A Survey on Throughput Maximization in IoT Networks

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***Abstract*-This paper presents a comprehensive survey on Non-Orthogonal Multiple access for multiple access in wireless networks. As networks are now migrating towards the wireless domain as opposed to the wired domain, the need for more efficient bandwidth allocation mechanism is necessary. With the advent of big data applications, increasing number of users, increased bandwidth and data requirement yet limited bandwidth availability have become serious challenges. Hence future generation wireless 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. This paper presents a comprehensive review and taxonomy of the NOMA based multiple access framework.**

***Index Terms*:- Non-Orthogonal Multiple Access, Wireless Networks, Quality of Service (QoS), Bit Error Rate, Throughput.**

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). 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. 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.

II. Comparison of FDM, OFDM and NOMA:

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

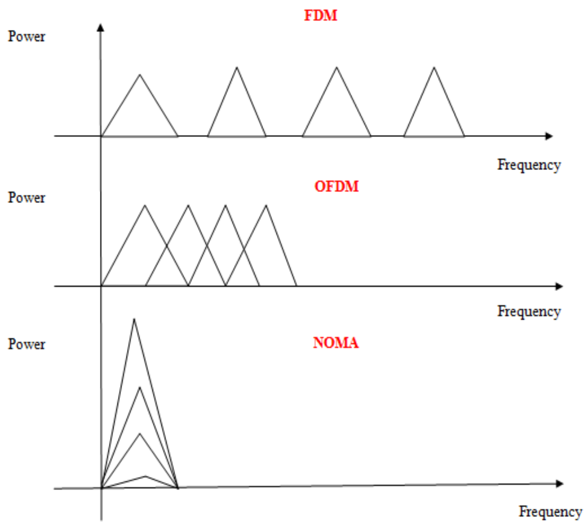

Fig.1 Comparative Spectra of FDM, OFDM and NOMA

It can be clearly observed that the bandwidth allottment for NOMA is much more efficient in terms of NOMA as comped to OFDM and FDM. This allows more users to be accomodated in tge limite dbandwidth available.

II. LITERATURE REVIEW

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

Xu et al. in [1] proposed an uplink secondary Internet of Things (IoT) device scheduling and power allocation problem based on imperfect channel state information (CSI) and imperfect spectrum sensing is investigated for industrial cognitive IoT over cognitive heterogeneous non-orthogonal multiple access (NOMA) networks. The joint secondary IoT device scheduling and power allocation problem maximizes the network throughput subject to total power constraint at each secondary IoT device, to e=increase the throughput based on a cognitive approach.

Zhao et al. in [2] 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.

Wang at al. in [3] 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.

Choi et al. in [4] 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.

Alodeh et al. in [5] 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.

Monsees et al. in [6] 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.

Wang et al. in [7] 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.

Tao et al. in [8] proposed a low complexity decision feedback mechanism for wireless channels. The approach used the concept of soft-output linear equalizer (Soft-LE), the soft-input, soft-output decision-feedback equalizer (Soft-DFE) is much less investigated.. The performance metrics was the Bit Error Rate (BER) of the system. It was shown through scatter plots that the proposed system attains coherent results in both the complex signaling points and the BER scenario of the proposed system.

Jung et al. in [9] proposed a 25 Gb/s CMOS Equalizer. The paper had developed the equalizer circuit on a hardware platform using the CMOS circuit design and was suitable for circuits sampled at Gb/s. The equalizer designed was susceptible to kickback noise effects and hence needed sharp spike reduction.

Kimura et al. in [10] proposed an equalizer with the sampling speed of 28 Gb/s. It was capable of operating at 560 mW multi-Standard SerDes systems. The approach had a Single-Stage Analog Front-End mechanism. The equalizer had a 14-Tap filter design mechanism. The tap weights were designed according to the samples of the errors that were obtained at the receiving end. The system was designed at 28 nm CMOS technology.

Bai et al. in [11] proposed a 3-Tap Equalizer. The system was further implemented on in 65nm CMOS technology. The equalizer design was done based on an FIR filter design approach that had a 3 tap or 3 level tap weight changing mechanism. The system had the dummy data being fed to the error estimator and the tap weight for the filter was changed accordingly. The 65nm design ensured low dye area and power consumption.

Kilinc et al. in [12] proposed an equalizer for molecular communication. The approach used a technique that aimed at optimizing the cost function for the design of the equalizer based on molecular communication. It was shown that the challenging aspect of this approach lies in the fact that wireless channels are frequency selective in nature i.e. a practical wireless channel has a frequency selective channel response leading to variable channel gain for different frequencies. The approach used the bit error rate as the performance evaluation parameter.

