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Research Article

An Access Network Selection Algorithm for Terrestrial-Satellite Networks Based on a QoS Guarantee

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Considering the communication requirements of different monitoring services and the performance of different access networks, to ensure the quality of service and reliability of sensor networks, we propose an access network selection algorithm based on a quality-of-service (QoS) guarantee. According to the service requirements, the attributes that affect the terminal access options are determined. Then, utility functions are designed for normalizing the attribute values of the network. In addition, we construct a weight calculation model that combines subjective and objective factors. Finally, the algorithm calculates the relative closeness between each pair of networks by the technique for order preference by similarity to an ideal solution (TOPSIS) and sorts the candidate networks to obtain the best candidate network of each monitoring terminal to access. Simulation results show that the proposed algorithm can effectively meet the communication needs of different monitoring services, ensures network reliability, and can improve the utilization rate of network resources.

1. Introduction

With the rapid development of the economy, transmission lines have more hidden dangers. A transmission line stretches for thousands of kilometers; hidden dangers may occur everywhere [1]. In some areas, the manual way is still used to maintain the lines. However, manual inspection has some disadvantages, such as high costs of resources, a heavy workload, untimely detection of hidden dangers, and limited inspection areas. Even though some transmission lines have been installed with online monitoring equipment, greatly improving their efficiency in detecting hidden dangers, due to high traffic fees, most areas adopt methods such as taking regular photos or watching short videos to monitor lines.

Compared with the existing transmission line monitoring technology, the number of terminals that will be used in the future is huge, and the monitoring content will tend to be video-based and possess high-resolution. Therefore, it will have higher requirements for the coverage, flexibility, and costs of communication methods than current content. With the construction of 5G networks, the coverage of mobile networks has been improved, as 5G networks provide reliable communication support for data streams. However, on the ground in poor areas, 5G networks capacity is limited, and network reliability and real-time performance cannot be guaranteed [2].

Aiming at transmission line monitoring in remote areas, the low Earth orbit (LEO) satellite network, whose coverage is not limited by terrestrial conditions and location, is introduced as a supplementary coverage method for the terrestrial mobile networks. Compared with other satellite networks, an LEO satellite has the characteristics of large bandwidth and low delay, so these satellites will be an important part of the integrated network in space and on Earth in the future [3, 4].

However, in the terrestrial-satellite network, the available network resources are relatively limited. There are many types of monitoring services, and their requirements vary greatly. Therefore, how to reasonably select access networks and maximize resource utilization rates, to meet the needs of different monitoring services, is a subject worth studying [5].

To solve the problem that traditional access networks selection algorithm is unable to correlate the service requirements with the network performance, this study focuses on an access network selection algorithm for a terrestrial-satellite network. Based on the analysis of transmission line monitoring in remote areas, the influencing factors of access network selection are determined, and the access network selection algorithm is studied to maximize the reliability of monitoring services.

The remainder of this article is organized as follows: Section 2provides an overview of the related work. Section 3 describes the proposed access network selection algorithm. A simulation is discussed in Section 4. Finally, Section 5concludes this article.

2. Related Work

Because LEO satellites and 5G networks are still in the early stage of construction, the study of terrestrial-satellite networks is rare. However, the terrestrial mobile networks, such as macro sites and base stations, are a hotspot of research; scholars have conducted many studies in this field. The terrestrial-satellite network used in this paper is similar to the existing heterogeneous wireless networks to some extent. The access network selection algorithms used for the sensor networks are analyzed and studied in the following subsections.

2.1. Access Network Selection Algorithm Based on the Received Signal Strength. An access network selection algorithm based on the received signal strength relies on a single index. Gwon [6] and Yan [7] set the threshold value for the received signal strength. If the access signal strength of the candidate network exceeds the threshold value of the received signal strength, it is considered that the network meets the needs of users and is regarded as an appropriate access network. Based on setting the threshold value for the received signal strength, Song [8] added network throughput as a reference index to comprehensively select access networks by combining the two indexes. Kunarak and Suleesathira [9] proposed a received signal strength prediction method based on fuzzy logic, and they took the signal strength predicted by a back propagation neural network (BPNN) at the next moment to select a network.

This kind of algorithm has low complexity and little difficulty in terms of implementation. However, the use of the received signal strength as the main indicator of access network selection does not meet the specific QoS demands of many users. Therefore, the network selected is often not the network that best meets the needs of these users.

