IJCSE International Journal of Computer Sciences and Engineering Open Access
Survey Paper Vol.-7, Issue-3, March 2019 E-ISSN: 2347-2693

Survey on Non Orthogonal Multiple Access (NOMA) - A key technique for future Radio Network Access

Shampal Singh[1*], A.S. Buttar[2], Dalveer Kaur[3]

[1,2,3]Dept. of Electronics & Communication Engg., IKGPTU Main Campus, IKG Punjab Technical University, Jalandhar, India

**Corresponding Author: Shampal.singh@yahoomail.com, Tel.: +91-8699108027*

DOI: https://doi.org/10.26438/ijcse/v7i3.794799 | Available online at: www.ijcseonline.org

Accepted: 09/Mar/2019, Published: 31/Mar/2019

Abstract— All Orthogonal Multiple Access techniques including Orthogonal Frequency Division Multiple Access (OFDMA) techniques fail to achieve the system limit due to individuality in resource allocation. To mitigate this issue Non Orthogonal Multiple Access (NOMA) introduce for 5th Generation (5G) wireless communication system. This paper presents the results and detailed survey of (NOMA) techniques that are helpful in improving the 5G system and meeting the demands of users. In this detailed survey, the prime focus is on the different proposed NOMA techniques in the literature and discussion of existing works on performance analysis, resource allocation, Multiple input multiple output NOMA (MIMO- NOMA), Single user NOMA (SU-NOMA), Multi User NOMA (MU-NOMA). Finally, we discuss the features and further research challenges of NOMA.

Keywords— OFDM,NOMA, IDMA, TDMA, PDMA, MIMO, Mulituser MIMO, SU MIMO, 3G, 4G, 5G, Wi-Fi

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) technique has been widely used in wireless communication systems such as Wi-Fi, Wi-Max, 3G, 4G, LTE, LTE Advance. Recent Mobile Networks have challenges of higher spectral efficiency, lower latency and massive connectivity. To resolve these challenges NOMA technologies have been recognized for 5G systems [1]. Multiple access techniques are fundamental function in a wireless communication system. Generally, multiple access techniques are classified into two categories (i) Orthogonal (ii) Non Orthogonal. In Orthogonal Multiple Access (OMA) every user served in different allocated time and frequency resources and cross correlation of signals from different users is zero. Some of the OMA techniques are Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA) and Orthogonal Frequency Multiple Access (OFDMA) [2,3]. But in NOMA multiple user's signals are superposed in the power domain by exploiting their respective channel gain differences so that all users can use resources simultaneously that is a non zero cross correlation between the signals from different users, which leads inter user interference [4,5]. To mitigate inter user interference a non linear detection algorithm used such as Successive Interference Cancellation (SIC), Maximum a Posteriori (MAP) or Maximum Likelihood (ML) at the receiver side. Some NOMA techniques are Interleave Division Multiple Access (IDMA) [6]. In recent years, a number of NOMA techniques proposed such as Pattern Division Multiple Access (PDMA) [7,8], Polar Coded NOMA (PC-NOMA) [9], Sparse Code Multiple Access (SCMA) [10], Bit Division Multiplexing (BDM) [11], Coordinated Operation Access Scheme and Multi User Sharing Access (MUSA) [12,13] etc.

II. BASIC OF NOMA TECHNOLOGY

In order to understand the basic concept of the NOMA, for simplicity, we take NOMA downlink system with User1 and User2 as shown in Fig. 1. As shown in figure a Base Station (BS) can serve two users at the same time, same frequency and same code, but with different power levels. In conventional techniques, by using water filling power allocation strategies, more power allocated to users with strong channel. But, in NOMA, more transmission power allocated to users with poor channel condition. To get the data at the receiver side, a user with the weaker channel condition and high transmission power will detect its data from signal directly by ignoring other user's data as noise. In particular, the message to the user with the weaker channel condition is allocated more transmission power, which ensures that this user can detect its message directly by treating the other user's information as noise. The second user with the stronger channel condition will detect data for its partner, then subtract it from its observed data and finally decode its own data. This is successive Interference Cancellation (SIC) scheme.

