Cooperative Non-Orthogonal Multiple Access Appraisal for Emerging Wireless Communication Technologies

Mr. B. Naveen Kumar [a], Anumula Sreeja [b], Pogula Chandana [c], Kashaboina Sruthi [d], Bathula Harish[e].

[a] Assistant Professor Dept. of ECE, Balaji Institute of Technology and Science Narsampet Warangal.

[a, b, c, d,e] Student, Department of Electronics & Communication Engineering, Balaji Institute of Technology & Science, Warangal.

ABSTRACT

One of the most dynamic and quickly expanding technology subfields within the communication industry is wireless communication. To be able to improve interaction between users and base stations, multiple access techniques must be employed. These various access techniques can be categorised broadly into two categories: non-orthogonal multiple access techniques and orthogonal multiple access techniques. We employed a variety of OMA strategies in 1G-TDMA, 2G-FDMA, 3G-CDMA, and 4G-OFDMA, among other generations. In the context of next-generation wireless technology, researchers aim to introduce the Non-Orthogonal Multiple Access (NOMA) technique to enhance reliability and facilitate multi-user access. This approach will mitigate the shortcomings of earlier generations and highlight the benefits of NOMA in 5G and future generations. Using the same resource in terms of time, frequency, and place, several users can be served by this NOMA technique. Superposition coding is used on the transmitter side to multiplex many users, while successive interference cancellation (SIC) is used on the reception side to separate multiple users[1,2]. There are strong users and weak users based on the strong and weak channel conditions between the users and the base station. In the NOMA approach, data from users 1 and 2 are received for decoding after being multiplexed on the transmitter side using the super position coding technique. Before decoding his own data, the near user decodes the distant user's data during decoding. Once the far user's data has been decoded, the near user sends the data to the far user. Both the base station's and the nearby user's copies of the identical signal are received by the far user. Relay transmits data from a nearby user to a distant user. We refer to this idea as cooperative relay. By using this method, we may boost the signal's dependability and quality while lowering the likelihood of a far user outage. This project analyzes and compares, across a channel, the performance of a two-user communication system in three phases: NOMA with cooperation, NOMA without cooperation, and OMA approaches. The comparison is done with respect to different parameters.

Keywords: OMA, TDMA, FDMA, CDMA, OFDMA, NOMA.

1. Introduction

The basic concept behind non-orthogonal multiple access (NOMA) is to provide time, frequency, and space for numerous users. TDMA, CDMA, FDMA, and OFDMA are examples of orthogonal multiple access (OMA) techniques that are not the same as these. The high requirements of future radio access systems are beyond the capabilities of these traditional OMA techniques. Every user in NOMA operates in the same band at the same time, with the exception of those whose power levels differ. NOMA is an OFDMA combination where the receiver uses successive interference cancellation (SIC) and the transmitter uses superposition coding. Specifically, information streams from many users are superimposed at the transmitter side. In order to achieve a better trade-off between system throughput and user fairness, sequential interference cancellation (SIC) is employed at the receiver side to decode the signals one at a time until the desired user's signal is achieved. Generally speaking, there are two sorts of NOMA plans[3,4]. Code-domain multiplexing is the other type, whereas power-domain multiplexing is the first. In order to attain excellent system performance, power-domain multiplexing assigns different power coefficients to each user based on their needs and the channel circumstances. When it comes to code-domain multiplexing, various users are given unique codes, which are then multiplexed above the same time frequency resources. Examples of these resources include low-density spreading (LDS), multiuser shared access (MUSA), and sparse code multiple access (SCMA). Other NOMA techniques include bit division multiplexing (BDM) and pattern division multiple access (PDMA), in addition to power domain multiplexing and code-domain multiplexing. Massive connectivity, low latency with excellent reliability, and increased spectrum efficiency are just a few of the desirable potential benefits that NOMA offers[5,6].

2. Objective:

The objective of the project is to analyze what the NOMA operates with regard to multiple attributes such as outage probability, channel capacity, bit error rate, and sum rate when using the joint relay idea. Through this project, we will be able to compete with the conventional NOMA technique in the areas of sum rates and data rates as well as system performance, signal quality, and reliability[7].

