Research on Multi-Agent Modeling Method of Space Based Network Information System

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Abstract: Space based information network system is a network system composed of spacecraft and spacecraft, which plays an immeasurable role in commercial and military, so it is very important to carry out simulation research on it. In this paper, the idea of Multi-Agent modeling is applied to study the simulation modeling of space-based network information system. This paper first introduces the space-based network information architecture, Multi-Agent system and RepastHPC, a Multi-Agent high-performance computing simulation toolbox. The simulation example is Starlink's information support capability under AIM-260 "A aims and directs B to strike" fire attack mode, and the process of message Starlink transmission is mainly studied. In this paper, the space-based network information system is abstracted into route agent and sat agent, the decision-making method is given for each behavior, and a feasible Multi-Agent system is established. The simulation experiment of information transmission is carried out on RepastHPC platform, and the feasibility of applying Multi-Agent system to space-based network information system is verified.

1. Introduction
The space-based network information system is a comprehensive information system that uses satellite, space station and other space-based resources as nodes, builds network system, carries scheduling system for management, and integrates all kinds of space-based information and computing resources into an organic whole. Space based network information system is of great significance for the future war, and it can play a supporting role in the systematic construction. Space based network information system can achieve a wide range of information transmission, real-time and comprehensive acquisition of situation information, high transmission rate and other functions. Therefore, it is of great practical significance to study the simulation of space-based information system.

There are many simulation methods, mathematical analysis is a common method, which can accurately express the state of the target system. However, due to the complex nodes in the space-based network information system, the state space is very large, so it is extremely difficult to apply mathematical analysis. Another kind of simulation method is realized by modeling and simulation, which is based on the existing software or modeling platform for the target system. The advantages of simulation software such as STK are easy to build model, visual view and easy to understand, but poor
scalability and poor portability, so the performance of the machine can not be fully utilized. Therefore, this paper adopts another way to realize Multi-Agent modeling and simulation.

There are many agent-based simulation development tools. The commonly used agent-based simulation development tools are RepastHPC, swarm, Pandora, anylogic, etc. Repashpc combines Multi-Agent concept and parallel computing technology. Repashpc uses C++ language to realize the underlying framework of parallel computing based on Multi-Agent system, encapsulates MPI and other libraries for users, which is convenient for users to carry out Multi-Agent modeling of complex system, and allows users to focus more on the underlying construction of complex software in planning. Users can use the API provided by RepastHPC for secondary development, and can build the required functional modules in a short time to realize the MAS system.

In this paper, the star chain system is taken as an example, and the data transmission function of the system in "A aims and directs B to strike" fire attack mode is modeled and simulated. The function service of the star chain system is abstracted, and an effective Multi-Agent simulation model of space-based network information system is established. The network system, propagation performance and other factors are simulated.

2. Space based network information system and Multi-Agent technology

2.1. Space based network information system

Space based network information system is an intelligent, self-organized, hierarchical security monitoring and resource scheduling network, which is composed of all kinds of spacecraft and near space vehicles distributed in different orbits and interconnected through inter satellite microwave link or laser link[1].

By integrating different orbital satellite groups, space-based information network can radiate around the world and enhance the transmission capacity in key regions. Finally, it can provide broadband Internet access to sea, land and air terminal users and realize a new generation of network communication capability of global coverage, on-demand access and on-demand service. At present, foreign countries are actively deploying LEO satellite constellations, and their LEO satellite constellations mainly include oneweb, O3b, Starlink, etc. Considering the broader military and civil development prospects in the future, this paper takes SpaceX's star chain plan as a case study.

The star chain plan is a direct translation of SpaceX's Starlink program, which, as its name implies, is a satellite based link plan. Through a constellation of satellites that can be connected in space, 5g level Internet notification services are provided to the world[2]. The completion of the satellite chain program can play an important role in the fields of communication, navigation, remote sensing observation, and even realize the potential military value of tracking hypersonic vehicles, passive interception, active interception, UAV command layer, and the transition from situation awareness to fine control.