2.2. Access Network Selection Algorithm Based on Multi-attribute Decision Making. A single-attribute access network selection algorithm cannot fully reflect the business requirements in a heterogeneous network environment. Due to the differences in network performances and the diversity of user requirements, the available bandwidth, delay, jitter, packet loss rate, and cost may affect the selection of networks and should be considered, as they can be used to synthesize additional information and make comprehensive decisions.

Wu et al. [10] adopted a weight calculation method combining subjective and objective weights to select an access network. Zineb [11] combined fuzzy logic with a sorting method, where the input parameters and fuzzy reasoning rules were integrated for access network selection.

2.3. Access Network Selection Algorithm Based on a Utility Function. In economics, utility describes to consumers how to use their limited funds to obtain maximum satisfaction. A utility function can characterize the corresponding relationship between consumers' pay and benefits. The function value represents the degree of consumer satisfaction regarding the consumption process to a certain extent.

Park et al. [12] designed utility functions for network costs and users' QoS demands, respectively, so that users could access a network with a minimal cost while meeting their QoS demands. Roveri et al. [13] comprehensively considered the revenue balance between users and the network, and they classified the factors affecting network selection. The factors include the QoS, network priority, and weighting. Their model could be used to meet business requirements and improve network performance.

2.4. Access Network Selection Algorithm Based on Fuzzy Logic. In heterogeneous wireless networks, network parameters are ambiguous and cannot be used to accurately express network performances. At this time, users' judgements regarding these network parameters are also inaccurate. Fuzzy logic can be used to analyze a network by simulating human thinking. The fuzzy logic theory uses a "membership degree" to represent the element-set relations of the research object and analyzes the data that cannot be accurately represented.

Kustiawan [14] proposed a vertical switching algorithm based on fuzzification. This algorithm combined fuzzy logic with indicators, such as bandwidth and delay, to judge whether to switch. Guo [15] combined fuzzy logic with a neural network, and indicators such as the bandwidth and number of users were considered comprehensively to improve the communication quality of users.

In summary, several studies focused on terrestrial mobile networks. However, the LEO satellite and 5G networks are still in the early stages of construction, so studies on access network algorithms are rare. There are still considerable gaps in terms of the actual applications of a terrestrial-satellite network. Therefore, we proposed an access network selection algorithm in a terrestrial-satellite network, and the access network selection algorithm is studied to maximize the reliability of the network and guarantee the QoS of users.

3. Access Network Selection Algorithm for Terrestrial-Satellite Networks Based on a QoS Guarantee

3.1. Description of the Algorithm. When using a QoS-guaranteed algorithm for access network selection, how to normalize the attributes, how to determine the weights of

attributes, and how to combine the weighted attributes to obtain a comprehensive evaluation value are important components. A variety of mathematical models are commonly used to calculate the normalized methods, but they are based on a comparison between the candidate networks. Thus, these normalized values can only reflect the relative attribute values without considering the needs of businesses. Therefore, the subjective and objective weights should be calculated separately and then combined in a certain way to obtain the comprehensive weights.

According to the analysis above, this paper proposes a terrestrial-satellite access network selection algorithm based on a QoS guarantee. In the algorithm, the attributes that affect the choice of access network are first determined. A utility function is defined for each attribute, and the attribute values are normalized by establishing the corresponding relationships between the network attributes and business requirements. Then, the analytic hierarchy process (AHP) is used to calculate the subjective weights, and the entropy weight method is used to calculate the objective weights. The comprehensive weights are obtained by combining the subjective and objective weights through the comprehensive weighting method [16]. Finally, by weighting the normalized attribute values, the positive and negative ideal networks are constructed, and the relative closeness degrees between the candidate network and the positive and negative ideal networks are calculated to obtain the comprehensive evaluation value of the candidate network. The network with the highest relative closeness degree is selected as the best access network.

3.2. Network Attribute Normalization. Network attributes can be divided into benefit-oriented attributes and cost-oriented attributes. Among them, benefit-oriented attributes are attributes where higher values are better, such as the network bandwidth and received signal strength. Cost-oriented attributes are the opposite, such as the delay and packet loss rate.

