Analysis of Signal Integration Techniques and System Performance in Multi-Level Satellite Communication Networks

Abstract: Satellite communication has gradually become an indispensable part of the global communication system because of its wide coverage, large transmission capacity and wide frequency band. This topic centers on the signal integration technology of satellite communication network for in-depth discussion, takes satellite communication resource allocation as the entry point, combs the communication resources and network state in satellite system, introduces a business rating model formula based on communication service demand, designs a communication resource allocation algorithm strategy for satellite system based on genetic algorithm based on network and business value characteristics, and conducts simulation test and system performance analysis. The results reveal the superiority of the genetic algorithm-based resource allocation method in computational complexity, task matching and matching rate, which improves the matching rate and matching update rate by 9% and 4% over the comparison method. Meanwhile, the system service satisfaction under this resource allocation method reaches 0.55 to 0.60, and the system throughput and utilization rate obtain 8% to 13% and 16% to 31% improvement, respectively, indicating that the resource allocation method based on service rating can effectively improve the overall performance of the satellite communication network system.

Keywords: service rating model; genetic algorithm; resource allocation; simulation test; satellite communication network

1. Introduction

With the development of satellite communication technology and the expansion of application fields, satellite communication network has become an indispensable part of modern society and is widely used in many fields such as national defense, aerospace, ocean, transportation, meteorology, resource exploration, radio and television broadcasting, etc. [1-3]. However, problems such as signal interference, faults and emergencies are inevitable in satellite communication networks, which may lead to serious consequences such as communication interruption, data loss and degradation of service quality. Therefore, it becomes especially important to establish an intelligent monitoring system for satellite communication network signals [4-6].

Satellite communication network site, mainly by the satellite transmits carrier and receives carrier from the satellite to realize the communication, and the carrier signal in the communication can be received almost anywhere in the network coverage area. This provides a prerequisite for the monitoring of satellite network systems [7-9]. At the same time, the performance parameters of the satellite communication system can basically be obtained by measuring and analyzing the channel carrier [10].

With the continuous development and wide application of satellite communication network, it becomes an important task to ensure the stability and reliability of satellite communication network [11-12]. And signal monitoring, as an important means of satellite communication network operation and maintenance, can effectively improve the stability and reliability of the network and guarantee the smooth communication [13-14]. The necessity of signal monitoring of satellite communication network mainly includes four aspects, namely, the stability of satellite network, the timely discovery of interference and faults of satellite network signals, the improvement of the efficiency of satellite communication and the guarantee of network security [15-16].

At present, the monitoring of the operation status of the domestic satellite communication network is mainly carried out through the network management system provided by the satellite communication network equipment production and supply vendors and some conventional instruments and meters [17-18]. After the signal transmission quality of the network system drops significantly or the main equipment at the remote site fails, resulting in the signal transmission can not be carried out normally or even interrupted, the network maintenance management personnel use the existing test instruments and meters (e.g., spectrum analyzers, power meters, etc.) to test and analyze the test by manual testing, and the test generally requires the interruption of relevant carriers [19-21]. As a result, it is impossible to realize automatic real-time monitoring of various technical parameters that affect network operation and signal transmission quality during system operation, and it is also impossible to realize the diagnosis and alarm of hidden operation faults [22]. Therefore, this monitoring method has great limitations, with slow response and low efficiency in fault confirmation and troubleshooting [23].

In this paper, after analyzing the composition architecture of the integrated management system of satellite communication network, the resource allocation method of satellite communication network is constructed. Specifically, QoS index is introduced as the evaluation standard, a service grading model is designed based on the service requirements for transmission delay, bandwidth and communication link reliability, the service value is evaluated, and a communication scene service model is established. After that, satellite communication resources and states are modeled, and then a communication resource allocation algorithm is designed based on genetic algorithm. The actual situation is simulated by MATLAB simulator, and the proposed resource allocation algorithm is simulated and analyzed from three dimensions of computational complexity, task matching and matching rate. Finally, the traditional allocation methods and related algorithms are selected and compared with the method of this paper in terms of system service satisfaction, throughput and resource utilization to explore the application performance of satellite communication network systems.

2. Integrated management system for satellite communications networks

With the development of satellite communication technology and the expansion of application fields, satellite communication network has become an indispensable part of modern society, and is widely used in many fields such as national defense, aerospace, ocean, transportation, meteorology, resource exploration, radio and television broadcasting. In the satellite communication network system, which contains many differentiated station types, an integrated management system is needed to carry out comprehensive management of network information, so as to accurately control the communication status of the overall network.

As shown in Figure 1, the integrated management system of satellite communication network is mainly for the comprehensive management of satellite main station, fixed station and mobile station, and its main functions include the comprehensive monitoring and alarm function of satellite small station, and it can also carry out scientific management and scheduling of emergency mobile station, realize scientific management and maintenance of the relevant equipment of the satellite main station, and carry out comprehensive monitoring and management of the satellite spectrum. In addition, the integrated management system of satellite communication network can also carry out comprehensive communication resource management and monitoring for the voice switching network, optical transmission network and ancillary facilities of the equipment room in the communication specialized network. Comprehensive monitoring and alarm subsystem for satellite small stations: through the integration of Agilis network management system, it can carry out centralized monitoring, management, signal analysis and business statistics for small stations in the whole network. Support VNO virtual network management function. Emergency mobile station management and scheduling sub-system: integrate emergency mobile command platform network management software, manage stations built in different places, and provide station interface software, hardware and installation and debugging. Satellite master station equipment management subsystem: centralized management of remote stations in the whole network, realizing configuration below and software upgrade, unified scheduling and management of satellite resources and links, and realizing management of satellite equipment, communication equipment and auxiliary equipment in the master station. Satellite spectrum resource monitoring and management subsystem: realizes real-time collection, storage, interface display and monitoring of satellite spectrum resource data. Communication Resources Convergence Management Subsystem: incorporates the above four subsystems into unified management, and at the same time requires the integration and functional development of the voice switching system, optical transmission system, and ancillary facilities of the equipment room (communication cables, power supply system of the equipment room, environment monitoring system, comprehensive business process management system, etc.), and centralizes the equipment, resources, status, and failures of the whole network through various forms and dimensions of the topology view. Monitoring and displaying of equipment, resources, status and faults of the whole network in various forms and dimensions. Reserve softswitch interfaces. Test and monitor communication cables and support QR code management of equipment and cables in the server room. Develop cell phone and mobile client for mobile remote management.