Let assume the overall system transmission bandwidth is to be 1 Hz. The base station transmits signal for both user1 and user2 are x_1 and x_2 respectively with transmitting power P_1 P_2. The sum of power is restricted to P at maximum. In NOMA, both signals are superposition coded as

$$x= \sqrt{P_1}x_1 +\sqrt{P_2}x_2 \quad (1)$$

The signal received at each user is represented as

$$y_i = h_i x + w_i \quad (2)$$

h_i = Complex channel coefficient between users and base station.

w_i = Gaussian noise, including inter-cell-interference (ICI) at receiver side. Where i=1 & 2 for user1 and user2, respectively.

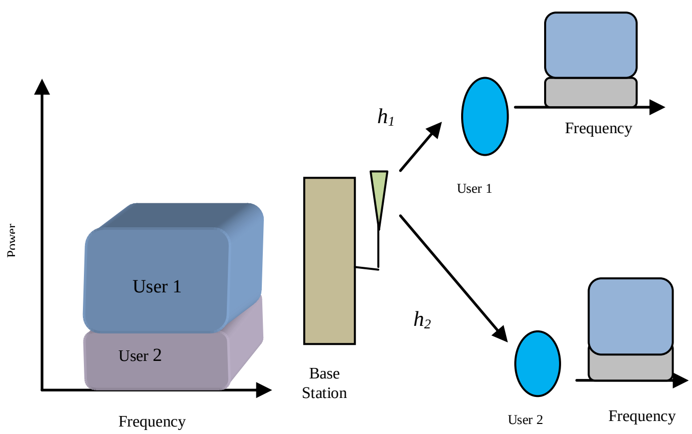

Fig. 1. NOMA Downlink system model with 2 users

Throughput of User1 and User2 are represented as

$$R_1 = \log_2(1 + P_1|h_1|^2/ N_{0,1}) \quad (3)$$

$$R_2 = \log_2(1 + P_2|h_2|^2/ N_{0,2}) \quad (4)$$

Where R_1 and R_2 are throughput of User1 and User2, respectively.

$N_{0,1}$ & $N_{0,2}$ are power densities of w_1 and w_2, respectively.

III. TYPES OF NOMA TECHNOLOGIES

Pattern Division Multiple Access based NOMA technique

Pattern Division Multiple Access (PDMA) technique proposed by Md Shipon Ali et al. A novel Non Orthogonal Multiple Access technique for future wireless network (5G). In this novel technique, PDMA defines the mapping of data of transmitting side to a resource group. System level results of this technique show at least 30% improvement in spectrum efficiency over Orthogonal Frequency Division Multiple Access (OFDMA) and support up to 6 times simultaneous connected users over conventional. This technique is based on SIC amenable multiple access and therefore SIC amenable pattern design used at transmitter and SIC based multiuser detection used at receiver which leads to its high complexity. Further, this technique can include the PDMA encoding and modulation, combined with multiple antennas.

A. System model for Uplink for PDMA:

PDMA System model is shown in Fig. 2. To describe the system model mathematically for uplink

Let

X_k = modulation symbols

V_k= PDMA modulation vector

K= number of users

N= number of Resources

Then we have

$$V_k= g_k x_k,\ 1 \le k \le K \quad (5)$$

Where g_k is N×1 binary vector with elements "0'' or "1''.

$$G_{PDMA}= [g_1, g_2, \ldots.., g] \quad (6)$$

G_{PDMA} is a PDMA pattern matrix with dimensions of N×K .

Received Signal y at receiver base station expressed as

$$y = \sum_{k=1}^{K} diag(h_k)v_k + n \quad (7)$$

from equation (5),(6) and (7) we can write in compact form as

$$y = Hx +n \quad (8)$$

Where x = $[x1, x2_{\ldots\ldots..} x_k]^T$

H = PDMA equivalent channel response matrix with K users multiplexed on N Resources

$$H = H_{CH} .* G_{PDMA} \quad (9)$$

$$H_{CH} = [h_1\, h_2 \ldots\ldots, h_k] \quad (10)$$

.* indicates the element wise product of two matrices.

A term Overload factor is defined as the ratio of the number of users and the number of Resources. It gives the multiplexing times of PDMA relative to orthogonal scheme.

