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Research Article

Power Resource Allocation Algorithm for Dual-Function Radar–Communication System

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In this paper, a power allocation algorithm of dual-function radar–communication system with limited power is proposed to obtain better overall system performance measured by the weighted summation of radar signal to interference plus noise ratio (SINR) and communication channel capacity. First, a power allocation model is established to maximize the radar SINR and communication channel capacity with limited transmitted power. Then, the Karush–Kuhn–Tucker (KKT) conditions are used to solve the optimal objective function under the condition that only radar SINR or communication channel capacity is considered, respectively. Finally, the optimal value is combined with the original model and transformed into a single objective optimization model, and the optimal power is obtained by solving the model through the iterative optimization algorithm. Simulation results show that, compared with other power allocation algorithms, the proposed algorithm can achieve better radar-communication integration performance under the same transmit power.

1. Introduction

1.1. Background and Motivation. Radar sensing and wireless communication are two important applications in modern radio technology that are designed and developed independently based on the different functions and frequency bands. In recent years, the rapid growth of wireless systems has led to a scarcity of spectrum resources, raising concerns [1]. As the communication system gradually develops to a higher frequency band, it overlaps with the operating frequency band of the radar system, resulting in an increasingly fierce resource scramble between the two, and the research on the integration of radar communication has become a research hotspot [2–8]. With the deepening of research, dual-function radar-communication (DFRC) system is proposed. DFRC system can coexist multiple applications in the same frequency band and alleviate spectrum congestion by sharing spectrum resources at the same time [9–12]. It can not only perform radar tasks but also communication tasks while sharing spectrum resources, which represents the development direction of active sensing and data transmission system to a certain extent. To achieve better performance in implementing radar and communication tasks on the DFRC system, transmission power can be simply increased. However, this approach will not only waste resources and increase the probability of interception but also is infeasible when transmission power is limited. Therefore, designing effective power allocation algorithms in different scenarios have significant importance in improving the performance of radar and communication.

1.2. Brief Survey of Similar Work. In recent years, significant progress has been made in the allocation of transmitted power in DFRC systems. In the study by Zhou et al. [13], a wireless power supply allocation strategy for DFRC systems was proposed to overcome limited energy limitations on their performance. With the constraints of radar performance and communication performance, the energy minimization model was proposed. Through the joint optimization of energy beamforming and radar-communication waveform, the energy consumption is minimized. In the study by Ahmed et al. [14], an orthogonal frequency division multiplexing (OFDM) based DFRC system was introduced, which utilizes OFDM waveforms to perform radar and communication tasks simultaneously. In this paper, all subcarriers are primarily allocated to radar tasks, with secondary communication tasks realized through the embedding of information in OFDM waveforms. To maximize communication performance, radar subcarriers are efficiently allocated to different communication users based on a criterion of maximizing mutual information (MI). In the study by Ahmed et al. [15], radar performance is ensured by reasonable distribution of transmit power, while communication performance is maximized. In the study by Tian et al. [16], the problem of maximizing radar SNR was studied while adhering to the constraints of word error probability (WEP) and total power. The alternative direction sequence relaxation programing algorithm was effective in solving this problem. In addition, a beamforming power allocation model was proposed to improve bit error rate performance and designed an alternate optimization algorithm that divided the nonconvex minimization problem into several low-complexity iteratively updated subproblems in [17]. In the study by Wang et al. [18], network utility maximization in dual-function radar-communication multi-UAV networks was studied. The UAV is divided into several groups by clustering method, and the transmitting power of UAV is obtained by coalition game method. Meanwhile, the subcarriers and power joint allocation problem aimed at minimizing transmitted power have been studied in [19, 20]. In the study by Shi et al. [19], subcarriers allocations for radar and communication tasks are determined first, and then power allocations are made for subcarriers for different purposes. In the study by Shi et al. [20], subcarriers used for radar tasks were selected and optimized for power, while the remaining subcarriers were reserved for communication tasks and their corresponding power was optimized. In the study by Yang et al. [21], orthogonal frequency division multiple access (OFDMA) technology was introduced to ensure OFDMA capability at a large number of users. The paper [22] optimized the transmitting power of each transmitter in a system consisting of multiple dual-function transmitters, radar receivers, and communication receivers. The optimization model was conducted under the condition of ensuring target positioning accuracy and information transmission rate while being guided by low probability of intercept performance.

Although the above studies are sufficient, there are still shortcomings: (a) In the research of power allocation of DFRC system, it is generally considered to maximize the radar performance or maximize the communication performance, but the comprehensive performance of DFRC system is rarely considered. (b) If the power used in a transmitted signal is too high, the interference between the signals will increase, and the imbalance between the radar performance and the communication performance of the system may also occur. But at present, there are few studies on how to deal with excessive transmission power.

The main contributions of this paper are described as follows:

(1) Based on DFRC system, a power optimization model considering both radar performance and communication performance is proposed. The radar signal to interference plus noise ratio (SINR) is applied as the index to measure radar performance while the communication channel capacity is used to gauge communication performance in the model. The power penalty term is introduced into the model to avoid excessive power of the transmitted signal.

(2) A method to solve the power optimization model is proposed. The method is composed of two parts. In the first part, the optimal values of the objective function are obtained by using Karush–Kuhn–Tucker (KKT) conditions to consider the system communication channel capacity and radar SINR, respectively. These values are used to transform the original model into a single objective optimization model. In the second part, the power allocation scheme is obtained by solving the single objective optimization model with an alternate iteration algorithm.

(3) Simulation experiments in four different scenarios are given, and the differences between the proposed algorithm and the comparison algorithms in radar SINR, communication channel capacity, and overall system performance are analyzed. It can be concluded that the proposed algorithm can effectively balance the radar SINR and the capacity of communication channel to obtain better overall performance.