3. Performance Analysis:

The performance of OMA methodologies, NOMA without cooperation and and NOMA with cooperation is evaluated, investigated, and opposed with one another in terms of establishing the parameters using the input power transmitted across the Rayleigh propagation channel.Wireless channels are vulnerable to fading and propagation of multiple paths. There are plenty of channel models that can be used for modeling the fading effects. Every model handles a specific situation. The Rayleigh fading model is one such model[8,9]. When there is no line of sight (LOS) path between the transmitter and the receiver, the Rayleigh scattering model can be implemented. In other words, each individual multipath component has gone through small-scale fading phenomena like include diffraction, scattering, reflection, and shadowing.

3.1 Parameters:

3.1.1 Outage Probability:

The probability that the information rate to noise, interference, or other disturbance ratio is less than the threshold information rate to noise ratio is known as the outage probability in wireless communication. The term "outage probability" refers to the likelihood that a distant user will not receive information from the base station. The outage probability can be expressed as the CDF of SNR, which is provided by: P(C<r) = P $(log2(1 + h2SNR) < r)$. Mathematically, the outage probability can be represented as the CDF of the SNR and is given by, Pout(R) = Pr [AR<R]. where R is the target rate or threshold value and AR is the rate that the individual user can achieve. Blocking rate is higher if R is high. The SNR threshold value needs to be maintained low in order to obtain output below a maximum value[10,11]. The outage happens if AR is lower than the

desired rate. When the target rate is high, noise overwhelms the original information, causing the outage probability to reach its maximum value. Plotting the number of times the calculated achievable rates fell below the goal rate after setting the target rate can help you determine the outage likelihood for each user. Because many antennas are employed in cooperative NOMA to maximize directivity gain, the outage probability lowers as directivity gain increases. It is clear that in order to obtain a meaningful outcome, the outage probability needs to be lower. It is well known that an efficient communication system should have a lower probability of outages. when matlab is used to simulate the outage probability vs. transmission power. When NOMA was used in conjunction with collaboration, we saw lower outage probabilities, and when OMA was used alone, we saw higher outage probabilities[12].

3.1.2 Bit Error Rate:

The rate at which individual bits of information change as they are conveyed via a communication channel, from source to destination, is referred to as the bit error rate.There could be noise, distortion, or interference causing this bit change. The bit error rate formula is BER=Errors received / Total number of bits.In the case of NOMA without cooperation, the bit error rate is higher than the case of NOMA with cooperation when the bit error rate vs. transmit power is simulated in Matlab. Since the bit error rate should be lower, NOMA cooperatively observes this[13,14],15]. The receiver side bit error rate (BER) of a communication system can be impacted by various factors such as attenuation, wireless multipath fading, interference, distortion, transmission channel noise, and bit synchronization issues. Strong signal strength (unless it leads to crosstalk and more bit errors), slow and reliable modulation techniques, line coding schemes, and the usage of channel coding schemes such redundant forward error correction codes can all help reduce bit error rate (BER).The transmission bit error rate (BER) is calculated by dividing the total number of bits transferred (including redundant error codes) by the number of wrong bits identified prior to error correction. The information BER is the number of decoded bits that remain erroneous after error correction, divided by the total number of decoded bits (the useful information). It is roughly equivalent to the decoding error probability. In most cases, the information BER is smaller than the transmission BER. The strength of the forward mistake has an impact on the information BER.

3.1.3 Channel Capacity:

The greatest speed at which data can be successfully transferred from a source to a destination over a communication medium.Channel capacity refers to the amount of information or signal that can consistently go over a wireless communication channel at the fastest possible rate. The Rayleigh fading channel is used to send a signal from the transmitter to the receiver. Cooperative-NOMA has a very high channel capacity due to very little additional noise or interference. The total of each user's individual achievable rates is the system's channel capacity. Ar1 + AR2 equals channel capacity. where AR1 and AR2 represent the total achievable rates of US1 and US2, respectively. When channel capacity versus transmit power is simulated using Matlab, it can be seen that achievable channel capacity is higher for NOMA with cooperation than for OMA, and lower for NOMA without cooperation[18,17].