B. System Model for downlink

Received signal Y_k at user k can be expressed as

$$Y_k = diag(h_k) \sum_{i=1}^{K} g_i x_i + n_k \quad (11)$$

$$=(diag(h_k)G_{PDMA})x + n_k \quad (12)$$

$$= H_k x + n_k \quad (13)$$

$$H_k = diag(h_k)G_{PDMA} \quad (14)$$

Where

n_k = noise and interference

h_k = downlink channel response of the kth user

H_k = PDMA channel response matrix of user k on N resource

NOMA technique for downlink Multiuser MIMO (MU-MIMO NOMA)

Md Shipon Ali et al. also proposed a NOMA technique for downlink Multiuser MIMO systems. In this multiuser MIMO-NOMA system, different User equipments (UEs) with distinct channel gains are grouped into clusters and all receiving antennas in each cluster are scheduled on power domain NOMA basis. The prime focus of this paper on inter-clustering interference cancellation. A new inter-clustering zero forcing beamforming technique introduced for downlink MIMO-NOMA, which eliminate inter-clustering interference also a dynamic power allocation for intra cluster and intra-cluster to maximize the throughput [3]. A simulation model of MIMO-NOMA system with 3 users shown in fig. 3.

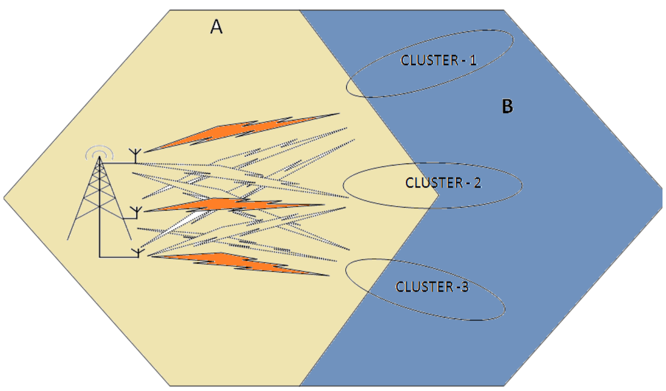

Fig.3. Simulation Model of MIMO-NOMA system with 3 users.

Desired MIMO Beam — Area distributed Cluster head

Interfering MIMO Beam — Area Distributed to Other users

Mohammd Al-Imari et al. proposed a uplink NOMA technique for 5G wireless network with novel subcarrier and power allocation algorithm which maximizes the users' sum rate by sharing the subcarriers. In this technique subcarrier and power allocation problem is formulated then respective novel algorithm proposed which are Local Rate Maximization (LRM) and Global Objective Maximization (GOM). The Results of this technique show that the proposed scheme attains BER close to the single user case and there is significantly progress in system spectral efficiency and fairness as compared to the conventional technique (OFDMA). Further work will be possible to study and investigate the performance of the NOMA scheme with Multi user detection and decoding techniques [14].

Signal Model

In this MIMO-NOMA downlink system, the received signal $y_{n,k}$ for kth user of nth cluster can be expressed as [3]

$$y_{n,k} = d_{n,k} h_{n,k} m_n p_{n,k} s_{n,k} + d_{n,k} h_{n,k} m_n \sum_{j=1}^{k-1} p_{n,j} s_{n,j} + d_{n,k} h_{n,k} \sum_{i=1, i\neq n}^{N} m_i x_i + d_{n,k} z_{n,k}. \quad (15)$$

Where

$d_{n,k}$ to be the decoding scaling weight factor in which the received signal is multiplied prior to decode at kth user and nth cluster end.

x_n = data stream for n cluster $\sum_{k=1}^{K} p_{n,k} s_{n,k}$

m_n, = nth column of th BF precoding matrix M

$p_{n,k}$ =Transmit power for kth user and nth cluster.

$s_{n,k}$ = Message Signal for kth user and nth cluster.

$z_{n,k}$ represents circularly symmetric complex Gaussian noise with variance σ^2.

The received signal to intra-cell interference plus noise ratio (SINR) can be expressed as follows:

$$SINR_{n,k} = \frac{|(d_{n,k} h_{n,k}) m_n|^2 p_{n,k}}{\underbrace{|(d_{n,k} h_{n,k}) m_n|^2 \sum_{j=1}^{k-1} p_{n,j}}_{\text{Intra-beam interference}} + \underbrace{\sum_{i=1, i\neq n}^{N} |(d_{n,k} h_{n,k}) m_n|^2 p_i}_{\text{Inter-beam interference}} + \underbrace{d_{n,k} z_{n,k}}_{\text{Noise}}} \quad (16)$$

Where p_i is the total transmit power for ith cluster.

