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An Optimal Power Allocation Scheme for Cooperative Communication Network with Non-Orthogonal Multiple Access

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ABSTRACT

Cooperative communication is helpful in improving the capacity of the modern telecommunication by utilizing antennas for applying the spatial diversity approach. Cooperative communication quality of service is highly dependent on allocation of resources which significantly focus on power control and the selection of relays. Non-orthogonal multiple access (NOMA) base model performance is demonstrated in this paper for enhancing the efficiency of the spectrums and achievable sum rate for the cooperative communication systems. Optimized allocation of power in cooperative communication is targeted by applying the Satin bowerbird optimization (SBO) algorithm. Using this algorithm, power allocation factors that are used in the transmitted signal are selected optimally by considering minimum outage probability as an objective function. The performance of the proposed SBO based power allocation is compared to the scenario when SBO is absent and results incorporates outage probability and achievable sum rate.

Key words: Cooperative communication, Non-orthogonal multiple access (NOMA), power allocation, Satin bowerbird optimization (SBO) algorithm, and outage probability

1. INTRODUCTION

The cooperative relaying system (CRS) is a novel procedure for wireless communications increases in throughput and energy productivity. The point of the cooperative relaying is to help remote source hubs to transmit their information to goals. As of late, Non-symmetrical numerous entrance (NOMA) has been considered as a leap forward innovation for fifth-generation (5G) wireless systems [1]. Non NOMA is skilled to address 5G necessities by upgrading phantom proficiency and supporting massive connectivity. NOMA allocates distinctive power levels to the clients so as to enable them to transmit all the while utilizing a similar recurrence/time asset. [2,3]. The primary standard of NOMA is that a similar frequency and time assets can be shared by different clients and the clients which have better channel conditions can utilize successive interference cancellation (SIC) to identify and expel sign expected for the clients which have more poorer channel conditions [4]. SIC is feed to the receiver to isolate the superimposed signals of various clients. Consequently, NOMA can able to improve both range productivity and client reasonableness contrasted with the conventional orthogonal multiple access scheme (OMA). SIC develops the presentation of remote systems by empowering both simultaneous gatherings and impedance rejection [5]. SIC is a close far safe system. Actually, the issue of inactivity happens in the system at each phase of recovery because of which its handy execution isn't valuable [6]. As indicated by different procedures for handling signals at the relay nodes, there are essentially two collaboration plans, the amplify-and-forward (AF) and the decode-and-forward (DF). They are prominent transfer types utilized in cooperative communication. The researcher has been introduced in [7] another Hybrid Decode-Amplify Forward (HDAF) relay scheme, which has consolidated the preferences from the previously mentioned AF and DF hand-off systems. However, in a cooperative communication network, power allocation is one of the main challenges. This power allocation problem is to be analyzed for enhancing the performance of a cooperative communication network. Contributions of this proposed approach are described as follows:

(a) To enhance the achievable sum rate, the NOMA technique is presented with a cooperative communication network. Using this technique, users are assigned with the same bandwidth resource. Besides, the SIC process is used to decode the signal by canceling the noise in it.

(b) By optimizing the power allocation factors in the transmitted superimposed signal, outage probability can be reduced. So, for optimal power allocation, the Satin bowerbird optimization algorithm (SBO)is proposed.

The paper is organized as follows. In section 2 surveys some recent literature that focused on research on cooperative communication. Section 3 devotes optimal power allocation for the cooperative NOMA system using the Satin bowerbird optimization (SBO) algorithm. The simulation results of this proposed approach using SBO are discussed in section 4. The conclusion of this paper is mentioned in section 5.

