Tactical Data Link Based on OMNET++

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Abstract: Simulation is an indispensable link in the technical index demonstration, scheme selection and protocol design of tactical data link. OMNET++, a discrete event simulation software, is introduced in the paper as the network simulation platform in order to analyze and make statistics of important parameters of tactical data link network. Also, the key technology of the realization of data link simulation is also analyzed in the context of OMNET++. In this paper TDMA protocol simulation is realized and Link 16 data link network model is established based on TDMA protocol. In the meanwhile, according to the performance parameter simulation of Link 16, it obtained various kinds of data link network performance indexes, such as network throughput, average end-to-end delay and data packets delivery ratio. The paper also suggests that the simulation result is particularly instructive in the practical application of tactical data link.

Keywords: Tactical Data Link(TDL); Network Simulation; OMNET++; Link-16

1 Introduction

Tactical data link can realize the tactical message switching between multi-platforms, becoming the core part of the C4ISR system of the modern war. More and more attention is paid to tactical data link network simulation as an effective means to research on tactical data link network performance. No matter the system technical index demonstration, scheme selection and protocol design of tactical data link or the system operational effectiveness assessment, all of them need the support of simulation[1].

OMNET++, as discrete event simulation device, is equipped with complete graphical interface and strong embedded simulation kernel. Different from network simulator such as OPNET and QualNet, OMNET++[2], with the functions of programming, debugging and traceability support, has good portability, fast simulation speed, little memory consumed and other advantages, possessing the ability to define network topology easily and offering support to FSMs(Finite State Machines) programming and Windows system collective development based on threads. It can be applied to the simulation of communication network and distributed system, which also can realize the communication simulation between complex infrastructures and meet the demand of digital battlefield network frame.

At first, this paper sets up the tactical data link standard node model in the MF framework of OMNET++, analyzes the very functions of each module and designs custom statistical model of the simulation indexes. Secondly, referring to the network characteristics and network mode of Link 16 tactical data link, this paper creates a practical tactical data link network simulation scene, bringing the network parameter configuration and simulation run into completion. At the same time, by taking advantage of the result analyzer provided by OMNET++, it also presents various kinds of performance parameters like average end-to-end delay, data packets delivery ratio, channel utilization, system response time and so on so forth. In the end, it provided the general idea and methods of conducting performance parameter simulation on the basis of OMNET++, which offers a reference for the research and analysis of our army tactical data link network.

2 System model design of tactical data link in the context of OMNET++

The basic tools and mechanism provided by OMNeT++ are used to write simulation code, but the specific simulation is supported by various real models and framework components, such as Mobility Framework[3]（MF) and INET Framework[4], these models are independent to the OMNet++ development.

2.1 Node model design

Ttactical data link node model is the composition of all hierarchical functions of simple modules and a relative independent center module in the simulation system, and the model with multiple nodes can be transformed into the final tactical data link network model through NED language. In this paper, the tactical data link node model is established on the basis of MF frame. At the same time, in response to the protocol requirements, some codes and functions of corresponding layer are revised and expanded respectively in this paper.

As shown in figure 1, the node model is composed of application layer module（appl.）, network layer(net), network interface layer(nic)., mobility module and blackboard module, among which the network interface layer module is a compound module, including physical layer and MAC sublayer of link layer.

Application layer module is applied to the development of network applications, in which the data packet in nodes is generated during the tactical data link simulation. The network layer is in charge of the route

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maintenance of tactical data link network; outside the node hierarchical protocol stack, the node model in figure 1 consists of mobility and blackboard.

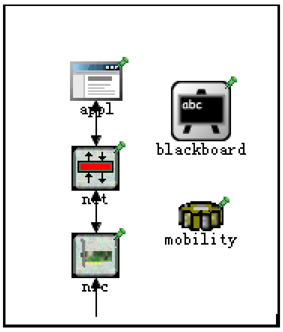

Figure 1 tactical data link node model

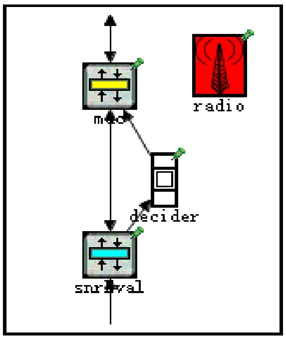

Figure 2 node model of nic. layer

The mobility mainly deals with the moving characteristics of network node. As each node owns its moving module , the moving path module can be designated only by changing the specified model parameters of the configuration system file omnetpp.ini.

