Научная статья
УДК 504.054
DOI:10.31854/1813-324X-2023-9-3-104-111

Hybrid-NOMA for Wireless Communication System

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Abstract: *The demand for spectral efficiency, security, energy efficiency, power efficiency, high data rate, and throughput increases with the advancement of wireless communication systems. Power domain non-orthogonal multiple access (NOMA) is one the famous algorithms to achieve the essential requirement of a wireless communication setup. This paper proposes a novel algorithm called hybrid NOMA (H-NOMA). The hybrid NOMA can improve power efficiency (PE), spectral efficiency (SE), symbol error rate (SER), and sum secrecy. It is based on Hybrid Constellation Shaping to support a wireless communication system. Security is another primary concern for all communication systems; the proposed H-NOMA also provides better secrecy capacity as compared to NOMA. This paper contains the basic structure of the proposed algorithm. Simulation analysis is done for the symbol error rate, energy efficiency, and secrecy capacity. Machine learning genetic algorithm is also used for the optimization of system parameters.*

Keywords: *dynamic power, genetic algorithm, hybrid constellation shaping, machine learning, NOMA, wireless communication*

For citation: Khan R. Hybrid-NOMA for Wireless Communication System. *Proc. of Telecommun. Univ.* 2023;9(3): 104–111. (in Russ.) DOI:10.31854/1813-324X-2023-9-3-104-111

Hybrid-NOMA для беспроводной системы связи

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Аннотация: *С развитием систем беспроводной связи возрастает потребность в спектральной эффективности, безопасности, энергоэффективности, высокой скорости передачи данных и пропускной способности. Неортогональный множественный доступ в домене мощности (NOMA) – один из известных алгоритмов для выполнения основного требования к настройке беспроводной связи. В этой статье предлагается новый алгоритм, называемый гибридным NOMA (H-NOMA). H-NOMA может улучшить энергоэффективность, спектральную эффективность, коэффициент ошибок по символам и секретность суммы. Он основан на Hybrid Constellation Shaping для поддержки системы беспроводной связи. Безопасность – еще одна первостепенная задача для всех систем связи; предлагаемый H-NOMA также обеспечивает лучшую секретность по сравнению с NOMA. Эта статья содержит базовую структуру предлагаемого алгоритма. Анализ моделирования выполняется для коэффициента ошибочных символов, энергоэффективности и секретности. Генетический алгоритм машинного обучения также используется для оптимизации параметров системы.*

Ключевые слова: *динамическая мощность, генетический алгоритм, формирование гибридного созвездия, машинное обучение, NOMA, беспроводная связь.*

Ссылка для цитирования: Хан Р. Hybrid-NOMA для беспроводной системы связи // Труды учебных заведений связи. 2023. Т. 9. № 3. С. 104–111. DOI:10.31854/1813-324X-2023-9-3-104-111

1. LITERATURE REVIEW

The demand for modern wireless technology is leading the world towards a better but more complex wireless communication system. The gigantic, anticipated data transformation necessitates better Energy Efficiency (EE), reliability, massive connectivity, and low latency. Non-Orthogonal Multiple Access (NOMA) is one of the algorithms that offers the use of the same frequency band for the transmission of multiple signals. Several research analysis show that the NOMA outperform OFDMA [1]. In NOMA, the source broadcasts each signal after Superposition Coding (SC) to the respective consumers [2]. Each consumer receives superposed signals, which contain the signal of all users. Users that are closer to the source receive high power signals from all other users and the signal strength decreases for the distant users accordingly. For N consumers, each consumer (Un-nth consumer) performs Successive Interference Cancellation (SIC) for users with $g_n < g$ to decode its own signal. However, distant users receive very low power signals of near consumers, consequently they consider near users' signals as interference.

The M-NOMA [3], target to reduce the SIC complexity of the system with the offer of minimal interference with the help of created orthogonality/slicing during the modulation process rather than spectrum. Generally, slicing prevents interference between far and near consumers. Therefore, the consumers closer to the message source receive message signals without interference with distant users' signal. Hence, they need to apply SIC only to subtract message signals of near users for $g_n > g$. Therefore, near and distant users need to perform SIC only within the same cluster of near or far users. Comparatively, the near consumers in M-NOMA perform $N/2$ times less SIC than NOMA but far users perform same number of SICs.

For the secrecy of NOMA, several authors are focused on providing secure regions to the legitimate users for healthier security. In [4], authors suggested to provide protected zones around the legitimate users or establish a prohibiting region for eavesdropper/s. In [5], a perfect cooperative scheme is presented that is contingent on the number of relays and their distances from the BS and eavesdroppers.

There are several other modulation-based techniques which are used to improve the overall performance of a system. Recently, the more focused and targeted techniques involve constellation shaping like Probabilistic Constellation Shaping (PCS), Geometric Constellation Shaping (GCS) and Hybrid Constellation Shaping (HCS) [6]. Constellation shaping was introduced to approach the Shannon capacity and better power efficiency. GCS contains equiprobable constellation points with non-uniform distribution is Euclidean space. On the other hand, PCS is more attractive due to closer approach towards Shannon capacity [7]. HCS improves the Spectral Efficiency by rearranging the constellation points to a non-equidistant and non-uniform arrangement [8]. In a HCS method, the total amount of energy of each constellation point remains same, just like the conventional M-QAM. However, the total constellation point energy varies in probabilistic and geometric shaping.

