A Channel Threshold Based Multiple Access Protocol for Airborne Tactical Networks

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Abstract. Airborne Tactical Network is a promising and special mobile Ad hoc network, connecting the ground stations and all kinds of flying combat aircrafts on battlefield through tactical data links. Designing a low delay, large capacity, high flexibility, strong scalability, and multi-priority traffic differentiated medium access control (MAC) protocol is a great challenge in the researches and applications of ATNs. In order to overcome the disadvantages in IEEE 802.11 Distributed Coordination Function (DCF) and Time Division Multiple Access (TDMA) protocols, we present a channel threshold based multiple access (CTMA) protocol for ATNs in this paper. The CTMA protocol is a novel random contention type of MAC protocols, and it can differentiate multiple priority services, and utilize multi-channel resource based on channel awareness. We intensively describe the channel occupancy statistic mechanism, multi-queueing and scheduling mechanism of multi-priority services, and channel threshold based admission control mechanism involved in the protocol. We further derive the channel threshold of each priority service, the expressions of the successful transmission probability and mean delay mathematically. Simulation results show that the CTMA protocol can differentiate services for different priorities in ATNs according to the real-time channel state, and provide effective QoS guarantee for transmissions of various information.

Keywords: Airborne Tactical Network · Medium access control protocol · Channel threshold · Priority differentiation · Multi-channel · Admission control

1 Introduction

In order to meet the requirement of Network Centric Warfare, the U.S. Air Force is engaging in developing Airborne Tactical Network (ATN) in recent years. ATN is a new type of wireless network, connecting the ground stations and all kinds of flying combat aircrafts on battlefield through tactical data links [1–5]. In essence, ATN is a special kind of Mobile Ad hoc Network (MANET), with the characteristics of great flexibility, high dynamics, rapid self-organizing, large capacity, good robustness and reliability. It can improve the capability of cooperative operation for combat aircrafts, and has become one of the most important developing trends of military aeronautical communication

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networks. In ATNs, such as TTNT (Tactical Targeting Network Technology) [6], JALN (Joint Aerial Layered Network) [7], BACN (Battlefield Airborne Communication Node) [8], QNT (Quint Networking Technology) [9], etc., the capabilities of quick finding and accurate attack against the ground and aerial targets with strong mobility, i.e., time-sensitive target, is regarded as one of the key technologies. Medium Access Control (MAC) protocol mainly solves the problem of sharing the wireless channel resources between nodes in ATNs efficiently, and is the main factor influencing the information transmission delay. In ATNs, there exist the issues of long transmission delay and unstable channel, etc., influencing on the real-time and reliability of information transmissions drastically. Thus, these issues put forward a higher requirement for MAC protocol than the traditional MANETs.

The existing MAC protocols in ATNs mainly contain IEEE 802.11 Distributed Coordination Function (DCF) protocol [10–14], and Time Division Multiple Access (TDMA) protocol [15–19]. The IEEE 802.11 DCF adopts RTS/CTS frames to reserve channel resources in order to avoid collisions. The RTS/CTS handshaking mechanism is not quite suitable for the delay-sensitive aeronautical communications, due to the large transmission delay of interactive information in long communication range. As a fixed allocation MAC protocol, TDMA has the advantages of high throughput and large capacity. However, it needs to pre-assign time-slots for each user, and the transmission delay is seriously influenced by user number. Thus, it is also not applicable to the delay-sensitive ATN. A MAC protocol based on burst communication and asynchronous frequency hopping is proposed for ATNs in [20]. However, it cannot differentiate multiple services.

The MAC protocol in ATN should meet the following requirements: (1) transmission delay for the high priority traffic is very low; (2) the first time packet delivery success rate reaches 99%; (3) different Classes of Service (CoS) is supported; (4) large number of users can be contained. Therefore, it is necessary to design a novel MAC protocol with low delay, large capacity, high flexibility, strong scalability, and multi-priority traffic differentiated for ATNs.

In our previous work, we have presented a priority differentiated and multi-channel (PDM) MAC protocol in [21] and a channel busy recognition mechanism combined with auto regressive forecasting in [22] for ATNs. The PDM protocol in [21] addressed the multi-priority services differentiation through an adaptive jitter mechanism. For different priority packets, time to access to channels is controlled by the adaptive jitter mechanism. The channel busy recognition mechanism in [22] can be an important module in PDM protocol.

