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Simulation Research of a Priority Satellite BTDAMA-FD Protocol

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Abstract: With the development of military space technology, space-based system plays an increasingly important role in the Ground Combat. According to characteristics of the space-based tactical communication network, high priority network group sites often need faster rate to get capacity for emergency data transmission, this study puts forward a suitable priority strategy for different priority needs of ground group after deeply analyzing the space-based tactics and BTDAMA protocol based on which this study establish a priority model applying to BTDAMA with combined Free and Demand (BTDAMA-FD) that is called priority BTDAMA-FD. This study particularly introduced the implementation process of priority BTDAMA-FD in OPNET Modeler software. Finally, by analyzing the simulation results via compare with the performance of standard BTDAMA-FD protocol, the simulation result can verify that the priority BTDAMA-FD has a better delay/throughput property.

Key words: OPNET modeler, satellite communication, tactical network, priority level, space-based, BTDAMA protocol

INTRODUCTION

In the space-based tactical network system, satellite access control protocol plays a key role in improving the channel utilization as well as guarantee the quality of broadband services (Yan and Qi, 2010; He *et al*., 2006). In the pure Demand Assigned protocol (DAMA), each VSAT terminal needs to make a request for the capacity when user gets the permission to send the data in its queue (Wang, 1999). The requests will generate a lot of waiting time in the case of long transmission delay in satellite communication. Variable rate demand assignment is often combined to other channel allocation scheme, such as Combined Free/Demand Assignment Multiple Access (CFDAMA) protocols (Mitchell *et al*., 2001), to reduce delay performance, However, these techniques which can be effective only in low channel loads, will become helpless in high channel loads (Mohammed and Le-Ngoc, 1994). The delay limitation of Variable rate demand assignment comes from the request of each individual packet and the delay is produced during the slots assignment.

BTDAMA (Burst Targeted Demand Assignment Multiple Access, BTDAMA) which is one of TDMA multi-access mode, can provide better delay performance for the data traffic modeled as a burst an burst interval resource (ON-OFF type data traffic sources), reaches lower limit of one RTD (Round Trip Delay) Delay (Xin *et al*., 2011; Mitchell *et al*., 2004). BTDAMA algorithm is divided into two ways: ground request algorithm and the scheduling algorithm, the separation of the request mechanism and scheduling mechanism which is the most notable features of this protocol, can allocate continual supply of slots for the terminal when it is in the burst moment, avoid waste of time from repeated requests. BTDAMA has been subject to significant development and analysis, generating a number of different variants, such as: Pure Demand BTDAMA-PD and Combined Free and Demand assignment BTDAMA-FD. The BTDAMA-FD protocol which is an extension of BTDAMA-PD, can distinctly reduce the end-to-end delay at low channel loads. The reason is that free assignment will be efficient at low channel loads, by assigning these free slots to the terminals that provisionally have no data in their queue at certain strategy, they can have the packets transmitted instantaneously on the channel without requesting for capacity, reduce the number of requests (Xin *et al*., 2011). But when the BTDAMA-FD protocol is deployed for Satellite communication in space-based tactical network system, it can't meet priority needs for different groups in the network, because of which this study add a priority strategy to this protocol to make it more adaptive and useful for space-based tactical network system.

BTDAMA-FD SCHEME ALGORITHM

Request algorithm: The uplink frame format for BTDAMA-FD scheme is shown in Fig. 1. The request slots are allocated to terminals on a round robin basis for

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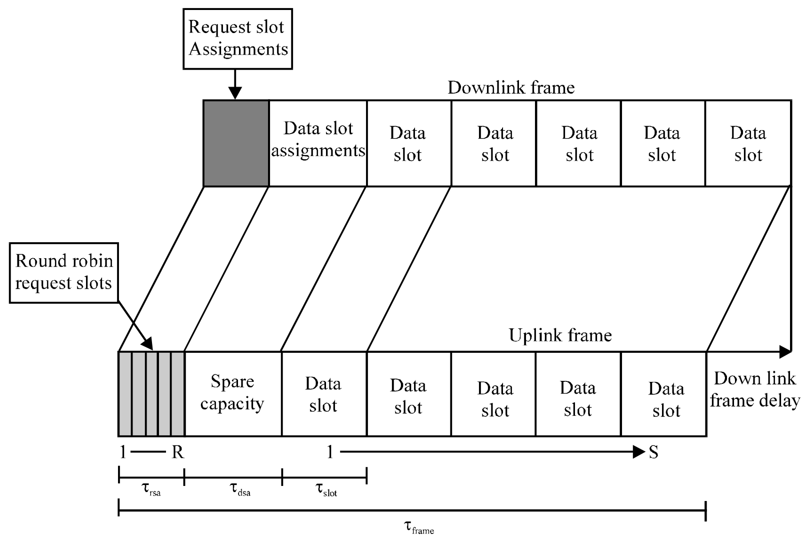

