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A Data-link Dynamic Slot Allocation Algorithm

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Abstract. Aiming at the problem of time slot resource allocation in tactical data link network, combining FPRP algorithm and P-TDMA algorithm, the exponential incremental exponential decrease (EIED) backoff algorithm is introduced, and the competition access probability is improved, propose a dynamic time slot allocation algorithm TDMA based on Adaptable Probability Contention (APC-TDMA). The algorithm collects two hop adjacent node information through multiple exchange information, and performs time slot allocation in two hop adjacent nodes, realizes the time slot space division multiplexing outside two hops, and solves the problem of node hiding and node exposure. The algorithm is simulated and analyzed using OPNET software. The simulation results show that the algorithm performs well in the end delay, network throughput and time slot utilization in large-scale network environment, and can meet the requirement of battlefield actual information transmission.

Introduction

According to DoD's definition of data link, tactical data link is a standard communication link used to transmit machine-readable tactical digital information[1]. Message real-time transmission is an important function of tactical data link. The media access control layer (MAC) determines the allocation mode of channel resources and has an important impact on the real-time performance of the network. At present, TDMA is widely used in tactical data link. TDMA has the advantages of simple operation, high communication quality, good secrecy and flexible networking. It can meet the needs of actual combat environment. TDMA slot allocation algorithm has important influence on data link network throughput, time slot utilization and message end to end delay. Therefore, the research on TDMA slot allocation algorithm has become the focus of data link network.

The slot allocation of tactical data link has achieved some results, and many TDMA slot allocation algorithms have been proposed. Some of them are aimed at Link-16, for example: heuristic slot assignment algorithm based on the minimum delay jitter[2],slot allocation algorithm for TDMA tactical data link based on genetic algorithm[3], Multi-Channel Priority Statistics(MCPS)[4],New Packing for Imagery Transmission[5] and D-MAC[6]. Some for Tactical Targeting Network Technology(TNNT), for example: Hop-Pattern Reservation Multiple Access(HPRMA)[7],Priority Differentiated and Multi-Channel (PDM) MAC Protocol[8]. Combined with the FPRP[9] and P-TDMA[10], a slot allocation algorithm for Link-16 is proposed. The FPRP is used to collect the information of the adjacent nodes that have the sending demand, and then the two hop node information is obtained by controlling the switching time slot, and then the time slot is allocated according to the priority algorithm.

II Protocol Description

The algorithm proposed in this paper needs the following conditions:
(1) the whole network node is completely synchronous;
(2) the communication mode is half duplex.
(3) the whole network node has a unique sequence number ID;
(4) the mode of data transmission for the whole network is broadcast.
(5) within one frame, the two hop neighbor nodes remain unchanged.

Frame Structure. In the proposed algorithm, the frame structure includes the Reservation sub frame (RF), the control information exchange sub frame (CF), and the information sub frame

(IF).The frame structure of the algorithm is shown in Figure 1.

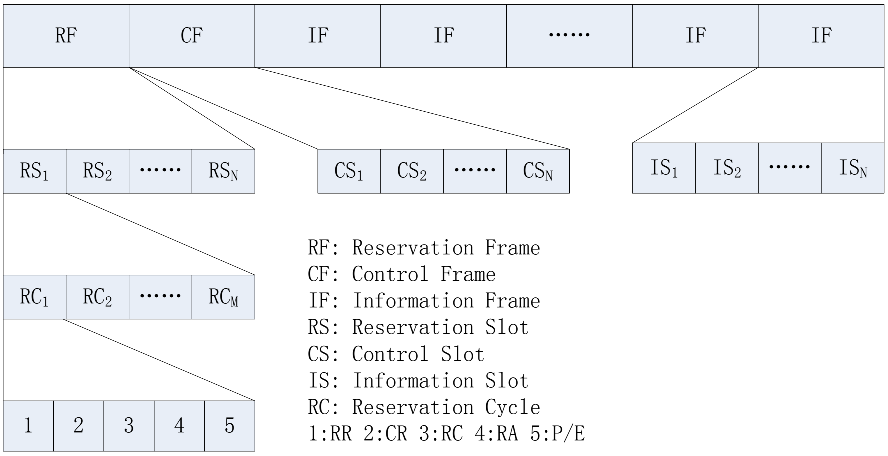

Figure 1. Frame structure of the APC-TDMA

Reservation Frame(RF). In the reservation frame(RF), an improved five phase reservation cycle is adopted. The five phase reservation process is as follows:

(1) Reservation Request (RR).At this phase, nodes with time slot reservation are required to broadcast packet RR by probabilistic *P* broadcast. The other nodes are in the listening state. The result of interception may conflict with the channel idle, the receipt of a RR packet and the receipt of multiple RR packets.

