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OPTIMIZED RESOURCE IN SATELLITE NETWORK BASED ON GENETIC ALGORITHM

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Abstract. *Satellite network is an all-around network which has high-complexity, dynamic and enormous, and its resources are very limited. So we have to optimize the resources on satellite network. This article has studied the resources optimization for task in the satellite network. We established the flow chart and mathematical model of resources optimization on the base of research for satellite network. At last design the resources optimization algorithm based on the genetic algorithm. The algorithm realized rational distribution of resources in satellite network effectively. The algorithm has given the task scheduling plans which achieve time optimization and resources balanced under the resource and the partial ordering of task dual factor restriction.*
Keywords: Satellite network, Resources optimization, Genetic algorithms

1. **Introduction.** The satellite network which is components of types of satellite system in different orbit is the future trend of the main developments in information technology. The various function equipment and logical resources in satellite constitute the whole network of computing resources, storage resources, reconnaissance resources, telemetry resources. The resources of satellite network are limited because its resource cannot be expanded after inter orbit. The satellite is more particularly valuable relative than ground resources. The fast development of modern satellite technology and the distributed satellite system, make the research have very important significance in theory and application problems.

Since the satellite network has huge military as well as the economic efficiency, every country researches the satellite networks actively. There are many research institutions and universities research the problems in relation to satellite networks, too. Literature [1,2] considered resources optimization in the ways of task scheduling. However, it only discusses the resources optimization from the task, and does not take into account the full utilization of the resources itself. Literature [3] considered how to distribute frequency resource of satellite. This paper proposes a new queuing model. Literature [4] described resources allocation of satellite transponders. Literature [2,5,6] analyzed the resource allocation process of the multimedia satellite network. The above documents only consider the resources allocation from a single angle. But satellite network is a network of comprehensive various resources, it will be involved various resources in the process of the user subtask. It is too one-sided considering communication resources optimization only.

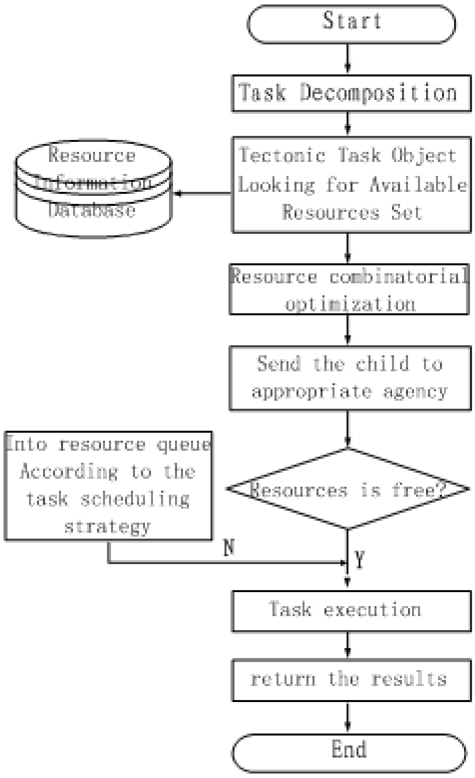

Figure 1. Flow chart of task creation and execution

2. **Resources Optimization Model.** Satellite network is a comprehensive network system, the service provider is not limited to one satellite, and service object does not correspond to a class of users. In satellite network, we consider how to complete the task optimum performance both balance the use of resources when the ground user submitted after several tasks.

Resources optimization model includes task submission, task decomposition, resource analysis, resource allocation and resource recovery. First of all, each user put forward task request to various part administer station, collected on task. The task collected refers to that management station collect tasks from user and register to local task list. Secondly, the management station will be for some task decomposition according to the characteristics of the task, there are certain dependent relationship son tasks the task decomposition. Then the center management looking for available resources database, which are allocated resources scheduling according to the resources optimization algorithm. Finally, the subtasks assigned to each agency later, satellite agent scheduling subtask and return the results according to the task scheduling algorithm. The flowchart of resources optimization for tasks is given.

3. **Establishing Mathematics Model.** Then we described the resources optimization for mathematical language and establish mathematical model.