In the algorithm proposed in this paper, to reflect the influences of terrestrial-satellite network performance on different service access network choices, four attributes, namely, the bandwidth, delay, packet loss rate, and cost, are selected as the deciding factors for access network selection. The roles of these attributes in remote transmission line monitoring scenarios are analyzed in detail below.

3.2.1. Bandwidth. Bandwidth is a huge bottleneck for current network applications in transmission line monitoring. In the future, line monitoring will include a large number of high-definition videos, images, and other services with large bandwidth requirements. Furthermore, the bandwidth resources allocated to individual users are also different to some extent.

3.2.2. Time Delay. Delay is an important part of the business demands, as it can reflect network connectivity. Time delay varies according to the type of service. In the transmission line monitoring service scenario, all services return data through the uplink. Due to the use of different return modes, the delays between base stations and the data center are quite different. Additionally, the processing delays of base stations also change dynamically according to different network loads.

3.2.3. Packet Loss Rate. The packet loss rate reflects the congestion degree of the network. When the load of a network is high, congestion occurs in the base station, and some data loss results in a decline of service performance. Among the various services in transmission line monitoring, real-time services, such as video services and voice services, have the highest requirements for the packet loss rate. In addition, the packet loss rate is also related to the return mode of the base station. Compared with a macro station, the packet loss rate of a small base station increases as the number of transmissions increases. Therefore, if the impact of packet loss caused by congestion is not considered, the packet loss rate also becomes an inherent attribute that can reflect different levels of network performance.

3.2.4. Cost. The cost reflects the use of different network resources. LEO satellite network resources are scarcer than those of a terrestrial network, so cost should be one of the deciding factors.

After determining the attributes that affect the access network selection decision, the terminal obtains the candidate network parameters. Assuming that there are m candidate networks at the mobile terminal and the number of attributes is n, the initial decision matrix X is as follows:

$$X = \left(x_{ij}\right)_{m\times n} = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix}. \tag{1}$$

Among the traditional normalization methods, the range transformation is most commonly used. According to the various attribute types, different calculation formulas are used to obtain the relative normalization value by comparing the attribute value of the current candidate network with the extreme value of the attribute from all candidate networks [17].

For the benefit attribute, the following equation exists:

$$b_{ij} = \frac{x_{ij} - \min_j x_{ij}}{\max_j x_{ij} - \min_j x_{ij}}. \tag{2}$$

For the cost attribute, the following equation exists:

$$b_{ij} = \frac{\max_j x_{ij} - x_{ij}}{\max_j x_{ij} - \min_j x_{ij}}, \tag{3}$$

where x_{ij} represents the parameter value of the jth indicator in the ith candidate network. $\max_j x_{ij}$ and $\min_j x_{ij}$ represent the maximum and minimum values of the jth candidate network, respectively. b_{ij} is the normalized value, which constitutes the normalized matrix $B = (b_{ij})_{n\times m}$.

Therefore, an attribute of the current network is characterized based on all candidate network attributes in the normalization process. The normalized attribute value of the largest network is 1, and the normalized attribute value of the smallest network is 0. When the performances of all candidate networks meet the business requirements, according to the normalization process above, the normalized value of the worst-performing network among the candidate networks is 0. At this time, it is most likely that a network with good performance is chosen, and this causes a waste of resources. Similarly, when the performances of the candidate networks are poor, the normalized value of the network with the best relative performance is 1. This causes the current service to occupy network resources but fail to meet its business requirements, resulting in an unreasonable allocation of resources.

To use as few network resources as possible to meet users' business needs, network performance should be linked to the users' business needs. Utility represents the users' satisfaction with the current service, and it can be expressed by using a utility function. By introducing a utility function to normalize the business attributes, the relationships between network performances and business requirements can be accurately reflected. For different attributes, user satisfaction with the network is different, so the utility function of each attribute is usually different. According to the characteristics of different attributes, scholars have conducted relevant studies and proposed various utility functions [18–20], as shown in Table 1.

When selecting an access network, different utility function models and model parameters are set according to the communication requirements of different services. In the following, to provide a basis for access network selection, utility functions are designed according to the characteristics of each attribute to replace the traditional normalization method, and the initial attribute value is normalized to a utility value that can accurately achieve business satisfaction.