Machine Learning (ML) techniques have been explored for several OMA algorithms in different scenarios including smart cities. Several ML algorithms have been introduced in a couple of year as Anderson-Darling test provided a ML based blind detection of modulation order opportunity in NOMA interference signals. Several future research works are open for ML-NOMA [9].

Genetic Algorithm (GA) is based on the principles of natural assortment and genetics. The complications with irregular variables, assorted continuous discrete variables and non-convex spaces involve optimization for the method design [10]. The GA is a suitable optimization ML process for an unconstrained optimization. It practices survival-of-the-fittest principle of nature to maximize the fitness function of the existing problem. MLGA is used in the few research articles of wireless communication systems. MLGA has been use for increasing the speed of the process of selection parameters [11], the optimization the BER in wavelength division multiplexing for four wave-mixing phenomena [12] and the optimization of major parameters in Vivaldi Antenna or Ultra-Wideband Communication [13]. MLGA is also useful to optimize parameters like data rate and energy efficiency [14].

The high energy consumption, limitation of power, SE, and band-width limitation, offers a great challenge for the implementation of an efficient wireless communication system. The requirements are the motivation towards proposing a novel Hybrid constellation-shaped NOMA (H-NOMA). The focus is to provide suitable way to efficiently use the available resources with maximum required output.

In this paper, the target is to use the required modulation constellation in a better way, by using the high energy level constellation point to modulate the high demand or far users and low energy levels to modulate the low demand or near users. As the users are modulated on one or more constellations, follows the same time and frequency, therefore, a name of H-NOMA is given.

H-NOMA can be used in several ways to avail yourself of the existing resources and algorithms. Depending on the distance of users from the source. If the distance is comparatively closer, there is no need to add additional power and only constellation point energies can be used. In the case of extremely far users, it can also be combined with NOMA, where far users are modulated on the high energy constellation point and allocated power to achieve the required Quality of Service. In the proposed H-NOMA, HCS is used to differentiate near and far users. The high energy constellation points of a 16-QAM are used to modulate a distant user and the near user is modulated on comparatively low energy level constellation point. Therefore, it leads to a power efficient system with low symbol error rate (SER) and high Achievable Data Rate (ADR).

2. SYSTEM MODEL

2.1. System Description

Figure 1 shows the considered downlink H-NOMA scenario, where each user is mapped on the respective energy level of the 16-QAM constellation; U_1 is mapped on the minimal and U_4 is mapped on the highest energy level. The system contains total four users $U_1 < U_2 < U_3 < U_4$, Rayleigh flat fading channel, distance $d_1 < d_2 < d_3 < d_4$ and 16-QAM constellation modulation. Four legitimate users and an Eavesdropper (Eve) with channel g_4 & $g_3 \approx g_{Eve} < g_1 < g_2$ is considered in the system as shown in the Figure 1Fig. . The channel condition of the Eve is worse than near users U_1 & U_2 and approximately same as far users: < U_3 < U_4. Therefore, Eve cannot eavesdrop on the message sent to near users with better channel conditions. There are two types of eavesdroppers: internal and external. In the considered scenario, there is only one external passive Eve. Since the Eve is external, therefore, it does not have the Channel State Information (CSI) information of any of any user to perform SIC.

2.2. Power Allocation

In the proposed scenario, the power of each source of the system is given as the set: $P_s = \{P_{s1}, P_{s2}, \dots, P_{sN}\}$. The sum of all power allocation coefficients, from each source to each user, $A = \{\alpha_{V1}, \dots, \alpha_{Vn}, \dots, \alpha_{VN/2}, \dots, \alpha_{VN}\}$ is given as:

$$\alpha = \sum_{m=1}^{N} \alpha_{V_m} = 1, \tag{1}$$

where α is the sum of coefficients of each user α_{Vm} involved in the transmission.

2.3. Sum Secrecy Capacity of the System

The data rate of Eve with NOMA is denoted as R_e and H-NOMA as R_{Me}. As per the considerations, the Eve's channel condition is worse than near users i. e., $g_e < g_{N/2}$; therefore, it cannot decode the near users' signals. For NOMA, the secrecy capacity for n^{th} user and the sum secrecy capacity can be written as:

$$S_{Mn} = R_{Mn} - R_{Me} \tag{2}$$

and

$$S_{MT} = \sum_{n=\frac{N}{2}}^{N} S_{Mn}. \tag{3}$$

For H-NOMA, the secrecy capacity for n^{th} user and the sum secrecy capacity can be written as:

$$S_{Mn} = R_{Mn} - RM_e \tag{4}$$

and

$$S_{MT} = \sum_{n=\frac{N}{2}}^{N} S_{Mn}. \tag{5}$$

It must be noted that the above equations are changed for the simulation results of section *V*.

