Simulation of MAC Protocol in Near Space Communication Network Based on TDMA

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Abstract—**A network model for the near space communication network is established by the means of OPNET as a development environment, and a medium access control (MAC) protocol based on TDMA (Time Division Multiple Access) is designed, leading to the channel resource being shared efficiently. A formula for the average end to end (ETE) delay of the network is delivered according to the queue theory. Simulation results show theoretic analysis can accurately estimate the average ETE delay of the network.**

Keywords- near space communication network; TDMA; queue theory; end to end delay; OPNET;

I. INTRODUCTION

Because of economic and technical reasons, a cellular mobile communications needs construction of numerous base stations and antennae for achieving sufficient coverage. A geostationary satellite (GEO) has quite vast coverage, however, it is far from the earth, great transmission attenuation and time delay can be caused. With regard to a medium or low orbit satellite (MEO/LEO) system, dozens of satellites are required to form a constellation so a number of problems may appear. Now the near space has been concentrated on research because of important values in application. Recently many research centers are researching the near space communication because of many merits such as low expense, fast deployment, convenient retrieve and so on[1][2][3].Near space communication network can realize connections between its terrestrial users, as well as between a near space platform and a communications satellite, it will become a new field for wireless communication.

There are some traditional medium access control (MAC) protocols in communication area, such as FDMA (Frequency Division Multiple Access), TDMA (Time Division Multiple Access), CDMA (Code Division Multiple Access), ALOHA, CSMA (Carrier Sense Multiple Access) et al. FDMA needs to power compensation in transponder which wastes the frequency and power resources; CDMA has good anti-jamming ability, the main disadvantage is the low throughput of the protocol; Random access schemes ALOHA or CSMA suffer from relatively limited capacity, and in the presence of burst traffic they can not accommodate real-time applications or guarantee quality of service (QoS). TDMA is good for making use of frequency and power resources, and higher channel throughput can be achieved.

As a result of these, in this paper, TDMA is used as MAC protocol in the near space communication network, in section 2 network delay is analyzed by queue theory, near space network model is presented in section 3, simulation results and conclusion are given in section 4 and section 5.

II. QUEUE MODEL AND TIME DELAY ANALYSIS

Generally speaking, time delay in the communication network contains four components. The first is the access delay, which is the time between a packet's arrival and the end of the frame time during which it arrives. This is simply because we measure the queue size only at the end of each frame. Second is the queuing delay, which is the amount of time the packet must wait in the queue. Third is the packet transmission delay. Fourth is the propagation delay, which is the time it takes for a bit to reach its destination, excluding access delay and queuing delay [4]. Considering the near space platform is 20 to 100 kilometers away from the earth, the influence of propagating delay is thus marginal, with the queuing delay emerging as a principal contributor to the network delay.

Consider a near space communication network with MAC protocol TDMA which is comprised of m subscribes. Let $1/\mu$ represents the packet size in bit; λ represents the packet arrival rate in packet per second and C the channel capacity in bit per second. The system constitutes m independent M/D/1 queue model [5] (Fig. 1).

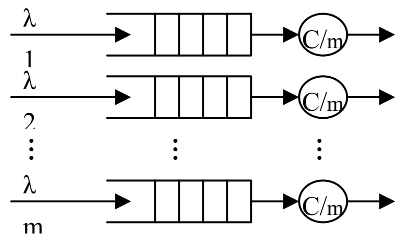

Figure 1. M/D/1 model

The end to end delay (T) a packet suffers mainly has three components.

- Transmission delay $\tau = 1/\mu C$;

- Queuing delay $W = \dfrac{\rho}{2(1-\rho)\mu C_0}$; where $\rho = m\lambda\tau$ is the traffic load and $C_0 = C/m$ is the equivalent channel capacity;
- Access delay. Consider the packet arrival is a Poission process, the access delay in the stable state is about mτ/2.

