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Research of Satellite Tactical Communication Network Routing Protocol Simulation Based on TDMA

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Abstract

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Keywords

hierarchical routing protocol, DSR routing protocol, TDMA, tactical communications network, network simulation

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基于 TDMA 的卫星战术通信网路由协议仿真研究

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摘要：为了构建一个面向全球的高效和无缝的战术通信网络系统，通过对移动卫星节点与地面移动通信网的组网技术研究，运用网络仿真软件 OPNET Modeler 的强大功能，*提出了基于模块化的天基战术通信网的协议框架，建立了基于 TDMA 的数据链路层和基于层次化路由的网络层协议模型，能够满足各个网络层次的功能，实现了高度模块化和层次化。*实现了基于 OPNET 的 DSR 路由协议和层次化路由协议并进行了仿真对比，为网络的规划设计提供客观、可靠的定量依据。

关键词：层次化路由；DSR 路由；TDMA；战术通信网；网络仿真
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Abstract: In order to build a globally oriented efficient and seamless tactical communication network system, on the research of satellite and mobile communication network technology, using simulation software OPNET Modeler, *a TDMA model and unique tactical communications network* was designed. *Its main feature is full-completion five layers network model which can satisfy the function of each network level, also provides a reliable basis for later work.* After compared with DSR routing, the hierarchical routing shows some advantages in simulation. Some valuable conclusions were drawn, which can provide objective, reliable information for network planning and design.

Keywords: hierarchical routing protocol; DSR routing protocol; TDMA; tactical communications network; network simulation

Introduction

With the development of the Internet on the ground and space technology, for the military battle command system, an important symbol of modern warfare is based on network as the center of information warfare, which makes full use of satellite coverage wide and the characteristic of the modern ground mobile communication network is efficient and flexible. Via the network of mobile satellite nodes, nodes and ground mobile communications and air nodes, a globally oriented efficient and seamless communication network system was built. Data link layer used the time division multiple access (TDMA), and it improved the communication performance of the system. In market competition, anyone who can

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quickly gain market information in time, will occupy the advantage place at the battle of military tactics, anyone who can efficiently quickly grasp the forefront of battlefield situation, will get the highest point of the strategy. The emergence of the mobile communication provides us with convenient, efficient and quick way of communications, which greatly satisfies the needs of the people, and becomes an important symbol of the information society. Through the network simulation, the development cycle can be effectively shortened, verifying network system performance and saving a lot of manpower, material and financial resources. Network simulation technology has improved the reliability of the design result of TDMA satellite tactical communication network, has reduced the investment risk of the construction of the network, and it can provide objective and reliable quantitative basis for battlefield network planning and design with its unique method, shortening the period of the sky to network platform construction, raising the scientific nature of the decision-making in the construction of network, reducing the investment risk of the construction of the network, which will play a major role in specific communications equipment research and development and military simulation training[1].

1 TDMA satellite tactical communication network protocol framework based on modular design

1.1 Tactical communication network system

Space-based mobile communication network system based on satellite communication nodes is regarded as the core of the wireless communication network, so the network model is proposed according to the OSI reference model for system Architecture (Architecture), the Service Definition (Service Definition) and protocol specifications for design, each of these satellites and ground network are respectively independent subnet, and the network interconnect through ground interface and system can also be connected by satellite system. The space-based mobile communication network has similarities with the traditional network, the biggest difference is the two involved range. So it is necessary to design an OSI network model, according to the characteristics of the space-based mobile communication network. The key is tactical communication network data link layer and network layer[2].

As shown in the Fig. 1 below for the design of communication network protocol framework model. The node is functional, and the basis covers five layer network model of each layer of the protocol, therefore, the work is mainly in the model on the basis of further development.

