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Optimal Scheduling for Simulation Resource of Tactical Communication Network Based on Cloud Computing

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Abstract: With the development of satellite-based tactical communication networks simulation, simulation system has been a strong demand for automatic management of the running of simulation and the sharing of simulation resources and so on. Aimed at the puzzles in current HLA-based simulation system and with the combination of a new Cloud idea, a framework of Simulation Cloud has been presented. This article is absorbed in the aim how to schedule the task under simulation cloud environment and explore the dynamic dispatch to the parallel tasks in the federation entity level. Finally a mended optimal scheduling algorithm has been designed. This method can optimize network resources and computing resources during static task assignment at the initial application and during dynamic assignment in the simulating process. By extending the cloud computing platform CloudSim to test the Air-Ground warfare simulation system, this algorithm dynamically adjusted decision-making through using the information of systematical real-time operating status. It could make a timely response dynamically according to the changes of the characteristics of simulation system, re-achieve balance and improve the system performance, fault-tolerant and load-balance ability according to the adjustment of the dynamic fluctuations of the loading.

Key words: Tactical communication network, cloud computing, static scheduling, optimal resource scheduling, cloudSim

INTRODUCTION

With the development of tactical satellite-based communication networks, the simulation application research has been extended from traditional ground-based network to integration of tactical communications based on satellite. As a result, the simulating object is more complex and the simulating scope (Chen and Zheng, 2009) is increasing. It's difficult to avoid the overloading and node collapsing of federal member in the traditional HLA simulation system. So it's necessary to design a new simulation system balancing the calculation and simulation resource traffic loading to all the members. How to use the key technology of cloud simulation platform to obtain an efficient scheduling performance in cloud simulation has become an important issue.

The research on optimizing the configuration task scheduling (Liu *et al*., 2011) that tactical communications network simulation system based on cloud computing resources is studied from three cloud simulation aspects, including the frame modal, the static scheduling algorithm and the load balancing.

Computing resources play an important role in the cloud simulation to connect the computing nodes in different regions. The power of each simulation task, completed by a certain each node independently, is bound to affect the advancement of the entire simulation time. The high-capacity computing nodes complete the task faster than the others. They need to wait for other computing nodes to complete the task. The load status of the computing nodes is dynamic in the running simulation. When a node has failed or overloaded, it should be transferred to the task in lighter-load node to avoid the failing run which will affect the entire simulation to promote the process (Li *et al*., 2009).

Therefore, selecting the appropriate nodes running a distributed simulation applications from a large number of computing nodes and managing the load of nodes, it has a major influence to achieve the optimal allocation of computing resources on the performance of grid-based simulation applications (Zhang *et al*., 2011).

On the basis of research on cloud simulation optimal allocation of resources model, this paper investigates the optimal allocation of network resources and computing resources to task assignments in the initial of distributed simulation and loading balance in the running of simulation. Finally, network traffic and average message transmission delay were reduced in the running distributed simulation applications based on cloud computing.

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FRAMEWORK DESIGN BASED ON SIMULATION OF TACTICAL COMMUNICATIONS IN SPACE

With the combination of object-oriented modeling approach, tactical communication space-based network has a simulating object distributed architecture and it has determined its distributed architecture of the prototype system. The separated federal members constituted the basic composition of the satellite, terrestrial backbone network and the ground semi-kind instance. Federal members publish or subscribe the communication data through the related communication nodes which in the same step advance the actual simulation. In general, the cloud simulation platform has three main functions, including registration, scheduling, monitoring.

Registration is a function that can manage the simulation users and information. In the cloud simulation system, all kinds of users submit their own mission requirements through the portal of the cloud simulation platform and then the system will find the resources in accordance with the needs of users. The whole simulation task will finish after managing these dynamic resources. Monitoring is a function that is able to monitor the state of the various resources of the distributed simulation system and support the expression of simulation requirement mission. The requirement mission mainly relates to the consumption of task computing, dependence relations and communications consumption in the interaction, expecting completion time, execution of task requirements to the hardware and software and so on. Generally, it needed to provide two interfaces that graphics and text for users to express the mission requirements.

Scheduling is a function that refers to the task static scheduling and dynamic scheduling. The static scheduling includes selecting the appropriate grid nodes according to the needs of the task and the dynamic scheduling considers the load balancing and task migration in the running of the simulation.

The general simulating model (Li *et al*., 2004) is a standardized process, such as conducting performance simulation is to developed federal in accordance with the FEDEP of HLA. Thus, the management of tasks and resources should support this reuse in the software so that all functions are modularized (Fig. 1).