(i) Bandwidth Utility Function. Bandwidth is a benefit attribute; that is, the bandwidth utility function is an increasing function. The greater the bandwidth is, the greater the utility. When the bandwidth provided by the network is lower than the minimum required bandwidth of the service, the normal communication of the service is seriously affected. When the bandwidth reaches the maximum required bandwidth of the service, the service can achieve the best communication, and further increase of the bandwidth does not improve the utility. The bandwidth utility function is designed to be an exponential type of function as follows:

$$U_B = \begin{cases} 0, & B \le B_{\min}, \\ 1 - e^{-\alpha B\left(B - B_{\min}\right)}, & B_{\min} \le B \le B_{\max}, \\ 1, & B > B_{\max}, \end{cases} \tag{4}$$

Table 1: Comparison table of various attribute and utility function types.

Attribute	Utility function type
Bandwidth	Exponential type, linear type, S type
Time delay	S Type
Packet loss probability	S type, exponential type
Cost	Linear type

where B is the bandwidth of the current network, $B_{\min}$ is the minimum bandwidth required by the service, $B_{\max}$ is the maximum bandwidth required by the service, and α_B is the shape parameter, which determines the increase rate of the bandwidth utility function. The larger α_B is, the higher the rising rate will be.

(ii) Delay Utility Function. The delay is a cost-type attribute; that is, the utility function is a decreasing function. When the delay is larger, the utility is smaller. For each business, there is a minimum delay required by the business and maximum delay tolerance. When the delay of the network is higher than the maximum tolerance, the network cannot provide access services for the business. When the delay is lower than the minimum delay required by the business, the utility does not change. The delay utility function is designed as an S-type function and is shown as follows:

$$U_D = 1 - \frac{1}{1 + e^{-\alpha_D\left(D - \beta_D\right)}}, \tag{5}$$

where D is the delay of the current network, $D_{\min}$ is the minimum delay required by the business, and $D_{\max}$ is the maximum delay tolerated by the business. α_D is the shape parameter that determines the rate of decline of the delay utility function. The larger α_D is, the higher the rate of decline will be.

(iii) Packet Loss Rate Utility Function. The packet loss rate can reflect the reliability of data transmission, and it is an important index of QoS. When the network packet loss rate is too high, data transmission errors are induced. Both the packet loss rate and delay are cost-type attributes, and their utility function models are the same:

$$U_L = 1 - \frac{1}{1 + e^{-\alpha_L\left(L - L_{\min}\right)}}, \tag{6}$$

where L is the packet loss rate of the current network, $L_{\min}$ is the minimum packet loss rate required by the service, and $L_{\max}$ is the maximum packet loss rate that the service can tolerate. α_L is the shape parameter for determining the drop rate of the utility function. The larger α_L is, the higher the drop rate will be.

(iv) Cost Utility Function. Cost is a cost-type attribute. The higher the access network cost is, the smaller its utility will be. Its utility function is designed as a linear function, as shown in

$$U_C = \begin{cases} 1, & C < C_{\min}, \\ 0.8 + 0.1 \times \dfrac{C_{\max} - C}{C_{\max} + C_{\min}}, & C_{\min} \le C < C_{\max}, \\ 0, & C \ge C_{\max}. \end{cases} \quad (7)$$

According to the business requirements of each terminal, the utility function of each selected attribute is calculated. The utility value on the interval [0, 1] is obtained to be as the normalized values of the initial decision values. The normalized decision matrix is shown as follows:

$$B = \left(b_{ij}\right)_{m\times n} = \begin{pmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{m1} & \cdots & b_{mn} \end{pmatrix}. \quad (8)$$

3.3. Comprehensive Weight Calculation

3.3.1. Subjective Weight Calculation Based on the Analytic Hierarchy Process. The analytic hierarchy process compares and judges the importance of attributes through the subjective judgement of humans and quantifies it. It is suitable for solving the problem that it is difficult to construct a mathematical model for a complete quantitative analysis, and it can be applied in the weight calculation for access network selection.

After the establishment of the hierarchical structure model, the relative importance between two attributes is obtained by comparing the importance of the two attributes, and a decision matrix is then constructed. The criterion layer contains n attributes, and the decision matrix $A = (a_{ij})_{n\times n}$ can be obtained by comparing two attributes. a_{ij} is the importance degree of attribute i compared with that of attribute j; it satisfies $a_{ij} = 1/a_{ij}$ and $a_{ij} = 1$. The subjective decision is quantified to obtain the value of a_{ij} by determining which attribute is more important.