Blackboard is widely utilized to cross-layer interactive design[5], by whose mechanism the cross-layer information exchange of the protocol layer in the host node can be realized so as to make effective communication using publishing--subscribing mechanism. There is only one blackboard in the tactical data link machine node, and the functions of the blackboard is derived from Blackboard Access class, providing needed data for all protocol layers.

In figure 2, the mac module of nic layer comprises tactical data link network protocol model, responsible for the simulation of channel access control. The mac module of node model completes the packet loss of all nodes after the system operation and the calculation of MAC end-to-end delay, and meanwhile displays the statistical results. The snrEval module is used to calculate the signal-to-noise ratio of receiving messages, and a comparison between the received power level and carrier wave detection threshold is made at the same time. If the power level of the packets received is lower than the carrier wave detection threshold, the packets will be discarded as noise, otherwise they will be sent to decider module which compares the power level with the receiving threshold. If the power level of the packets received fails to reach the level of receiving threshold, the packets will be marked as erroneous packets before sending it to MAC layer, or they will be regarded as effective packets by physical layer and send to MAC layer. At the end of the processing, snrEval module deals with the following work: calculatig response time of all nodes when the calculation system is running; calculating channel utilization and displaying the statistical results simultaneously.

2.2 Statistics model design

In order to analyze relevant performance indexes, three statistical models (time delay, package loss rate and channel utilization) are added to the tactical data link simulation system.

Packet delay in the tactical data link network refers to processing delay of each layers, transmission delay and channel transmission delay, which is an important parameter to evaluate the network real-time and MAC protocol[6]. By adding timestamp field to NED model of MF corresponding protocol layer, when making statistics of the occurrence of time delay, the time when the event of making statistic for time dely took place is recorded and the time value should be assigned to delay initial timestamp. Then, when the data packet transmits in the network, a time window should be set at the related intermediate processing link to record the time value as the delay end timestamp when data packet arriving at the module destination. Thus, the time difference between these two timestamps is regarded as time delay. By these two means, two time indexes: MAC end-to-end delay and system response processing delay are established.

Due to the interference from channel conflict, signal fading and noise jamming, data packet will not be received accurately by the node during the data transmission, thus appearing the phenomenon of package loss. Quantity forwarded and received of data packet is defined in the NED model of the corresponding layer of node, making duplicate record respectively and then comparing the record with that of other nodes. The reason of packet loss in the simulation system is that the signal power is lower than the carrier detection threshold of snrEval module, which mistakes it as noise and abandons it or that the signal power is lower than the receiving threshold, thus regarding it as a wrong packet and dropping it. Accordingly, the quantity received statistics of data packet must be defined on the MAC layer and the quantity forwarded respectively on the physical layer.

According to the definition of channel utilization: the ratio between the channel times spent respectively by the actual effective information transmission and actual information transmission, the delay initial timestamp and delay end timestamp are defined in snrEval module. In the meanwhile, the present value is assigned as the delay initial timestamp in the sendDown() function which is responsible for forwarding packets to channel, and the present value is defined as the delay end timestamp in the sendUp() function in charge of uploading packet to the upper layer decider module. The ratio of specific value between the difference of the two (as denominator) and the run time of simulation channel is the channel utilization.

2.3 TDMA internetworking protocol model design

The flow figure of implementing the TDMA network protocol is shown in figure 3: based on the existing documents[4,7] about the methods of expanding protocol in OMNeT++, TDMA model is built in MF frame, and the model includes three timer messages: the timeslot arrival timer MAC _WAKEUP in MAC layer, channel state detecting timer MAC_CHECK_CHANNEL, detection time limit timer MAC_TIMEOUT, a news broadcast packet, and four method functions(encapsulation function encapsMsg ( ), unpacking function decapsMsg( ), initialize function initialize( ) and end function finish( ).