Fig. 1: BTDAMA frame

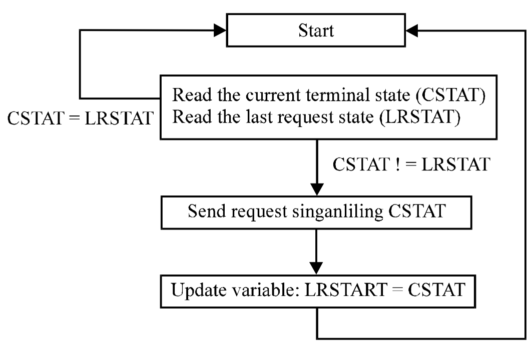

Fig. 2: BTDAMA request algorithm in VSAT

not contention request packet transmission and the sign of burst transmission. VSAT terminals essentially make request for capacity and later receive the continuous assigned slots. Choosing polling mechanism is because it's inherent fairness.

At any instant in time each terminal exists in one of two possible states: ON if there is a requirement for capacity; OFF if there isn't. Request algorithm for BTDAMA-FD is shown in Fig. 2. The state of each terminal changes from ON to OFF when the need for capacity changes. Every terminal keeps certain number of packets in the queue no matter whether it is in the state of receiving packets in a burst or not, when the first packet in a burst is received in a ground terminal queue, the current state (CSTAT) is set to ON, as the terminal needs the capacity. When the last packet in a burst is transmitted on the uplink and the ground terminal queue becomes empty, CSTAT is set to OFF. Alternatively, terminals can repeatedly signal their current state at every request opportunity, not just when there is a change in terminal state. This is the preferred method for satellite channels that may be subject to bit errors or connection loss for brief moments in time.

Scheduling strategy: The BTDAMA-FD scheme employ a centralized scheduling algorithm, located at the satellite, A satellite-based scheduler maintain two lists, one containing the terminals that have signaled ON and the other containing the terminals that have signaled OFF. Each time a request is received, indicating a change of requirement, the corresponding terminal is removed from its current list and placed at the bottom of the other list. Capacity is assigned on a frame-by-frame basis to terminals in the ON table state only. Successive slots are allocated one-by-one, to the terminals currently at the head of the ON list. Terminals are moved to the bottom of the ON list following each slots allocation. This strategy ensures that capacity is targeted only to terminals that need it and that each terminal receives an equitable share of the available capacity. If some spare slots exit after the slots allocation to the terminals in ON table, they will be assigned on a round robin basis to the OFF terminals for use if they happen to have packets to send at the instants of the free assigned slots.

Priority strategy: Intelligence information service, a important part in the tactical communications network transport services, often needs to be transmitted in high real-time performance, Intelligence information which mainly consist of the air target track and track, is usually transmitted in a small packet, adding the necessary

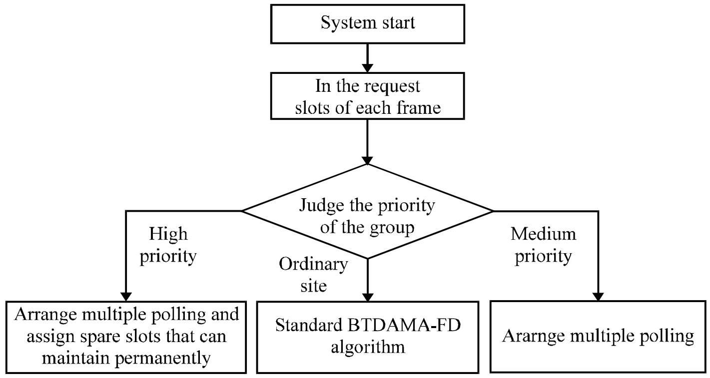

Fig. 3: Flow charts of scheduling priority BTDAMA-FD scheme algorithm with priority strategy

header, it reach a few dozen bytes in transport layer. Under normal circumstances, as the uncertainty of emergence of aerial targets, the intelligence flow is likely to mutate. So real-time is very important for the transmission of this information, high priority in slots allocation must be given to the terminals that primarily transmit Intelligence information, ensure that this information can be send in time and also avoid the backlog of data or lost.