2. RELATED WORKS

Ozduran, V [8] proposed a progressed successive interference cancellation system for the non-symmetrical numerous access methods. The methodology depends on mapping the got signal into sub-gatherings. The mapping procedure expects to accomplish the most astounding rates for every one of the sub-gatherings. As per systematic, analytical and Monte-Carlo recreation results, the progressed successive wiping out technique outflanks the regular successive interference cancellation methodology as far as the blackout execution. In addition, the new methodology additionally gives another point of view to the client postpone the decoding process. Liu, Y., et al [9] proposed hybrid DF/AF in NOMA and HDAF-NOMA transmission. This is among the initial attempts that includes decode- forward (DF), amplify-forward (AF) and NOMA in common configuration. Results demonstrated that the proposed HDAF-NOMA plan can accomplish a bigger entirety channel limit with regards to the transmission and it can likewise accomplish a bigger throughput value at high values of the SNR. The NOMA is found to be very effective in improving spectral productivity due to violation of the point of confinement of the symmetry forced on the transmitted information streams. Wan, D., et al (2018) demonstrated double-hop diamond relay network exploiting NOMA where a source communicates with a goal by means of two decode-and-forward (DF)[10]. Simulation concludes firstly NOMA is better than the conventional scheme as far as attainable aggregate rate is concern, particularly for the cases where the close far impact are extreme; secondly the HPA system can be a successful arrangement with compromise computational complexity and better execution. Zeng, J., et al. [11] explored Single-bearer NOMA with Multi-carrier NOMA in 5G. It gives high system limit, low idleness and enormous network, to address a few difficulties in the fifth era 5G wireless network. Research challenges of code multiple entrances and pattern division different access may be tended to with the incitement of the progressed and developed advancement in SC-NOMA. Datta, J. and Lin, H.P., [12] used Joint SIC and Cyclic FRESH Filtering to detect Uplink NOMA Systems. NOMA can be integrated with OFDM with the impact that various clients' transmissions could be multiplexed in power space over the every single subcarrier. Al Rabee F, et al. [13] proposed the optimized power levels for Uplink NOMA signals. The NOMA can be categorized in power-domain or code-domain. In power-domain at different power levels users are allowed to share information at the same frequency time and code .In 2017 Shahab, M.B. and Shin, S.Y. [14] investigated a period sharing (TS) based client blending methodology to suit comparable addition clients in non-orthogonal various access (NOMA) systems, named as TSNOMA. It is utilized conventional multiple access (OMA) plans. It has appeared through recreations that the exhibition of TS-NOMA as far as the ergodic total limit is superior to C-NOMA and OMA [15,16].

3. POWER ALLOCATION OPTIMIZATION IN COOPERATIVE NOMA SCHEMES

3.1. Overview

In this paper, an optimal power allocation scheme is presented for achieving the maximum achievable sum-rate in the cooperative NOMA system. In this paper cooperative communication, one half-duplex relay nodes are employed with decode and forward (DF) protocol. The source node splits the data symbols into two equal bit streams and forwards the streams towards the destination via the relay node in the superimposed mode. The NOMA scheme exploits the adoption of the superposition model so the problem of power allocation among the source and relay arises. So, to overcome this problem, the power allocation factors in the superimposed signal which is transmitted from the source node are optimally selected using the Satin bowerbird optimization (SBO) algorithm. In this algorithm, these factors or solutions are evaluated using outage probability.

3.2. System model: The system model (figure 1) of the NOMA based cooperative relay system is shown in figure 1. In this system model a source, destination and relay node is shown. The relay node operations are defined in the DF-mode. Other nodes of network communicate through the scheme of half-duplex mode Since the direct link in between source and destination is absent hence the source forwards the signal via a relay node. The communication model system has channel coefficient between source-to-destination, source-to-relay and relay-to-destination and represented as the function h_{sd}, $h_{sr,}$ and h_{rd} respectively. At the source end transmitted signal gets divided into the two symbol streams s_1 and s_2 and transmits them towards the relay node in the superimposed mode. In first time slot, the source is capable of forwarding the symbols to relay node as well as to the destination. The received signal by the relay node from source is given by the following expression.

$$y_{sr} = \left(\sqrt{\alpha_1 p_{tx}}\, s_1 + \sqrt{\alpha_2 p_{tx}}\, s_2\right) h_{sr} + n_{sr} \qquad (1)$$

The received signal at the destination through the source is denoted as follows,

$$y_{sd} = \left(\sqrt{\alpha_1 p_{tx}}\, s_1 + \sqrt{\alpha_2 p_{tx}}\, s_2\right) h_{sd} + n_{sd} \qquad (2)$$

Where, α_1 and α_2 represent the power allocation factors, these factors should follow the condition $\alpha_1 + \alpha_2 = 1$. p_{tx} represents the transmit power. s_1 and s_2 represent the transmitted symbols. n_{sr} and n_{sd} denote the additive white Gaussian noise introduced in between the source to relay and source to destination communication channel respectively.