Overall throughput of cell system

$$R_{cell} = R \sum_{n=1}^{N} \sum B \log_2 \left[1 + \frac{g_{n,k} p_{n,k}}{g_{n,k} \sum_{j=1}^{k-1} p_{n,k} + 1} \right] \quad (17)$$

Where

B = Total system bandwidth utilized by each transmit beam.

TABLE I [3]
SIMULATION PARAMETERS

Parameter	Value
Inter-site distance	0.6 Km
System effective bandwidth, B	8.64MHz
Bandwidth of one resource block	180 KHz
Number of available resources units	48
Number of antennas at BS end, N_t	3,5,10
Number of antennas at each UE end	1
Number of user/R_x antennas in each cluster	2,3,4
BS per antenna transmit power budget, p_n	43dBm
Antenna gain at BS/UE end	0dBi
SIC receiver's detection threshold, p_{tol}	10dBm
Path loss exponent, α	4
Receiver noise density, N_0	-169 dBm/Hz

NOMA technique for downlink Single User MIMO (SU-MIMO NOMA)

Xiaohang Chen et al. proposed a combination of NOMA with Single User MIMO (SU-MIMO) techniques to enhance the performance of the future radio network. Simulation result shows that NOMA with open loop and closed loop SU-MIMO can achieve performance gains of 23% for cell average throughput and 33% for cell edge user throughput as compared to the Orthogonal multiple access system. Further research can be done as an optimization of transmission power assignments and link adaptation, which leads to a further increase in performance gain of NOMA [15].

Combination of NOMA with SU-MIMO

Signal model

In this system a Base station (BS) with two numbers of transmitter and two user UE_1 (cell interior user) UE_2 (cell edge user). BS transmits a superpose signal for both the users with different transmission power of Power level 1 (for UE_1) and Power level 2 (for UE_2). Now higher power assigned to worse channel state (for UE2) and low power assigned to better power channel state (for UE_1) [2].
Received Signal Y_n at UE_n can be represented as

$$Y_n = H_n W_n \sqrt{(\beta_1 P)}\, S_1 + W_2 \sqrt{(\beta_2 P)}\, S_2 \qquad (18)$$

Where
β_1 = power ratio for power level *i*
$\beta_1 + \beta_2 = 1$
P = Transmission power of BS
Data detection performed using SIC technique at cell user UE_1 to remove the data signal of UE_2 and collect its own signal.

Polar Coded Non Orthogonal Multiple Access (PC-NOMA)

Jincheng Dai et al. proposed a Polar Coded Non Orthogonal Multiple Access (PC-NOMA) in which NOMA channel is decomposed into a series of binary input channels under a two stage channel polarization transform. In first stage multilevel coding structure used to divide NOMA channel into a group of user synthesized channels and in the second stage these channels are further divided into binary polarized channels using structure based on bit interleaved code modulation [9].

System model

PC-NOMA system model shown in fig. 4 with n number of users with different codebooks assigned to them. K_v number of bit input block of error correcting encoder u_v i.e
$K_v = k_v + m.$
Where k_v = information bits
M = number of bits of cyclic redundancy check (CRC)