The rest of this paper is organized as follows: Section 2 gives the complete system and signal model. Section 3 introduces the proposed power allocation model of dual-function radar–communication system. The simulation and analysis are conducted in Section 4. In Section 5 the conclusions of the paper can be found.

2. System and Signal Model

2.1. System Model. This paper considers the existence of dual-function transmitters, radar receivers, and communication receivers in a DFRC system. DFRC system uses space division multiplexing technology to transmit signals. Based on the modern digital array technology, active electronically scanned arrays (AESA) beamforming technology is used to control the energy direction of the communication beam and the radar waveform, so that the integrated waveform of the air division multiplexing communication radar can be completed at the same time. There are N dual-function transmitters in the system, located at $(x_{m,n}, y_{m,n})$, for $n = 1, \dots, N$. Each dual-function transmitter can transmit radar signal and communication signal simultaneously. There are also a radar receiver and a communication receiver in the system, located at (x_r, y_r) and (x_t, y_t), respectively. The detection target is located at (x_o, y_o). The DFRC system is shown in Figure 1.

2.2. Signal Model. After transmitting the radar signal from the nth transmitter, the received signal of the radar receiver is written as follows [23]:

$$\begin{aligned} R_r(t) = &\sum_{n=1}^{N} \sqrt{p_{r,n}} H_{r,n} s_{r,n}\left(t - \tau_{r,n}\right) \\ &+ \sum_{n=1}^{N} \sqrt{p_{t,n}} H_{t,n} s_{t,n}\left(t - \tau_{t,n}\right) + w(t), \end{aligned} \tag{1}$$

where $p_{r,n}$ represents the transmitting power of the nth transmitter, $H_{r,n}$ is the channel gain for radar tasks, $s_{r,n}(t)$

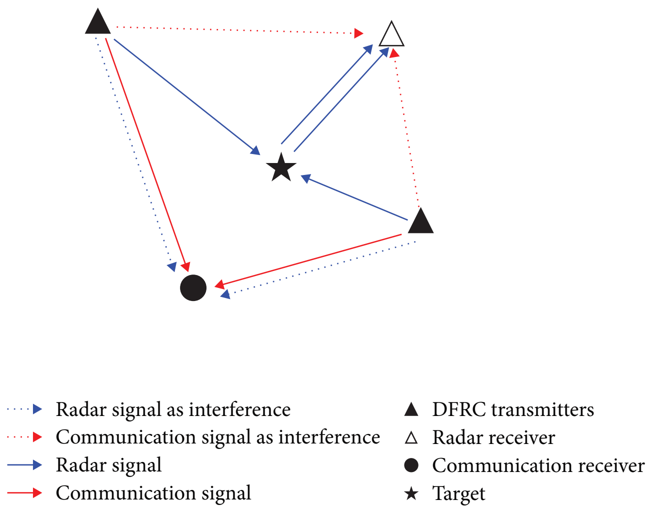

Figure 1: Dual-function radar–communication system.

denotes the radar signal from the nth transmitter, $p_{t,n}$ represents the transmitting power of signal $s_{t,n}(t)$ transmitted by the nth transmitter, and $H_{t,n}$ is the channel gain for communication tasks, $s_{t,n}(t)$ is the communication signal transmitted by nth transmitter, $w(t) \sim \mathrm{CN}(0, \delta_w^2)$ represents the circularly symmetric zero-mean complex white Gaussian noise, δ_w^2 denotes the noise power, $\tau_{t,n}$ represents the time delay for the path from the nth transmitter to the communication receiver, $\tau_{r,n}$ represents propagation time of the signal transmitted by the nth transmitter, reflected by the target, and received by the radar receiver, which can be written as follows:

$$\tau_{r,n} = \frac{D_{m,n} + D_{r,n}}{c}, \tag{2}$$

where c is the speed of signal transmission,

$$D_{m,n} = \sqrt{(x_o - x_{m,n})^2 + (y_o - y_{m,n})^2}, \tag{3}$$

$$D_{r,n} = \sqrt{(x_o - x_r)^2 + (y_o - y_r)^2}. \tag{4}$$

The communication signal of the communication receiver is written as follows:

$$\begin{aligned} T_{t,n}(t) = & \sum_{n=1}^{N} \sqrt{p_{t,n}} H_{t,n} s_{t,n}(t - \tau_{t,n}) \\ & + \sum_{n=1}^{N} \sqrt{p_{r,n}} H_{r,n} s_{r,n}(t - \tau_{r,n}) + v(t) \end{aligned}, \tag{5}$$

where $v(t) \sim \mathrm{CN}(0, \delta_v^2)$ represents the circularly symmetric zero-mean complex white Gaussian noise, δ_v^2 is the noise power. $\tau_{t,n}$ can be written as follows:

$$\tau_{t,n} = \frac{D_{t,n}}{c}, \tag{6}$$

where $D_{t,n}$ can be written as follows [18]:

$$D_{t,n} = \sqrt{(x_{m,n} - x_t)^2 + (y_{m,n} - y_t)^2}. \tag{7}$$

3. Power Resource Allocation Algorithm in DFRC System

3.1. Radar Signal-to-Noise Ratio and Communication Channel Capacity. The radar SINR can measure the radar performance in the system. The larger the SINR is, the better the radar performance is. The radar SINR in the system can be written as follows [23]:

$$\gamma = \sum_{n=1}^{N} \frac{p_{r,n} H_{r,n}}{\sum_{n=1}^{N} I p_{t,n} H_{t,n} + \sigma_r}, \tag{8}$$

where σ_r represents the ambient noise power during radar signal transmission; interference between radar signals and communication signals can be eliminated through serial interference cancelation. I represents elimination factor.

Channel capacity describes the maximum capacity of a channel to transmit information without error and can be used to measure communication performance in a system. The communication channel capacity in the system can be written as follows [18]:

$$\eta = \sum_{n=1}^{N} B\log_2\left(1 + \frac{\mathrm{p_{t,n} H_{t,n}}}{\sum_{\mathrm{n=1}}^{\mathrm{N}} \mathrm{I p_{r,n} H_{r,n}} + \sigma_{\mathrm{t}}}\right), \tag{9}$$

where B represents signal bandwidth and σ_t represents the ambient noise power during communication signal transmission.