PRIORITY BTDAMA-FD SCHEME ALGORITHM

Request algorithm: All terminals request in the same manner as before to the BTDAMA-FD Request algorithm and are divided into different groups, priority strategy is mainly reflected in scheduling strategy. As to ensure that terminals in high priority group can obtain the slots more faster than them in low priority groups, in the scheduler of satellite, each group maintain ON table an OFF table for itself.

Scheduling strategy: Scheduling algorithm in this way is basically the same as BTDAMA-FD, each group have the ON table of its owe, algorithm process is shown in Fig. 3.

Three optional priority have been set in this system: high priority group, medium priority, normal group. Satellite-based scheduler will adopt different allocated strategy to terminals according to their Priority level in the request slots of a frame, for high priority group, multi-polling strategy in request slots enable them to get response to their request from satellite more faster than other lower priority group. In order to give high priority group better service, they can permanently maintain some number of spare slots to transmit urgent business data, providing better transmitting performance for high priority groups. In conclusion, high priority group can get faster slots allocation than others.

EXPERIMENT OF SIMULATION MODEL

OPNET Modeler adopts three-tier modeling mechanism (Wang and Zhang, 2003), namely, the modeling process is done in three different environments that are called three regions: network model, node model and process model. Process model which works in the bottom of the network model constructs the protocol with finite DFA (finite state machine) that is implemented by C programming language. Secondly, Node model is composed of protocol modules and lines between them, reflects the trait of each module that corresponds to one or more process models. Finally, network model which works at the top level is comprised of network nodes and communicating lines between those nodes and by which the topology of simulation network can be established directly. The three-tier model, corresponding to the actual layers of network, equipment and protocol, fully reflect the relevant characteristics of the real network.

Network model: Network model depicts the communication system in the top level, communication equipment and communication links together form the topology of the communication system model. Network model describes the location of the nodes, the link between nodes and configuration of the nodes in the network, including one or more nodes or subnets and the size of which can be designed depending on actual requirements.

In this study, the network model consist of server ground sites and a satellite node that forwards packets from terminals, all ground sites are divided into three groups, the first group has the highest priority, followed by second group, the lowest priority for normal nodes to third group, it is in the Multiple Access Uplink Channel that all terminals in the three group communicate to the

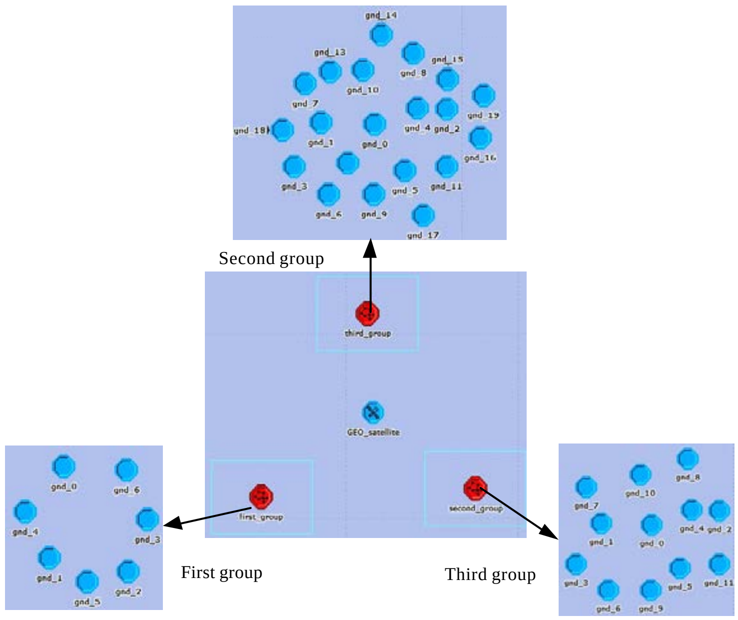

Fig. 4: VSAT terminals' network model

satellite by using priority BTDAMA-FD protocol. Every group which owns some number of ground nodes (Fig. 4) is only a formal model, the real number of ground nodes in certain group lies in the simulation parameter of part 4) which randomly forwards information with satellite. The average end-to-end delay of each group will be separately collected for the purpose of confirming the accuracy of priority BTDAMA-FD protocol after the analysis of them.