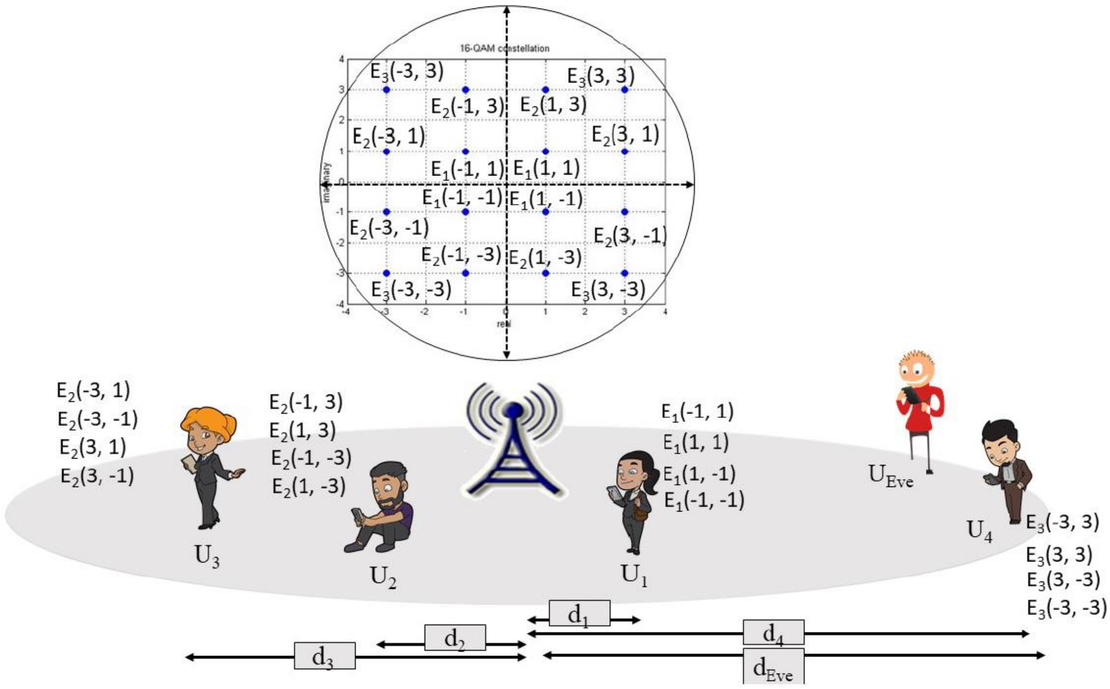

Fig. 1. Graphical Representation of H-NOMA with Four Users

3. THE NEW POWER EFFICIENT HYBRID CONSTELLATION SHAPING BASED NOMA (HCS-NOMA) WITH M-QAM SHAPING

There are three types of Constellation Shaping techniques, for making the data rate or capacity of a system close to the ideal Shannon capacity. In this paper, HCS is used to design a novel NOMA technique called H-NOMA. In HCS, the Constellation Points (CPs) are shaped according to their amplitude and symbol occurrences which changes the ratio of amplitude and symbol in each CP. In HCS, the total energy in each CP is constant irrespective of the degree of shaping.

The CPs $A^{[s]}$ can be represented in its complex form as given below:

$$A^{[s]} = \pm \frac{\rho_\mu}{\rho} a \pm \frac{\rho_\mu(ja)}{\rho(ja)} ja, \tag{6}$$

where in the equation, $\rho(a)$, $\rho_\mu(a)$, $\rho(ja)$ and $\rho_\mu(ja)$ show the non-uniform and uniform probability of occurrences of a and ja.

To satisfy the HCS of QAM, the signal stream $x^{[k]}$ of each $A^{[s]}$ must satisfy the following condition:

$$\mathbb{E}\left[\pm \frac{\rho_\mu}{\rho} a \pm \frac{\rho_\mu(ja)}{\rho(ja)} ja\right] = \\ = \mathbb{E}\left[\pm \rho_\mu(a) ja \pm \rho_\mu(ja) ja\right]. \tag{7}$$

For the above condition the expected value is the same of HCS and uniform symbol distribution.

3.1. Channel Description

For the H-NOMA, four users are modulated on a 16-QAM constellation for the transmission of the signal. It is helpful for developing a PE system. In H-NOMA, there is no need to allocate high power to the far user with weak channel condition $g_n < g_{n-1}$. Rather for fulfilling the quality of service requirement, the distant user of worst channel condition is modulated on the constellation point with better energy level and the near user of better channel condition is modulated on the low energy level constellation point.

For a conventional power domain NOMA, power is allocated to each user with respect to its distance and channel condition. A superposed NOMA signal for four user can be written as: $x = \sum_{n=1}^{4} \sqrt{\alpha_n P_T x_n}$, where α is the power coefficient and it is given as; $\alpha = \alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 = 1$.