The NOMA technique is used for the transmission in second time slot, each node processes successive interference cancellation (SIC) on the signal arrival. Using SIC, the relay node performs the decoding of the receiving end symbol. If the power allocation factor $\alpha_1 > \alpha_2$, then the relay node decodes the symbol s_2. Finally, the received signal on destination are directed from the source and they are denoted by following equation:

$$y_{rd} = \left(\sqrt{p_{tx}}\, s_2\right) h_{rd} + n_{rd} \qquad (3)$$

Where, n_{rd} denotes the additive white Gaussian noise of relay–destination.

After applying SIC, the achievable sumrate at relay node can be defined as follows,

$$R_r = \frac{1}{2}\log_2\left(1 + \frac{\alpha_1 h_{sr}^2}{N_0}\right) \qquad (4)$$

The achievable sum rate on destination is described by following equation:

$$R_d = \frac{1}{2}\log_2\left(1 + \frac{\alpha_1 h_{sd}^2}{\alpha_2 h_{sd}^2 + N_0}\right) \qquad (5)$$

Where N_0 represents the variance.

For differentiating the superimposed data received on destination an optimal-power-allocation method is applied on all nodes while targeting to maximize the performance in terms of achievable sum rate. For this purpose values of power allocation factors defined in the superimposed signal are chosen optimally. These factors are selected based on the outage probability (p_{out}) and constraints.

$$P_{out} = pr\left(\frac{1}{2} min\left\{log_2\left(1 + \frac{\alpha_1 h_{sr}^2}{N_0}\right), log_2\left(1 + \frac{\alpha_1 h_{sd}^2}{\alpha_2 h_{sd}^2 + N_0}\right)\right\} < R\right) \qquad (6)$$

Where, R denotes transmission rate.

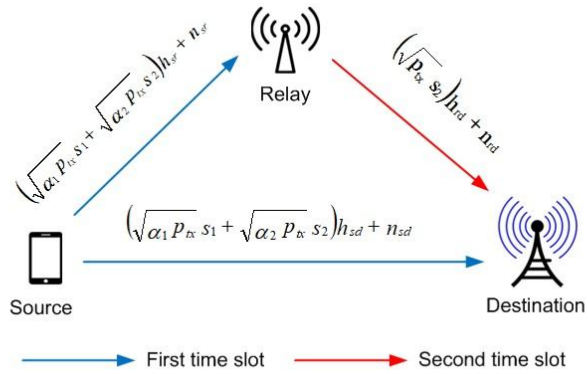

Figure 1: System model

3.3. SATIN BOWERBIRD OPTIMIZATION (SBO) ALGORITHM BASED POWER ALLOCATION

In the algorithm of SBO, bower is built by adult males utilizing various materials on their land amid the season of mating. They tend to use different materials like sparkling objects, branches, flowers and fruits along with dramatic gestures which are also considered as parameters for attracting females. The males make use of their inborn tendency to construct the bower and lampoon of other male birds. SBO algorithm is organized based on the principles of satin bowerbird life in several stages.

3.3.1 Initialization: The SBO algorithm is initialized by creation of an initial population in random. A set of localityis incorporated in for the bowers and translatetoa n-dimensional vector space of those parameters which has to be optimized. Upper and lower limit parameters as the initial population is arbitrarily initialized. The numbers of variables in the optimization problem are same as the parameter in every bower.In this approach, optimal power factors are considered as candidate solutions or bowers. These solutions are initialized as follows:

$$X_p = (x_1, x_2, ..., x_m) \quad (7)$$

Where, x_m denotes the m^{th} solution in the p^{th} population and it can be represented as follows.

$$x_m = \{\alpha_1, \alpha_2\} \quad (8)$$

Where, α_1 and α_2 represents the optimal power factors in the m^{th} position of the solution.

3.3.2 Fitness evaluation: Bower's attractiveness is the probability chosen by a female bird. Likewise, by choosing a bower depending on the probability assigned to the male, it mimics the building of the bower. Here the fitness fit_h is

$$fit_h = Min\{p_{out}\} \quad (9)$$

Elitism: Elitism preserves the best solution at each stage of the optimization problem. Generally, every bird builds its nest utilizing its natural instinct. The male bird utilizes its instinct on its likeness of every other bird in mating season to build and decorate its bower. But, the experience is one of the primary factors that can attract a lot of attention to a particular male's bower. In enhancing both the building of bower and dramatic gestures, the experience contributes a lot. This implies that older males are capable of attracting more attention to their bower. This is because the experienced male birds build better bower with better fitness than other bowers. Here, the best-built bower's position is referred to as the elite of iteration.