Node model: Ground nodes mainly send and receive packets, as shown in Fig. 5, the packet links in solid lines is used to connect two modules and as a channel to transmit packets from source to destination, the dotted line is statistics line, helping to monitor state changes. The core module is priority BTDAMA-FD in which contains the process model process implementing the logic behavior of priority BTDAMA-FD protocol. Source module generates packets with constant rate , then gives them down to priority BTDAMA-FD module in which slots request and slots judgment will be done to ultimately decide whether the data packets should be delivered to the wireless transmitter rt-0. Statistical line is responsible for listening on the wireless transmitter to see whether the channel is busy or not, the packets received from rt-0 module is given to priority BTDAMA-FD module to make judgment and subsequent disposal in sink module.

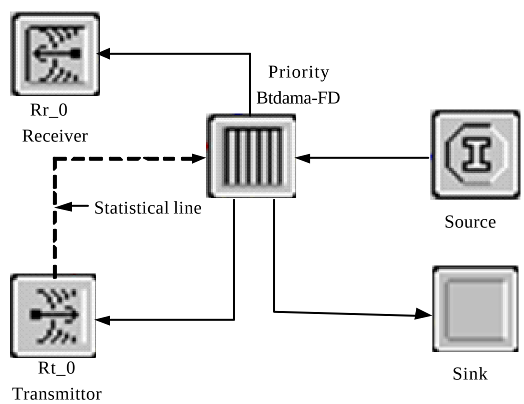

Fig. 5: Ground node model

The structure of satellite model, shown in Fig. 6, is relatively simpler to ground site model because satellite will not analyze the packets but directly forward them down to ground terminals (Li *et al*., 2005; Nie *et al*., 2006), its core module is priority BTDAMA-FD which implements the logic behavior of the satellite with the process model inside. In addition to the priority BTDAMA-FD module, it includes other three modules: satellite receiver, satellite transmitter and the two antennas as shown in Fig. 5.

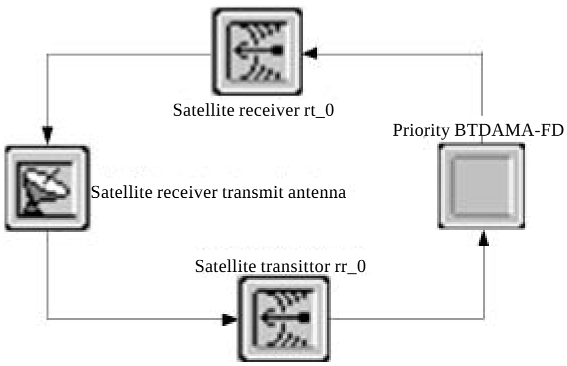

Fig. 6: Satellite model

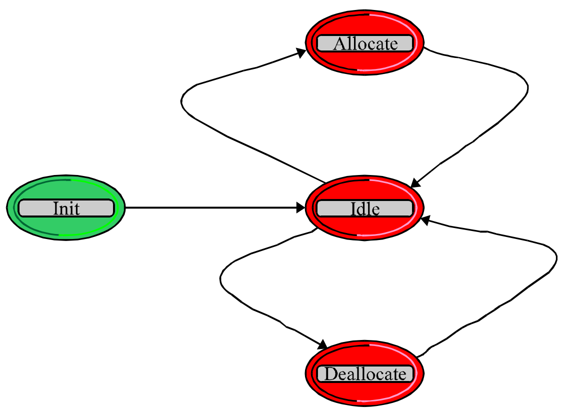

Fig. 7: Slot allocation process model

Process model: Process model corresponds to the FSM in OPNET Modeler which stands for the logic behavior of the process, FSM consist of state and transition, C/C++ programming language is chosen to describe the running procedure in each state. In this study, multi-process mechanism is adopted to implement priority BTDAMA-FD protocol.

This model is response to allocate and release slot, its structure is shown in Fig. 7. "Init" State completes the initialization of variables, set each slot to unused state when the system starts, initializes priority table, ON table and OFF table, judge level of the priority when certain terminal makes a request in request slots, if this ground site belongs to a group with high priority, polling sequence will be temporarily changed as to put the ID of this ground site in the first of the new sequence and one or more ID of this ground site will be placed in the new sequence according to the number of packets in its queue to complete multi-polling, by which can complete the purpose that terminal in group with high priority get the capacity more faster than lower priority sites. Idle state analyzes the packet received by antenna, if it is a slots-request packet, turn to "Allocate" state to assign enough slots to the request terminals, otherwise turn to "Deallocate" state to release slots assigned to the terminal if the received packet is slots-release packet. The scheduler will search slot table to find a number of continuous slots to meet the terminal's capacity need in "Allocate" state, if those slots don't exist, back to "Idle" state and then turn to "Deallocate" state to notice the earth site that its request has been failed.