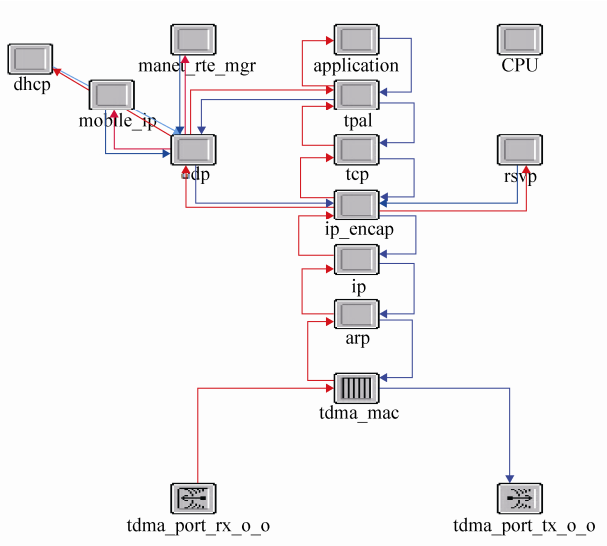

Fig. 1 Communication network protocol framework model

The node model is composed of 12 process models, one of the top application modules is the application layer, and it is responsible for the users to directly use a variety of business data, such as FTP, HTTP, voice or video calls meetings, etc. TCP

module is responsible for the transport layer of the simulation network system, in the middle of the IP and IP_encap module is network layer of five layer network. It is mainly responsible for various routing protocol between the simulation nodes, for example, in this article to study the hierarchical routing and the DSR routing protocol, etc., they are implemented within the two modules[3]. The lower tdma_mac module simulation is TDMA protocol of data link layer. tdma_mac module is responsible to send data to physical layer. The packet will be handed down from upper layer, then it was fragmented, encapsulated, queued, and send. The physical layer fragment was send to network layer. For conflict detection in data link layer, packets forwarding function is implemented in this module. At the bottom, the transmitter and receiver module wlan_port_rx0 module wlan_port_tx0 forms the physical layer, and it is responsible for sending and receiving data packet.

1.2 TDMA protocol model of tactical communication network data link layer

Compared with cable communication network, satellite communications system can provide users with a global and multiple business communications services, satellite channel resources tend to be in short supply now, however, if more than one user at the same time to send, multiple users' frame in the physical channel will overlap (collision), and make the receiver cannot receive correctly. In order to communicate effectively, you need a mechanism to determine the use rights of resources, which is the multiple access control problem of the network. TDMA (time division multiple access) protocol is to solve multiple users how to efficiently share a physical link resources technology in a network. MAC layer distribute limited resources to multiple users, making the fairness between many users in sharing the limited bandwidth resource effectively. In order to achieve good connectivity between all users, the system must have good throughput capacity and low delay. The principle diagram 2 as shown Fig. 2.

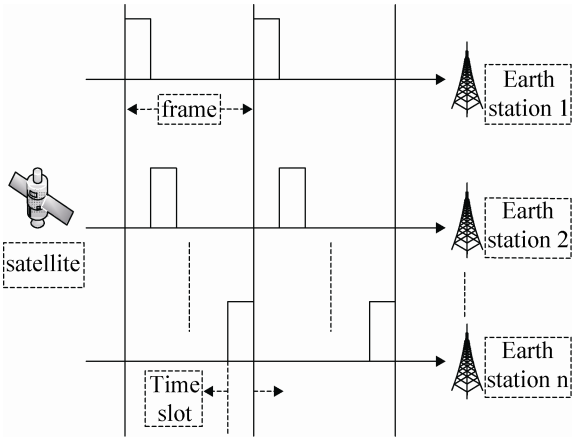

Fig. 2 TDMA satellite working principle diagram

Normally fixed TDMA allocation method will lead to the low channel utilization and serious problems of wasting a lot of satellite channel resources. Based on the research of the TDMA protocol several dynamic allocation algorithm, in view of the needs of the mobile communication, in order to meet high-priority sites, demand for emergency mobile information quickly sends this system to use a priority allocation method.

In the concrete algorithm, each frame is divided into synchronous time slot, control time slot and data time slot. As shown in Fig. 3.

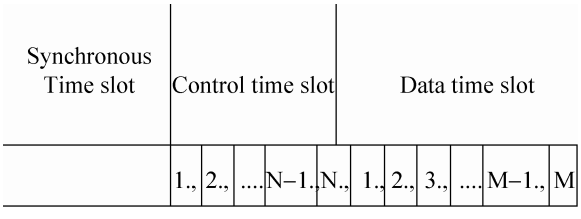

Fig. 3 frame structure

1) synchronous time slot

Node listening to the synchronization

information from the network nodes, modify the local time slot benchmark first, then access networks to participate in the allocated time slot.