According to the characteristics of distributed management applications, the HLA framework has been improved to make it suitable for the implementation of the simulation task and expanse the support for the distributed simulation and parallel simulation applications based on HLA / RTI.

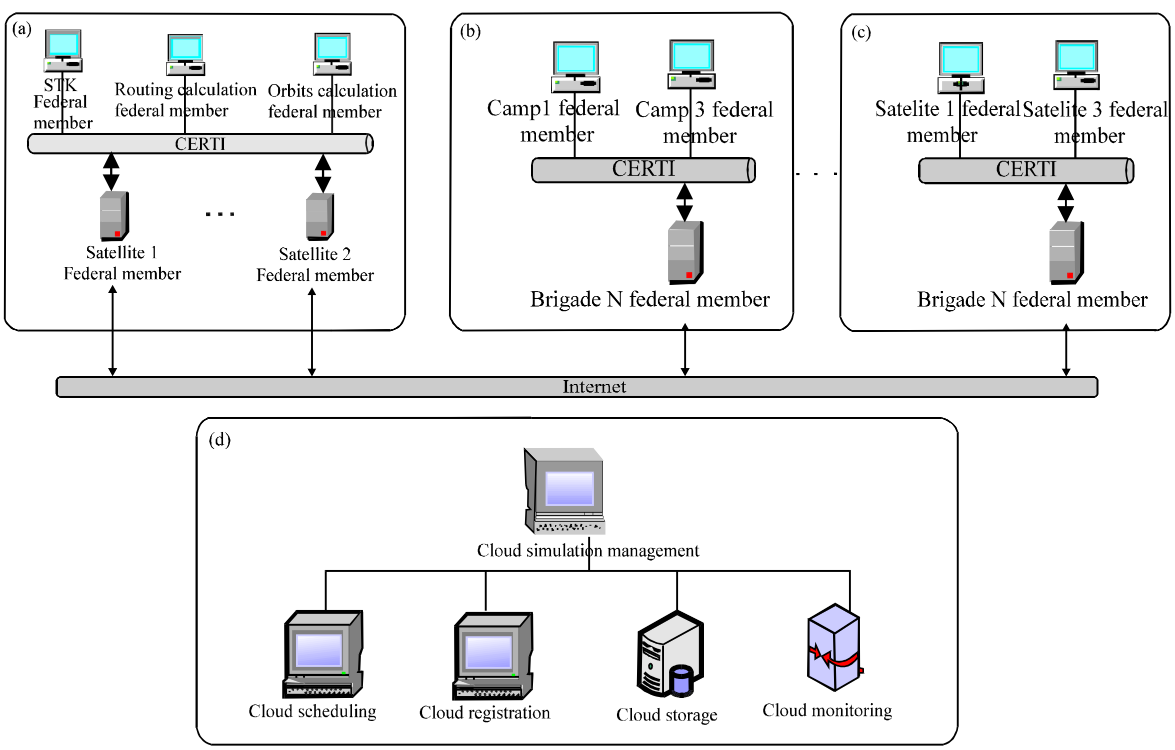

Fig. 1(a-d): The Framework design based on the simulation of (a) Satellite federal member (b) Camp federal member (c) Satellite federal member (d) Cloud management center

The design idea of this platform is to improve the efficiency of resource management (Tan *et al*., 2012) and task scheduling in cloud simulation with the simulation method. This paper improves the process of simulation development on the method, proposes submission and distribution of simulation assignment method and designs optimization algorithm to select the cloud resources and implementation of task scheduling. Finally, through the transparent, the users can get the simulation run and task management service.

OPTIMAL SCHEDULING ALGORITHM (OSA) FOR CLOUD SIMULATION RESOURCE

Improvement on the method of simulation development process, submission and distribution of simulation tasks, a new optimization algorithm has been designed (Cao *et al*., 2008) to select the cloud resources and implementation of task scheduling, ultimately provide users with transparent simulation run and task management service.

According to simulation running course the method of OSA is comprised of two parts, static and dynamic scheduling. Which optimal scheduling algorithm has been used is based on the characteristic of simulation task.

At the beginning of a simulation allocation, all the irrational resources arise from the load imbalance and errors in static scheduling algorithm which is the most popular heuristic method. Static scheduling needs monitoring information according to the performance of initial resources in simulation tasks.

During running of simulation, process can produce special events including user error or setting error in setting a number beyond the load threshold will be transferred to dynamic scheduling and be treated timely. The system looks for the suitable simulation node to run through dynamic scheduling strategy which based on the information provided by the monitoring system. The simulation tasks will be distributed to the selected node. There are many tasks in one node. Dynamic scheduling system needs monitoring information which used in the process of real-time monitoring simulation. The overall performance of simulation system can be improved by the optimal scheduling algorithm which achieves the system loading status and completes the dynamic scheduling in the distributing simulation task.

