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QoS Analysis of MIMO-NOMA for Uplink Transmission using Successive Bandwidth Division

Saniya Aleem [1], Dr. Arathi R Shankar [2]

[1] Dept. of Electronics and Communication, BMSCE, Bangalore, India
[2]2Associate Professor, Dept. of Electronics and Communication, BMSCE, Bangalore, India

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Abstract - *Non-Orthogonal multiple access (NOMA) technique is known as the most favorable multiple access scheme for the future generation cellular communication networks. NOMA is a novel proposal for the encoding technology. The key and main opinion of this technique is to utilize power domain for multiple access scheme, however the preceding generations of mobile networks such as 4G were depending on the frequency or time or code-domain. For its ability to deliver a larger spectral efficiency, NOMA is recognized as a vital enabling technology for 5G networks. The application of MIMO technique to the NOMA systems is very significant to enhance the performance gains of NOMA. In this work, an attempt has been made to implement MIMO-NOMA for uplink transmission using Successive Bandwidth Division (SBD). A suboptimal algorithm is proposed which not only diminishes the receiver complexity and also enriches the total SINR (signal to interference plus noise ratio) by aiding 2N users with N number of base stations (BS). Computer simulations are carried out using MATLAB R2016a and QoS analysis of this proposed scheme is determined by plotting the QoS parameters such as throughput, delay and jitter.*

Key Words: **NOMA, MIMO, 5G, Successive Bandwidth Division, Throughput, Delay, Jitter**.

1. INTRODUCTION

Various sensors, house hold appliances, wearable sensors and even vehicles can be connected to the core network through Internet-of-things (IOT) to establish a "smarter life" for convenience, economy and personal health. Due to rapidly increasing devices anytime and anywhere, the future fifth generation network (5G) provides a high performance communications. Various numbers of devices including tablets, smart phones and laptops for daily purpose work on one hand require a remarkably larger data rate with enhanced cell edge rate. The reason for this is that in 2020 as predicted the data traffic from social networking, software downloading, web surfing or browsing, multimedia streaming and file sharing will be enhanced significantly where the high- definition (HD) video traffic, with specified data rate and real time playing, is going to get increased by 13 times as that in 2014.[1]

Basically the multiple access schemes in 5G are classified in terms of sharing offered in resource allocation as orthogonal multiple access (OMA) schemes and NOMA schemes. In case of OMA technologies to overcome the multiple access interference (MAI), orthogonal users are assigned to different users in time, frequency, or code domain. OMA schemes are incapable of providing gigantic connectivity with diverse QoS requirements. This is due to scarcer degrees of freedom (DoF), definite number of users with advanced channel quality have to be assisted with advanced priority while the users with inferior channel quality have to delay for some time. This indicates that improvement is needed in terms of latency and excessive unfairness. It is also unproductive when allocating Degree of freedom (DoF) with reduced channel quality. [2]

The OMA technique involves FDMA and the conventional TDMA systems. The OMA technique is based on orthogonal frequency division multiple access technique (OFDMA) which assigns each tone of frequency to at most one user so that disjoint set of sub carriers is assigned to every user and thus a diverse channel gain is experienced by every user on each sub carrier in 4G wireless network systems. The rate and power on each tone has to be dynamically allocated by the transmitter of OFDMA systems to fulfil numerous Quality of service (QoS) requests of every user. The transmitter must have the information of perfect CSI (Channel state Information), which is needed in multi user communications. Thus OFDMA and single carrier FDMA (SC-FDMA) are implemented in several systems like LTE (Long Term Evolution) and LTE- Advanced (Long Term Evolution-Advanced) but they lack user fairness. Hence NOMA was adopted because of its user fairness and higher spectral efficiency, greater cell edge through put and offers significant interference and low transmission latency which offer an important empowering knowledge for 5G networks.[2,3]

NOMA is considered as the most favourable radio access methods for performance enrichment in the future generation cell networks. NOMA and MIMO are advances for enhancing the spectrum efficiency for the 5G networks. The advancements have substantial advantages as far as spectrum efficiency, energy efficiency, reliability, and robustness. The main use of MIMO (Multiple Input Multiple Output) technology to NOMA is very significant because MIMO provides extra degrees of freedom which improves the system performance. Subsequently, coordination of massive MIMO and NOMA advancements turns into a promising arrangement in acquiring high spectral efficiency in 5G frameworks.