2) Time control slot

The node send data in their own data slot. when the node complete data transmission, it will on the time slot which occupied by itself.

3) data time slot

Nodes send data in his appointment to the data time slot, a frame of data time slot number is certain. The data time slot number M used in this article is greater than the number of network nodes, a data node can make an appointment to multiple data time slot to transmit data[4].

1.3 TDMA protocol process modeling

1.3.1 The process model of communication network station subnet

This model is the specific implementation of the DAMA module in ground station node model, reflecting the working process of the TDMA protocol, the model as shown in Fig. 4.

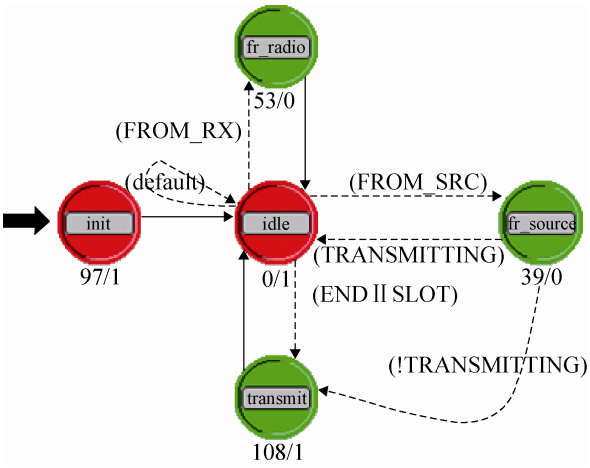

Fig. 4 TDMA protocol ground station subnet process model

The explanation of transfer conditions:

FROM_RX: Disruption in the flow, if the current data packet derives from a receiver rr_0, then the process jump to fr_radio state.

FROM_SRC: Disruption in the flow, if the current data packet derived from the source module of node model, transfer to the transmit mode.

[END||SLOT]&&DATA_ENQ: self interruption, if wireless transmitter sends packets or current time fall into the site in the slot at the same time the queue is not empty, jump to the transmit mode.

This process mainly includes the following four states, each state function is introduced in detail as follows:

The init state: it is the start state of the process transfer diagram, also the entrance of the process model. The state is responsible for completion of related parameters and statistical variable initialization. Including one of the most important two parameters: the number of time slots, the current site time slot position.

Idle state: free waiting, waiting for the sending and receiving data packets.

Fr_source status: will process a formatted data packet from the data source, set the value of corresponding domain package and inserted into the queue.

Fr_radio status: will transmit receive packets from wireless transmitter, and record related statistics.

The transmit status: judge whether the current simulation time fall into the time slot of the node and calculate if the rest of the time can complete the entire package to send, if the above two conditions set up at the same time, sending packets. Otherwise calculate the starting time of next frame in the site itself time slot, arrange an interrupt at the moment for the current site.

1.3.2 Satellite process model

In TDMA protocol, data time slot has been

assigned to completely during system initialization, satellite data are forwarded by broadcasting group only, do not need to undertake time slot allocation, and other functions, so the process model is relatively simple. The model is shown in Fig. 5.

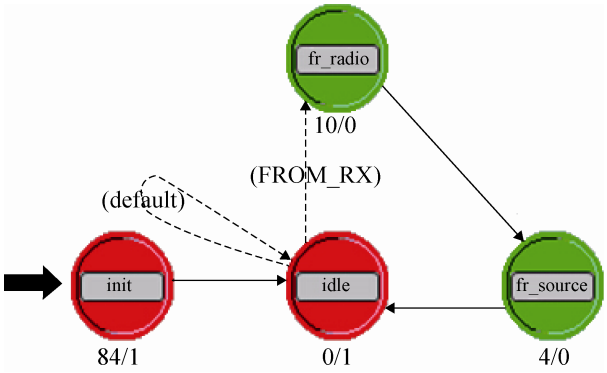

Fig. 5 TDMA protocol satellite process model

The explain of transfer conditions:

FROM_RX: data flow interruption, and if the current received data packet from the wireless receiver module, trigger the terminal make from the idle state to fr_radio state.