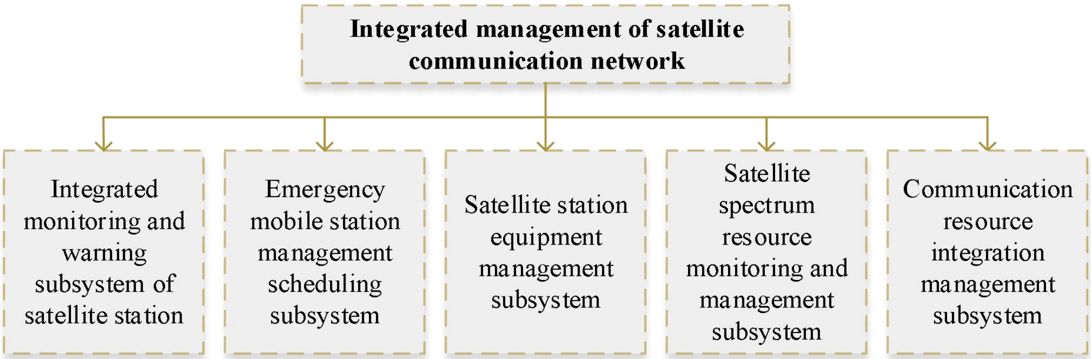

Figure 1 Integrated management of satellite communication network

3. Resource allocation methodology in the multilevel satellite network

Signal integration technology is a kind of signal integration method, which mainly collects, organizes and analyzes the signals from different signal sources comprehensively, realizes the merging and sharing of signals, and exploits their value significance comprehensively. Based on the signal integration technology, this chapter mainly starts from the satellite network resource allocation, designs a communication resource allocation algorithm based on the service hierarchy model and performs simulation analysis.

3.1 User business hierarchy modeling

3.1.1 QoS indicators for satellite systems

The purpose of the quality of service (QoS) mechanism is to provide communication services that meet the needs of various types of services, thus guaranteeing the rational planning and use of satellite communication resources. The QoS mechanism in satellite communication networks mainly considers: multimedia service transmission, message service transmission, support for large-capacity user access and compatibility with other types of networks.

3.1.2 Grading and modeling of ground operations

The terrestrial service evaluation model is established based on service types and service requirements, etc., to serve the beam resource allocation algorithm. Service grading is mainly based on the class of service (CoS) for grading and modeling the services that may be involved in the system, such as session interaction, streaming media and backend. It is divided into three gradients, CoS1-3, in which CoS1 has the lowest priority and CoS3 has the highest priority, and in increasing order.CoS1 is a message class application, mainly for application services such as web browsing and e-mail.CoS2 is a real-time class application, mainly for online banking, electronic payment and file transfer, etc.CoS3 is a constant-rate application, mainly for audio and video applications.

The rating of services is mainly evaluated with the help of network state information, through bandwidth utilization, transmission delay, and link packet loss rate, etc. Due to the nature of the network, this network state information has multiple manifestations. It mainly includes the following parameters, $m(l_i)$ is the link l_i metric parameter, and $m(p)$ is the total metric parameter.

(1) Transmission delay

The sum of the transmission delay of the packets of this service in each link:

$$m(p)=\sum_{i=1}^{n} m(l_i) \tag{1}$$

(2) Available bandwidth

The minimum link bandwidth requirement for the service in the transmission process, the larger the value indicates that the service has a higher degree of demand for the network:

$$m(p)=\min[m(l_i)] \tag{2}$$

(3) Transmission success rate (reliability)

The reliability of the transmission of the service through the network:

$$m(p)=\prod_{i=1}^{n} m(l_i) \tag{3}$$

(4) Packet loss rate

The packet loss rate (transmission error rate) can be expressed by the transmission success rate, and $f(p)$ in equation (4) is the transmission failure rate of the task:

$$f(p)=1-\prod_{i=1}^{n} m(l_i) \tag{4}$$

So transmission success rate:

$$m(p)=1-f(p) \tag{5}$$

Transformation of the above equation yields equation (6):

$$\lg(m(p))=\lg\left(\prod_{i=1}^{n} m(l_i)\right)=\sum_{i=1}^{n}\lg(m(l_i)) \tag{6}$$

Constructing the terrestrial service model requires mapping multiple QoS metrics into a single metric parameter, which is convenient for the next resource algorithm to operate. Therefore, different QoS metrics are weighted and calculated to meet different service requirements of different services by adjusting the weighting coefficients, and the terrestrial service model mainly refers to the three aspects of bandwidth, transmission delay and transmission reliability, in which bandwidth and reliability are directly proportional to the quality of service, and delay is inversely proportional to the quality of service. Let k_1, k_2 and k_3 be the weighting coefficients of bandwidth, reliability and delay, respectively, and the terrestrial service hierarchical modeling formula is shown in equation (7):

$$C(p) = k_1 B(l_i) + k_2 \sum_{i=1}^{n} \lg[M(l_i)] + k_3 \frac{1}{\sum_{i=1}^{n} T(l_i)} \tag{7}$$