3.1.4 Sum Rate:

It is described as the mean total of all the network's user rates. Sum rate=mean (R1+R2+R3+..+Rn) is the formula that yields it. Ri stands for user rate, and i=1, 2, 3,..., n. When comparing NOMA with cooperation to NOMA without cooperation and OMA approaches, we can observe that the possible total rate for an efficient communication system should be higher. When working together, NOMA has demonstrated superior performance than the other two approaches in this parameter of the possible sum rate. The feasible sum rate is higher in NOMA with cooperation than in NOMA without cooperation, and it is less achievable in the case of OMA, according to the plot of the achievable sum rate against transmit power[18,19].

4. Simulation Results:

4.1 Outage Probability VS Transmit Power

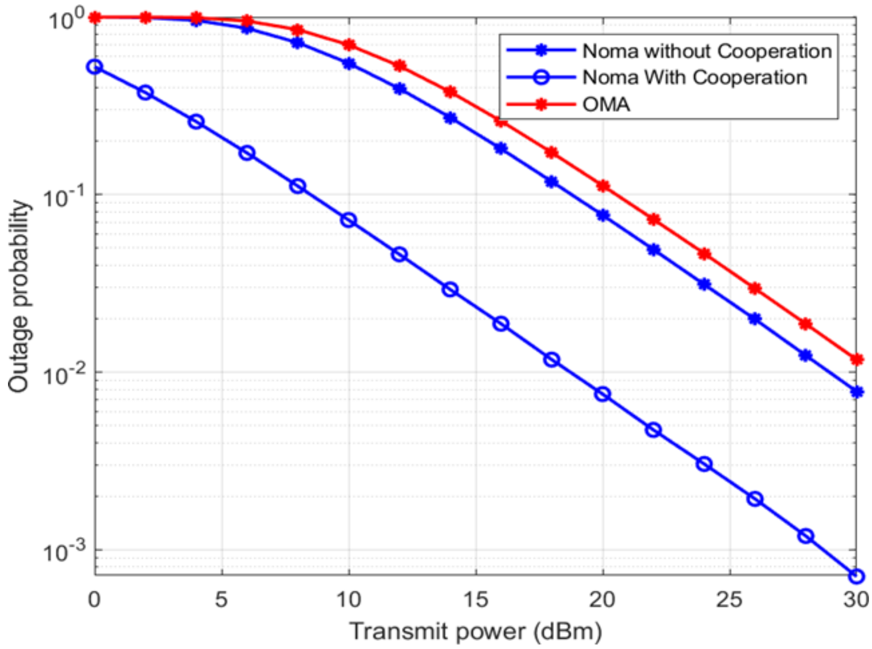

Figure 4.1 Outage Probability vs Transmit power

TRASNMIT POWER/OUTAGE PROBABILITY	NOMA WITHOUT COOPERATION	NOMA WITH COOPERATION	OMA
4 dBm	**0.9576**	**0.2568**	**0.9912**
8 dBm	**0.718**	**0.1114**	**0.8499**
12 dBm	**0.3958**	**0.04602**	**0.5304**
16 dBm	**0.1818**	**0.01854**	**0.2596**
20 dBm	**0.0771**	**0.007522**	**0.1134**
24 dBm	**0.03162**	**0.003002**	**0.04671**

Table 4.1 Outage Probability VS Transmit Power

The plot of Outage Probability vs. Transmit Power is shown in Figure 4.1. By pre-defining a user rate, the outage probability is meant to be calculated using the equations of possible rates of far users. Therefore, it is considered an outage if the usage rate falls below that threshold at any given time. According to the outage probability vs. transmit power graph, the outage probability at 4 dBm of transmit power for NOMA without collaboration is 0.9576, for NOMA with cooperation it is 0.2568, and for OMA approach it is0.9912. Likewise, for transmission powers of 8 dBm, 12 dBm, 16 dBm, and 20 dBm, the outage probability for NOMA with collaboration is 0.0075, for NOMA without cooperation it is 0.077, and for OMA and at 24 dBm it is 0.1134. As is well known, the likelihood of an outage in an effective communication system should be lower, and this is what we see when comparing NOMA with cooperation to OMA approaches and NOMA without cooperation[20]. When it comes to this Outage Probability parameter, NOMA collaborates better than the other two strategies.