3.3.3 Updation: New alterations at any bower are determined using equation.

$$W_{hj}^{new} = W_{hj}^{old} + \lambda_j \left(\frac{w_{ij} + w_{elite,j}}{2} \right) - W_{hj}^{old} \quad (10)$$

Where, W_h represents the h^{th} bower or solution vector, W_{hj} represents the j^{th} member of this vector and W_i represents the target solution from every solution in the present iteration.W_{elite}indicates the elite's position that is stored in each algorithm cycle. The parameter λ_j determines the attraction power in the target solution or target bower. By using the equation, the parameter λ_j is determined.

$$\lambda_j = \frac{\beta}{1 + o_i} \quad (11)$$

Where, the greatest size of the step is represented as β and utilizing the target bower, the probability obtained by equation 1 is represented as o_i. The size of the step is inversely proportional to the target position's probability.

Mutation: The male birds can get attacked or be completely ignored by other animals when they are involved in building a bower. Arbitrary modification is applied to W_{hj} with a certain probability. A normal distribution (L) is utilized with variance α^2 and average of W_{hj}^{old} as in equation.

$$w_{hj}^{new} \sim L\left(w_{hj}^{old}, \alpha^2\right) \tag{12}$$

$$L\left(w_{hj}^{old}, \alpha^2\right) = w_{hj}^{old} + \left(\alpha * L(0,1)\right) \tag{13}$$

The value of α that is evaluated in equation is a part of space width.

$$\alpha = y * \left(\mathrm{var}_{\max} - \mathrm{var}_{\min}\right) \tag{14}$$

Where, the significant of the difference between lower and upper bound which is variable is represented by the parameter *y*. The upper and lower limit assigned to the variable is denoted by var_{max} and $\mathrm{var}_{min.}$Here the old population and new one attained after the changes are combined and sorted after the evaluation. The new population is created. When the end criterion is satisfied, the functioning of the SBO algorithm is terminated. Figure 2 shows the flowchart of SBO algorithm.

Algorithm 1: Selection of optimal power allocation factors using SBO

Input: Random values of power allocation factors
Output: Optimal power allocation factors

1. Assign the first population of bowers or solutions at random
2. Evaluate the fitness using equation (9)
3. Find the best bower and it is assumed to be the elite
4. **While** the end criterion is not follow
5. Evaluate the probability of bowers
6. **For loop 1** each bower
7. **For loop 2** each element of the bower
8. Apply the roulette wheel mechanism to select the bower
9. Evaluate $\lambda_k$by equation (11)
10. Modernize the bower position by eq. (13)
11. **End** for loop 2
12. **End** for loop 1
13. Calculate the latest cost value for all the bowers
14. Update the elite bower if any of the bower found to be fitter than the recent elite
15. **End** while loop
16. Return to the best bower

4. RESULTS AND DISCUSSION

The proposed technique used in this paper is implemented using MATLAB programming and the experimentation is done utilizing an arrangement of having 8 GB RAM and 1.60 GHz Intel i5 processor. Table 1 describes the different simulation parameters settings and assumptions. For the simulation of this proposed approach, 200 mobile nodes are used where 198 nodes are considered as relay nodes while the remaining two nodes are considered as source and destination. With the NOMA technique, the source side transmitter forwards the superimposed symbols towards the destination via the relay node. The source node has initial energy assigned to be 0.3J and the initial energy for the relay nodes is uniformly assigned as [0.1J, 0.5J].

Table 1: Simulation setting

Parameters	**Assumptions**	**Parameters**	**Assumptions**
Number of nodes	200	Bandwidth of channel	1MHz
Initial energy of source	0.3J	Relaying protocol	Decode and Forward (DF)
Initial energy of RNs	[0.1J, 0.5J]	Receiver noise	Additive White Gaussian Noise
Channel model	Rayleigh fading channel	Data rate	100-500kb/s

In this approach, the Rayleigh channel fading is considered with 1MHz. Besides, at destination noise modeled using the Additive White Gaussian Noise (AWGN). DF relaying protocol is applied and the transmission rate is taken as 1bit/s. Noise associated with the channel is an AWGN with zero mean and variance $N_0 = 1$.