$B(l_i)$ is the bandwidth of link l_i, $M(l_i)$ is the transmission success rate of link l_i, $T(l_i)$ is the transmission delay of link l_i, and $C(p)$ is the QoS metric parameter, the larger the value of the function, the higher the quality of service of this communication link, and the higher the quality of service, and the higher the demand for the task can be carried. This metric function can also be referred to as the resource overhead metric (RCM) function. Since the algorithm needs to be simulated and implemented on the communication simulation software, Eq. (7) is further optimized:

$$S(m) = k_1 X(m) + e_1 \left(k_2[1 - D(m)] + k_3 \frac{1}{T(m)} \right) \tag{8}$$

Eq. (8) is the evaluation formula for the ground service classification in this chapter, and the subsequent resource allocation algorithm scenario models are established using this as a template. In the formula, m is the type of service, $S(m)$ is the value of the service, $X(m)$ is the data rate of the service (the link throughput of the bearer task), $D(m)$ is the packet loss rate of the service on the link queue, taking the highest value in the transmission process, and $T(m)$ is the transmission delay of the service. k_1, k_2 and k_3 are the weight coefficients of each attribute, reflecting the degree of service demand for different parameters, the larger the value of the coefficients, the higher the degree of service demand for this parameter.

3.2 Satellite communication beams

3.2.1 Satellite resource and network state modeling

The main communication resources of the satellites in the communication network designed in this chapter are as follows:

(1) The total transmit power of satellite i is modeled as P_i, and the power sum of all its beams is less than or equal to P_i.

(2) The total bandwidth of satellite i is modeled as B_i, and the bandwidth sum of all its beams is less than or equal to B_i.

(3) The number of wide beams of satellite i is $N_{1,i}$ and the coverage radius of each wide beam is $R_{1,i}$.

(4) The number of spot beams of satellite i is $N_{2,i}$, and the coverage radius of each spot beam is $R_{2,i}$.

The static state of the satellite communication network is as follows:

t moment satellite i at longitude $x_i(t)$, latitude $y_i(t)$ and altitude $h_i(t)$ the orbit is modeled as:

$$[x_i(t), y_i(t), h_i(t)] = l_i(t) \tag{9}$$

The dynamic state of a satellite is as follows:

(1) Power $p_{i,k}(t)$ of satellite i on moment t beam k with bandwidth $b_{i,k}(t)$.

(2) Satellite i position $l_{i,k,u}(t)$ of the user u within the coverage of the wide beam at moment t and the required data rate $a_{i,k,u}(t)$.

(3) The position $c_{i,k,n}(t)$ of the center point of the satellite i at the moment t point beam n.

The optimization objective for resource allocation to the satellite network in this chapter is:

$$
\begin{aligned}
&[p_{i,k}^*(t), b_{i,k}^*(t), c_{i,k,n}^*(t)] \\
&= \arg\max[e_i \gamma(p_{i,k}(t), b_{i,k}(t), c_{i,k,n}(t)) \\
&+ e_2 \delta(p_{i,k}(t), b_{i,k}(t), c_{i,k,n}(t))] \\
&s.t., \sum p_{i,k}(t) \le P_i, \\
&\sum b_{i,k}(t) \le B_i,
\end{aligned}
\tag{10}
$$

$c_{i,k}(t)$ within the coverage $\delta(p_i, k(t), b_{i,k}(t), c_{i,k,n}(t))$. In equation (10) e_1, e_2 is a constant factor, $\gamma(p_i, k(t), b_{i,k}(t), c_{i,k,n}(t))$ is the user coverage, and $\delta(p_{i,k}(t), b_{i,k}(t), c_{i,k,n}(t))$ is the total data rate.

3.2.2 Point-beam communication resources

This chapter focuses on the resource allocation problem of movable spot beam communication, which can be flexibly adjusted according to the need to cover a specific area and become the communication medium in that area. Figure 2 shows the schematic diagram of the off-axis angle of the spot-beam antenna, φ is the radiation angle of the spot-beam antenna, θ is the angle (off-axis angle) of the user P deviating from the antenna pointing to the center E, ω is the angle of view between the user P and the satellite S, and γ is the lowest communication elevation angle within the visible range of the satellite. If the target user satisfies Equation (11), i.e., the user's off-axis angle is less than the half-power angle of the spot-beam antenna and the user's angle of view with the satellite is greater than the lowest communication elevation angle, then the user can receive spot-beam communication services. Equation (11):