3.2. Power Allocation Model and Solution

3.2.1. Power Allocation Model. According to the above analysis of the SINR and the channel capacity, it can be seen that under the constraint of limited power resources, the optimal SINR and channel capacity can be obtained by allocating the transmitted power reasonably. In order to eliminate the influence of the magnitude of SINR and channel capacity on the solution results, it is normalized and a penalty term is added at the same time. Therefore, the power allocation model proposed in this paper can be written as follows:

$$\max\begin{cases}\alpha\dfrac{\sum_{n=1}^{N}\mathrm{B}\log_2\left(1+\frac{\mathrm{p_{t,n}H_{t,n}}}{\sum_{\mathrm{n=1}}^{\mathrm{N}}\mathrm{Ip_{r,n}H_{r,n}}+\sigma_{\mathrm{t}}}\right)}{R}-(1-\alpha)\dfrac{\sum_{n=1}^{N}p_{t,n}}{\sum_{n=1}^{N}p_{t,\max}},\\ \beta\dfrac{\sum_{n=1}^{N}\frac{p_{r,n}H_{r,n}}{\sum_{n=1}^{N}Ip_{t,n}H_{t,n}+\sigma_r}}{S}-(1-\beta)\dfrac{\sum_{n=1}^{N}{p_{r,n}}^2}{\sum_{n=1}^{N}{p_{r,\max}}^2}\end{cases} \tag{10}$$

$$s.t.\begin{cases}\sum_{n=1}^{N}\left(p_{r,n}+p_{t,n}\right)=P_{\mathrm{total}}\\ p_{\min}\leq p_{r,n}+p_{t,n}\leq p_{\max}\\ p_{r,\min}\leq p_{r,n}\leq p_{r,\max}\\ p_{t,\min}\leq p_{t,n}\leq p_{t,\max}\end{cases}, \tag{11}$$

where α and β represent the ability of the system to resist interference caused by an excessive transmission power. The higher the α and β values, the stronger the antijamming ability. P_{total} denotes the total power of the system, and $p_{\max}$ and $p_{\min}$, respectively, denote the maximum and minimum power transmitted by each transmitter. $p_{r,\max}$ and $p_{r,\min}$, respectively, represent the maximum and minimum power used by each transmitter to transmit radar signals. $p_{t,\max}$ and $p_{t,\min}$, respectively, denote the maximum and minimum power used by each transmitter to transmit communication signals. S and R, respectively, are radar SINR and communication channel capacity when each transmitter transmits the radar signal and communication signal with the power of $p_{r,\max}$ and $p_{t,\max}$. R and S can be written as follows:

$$R=\sum_{n=1}^{N}\mathrm{B}\log_2\left(1+\frac{\mathrm{p_{t,max}H_{t,n}}}{\sum_{\mathrm{n=1}}^{\mathrm{N}}\mathrm{Ip_{r,min}H_{r,n}}+\sigma_{\mathrm{t}}}\right), \tag{12}$$

$$S=\sum_{n=1}^{N}\frac{p_{r,\max}H_{r,n}}{\sum_{n=1}^{N}Ip_{t,\min}H_{t,n}+\sigma_r}. \tag{13}$$

3.2.2. The Solution to the Problem. In order to solve the above optimization problems and obtain the best overall performance, a new optimization algorithm is composed of three steps.

Step 1: The mathematical model is designed only for communication tasks as follows:

$$\min -\alpha\frac{\sum_{n=1}^{N}\mathrm{B}\log_2\left(1+\frac{\mathrm{p_{t,n}H_{t,n}}}{\sigma_{\mathrm{t}}}\right)}{R} +(1-\alpha)\frac{\sum_{n=1}^{N}p_{t,n}}{\sum_{n=1}^{N}p_{t,\max}}, \tag{14}$$

$$s.t.\begin{cases}\sum_{n=1}^{N}p_{t,n}=P_{\mathrm{total}}\\ p_{t,\min}\leq p_{t,n}\leq p_{t,\max}\end{cases}. \tag{15}$$

Obviously, subproblem ($\boldsymbol{p1}$) is a convex optimization problem.

KKT conditions are used to describe an optimal solution in mathematical optimization. They are suitable for constrained optimization problems, including linear programing, nonlinear programing, and convex programing. In convex optimization problems, KKT conditions are a set of conditions about primitive variables, dual variables, and complementary relaxation variables derived by constructing Lagrange function and applying Lagrange duality. KKT conditions are sufficient and necessary conditions for the optimal solution. This makes it possible to determine whether a given point is an optimal solution by checking the KKT conditions, or to find the optimal solution by solving for points that satisfy the KKT conditions.

Subproblem ($\boldsymbol{p1}$) can be solved by using the KKT conditions. We define the Lagrange function as $\mathcal{Q}(p_{t,n},\varphi_{1,n},\varphi_{2,n},\varphi_3)$, which can be written as follows:

$$\begin{aligned}\mathcal{Q}\left(p_{t,n},\varphi_{1,n},\varphi_{2,n},\varphi_3\right)&=-\alpha\frac{\sum_{n=1}^{N}\mathrm{B}\log_2\left(1+\frac{\mathrm{p_{t,n}H_{t,n}}}{\sigma_{\mathrm{t}}}\right)}{R}\\&+(1-\alpha)\frac{\sum_{n=1}^{N}p_{t,n}}{\sum_{n=1}^{N}p_{t,\max}}+\varphi_{1,n}\left(p_{t,\min}-p_{t,n}\right)\\&+\varphi_{2,n}\left(p_{t,n}-p_{t,\max}\right)+\varphi_3\left(\sum_{n=1}^{N}p_{t,n}-P_{\mathrm{total}}\right),\end{aligned} \tag{16}$$