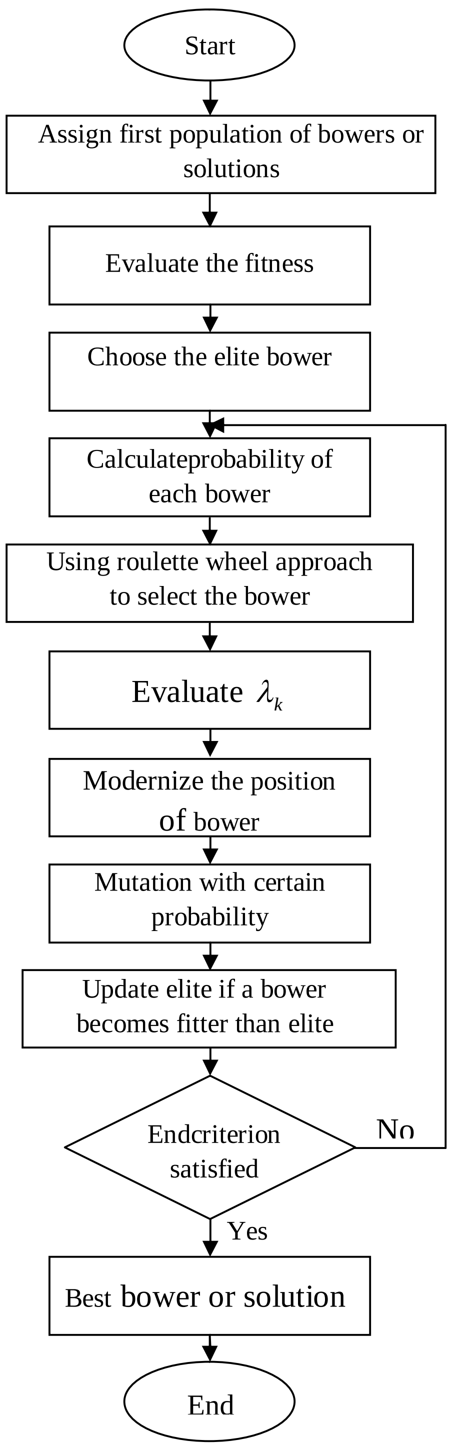

Figure 2: Flowchart of SBO algorithm

4.1. Performance analysis: The outage probability evaluated as the measure of performance in cooperative system along with the achievable sum rate. The results of proposed SBO based power allocation optimization is compared to the situation without the inclusion of SBO. The following section analyzes the performance metrics by varying total power and SNR.

4.2. Performance-based on varying total transmit power: Figure 3 shows the comparison of the outage probability of the SBO based power allocation with that of without using SBO. In the figure it is shown that the outage probability gets decrease when the total transmitted power increases. By exploiting the SBO technique in power allocation outage probability minimized to 11% compare to that of without using SBO. As the SBO algorithm has good convergence speed and accuracy, optimal values are chosen for power factors in the superimposed signal. So, this algorithm will result in minimizing the outage probability than the scheme without using the SBO. Figure 4 show the comparison of the achievable sum-rate of different power allocation schemes.Achievable sum rate of the power allocation schemes is increased when the total power increases as shown in the figure. Also, compared to the existing power allocation scheme, the achievable sum rate of the proposed power allocation scheme based on SBO is improved to 7%. Namely, the achievable sum rate using the SBO is 2.6bps/Hz at 20dB of transmitted power while without SBO it is observed to be 2.45bps/Hz.