$$
\begin{cases} \theta \le \varphi \\ \omega \ge \gamma \end{cases}
\tag{11}
$$

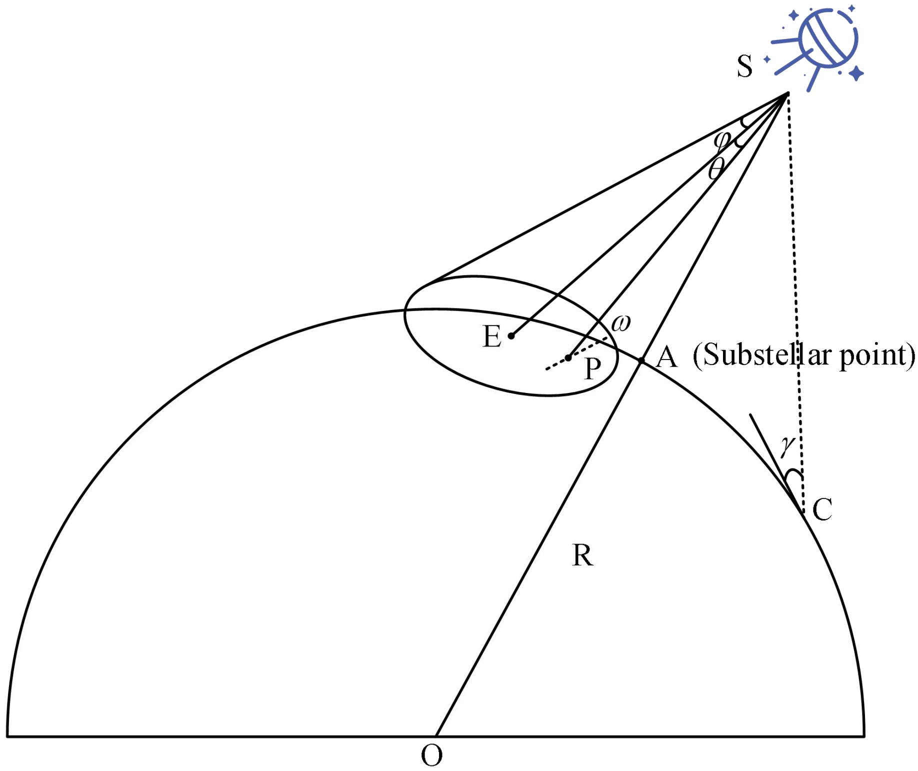

Figure 2 Satellite spot-beam antenna off-axis Angle diagram

As for the point beam with an approximate circular coverage, the closer to the center of the beam, the stronger the signal gain. Therefore, algorithms need to be designed to optimize the pointing of the point beam antenna to improve the efficiency of beam usage.

3.3 Beam Resource Allocation Algorithm

This algorithm focuses on the integration and allocation of directional communication resources in a multimedia mobile base station communication scenario, which mainly provides services to users within a certain range for a certain period of time. Since the solution algorithm for this scenario is complex and computationally intensive, it is solved by an optimized search algorithm, the genetic algorithm.

The flow of genetic algorithm is shown in Figure 3. Genetic algorithm, as a kind of intelligent algorithm for global search and optimization based on the mechanism of biological genetic evolution, is to complete the search for the optimal solution by the mechanism of selection, crossover, and mutation in biological heredity and evolution when mimicking the genetic characteristics of organisms with genetic operators. For the optimization problem, the traditional solution mainly consists of two categories: numerical method and analytical method, but due to the complexity of the problem becomes larger, the traditional solution method can not solve the problem well, while the genetic algorithm solution is not subject to the specific problem constraints, and can be solved for complex problems, which provides a new way of thinking for the solution of these problems.

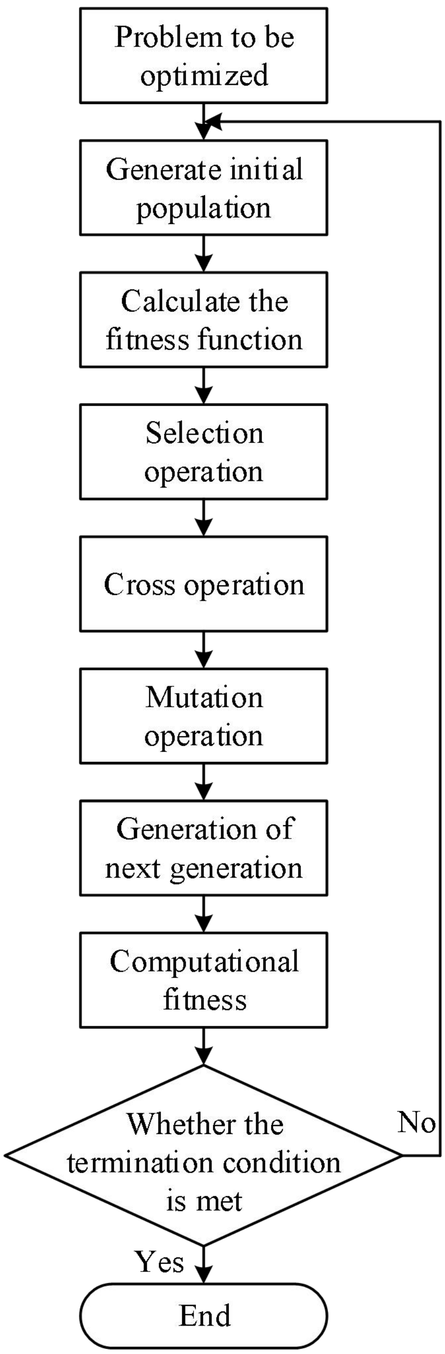

Figure 3 Genetic Algorithm flowchart

3.3.1 Variable representation

Coding is the process of representing each possible point in the search space of a problem as a feature string of definite length. The feature string is the individual or chromosome, and the individual is represented by a string, when coding a multivariate problem, a variable corresponds to a component in the whole string, this component is also called a gene or genetic factor, and all the individuals form a population. The binary coding method is widely used because of its simplicity, ease of implementation of genetic operations, and short solution time, etc., and in this paper, we adopt the binary coding method.

3.3.2 Adaptation function

Fitness is a measure used to distinguish between good and bad degree of superiority of population survival, fitness is calculated by fitness function, the algorithm in the search of evolution is only based on the fitness function and the fitness value of each individual to carry out the search. Therefore, the fitness function is related to whether the algorithm can quickly and accurately complete the search for the optimal solution.

The design of the fitness function should be reasonable so that it can accurately reflect the advantages and disadvantages of the corresponding solution, and it should be simple to reduce the complexity of time and space, and improve the efficiency of the operation. The fitness function:

(1) If the objective function is a maximum solution problem, there are:

$$F(x)=\begin{cases} C_{\max}+f(x), f(x)<C_{\max} \\ 0, \text{other} \end{cases} \tag{12}$$

where $C_{\max}$ is the maximum estimate of the objective function $f(x)$, $f(x)$ is the objective function, and $f(x)$ is the fitness function.