where $\varphi_{1,n}$, $\varphi_{2,n}$, and φ_3 are Lagrangian multipliers. The KKT conditions are employed as follows:

$$\begin{cases}\dfrac{\partial\mathcal{Q}\left(p_{t,n},\varphi_{1,n},\varphi_{2,n},\varphi_3\right)}{\partial p_{t,n}}=0\\ \varphi_{1,n}\left(p_{t,\min}-p_{t,n}\right)=0\\ \varphi_{2,n}\left(p_{t,n}-p_{t,\max}\right)=0\\ \varphi_{1,n}\geq 0\\ \varphi_{2,n}\geq 0\\ \sum\limits_{n=1}^{N}p_{t,n}-P_{\mathrm{total}}=0\\ p_{t,n}\geq p_{t,\min}\\ p_{t,n}\leq p_{t,\max}\end{cases}. \tag{17}$$

Then the optimal power allocation corresponding to the communication tasks of subproblem ($\boldsymbol{p1}$) can be obtained in (20). The specific solving process of subproblem ($\boldsymbol{p1}$) is shown in Algorithm 1.

Input: $N, B, \sigma_t, R, \alpha, p_{t,\min}, p_{t,\max}, H_{t,n}, \varphi_3$, where $n = 1 \ldots N$
Output: $p_{t,n}$, $Z1$
Calculate allocation solution $p_{t,n}$ according to (20)
While $|\sum_{n=1}^{N} p_{t,n} - P_{\text{total}}| \neq 0$ do
Set a small feasible perturbation Δ;
If $\sum_{n=1}^{N} p_{t,n} > P_{\text{total}}$ then
Else $\varphi_3 = \varphi_3 - \Delta$
End
Update allocation solution $p_{t,n}$ according to (20)
End
Update: $p_{t,n}^* = p_{t,n}$
Calculate: $Z1 = -\alpha \frac{\sum_{n=1}^{N} B\log_2\left(1+\frac{p_{t,n}^* H_{t,n}}{\sigma_t}\right)}{R} + (1-\alpha)\frac{\sum_{n=1}^{N} p_{t,n}^*}{\sum_{n=1}^{N} p_{t,\max}}$

Algorithm 1: Power allocation algorithm for subproblem (***p*1**).

$$p_{t,n}^* = \begin{cases} p_{t,\min} & p_{t,n}^* < p_{t,\min} \\ -\dfrac{\alpha B}{R\left(\frac{(1-\alpha)}{\sum_{n=1}^{N} p_{t,\max}}\right) + \varphi_3} - \dfrac{\sigma_t}{H_{t,n}} & p_{t,\min} \le p_{t,n}^* \le p_{t,\max} \\ p_{t,\max} & p_{t,n}^* > p_{t,\max} \end{cases} . \tag{18}$$

Step 2: The mathematical model is designed only for radar tasks as follows:

$$\min -\beta \frac{\sum_{n=1}^{N} \frac{p_{r,n} H_{r,n}}{\sigma_r}}{S} + (1-\beta)\frac{\sum_{n=1}^{N} p_{r,n}^2}{\sum_{n=1}^{N} p_{r,\max}^2}, \tag{19}$$

$$s.t. \begin{cases} \sum_{n=1}^{N} p_{r,n} = P_{\text{total}} \\ p_{r,\min} \le p_{r,n} \le p_{r,\max} \end{cases} . \tag{20}$$

The KKT conditions are employed to solve the subproblem (***p*2**). The optimal power allocation corresponding to the radar tasks of subproblem (***p*2**) is given in (23), where μ_3 are Lagrange multiplier. The iterative algorithm mentioned in Algorithm 1 can be used to solve $p_{r,n}^*$ and $Z2$.

$$p_{r,n}^* = \begin{cases} p_{r,\min} & p_{r,n}^* < p_{r,\min} \\ \dfrac{\left(\frac{\beta H_{r,n}}{S\sigma_r} - \mu_3\right)\sum_{n=1}^{N} p_{r,\max}^2}{2(1-\beta)} & p_{r,\min} \le p_{r,n}^* \le p_{r,\max} \\ p_{r,\max} & p_{r,n}^* > p_{r,\max} \end{cases} . \tag{21}$$

Step 3: The original optimization problem is transformed into a new optimization problem.

In order to simplify the original problem and effectively solve the problem of unreasonable power distribution caused by the difference of magnitude between SINR and channel capacity data, the original optimization problem is transformed into model ***F*** according to the Z1 and Z2 obtained from subproblem (***p*1**) and subproblem (***p*2**). ***F*** can be written as follows:

$$\min \frac{f1 - Z1}{|Z1|} + \frac{f2 - Z2}{|Z2|}, \tag{22}$$

$$s.t. \begin{cases} \sum_{n=1}^{N} \left(p_{r,n} + p_{t,n}\right) = P_{\text{total}} \\ p_{\min} \le p_{r,n} + p_{t,n} \le p_{\max} \\ p_{r,\min} \le p_{r,n} \le p_{r,\max} \\ p_{t,\min} \le p_{t,n} \le p_{t,\max} \end{cases}, \tag{23}$$

where

$$f1 = -\alpha \frac{\sum_{n=1}^{N} B\log_2\left(1 + \frac{p_{t,n} H_{t,n}}{\sum_{n=1}^{N} I p_{r,n} H_{r,n} + \sigma_t}\right)}{R} + (1-\alpha)\frac{\sum_{n=1}^{N} p_{t,n}}{\sum_{n=1}^{N} p_{t,\max}}, \tag{24}$$

$$f2 = -\beta \frac{\sum_{n=1}^{N} \frac{p_{r,n} H_{r,n}}{\sum_{n=1}^{N} I p_{t,n} H_{t,n} + \sigma_r}}{S} + (1-\beta)\frac{\sum_{n=1}^{N} p_{r,n}^2}{\sum_{n=1}^{N} p_{r,\max}^2} . \tag{25}$$

In order to solve the above optimization problems, iterative optimization algorithm is adopted in this paper. When an iterative algorithm is used, the optimal solution can be obtained if the iteration terminates within a finite number of times. However, in practical applications, it may not converge to the optimal solution terminating the iteration within a certain number of times. In order to reduce the number of iterations and thus reduce the time complexity of the algorithm, termination conditions are set to ensure that the iteration stops on the approximation solution with certain precision. That is, when the difference between the two iterations is less than the given value, the calculation is stopped. Although, the obtained solution is not the exact optimal solution, the error between it and the optimal solution is within the acceptable range, and it is regarded as an optimal solution.