Using (9), we calculate the geometric mean of the jth column.

$$o_j = \sqrt[n]{\prod_{k=1}^{n} a_{jk}}, \quad j = 1, 2, \ldots, n. \quad (9)$$

The weight value of the decision index is calculated from a subjective point of view, and the weight is calculated as shown in

$$sw_j = \frac{O_j}{\sum_{k=1}^{n} O_k}, \quad j = 1, 2, \ldots, n. \quad (10)$$

Due to subjective bias, decision-makers' judgements regarding attributes may be contradictory, so it is necessary to conduct a consistency check on the decision matrix to ensure that the judgements on the importance of attributes are reasonable [16].

3.3.2. Objective Weight Calculation Based on the Entropy Weight Method. The entropy weight method is an objective weight calculation method that calculates the information entropy of each attribute by observing the amplitude variation of each attribute in different candidate networks. The larger the range of variation an attribute has in each candidate network, the smaller the information entropy is, the greater the amount of information provided for the decision is, and the greater the corresponding weight should be [20]. The main steps of calculating objective weight by entropy weight method are as follows:

The proportion of the attribute value for the jth index in the ith candidate network p_{ij} is calculated:

$$p_{ij} = \frac{b_{ij}}{\sum_{i=1}^{m} b_{ij}}. \quad (11)$$

The entropy value E_j of the jth index in different candidate networks is calculated:

$$E_j = -\frac{1}{\ln m} * \sum_{i=1}^{m} p_{ij} \ln p_{ij}. \quad (12)$$

The objective weight ow_j of the jth index is calculated:

$$ow_j = \frac{1 - E_j}{\sum_{i=1}^{m} 1 - E_j}. \quad (13)$$

The objective weights calculated by the entropy weight method can highlight the attributes that change significantly in different candidate networks and weaken the attributes that change little. This can provide useful information for objective decision making.

3.3.3. Comprehensive Weight Calculation. Subjective weight sw_j and objective weight ow_j are obtained by the AHP and entropy weight method, respectively. The deviation minimization method is used to calculate the comprehensive weights.

α is used to represent the weight coefficient of the subjective weight vector, and β is used to represent the weight coefficient of the objective weight vector. Combined with moment estimation theory, α and β can be calculated as

$$\begin{cases} \alpha_j = \dfrac{sw_j}{sw_j + ow_j}, \\ \beta_j = \dfrac{ow_j}{sw_j + ow_j}, \end{cases} \quad j = 1, 2, \ldots, n. \quad (14)$$

The weight coefficients of the subjective and objective weight vectors are used for weighted calculations, and the comprehensive weight W is calculated as

$$w_j = \frac{a_j ow_j + \beta_j sw_j}{\sum_{j=1}^{n} a_j ow_j + \beta_j sw_j}, \quad j = 1, 2, \ldots, n. \quad (15)$$

3.3.4. Selecting the Best Candidate Network. After the comprehensive weight set $W = \{w_1, w_2, \ldots, w_n\}$ is calculated in (15), it is multiplied by the normalized decision matrix in (8). The weighted normalized matrix can be obtained:

$$Z = \left(z_{ij}\right)_{m\times n} * W^T = \begin{pmatrix} w_1 b_{11} & w_2 b_{12} & \ldots & w_n b_{1n} \\ w_1 b_{21} & w_2 b_{22} & \ldots & w_n b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_1 b_{m1} & w_2 b_{m2} & \cdots & w_n b_{mn} \end{pmatrix}. \tag{16}$$

The candidate network is sorted by an approximate ideal sorting algorithm. The main steps are as follows:

According to the weighted normalized matrix, the positive ideal network Z^+ and the negative ideal network Z^- can be determined, where the positive ideal network can be expressed as

$$Z^+ = \left(z_1^+, z_2^+, \ldots, z_n^+\right). \tag{17}$$

The negative ideal network can be expressed as

$$Z^- = \left(z_1^-, z_2^-, \ldots, z_n^-\right). \tag{18}$$

The distance between the candidate network and the positive ideal network can be calculated as follows:

$$L_i^+ = \sqrt{\sum_{j=1}^{n} \left(z_{ij} - z_j^+\right)^2}, \quad i = 1, 2, \ldots, m. \tag{19}$$