The suitable technique for NOMA is to permit every users to share resources and subcarrier but this will rise the complexity of receiver to greater extent. Few techniques that use NOMA are Low Density Spreading technique (LDS) and CDMA. But these techniques will enhance redundancy at the receiver to facilitate the user's separation. Works on the implementation of uplink NOMA were proposed, but these techniques are more channel oriented and are not capacity approaching, and the spectral efficiency of the system is also degraded. The current capacity approaching methods cannot be adopted due to limited users.

In order to attain through put gain of NOMA, many capacity approaching methods have been proposed but they are limited to less users. Hence capacity approaching technique such as Successive Bandwidth Division technique (SBD) is proposed. [5]

2. SYSTEM MODEL

In case of SBD, the users are distributed as orthogonal groups with restricted users in every group. For the reason of orthogonality between the users, at the receiver side no joint processing is needed to recover the user's signals. The users inside the identical sub band are paired in order to mitigate inter symbol interference. Within sub bands the user paired are participants of two unique sets known as strong and weak set. Weak set members is selected in such a way that it deals with a less or no interference within the sub band to the further user. Since this technique is designed by merging OMA technique and NOMA methods, hence this receives rewards of both methods.[5]

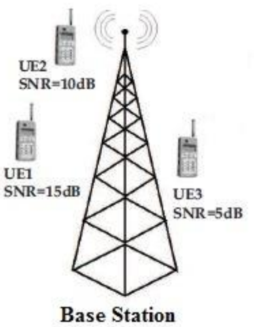

Fig-1: NOMA technique with multiple users for uplink

Consider the uplink transmission where a BS is armed with N antennas while users are armed with one antenna each. Let K be the overall users in a cell such that $K \geq 2N$. In the projected SBD uplink outline, by superposition coding the base station supports K users and ξ represents the set of all K users. The set ξ is split into two unique set; strong set A and weak set B in conventional NOMA scheme so that $A \cap B = \emptyset$ and $A \cup B = \xi$. These two sets are well defined on the origin of channel gains which each user will experience. Users with high channel gains are grouped as strong set A members and the users with relatively lesser channel gain is grouped as members of weak set B.

In OMA system, the channel is distributed into indistinguishable subbands denoted by K in order to permit access from the K unlike users. Here all users are allocated with distinct band of frequency and the other users cannot utilize frequency band which is assigned to other user and further than one assigned to them. Henceforth at the receiver end, signals can be decoded autonomously and ideally there will be no interference arises. But the overall spectral efficiency is reduced because the bandwidth allocated to individual user is degraded to 1/K in the OMA system. The users are embraced in similar band of frequency in conventional NOMA systems. Here the users in both the sets are assigned to similar frequency band. Since more number of user's are assigned at identical frequency band, there will be great interference presented at them by supplementary users inside subband. The weak sets users are continuous source of inter set interference compared to that of strong set users. Hence user signals of strong set will be decoded first with interference and then the user signals of weak set are decoded with no interference. Thus at receiver side the complexity of decoding is higher even with the help of joint decoding and SIC. Nevertheless, for both limits, it is observed that reliability and capacity are interrupted for NOMA and OMA schemes. Hence in order to mitigate complexity of receiver, outage probability, interference, and to increase sum capacity; SBD technique is being proposed.[5]

2.1 MIMO-NOMA using Successive Bandwidth Division Scheme

In this scheme the resources of bandwidth are first divided orthogonally in to numerous identical subbands. The subbands which are designed are to be governed by number P where $\{P \in N \mid 1 \leq P \leq K\}$, and N is the group of natural intergers.

For instance, consider over-all users to be K = 32. A set $\emptyset$ is defined such that it is a set of factors of K. For K = 32, the set $\emptyset$ is defined as $\emptyset = \{1, 2, 4, 8, 16, 32\}$. Since the number of users is assumed to be even so all elements which are even from the set $\emptyset$ are considered except P = 1. P = 1 is the exceptional case of NOMA which stipulates the case of OMA. The users will be clustered into K/P subbands through OMA method. For example OFDMA contains P users in every subband as shown in Fig-2. The P users are selected from strong and weak set such that they channel coefficients are orthogonal pairwise and hence they provide less or zero interference. The value P changes the interferers, subbands, dimensions of received signal, dimensions of channel matrix and the dimension of detection matrices, and the users in respective subband. Though, the overall amount of user's residues the same one. The value P splits both the set into K/P lesser set provided $\sum_{i=1}^{K/P} A_i \cup B_i = \xi$ such that cardinality of both vectors for all i value is P/2. Hence there are P users in respective subband and P/2 interferers in every subband. Moreover at the base station K/P is the overall number of received signals. The System bandwidth becomes BW/P and the noise variance correspondingly becomes $\sigma^2 P/K$ where total bandwidth is denoted by BW and noise variance by σ^2. [5]