We assuming there are S-number satellite in satellite networks, the satellite sets are

$$S = \{S_1, S_2, \cdots, S_S\} \tag{1}$$

There are m class resources in satellite network; every satellite has several resources, and can complete the corresponding task. Then each satellite has multidimensional resources:

$$R_k = (R_{k1}, R_{k2}, \cdots, R_{km}), \quad k = 1, 2, \cdots s \tag{2}$$

So the whole network of total resources for

$$R^{total} = \sum_k R_k = \sum (R_{k1}, R_{k2}, \cdots, R_{km}) = \left(R_1^{total}, R_2^{total}, \cdots, R_m^{total}\right), \tag{3}$$

where

$$R_l^{total} = R_{1l} + R_{2l} + \cdots R_{sl} = \sum_{k=1}^{s} R_{kl}, \quad l = 1, 2, \cdots m \tag{4}$$

Hypothesis user submitted task number is n, with task set

$$Task = \{Task_1, Task_2, \cdots, Task_n\} \tag{5}$$

$Task_i$ is composed of Q_i subtask which have order constraints.

$$Task_i = \{Task_{i1}, Task_{i2}, \cdots, Task_{iQ_i}\} \tag{6}$$

Each subtask of the task maintains a poset relation "$<:$"

$$Task_{i1} < Task_{i2} < \cdots < Task_{iQ} \tag{7}$$

Subtask $Task_{ij}$ have Execution time T_{ij} and resource demand subset $R(Task_{ij})(R(Task_{ij}) \subseteq S)$, set the resources of complete the subtask $Task_{ij}$ for R_{ij}, the start time and end time of $Task_{ij}$ for ST_{ij} and FT_{ij}.

We determine the resources types needed and time of every subtask after the division for multiple tasks, and pay attention to satisfy the interdependence between subtasks. The problem that we need to solve is how to assign each subtask to satellite reasonably, and make the time of complete all the tasks as short as possible. Namely:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{Q_i} T_{ij} \tag{8}$$

In fact, we could not find the optimal method of polynomial time because of the problem is a NP-hard problem. Therefore, we are looking for sub optimal algorithms effectively. Optimization method can be classified into two categories: traditional optimization method and intelligent optimization method. Traditional optimization method, the optimal solution can be obtained, but the problem is too big, the computational complexities in engineering often are not practical. Intelligent optimization method is good for this one defect, they are usually based on probability theory, the transfer of the rules in the solution space as far as possible to meet the requirements of rapid search out an approximate optimal solution, can shorten the time of combinatorial optimization problem solving. Genetic Algorithm (GA) is a powerful, application range of random search optimization technology, can be used to solve the industrial engineering in the traditional method to solve the problem [7,8].

4. The Application of GA.

4.1. The basic process of GA.

In recent years, the application domain of artificially intelligent expands unceasingly, the traditional artificial intelligence method based on symbol processing mechanism is more and more difficult in knowledge representation, information processing and solve the combinatorial optimization problem. In 1975 years, J. Honand professors and his students puts forward the genetic algorithm. Genetic algorithm for solving the problem will be expressed as "survival of the fittest" chromosome. Through the generations of chromosome population, including the choice and evolving crossover and mutation operations, eventually converge to the most suitable environment, the individual, thereby the optimal solution or satisfactory solution. In the genetic algorithm,