（2）Collision Report（CR）.When a node in the RR phase is in the listening state, when multiple RR packets are received, a conflict report CR packet is sent at this stage to notify the sending node to conflict; otherwise keep silent. At the same time, the request node is in the listening state at this stage. If CR packets are not received, all neighbor nodes correctly receive the RR packet. At this point, the request node is transformed to the transmission node (TN).

（3）Reservation Confirmation (RC).At this phase, the nodes that have not received the CR packets need to send the reserved Reservation Confirmation packet (RC). After receiving the RC packet, all adjacent nodes in the one hop area confirm that the slot is reserved successfully. All hop nodes will no longer compete for the same slot. The key information in the RC packet is the unique identity ID of the transmission node, which is used to modify the neighbor node information table for each node.

（4）Reservation Acknowledgment (RA).At this phase, the neighbor node that receives the RC node of the transmission node will send the reservation acknowledgement packet RA. When the transmission node receives the RA packet, it confirms that the slot is reserved successfully. If the s transmission node is an isolated node, the first three phases can also be successfully completed. After sending the RA packet, the transmission node confirms that it is a non isolated node. In addition, the RA packet is sent in the form of broadcasting, and it tells the sending node two hopping adjacent nodes, and the current time slot has been reserved. The adjacent nodes in the two hop range will no longer compete for the same slot.

（5）Packing and Elimination(P/E).At this phase, a packet PP is sent to all nodes from the two hop interval of the sending node. The neighbor node of the three jump interval of the distance sending node receives the PP packet, and it is considered that one node in the three jump interval is successful in appointing a slot, and some adjacent nodes of the node may be prevented from competing the current slots. Therefore, the competition access probability P should be improved properly. At the same time, the successful node will send out the exclude packet EP at the probability of 0.5 and the segment to solve the possible deadlock problem.

Control information exchange frame (CF). In the control information exchange frame CF, each node is packed into a control information exchange packet CF in the RF stage of each node in its competitive control information exchange slot CFn, which is sent to each one of the one hop neighbor nodes in a broadcast manner. At this time slot, the other nodes are in the receiving state.

Through this stage of interception, each node will collect the ID of the active neighbor in the two hop. According to these information, each node obtains the priority of every two hop adjacent nodes in each data information slot ISn by calculating, and generates priority list. By finding the priority table, each node confirms the right to use the slot ISn of its own data information. According to the following priority algorithm, the priority of each node in each time slot is obtained.

$$I_{prio}=i\oplus t$$

(1)

The unique identity ID, which represents the node, t represents the number of data information slot ISn. In this algorithm, the value of t is behind [1,N],N is a preset constant. In each slot, the highest priority node takes up the time slot of the data information.

Information Frame(IF). In the information frame IF, the active nodes are in the sending state in the data transmission slot ISn that they have reserved, sending the data packet DATA, and the other nodes are in the receiving state in the time slot. After the end of a frame, each node enters the next frame.

Node Competition Probability Algorithm. In the FPRP algorithm, at the reservation request phase RR, the node with transmission demand initiates time slot competition with probability *P* （*P=1/n*）. Each node should estimate the number of competitors of its two hop adjacent nodes *N* and adjust the probability *P*. The estimated value of the number of competitors is n obtained by pseudo-Baysian algorithm. When an appointment is successful, a node with a certain ratio of *R1* in one of its adjacent nodes stops the current slot competition, the ratio of two hop nodes is *R2*, and the ratio of the three hop nodes is *R3*.