The specific flow of alternating optimization algorithm is shown in Algorithm 2.

In order to verify the effectiveness of the proposed algorithm, an evaluation standard for the overall performance of DFRC system is established based on the study by Liu et al. [24]. Evaluation standard can be written as follows:

$$K = \omega \frac{R^*}{R} + (1-\omega)\frac{S^*}{S}, \tag{26}$$

where ω denotes the weight of communication performance in the overall system performance. In DFRC system, radar

Input: N, B, σ_t, R, α, $p_{t,\min}$, $p_{t,\max}$, φ_3, σ_r, S, β, ε, $p_{r,\min}$, $p_{r,\max}$, μ_3, $H_{r,n}$, $H_{t,n}$, where $n = 1 \ldots N$
Output: Optimal power allocation scheme ${p_{r,n}}^*$ and ${p_{t,n}}^*$
Initialization: ${p_{t,n}}^*$, ε
Let $p_{t,n} = {p_{t,n}}^*$ and Using CVX toolbox to solve for the solution ${p_{r,n}}^*$ of $\boldsymbol{F}$, where $p_{t,n}$ is considered to be a fixed value in $\boldsymbol{F}$.
Calculate $F0({p_{r,n}}^*, {p_{t,n}}^*) = \frac{f1-Z1}{|Z1|} + \frac{f2-Z2}{|Z2|}$
Let ${p_{t,n}}^* = {p_{t,n}}^* - \varepsilon$
While 1
  Let $p_{t,n} = {p_{t,n}}^*$ and use CVX toolbox to solve for the solution ${p_{r,n}}^*$ of $\boldsymbol{F}$, where $p_{t,n}$ is considered to be a fixed value in $\boldsymbol{F}$.
  Let $p_{r,n} = {p_{r,n}}^*$ and use CVX toolbox to solve for the solution ${p_{t,n}}^*$ of $\boldsymbol{F}$, where $p_{r,n}$ is considered to be a fixed value in $\boldsymbol{F}$.
  Calculate $F1({p_{r,n}}^*, {p_{t,n}}^*) = \frac{f1-Z1}{|Z1|} + \frac{f2-Z2}{|Z2|}$
    If $(F1 \leq F0)$
      ${p_{t,n}}^* = {p_{t,n}}^* - \varepsilon$
    Else
      Break
    End
  $F0 = F1$
End

Algorithm 2: Iterative optimization algorithm.

Table 1: Simulation parameters table.

Parameter	Value	Parameter	Value
α	0.8	$p_{t,\min}$	100 (w)
β	0.8	$p_{t,\max}$	700 (w)
B	1×10^7 (hz)	$p_{r,\min}$	100 (w)
σ_t	1×10^{-13} (w)	$p_{r,\max}$	700 (w)
σ_r	1×10^{-13} (w)	P_{total}	2,000 (w)
φ_3	3×10^{-10}	$p_{\min}$	200 (w)
μ_3	3×10^{-10}	$p_{\max}$	700 (w)
Δ	1×10^{-10}	θ	1×10^{-10}

SINR and communication channel capacity are regarded as equally important in this paper. The value of ω is set to 0.5. R^* and S^* represent communication channel capacity and radar SINR under optimal power distribution, respectively.

4. Simulation Results and Analysis

In order to verify the effectiveness of the proposed algorithm, the following simulation experiments are designed in this paper. Assume that in a DFRC system, there are four dual-function transmitters and one detection target. There is also a radar receiver and a communication receiver in the system. The remaining parameters are listed in Table 1.

In this paper, four different scenarios are randomly designed, in which the position of transmitter, receiver, and target is different. This kind of random setting can reflect the effectiveness of the algorithm in this paper and avoid the accidental situations. The four different scenarios assumed in this paper are shown in Figure 2.

The channel conditions in four different scenarios assumed in this paper are shown in Figure 3.

Figure 4 illustrates the power allocation results in different scenarios, as can be seen from the figure, the power transmitted by each transmitter to perform radar tasks is related to the radar channel gain. A larger gain results in a higher transmitted power, while a similar trend exists between power used for the communication tasks and communication channel gain. The result demonstrates the ability of the proposed algorithm to allocate power reasonably based on a priori knowledge of channel gain, significantly improving the total radar SINR and communication channel capacity of the system.

In the field of power resource allocation, the average algorithm is a classical approach that allocates power equally. The Minimax algorithm operates on the principle of identifying the best possible outcome under the most adverse conditions. This algorithm can effectively solve the conflicting multi-objective optimization problem and identify the best tradeoff comprehensive optimal solution, while taking into account the required performance index. In the study by Zhang et al. [25], combining the derivation of KKT conditions and using block coordinate descent method to iteratively obtain the optimal power of transmit power, simulation results show that this algorithm has certain advantages. We compare the proposed algorithm with the previously discussed three algorithms to verify its efficacy.

Figures 5 and 6 show the communication channel capacity and radar SINR, obtained by different algorithms in four scenarios. The results indicate that the Minimax algorithm achieves better SINR performance but at the expense of channel capacity compared to the other algorithms. Algorithm in the study by Zhang et al. [25] is more inclined to communication channel. Among the four comparison algorithms, algorithm in [25] obtains the maximum communication channel but the SINR is the smallest.