2.2. Multi-Agent System

2.2.1. Introduction to Multi-Agent

The concept of agent first appeared in 1970s, and its prototype is actor model. Agent is a software system with autonomy, social ability, reaction ability and initiative. As shown in Figure 1, agent uses sensors to perceive the environment and acts on the environment through effectors. Different from object-oriented technology, agent is a higher granularity abstraction with the ability of thinking and decision-making. The research of agent includes three interrelated parts: agent oriented programming, MAS system and intelligent agent.
Multi-Agent System (MAS) is a model system composed of multiple agents. Multi-Agent system can describe the complex system better through the proper combination of multiple agents. Compared with single agent, MAS has much more powerful function. When expressing the actual system, MAS expresses the function, structure and behavior characteristics of the system through the control, management, communication, scheduling, coordination and cooperation among agents. MAS system has more powerful flexibility and autonomy, compared with single agent modeling technology, it can better complete the modeling and Simulation of complex system, better complete the complex computing tasks.

2.2.2. RepastHPC
RepastHPC (repast for high performance computing, simulation toolbox for High Performance Computing) is an open source class library [3] written by the Institute of social science computing of the University of Chicago and researchers from Argonne National Laboratory of the United States. Now Road (repast organization for architecture and development) is responsible for updating and maintaining it.

RepastHPC encapsulates many class libraries for displaying process and storing data. RepastHPC is derived from repast (recursive group agent simulation toolkit) series libraries which are dedicated to developing high performance computing software and providing platform support. It provides a series of class libraries for generating, running, displaying and collecting data, and can "snapshot" the running model to record the current state of the model at a certain time [4]. RepastHPC is written in C++ language, and its internal implementation process and platform framework draw lessons from repast Simphony. The parallel simulation engine in RepastHPC is responsible for the simulation promotion of RepastHPC simulation model. The main task of parallel simulation engine is to initialize and maintain the scheduler, which is composed of two parts: the current task and the next task. The running process of the scheduler is shown in Figure 2. The chief uses MPI to obtain all tasks, and then determines the current task and executes it by judging the global task time, so as to activate the corresponding agent. In this way, the task is read and executed continuously, and the whole model simulation is promoted [5].
3. Modeling method of space based information system based on Multi-Agent

The case of this study is the scenario modeling of AIM-260 missile's ability to achieve "A aims and directs B to strike" with the support of satellite chain information. The satellite chain system is responsible for the transmission of situation information as the data transmission layer.

AIM-260 is a "joint air Tactical Strike Missile" developed by the US air force. It is equipped with two-way data link, and can communicate with its own fighters in two ways. It can obtain guidance and observation information from the platform outside the aircraft, conduct accurate long-range aiming, and engage with the target through other sensor data, so as to realize the so-called "A aims and directs B to strike" capability. This case study focuses on the ability of the star chain system to provide data exchange services in the "A aims and directs B to strike" fire attack mode. In this model, four kinds of agents are studied: SAT agent, route agent, mission agent and recon agent.

At present, the data transmission and resource scheduling between satellite chains have not yet formed mature technology, so the satellite chain system is abstracted as sat agent and route agent. Route agent abstracts the data transmission service from all satellite chains to form a single agent. Mission agent receives the external information and its own guidance to attack the target, while Recon agent is responsible for the reconnaissance work of the target area, and transmits the information about the target to sat agent. Sat agent transmits the information through the route table provided by route agent, and finally to mission agent.

Next, we will simulate the attributes and behavior rules of each part of the system.

3.1. Sat Agent

Sat agent is mainly responsible for information transmission as a communication node, and sends and receives data according to route table.

- **ID**: the unique identification number of SAT agent, and the type is integer;
- **TLE**: it is defined as the number of orbit elements of the modified satellite, which can be used to calculate the specific position of the satellite at any time. The type is stringlist;
- **Tar_TLE**: it is defined as the tle attribute of the next transmission node, according to which information is transmitted.

Sat agent can accept the target location information of Recon agent and send data transmission request to route agent; It can accept and process route table information and decide the next node according to the table. When transmitting to the next node, the next satellite ID will be determined according to the route table, and then the tar of the target sat agent will be changed according to the index_ TLE data, through the local calculation of its specific location information at that time, through the laser directional link communication for point-to-point information transmission, to avoid the information storm caused by broadcast information.
3.2. Route Agent
Route agent is responsible for the calculation of route data, and it stores the information of all sat agents. Route agent contains the attribute of time stamp, that is, the time stamp when calculating route table. Because the mobility of SAT agent is not considered, route agent and all sat agents can calculate the location of any sat agent according to the time stamp.

