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Genetic Algorithm Model for Information Security Communication

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ABSTRACT

With the increase in the scale and complexity of information communication networks, the security of communication networks has become increasingly prominent, making it a key research direction in communication network studies. In this paper, a mathematical model for information communication is constructed, and a genetic algorithm is introduced for model optimization. Experimental results show that the genetic algorithm effectively enhances network reliability and significantly reduces link costs. In the application experiments, this model can analyze the advantages of different optimization paths and select the optimal solution based on actual conditions, ensuring both network reliability and economy, and increasing overall satisfaction with the network

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1. Introduction

Internet technology has rapidly developed with the support of communication and optical fibre technology, and the scale and functionality of networks continue to grow. This development has promoted social informatization, allowing people to easily access high-quality services based on the network in daily life, work, and study, making communication in various aspects of society more convenient, fast, accurate, and secure [1]. At the same time, based on the increasingly powerful internet systems, many new devices and systems with high complexity have been developed and created. These systems require complex software and hardware support to achieve their intended functions [2]. The normal operation of these complex devices and systems is related to the development of various fields, society, the economy, and the environment. Once malfunctions or communication security issues occur, they will cause a wide range of negative impacts or incur irremediable losses. Therefore, the research on the reliability of information security communication networks has always been one of its important research directions and has significant theoretical and practical significance.

Many computers are interconnected through communication devices and transmission media and combined with communication software to achieve secure and efficient data information transmission between computers. Such communication networks can complete the rapid transmission and sharing of data information while ensuring the normal, secure, and stable operation of the systems [3]. At the same time, communication networks using distributed processing can effectively manage and supervise target objects in real time, prevent malicious network attacks, and enhance the security and authenticity of data information. It can be seen that security communication is crucial when networks operate under certain conditions, as well as communication quality, network connection stability, and probability of successful completion. When designinginformation communication methods, their reliability and dependability must be ensured to meet their application requirements. To improve information communication security, this paper introduces a genetic algorithm for optimization based on constructing a reliable data model. This algorithm has good global properties, can achieve parallel search and swarm optimization, and has strong operability, which can enhance the security and reliability of information communication methods.

2. Current Research Status of Information Security Communication

The concept of reliability in information communication networks originated from an incident where the total transmission capacity of a telecommunication exchange network significantly decreased due to a failure in the communication network component, resulting in call congestion. At that time, this event was defined as a link failure in the telecommunication exchange network, and network connectivity was taken as the measure of its reliability [4]. Initially, this connectivity standard only required information communication networks to maintain normal operation, meaning there were no barriers between user terminals and communication network nodes. However, with the rapid development of computer technology,communication network technology has also evolved and been widely applied in many fields. As a result, the evaluation and calculation of network reliability and its metrics have continuously improved and changed to adapt to the expanding network scale, provide better service quality to users, reduce the network failure rate caused by user errors, enhance the reliability of network links, and more [5].

Regarding the optimization of information communication network reliability, some researchers have proposed optimization schemes from the perspective of network topology structure to address network reliability optimization and network structure planning issues [6]. Other researchers have used heuristic methods and intelligent algorithms to optimize the full terminal reliability problem of array networks, resulting in improved user satisfaction compared to traditional methods. Some scholars have developed calculation formulas for the upper bound of the full terminal reliability and made improvements to provide a solid foundation for future enhancements [7]. Some researchers have proposed and applied a concept of communication network cutsets and corresponding algorithms to analyseinformation communication network reliability. It has been pointed out that besides connectivity, measuring information communication network reliability should also include cohesion as a metric, becoming an important criterion for further research [8]. With the widespread application of intelligent algorithms in various fields, some researchers have introduced approximate evaluation methods in optimising information communication networks to analyze existing issues and optimize designs based on reliability evaluation metrics [9]. Furthermore, the combination of coarse-grained parallel genetic algorithms has been used to optimize information communication network problem-solving, demonstrating better optimization results than traditional serial genetic algorithms. Researchers have also designed network topology structures by considering network minimum cost as a constraint to achieve the purpose of network reliability optimization. Additionally, multi-objective decision-making and genetic algorithms have been integrated to solve network topology design problems [10]. Currently, research on the optimization of large-scale information communication networks is still in its early stages, requiring further application analysis and research based on theoretical principles in practice.