The distance between the candidate network and the negative ideal network is calculated as follows:

$$L_i^- = \sqrt{\sum_{j=1}^{n} \left(z_{ij} - z_j^-\right)^2}, \quad i = 1, 2, \ldots, m. \tag{20}$$

The relative closeness between the candidate network and the ideal network can be calculated as follows:

$$C_{\text{TOPSIS}} = \frac{L_i^-}{L_i^+ + L_i^-}, \quad i = 1, 2, \ldots, m. \tag{21}$$

The candidate networks are sorted according to the degrees of relative closeness. The greater the degree of relative closeness is, the better the network will be. Then, the best access network is selected [21].

4. Simulation and Results

4.1. Simulation Scenario. The simulation scenario is shown in Figure 1. It consists of small conventional terrestrial stations and other base stations. The macro station is located in the center of the scene, and small conventional terrestrial base stations are randomly distributed within the coverage range of the macro station. The monitoring terminals are distributed in the overlapping coverage of the network. Three kinds of networks can provide communication transmission line monitoring terminal access. The simulation is mainly aimed at the overlapping coverage area of the networks. Since the network environments are dynamically changing, each attribute parameter in the simulation is randomly generated within the predefined interval. As the number of service access networks increases, the available load of each network decreases, and the delay and packet loss rate of each network also start to increase; that is, the network parameters change with the decrease of the available load.

In the simulation scenario shown in Figure 1, each monitoring terminal completes access control and executes the access network selection algorithm based on a QoS guarantee. Each monitoring terminal evaluates the networks and selects the best candidate access network by collecting network attribute information. Therefore, the access network selection algorithm based on a QoS guarantee is implemented by the distributed computing of each monitoring terminal. Each monitoring terminal independently completes the algorithm process, while the different types of networks in the terrestrial-satellite network only provide network access in the scenario; they do not participate in access control, and there are no algorithmic calculations.

Due to the particularity of the transmission line monitoring business, the business models that are considered in the scenario are uplink communications. The simulation is mainly aimed at the overlap area of the network. Considering the maximum reliability of the networks, it is assumed that all businesses retain their communication connections. Businesses include videos, images, data, and voice clips. For these four types of businesses, the number of business monitoring terminals is randomly generated. Because the network environment is dynamically changing, the parameters of each decision index in the simulation are generated randomly during the interval at a certain moment.

MATLAB is used to build the test scenarios of terrestrial-satellite networks. The proposed access algorithm and comparison algorithm are, respectively, run 10 times; the access network selection and data processing results are recorded. The average results of the two algorithms are taken for comparison. Because the experiments regarding the initial attribute and terminal business types of the scenario are randomly generated, to ensure that the scenes are the same, different random seed numbers are set for the experiment in MATLAB. When the random seed number remains unchanged, the random numbers generated by the program remain the same, and the execution of each experimental algorithm scenario is the same.

According to the preferences of a given service regarding the bandwidth, delay, packet loss rate, and cost, the comparison judgement matrix is obtained through a pair-to-pair comparison of the importance values. The comparison judgement matrix is verified by consistency, and the subjective weights calculated by the AHP are shown in Figure 2.

4.2. Analysis and Results. To test the performance of the algorithm proposed in this paper under the background of the transmission line monitoring application in remote areas, MATLAB is used to simulate the algorithm. In the access network selection scenario for multi-transmission

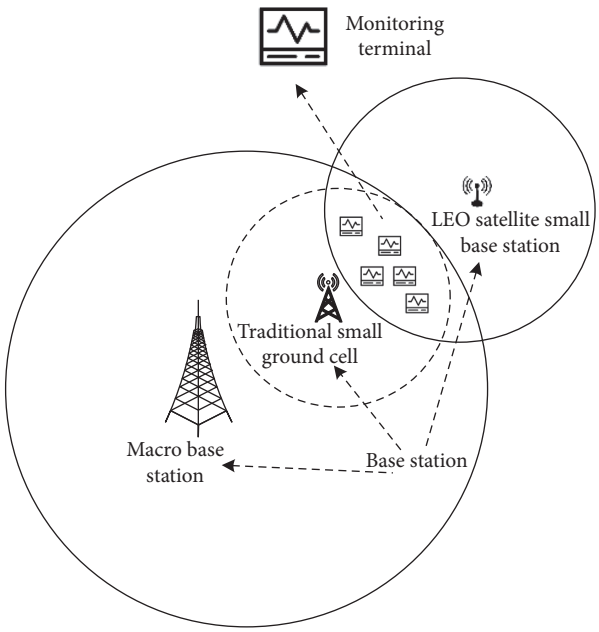

Figure 1: Schematic diagram of the simulation scenario.