This process mainly includes the following:

The init state: the entry state of process, is responsible for the initialization of some parameters and statistics.

Idle state: idle state, waiting to receives packets from the satellite receiver.

Fr_radio: make team operation to received packets.

Fr_source: took out data packet from the queue head and send it.

2 Tactical communication network layer routing protocol model

2.1 The DSR routing protocol model

The DSR protocol implementation process as shown in Fig. 6～7.

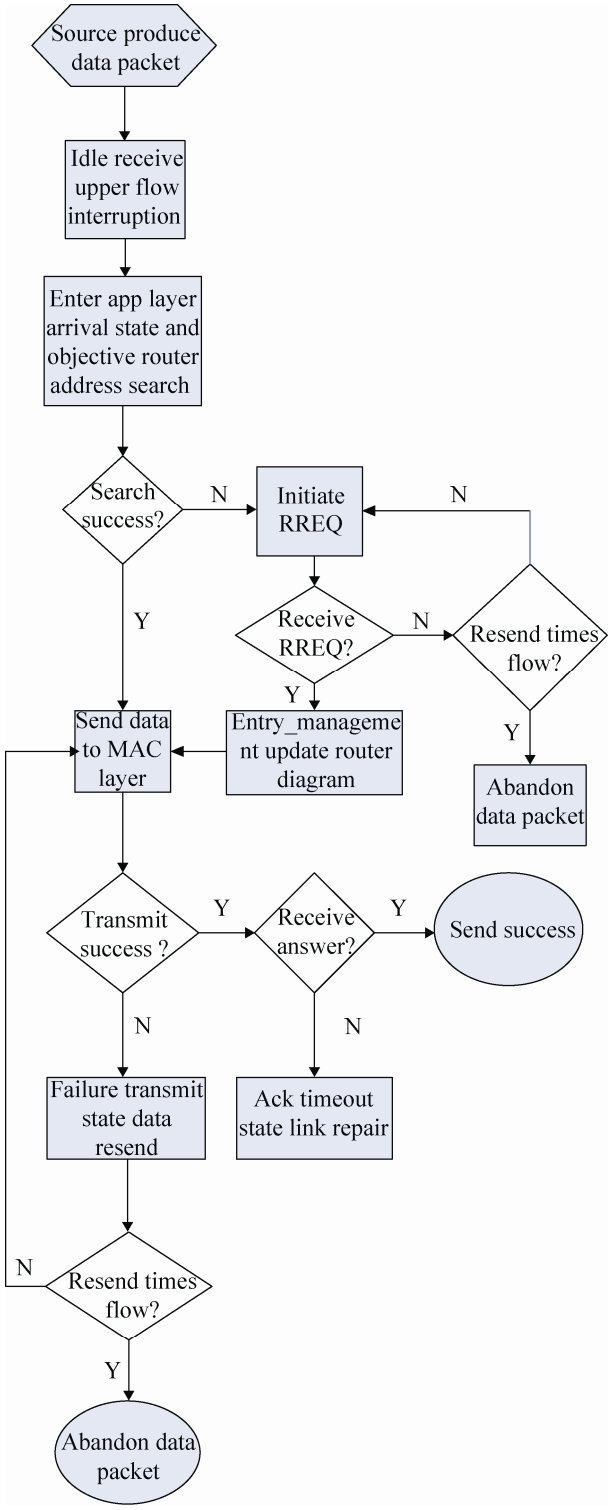

Fig. 6 send packet flow chart

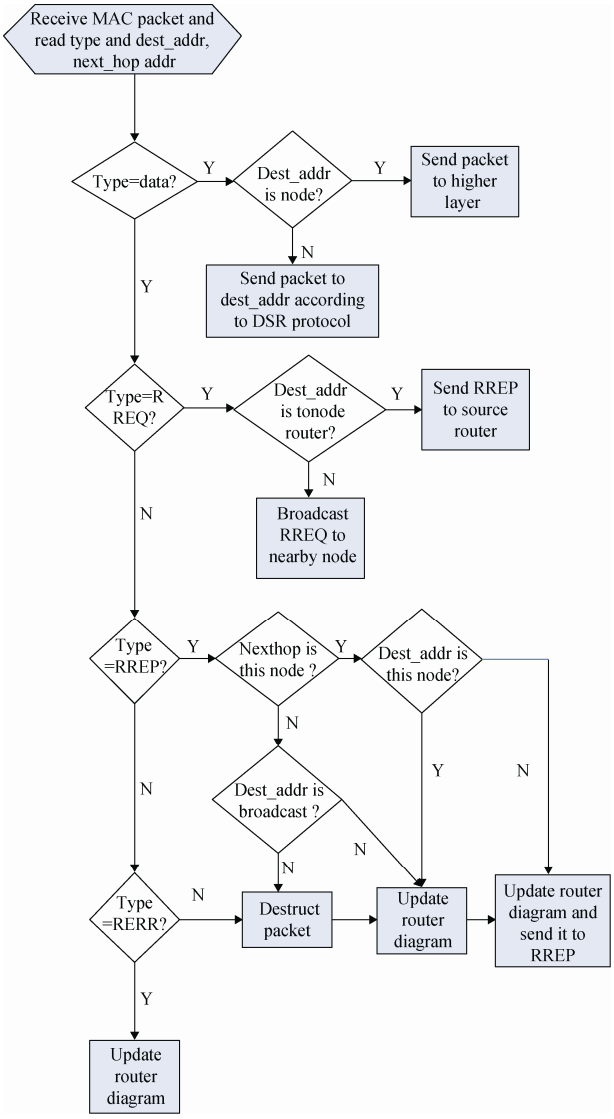

Fig. 7 The flow chart of receives packets

The DSR routing protocol is an on-demand routing protocol, the DSR routing protocol has characteristics of improved n-demand distance vector routing protocol, which every node in the network to send routing data only when needed, rather than on a regular basis to exchange routing information for all other host routing; The DSR routing protocol also has some advantages of distance vector routing protocols, namely in the routing table contains only the node to the other node routing, and do not need get the entire network topology.

2.2 Hierarchical routing protocol model