The proposed algorithm is superior to algorithm in [25], Minimax algorithm, and average algorithm in balancing communication channel capacity and radar SINR. It can be

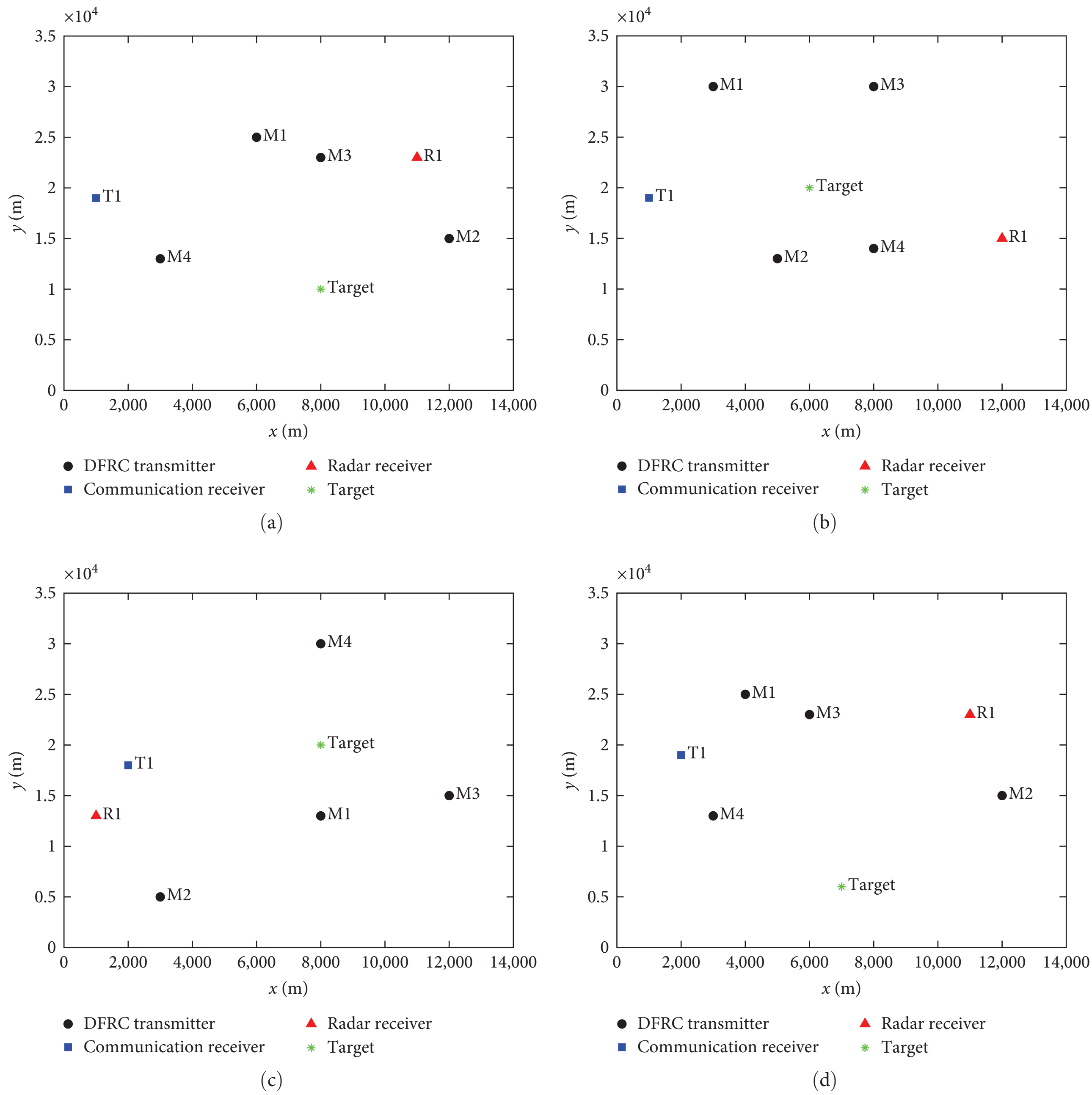

Figure 2: The simulation layout for DFRC system in different scenarios: (a) Scenario 1, (b) Scenario 2, (c) Scenario 3, and (d) Scenario 4.

seen from Figures 5 and 6 that the proposed algorithm significantly improves the communication channel capacity while maintaining a comparable radar SINR. The reason is that the proposed algorithm uses normalization and weighting to transform the multi-objective optimization problem into a single objective problem, which avoids the difference of the magnitude of the radar SINR data and the communication channel capacity data leading to the bias of the results to a certain performance.

Figure 7 illustrates the overall performance of DFRC system when different algorithms are adopted in the different scenarios. The proposed algorithm performs the best and the average algorithm performs the worst. Algorithm in the study by Zhang et al. [25] performs better than the Minimax algorithm in Scenario 3. But in Scenario 1, Scenario 2, and Scenario 4, Minimax algorithm performs better than the algorithm in [25]. The above simulation results the advantages of the proposed algorithm in optimizing power allocation in DFRC systems, providing higher