4.2 Bit Error Rate:

The plot of bit error rate (BER) against transmit power is shown in Fig. 4.2. Two users' worth of random data are generated for this computation. Superposition coding comes after modulation. The transmitted and decoded data are compared at the remote user's receiver end, and a Matlab function called B.E.R (Tx Data, Rx Data) is used to determine the bit error rate. and made plans to undermine Transmit Power[21,22]. According to the plot of bit error rate against transmit power, for NOMA with cooperation, the bit error rate is roughly 0.0001, and for NOMA without cooperation, it is 0.01. As is well known, an efficient communication system should have a lower bit error rate, which is what is seen in NOMA with cooperation as opposed to NOMA without cooperation. When working together, NOMA has demonstrated greater performance than the other two approaches in this bit error rate parameter.

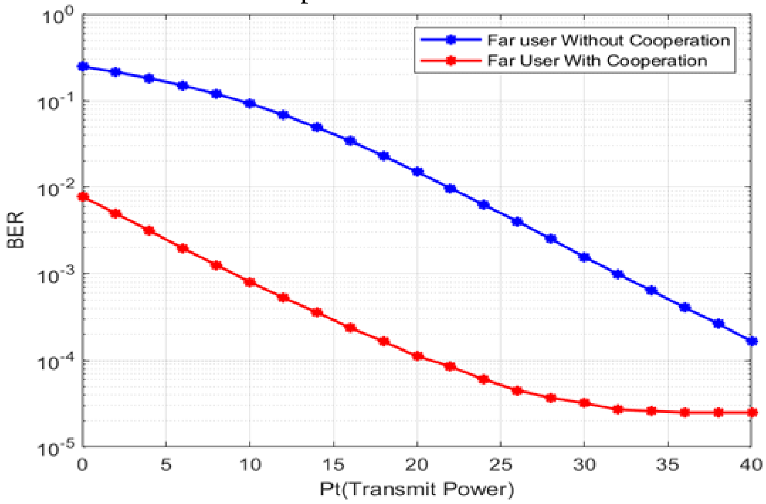

Figure 4.2 Bit Error Rate VS Transmit Power

4.3 Channel Capacity VS Transmit Power:

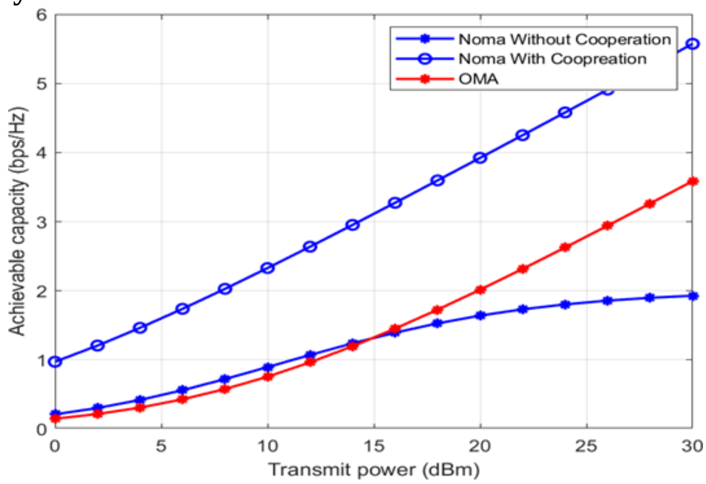

Figure 4.3 Achievable Capacity VS Transmit Power

TRASNMIT POWER/ACHIEVABLE CAPACITY(bps/Hz)	NOMA WITHOUT COOPERATION	NOMA WITH COOPERATION	OMA
4 dBm	**0.4209**	**1.465**	**0.3101**
8 dBm	**0.7228**	**2.029**	**0.5784**
12 dBm	**1.0710**	**2.639**	**0.9639**
16 dBm	**1.3940**	**3.274**	**1.4520**
20 dBm	**1.6400**	**3.924**	**2.0141**
24 dBm	**1.8030**	**4.581**	**2.6240**