Design the network model as shown in Fig. 8, distribution of each node in the hierarchy, the top layer is the first-level node, the middle layer is the secondary node, the next layer is the tactical vehicle nodes. For this distributive level of this network simulation model is a reference army hierarchy and complex structures of tactical communication network itself, so when carries on the simulation to set up similar network hierarchy.

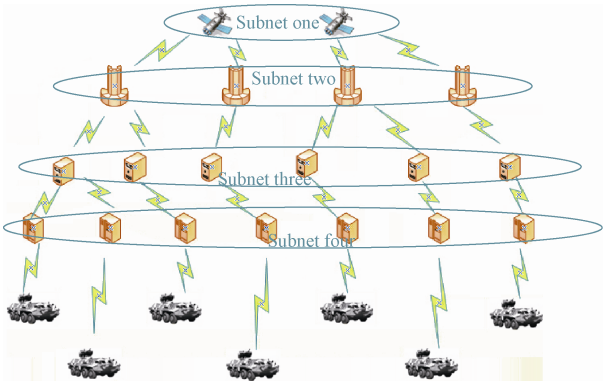

Fig. 8 Designing of tactical network hierarchical routing

According to the above, the distribution of each node, the design forwarding routing protocol in the OPNET IP was proposed[5]. Each node at the same layer belongs to a same subnet, communication data between them directly to arrive, data communication between subnets forwarding by IP routing.

Information and communication in network communication transfer the data pocket according to the hierarchy of the military establishment, which requires setting the routing tables of packet transmission. Each site make corresponding processing on the data packet after receiving information about it and check it. The routing table records the situation of these sites handling of received forwarding packets.