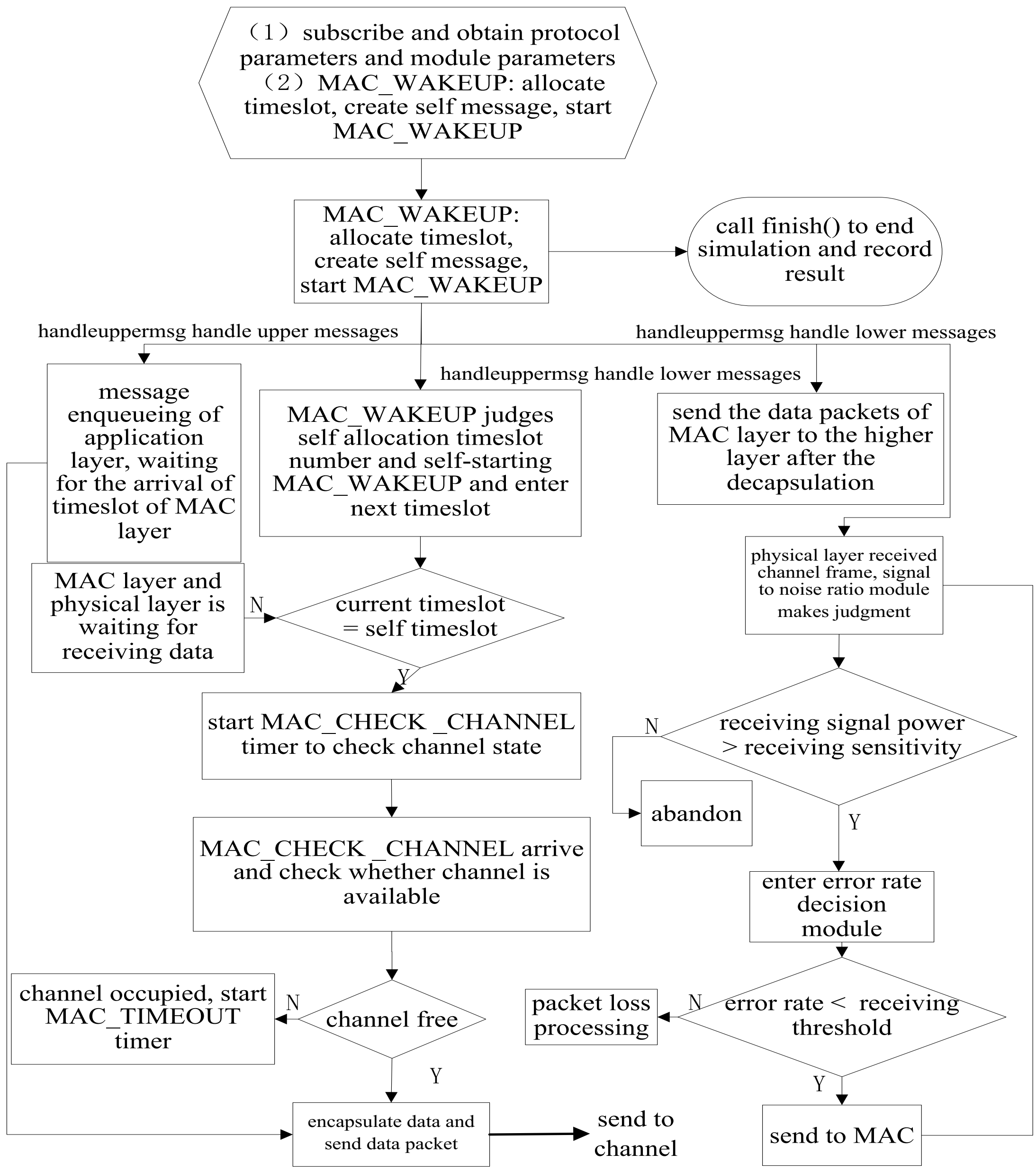

Figure 3 TDMA protocol execution flow figure

The workflow of TDMA protocol is made up of six parts

(1) Call initialize() to initialization module and protocol parameters, allocate the member timeslot in the network, set MAC_WAKEUP timer.

(2) The message packet generated from the application layer enters the queue of MAC layer, waiting for the arrival of the timeslot.

(3) When the MAC_WAKEUP arrives, all members compare the present timeslot with each local timeslot number, if they are the same, the

MAC_CHECK_CHANNEL will be launched to exam the channel condition and make preparation to send broadcast packets to the network; if they are different, they will be waiting to receive data packets.

(4)When MAC_CHECK_CHANNEL arrives, the channel is checked, if it is free , the information packets in the queue of MAC layer are packed and send it to the mailbox of physical layer. If it is occupied, the MAC_TIMEOUT will be started. Meanwhile, the information packets that are not sent before the timeout will be regarded as packet loss.

(5) All the network members who received broadcast packets are required to estimate the signal to noise ratio and error rate. If the signal to noise ratio is lower than sensitivity threshold or the error rate is higher than receiving threshold, the packets will be treated as wrong packets or packet loss. If the packets meet the requirements, they will be sent to MAC layer by physical layer, and finally sent to network layer and application layer after unpacking.

(6) When the simulation time is up or terminated in the midway, finish( ) will be called to record the performance data and then end the simulation process.