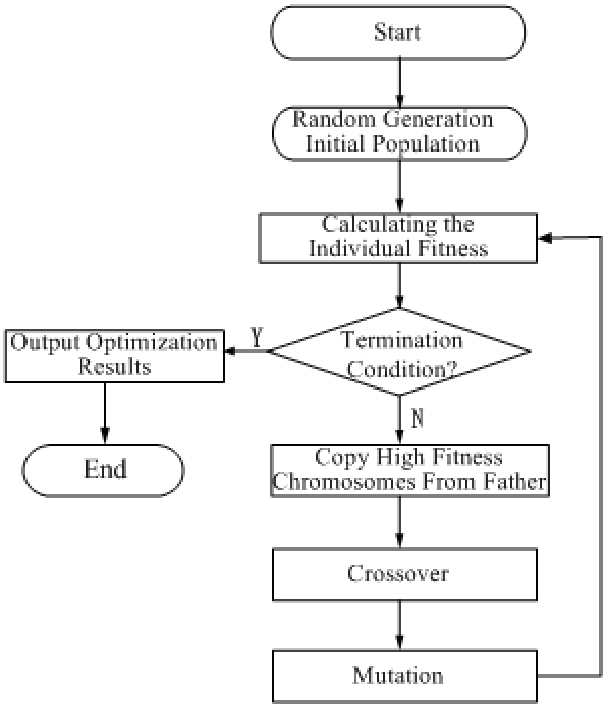

FIGURE 2. The flow chart of standard GA

the coding method, fitness function and design of genetic operator is one of the key. The flow chart of standard genetic algorithm is given below.

4.2. **The application of GA in satellite network.**

4.2.1. *Calculation matrix design.* In order to express the tasks and subtasks more conveniently, algorithm design dimensional matrix on below.

(1) Resources occupation matrix

We used matrix TR to describe the situation of occupancy resources of task that user submit.

$$TR = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1r} \\ r_{21} & r_{22} & \cdots & r_{2r} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nr} \end{bmatrix} \tag{9}$$

where,

n = number of task

r = number of resource

$$r_{ij} = \begin{cases} 1, & \text{if resources } i \text{ is occupied by a subtask of task } j \\ 0, & \text{if resources } i \text{ is not occupied by task } j \end{cases}$$

and

$$\max\left(\sum_{i=1}^{n} t_{ij}\right) \le r \le \sum_{j=1}^{t}\sum_{i=1}^{n} t_{ij} \quad i = 1, 2, \cdots, n; \quad j = 1, 2, \cdots, r \tag{10}$$

The above formula states that resources number r is greater than or equal to maximum number of subtask that involved scheduling task. The value of r is not more than sum of all the subtasks involved in scheduling. The values of n have relation with resources occupancy situation of each subtask which participate task scheduling. If the percentage of system resources occupied by most subtasks is big, n should take larger value, conversely, n should take smaller values.

(2) Subtask poset matrix

We used matrix TO to describe the partial order between subtasks.

$$TO = \begin{bmatrix} o_{11} & o_{12} & \cdots & o_{1r} \\ o_{21} & o_{22} & \cdots & o_{2r} \\ \vdots & \vdots & \vdots & \vdots \\ o_{n1} & o_{n2} & \cdots & o_{nr} \end{bmatrix} \tag{11}$$

When r_{ij} equal to 0, the o_{ij} in corresponding position equal to 0, and r_{ij} equal to 1, the o_{ij} in corresponding position is executive order of subtask j of task i.

(3) Time consumption matrix

We used matrix TT to describe the time of each subtask occupancies resources.

$$TT = \begin{bmatrix} t_{11} & t_{12} & \cdots & t_{1r} \\ t_{21} & t_{22} & \cdots & t_{2r} \\ \vdots & \vdots & \vdots & \vdots \\ t_{n1} & t_{n2} & \cdots & t_{nr} \end{bmatrix} \tag{12}$$

When r_{ij} equal to 0, the t_{ij} in corresponding position equal to 0, and r_{ij} equal to 1, the o_{ij} in corresponding position is the time of subtask occupancies resources.

4.2.2. *Design of GA.*

(1) Encoding and decoding

We were encoding according task order to Will coding, form a length of $n \times Q_i$ coding. After find the better chromosomes through the algorithm, the corresponding decoding process makes code strings expressed as practical problems. We adopt integer form coding solution vectors. There are m class resources available in the problem model. Now we assume that $Task_{ij}$ invoking the kind of resources k. The available total resources of k kind in system is R_k^{total}, $k = 1, 2, \cdots, m$. A feasible solution to problems can show as $e = (e_1, e_2, \cdots, e_{n \times Q_i})$, $e_i \in [0, R_k^{total}]$.

(2) Produce the initial population

The algorithm creates initial chromosomes using random generation method.