(2) If the objective function is the minimum value to solve the problem, then there are

$$F(x)=\begin{cases} f(x)-C_{\min}, \text{when } f(x)>C_{\min} \\ 0, \text{other} \end{cases} \tag{13}$$

where $C_{\min}$ is the maximum estimate of the objective function $f(x)$, $f(x)$ is the target function, and $F(x)$ is the fitness function.

3.3.3 Determining the genetic operator

The eugenic and hereditary process of simulating biological evolution in genetic algorithms is accomplished through three basic operational operators: selection, crossover, and mutation.

(1) Selection

Before performing the selection operation, the fitness is first calculated. The fitness of individuals in the population and its distribution determine the selection probability of each individual in the alternative set. The operator chosen in this paper is the proportional fitness distribution, also known as roulette selection.

The magnitude of the likelihood of offspring retention is determined by calculating the probability of each individual's fitness. If an individual i, whose fitness is f_i, is selected, the probability of its selection is expressed as:

$$p_i = \frac{f_i}{\sum_{i=1}^{u} f_i}(i = 1, 2, \ldots\ldots, u) \quad (14)$$

where p_i is the probability of an individual being selected, u is the size of the population, and f is the fitness of the individual.

(2) Crossover

Crossover is a process in which two new individuals are produced through partial gene crossover between two paired chromosomes of the two parents according to certain principles. There are different crossover methods, such as single-point crossover, multi-point crossover and uniform crossover, etc., which are commonly used. Single-point crossover is the classic crossover form, and compared with other crossover methods, single-point crossover can cause less damage in the structure.

The good genes in the parent generation are inherited to the offspring, and the bad performance after crossover can be eliminated in the subsequent selection process.

(3) Mutation

After the crossover operation, the mutation operator is a small probability of individual string of certain genes in the population changes, in the expansion of population diversity at the same time on the premature convergence of the algorithm plays a limiting role. The common way of variation operation is binary variation, which is used in this paper.

The main parameters of the genetic algorithm are the population size N (i.e., the number of individuals in the population), the maximum number of algebraic iterations M, the crossover probability P_c, and the probability of variation P_m. The setting of these parameters is determined according to the actual problem and is not yet standardized. If the population size N is too small, the problem of incomplete search and premature convergence will occur, and if the population size N is too large, the number of samples is too large, the computational volume increases and the computational speed is slow, so it is not reasonable to arrive at an accurate solution. A crossover probability P_c that is too large leads to a higher probability that a well-adapted string will be corrupted, and a crossover probability P_c that is too small can cause the search to stop. Mutation probability P_m is too large to cause the search of the algorithm to be close to random search while mutation probability P_m is too small to cause the lack of individual diversity and make the algorithm's performance decrease. Therefore, the parameter settings should be obtained based on experimental debugging.

3.3.4 Decommissioning guidelines

The convergence of the genetic algorithm is heuristic, there is no strict convergence criterion, the current commonly used basis for judging convergence is through the number of calculations whether to reach the maximum number of iterations, the optimal solution in a certain time number of times within the scope of the conditions to determine whether the algorithm reaches convergence.

3.4 Simulation results and analysis

The connectivity relationships of interstellar links and star-earth links during the simulation period are obtained by STK software, and the performance of the algorithm is verified by MATLAB simulator. The system planning period is set from May 1, 2023, 14:00 to May 1, 2023, 16:00, and the length of each time slot t is 300 seconds.

3.4.1 Computational complexity

The computational complexity of the T-O GS matching algorithm and this paper's communication resource allocation method based on the service hierarchy model is analyzed in terms of time gap variation. The computational complexity is defined as the number of new matching pairs generated. The variation in the number of iterations of different methods is shown in Fig. 4. From a global perspective, the computational complexity of both the T-O GS matching algorithm and the satellite communication resource allocation method in this paper is lower than that of the random matching algorithm, but the random matching algorithm is much better than the other algorithms in the beginning stage.The complexity of the T-O GS matching algorithm is maintained around 45, while the communication resource allocation method based on the service hierarchy model in this paper has a lower computational complexity, which is around 8, which means that the participants' average number of service requests in 8 iterations is lower than that of the random matching algorithm. That is, participants can realize stable matching after 8 service requests on average.