3. Optimization Design of Information Security Communication Based on Genetic Algorithm

3.1. Construction of Information Security Communication Reliability Information Model

In a broad sense, information communication networks consist of user devices, transmission and exchange devices, and network software. The topology structure of such networks is one of the key factors influencing network reliability. Therefore, when designing a network, meeting all user communication requirements is essential while adapting to the communication environment between buildings and premises and achieving the expected design objectives [11,12]. Simultaneously, convenient construction factors and conditions should be fully considered, appropriate network link media should be employed, and the design requirements for network openness should be met, aiming to be compatible with a wide range of network products and devices [13]. Additionally, the network topology structure's design should also consider future development potential, allowing for certain local expansion and upgradability.

The factors that influence communication network reliability can be divided into three aspects: the impact of network devices, network management, and network topology structure. Network devices include user devices and transmission and exchange devices. User devices are critical factors for communication network reliability, and network reliability is positively correlated with the interactive capabilities of user terminals. The error recovery capability and response time of servers are also positively correlated with network reliability [14,15]. For transmission and exchange devices, it is essential to fully consider their redundancy and fault-tolerance capabilities to meet the requirements for improving communication network reliability and future development needs, implementing practical and effective measures to ensure network reliability. The impact of network management refers to the existence of certain differences in various types of network products and devices, which require the adoption of effective network management techniques and methods to reduce bit errors, error rates, information loss rates, fault occurrence rates, etc., ensuring the integrity and authenticity of information transmission, and achieving real-time monitoring of network operation status, timely detection and elimination of faults [16]. As a planning problem for communication networks, the network topology structure is an inherent factor. According to relevant practical results, different network topology structures must be applied to different domains and networks of different scale levels to effectively enhance communication networks' reliability.

Based on the above, this paper sets the network topology structure as a weighted undirected graph denoted as, where the set of network nodes is denoted as, and the set of communication links is denoted as. The direct link between nodes is denoted as, and if, it means that the link cannot be established. The cost matrix of communication links between network nodes is represented as, and the cost of the link between nodes and is denoted as. The cost matrix is given by Formula (1):

$$C = \begin{bmatrix} c_{11} & \dots & c_{1n} \\ \dots & \dots & \dots \\ c_{m1} & \dots & c_{mn} \end{bmatrix} \qquad (1)$$

The reliability matrix formula is shown in (2):

$$R = \begin{bmatrix} r_{11} & \dots & r_{1n} \\ \dots & \dots & \dots \\ r_{m1} & \dots & r_{mn} \end{bmatrix} \qquad (2)$$

Among them, the reliability of the link between nodes is denoted.

The states of all nodes and links contained in a weighted undirected graph can be represented by metrics, where the states of edges include propagation delay, and their costs and reliability are represented by, respectively. Under the defined conditions of node communication matrix, link capacity range, communication cost function, and reliability probability of links and nodes, the mathematical model ofinformation communication is shown in (3):

where the total cost of the communication network is denoted, the mean delay is denoted, reliability is denoted, and the corresponding performance indicators are satisfaction functions, respectively. The corresponding control weight coefficients are represented as W, and it is a constant.

$$\begin{cases} Gen\_sat(G) = W_c Sat\_cost(G) + W_d Sat\_delay(G) + W_r Sat\_rel(G) \\ Sat\_cost(G) = g(Z(G)) \\ Sat\_delay(G) = h(D(G)) \\ Sat\_rel(G) = s(R(G)) \\ d_i a_{ij} \le \alpha \\ \sum_{j=1, j \ne i}^{N} g_{ij} \ge \beta \end{cases} \tag{3}$$

3.2. Genetic Algorithm-Based Optimization of Information Security Communication

A genetic algorithm is a global stochastic search algorithm that draws inspiration from biological selection ideas and genetic mechanisms. It can effectively solve optimization problems involving combinations and complex functions. Genetic algorithms have four advantages in the optimization of information communication methods. Firstly, the genetic algorithm has a large search range in the optimization selection process, as it can encode all optimization variables as search objects, enabling an efficient optimization selection scope. Secondly, the genetic algorithm demonstrates high efficiency during the optimization process, enabling better optimization design by searching from one solution group to another. Thirdly, the genetic algorithm's high specificity can exclude data information outside the target function value during the optimization process, achieving optimization through the optimal approach. Fourthly, the genetic algorithm optimizes information communication security problems through spatial optimization, following probability principles, which reduces the difficulty of obtaining optimal design objectives.