3 OPNET simulation data collection and validation

In Tactical communication network model, the structure of network model which on the basis of the existing in depth of analysis and extract statistic in sites communication with each other. To establish the network simulation model, the main purpose is extract statistics in network. It will provide reference for the real network model in the future. Which statistics will be extracted is depend on the statistics results of researchers and users care about[6]. In this paper, the statistics is mainly about receive the message p2p delay, the number of send and receive the message in network. Statistical information is order to analysis how the network model is suit for the basic of theory and have highly reliability.

3.1 TDMA Time slot allocation

First TDMA protocol model will be verified in the simulation, net_1, for example, a specific set of the length of time slot frames, frame length, control slot length and data time slot. Also set the priority and special time slot number.

Net_1's subnet data time slot allocation table, are listed in Fig. 9 , n1, and n2 and n3 is the three vehicle node, an interface of L1 node access net_1's subnet, participate in net_1's subnet TDMA protocol time slot allocation. As can be seen in a frame for a total of 90 data time slot, n3 set with 5 exclusive time slot, which has a time slot 0~4, remaining slots average assigned to four interfaces, the L1 node has 21 time slot, n1 and n2 node has 21 time slot, n3 node has 27 time slot. Because of n3 node priority is higher than the rest of the nodes, therefore, whenever a frame at first, n3 node has a slot in the first place.

Name	0	1	2	3	4	5	...	25	26	...	46	47	...	67	68	...	88	89	total solts
1 L1											...	u	u	u					21
2 n1											...				u	u	u		21
3 n2									u	u	u								21
4 n3	s	s	s	s	s	u	u	u			...							u	27

Fig. 9 TDMA time slot allocation

3.2 End-to-end delay

End-to-end delay refers to the time taken for a packet to be transmitted across a network from source to destination. It's include the delay caused by the cache in Routing discovery phase, at the interface of queuing delay in the queue, relay time delay In MAC layer, and All the time delay of electromagnetic wave propagation time, etc. end-to-end delay is the most important parameters in the network simulation a review system performance, time delay is often directly affects the size of the user perception of the network.

At this point, this paper emphatically analyzes the most representative business flow between node n5 to L3, because the two nodes across four subnets, there is more to the other side of the path, and passes through a router between processing requests is very busy, the result of the best reference.

As shown in Fig. 10, a fine blue dashed line in figure for simulation Settings before the n5 to L3 business flow, coarser some blue dashed line is the end of the simulation, the route packets arrive n5 L3.

You can see that the n5 after A1 forwarding node L2 to superiors, to forward battalion A1 to battalion node A2. A2 battalion node then forwards the packet to L3, middle has experienced four jump to arrive at the destination node.

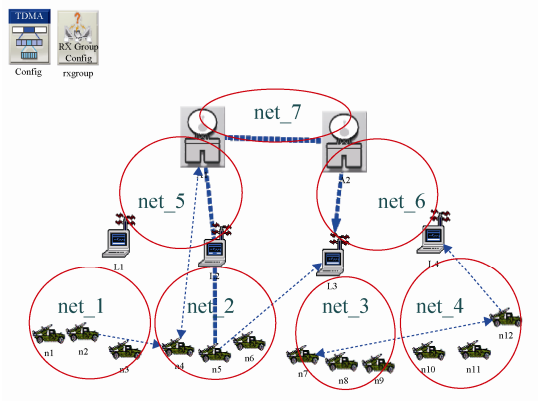

Fig. 10 Hierarchical routing selected path graph

As shown in Fig. 11 for the application of the network model of the DSR routing protocol, at the end of the simulation of routing, it can be seen that packets from node n5, because is too far away from company level node L3, forward n7 to L3 company level node by node, altogether has experienced two jump.

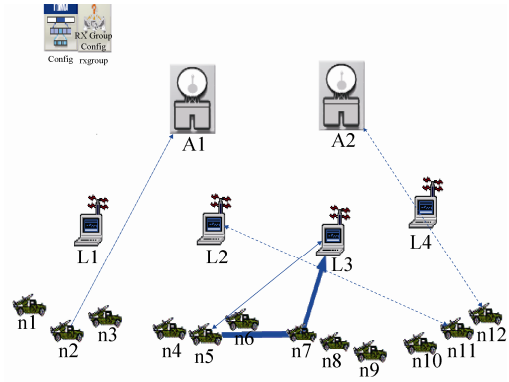

Fig. 11 The DSR routing selected path graph

Abscissa in Fig. 12 as the simulation time, y coordinate for the delay, the unit is in seconds, can be seen from the diagram in the process of simulation, the hierarchical routing time delay between the 1 s and 4 s fluctuation, the relatively small range, and maintained at a stable level, individual volatile time delay is related to the business layer simulation of packet traffic increases suddenly. In general the average delay of hierarchical routing is shorter, but when the network increases, the total business volume will cause certain network bottlenecks. There is some problem.