The superposed signal of four users for H-NOMA with 16-QAM can be written as:

$$\mathbb{X} = \sqrt{P_T} X_{Hn}(x_1, x_2, x_3, x_4), \tag{8}$$

where in the equation, PT represents the total transmission power of the constellation's signal; x_1, x_2, x_3, x_4 are the symbols of four different users, modulated in one 16-QAM constellation X_{Hn}. 16-QAM has four energy levels, therefore, four users are modulated on each constellation, as each user needs to have a unique energy/power level with respect to its distance. For more traffic, higher modulations with more energy levels like 64-QAM and 256-QAM can be used. The modulation higher than 16-QAM is not the scope of this paper. However, it will be explored in future research. In H-NOMA, N constellations can be superposed together with SC before broadcasting. It is possible to modulate more than four users in a single transmission, with each constellation X_{Hn} carrying four users' symbols. Hence, for N consumers, (8) can be written as $\mathbb{X} = \sqrt{P_T} X_{Hn}(x_1, x_2, x_3, x_4) + \sqrt{P_T} X_{Hn}(x_5, x_6, x_7, x_8)$.

$$\mathbb{Y}_n = \sqrt{g_n \mathbb{X}} + W(t). \tag{9}$$

Each user will receive the same signal with different power dissipation. Each receiver is considered to know the level of energy at which its signal is modulated. Knowing the energy level, each user will simply decode its signal. For n users, if transmitter transmitted n symbols and four users are modulated on each constellation, then transmitter needs to distinguish the signal by encapsulating code of different users on the transmitted signal. Addition of code is out of scope of this paper and will be addressed in the extended version.

3.2. Symbol Error Rate

This section explores the discussion of the symbol error rate of the constellation shaping of M-QAM. In a general M-QAM scheme, there are three CPs regions for symbols. The distribution of the symbols' location contains four symbols in the corner, $\left(\sqrt{M}-2\right)^2$ symbols inside and $\sqrt[4]{M}-2$ symbols are on the edges of CPs. Hence, the SER distribution is also affected by the corner, inside and edge location of respective CPs symbols, $2\kappa_C$, $4\kappa_I$ and $3\kappa_E$.

The SER κ_{xi} for each CPs' symbol, with respect to the respective position of the constellation map, κ_{xi} □ $2\kappa_C$, $4\kappa_I$ and $3\kappa_E$ is given as:

$$\kappa_{xi} = \int_0^\infty Q\left(2d_{x_i^{[k]}}\right) 2L\exp - (L^2) dL = \\ = \frac{1}{2}\left(1 - \sqrt{\frac{d_{x_i^{[k]}}\zeta}{1 + d_{x_i^{[k]}}\zeta}}\right), \tag{10}$$

where in the above equation, L – the amplitude of the channel.

The average SER of modulated shaping is derived on the bases of the conventional uniform shaping SER. However, the SER of non-uniformly shaped constellation with $d_{x_i^{[k]}}$, $x_i^{[k]}$ and $A_i^{[s]}$ differs from the conventional one. The probability of error decreases with the distance $d_{x_i^{[k]}}$. Hence, when the symbol $\boldsymbol{x}$ moves away from its neighbouring CPs and towards the distant CPs then the chance of error decreases.

The SER for individual symbol for $x_i^{[k]}$ with non-uniform HCS of M-QAM is given as in (11), where for 16-QAM, $m_i = 1$, for $M > 16$, $m_i = \left\{1, \dots, \frac{\sqrt{M}}{2} - 1\right\}$ and the corner CPs have not been considered.

For Modulation Shaping (MS), the average SER of the symbols of x_i is $\zeta_M \approx \frac{1}{K}\sum_{k=1}^{K} \kappa_M\left[x_i^{[k]}\right]$ where k is the number of symbols in the constellation.

$$\kappa_M\left[x_i^{[k]}\right] \approx \begin{cases} 3\kappa_E, & = \left\{\pm\frac{\rho_\mu(a)}{\rho(a)}a \pm \frac{\rho_\mu(ja)}{\rho(ja)}j\right\} \\ 3\kappa_E, & = \left\{\pm\frac{\rho_\mu(a)}{\rho(a)}a \pm \frac{\rho_\mu(ja)}{\rho(ja)}ja\right\} \\ 4\kappa_I, & = \left\{\pm\frac{\rho_\mu(a)}{\rho(a)}(2m_i - 1) \pm \frac{\rho_\mu(ja)}{\rho(ja)}ja(2m_i - 1)\right\} \end{cases} \quad (11)$$

3.3. Achievable Data Rate

In this paper, the achievable data rate is optimized by HCS. The symbol energy E_s is supposed to be constant for the whole constellation, that the total energy of the constellation is always constant.

The ADR for the probabilistic and geometric shaping can be defined according to [15] as:

$$R_{cs_p}(SNR, \boldsymbol{X}) \triangleq \max_{p_S: E_S = 1} I^{cs_p}(SNR, \boldsymbol{X}, p_s) \quad (12)$$

and

$$R_{cs_g}(SNR, \boldsymbol{p_s}) \triangleq \max_{\boldsymbol{X}: E_S = 1} I^{cs_g}(SNR, \boldsymbol{X}, p_s). \quad (13)$$

It can be seen from the above equations that in the PCS, the probabilities of the constellation symbols are being optimized and, in the GCS, constellation symbols are being optimized.