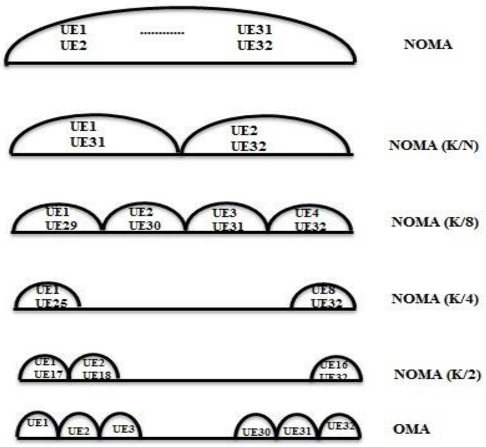

Fig -2: OMA versus NOMA and suggested SBD scheme (when K=32)

P=1 is the distinct case in SBD technique where SBD NOMA contains K sub bands which specializes the case of Orthogonal Multiple access. Every user from strong and weak sets acquires a separate band of frequency. For example when P=2, NOMA contains K/2 subbands. Similarly when P=4, NOMA attains K/4 sub bands and so on. Furthermore, in $NOMA_P$ there is formation of K/P subbands and one sub band is utilized by K/P users and in every sub band conventional NOMA scheme will work.

Consider a scenario where the overall number of users K=32 as shown in Fig-2. The overall set ξ is distributed into strong set A and a weak set B, where strong set is considered as A = $\{u_1, u_3, u_5, \ldots, u_{K-1}\}$ and weak set B as ξ- A. The amount of users in both sets are expected to be equal. The required technique is $NOMA_2$ for P=2, and it contains 2 users in every subband. From both sets A and B, the cardinality is 2 for A_i and B_i. It has 1 interferer in each sub band. For P=8, the required scheme is $NOMA_8$, and it contains 8 users in every subband and the cardinality is 8 for A_i and B_i. It has 4 interferers in each sub band. The case K=P specify the conventional NOMA case for uplink transmission with N interferers and single sub band.

Since only P users within the sub band can transmit their signals at the same time, henceforth the acknowledged received resultant signal is the superposition of signals. The further left over users is decoded autonomously with no interference. Additionally as superimposed users are only P in number, the decoding complexity and construction of SBD scheme is lesser than the direct superposition technique where it consists of K superimposed users. So, the projected SBD scheme at receiver end limits number of multi user detection and provides higher spectral efficiency.[5]

2.2 Implementation

The signal which is received at the base station within K/P sub bands from the overall group of users is denoted by

$$y = H_1 s_1 + H_2 s_2 + n \quad (1)$$

Where y represents the received signal vector of uplink transmission and it is of the order N x 1, H_1 and H_2 are the channel matrix of strong and weak set of order N x P/2 respectively. n is the AWGN vector with no mean and with unit variance.

The channel matrices of strong set H_1 and weak set H_2 can be expressed as

$$H_i = [h_{i,1}\ h_{i,2}\ \ldots\ h_{i,P/2}] \quad (2)$$

Where i ϵ {1, 2}. $h_{i,n}$ represents channel vector of n^{th} user of order N x 1. The transmitted symbol s_1 and s_2 from each user can be written as

$$s_1 = \left[\sqrt{\alpha_{1,1}}x_{1,1} \quad \ldots \quad \sqrt{\alpha_{1,\frac{P}{2}}}\, x_{1,\frac{P}{2}}\right]^T \quad (3)$$

$$s_2 = \left[\sqrt{\alpha_{2,1}}x_{2,1} \quad \ldots \quad \sqrt{\alpha_{2,\frac{P}{2}}}\, x_{2,\frac{P}{2}}\right]^T \quad (4)$$

Where $(.)^T$ represents the transpose of a vector and $\alpha_{1,1}$ denotes the power allocation co-efficient of NOMA technique for users of both the set and $x_{(i,j)}$ denotes the transmitted symbol by the i^{th} user to the j antenna base station. Symbols s_1 and s_2 are the signal vector of both sets respectively. P/2 is the quantity of interferers in every subband whereas in each sub band P is the overall users. K/P is the overall received signals at base station.