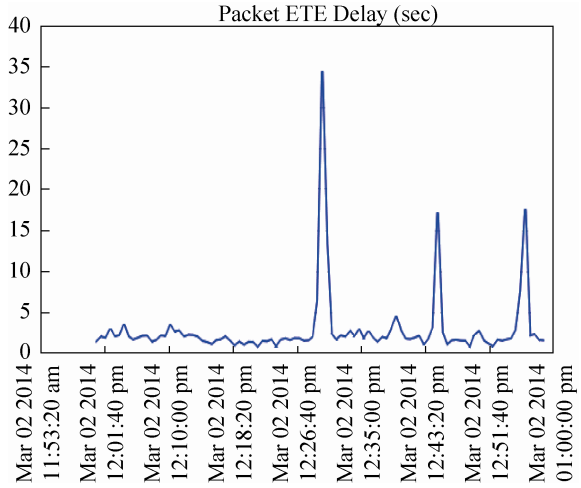

Fig. 12 Hierarchical routing protocol average end-to-end delay

Abscissa in Fig. 13 to the simulation time, y coordinate for the delay, the unit is in seconds, can be seen from the diagram in the process of simulation, the DSR routing time delay between the 5 s to 15 s fluctuation, the network has just started, the network has not yet been packets, with increasing data packets over the Internet, the network bottleneck effect increases, the average delay start to rise, their reach maximum delay 17 s, in the process, time delay has been relatively large fluctuations, contrast routing for network link quality influence is more serious, the results of waveform figure in fracture, this shows that there is the phenomenon of packet loss.

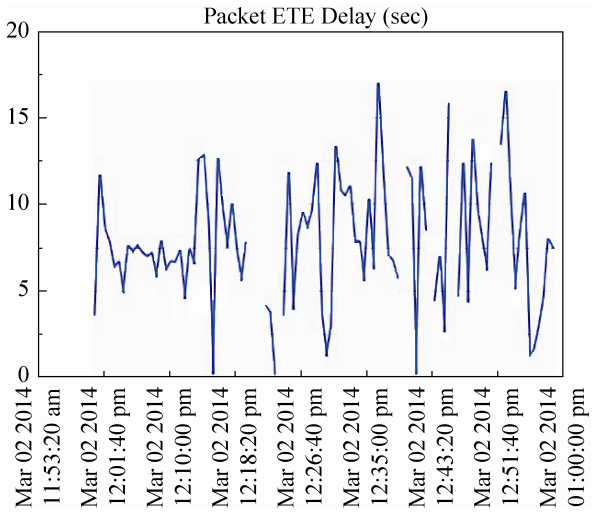

Fig. 13 The DSR routing protocol average end-to-end delay

4 Conclusion

Based on TDMA protocol modeling are introduced in detail, and the comparison of the DSR and hierarchical routing protocol, get the following conclusion:

(1) Through the analysis of the data link layer, according to its synchronization, time slot allocation mechanism, finally determine a suitable satellite TDMA protocol model for tactical communication network.

(2) By using a hierarchical routing network and the contrast between the DSR routing network simulation, we got some reference significance to the data, examining the end-to-end delay of the simulation, the DSR routing than hierarchical routing and some performance gap, because in terms of routing, the DSR routing protocol dynamically and automatically determine and maintain all routing, according to the network load to seek a stable path, so its end-to-end delay without sudden increase. For hierarchical routing tree structure of the network is more easy to manage each site at a lower level, the lower the subnet structure can good planning, data forwarding path can be controlled. And send packet according to the defined subnet.

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