As the HCS involves the optimization of probabilities of constellation symbols and the symbols, therefore, the ADR of the HCS can be written as:

$$R_{cs_h}(SNR, p_s, \boldsymbol{X}) \triangleq \max_{\boldsymbol{X}, p: E_S = 1} I^{cs_h}(SNR, \boldsymbol{X}, p_s). \quad (14)$$

In this paper, Rayleigh fading channel is considered for the transmission of signal. Therefore, according to the fading application of Shannon capacity, the ADR can be written as:

$$R_{cs_h}(SNR, p_s, \boldsymbol{X}) = \log_2\left(1 + \zeta_{V_{MT}}\right) \quad (15)$$

4. IMPLEMENTATION OF GENETIC ALGORITHM WITH MACHINE LEARNING

There are several methods for the optimization of physical parameters. In this paper, MLGA is being used for the optimization of multi-source system with respect to EE and the secrecy.

4.1. Energy Efficiency Optimization Problems

The use of power is a focus of attention for the integration of modern technology and therefore is highly subjected to energy limitations. For the proposed Intelligent Transportation System H-NOMA system, the EE is optimized for better system capability.

The EE of the system is given as:

$$\eta_{EE} = \frac{R_{M_{\text{sum}}}}{2P_{sn}} = \frac{\sum_{n=1}^{N}\log_2\left(1 + \zeta_{V_{MT}}\right)}{2P_{sn}}. \quad (16)$$

It is clear from (16), that the EE is directly related to the sum data rate of the system and inversely proportional to twice the total power of each transmitter since each user receives the same signal with two transmitters. The optimized sum data rate consequently optimizes the system's EE.

For the problem formulation, eight users are supposeed according to the system model of Figure 1. The sum data rate maximization problem can be formulated as:

$$P1\colon \max\colon R_{M_{\text{sum}}} = \sum_{n=1}^{\frac{N}{2}} R_{V_n} + \sum_{n=1}^{N} R_{V_n}\hat{\imath}\,. \quad (17)$$

For the optimization of data rate, the sum data rate is set as the fitness function in the genetic algorithm. The data rate is subjected to the respective NOMA power coefficients and the received SINR. The constraints are the power coefficients. According to NOMA, the offered constraints are:

$$C1\colon A(\alpha_1, \dots, \alpha_N) = \sum_{n=1}^{N} \alpha_n = 1,$$
$$C2\colon \alpha_n > 0, n = \{1, \dots, N\}.$$

4.2. Sum Secrecy Capacity Optimization Problems

Alongside EE and demands the system, the security of the system is being focused to meet the security demand of the modern Intelligent Transportation System. Security is the basic requirement of any modern system of IoT due to the connection of plenty of objects and systems together.

In this section, the proposed system's sum secrecy capacity of the system is optimized as shown below:

$$S_{M_n} = R_{M_n} - R_{M_e} \quad (18)$$

and

$$S_{MT} = \sum_{n=\frac{N}{2}}^{N} S_{M_n}. \quad (19)$$

It can be seen from (19) that the sum secrecy capacity depends on the capacity or data rate of each individual user of the system and the Eve. Hence, it is highly subjected to the individual's characteristics. It includes the channel, power, power coefficient, SINR and the interference. For the MLGA optimization, only system power, data rate and power coefficients of the system have been targeted.

For the formulation of problem, eight users are considered as given is the system model of Fig. , however due to worst channel condition of Eve as compared to near users, it cannot decode their signals. The sum data rate maximization problem for affected four far users can be formulated as:

$$P2\colon \max\colon S_{M_T}. \qquad (20)$$

For the optimization of sum secrecy capacity of the affected users, the sum secrecy capacity is used as the fitness function. The constraints for this case are again the NOMA power coefficients and the data rate. The reason for choosing the secrecy capacity as fitness function is to keep the difference of data rate optimized. Since the optimization of the power coefficients also optimizes the interference of both Eve and the affected users.

$$C3\colon A(\alpha_1, \dots, \alpha_N) = \textstyle\sum_{n=1}^{N} \alpha_n = 1,$$

$$C4\colon \alpha_n, n = \{1, \dots, N\}$$

$$C5\colon R_{M_n} > R_T \text{ Threshold}, n = \{1, \dots, N\}$$

5. PERFORMANCE EVALUATION

This section presents the simulation results of the proposed H-NOMA comparison with the base line conventional power domain NOMA. The first simulation result shows the basic comparison, the other two show the comparison with MLGA. For simulating the comparative results, 16-QAM, Rayleigh flat fading channel is used with four users. For more than four users, higher modulation techniques are required, which is not the scope of this paper.