STATIC SCHEDULING ALGORITHM MODELING FOR RESEARCH AND IMPLEMENTATION

Static scheduling algorithm is the most popular heuristic method. Heuristic method mainly obtains some information in advanced (including the task of particle size, tasks communication etc.) and it is a non-analytical, similar, gradually approaching method lead to the optimal solution.

The experiments show that confrontation simulation systems are often due to greater communication with individual entities or at the beginning of a simulation irrational allocation of resources arising from the load imbalance and an error.

How the static scheduling system completes is close with monitoring system. According to the massive load situation in real-time, it will be up to static scheduling system to decide how to choose and allocate simulation task by the research of scheduling algorithm. This algorithm mainly resolve scheduling question which schedule some tasks to some cloud nodes in order to enables the simulation running well on the match resources.

Dynamic scheduling algorithm is the main ideas that the task scheduling problem recapitulates into a general optimization problem and then using mathematical programming techniques to solve it.

Definition 1: Federal entities have m members, $f = \{f_1, f_2,\ldots,f_m\}$ the simulation cloud system can make use of n processors $P = \{p_1, p_2,\ldots,p_n\}$, the general conditions, m>n. In order to achieve algorithm, many matrix needs as follows:

Definition 2: Running Costs Matrix Qm×n

$$Q_{m\times n} = \{q_{i/j} \mid 1 \le i \le m, 1 \le j \le n\} \tag{1}$$

where, $q_{i,j}$ show the running costs that ti federation member run in the Pk processor which is the measure by federation members running. If $q_{i,j} = 0$, then ti federation member can not run in the Pj Processor.

To show the distribution of tasks to the processor, the definition of distribution matrix is:

$$x_{i,j} = \begin{cases} 1, & \text{if } f_1 \text{ federation member distribute to } p_k \text{ processor} \\ 0, & \text{if } f_1 \text{ federation member do not distribute to } p_k \text{ processor} \end{cases} \tag{2}$$

To show communication expenses, $C_{m\times n}$ is the traffic matrix:

$$C_{m\times n} = \{c_{i,j}\},\ i,j = 1,2,\ldots,m \tag{3}$$

where, $c_{i,j}$ express data traffic that fj federation member subscribe object class and interaction class's number of fj federation member, if $c_{i,j} = 0$, between f_i and f_j is not data exchange.

The Federation members must have a choice in the allocation of processors, for example, visual federation member must be allocated to the image display workstations; some federation members' the entities need to use MATLAB or Semi-physical simulation system (21). Definition of priorities matrix is $A_{m\times n}$:

$$A_{m\times n} = \{q_{i,j} | 1 \le i \le m,\ 1 \le j \le n\} \quad (4)$$

If $A_{i,j}$ = 1, mean that f_i can not be allocated to p_j, otherwise = 0.

The load on the processor shows U_k, k = 1,2,...,n, it measure the implementation load of federation members in one processor.

In accordance with the based-HLA simulation system, dynamic scheduling methods should have the following principles:

Principles: The dynamic scheduling of federation members achieve through the imposition of certain restrictions. Simulation grid system mainly takes into account constraints that are processor load, storage capacity and real-time simulation step-side.

Processor load the restrictions can be expressed as:

$$\sum u_i x_{i,k} \le \text{Threshold}_k,\ k = 1,2,...,n \quad (5)$$

where, u_i show load value of the federation members in i processors, Thresholdk show the load capacity of Pk processor (This was mainly due to simulation grid system may exist in heterogeneous resources and its ability is different): Actual load can not exceed the sum of the processor load capacity, load comprise all the tasks running in some processor.

The following is the static scheduling algorithm:

Step 1: To initialize static scheduling parameters. Select the number of load indicators and set the threshold value of the indicators

Step 2: To import the results table of static scheduling. This table preserves all the one-to-one relationship of the grid nodes and the federation members. Static scheduling is as the basis for scheduling

Step 3: To set up low-level polling frequency. This order sent to the monitoring system, monitoring systems go on the polling frequency to monitor the load of the grid nodes or federal members

Step 4: To establish load regulation queue. According to the information reported in the monitoring system, load conditions can assess the current grid nodes through grey cluster approach. The head of the queue is the lightest load processor; the end of the queue is the worst load the processors

Step 5: For (j = 1; j<n; j ++)// find a node contained:

```
POSITION pos = list.GetHeadPosition ();
While (pos! = NULL)
(Cstring state = list.GetNext (pos);
 If (state = "General")
(
 Polling set up high-frequency;
   )
 else (state = "heavy load")
(Step into f;
 List.RemoveAt (pos);
  )
)
```