This model is response to retransmit data from VSAT terminals, its structure is shown in Fig. 8. Scheduler initializes the time of single frame and single slot in "Init" state, calculate start time of current frame, the numbers of current frame and the numbers of slot in current frame, if current slot is not the start slot of capacity that has been allocated to certain ground site, arrange a interrupt at the start slot of next frame and queue the packets in a burst, then turn to "Send" state to send packets after divide and assembly of packets in queue in "Retrieve" state when current simulation time enter its start slot time. Interrupt in start slot in each frame is made in "Schedule-Next" state and this process itself will be aroused at the arrival of the interrupt in "Wait2" state, then turn to "Send" state to send packets, looping in these three states until the data queue is empty. In "Check" state scheduler checks the data queue to search whether it still contains packets inside, if the queue is empty turn to "CleanUp" state to release the buffer of the list. This process completes forwarding of the data.

This model is response to retransmit data in data queue of VSAT terminals, its structure is shown in Fig. 9. It is based on a mechanism which activated by interrupt of its own. Slots hold time is installed to the terminal, once some packets in a burst emerge in the queue and interrupt type is self-interrupt, this process will be activated and create a slots application process in "Init" state at the same time. All packets are lined up in "No-Assigned" state before sending out, slots application process (Fig. 9) will be wacked up in "Request" state to make a request for capacity, not until get the acknowledgment of successful allocation, waiting in "Wait" state, can this process be aroused to run again. The loop between "Send" state and "Sending" state is about to send packets, getting out to "Hold-Slot" state until the queue is empty, to release assigned slots in "Release" state waiting for release successfully in "Wait" state, then turn to "Clear" state to clear the buffer of the list, finally turn to "Request" state to make the next round of application if some new packets arrival in the burst.