Two different fitness functions are used including EE and sum secrecy capacity. MLGA works on the optimization of the fitness functions with respect to constraints. By checking all the combined possibilities, it provides the maximum possible output. Each simulation result in this section is the output of the similar MLGA procedure.

Figure 2 shows the simulated result of SER, for the comparison of NOMA with H-NOMA for four users. The comparison results show that H-NOMA transmission overall outperforms NOMA. In Figure 2, $n = \{1, 2, 3$ and $4\}$ is used to differentiate between each user. Where $n = 1$ is the nearest user with better channel condition and $n = 4$ is the furthest with the worst channel condition. It can be noticed that even when no extra power is used for the H-NOMA transmission, it performs approximately the same or better in some of the users' cases.

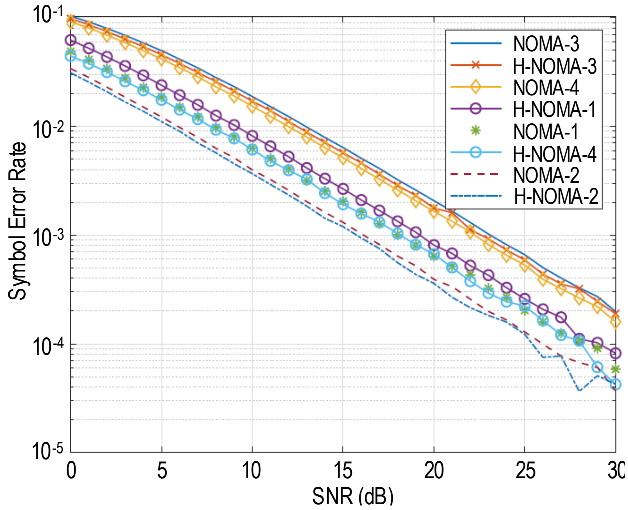

Fig. 2. Comparison for NOMA, HCS-NOMA and HCS-MSNOMA with and without HCS

Figure 3 shows the simulated comparison for the EE of H-NOMA and NOMA. The simulation is done with four users' sum data rate and their EE. ADR and EE are directly related to power, and power coefficients are possible constraints in power domain NOMA. Therefore, for a fair comparison, the same power coefficient is used for H-NOMA as well.

If constellation energy levels will be used for ML iteration, then the number of possible iterations will remain 4 (total no. of energy levels in a 16-QAM constellation), which will affect comparison fairness. Result shows the better EE for H-NOMA than NOMA. It is interesting to notice that H-NOMA outperforms ML-HNOMA, this is since H-NOMA itself is an optimization technique. Therefore, in this case of EE, HCS-NOMA outperforms due to its optimized nature.

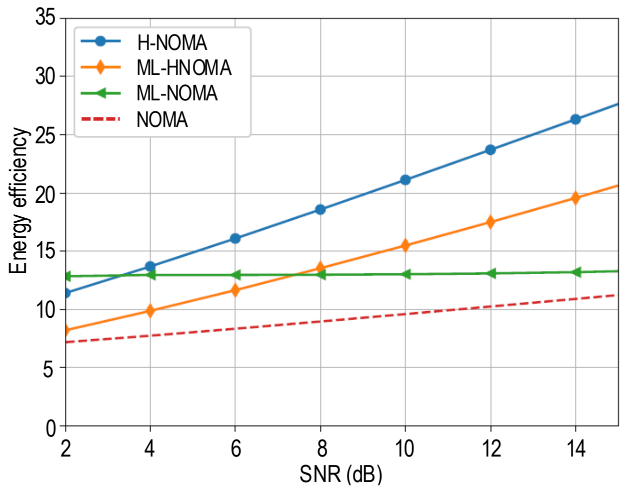

Fig. 3. Comparison Results for the Effect of MLGA on HCS-NOMA and NOMA for EE

Figure 4 shows the simulated comparison of H-NOMA and NOMA for the sum secrecy capacity. It is considered that the near users 1 and 2 are not affected by the eavesdropper, therefore, Eve can overhear only user 3 and 4.

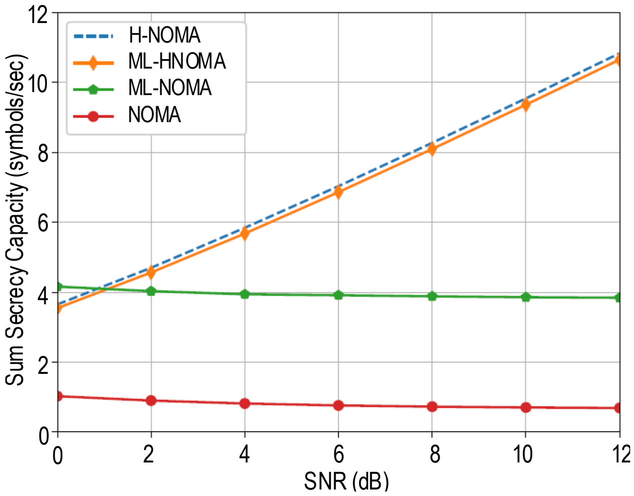

Fig. 4. Comparison Results for the Effect of MLGA on HCS-NOMA and NOMA

The Eve does not have the information about hybrid shaping and CSI. Eve cannot differentiate between the signals; therefore, it always receives the signal with high interference and cannot decode the exact signal. The high interference at the Eve's node results in the better sum secrecy capacity of the H-NOMA system. The sum secrecy capacity increases with SNR. However, only a slight difference is observed with the use of MLGA for H-NOMA, due to ideal interference amongst each symbol. HCS-NOMA accomplishes better secrecy capacity, even without MLGA. For the positive secrecy capacity of NOMA, SIC is performed at the receiver of the intended user and no SIC at Eve.