Step 6: To traverse C_{m*n} and find fi federation member which minimal communicate each other in Pi processor

Step 7: To choice Pk processors through the prediction model which meet the performance needs of the largest processors and if fi join still meet the three restrictions, fi will be assigned to the Pk ,at the same time migratory instructions sent to Pk and Pi agents

To solve the problem of static scheduling in Simulation System, it needs to propose a federation partitioning strategy based on interaction priority algorithm. The strategy greatly improves the efficiency of simulation running than traditional strategy. The algorithm partitions entities into groups according to their interaction frequency, namely, the entities with high interaction frequency are aggregated into one group and will be mapped onto the same processor to be simulated.

DYNAMIC SCHEDULING ALGORITHM MODELING FOR RESEARCH AND IMPLEMENTATION

The core of dynamic scheduling algorithm is Hungarian Algorithm, solving various forms of assignment problem in the easiest and most effective way, was proposed by Hungarian mathematician Edmonds in 1965 (Chang and Han, 2004). If each worker has a different efficiency in the completion of the work, at the same time considering the overall efficiency of the highest requirements in the assignment which is the optimal matching problem, also known as the assignment problem.

In the cloud simulation, if the amount of computer is m while the simulation tasks is n, considering every machine complete each task and the different of machines loads and network bandwidth, the establishment of the mathematical model is as follows (XU *et al*., 2004).

In order to the analysis of the problem, we define T_k, (k = 1,2,3...,m) as the time used in cloud simulation, U_k, (k = 1,2,...,m) as the loading and D_k, (k = 1,2,...,m) as the network latency. $W_{i,j}$>0 (i,j = 1,2,...,n) is the comprehensive weight which assigning the computer named No.i to complete the cloud simulation tasks named No.j which the smaller it is the better performance, so we define the decision variables as follow:

x_{ij} = {1 the computer named No.i to complete the cloud simulation tasks named No.j
0 else (6)

The problem can be transformed into a 0-1 linear programming problem:

$$\min z=\sum_{i=1}^{n}\sum_{j=1}^{n}(T_{ij}+U_{ij}+D_{ij})x_{ij}=\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}x_{ij} \tag{7}$$

$$\text{s.t.}\begin{cases}\sum_{i=1}^{n} x_{ij}=1, & i=1,2,3,\ldots,n\\ \sum_{j=1}^{n} x_{ij}=1, & j=1,2,3,\ldots,n\\ x_{ij}=1\text{或}0, & i,j=1,2,3,\ldots,n\end{cases} \tag{8}$$

According to the drawback of Hungary algorithm, we employ a improved Hungary algorithm which, Combined with specific clouds simulation environment, to solve this problem. Here is the running step below:

Step 0: Initialize the efficiency matrix

Step 1: Transform the coefficient matrix to put "0" elements in each line and each column, then eliminate the 0 elements from the each line (column) if it have the minimum numbers of 0 elements

Step 2: Compare the resources of cloud simulation with the number of cloud tasks, go to step 3 if they are equal, else add virtual task (efficiency value is 0) when resources more than cloud simulation or break apart the efficiency matrix into two matrixes when resources less than cloud simulation. One matrix dimension is equal to number of resources, another matrix need complement of one or more columns by adding resources which equals to the number of virtual task (efficiency value is 0)

Step 3: Try to make assignment in order to find the optimal solution, the detailed steps are as follows:

- Record 0 * from which has only one 0 element of the row or column and then cross out other zero elements of the column or row as Φ
- Mark to only one element column (row) elements, denoted by 0 *, then crossed out 0 * row (column) elements, recorded as of Φ
- Repeated the above two steps until all 0 elements are marked and crossed
- If there are still no marked elements and peer (column) 0 elements have at least two, you can use different options to test

Step 4: Draw the straight line at least to cover all elements to determine the most independent element in the coefficient matrix

Step 5: Add 0 elements for the transformed coefficient matrix. Select the least element which is not covered by the straight line and then subtract it some rows marking with x while add the least element in the rows which are not marking with x to ensure that the original 0 elements are not changed

The dynamic scheduling algorithm flow chart is shown in Fig. 2.