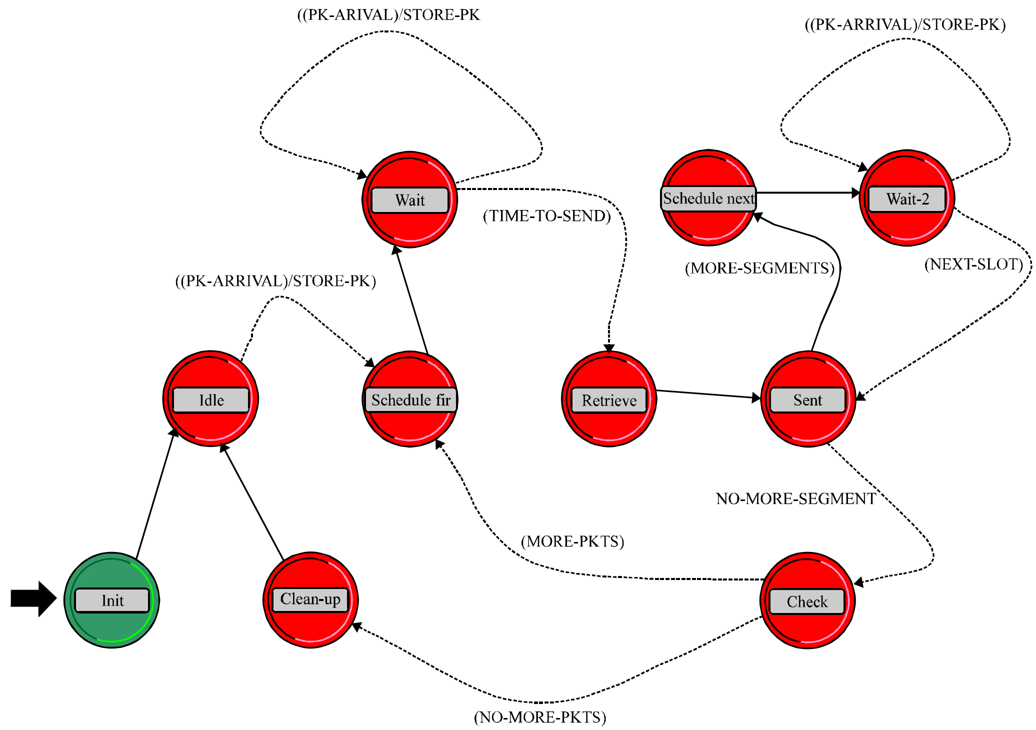

Fig. 8: Sending child process model for satellite

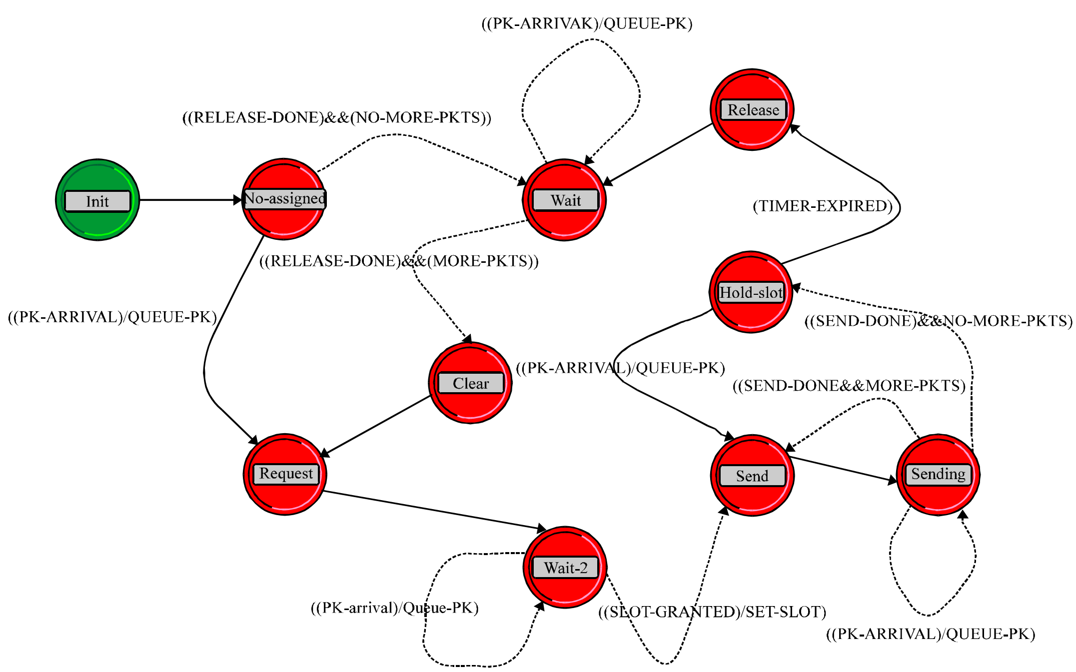

Fig. 9: Sending process model

This process is responsible for requesting capacity, its process structure is shown in Fig. 10. "Init" state initializes some local and global variables including request timeout, failure for request, the level of priority etc. Packet for capacity request will be send in "A-reg" state, packet of acknowledge from satellite will be