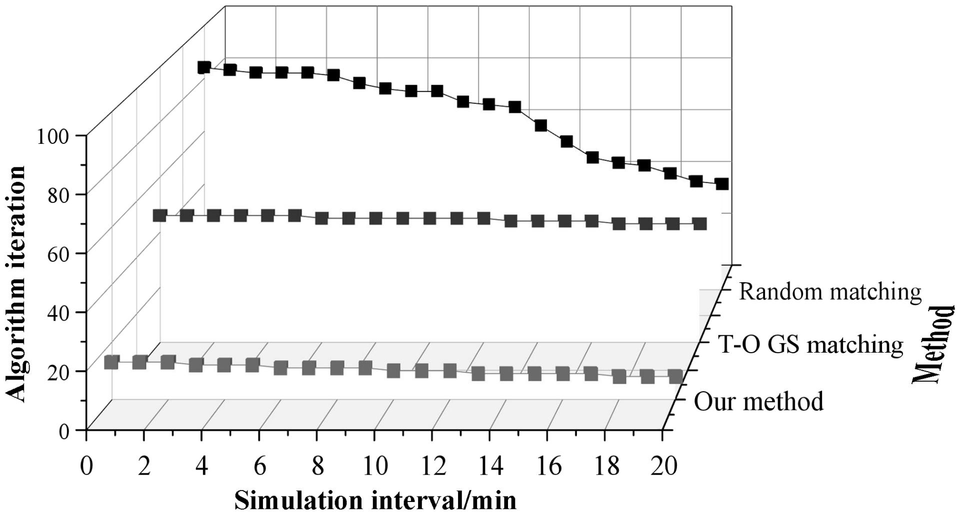

Figure 4 Changes in the number of iterations of different methods

3.4.2 Task-side matching performance

The task satisfaction performance of the satellite communication resource allocation method in this paper is shown in Fig. 5. Satisfaction is defined as the rank order of the matched beam resource in its preference list, and a higher rank indicates a higher satisfaction. At simulation time slot t, tasks 2, 3, and 5 are matched with the first-ranked pair of beam resources in the preference list, i.e., satisfaction is 1. Tasks 1 and 4 are both matched with the third-ranked pair of beam resources in the preference list. At simulation time slot t+1, tasks 1 and 2 were matched with the first-ranked pair of beam resources in the preference list. Overall, all tasks were matched with beam resources ranked higher in the preference list at different simulation time slots.

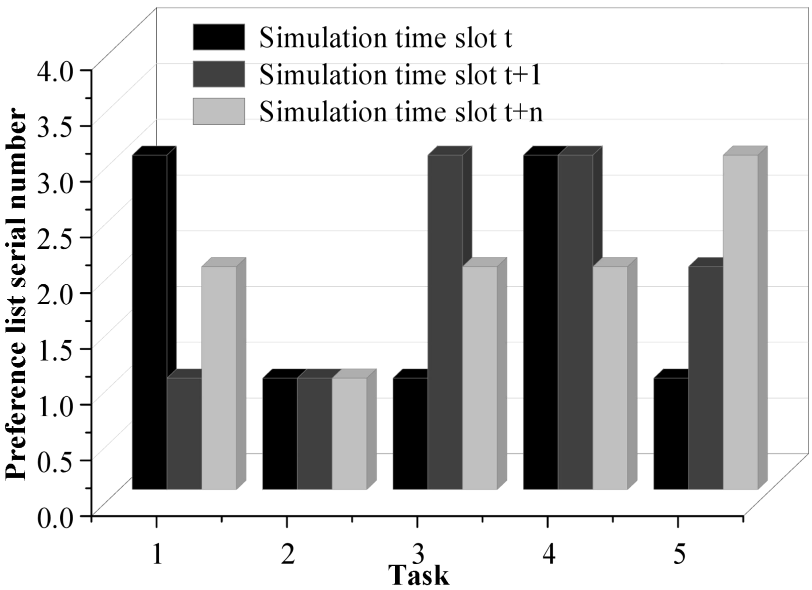

Figure 5 The mission satisfaction of the satellite communication resource allocation method

3.4.3 Matching rate

Match rate refers to the percentage of the total number of observation tasks for which matching pairs are formed through service requests made by participants and passed the accept/reject operation. Matching update rate refers to the ratio of the number of matching pairs whose matching results in the current time slot are different from the matching results in the previous time slot to the total number of current matching pairs. Fig. 6 shows the matching rate and matching update rate of the T-O GS matching algorithm and the resource allocation method in this paper. It can be seen that the match update rate of the T-O GS matching algorithm is 1 at t=0. This is because the algorithm is assumed to start with an empty match. At time slot t+1, the matching update rate drops to near 0.37 because of the matching result for time slot t. The matching rate of the algorithm then stays near 0.23. In this paper, both the matching rate and the matching update rate of the genetic algorithm-based beam resource allocation algorithm are relatively smooth, with the matching update rate remaining near 0.46 and the matching rate remaining near 0.27.

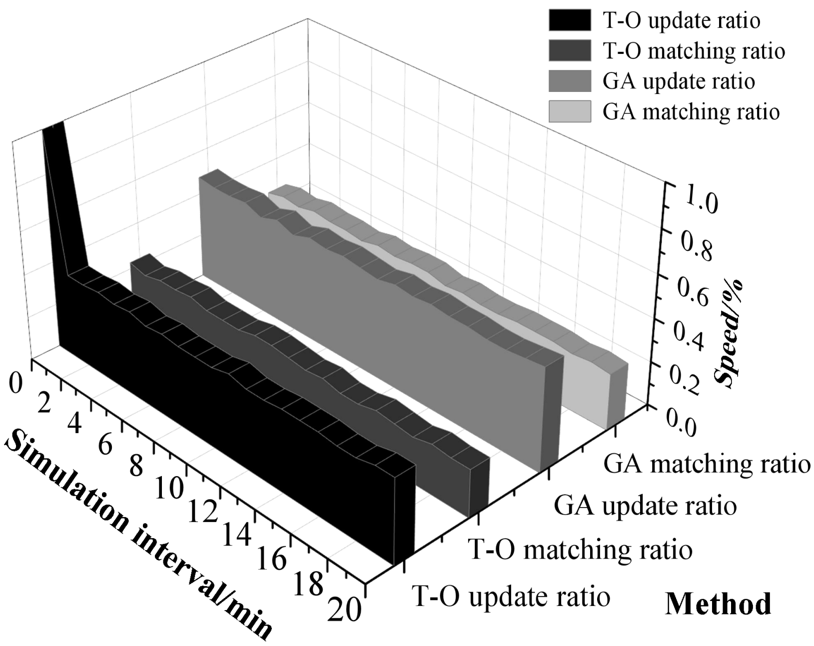

Figure 6 The update ratio and matching ratio of T-O GS matching algorithm and our method

4. System performance analysis

In the beam system studied in this paper, a total of 20 service wave positions are planned and the total system bandwidth is 500 MHz.The proposed resource allocation method optimized by service demand-driven genetic algorithms is compared and evaluated with the allocation methods proposed in the related literature in terms of system service satisfaction, throughput and resource utilization.