(3) Designing fitness function

Fitness is the adaptation to the living environment of individual. In this paper, the fitness function of chromosomes is designed as follows.

$$f = \max(TM_i) \quad 1 \leq i \leq s \tag{13}$$

TM_i is the end time of satellite i finish the last mission in current chromosome of current generation. Calculate the f value of each chromosome in current population, choose the optimal solutions.

$$Nf = \min(f_j) \quad 1 \leq j \leq N \tag{14}$$

We choose the optima after evolved m generation.

$$Mf = \min(Nf_k) \quad 1 \leq k \leq M \tag{15}$$

So, the fitness function is

$$Mf = \min\left\{\min\left[\max(TM_i)_j\right]_k\right\} \quad 1 \leq i \leq s, \quad 1 \leq j \leq N, \quad 1 \leq k \leq M \tag{16}$$

(4) Generate new population

The algorithm generates a new generation of chromosome groups according to the fitness value with certain rules selected from groups of chromosome. In choosing operation, we select several optimal solutions reserved to the next generation through the elite strategy, and the rest of individual select in the offspring through the wager roulette method.

(5) Crossover

Table 1. Optimization algorithm indexes: C-Computing, R-Reconnaissance, S-Storage

Task	Task 1			Task 2				Task 3			Task 4				Task 5			
Subtask	1	2	3	1	2	3	4	1	2	3	1	2	3	4	1	2	3	4
Task Type	R	C	S	C	S	R	S	R	C	S	C	R	S	C	C	C	R	R
Time	2	3	1	3	2	3	2	3	4	2	1	5	2	3	6	6	5	7
Task	Task 6				Task 7			Task 8			Task 9				Task 10			
Subtask	1	2	3	1	2	3	4	1	2	3	1	2	3	4	3	2	1	2
Task Type	C	R	S	R	C	R	C	R	C	R	C	S	R	S	S	R	S	C
Time	3	3	2	2	2	5	2	6	5	3	1	2	4	2	3	7	3	5
Task	Task 11			Task 12				Task 13				Task 14			Task 15			
Subtask	1	2	3	1	2	3	4	1	2	3	1	2	3	4	2	1	2	3
Task Type	R	C	S	C	S	R	S	R	C	S	C	R	S	C	R	R	C	S
Time	4	3	1	3	2	3	2	5	4	2	1	5	2	3	5	4	3	3

The algorithm uses modified POX crossover method in crossover operation.

(6) Mutation

The algorithm make mutate to chromosome in new population according to the mutation probability, make it is avoid falling into local optimal solution, prevent premature convergence.

5. **Simulation and Results.** Now we assume that ground user submitted some task, each task contains several subtask, need appropriate resources to complete.

We assume that the user submitted 15 tasks shown in Table 1. Each task has 3 to 4 subtask. The table given the time required and type for the subtask, and sort order in accordance with the subtask partial order. The optimization results are also an executive order for each task.

We assume that the total number of system resources is 10 in simulation experiments. 1, 2, 3 are reconnaissance resources, 4, 5, 6 are computing resources and 7, 8, 9, 10 are storage resources. Calculation matrix is shown below:

$$TO' = \begin{bmatrix} 1 & 0 & 0 & 2 & 0 & 2 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 3 & 0 & 0 & 2 & 4 & 0 & 0 & 3 & 0 & 0 & 3 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 3 & 0 & 2 & 0 & 0 & 2 & 0 & 0 & 1 & 0 & 2 \\ 2 & 0 & 0 & 1 & 4 & 1 & 0 & 0 & 1 & 0 & 2 & 0 & 2 & 0 & 0 \\ 0 & 1 & 0 & 4 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 3 & 0 \\ 0 & 0 & 2 & 0 & 1 & 0 & 0 & 2 & 0 & 4 & 0 & 0 & 4 & 0 & 3 \\ 3 & 0 & 0 & 3 & 0 & 0 & 0 & 3 & 0 & 3 & 0 & 0 & 3 & 0 & 0 \\ 0 & 2 & 0 & 0 & 5 & 0 & 0 & 0 & 2 & 0 & 3 & 0 & 0 & 2 & 0 \\ 0 & 4 & 0 & 0 & 0 & 3 & 0 & 0 & 4 & 0 & 0 & 2 & 0 & 4 & 0 \\ 0 & 0 & 3 & 0 & 0 & 0 & 3 & 0 & 0 & 5 & 0 & 4 & 0 & 0 & 4 \end{bmatrix}$$