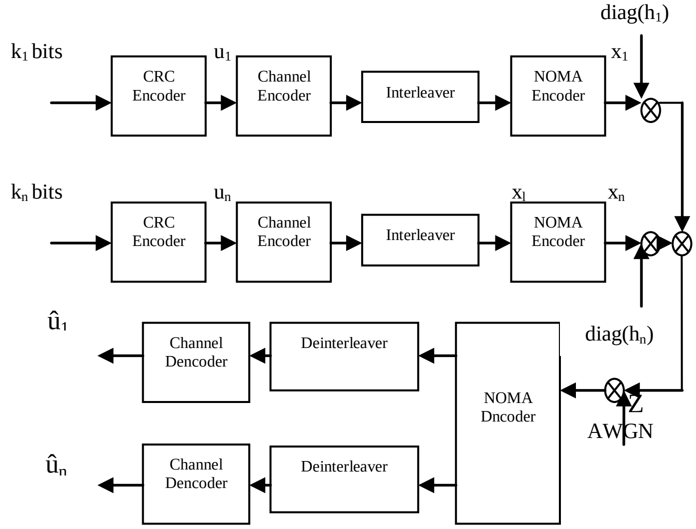

Fig.4. Block diagram of an uplink code-domain multiplexing NOMA system

For the n^{th} user, every M coded bits in c_n form a vector

$$b_n = c_{n,(t-1)J+1}, c_{n,(t-1)J+2}, \ldots\ldots, c_{n,tJ}) = (b_{n,1}, b_{n,2}, \ldots\ldots, b_{n,J}) \qquad (19)$$

Where t=1,2,3…….N/J is time slot and J denotes the modulation order.
Uplink NOMA system, the received signal y' is represented as

$$y' = \sum_{n=1}^{V} diag(h_n)\, x_v' + z' \qquad (20)$$

Where h_n is channel gain vector of n^{th} user and z is Additive White Gaussian Noise (AWGN).
After receiving y', multiuser detection and channel decoding are employed each user's information bits and can be done in either a separate concatenated manner or jointly combined manner.

Bit Division Multiplexing (BDM) for Broadcasting

BDM technique used for broadcasting multiple services. In this technique channel resource allocation is done at the bit level which extends the multiplexing from symbols level to bit level. The channel is divided into two sub channel at bit level. Capacity of each sub channel can be find by the knowledge of positions of bits within the symbol and independent de-mapping at receiver end [11]. System model of the 2 data (data1 and data2) for BDM broadcasting system as shown in fig.5. Data is encoded first then interleaved bit wise. Multiplexed constellation mapping of bits and then forward to channel. Reverse process is carried out at receiver end.

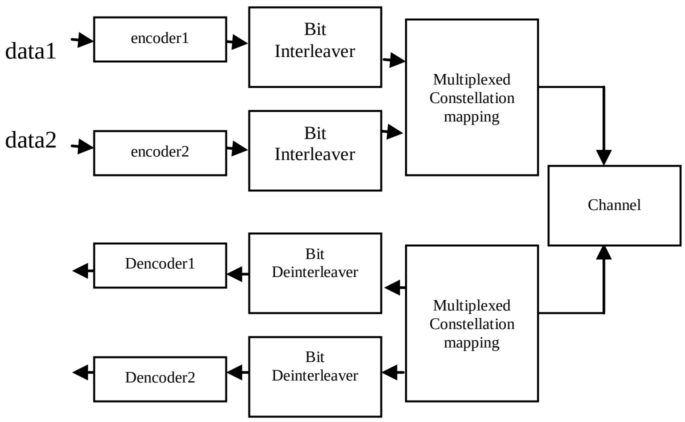

Fig.5 System model of broadcasting system with BDM

IV. CONCLUSION

In this paper, we discussed about the Non Orthogonal Multiplexing Technique and different types of NOMA Techniques exists in the literature for the emerging 5G mobile communication technology with their system model and mathematical expressions. These mathematical models and Concepts help researchers to understand the implementation and innovate a new Radio access technique. Each NOMA technology has its own unique way of implementation and lead to high performance in spectral efficiency and throughput of the system which shows that NOMA technology is emerging multiple access technology future wireless communication systems for high gain, high data rate and high spectral efficiency. In future, existing NOMA techniques may be improved with better performance and low complexity algorithm. Two or more NOMA techniques may combine to get high spectral efficiency. A better noise cancellation scheme may develop for high accuracy data receiving with low complexity. A hybrid form of Orthogonal and Non-Orthogonal radio access technique may be possible, which will lead to another novel access technique.

ACKNOWLEDGMENT

The Authors would like to thank I.K.G. Punjab Technical University for providing research environment and colleagues at I.K.G. Punjab Technical University for their valuable discussions and feedback.