6. CONCLUSION

In this paper, a novel H-NOMA is proposed to support PE, SER, and security. The proposed algorithm is a new type of NOMA with HCS called H-NOMA. In H-NOMA, an approach is made to save the power for distant users by utilizing the higher power of the constellation point, to modulate the signal of distant users. It supports the transmission of multiple signals for all users. The simulation results also show the better SER, ADR, Sum Secrecy Capacity, and EE performance as compared to the traditional scheme with and without MLGA.

The main motivation of this paper was towards the efficient usage of the power levels of the modulation constellation and save enough additional power added for distant users in NOMA. Alongside power, it also provides better utilization of Band Width. Not only due to same channel usage but also by sending multiple users' signals on the same constellation.

References

1. Khan R., Asif R. Reflective In-Band Full Duplex NOMA Communications for Secure 5G Networks. *Proceedings of the International Conference on Smart Applications, Communications and Networking, SmartNets, 22–24 September 2021, Glasgow, United Kingdom*. IEEE; 2021. DOI:10.1109/SmartNets50376.2021.9555418

2. Khan R., Jayakody Nalin D.N.K. An ultra-reliable and low latency communications assisted modulation based non-orthogonal multiple access scheme. *Physical Communication*. 2020;43:101035. DOI:10.1016/j.phycom.2020.101035

3. Khan R., Jayakody D.N.K., Parvaiz H., Tafazolli R. Modulation Based Non-Orthogonal Multiple Access for 5G Resilient Networks. *IEEE Globecom Workshops, GC Wkshps, 09–13 December 2018, Abu Dhabi, United Arab Emirates*. IEEE; 2018. DOI:10.1109/GLOCOMW.2018.8644085

4. Gomez G., Martin-Vega F.J., Lopez-Martinez F.J., Liu Y., Elkashlan M. Uplink NOMA in Large-Scale Systems: Coverage and Physical Layer Security. *arXiv*. 2017. DOI:10.48550/arXiv.1709.04693

5. Arafa A, Shin W., Vaezi M, Poor H.V. Securing Downlink Non-Orthogonal Multiple Access Systems by Trusted Relays. *Proceedings of the Global Communications Conference, GLOBECOM, 09–13 December 2018, Abu Dhabi, United Arab Emirates*. IEEE; 2018. DOI:10.1109/GLOCOMW.2018.8648037

6. Szczecinski L., Alvarado A. *Bit-Interleaved Coded Modulation: Fundamentals, Analysis and Design*. John Wiley and Sons, 2015. 320 p.

7. Batshon H.G., Mazurczyk M.V., Cai J-X., Sinkin O.V., Paskov M., Davidson C.R., et el. Coded Modulation based on 56APSK with Hybrid Shaping for High Spectral Efficiency Transmission. *Proceedings of the European Conference on Optical Communication, ECOC, 17–21 September 2017, Gothenburg, Sweden*. IEEE; 2017. DOI:10.1109/ECOC.2017.8346117

8. Rajaram A., Jayakody D.N.K., Chen B., Dinis R., Affes S. Modulation-Based Simultaneous Wireless Information and Power Transfer. *IEEE Communications Letters*. 2020;24:136–140. DOI:10.1109/LCOMM.2019.2946236

9. Khan R., Kumar P., Jayakody D.N.K., Liyanage M. A Survey on Security and Privacy of 5G Technologies: Potential Solutions, Recent Advancements, and Future Directions. *IEEE Communications Surveys & Tutorials*. 2020;22(1):196–248. DOI:10.1109/COMST.2019.2933899

10. Rao S.S. *Engineering Optimization: Theory and Practice*. John Wiley and Sons; 2019. 832 p.

11. Yakzan A., Green R., Hines E. A Neuro-Genetic Hybrid Algorithm Utilizing Outdoors LOS Optical Wireless Channels. *Proceedings of the Fourth International Conference on Computational Intelligence, Communication Systems and Networks, 24–26 July 2012, Phuket, Thailand*. DOI:10.1109/CICSyN.2012.18

12. Singh K., Bhattacharjee R. Bit error rate performance of genetic algorithm optimized WDM systems. *Proceedings of the IFIP International Conference on Wireless and Optical Communications Networks, 11–13 April 2006, Bangalore, India*. IEEE; 2006. DOI:10.1109/WOCN.2006.1666661