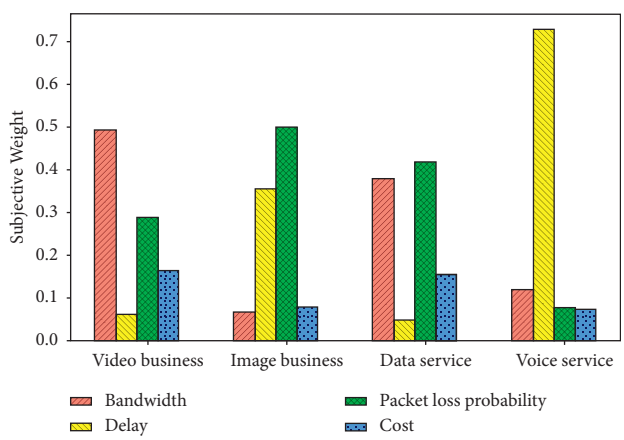

Figure 2: The subjective weight distributions of different businesses.

line monitoring services, the access network selection algorithm proposed in this paper based on a QoS guarantee and the access network selection algorithm based on comprehensive weights in the literature [10] are used to evaluate the candidate networks and select the best candidate access network. The performances of the algorithms are compared from three aspects: the traffic blocking rate, network selection rate, and network resource utilization.

4.2.1. Traffic Blocking Rate Analysis. The blocking rates of the two algorithms are shown in Figure 3. When the terminals use the access network selection algorithm based on comprehensive weight, most of the monitoring terminals give priority to the macro station based on the performance comparison between the networks. Due to the limited number of connected terminals in a macro station, the traffic blocking rate increases. When the terminal uses the access

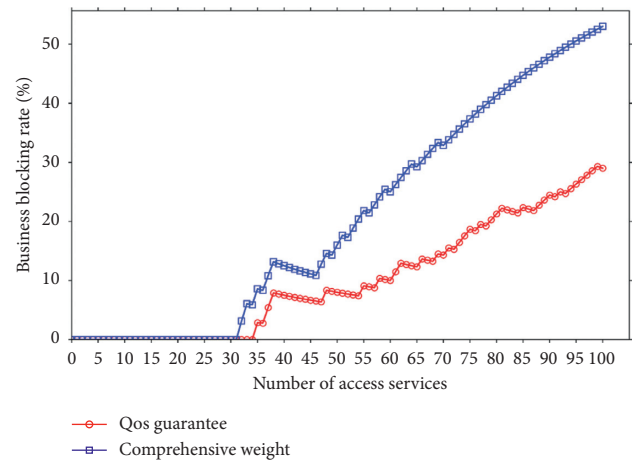

Figure 3: Comparison of the traffic blocking rates of two algorithms.

network selection algorithm based on a QoS guarantee, the utility function replaces the traditional range transformation method for normalizing the network parameters. Rather than blindly choosing the network with the best performance, the evaluation value of the network is closer to the service requirements, so the traffic blocking rate is lower.

4.2.2. Network Selection Rate Analysis. The network selection rates are shown in Figures 4 and 5. It is assumed that each network is in a no-load state at the beginning, and the performance of each candidate network remains relatively good. The goal of the business is to choose the network with the best performance, but as the number of businesses increases, the available loads of access networks gradually decrease, and other networks start to be chosen. This finally balances the selection rates of all networks. With the use of the access network selection algorithm based on the comprehensive weight, the changes in network selection rate are more dramatic. If the number of access businesses is small, the network with better performance is preferred. As the network performance degrades, businesses gradually begin to choose other networks. By using the QoS guarantee-based access network selection algorithm, when the number of businesses is small, each network has a probability of being selected, and the selection rate is flat.