Route agent can accept the data transmission request of SAT agent, calculate the location information of each sat agent according to the current time stamp, and then simplify the problem to TSP problem. Calculate how to transmit the shortest distance from the current sat agent to the target, calculate the route table and return to the original sat agent.

3.3. Route Table
After the SAT agent receives the target location information sent by the Recon agent, it needs to transfer this information to the mission agent. This requires the route table provided by the route agent. The table contains the routing information that can be sent to the mission agent by passing the information from the current sat agent.

![Route Table](Figure4.jpg)

3.4. Missile Agent
Mission agent is the modeling of AIM-260 missile. The attributes are quantified as follows:

Status: an array of six floating-point numbers, representing the position and velocity vectors of the missile; Found: a value of 0 indicates that the seeker has not captured the target, and a value of 1 indicates that the seeker has captured the target;

Mission agent can transmit missile location information to route agent according to certain event interval; It can accept the target location information transmitted by sat agent; It can calculate the flight path according to the missile position information and target position information, and determine the power size and direction.

3.5. Recon Agent
Recon agent is an invisible UAV located in the airspace near the target, which is mainly responsible for detecting and photographing the target and uploading the location information of the target. Recon agent contains the found attribute. Its value of 0 means that the target is not seen, and its value of 1 means that the target is in the field of vision.

If the value of found is 1, reconnaissance and photographing are carried out to determine the target location information, and the target location information is broadcast and sent to sat agent.

4. Experimental simulation and results
In order to verify the feasibility of this model, a simple communication experiment is carried out. The information transfer process from UAV agent to mission agent is realized through modeling, and the transmission time is tested. By changing the number and time of SAT agents, the change of data transmission time is observed.

4.1. Introduction of model parameters
Using RepastHPC tool to create the above Multi-Agent model, this model focuses on demonstrating the process of data transmission. After the model is built, the size of the whole satellite space needs to be set, which is determined by the number of sta agents; It is necessary to define the number of processes...
run by the model and the number of threads run by each process; Finally, you need to specify the starting sta agent and ending sta agent for data transmission. The defined input parameters are shown in the following table:

| Input Parameters | Value | Description |
|------------------|-------|-------------|
| Start_Sta        | 010100| The beginning of data transmission Sta Agent |
| End_Sta          | 050500| The ending of data transmission Sta Agent |
| Pro_Num          | 50    | The number of processes running |
| Thr_Num          | 50    | The number of running threads in a process |
| Tick             | 50    | Simulation 50 steps |

After the model is configured with table parameters, the program is run on RepastHPC platform.

4.2. Program implementation process

This part introduces the running process of the model:

Step 1: initialize the simulation environment, use the boost library to initialize the MPI environment, initialize the repastprocess class, load the MAS model, and start the discrete event scheduler;

Step 2: start running the model, and use tle file to generate agents;

Step 3: with the increase of tick, the information of agents in the same process will be changed directly if the message is transferred between the same process. If the message is transferred between agents in different processes, the resources will be synchronized by using the distributed agent instance management service provided by RepastHPC;

Step 4: if the message has been delivered to the ending sta agent, save the running time and result;

Step 5: stop running model, release heap memory, end simulation.

4.3. Running results

Figure 5 shows all the output information in the running process of the model. Messages are delivered through the route table. You can see the status of message delivery in each tick. At the same time, you can see that the message is delivered to the target agent in the first tick, and you can also see the time consumed in the message delivery process.

Figure 6 shows the change of delivery time as the length of routing link table increases. We can see that with the increase of the number of messaging nodes, the time consumed by messaging also increases.
5. conclusion
The model of space-based network information system based on Multi-Agent established in this paper can effectively simulate the information exchange ability of Starlink in AIM-260 "A aims and directs B to strike", and the experiment proves that the system has strong support for combat. Through the Multi-Agent model constructed in this paper, the rapid corresponding ability of space-based information system is proved, which provides a new idea and method for the modeling method of space-based network information system.

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