1． At the start of the program, set the initial value n_0

2． update n after each appointment cycle based on node listening.

Idle: $n = n-1$;

Collision: $n = n+(e-1)^{-1}$;

Success: Suppose the distance between the successful node and this node is *X* hop:

*X=0,*This node competes successfully and completes the competition process

X=1, Nodes will not compete against the same time slot

$n=n*(1-R1)-1$;

X=2, Nodes will not compete against the same time slot

$n= n*(1-R2)-1$;

X=3：

$n=n*(1-R3)$;

This method has good performance when it is small in network size and node density, but with the increase of network size and node density, the method estimates the number of adjacent nodes is slow, and the number of adjacent nodes can not be estimated quickly and accurately, and the applicability is reduced. In order to get closer to the estimated number of real neighbor nodes, this paper adopts improved exponential incremental exponential decrease (EIED).

In the EIED, each node should estimate the number of its active neighbor nodes n, and adjust its initiating appointment probability *P*. According to the feedback information received by the neighboring nodes, update the estimated value *n*: When the node competes successfully or listens to idle channels, $n=n/R_D$, When it is collision, $n=n*R_I$. R_I and R_D can be set according to network size and network node density.

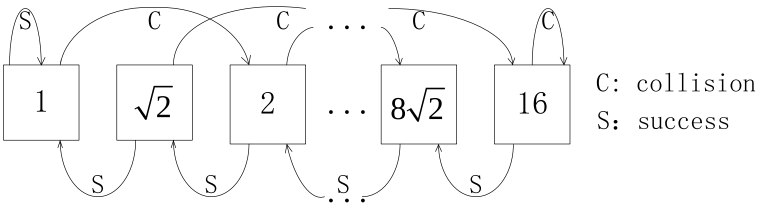

Figure 2 mechanism of EIED: $R_I = 2$ and $R_D = \sqrt{2}$

Figure 2 shown mechanism of EIED when $R_I = 2, R_D = \sqrt{2}$ and *n* is behind 1 and 16.In the multi hop environment, we use the multi hop Bayesian algorithm to modify the EIED, The calculation method of n is as follows:

1. At the start of the program, set the initial value n_0
2.update n after each appointment cycle based on node listening.

Idle: $n = n/R_D$;
Collision: $n = n*R_I$;
Success: Suppose the distance between the successful node and this node is *X* hop:
X=0,This node competes successfully and completes the competition process
X=1, Nodes will not compete against the same time slot
n=n(1-R1)-1*;
X=2, Nodes will not compete against the same time slot
n= n(1-R2)-1*;
X=3：
n=n(1-R3);*

The node adjusts the competitive probability of *P* to *P=1/n* according to the estimated value of *n*.

Simulation Result

In this paper, OPNET is used as a simulation tool to simulate the performance of the algorithm.The simulation network scenario is 600km*800km area, the number of nodes is set to 10~50, and the simulation parameters are shown in Table 1.

Table 1 Simulation Parameter Setting

Parameter Name	Value	Parameter Name	value
R_I	1.089	R_D	1.089
M	2	N	7
Distance	350km	Transmission Rate	1Mb/s
Speed of Node	200m/s	Distribution	Poisson
Packet Size	444b/packet	Packet Rate	50 packet/s

Statistical analysis is carried out from different network throughput, time slot utilization and end to end delay. The transmission performance of APC-TDMA algorithm and P-TDMA algorithm is compared.