Let y_n be the received signal in the strong set of n^{th} user which is the super imposed signal and is expressed as

$$y_n = h_{1,n}\sqrt{\alpha_{1,n}}x_{1,n} + \sum_{j=1}^{P/2} h_{2,j}\sqrt{\alpha_{2,j}}x_{2,j} + n \quad (5)$$

Where $h_{1,n}$ and $h_{2,n}$ are N x 1 channel vectors and n is the AWGN signal with zero mean and with a variance of unity. In the meantime since base stations receive only the superimposed signals, a novel named SIC technique is needed for decoding at the receiver end. The strong set signals are always decoded with some interference first compared to weak set whereas weak set users will be decoded afterwards with no interference. Since only P users are present in every sub band, an interference originates from weak channel gain users and the remaining users proposes nil interference and are orthogonal to each other.

Zero forcing (ZF) decoding is used at the receiver end to obtain post coded or detection matrix in order to detect signals from both the sets. The detection matrix is generated at the BS by utilizing channel sate information of the users. The equivalent post coded matrix of H_1 and H_2 matrices are expressed as

$$Z_i = \left[z_{i,1}^T \; z_{i,2}^T \; \ldots \; z_{i,\frac{P}{2}}^T\right]^T = (H_i)^*\left((H_i)(H_i)^*\right)^{-1} \quad (6)$$

Where $(.)^{-1}$ represents the inverse of a matrix and $(.)^*$ denotes the complex conjugate. In equation 6, Z_1 is of the order of P/2 x N.

In order to calculate the SINR of both the users of strong and weak set, firstly after applying Z_1 post coded matrix the received resultant signal becomes

$$r^{(1)} = Z_1 H_1 s_1 + Z_2 H_2 s_2 + Z_1 n \quad (7)$$

Where $r^{(1)}$ denotes the received signal of order (N/(K/P)) x 1. Considering equation 7, $r_{1,n}$ which is the signal of user n from strong set becomes

$$r_{1,n}^{(1)} = z_{1,n} h_{1,n}\sqrt{\alpha_{1,n}}\, x_{1,n} + \sum_{j=1}^{P/2} z_{1,n} h_{2,j}\sqrt{\alpha_{2,j}}\, x_{2,j} + z_{1,n} \quad (8)$$

Where desired signal of strong user is denoted by $z_{1,n} h_{1,n}\sqrt{\alpha_{1,n}}\, x_{1,n}$ whereas from the weak user the inter-set interference is represented by $\sum_{j=1}^{P/2} z_{1,n} h_{2,j}\sqrt{\alpha_{2,j}}\, x_{2,j}$. N is the total number of interferers for conventional NOMA when K = P. The total no. of interferers in conventional uplink NOMA reduces as the number P declines in projected SBD technique with zero interferer in P = 1 case. The resultant received SINR is expressed by

$$SINR_{1,n} = \frac{\|z_{1,n} \odot h_{1,n}\|^2 \alpha_{1,n}}{\sum_{j=1}^{P/2} \|z_{1,n} \odot h_{2,j}\|^2 \alpha_{2,j} + \sigma_n^2} \quad (9)$$

Before its message has been decoded, each strong set user first needs to decode the weak set user message. After decoding of the message has been done successfully, the strong set user will decode its own message. In order to decode the weak set user, SIC has to be carried out therefore there will be zero interference. Henceforth after ZF matrix has been applied, the weak set signals becomes

$$r^{(2)} = Z_2 H_2 s_2 + Z_2 n \quad (10)$$

The received signal and the corresponding SINR of n^{th} user of the weak set are given by

$$r_{2,n}^{(2)} = z_{2,n} h_{2,n}\sqrt{\alpha_{2,n}}\, x_{2,n} + z_{2,n} n \quad (11)$$

$$SINR_{1,n} = \frac{\|z_{2,n} \odot h_{2,n}\|^2 \alpha_{2,n}}{\sigma_n^2} \quad (12)$$

The sum capacities in strong set and weak set of all the users of Bandwidth BW is expressed as

$$R_i = BW/P \sum_{n=1}^{N} \log_2\left(1 + SINR_{i,n}\right) \; ; \; i \in \{1,2\} \quad (13)$$

Although if the amount of users and antennas used are such that the resulting matrix is in rectangular form then both the set users will experience interference from the other users of strong set and weak set respectively. Therefore the received resultant SINR in the strong set of nth user can be expressed as

$$SINR_{1,n} = \frac{\|z_{1,n} \odot h_{1,n}\|^2 \alpha_{1,n}}{I + \sigma_n^2} \quad (14)$$