Lamare et al. in [13] proposed an adaptive and Iterative Multi-Branch system for equalization. The approach used an adaptive training and weight adaptation mechanism for the equalizer tap weight updating rule. As the number of iterations was increased, more accuracy in terms of filter tap weights was obtained. The designed system was particularly suited for Multi-Antenna Systems, wherein multiple transmitters and multiple receivers would make u the system and an adaptive algorithm would be used for the weight adaptation.

Shahramian et al. in [14] proposed Equalizer Architectures that used the concept of multiple filters. The filters were Continuous-Time Infinite Impulse Response Filters having one tap simple structures. The equalizer architecture also made use of the fact the IIR filter design using the windowing technique would be possible using the detection of spectral knowledge of noise or degradation effects.

Li et al. in [15] the authors proposed an equalization mechanism using constellation constraints for MIMO systems. The scatter plots for the constellation diagram approach were used so as to simulate the MIMO systems for various channel models. The constellation limitation posed the challenge on the MIMO systems to limit spectral re-growth

III. 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.

$$Find: \max(Sn)\ to\ evaluate\ x1 = max1 \qquad (4)$$

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:

$$\bar{L}(d) = \bar{L}(d_0) + 10n\,log_{10}\left(\frac{d}{d_0}\right) \qquad (5)$$

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

$$L(d) = \bar{L}(d_0) + 10n\,log_{10}\left(\frac{d}{d_0}\right) + X_\sigma \qquad (6)$$

IV. THE SUCCESSIVE SIGNAL DETECTION ALGORITHM

Since the NOMA signal is separated in power domain, hence frequency or time based separation at the receiver is not possible. Hence the successive detection of signals based on the descending magnitudes of power is the optimal choice. The mathematical modeling for the same is given below:

Step1. Generate random data stream S in binary form.

Step2. Design a multi path model with variable channel gain (g)

Here,

G1 is the path gain for strongest user

G2 is the path gain or the weakest user

G3 is the path gain for the average user

Step3. Generate the complex modulated signal given by:

$$x(t) = K_1 \sin(\omega t) + jK_2 \sin(\omega t) \quad - \quad (7)$$

The signal can also be expressed as a complex exponential,

$$x(t) = K_1 s e^{j(\omega t-\varphi)} + K_2 s e^{j(\omega t-\varphi)} \quad - \quad (8)$$

Step4. Design a channel with impulse response h(t) in the time domain.

Step5. Obtain the channel frequency response in the frequency domain by computing the integral:

$$H(f) = \int_{-\infty}^{+\infty} h(t) e^{-j2\pi f t} dt \quad - \quad (9)$$

Step.6 Generate an Additive White Gaussian Noise environment with noise psd of $N_0/2$

Step7. From the Db scale, convert the noise into linear scale using the equation:

$$n(t) = 10^{\left[\frac{SNR\ in\ dB}{10}\right]} \quad - \quad (10)$$

Step8. Add noise to the signal in time domain to obtain the noise added signal in channel:

$$S_{channel} = s(t) + n(t) \quad - \quad (11)$$

Step9. Find the strongest signal among the multitude of signals in the composite signal S given by:

$$S_{composite}(t) = x_1(t) + x_2(t) + \cdots x_n(t) \text{ - } (12)$$

The strongest among all can be found by evaluation:

$$S_{strongest} = \max\{S_{composite}(t)\} \quad - \quad (13)$$

Step10. Compute the system load given by:

$$\beta = \frac{N_b K}{N_b N_s - (N_b - 1)N_0} \quad - \quad (14)$$

Here,

N_b is the number of users

N_s is the sub-carrier spacing

K is the number of data nodes

Step11. Computation of BER:

BER is defined as:

$$BER = \frac{No\ of\ Error\ Bits}{Total\ Number\ of\ Bits} \quad - \quad (15)$$

Step.12 The system BER can be evaluated as:

$$BER_i = 1 - \sum(s_i - s_i')/nN_0 \quad - \quad (16)$$

$$BER_q = 1 - \sum(s_q - s_q')/nN_0 \quad - \quad (17)$$

Here,

I represents the in phase component and Q represents the quadrature component.

N is the number of bits

N_0 is the oversampling ratio

Thus the overall average BER can be computed as:

$$BER = \frac{K[BER_i + BER_q]}{2} \quad - \quad (18)$$

The overall BER of the system for different conditions depict the Quality of Service (QoS) of the system.

Conclusion: It can be concluded from previous discussions that NOMA is an effective prospect for future generation wireless networks 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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