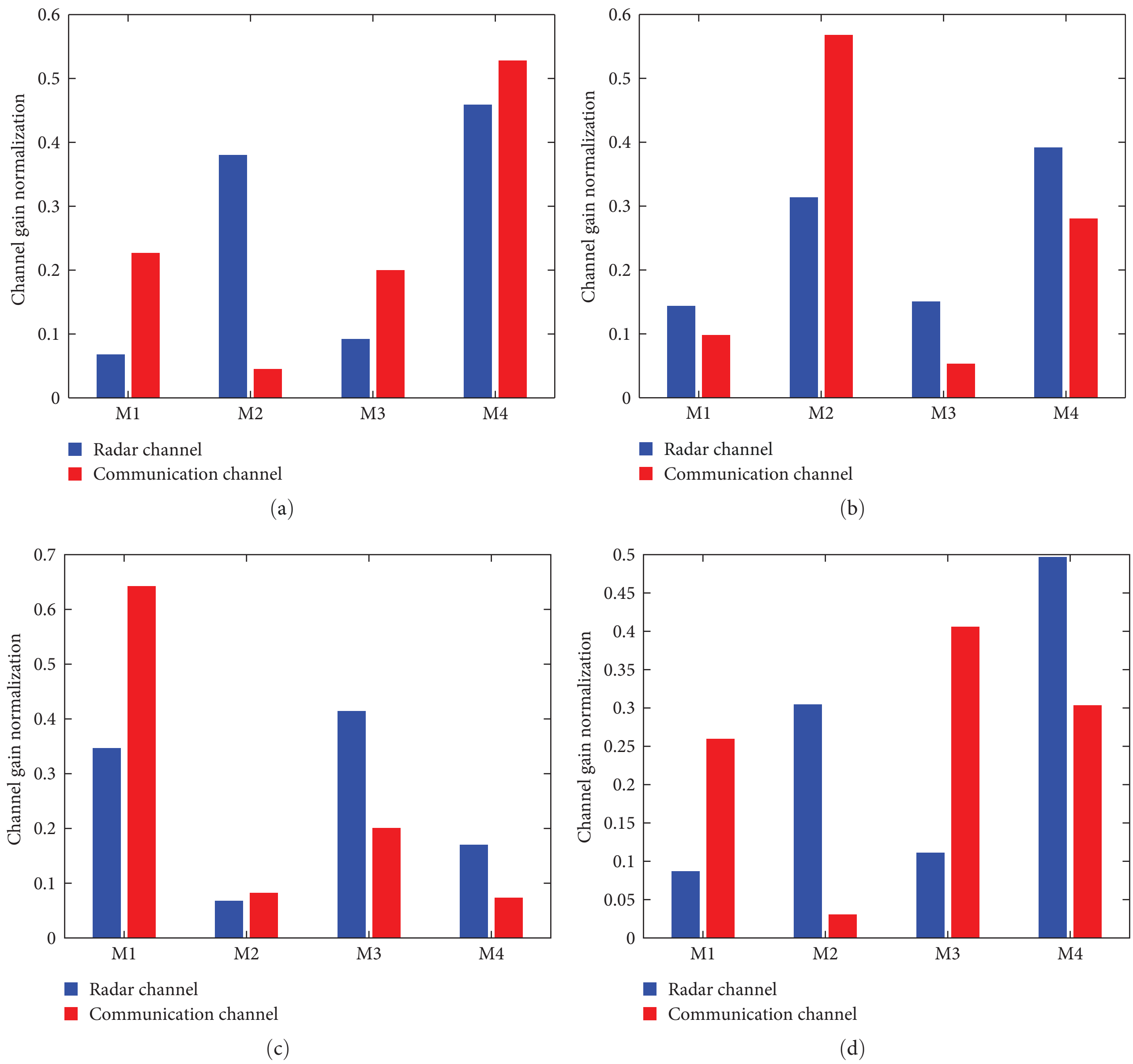

FIGURE 3: Channel conditions in different scenarios: (a) Scenario 1, (b) Scenario 2, (c) Scenario 3, and (d) Scenario 4.