Where I denotes the interference and is expressed as

$$I = \sum_{j=1}^{P/2} \| z_{1,n} \odot h_{2,j} \|^2 \alpha_{2,j} + \sum_{j=1, j\neq n}^{P/2} \| z_{1,n} \odot h_{1,j} \|^2 \alpha_{1,j} \quad (15)$$

The resultant received SINR in the weak set of the nth user can be expressed as

$$SINR_{2,n} = \frac{\|z_{2,n} \odot h_{2,n}\|^2 \alpha_{2,n}}{\sum_{j=1, j\neq n}^{P/2} \|z_{2,n} \odot h_{2,j}\|^2 \alpha_{2,j} + \sigma_n^2} \quad (16)$$

2.3 QoS in 5G

QOS is the confirmation of better performance of the system as observed by users. QoS gives diverse need to various applications, clients, or data flow. QoS is a component that permits organize network applications or administrations can work as expected. QoS can be characterized and additionally to give performance guarantee in the system. To give and support QoS, resource management must always be QoS-driven. In order assign resource, the resource management framework must consider the diverse parameters such as resource accessibility, resource control strategies, and QoS prerequisites of uses, which are evaluated by QoS parameters (e.g. Jitter, Delay, and Throughput). The estimation of QoS depends on parameters like latency, jitter, error rate, through put and so on. [6,7]

The common QoS parameters which are considered are shortened underneath:

- **Throughput**: In communication networks, throughput is defined as the rate of message delivered successfully.
- **Delay:** It is not quite the same as throughput as the delay is worked after some time however

throughput stays normal. It can likewise be called as latency. Latency is the time, longer than typical, taken by every packet to achieve the specified goal.

- **Jitter:** Jitter is defined as the delay variation and it is brought together by the variable transmission of the packets in delay. When the value of jitter is too high it will damage the performance of the network.

2. RESULTS

Computer simulations are carried out using Matlab R2016a. In Fig-3 the Energy efficiency (EE) and Spectral efficiency (SE) of conventional NOMA is compared with OFDMA. The system bandwidth is considered to be 4.32MHz.

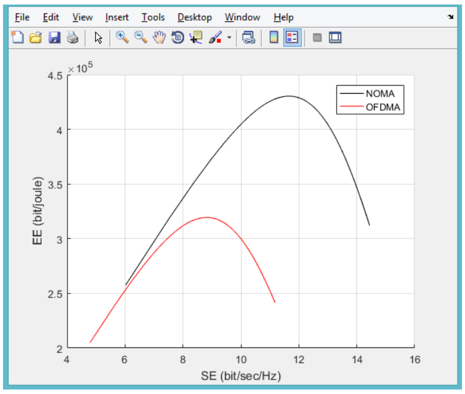

Fig -3: EE and SE curve for OFDMA and NOMA

Energy efficiency (EE) can be defined as the ratio of sum rate to the total power consumed at the base-station and given as

$$EE = \frac{R_T}{P_{total}} = SE * \frac{W}{P_{total}} \text{ bits/joule} \qquad (17)$$

The channel gains for two users are respectively taken as −120dB and −140dB. Fig-3 depicts the EE-SE curves for the uplink transmission. It is observed that NOMA accomplishes greater EE and SE compared to OFDMA system.

In order to explore the performance of SBD technique the cell radius of the cell is considered to be of 1000m and the users are randomly distributed. We have considered transmission power of 24dBm and working SNR of 10dB. Fig-4 demonstrates the sum capacity of NOMA with the suggested SBD scheme. This compares the variation of sum capacity with the users used. It can be observed that the sum capacity increases with the growth in the range of users buts this enhancement is not substantial in case of $NOMA_4$ and $NOMA_8$ schemes after a certain limit is exceeded in number of users. Nevertheless, the complexity offered by $NOMA_4$ and $NOMA_8$ is lesser compared to conventional NOMA system. Similarly by decreasing the system bandwidth the sum capacity also reduces.

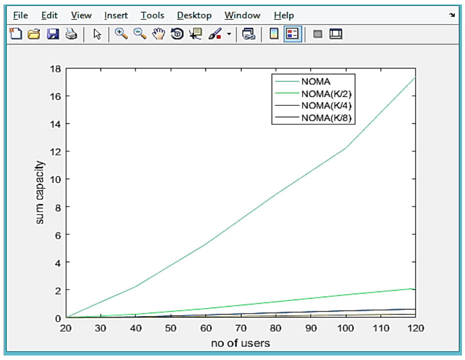

Fig -4: Sum capacity graph for the suggested SBD technique

Fig-5 depicts the outage probability of NOMA with the suggested SBD technique. It can be noted that suggested SBD technique achieves higher outage probability than conventional NOMA. The decrease in outage probability is due to the fact that the noise variance and bandwidth are divided among the users and there corresponding SINR of user's increases.