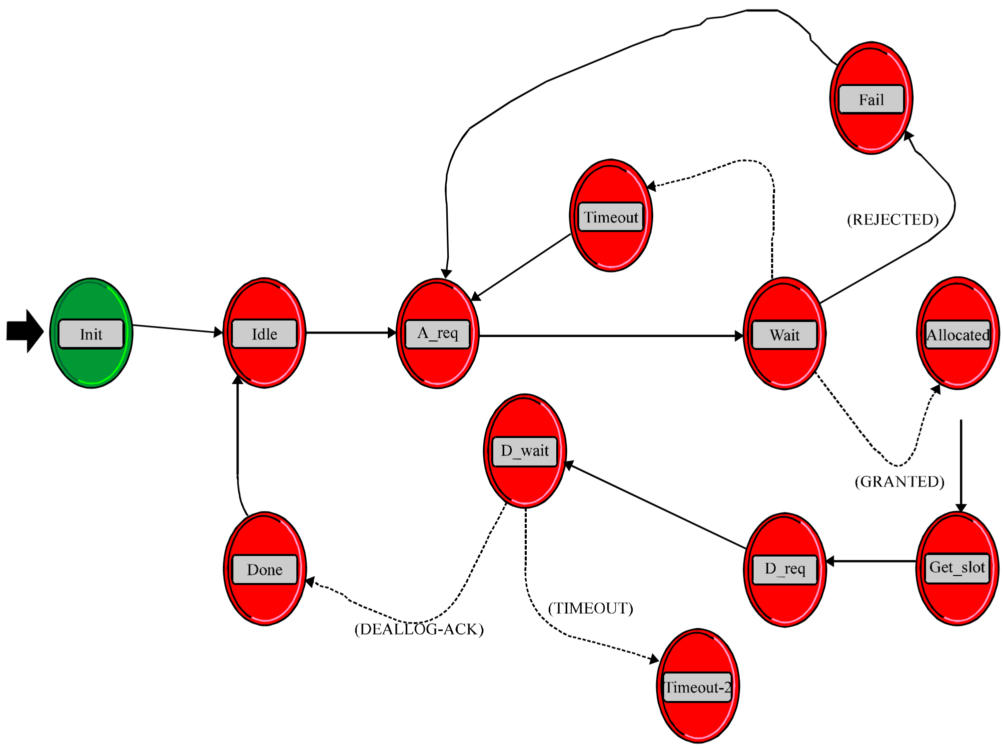

Fig. 10: Slot application process

analyzed in "Wait" state, turn to "Fail" state for rejection of slots request, to "Timeout" state for timeout, in both case a new request for capacity will be resend to satellite after back to "A-reg" state, successful allocation makes it turn to "Allocate" state in which destroy the interrupt installed in "A-reg" state and wake up parent process, then turn to "Get-Slot" state passing the value of the start slot. After packets transmission is done, turn to "D-reg" state to release slots assigned by sending a deallocated packet, go to "Idle" state for next loop of request with successful deallocation, or turn to "Timeout" state if timeout for not get the acknowledge from satellite.

SIMULATION OF PRIORITY BTDAMA-FD

Simulation conditions and parameters: The performance of delay/channel of the protocol play a key rule in valuates a satellite access control protocol in space-based tactical network system. This study proposed the simulation of the protocol with OPNET Modeler, includes 200 ground VSAT terminals which are divided into three group, first group contains 20 terminal with the highest level of priority, 100 terminals for second group with lower level of priority, 80 terminals for third group with lowest level of priority. The simulation parameter for some device used in the system is shown in Table 1.

Table 1: Simulation parameters

Parameters	Value
Satellite altitude (km)	37,500
Number of VSAT terminals	200
Channel data rate (Mbit sec^{-1})	2
Number of data slots in the uplink frame	256
Time of one frame (sec)	0.273
Channel load	0.1-1.0 Erlang's
Number of round robin request slots	100

Analysis of simulating result: The simulating result has shown in Fig. 11, it indicates that the first group combined with the second group and third group works in a minimum end-to-end delay comparing to whole system, meanwhile. The performance of BTDAMA-FD is close to priority BTDAMA-FD in low Channel Load, however, a little better in high Channel Load. The explanation for the phenomena could be more faster rate of channel access for high priority group with the strategy of multi-pooling and maintain permanently the spare slots, on the contrary the accumulation of the packets in low priority ground site produce more waiting time, that is why BTDAMA-FD performs better than Priority BTDAMA-FD in high

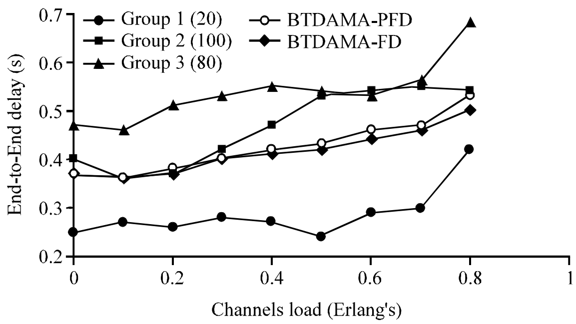

Fig. 11: The performance of delay/channel with Priority BTDAMA-FD

Channel Load. The Theory proposed by this study has achieved the expected goal, namely high priority group in space-based tactical network performs better with the minimum end-to-end delays.

CONCLUSION

Traditional BTDAMA protocol is improper for satellite communication in tactical network without priority strategy, as certain tactical subnet often need higher priority to complete transmit real-time transmission. This study has proposed a available priority strategy applying for BTDAMA-FD in order to match the need of priority for different subnet in tactical network, finally a model of the new protocol has been set up in OPNET Modeler software, in the end the simulation result have proved that the performance of the whole system meet the requirement.

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