The steps of optimizing information communication methods using genetic algorithms are shown in Figure 1. All nodes are encoded using binary coding, and a random set is selected as the initial population. Based on this, individual fitness evaluation is performed on the initial population, determining the fitness function. To avoid deception, individuals in the population are arranged according to their respective cost values, as shown in (4):

$$F = h[\sum_{i=1}^{n} abs(y_i - d_i)] \tag{4}$$

The individual fitness is denoted as F, and the individual output and target output are denoted as y, d, and h,As a parameter, the output scale is denoted as n. The selection formula is shown in (5):

$$\begin{cases} f_i = h/F_i \\ P_i = \dfrac{f_i}{\sum_{i=1}^{n} f_i} \end{cases} \tag{5}$$

The probability of an individual being selected is denoted as P.Then select excellent individuals to form a new species group and cross over, as shown in (6):

$$\begin{cases} a_{ij} = a_{ij}(1-\beta) + a_{nj}\beta \\ a_{nj} = a_{nj}(1-\beta) + a_{ij}\beta \end{cases} \tag{6}$$

Among them, excellent individuals are described as *a* and *b* as parameters.Finally, perform cross mutation operation, and the mutation results are shown in (7) and (8):

$$a_{ij} = \begin{cases} a_{ij} + (a_{ij} - a_{\max}) \times f(u) & r > 0.5 \\ a_{ij} + (a_{\min} - a_{ij}) \times f(u) & r \le 0.5 \end{cases} \quad (7)$$

$$f(u) = r(1 - g/U_{\max})^2 \quad (8)$$

Among them, the current number of completed iterations is denoted as u, with a maximum limit of U. In the process of mutation calculation, full consideration should be given to the specific requirements and satisfaction of communication networks, with the primary issues being network cost and delay. Considering the cost of achieving reliability in practical applications to pursue higher cost-effectiveness, the weight of network cost and delay is important to choose appropriate values.