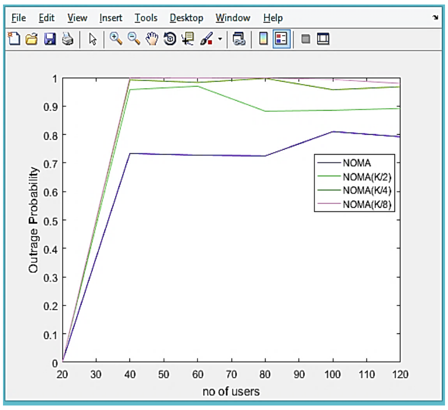

Fig -5: Outage probability versus number of users of proposed SBD Scheme

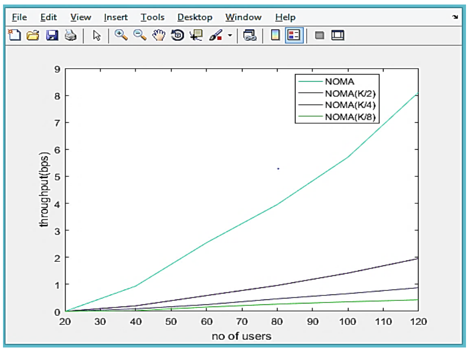

Fig -6: Through put of the suggested SBD technique

Fig-6 shows the throughput of the projected SBD scheme. Throughput is higher in case of NOMA when compared to NOMA(K/2), NOMA(K/4) and NOMA(K/8) schemes.

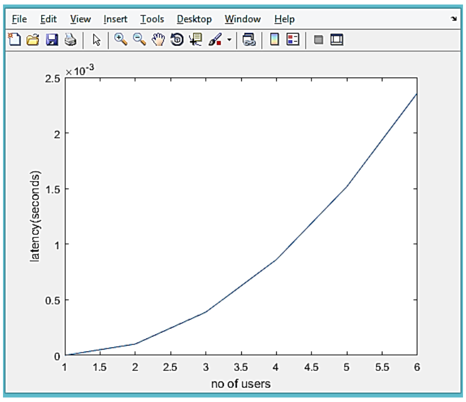

Fig -7: Latency for the proposed SBD Scheme

Fig-7 shows the latency when the system bandwidth is 4.32 MHz . The latency obtained for this proposed scheme is in the order of milliseconds. For truly immersive applications, the latency requirements should be in the tens of milliseconds. This proves that the scheme is more efficient as it provides lower latency and it is more efficient.

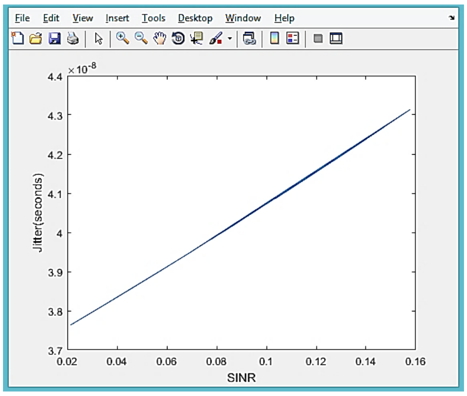

Fig -8: Jitter for the proposed SBD Scheme

Fig-8 depicts the jitter versus SINR graph for the proposed SBD scheme. This scheme offers a low jitter in microsecond range which infers that SBD scheme is more efficient scheme for uplink transmission.

3. CONCLUSION

Fifth generation wireless system require a greater spectral efficiency in order to meet the demand in increasing traffic in communication systems for which NOMA was introduced as it is a novel and favorable technology. Though, it provides a higher complexity at the receiver mainly in the massive access scenarios. Hence in this work the performance of conventional OMA, NOMA and the proposed Successive Bandwidth Division scheme is evaluated. The proposed scheme at the receiver side decreases the number of interferers, which lessens the use of multi-user algorithms needed to recover the given signal and moreover provides user fairness, higher outage probability and sum capacity compared to the conventional NOMA. The proposed scheme is more efficient as it provides higher throughput, lower latency and a very low jitter in the range of micro seconds.

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