REFERENCES

[1]. J.G. Andrews, et al. , " What will 5G Be ?" IEEE Journal on Selected Areas in Communications, Vol. 32, no. 6, June, 2014
[2]. J. Thompson et al, "5G wireless communication systems: prospects and challenges [Gest Editorial]," IEEE Communications Magazine, vol. 52, no. 2, pp. 62-64, Feb. 2014.
[3]. P. Wang, J. Xiao, and L. Ping, " Comparison of orthogonal and non-orthogonal approaches to future wireless cellualr systems," IEEE Vehicular Technology Magazine, vol. 1, no. 3, pp. 4-11, Sept. 2006.
[4]. M. Agiwal et al, " Next Generation 5G Wireless Networks: A Comprehensive Survey," in IEEE Communications surveys & Tutotials, Vol. 18, No. 3, Third Quarter 2016.
[5]. Andrea Goldsmith,"Wireless Communication,"Stanford University, 2005
[6]. Li Ping *et al*, " On Interleave Division Multiple Access," in IEEE Communication Society 2004, pp. 2869-2873.
[7]. Jie Zeng et al., " Pattern Division Multiple Access (PDMA) for Cellular Future Radio Access," in IEEE, 2015.
[8]. Shanzhi Chen *et al*, "Pattern Division Multiple Access (PDMA) – A Novel Non-orthogonal Multiple Access for 5G Radio Networks," in IEEE transaction on Vehicular Technology, 2016.
[9]. J. Dai *et al*, "Polar Coded Non Orthogonal Multiple Access," in IEEE International Symposium on Information Theory 2016 ,pp. 988-992, August 2016.
[10]. Hoseing Nikopour and Hadi Baligh, " Sparse Code Multiple Access," in IEEE 24th International Symposium on Personal, Indoor and Mobile Radio Communications on 8-11 Sept. 2013, pp. 332-336.
[11]. H. Jin, K.Peng and J. Song, "Bit Division Multiplexing for Broadcasting, " in IEEE transactions on Broadcasting, 2013.
[12]. Luis A. Vasquez-Toledo, D. L Rodriguez, " A coordinated Operatoin Access Scheme for 5G cellular systems," in IEEE ICUFN, pp. 604-606, 2017
[13]. W. Shin et al., " Coordinated Beamformming for Multi-Cell MIMO-NOMA," in IEEE Communicatioin letters in 2016.
[14]. Md Shipon Ai, Ekram Hossain and Dong In Kim, " Non-Orthogonal Multiple Access (NOMA) for Downlink Multiuser MIMO Systems: User Clustering, Beamforming, and Power Allocation." in IEEE access, 2016.
[15]. X.Chaen *et al*, "Evaluations of Downlink Non-Orthogonal multiple Acces (NOMA) Combined with SU-MIMO," in IEEE 25th International Symposium on Personal, Indoor and Mobile Radio Communication 2014,pp. 1887-1891.

Authors Profile

Mr. Shampal Singh is a PhD Scholar in the Department of Electronics and Communication at IKG Punjab Technical University Main Campus, Kapurthala, Punjab, India. He obtained His graduation (Electronics and Communication Engineering) from Guru Nanak Dev University. He obtained his Post graduation (specialization in Wireless Communication Engineering) from IKG Punjab Technical University Main Campus. His research area interests includes wireless communication network and OFDM system SISO,MIMO, Multiple Access techniques, 3G, 4G and 5G

Dr. Avtar Singh Buttar is presently working as Associate Professor & HOD, Electronics and Communication Engineering, IKG Punjab Technical University, Main Campus Jalandhar (Pb.) India. He obtained his B.E. in Electronics & Communication Engineering. from Punjab University in 1989. He qualified his Masters Degree in 1995 from National Institute of Technology Kurukshetra. He obtained his PhD degree From IKG Punjab Technical University. He has 24 years of Experience of Teaching, Guidance, and Research. His research interests include Wireless Communication and Computational Intelligence.

Dr. Dalveer Kaur is working as Assistant professor, Electronics and Communication Engineering in IKG Punjab Technical University Main Campus, Jalandhar, Punjab, India. She obtained her **M.Tech. (Microelectronics)**, University Gold Medalist, Guru Nanak Dev University, Amritsar (2003) and **Ph.D. (Complex Microwave Electronic Ceramics)**, Guru Nanak Dev University, Amritsar (2010). She has more than 9 years of teaching experience.