4.1 Satisfaction with system operations

The system service satisfaction index is expressed as the ratio of the actual allocated capacity to the end-user service request capacity. In the case of uneven distribution of service demand, discrete factors are used to characterize the discrete coefficients of service distribution, and firstly, the traditional resource allocation method, resource allocation method 1 and resource allocation method 2, and the proposed allocation method in this paper are simulated and compared in terms of service satisfaction.

The business satisfaction with different business discretization factors is shown in Fig. 7. Among them, the wave position business discretization factor takes values in the range of [0,1], the X-axis coordinate takes values tending to 0 indicating that the demand for business volume within the wave position is basically the same, the value takes values tending to 1 indicating that the difference in the demand of the wave position is relatively large, and the Y-axis coordinate takes values tending to 1 indicating that the higher the business satisfaction of the system is. Under different discrete factors, the system business satisfaction of the communication resource allocation method based on the business hierarchy model proposed in this paper is concentrated at 0.55~0.60, which is significantly higher than other resource allocation methods. The business satisfaction of the traditional resource allocation method and the two contrasting resource allocation methods are concentrated at 0.33~0.37 and 0.42~0.47, respectively.

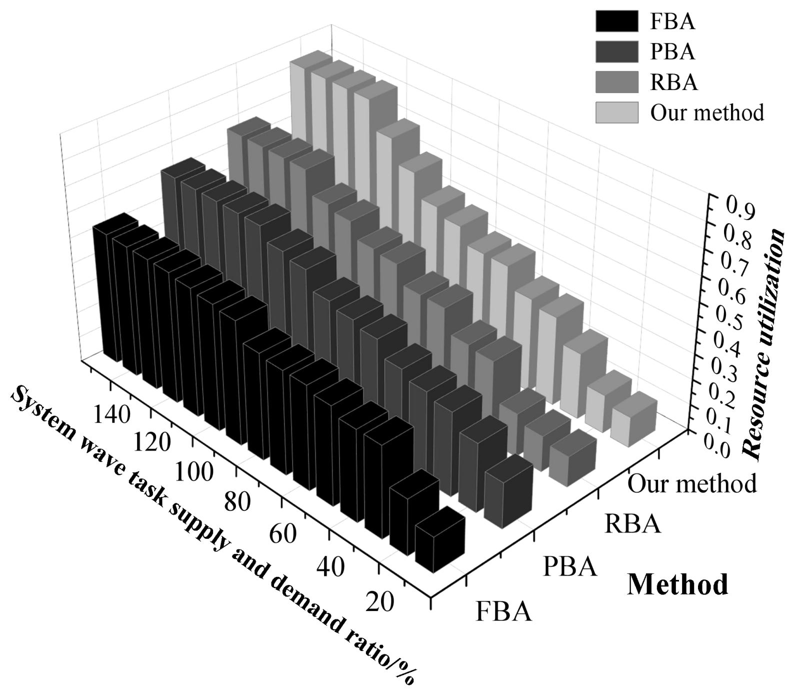

Figure 7 Business satisfaction and different business discrete factors

4.2 System throughput performance

System throughput is an important indicator of HTS system performance, and normalized throughput is used to carry out the system throughput performance comparison between the resource allocation method proposed in this paper and other beam allocation methods. The results of the comparison of system throughput with different resource allocation methods are shown in Fig. 8. Among them, the vertical coordinate normalized throughput tends to 1 indicating high system throughput and maximized utilization of system resources. The analysis shows that the system throughput of the traditional fixed resource allocation method is low, and the system throughput is below 0.7, which cannot meet the actual demand within the wave position and lacks flexibility. The resource allocation method proposed in this paper improves 13% and 8% in terms of system throughput compared with resource allocation method 1 and resource allocation method 2, and the overall system throughput performance is improved.

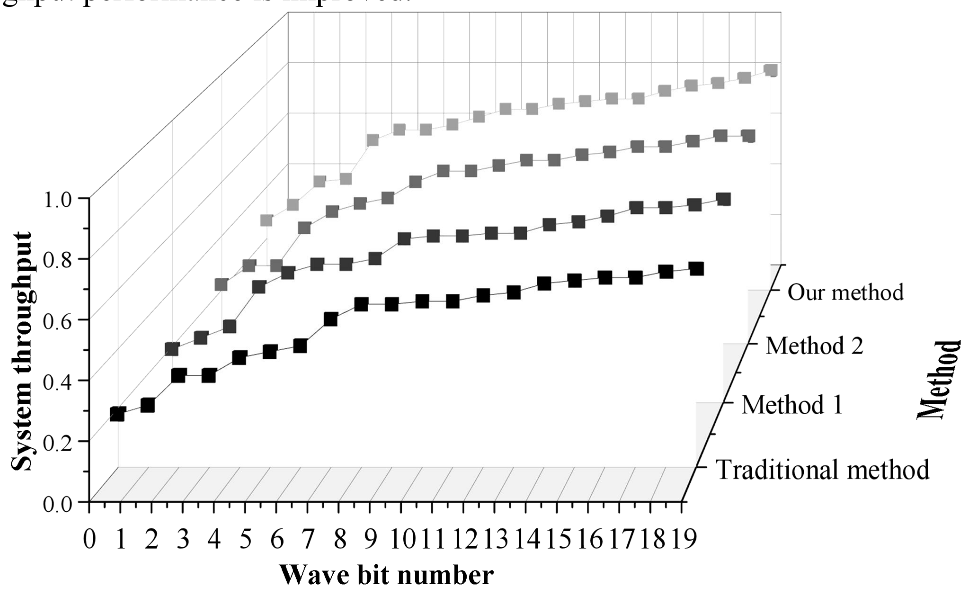

Figure 8 The system throughput compares with different resource allocation methods