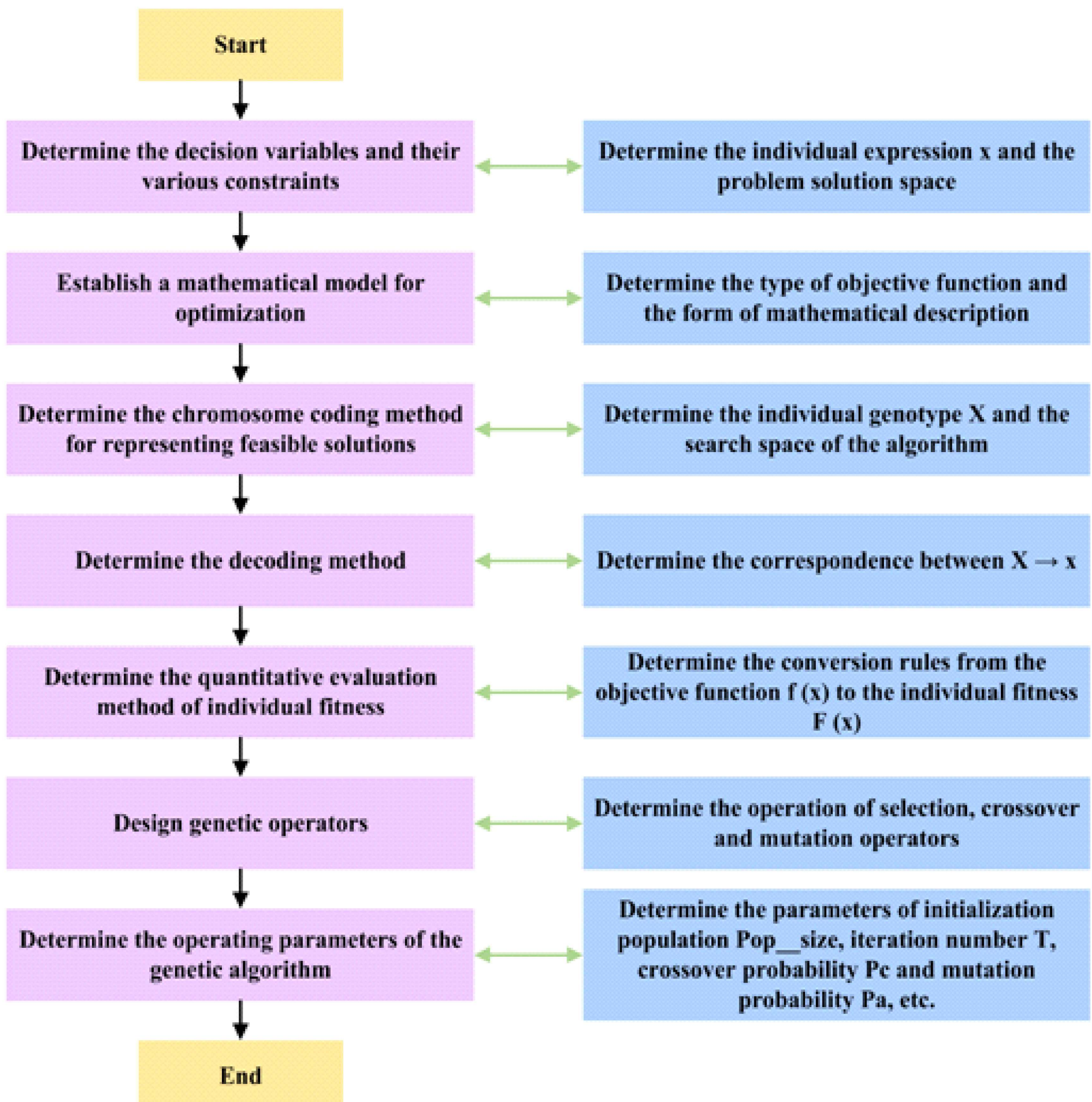

Figure 1. Flowchart of Genetic Algorithm-Based Optimization of Information Security Communication

4. Genetic Algorithm-Based Optimization of Information Security Communication

To verify the performance of the genetic algorithm-based optimization model for information security communication in practical applications, this study conducted simulation solutions based on the algorithm's process and adjusted the algorithm's flow. The number of iterations was set to one hundred, meaning that the simulation process terminated after one hundred iterations. The minimum cost of communication network links was forty-five, and to ensure the network's reliability, the maximum reliability was set to 0.875. Figure 2 shows the simulation curve results of information communication network link cost and reliability. The data in the figure shows that the total cost of network links is negatively correlated with the number of iterations, but it does not continuously decrease. Within the first ten iterations, the total cost rapidly decreases. The total cost decreases slowly when the number of iterations is less than forty-five. After forty-five iterations, the total cost converges and stabilizes at the minimum design cost. The overall variation in the reliability of the information communication network is small, and it is positively correlated with the number of iterations. The reliability gradually improves with increasing iterations, eventually reaching the required maximum reliability value.

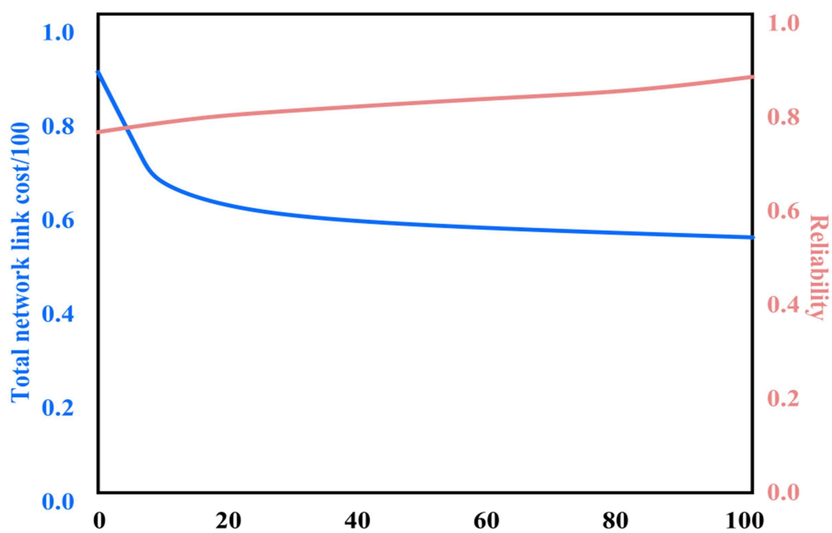

Figure 2. Simulation Curve Results of Information Communication Network Link Cost and Reliability