3 Network performance simulation of Link 16 based on OMNET++

3.1 Simulation scene construction

In the simulation scene with a fixed node number (10 nodes), simulation experiment on the Link-16 tactical data link network is carried out, and statistics about the performances of the physics layer, MAC layer, network layer and application layer of each node will be made. Then the node broadcast data packets of timeslot access authority will be obtained with a flexible packet length of each packet and adjustable velocity of each node. Through simulation to compare the performance differences of various nodes, this paper makes statistics of each node's MAC end-to-end delay, packet loss rate, response time and the channel utilization of the whole network. Afterwards, it adds five nodes to the network to observe the changes of network performance until the network scale reaches 50 nodes.

The parameter settings[9] of the simulation scene are as follows: simulation range: 5000m×5000m, simulation time: 100s, working frequency (in the single network structure): 969MHz, node number:10 (increasing 5 nodes in proper sequence from the node station, one airborne, two ship-bones, one vehicle and individual soldier, to 50 node stations). And the mobile model is linear directed moving model (Linear Mobility) with the airborne movement speed of 200m/s, ship-bone movement speed of 15m/s, vehicle movement speed of 10m/s, and solider movement speed of 1m/s. The fixed timeslot assigns TDMA as the communication protocol with the timeslot duration of 8ms, timeslot protection time of 0.2ms. The abstract model in OMNeT++ is regarded as the model of physical layer and its channel transmission rate is 119.04Kbps, which is determined by the average flow of Link-16 terminal in the model of two times compression double pulse and its transmit power is 200w; noise detection threshold is 10-12mW; receiving threshold is 10-9mW; path loss coefficient is 3.0; queue length of MAC layer is 10; data packet length is 59Byte; masthead is 10Byte; delay type: delaying a time at random within the time window interval [T1,T2]. Simulation run scene is shown in figure 4.

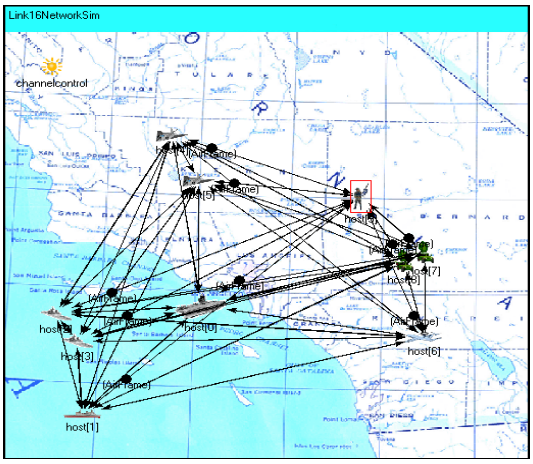

Figure 4 simulation run scene

3.2 Link-16 tactical data link network performance analysis

Taking use of the result analyzer provided by OMNeT++, this paper conducted analysis and statistics on the simulation results, and made simulation analysis on MAC end-to-end delay response time of link-16 network model, success rate of data packet transmission and channel utilization.

As shown in figure 5: the average delay of the node is around 1.5s; the delay of bank-based nodes 7, 8, 9 and ship-based nodes 1, 2, 3 is stabilized in less than 2s; the airbone 4, 5, 6 nodes feature a relative higher delay, of which the airbone node 6 is close to 6s, generating a large deviation. It is because airborne node movement speed in network parameter configuration is 13.3 times higher than that of the ship-based node and 20 times of that of shore-based node, which accords with the real situation.

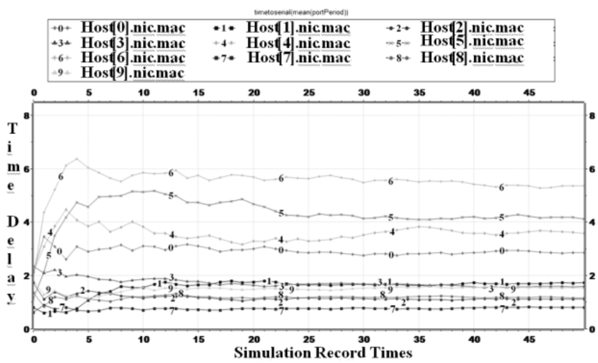

Figure 5 MAC end-to-end delay

The sum of the data packet the physical layer received and the number of clusters of packets successfully sent to the MAC layer after eliminating the wrong packets and noise packets are showed in figure 6. In figure 7, further analysis is carried out on group receiving rate of each node, among which the node 0 acting as network time reference and the shore-based nods 8, 9 can reach 90%, and the success rate of another shore-based node 7 declines to 61% for its motion path is diverging increasingly from network center which increases the rate of error packets and packet loss. The parameter settings of ship-based nodes 1, 2, 3 are the same with similar indexes except for different distance. The airbone nodes are generally low in the fast moving, especially the airbone 6 is low to 50%. In general, the success rate of data packets should be maintained above 50% to ensure the reliability of the network.