Table 4.2 Achievable Capacity VS Transmit Power

A plot of achievable capacity against transmit power is shown in Fig. 4.3. Plotting the possible capacity against transmit power at each transmit power point is done using the equations. According to the channel capacity and transmit power plot, the feasible capacity for NOMA without collaboration is 04209, for NOMA with cooperation it is 1.465, and for OMA method it is 0.3101 at 4dBm of transmit power. Similarly, the achievable capacity is 1.64 in the case of NOMA without collaboration, 2.0141 in the case of OMA, and 3.924 in the case of NOMA with cooperation when compared at transmit powers of 8 dBm, 12 dBm, 16 dBm, and at 20 dBm of transmit power.

4.3 Sum Rate VS Transmit Power:

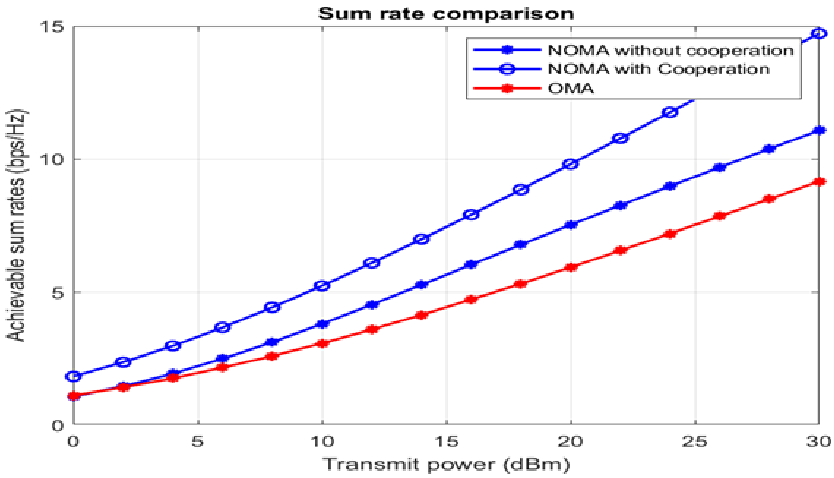

Figure 4.3 Sum Rate VS Transmit Power

TRASNMIT POWER/ ACHIEVABLE SUM RATES	NOMA WITHOUT COOPERATION	NOMA WITH COOPERATION	OMA
4 dBm	**1.940**	**2.984**	**1.768**
8 dBm	**3.122**	**4.429**	**2.60**
12 dBm	**4.530**	**6.097**	**3.595**
16 dBm	**6.031**	**7.912**	**4.72**
20 dBm	**7.529**	**9.812**	**5.934**
24 dBm	**8.981**	**11.760**	**7.202**

Table 4.3 Sum Rate VS Transmit Power

Plotting feasible total rate against transmit power is shown in Fig. 4.3. Plotting the possible capacity against transmit power at each transmit power point is done using the equations.According to the achievable sum rate and transmit power plot, the achievable sum rate for NOMA without collaboration is 1.940, for NOMA with cooperation it is 2.984, and for OMA technique it is 1.768 at 4dBm of transmit power. The feasible total rate is likewise 9.812 in the case of NOMA with cooperation, 7.529 in the case of NOMA without cooperation, and 5.934 in the case of OMA and at 24 dBm when compared at the transmit powers of 8 dBm, 12 dBm, 16 dBm, and at 20 dBm of transmit power. When comparing NOMA with cooperation to NOMA without cooperation and OMA approaches, we can observe that the possible total rate for an efficient communication system should be higher. When working together, NOMA has outperformed the other two approaches in this possible sum rate parameter[23].

5. Conclusion:

NOMA can be combined with other methods such as MIMO technology and cooperative communication. In this study, NOMA is combined with the cooperative communication idea in order to increase reliability and improve system performance. Performance is monitored and compared with NOMA without cooperation and OMA approaches. When the communication system's performance is compared to various parameters, such as bit error rate, achievable channel capacity, sum rate, and outage probability, it is observed that an effective communication system will have lower bit error rates, higher achievable channel capacities, lower outage probabilities, and higher sum rates. These results are derived from simulations where the parameters are plotted against the transmit power in NOMA with cooperation versus NOMA without cooperation and OMA techniques. Therefore, NOMA and the cooperative communication concept can be combined to enable efficient user-to-user communication in a network.