4.3 System resource utilization

Under different conditions of system service supply and demand ratios, different resource allocation methods proposed in related literature are simulated and compared with the resource allocation method based on service hierarchical model proposed in this paper in terms of resource utilization, i.e., simulation and comparison with the resource fixed allocation method, the resource polling allocation method, and the resource random allocation method, and the results of the system resource utilization compared with different resource allocation methods are shown in Fig. 9. Among them, ① Resource fixed allocation method (FBA): adopts traditional fixed-beam coverage, on-planet resources are fixedly allocated to user terminals, and frequency multiplexing reduces inter-beam co-channel interference without using BH technology; ② Resource polling allocation method (PBA): the service wavelengths are covered in zones, and BH technology is used to poll the wavelengths periodically for resource allocation; ③ Resource random allocation method (RBA): the system resources utilization rate and different resource allocation methods are shown in Fig. 9. (RBA): the service wave position is covered in partitions, and the BH technique is used to allocate resources to wave positions in a random way; ④ this paper takes the resource allocation method based on the service hierarchy model.

The resource utilization rate of this paper's resource allocation method is higher than the other three allocation methods. When the system service supply/demand ratio is less than 50%, the available resources of the system are more, and the resource utilization rate is basically the same with the first three allocation methods, because the simple allocation methods of the system can satisfy the service demand within the wave position. When the system business supply-demand ratio is more than 80%, the difference in resource utilization of different resource allocation methods is relatively large. When the system business supply/demand ratio is greater than 100% or more, the resource allocation method proposed in this paper improves the resource utilization of the system by 31%, 21% and 16% compared with the resource fixed allocation method, the resource polling allocation method and the resource random allocation method, i.e., the resource allocation method in this paper can effectively improve the resource utilization of the satellite system.

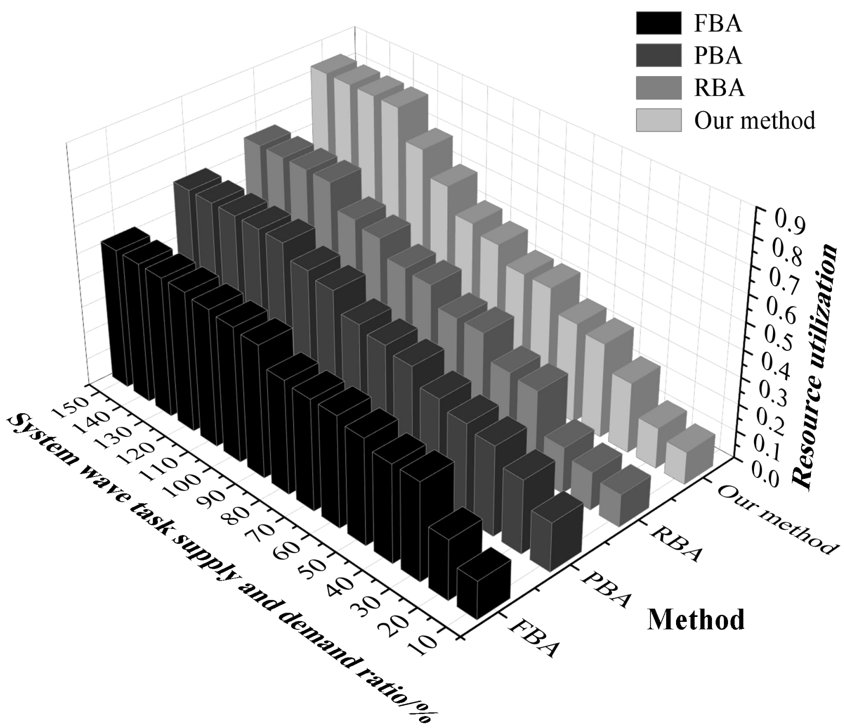

Figure 9 The comparison results of system resource utilization and different methods

5. Conclusion

The wide application of satellite communication networks has become an indispensable part of modern society. This study investigates the signal integration technology in satellite communication networks, takes beam resource allocation as an example, and designs a resource allocation method for multilevel satellite communication networks through service hierarchy and satellite resource modeling as well as genetic algorithm optimization, and discusses the performance of the method and the system through experiments.

(1) The beam allocation method based on genetic algorithm in this paper has lower computational complexity and higher matching rate, and the user can realize stable resource matching after 8 service requests, and the matching rate and matching update rate are 9% and 4% higher than the T-O GS matching algorithm, respectively. The effectiveness and superiority of this method for beam resource allocation are verified.

(2) The system service satisfaction, throughput and resource utilization of the service hierarchical resource allocation method based on the service hierarchy are better than the comparison method. The system service satisfaction is 0.55 to 0.60, and the system throughput and utilization are improved by 8% to 13% and 16% to 31% compared with other methods. The beam resource allocation method proposed in this paper enables the system resources to match resources according to the service hierarchy, and the resource allocation has high flexibility, which improves the overall system performance.

(3) This paper has achieved certain results in the research of signal integration and resource management strategies for satellite communication networks, and the application of the resource allocation method based on service hierarchy to satellite communication systems has been verified to be a better way to improve system performance. However, from the point of view of continuing to optimize system performance and reduce system complexity, it is necessary to consider system delay and complexity in future research, as well as how to maximize system performance on the basis of ensuring service quality.

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