4.2.3. Network Resource Utilization Analysis. The utilization rate of network resources changes as shown in Figure 6. When using the access network selection algorithm based on the comprehensive weight, because the business does not evaluate the candidate networks in combination with business demand, it prefers to choose a network with better performance. As a result, the number of accessible businesses on this network will soon reach the upper limit. By considering the needs of the businesses, the access network selection algorithm proposed in this paper with a QoS guarantee chooses the most appropriate network. The simulation results show that the algorithm improves the network resource utilization of the whole system to a certain extent.

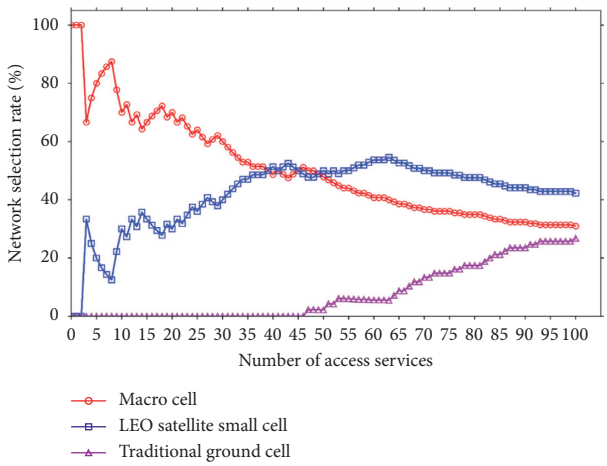

Figure 4: Network selection rate of access network selection algorithm based on service QoS guarantee.

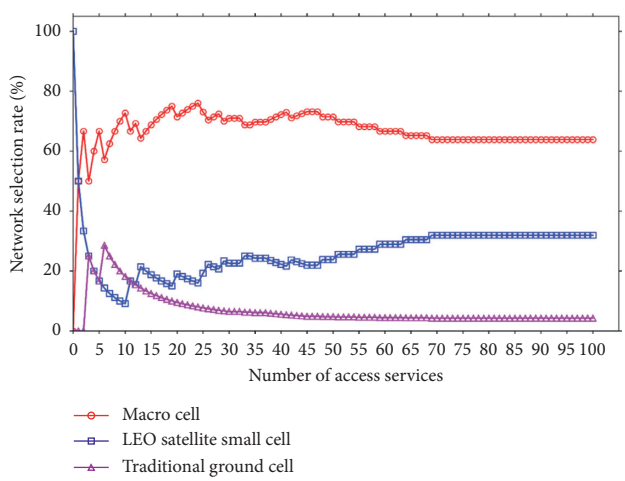

Figure 5: Network selection rate of the access network selection algorithm based on comprehensive weight.

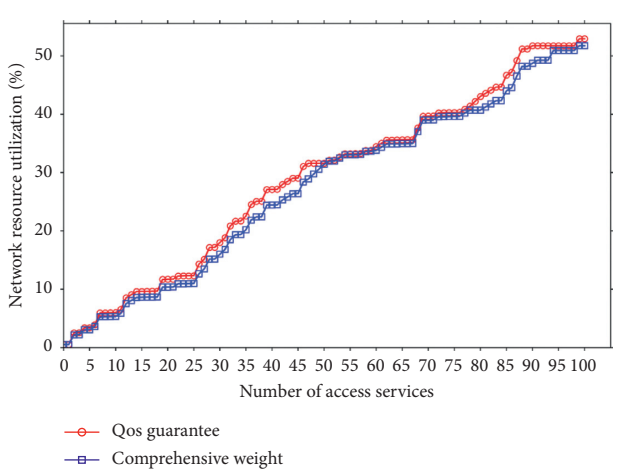

Figure 6: Comparison of network resource utilization between the two algorithms.

5. Conclusion

Considering different business requirements and network performances, this paper proposes an access network selection algorithm based on a QoS guarantee for terrestrial-satellite networks in remote areas. According to the characteristics of the network attributes, utility functions are designed to normalize the attributes. A sorting method is used to sort the candidate networks and complete the access network selection from the best candidate networks. By establishing the association between network attributes and business requirements, this algorithm can accurately reflect the roles of business requirements in candidate networks and realize the accurate evaluation of candidate network performances. Through a comparison with the access network selection algorithm based on the comprehensive weight, the proposed algorithm can reduce the blocking rate while improving the load balance and resource utilization. It not only guarantees the demand of the business but also avoids the waste of network resources. Therefore, it can provide highly reliable network access for the existing monitoring terminals under the scenario of limited network resources.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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