13. Behera B.R. Vivaldi antenna for UWB communications: Design modelling and analysis of Vivaldi Antenna with genetic algorithm. *Proceedings of the International Conference on Control, Computing, Communication and Materials, ICCCCM, 21–22 October 2016, Allahbad, India*. IEEE; 2016. DOI:10.1109/ICCCCM.2016.7918252

14. Khan R., Tsiga N., Asif R. Interference Management with Reflective In-Band Full Duplex NOMA for Secure 6G Wireless Communication System. *Sensors*. 2022;22(7):2508. DOI:10.3390/s22072508

Список источников

1. Khan R., Asif R. Reflective In-Band Full Duplex NOMA Communications for Secure 5G Networks // Proceedings of the International Conference on Smart Applications, Communications and Networking (SmartNets, Glasgow, United Kingdom, 22–24 September 2021). IEEE, 2021. DOI:10.1109/SmartNets50376.2021.9555418

2. Khan R., Jayakody D.N.K. An ultra-reliable and low latency communications assisted modulation based non-orthogonal multiple access scheme // Physical Communication. 2020. Vol. 43. P. 101035. DOI:10.1016/j.phycom.2020.101035

3. Khan R., Jayakody D.N.K., Parvaiz H., Tafazolli R. Modulation Based Non-Orthogonal Multiple Access for 5G Resilient Networks // IEEE Globecom Workshops (GC Wkshps, Abu Dhabi, United Arab Emirates, 09–13 December 2018). IEEE, 2018. DOI:10.1109/GLOCOMW.2018.8644085

4. Gomez G., Martin-Vega F.J., Lopez-Martinez F.J., Liu Y., Elkashlan M. Uplink NOMA in Large-Scale Systems: Coverage and Physical Layer Security // arXiv. 2017. DOI:10.48550/arXiv.1709.04693

5. Arafa A, Shin W., Vaezi M, Poor H.V. Securing Downlink Non-Orthogonal Multiple Access Systems by Trusted Relays // Proceedings of the Global Communications Conference (GLOBECOM, Abu Dhabi, United Arab Emirates, 09–13 December 2018). IEEE, 2018. DOI:10.1109/GLOCOMW.2018.8648037

6. Szczecinski L., Alvarado A. Bit-Interleaved Coded Modulation: Fundamentals, Analysis and Design. John Wiley and Sons, 2015. 320 p.

7. Batshon H.G., Mazurczyk M.V., Cai J-X., Sinkin O.V., Paskov M., Davidson C.R., et el. Coded Modulation based on 56APSK with Hybrid Shaping for High Spectral Efficiency Transmission // Proceedings of the European Conference on Optical Communication (ECOC, Gothenburg, Sweden, 17–21 September 2017). IEEE, 2017. DOI:10.1109/ECOC.2017.8346117

8. Rajaram A., Jayakody D.N.K., Chen B., Dinis R., Affes S. Modulation-Based Simultaneous Wireless Information and Power Transfer // IEEE Communications Letters. 2020. Vol. 24. PP. 136–140. DOI:10.1109/LCOMM.2019.2946236

9. Khan R., Kumar P., Jayakody D.N.K., Liyanage M. A Survey on Security and Privacy of 5G Technologies: Potential Solutions, Recent Advancements, and Future Directions // IEEE Communications Surveys & Tutorials. 2020. Vol. 22. Iss. 1. PP. 196–248. DOI:10.1109/COMST.2019.2933899

10. Rao S.S. Engineering Optimization: Theory and Practice. John Wiley and Sons, 2019. 832 p.

11. Yakzan A., Green R., Hines E. A Neuro-Genetic Hybrid Algorithm Utilizing Outdoors LOS Optical Wireless Channels // Proceedings of the Fourth International Conference on Computational Intelligence, Communication Systems and Networks (Phuket, Thailand, 24–26 July 2012). DOI:10.1109/CICSyN.2012.18

12. Singh K., Bhattacharjee R. Bit error rate performance of genetic algorithm optimized WDM systems // Proceedings of the IFIP International Conference on Wireless and Optical Communications Networks (Bangalore, India, 11–13 April 2006). IEEE, 2006. DOI:10.1109/WOCN.2006.1666661

13. Behera B.R. Vivaldi antenna for UWB communications: Design modelling and analysis of Vivaldi Antenna with genetic algorithm // Proceedings of the International Conference on Control, Computing, Communication and Materials (ICCCCM, allahbad, India, 21–22 October 2016). IEEE, 2016. DOI:10.1109/ICCCCM.2016.7918252

14. Khan R., Tsiga N., Asif R. Interference Management with Reflective In-Band Full Duplex NOMA for Secure 6G Wireless Communication System // Sensors. 2022. Vol. 22. Iss. 7. P. 2508. DOI:10.3390/s22072508

Статья поступила в редакцию 01.05.2023; одобрена после рецензирования 24.05.2023; принята к публикации 02.06.2023.
The article was submitted 01.05.2023; approved after reviewing 24.05.2023; accepted for publication 02.06.2023.

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