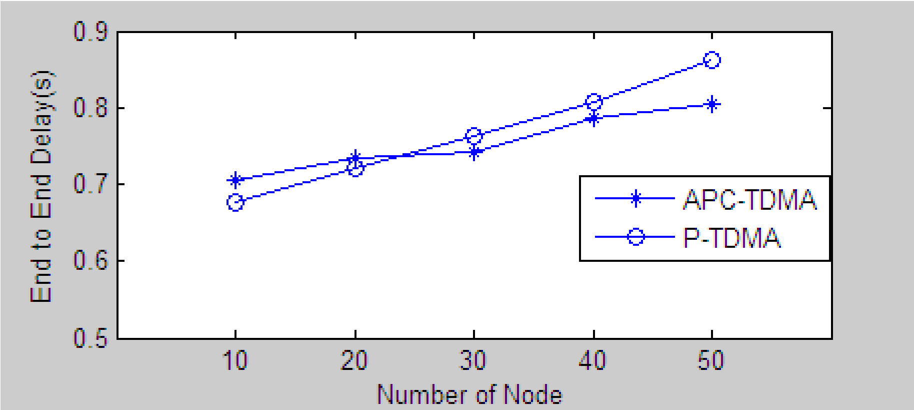

Figure 3 End to End Delay

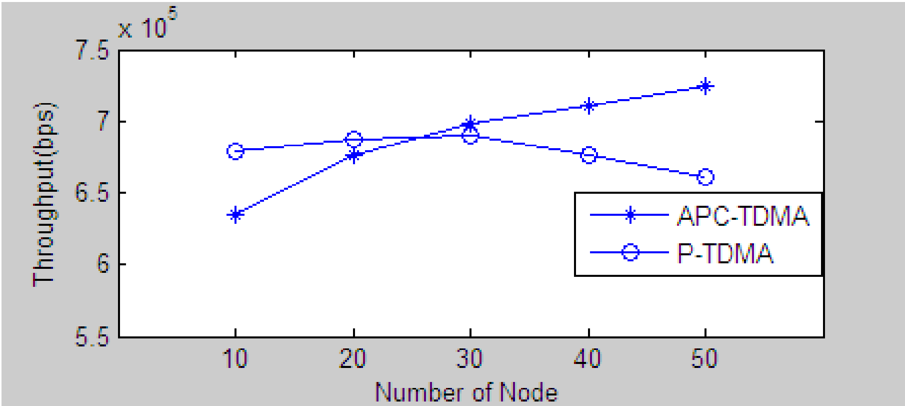

Figure 4 Throughput

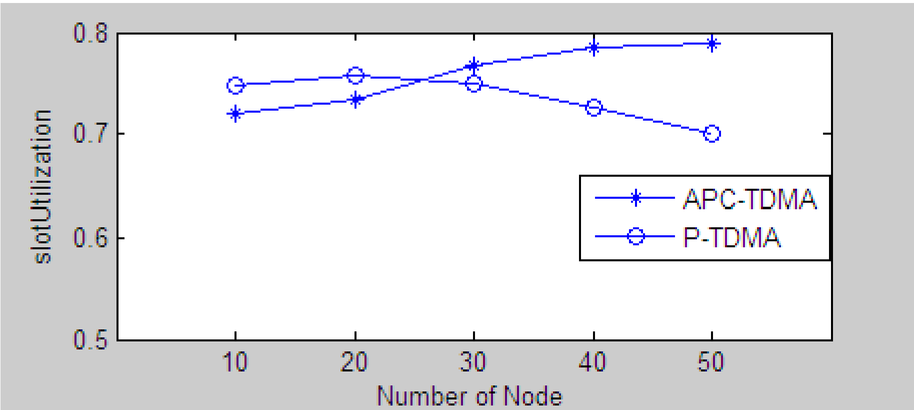

Figure 5 SlotUtilization

Figures 3, 4, and 5 show the end to end delay, network throughput and time slot utilization respectively under different node numbers. The results show that, when the number of nodes is less, the P-TDMA algorithm has good performance. With the increase of nodes, the network size increases and the cost of P-TDMA protocol increases, resulting in performance degradation. APC-TDMA algorithm does not perform as well as P-TDMA when the number of nodes is small. With nodes, the algorithm shows advantages and outperforms P-TDMA in performance. Compared with P-TDMA, the algorithm proposed in this paper is more suitable for larger networks.

Conclusion

Based on the existing TDMA slot allocation algorithm, this paper proposes a new slot allocation algorithm, APC-TDMA algorithm, combined with FPRP algorithm and P-TDMA. The algorithm solves the problem of node hiding and node exposure to a certain extent. In addition, the algorithm solves the problem of repeated utilization of time slot besides the two hop. Simulation results show that the algorithm has advantages in end-to-end delay, time slot utilization and network throughput under certain circumstances, and has practical value.

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