6. Future Work:

The main objective of this study was to monitor cooperative NOMA's performance in a communication system. For improved system performance, this work can be expanded in the future by integrating this technology with MIMO (Multiple Input and Multiple Output).

References:

[1] Madhu Kumar Vanteru, K.A. Jayabalaji, i-Sensor Based healthcare monitoring system by LoWPAN-based rchitecture,Measurement: Sensors,Volume 28,2023,100826,ISSN 2665-9174,https://doi.org/10.1016/j.measen.2023.100826.

[2] Ramesh, P.S., Vanteru, Madhu.Kumar., Rajinikanth, E. et al. Design and Optimization of Feedback Controllers for Motion Control in the Manufacturing System for Digital Twin. SN COMPUT. SCI. 4, 782 (2023). https://doi.org/10.1007/s42979-023-02228-8

[3] Madhu. Kumar. Vanteru, T. V. Ramana, et al , "Modeling and Simulation of propagation models for selected LTE propagation scenarios," 2022 International Conference on Recent Trends in Microelectronics, Automation, Computing and Communications Systems (ICMACC), Hyderabad, India, 2022, pp. 482-488, doi: 10.1109/ICMACC54824.2022.10093514.

[4] Allanki Sanyasi Rao, Madhu Kumar Vanteru et al. (2023). PAPR and BER Analysis in FBMC/OQAM System with Pulse Shaping Filters and Various PAPR Minimization Methods. International Journal on Recent and Innovation Trends in Computing and Communication, 11(10), 2146–2155. https://doi.org/10.17762/ijritcc.v11i10.8899.

[5] N. Sivapriya, Madhu Kumar Vanteru, et al , "Evaluation of PAPR, PSD, Spectral Efficiency, BER and SNR Performance of Multi-Carrier Modulation Schemes for 5G and Beyond," SSRG International Journal of Electrical and Electronics Engineering, vol. 10, no. 11, pp. 100-114, 2023. Crossref, https://doi.org/10.14445/23488379/IJEEE-V10I11P110

[6] Chandini Banapuram, Azmera Chandu Naik, Madhu Kumar Vanteru, et al, "A Comprehensive Survey of Machine Learning in Healthcare: Predicting Heart and Liver Disease, Tuberculosis Detection in Chest X-Ray Images," SSRG International Journal of Electronics and Communication Engineering, vol. 11, no. 5, pp. 155-169, 2024. Crossref, https://doi.org/10.14445/23488549/IJECE-V11I5P116.

[7] Madhu. Kumar. Vanteru, et al, "Empirical Investigation on Smart Wireless Autonomous Robot for Landmine Detection with Wireless Camera," 2022 5th International Conference on Contemporary Computing and Informatics (IC3I), Uttar Pradesh, India, 2022, pp. 200-205, doi: 10.1109/IC3I56241.2022.10072936.

[8] S. Bhatnagar, Madhu. Kumar. Vanteru et al., "Efficient Logistics Solutions for E-Commerce Using Wireless Sensor Networks," in IEEE Transactions on Consumer Electronics, doi: 10.1109/TCE.2024.3375748.

[9] V, Sravan Kumar, Madhu Kumar Vanteru et al. 2024. "BCSDNCC: A Secure Blockchain SDN Framework for IoT and Cloud Computing". International Research Journal of Multidisciplinary Technovation 6 (3):26-44. https://doi.org/10.54392/irjmt2433.

[10] Madhu Kumar, Vanteru. & Ramana, T.. (2022). Fully scheduled decomposition channel estimation based MIMO-POMA structured LTE. International Journal of Communication Systems. 35. 10.1002/dac.4263.

[11] Vanteru. Madhu. Kumar and T. V. Ramana, "Position-based Fully-Scheduled Precoder Channel Strategy for POMA Structured LTE Network," 2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), Coimbatore, India, 2019, pp. 1-8, doi: 10.1109/ICECCT.2019.8869133.

