BER Analysis

BER	SNR Range	Case
10^{-1}	0dB	Strongest User
10^{-1}	0dB	Weakest User without Proposed
10^{-1}	0dB	Weakest User with Proposed
10^{-1}	0dB	Average User without Proposed
10^{-1}	0dB	Average User with Proposed System
10^{-2}	4dB	Strongest User
10^{-2}	10dB	Weakest User without Proposed
10^{-2}	4dB	Weakest User with Proposed
10^{-2}	8dB	Average User without Proposed
10^{-2}	4dB	Average User with Proposed System
10^{-3}	7dB	Strongest User
10^{-3}	N.A.	Weakest User without Proposed
10^{-3}	7dB	Weakest User with Proposed
10^{-3}	11dB	Average User without Proposed
10^{-3}	7dB	Average User with Proposed System
10^{-4}	8.2dB	Strongest User
10^{-4}	N.A.	Weakest User without Proposed
10^{-4}	8.4dB	Weakest User with Proposed
10^{-4}	N.A.	Average User without Proposed
10^{-4}	8.2dB	Average User with Proposed System
10^{-5}	8.7dB	Strongest User
10^{-5}	N.A.	Weakest User without Proposed
10^{-5}	10dB	Weakest User with Proposed
10^{-5}	N.A.	Average User without Proposed
10^{-5}	10dB	Average User with Proposed System

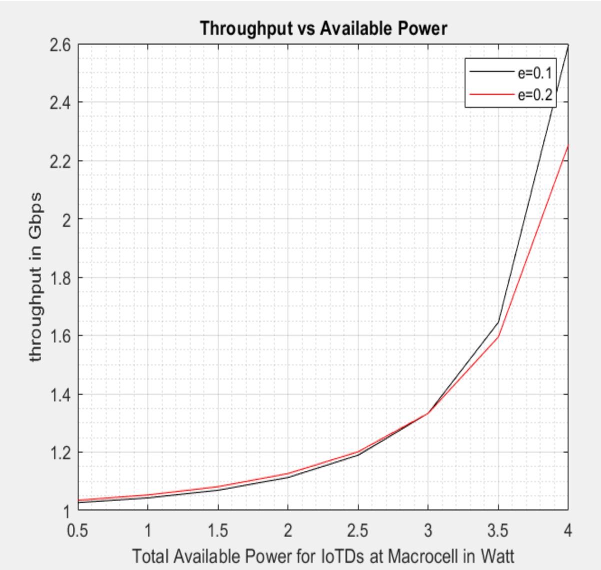

Fig 6: Throughput w.r.t power

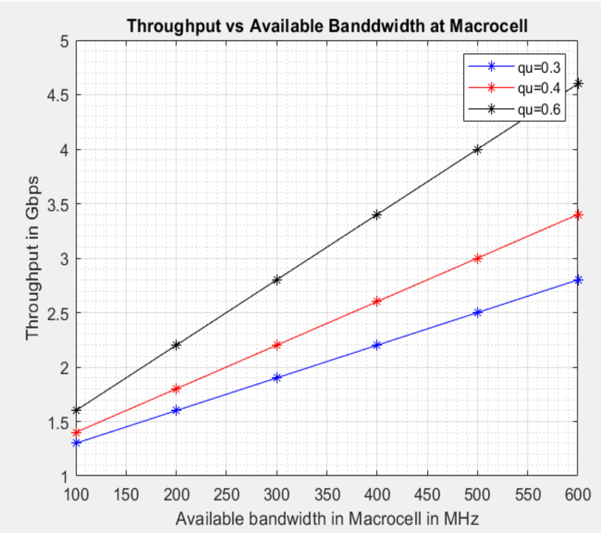

Fig 7: Throughput w.r.t bandwidth

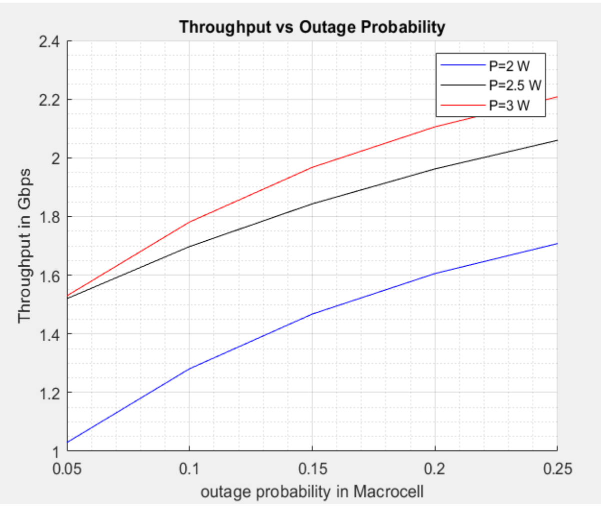

Fig 8: Throughput w.r.t outage

Here e denotes the path loss co-efficient. Higher value of path loss co-efficient results in higher fading and lesser throughput.Here ‘qu’ denotes the power value to balance decoding complexity. Higher values of qu would result in increased throughput but would also result in higher power consumption and lesser battery life of IoTDs.Typically, as the throughput increase, the data which is shared also increase with respect to time, which increases the system outage. Here ‘P’ denotes the transmitted power. Higher values of P would result in increased throughput by increasing the SNR, but would also result in lesser battery life of IoTDs.

Moreover, increasing the power after a point saturates the throughput i.e. the throughput CAN NOT be increased any further even by increasing power levels due to the limitations of the system in terms of capacity w.r.t. bandwidth.

5. CONCLUSION

It can be concluded from previous discussions that IoT networks suffer from limitations in throughput and degradation in system BER. Massive IoT clusters share common resources such as bandwidth which is limited and needs to be utilized effectively. Hence in this approach, non-orthogonal multiple access (NOMA) based IoT macro-cells are designed with an aim to effectively utilize the bandwidth. The proposed system uses the successive interference cancellation (SIC) algorithm along with the zero forcing equalization mechanism to effectively decide the data of near as well as far users corresponding to weak and strong power levels. The throughput is computed with respect to the transmitted power, the available bandwidth at the macro-cells and the outage probability at the macro-cells. The BER is computed for weak, strong and average user scenarios in the macro-cells. It has been shown that the proposed system achieves very low BER values and outperforms the existing work [1] in terms of the system throughput. to attain higher accuracy compared to existing systems.

Future enhancements in the proposed work can done in the following domains:

- Analysis and increasing the network lifetime by design of effective clustering algorithms.
- Designing a Switching Mechanism between networks such as NOMA, WiMax etc. in case one of the systems experience high outage.

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