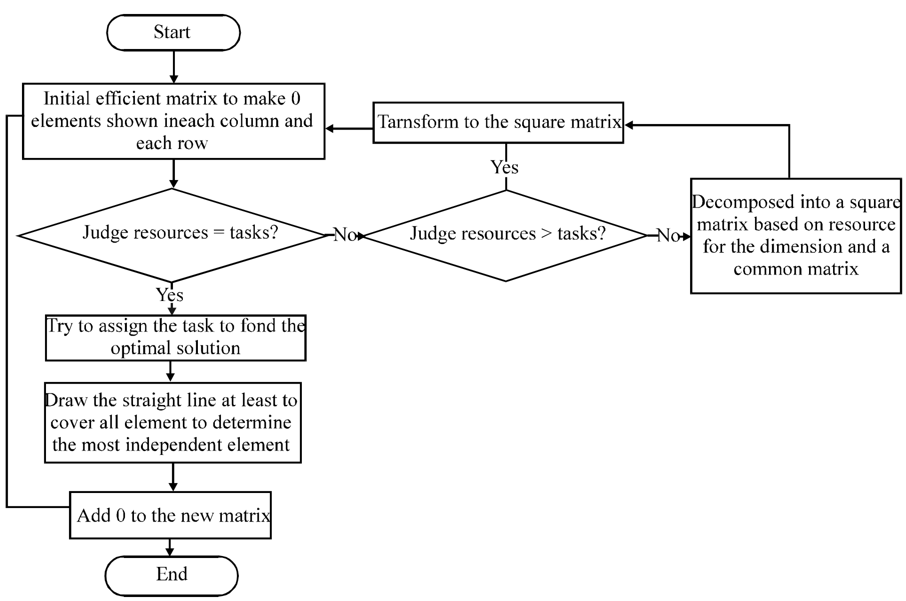

Fig. 2: The dynamic scheduling algorithm flow chart

SIMULATION AND ANALYSIS

To verify the feasibility of cloud simulation resource scheduling strategy based on the Optimize Scheduling Algorithm (OSA), the experiment in this paper extends the cloud simulation platform CloudSim and uses Myeclipse6.0 which is the program tool. DataCenterBroker that realizing resource discovery and exchange of information is the core of the simulation scheduler.

In the Air-Ground warfare simulation system, the simulation system has three types of model entity which including missile entity, ground targets entity and interceptor missile entity. In this experiment, a total of 18 entities that six missiles, six ground targets and six interceptor missiles was called. The launch vehicle is far from the ground targets that blue square 10,000 m at first. The missile model which is the most complex in the three types of models takes the most CPU. The performance is different for running different algorithm in the same system. If the cloud simulation computer is idle, the first cloud simulation task accesses to the service which is called first come first served or FCFS. Meanwhile, Static Scheduling Algorithm (SSA) gives each cloud simulation the optimal allocation of resources cloud simulation task. While the Optimize Scheduling Algorithm (OSA) make a combination of the static scheduling and dynamic scheduling.

In the Fig. 3 task scheduling are on x axis, meanwhile, FCFS is short for first come first service; SSA is the abbreviation of Static Scheduling Algorithm m; OSA stands for the Optimize scheduling algorithm. As a result, the loading of each task scheduling on a computer of the cloud simulation is shown in Fig. 3.

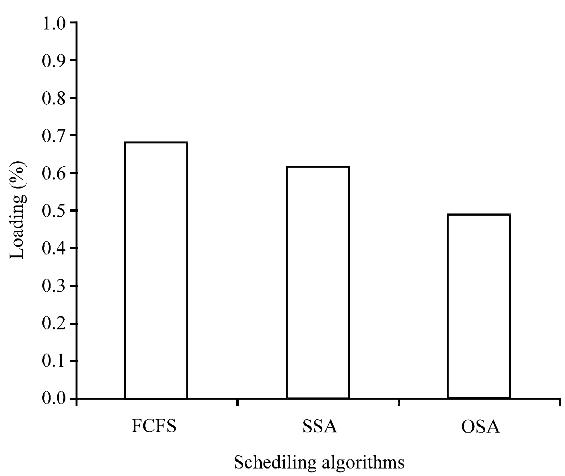

Fig. 3: Comparison of loading to three different scheduling algorithms on the computer

Under the same experimental conditions, the loading of FCFS Algorithm is heavier than Static Scheduling Algorithm. With the increasing number of cloud task, the loading of the Optimize scheduling algorithm is minimum than the other two algorithms and the efficiency is best.

CONCLUSION

By using computing technology to attempt to achieve full connectivity of the resources and tasks in the simulation environment, the construction of cloud simulation platform framework is provided for the reliable and universal scheduling to resources and tasks. The cloud simulation optimal algorithm is proposed to solve the problem of the resources allocation in the cloud simulation environment. Meanwhile, considering the difference in the running time of each task, the loading of each machine and network latency, the optimal algorithm achieves a reasonable and effective distribution of the simulation of cloud resources and improves the efficiency of the system.

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