[12] Madhu. Kumar. Vanteru, T. V. Ramana, A. C. Naik, C. Adupa, A. Battula and D. Prasad,

"Modeling and Simulation of propagation models for selected LTE propagation scenarios," 2022 International Conference on Recent Trends in Microelectronics, Automation, Computing and Communications Systems (ICMACC), Hyderabad, India, 2022, pp. 482-488, doi: 10.1109/ICMACC54824.2022.10093514.

[13] Vanteru.Madhu Kumar,Dr.T.V.Ramana" Virtual Iterative Precoding Based LTE POMA Channel Estimation Technique in Dynamic Fading Environments" International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-6, April 2019

[14] Vanteru .Madhu Kumar,Dr.T.V.Ramana, Rajidi Sahithi" User Content Delivery Service for Efficient POMA based LTE Channel Spectrum Scheduling Algorithm" International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-9 Issue-2S3, December 2019.

[15] Vanteru.Madhu Kumar,Dr.T.V.Ramana" Virtual Iterative Precoding Based LTE POMA Channel Estimation Technique in Dynamic Fading Environments" International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-6, April 2019

[16] Karthik Kumar Vaigandla and J. Benita, " PAPR REDUCTION OF FBMC-OQAM SIGNALS USING PHASE SEARCH PTS AND MODIFIED DISCRETE FOURIER TRANSFORM SPREADING," ARPN Journal of Engineering and Applied Sciences, VOL. 18, NO. 18, pp.2127-2139, SEPTEMBER 2023

[17] aigandla, Karthik Kumar and Benita, J. 'Selective Mapping Scheme Based on Modified Forest Optimization Algorithm for PAPR Reduction in FBMC System'. Journal of Intelligent & Fuzzy Systems, vol. 45, no. 4, pp. 5367-5381, October 2023, DOI: 10.3233/JIFS-222090.

[18] Vaigandla, K. K. ., & Benita, J. (2023). A Novel PAPR Reduction in Filter Bank Multi-Carrier (FBMC) with Offset Quadrature Amplitude Modulation (OQAM) Based VLC Systems. International Journal on Recent and Innovation Trends in Computing and Communication, 11(5), 288–299. https://doi.org/10.17762/ijritcc.v11i5.6616

[19] Karthik Kumar Vaigandla, J.Benita, "PRNGN - PAPR Reduction using Noise Validation and Genetic System on 5G Wireless Network," International Journal of Engineering Trends and Technology, vol. 70, no. 8, pp. 224-232, 2022. Crossref, https://doi.org/10.14445/22315381/IJETT-V70I8P223

[20] Karthik Kumar Vaigandla and J.Benita (2022), Novel Algorithm for Nonlinear Distortion Reduction Based on Clipping and Compressive Sensing in OFDM/OQAM System. IJEER 10(3), 620-626. https://doi.org/10.37391/IJEER.100334.

[21] K. K. Vaigandla, "Communication Technologies and Challenges on 6G Networks for the Internet: Internet of Things (IoT) Based Analysis," 2022 2nd International Conference on Innovative Practices in Technology and Management (ICIPTM), 2022, pp. 27-31, doi: 10.1109/ICIPTM54933.2022.9753990.

[22] Vaigandla, K. K., Karne, R., Siluveru, M., & Kesoju, M. (2023). Review on Blockchain Technology : Architecture, Characteristics, Benefits, Algorithms, Challenges and Applications. Mesopotamian Journal of CyberSecurity, 2023, 73–85. https://doi.org/10.58496/MJCS/2023/012

[23] Karthik Kumar Vaigandla, Allanki Sanyasi Rao and Kallepelli Srikanth. Study of Modulation Schemes over a Multipath Fading Channels. International Journal for Modern Trends in Science and Technology 2021, 7 pp. 34-39. https://doi.org/10.46501/IJMTST0710005

[24] Karthik Kumar Vaigandla, Bolla Sandhya Rani, Kallepelli Srikanth, Thippani Mounika, RadhaKrishna Karne, "Millimeter Wave Communications: Propagation Characteristics, Beamforming, Architecture, Standardization, Challenges and Applications". Design Engineering, Dec. 2021, pp. 10144-10169,