As a result, the total delay (T) can be derived as (1).

$$T = \tau + \frac{m\tau}{2} + \frac{\rho}{2(1-\rho)\mu C_0} = \tau + \frac{m\tau}{2} + \frac{m\rho\tau}{2(1-\rho)} \quad (1)$$

III. NEAR SPACE COMMUNICATION NETWORK MODEL

This part establishes a near space communication network model using network simulation software OPNET which provides a comprehensive development environment for the specification, simulation and performance analysis of communication networks. It employs a hierarchical structure to modeling. Each level of the hierarchy describes different aspects of the complete model being simulated. Models developed at one layer can be used by another model at a higher layer. So Models in network domain, node domain and process domain are created respectively.

A. Network Model

Network model is used to specify the physical topology of a communications network, which define the position and interconnection of communicating entities. In this paper, the near space communication network is comprised of ground stations and a near space platform with bent-pipe transponder. The coverage area of a near space platform can be formulated as (2).

$$\boxed{d = R \times [\frac{\pi}{2} - \alpha - \arcsin(\frac{R\cos\alpha}{R+h})]} \quad (2)$$

Where d represents the communication radius in kilometers, R represents the earth radius in kilometers, α represents the elevation of the antenna in radian and h the altitude of the platform in kilometers.

We define the altitude of the platform is 30 kilometers and the elevation of the antenna is 3 radian, so the communication radius is figured out to be 367.733 kilometers. So the scenario in this paper is assumed that ten ground stations distribute randomly in an area of 300 kilometers × 300 kilometers, but because the earth is modeled as a sphere, the location of the ground stations in simulation is determined according to their geocentric Cartesian coordinate, the near space platform is located at an altitude of 30 kilometers, making sure that the ground stations can communicate with each other through the near space platform. Fig. 2 shows the topology of the network.

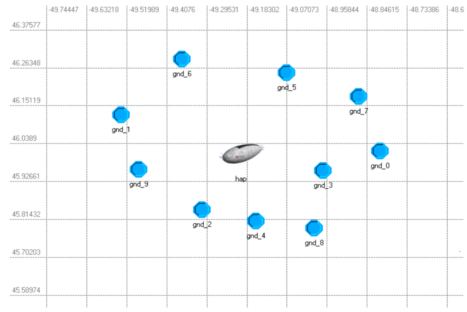

Figure 2. Network model

B. Node Model

Communication devices created and interconnected at the network level need to be specified in the node domain. Node models are expressed as interconnected modules. Modules are interconnected by either packet streams or statistic wires. Packets are transferred between modules using packet streams. Statistic wires could be used to convey numeric signals.

1) Ground node model

The function of ground node is to send packets came from the "source" module in its slot time, and transmit them to the near space platform through directional antenna. If there are some packets remain in the queue module "my_tdma" in a frame time, they have to be sent in the same slot time of the next frame. At the same time, the ground node receives the packets from the near space platform, and sends them to "sink" module to collect the statistics of average end to end delay. The ground node model is shown in Fig. 3.The statistic wire from "rt_0" module to "my_tdma" module denotes whether the channel is free or not.

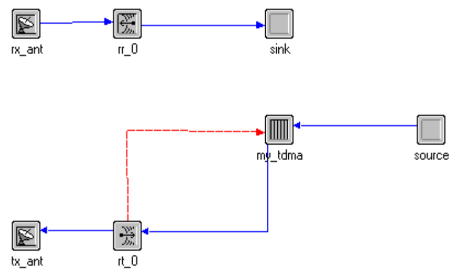

Figure 3. Ground node model

2) Near space platform node model

The function of the near space node model is to receive packets from the ground nodes and transmit these packets to the nodes within its coverage. It acts as a bent-pipe transponder in satellite communication. In the node editor, we place a isotropic receive antenna module, a radio receiver module, a hap module which has the capability of transferring packets, a radio transmitter module and a isotropic transmit antenna module. The near space platform node model is shown in Fig. 4.

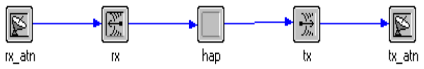

Figure 4. Near space platform node model

C. *Process model*

OPNET's process editor expresses process models in a language called Proto-C, which is specifically designed to support development of protocols and algorithms. Proto-C is based on a combination of state transition diagrams (STDs), a library of high-level commands known as Kernel Procedures (KP), and the general facilities of the C or C++ programming language [6]. In this paper we choose TDMA as the MAC protocol of near space communication network, the detailed protocol is realized through "tdma" process model. The "tdma" process model is shown in Fig. 5.