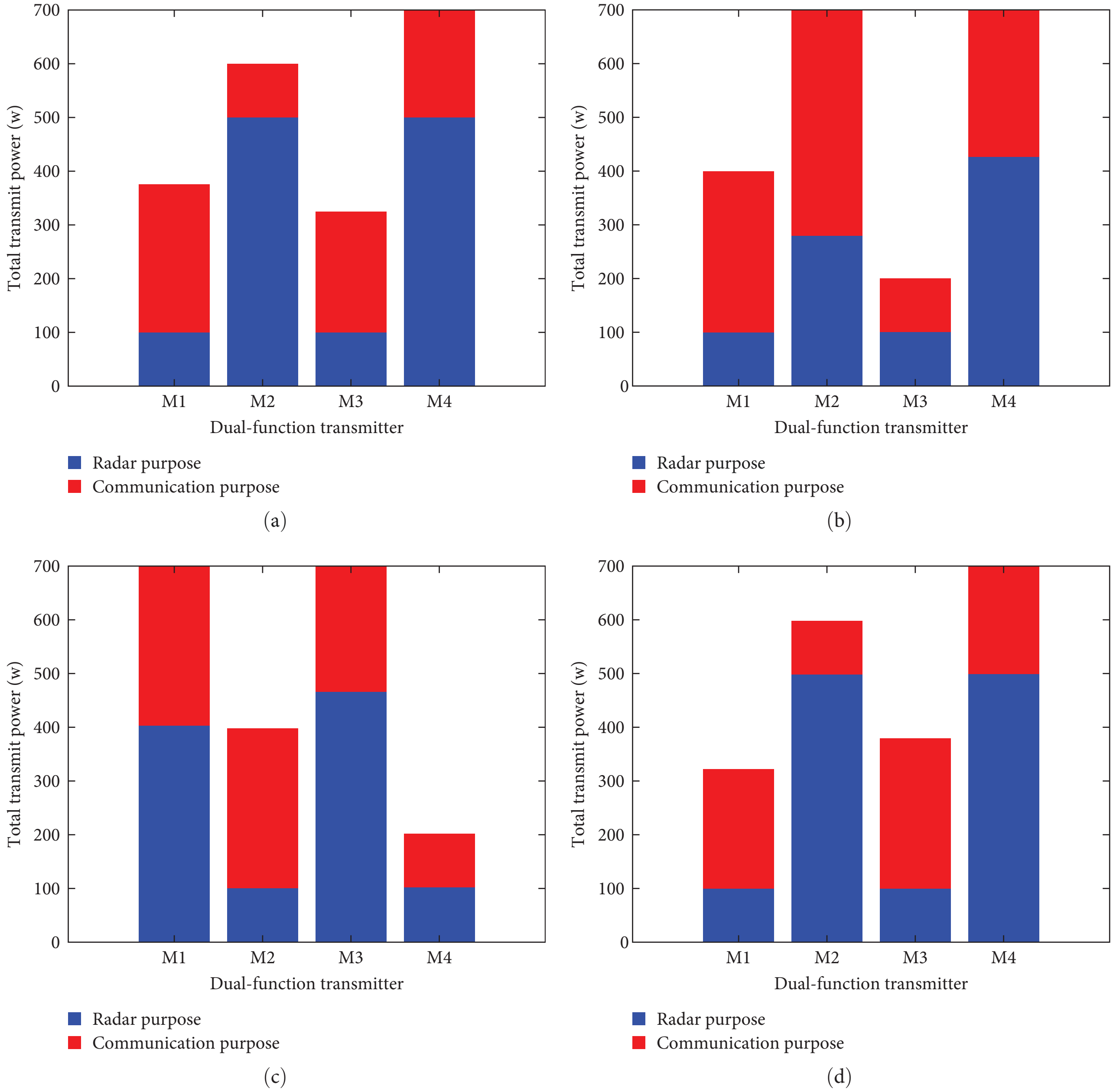

Figure 4: Power allocation in different scenarios: (a) Scenario 1, (b) Scenario 2, (c) Scenario 3, and (d) Scenario 4.

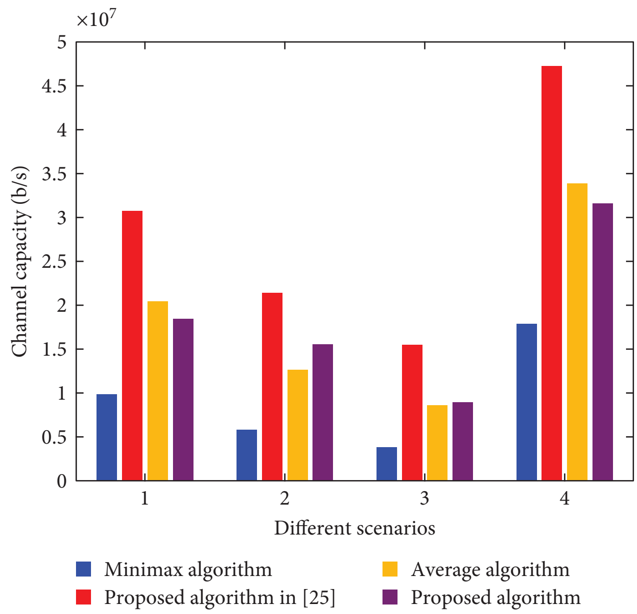

FIGURE 5: Channel capacity in different scenarios.

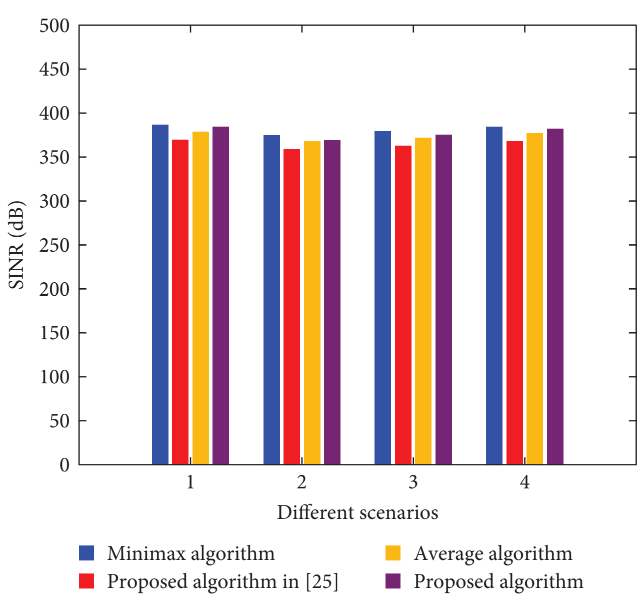

FIGURE 6: SINR in different scenarios.

overall performance while balancing communication channel capacity and radar SINR.

5. Conclusion

In this paper, a power allocation algorithm is proposed based on a DFCR system. The goal of this algorithm is to improve the overall system performance measured by the weighted summation of radar SINR and communication channel capacity through reasonable power allocation with limited power. A mathematical model is constructed to maximize both radar SINR and communication channel capacity, and the optimal solution is obtained by KKT conditions and

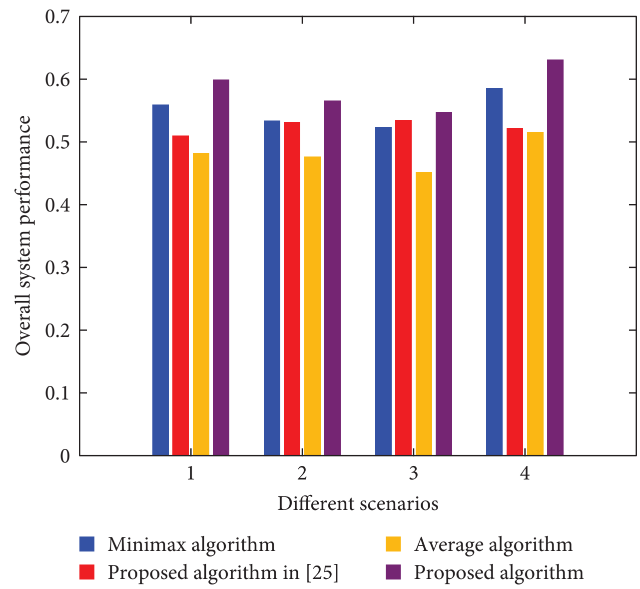

FIGURE 7: Overall system performance in different scenarios.

iterative optimization algorithm. Simulation results show that the proposed algorithm is effective in improving the overall performance of the system.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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