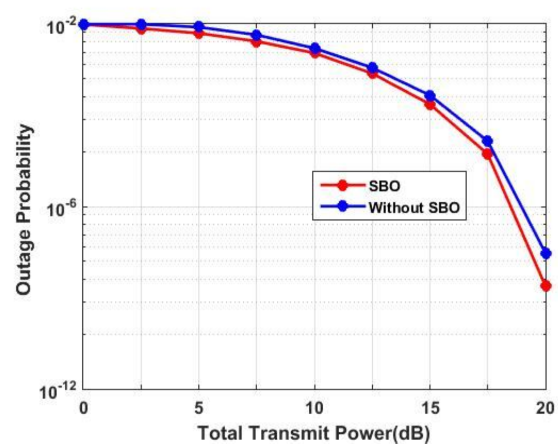

Figure 3: Total transmit power Vs Outage probability

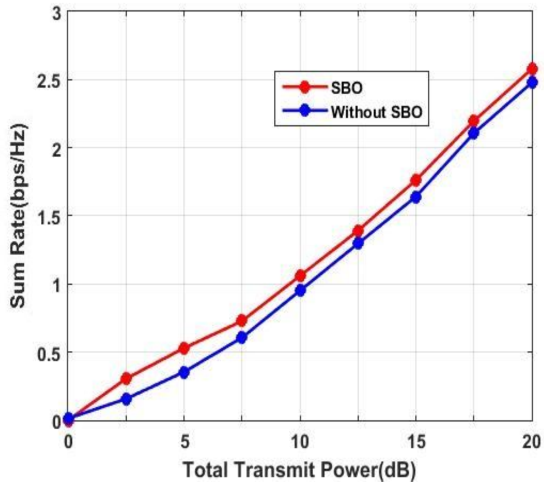

Figure 4: Total transmit power vs Achievable sum rate

4.3. Performance-based on varying SNR: Figures 5 show outage probability and 6 show the comparison of and achievable sum rate with and without SBO based power allocation. Figure 5 shows the tradeoff between SNR and outage probability for different power allocation schemes by varying SNR. As shown in the figure 5, when SNR increases, outage probability is reduced. Namely, at 5dB of SNR, the outage probability without applying the SBO is 0.98 while it attains 0.06 at 40dB of SNR. Compared to the existing technique, the outage probability using SBO is reduced to 16% at the SNR value of 5dB, while that of the proposed scheme is reduced to 83% at 40dB of SNR.

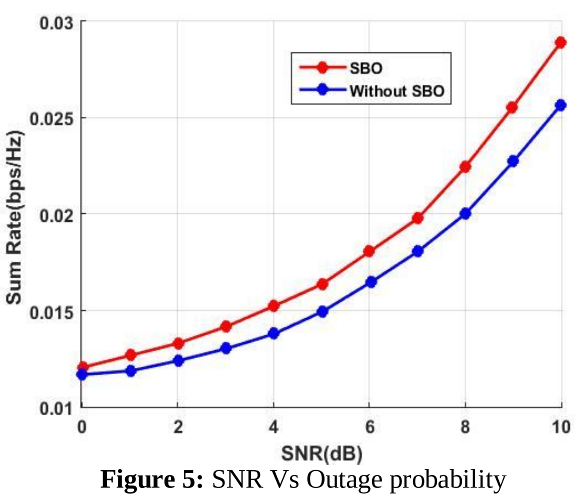

Figure 5: SNR Vs Outage probability

A comparative analysis for the achievable-sum-rate of power allocation techniques for varying SNR is shown in figure 6. As shown in the figure 6, the achievable-sum-rate on applying the proposed SBO based power allocation optimization is increased when the SNR increases. Namely, the achievable sum rate without using the SBO is 0.012bps/Hz at 5dB of SNR while that of the existing scheme is 0.026bps/Hz at 40dB.

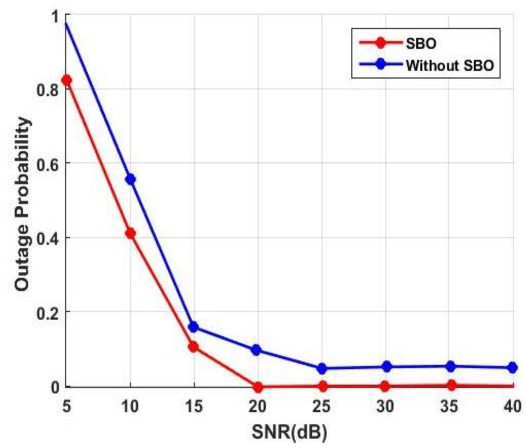

Figure 6: SNR vs Achievable-sum-rate

However, comparison related to the existing power allocation scheme, the proposed SBO optimization attains gives a better achievable sum rate. Namely, at 5dB of SNR, the achievable-sum rate of the proposed SBO based power allocation scheme is 0.0125bps/Hz while that of the without SBO related power allocation optimization has value 0.029bps/Hz at 40dB of SNR.

5. CONCLUSION

In this paper, optimal-power-allocation scheme is applied for the cooperative NOMA based communication system by considering the maximum achievable sum-rate. Power allocation factors that are in the transmitted signal have been optimized by using SBO algorithm. In this algorithm, solutions with minimum outage probability are obtained as the optimal power allocation factors. The performance of the proposed scheme has been compared with that of the power allocation scheme without SBO. The performance of the proposed scheme has been evaluated in terms of variation of outage-probability and the achievable-sum-rate by varying SNR and total transmit power. Simulation results showed that the outage probability and achievable sum rate of the proposed SBO based power allocation scheme are improved to 11% and 24% than that of the power allocation scheme without SBO.

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