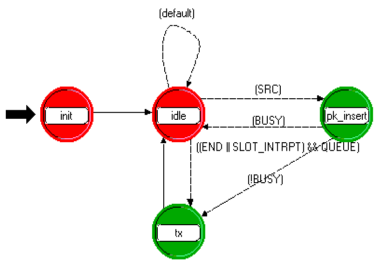

Figure 5. tdma process model STD

OPNET supports discrete event simulation (DES) technology which disposes the change of state through interrupts. In this paper, we use self intrpt in node's transmit slot time to realize TDMA protocol. An alternative method is to invoke regular interrupt via simulation kernel at every slot time. If this slot time belongs to its own transmit slot time with some packets remaining in the queue module, process will invoke remote interrupt to send them.

D. *Pipeline model*

Near space channel model is established by invoking pipeline stage in OPNET. Because radio links provide a broadcast medium, each transmission can potentially affect multiple receivers throughout the network model. In addition, for a given transmission, the radio link to each receiver can exhibit different behavior and timing. As a result, a separate pipeline must be executed for each eligible receiver.

The radio transceiver pipeline consists of fourteen stages; we mainly consider the dra_closure stage. Link closure is computed for all transmitted packets based on a ray-tracing line-of-sight model. The algorithm tests the line segment joining the transmitter and receiver for intersections with the earth's surface. If an intersection exists, the receiver can not be reached and the remainder of the pipeline stages will not be executed for the packet of interest.

Generally speaking, the quality of pipeline model directly influences the realization of the high level MAC protocol.

IV. SIMULATION RESULTS ANALYSIS

Table 1 shows the values of the parameters in simulation scenario.

TABLE I. VALUES OF THE PARAMATERS

Simulation parameters	**values**
Simulation time(second)	1200
Frame time(second)	1
Slot time(second)	0.1
Number of ground nodes	10
Up frequency(GHz)	31
Down frequency(GHz)	28
Packet arrival interval(second)	exponential(5)

An advanced mechanism supporting the capture of statistical data in OPNET is called a probe. A probe represents a request by the user to collect a particular piece of data about a simulation. Statistics collected by a probe are stored in output vector files or output scalar files. We can define statistics by ourselves. In this paper, in order to obtain the ETE delay of the network, we define the statistics in process model, and use kernel procedure (KP) op_stat_write() to write the variable to its statistical handle.

The average ETE delay of the network belongs to vector statistic; there are four kinds of capture mode for it in OPNET. In this paper, we choose "all values" mode to collect the average ETE delay of the network; it can collect every data point from a statistic.

Fig. 6 shows the simulation results, with the abscissa representative of simulation time in minutes, and the ordinate representative of the average ETE delay of the network in seconds.

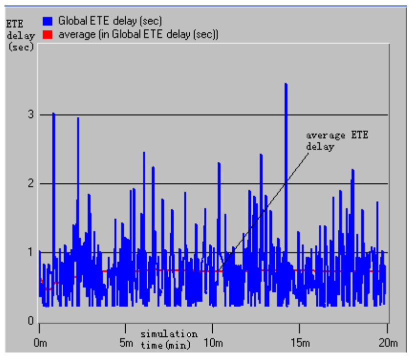

Figure 6. ETE delay of network

Through the analysis of 4431 time delay samples collected by simulation, we obtain the average ETE delay of the network is 0.7281 second; while the time delay derived from equation (1) is 0.7250 second. The values from the simulation results and the theoretic analysis are basically equal, with the latter a little smaller. The main reason for this is that we have reckoned without packets' propagation delay in near space channel.

V. CONCLUSIONS

In this paper, TDMA protocol is applied to near space communication network; we introduce the queue theory to the research of the average ETE delay of the network, and establish a near space communication network model to assess the performance of the protocol. Time delay derived from simulation is basically equal to that from theoretic analysis, proving that the theoretic analysis can accurately estimate the average ETE delay of the network. Further research is needed to improve the protocol so that the ground stations can make better use of near space channel resource.

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