$$TT' = \begin{bmatrix} 2 & 0 & 0 & 5 & 0 & 3 & 0 & 6 & 0 & 0 & 4 & 0 & 0 & 5 & 0 \\ 0 & 3 & 0 & 0 & 5 & 2 & 0 & 0 & 4 & 0 & 0 & 3 & 0 & 0 & 5 \\ 0 & 0 & 3 & 0 & 4 & 0 & 5 & 0 & 0 & 7 & 0 & 0 & 5 & 0 & 4 \\ 3 & 0 & 0 & 1 & 3 & 3 & 0 & 0 & 1 & 0 & 3 & 0 & 4 & 0 & 0 \\ 0 & 1 & 0 & 3 & 0 & 0 & 2 & 0 & 0 & 6 & 0 & 3 & 0 & 3 & 0 \\ 0 & 0 & 4 & 0 & 6 & 0 & 0 & 5 & 0 & 5 & 0 & 0 & 1 & 0 & 3 \\ 1 & 0 & 0 & 2 & 0 & 0 & 0 & 3 & 0 & 3 & 0 & 0 & 2 & 0 & 0 \\ 0 & 3 & 0 & 0 & 3 & 0 & 0 & 0 & 2 & 0 & 1 & 0 & 0 & 2 & 0 \\ 0 & 2 & 0 & 0 & 0 & 2 & 0 & 0 & 2 & 0 & 0 & 2 & 0 & 6 & 0 \\ 0 & 0 & 2 & 0 & 0 & 0 & 2 & 0 & 0 & 2 & 0 & 2 & 0 & 0 & 3 \end{bmatrix}$$

There are subtask poset matrix TO and time consumption matrix TT be given only. It is because that we can know the TR from TO and TT. The location of TR is one when the location of TO or TT is not zero, in or the position of 1, if not the location of TR is zero.

A good scheduling scheme should be completed the same work need time to a minimum. Therefore, the main index of judgment scheduling is minimum duration of task running. From the defining of fitness function we know that the running time more less, the fitness higher. Theoretically, the most ideal fitness should be system resources occupation are 100% to acquire, we can compute the best time from the table 1 is 30.

The ideal value cannot achieve because of the subtask partial order and task granularity, but it can be used as a judgment standard for scheduling scheme.

The selection of parameters is very important for the genetic algorithm. Crossover probability should select the high value, is generally choose between 0.5 and 0.9. Mutation probability selected low value, the reasonable choice range is 0-0.1 generally. The less iteration times can improve the running speed of genetic algorithm value is, but can lead to the bad operation results. But iteration times have no influence for optimization results when it improves to a certain degree. In the same iteration times, the value of the initial population is small, can improve the running time of algorithm, but could be reduced the diversity of the population also.

After analysis for group numerical, the crossover probability should choose 0.6, the variation should choose 0.005, the initial population for 50, and the iterative number positioning 100 can get more ideal test results in this trial.

After selecting the above parameters, once run of program give us the task execution order is

1 14 12 4 5 13 10 2 10 11 12 4 6 1 10 7 2 11 5 2 13 3 14 9 7 11 3 6 8 1 15 13 3 14 8 15 10 6 2 8 5 15 9 14 13 5 9 10 5 6 12 15 7 4 9 12 4

Execution time: 32

This result is very close to the theory optimal value and the operation speed is much quicker than integer programming. In fact, genetic algorithm is more superior when the question scale is large.

6. **Conclusion.** In order to use satellite network high costs resources more effectively, this paper designed a resources optimization algorithm based on genetic algorithm. Simulation experiments show that the algorithm can realize to resources distribution effectively. Algorithm gives task scheduling scheme under the double restraints of resources and task poset order. Compared with the traditional method, the new algorithm can get resources optimization results more quickly, and more reasonable and effective for the use of resource.

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