Due to the relatively large information communication network scale, the experiment includes four service centers and eight workstations. Each service center can connect to three workstations simultaneously. In the actual situation, the link cost between service centers is relatively high, ranging from 100 to 300, while the link cost between service centers and workstations is relatively low, ranging from 1 to 100. The reliability of service centers is set at 0.95, and the corresponding link reliability between service centers and workstations is set at 0.9, with a minimum reliability of 0.85. To better verify the optimization performance of the genetic algorithm-based information security communication optimization model, a population size of one hundred and a maximum iteration number of five hundred were set. During the optimization process, there are three optimization paths: one with equal weights for all three metrics, another focusing on cost and delay with both weights set to 0.5, and the third emphasizing cost without considering reliability weight. Figure 3 shows the optimization results for the information communication network under these three scenarios. The figure shows that the network cost is essentially the same in the first two cases, but the cost is significantly reduced in the third case. The first case has the highest reliability and the highest satisfaction, but its overall satisfaction is the lowest among the three cases. The second case has moderate reliability and relatively good satisfaction, and although the cost satisfaction is the lowest, the difference between the overall satisfaction and the highest value is small. In the third case, the cost and overall satisfaction are the highest among the three cases, while the reliability is relatively lower but still above 0.9.

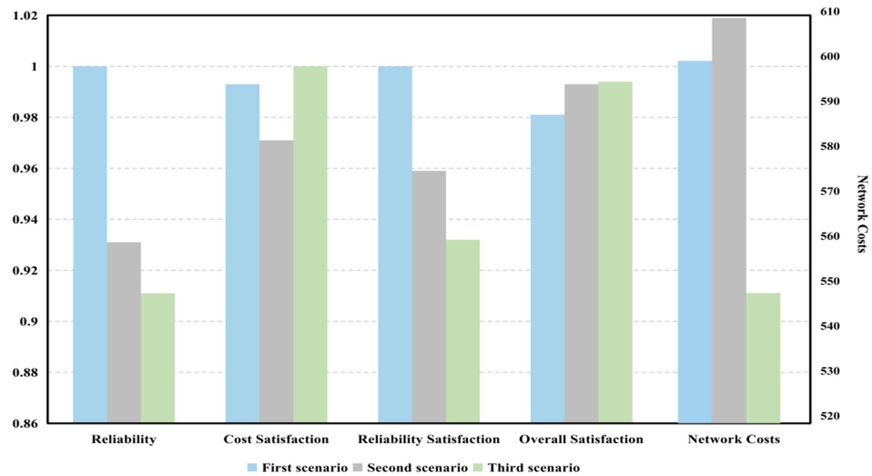

Figure 3. Optimization results of information communication network under three different scenarios

In conclusion, the genetic algorithm-based optimization model for information security communication can effectively achieve optimization solutions for information communication networks through genetic algorithms. All metrics have significantly improved, obtaining highly satisfactory optimal solutions. The model ensures the reliability of the communication network while reducing the total cost of links between network nodes, significantly increasing the overall satisfaction of the information communication network and enhancing its practical value.

5. Conclusions

The demand and requirements for information communication networks have grown with the rapid increase in internet users. Especially in many fields, larger-scale and more complex communication network devices have been created, and their communication security is vital for various aspects of development and economy. Therefore, this study constructed an information security communication optimization model and employed genetic algorithms to achieve the optimal design of information communication networks. The experimental results show that the genetic algorithm-improved information communication network has significantly reduced link costs and gradually increased reliability. The application experiments demonstrate that the genetic algorithm-based information security communication optimization model can effectively select the optimal solution under different scenarios, significantly increasing the overall satisfaction of the information communication network while meeting the requirements of economic costs and improving the network's reliability compared to the pre-improved network.

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