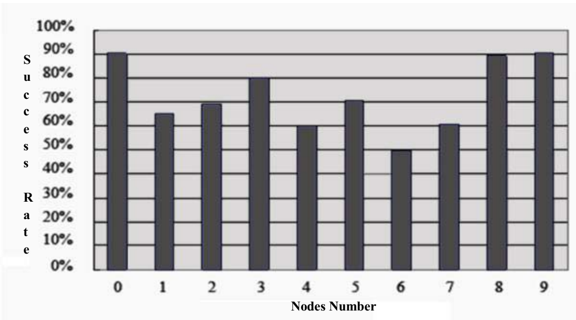

Figure 6 the total number of packets sent and successful receiving number of clusters

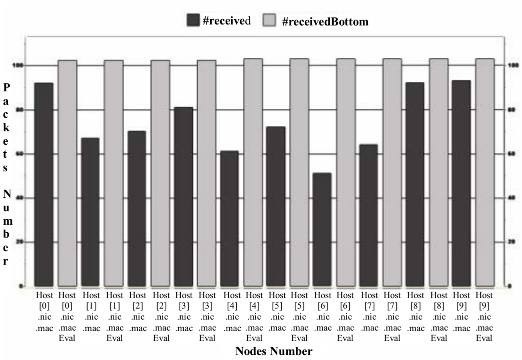

Figure 7 Successful receiving group rate

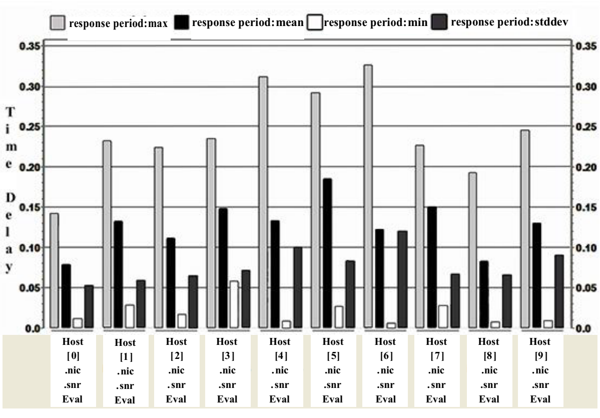

Figure 8 response time

The figure 8 shows the extremum of response time, average value and partial variance of each node. This index indicates the message handling delay of each node, which can be regarded as the reference to measure system effectiveness. Node 0, as the network time reference with a low processing delay and sound stability, meets the requirements of acting as the network time reference. The delay of airbone node is relatively large, and being affected by speed, distance, geographical location and other factors, quantity value and stability of the delay are not ideal, which is also consistent with the index characteristics of the aforesaid end-to-end delay and data packets delivery ratio.

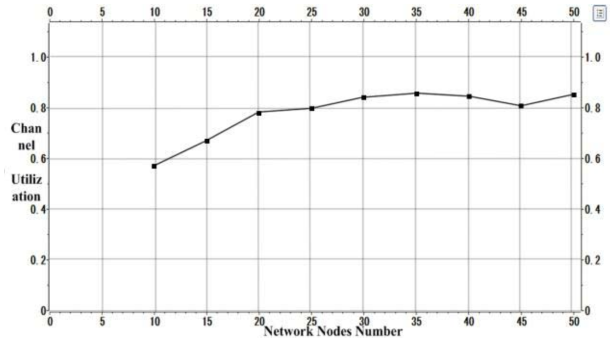

Figure 9 channel utilization vs. Network load

In figure 9, when network nodes increasing, according to the change rules of channel utilization: at first channel utilization rises with the increase of the number of nodes, and when the number reaches 35, an extremum arises 85.2%; after that, it will fluctuates around 80%. From this, it is obvious that the optimal load number of link-16 network is about 35 nodes and the channel utilization is around 85%, which also corresponds to the maximum throughput of the channel.

4 Conclusions

Overall, this paper established tactical data link standard node model in the MF framework of OMNET++, analyzed the very functions of each module and designed custom statistical model of the simulation performance indexes. According to the network characteristics and network mode of Link 16 tactical data link, this paper created a practical tactical data link network simulation scene, bringing the network parameter configuration and simulation run into completion. Meanwhile, by taking advantage of the result analyzer provided by OMNET++, it also presents all kinds of performance parameters like average end-to-end delay, success rate of data packet transmission, channel utilization, system response time and so forth. Therefore, the following work will be centered on the analysis of the network technology system of tactical data link based on the accumulated network performance parameters. Meanwhile, further researches on the multilink situation of tactical data link and cross-layer protocol should be carried out.

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