In order to guarantee the co-transmissions of traffic of multiple priorities and meet the strict QoS requirement of delay-sensitive information transmissions in ATNs, some effective mechanisms, such as multiple priority differentiation and channel awareness, should also be adopted in the MAC protocol. Therefore, we are motivated to propose a novel Channel Threshold based Multiple Access (CTMA) MAC protocol in this paper. Based on the real-time channel occupancy awareness, the protocol can differentiate multiple priority traffic, and provide effective QoS guarantee for information transmissions. The protocol employs a simple and effective channel occupancy statistic mechanism. It introduces a multi-queueing and scheduling strategy for multi-priority traffic. It also adopts a novel channel threshold based admission control mechanism to control the access of packets with different priority services to multi-channel.

The proposed MAC protocol has the following attractive advantages: (1) It can support multiple service classes. (2) It can guarantee the extremely low delay and extremely high successful transmission ratio for the highest priority service. (3) It involves a novel adaptive backoff algorithm for multiple service types. (4) It controls the access of packets (except the highest priority service) to channel according to the busy degree of the channel.

The reminder of the paper is organized as follows. Section 2 presents the CTMA protocol for ATNs, describes the its main components in detail, and models it theoretically. Section 3 derives the mathematical expressions of some key metrics of the protocol. In Sect. 4, we conduct simulations to show the protocol performance and verify the mathematical derivations. Finally, we conclude our work in Sect. 5.

2 Protocol Description

2.1 General Description of CTMA Protocol

The CTMA protocol proposed in this paper is a distributed random contention MAC protocol. It includes 4 components, namely the channel occupancy statistic mechanism, multi-queuing and scheduling mechanism, channel threshold admission control mechanism, and multi-priority adaptive backoff mechanism, as shown in Fig. 1.

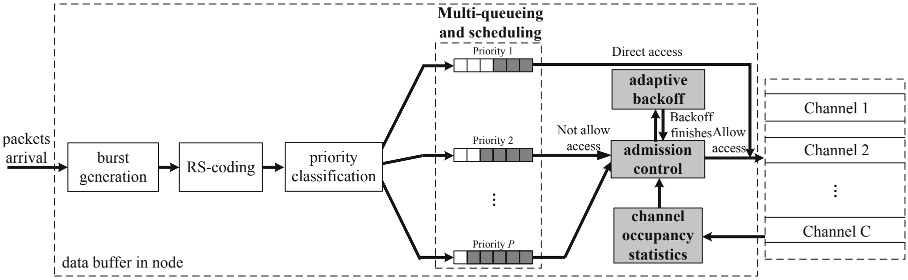


Fig. 1. Main components of the CTMA protocol.

(1) Burst generation module. In order to improve the reliability of packet transmission in wireless channel, the CTMA protocol employs the burst communication, i.e., each packet is split into short bursts to be transmitted in channel. Therefore, each packet arrived from the upper layer is firstly split into a bunch of bursts with equal length.

(2) RS-Turbo coding module. After burst generation, each burst is coded with RS-Turbo to have a fault-tolerant ability [23].

(3) Priority classification module. In this module, each burst is classified according to their priority.

(4) Multi-queueing and scheduling module. In the buffer of each node, packets of each priority wait in an individual queue. And each priority maintains a First-In-First-Out (FIFO) queue. The arrived bursts will be discarded when the node buffer is full.
(5) Channel occupancy statistic module. This module records the number of bursts transmitted during a period of time in each channel in order to calculate the channel occupancy rate and provide reference to the subsequent admission control module.
(6) Channel threshold based admission control module. This module judges whether a burst can be accessed to channel immediately. If the channel occupancy rate is higher than the channel access threshold of the burst's priority, it cannot be transmitted immediately and the backoff mechanism will be started. If the channel occupancy rate is lower than its channel threshold, it will be accessed to channel.
(7) Adaptive backoff module. This module adopts a multi-priority backoff algorithm based on channel busy-idle sensing, and the contention window can be adaptively and dynamically adjusted with the occupancy of channel in real time. In this paper, for ease of analysis, we adopt a simplified backoff algorithm with a fixed contention window for all priority services. The multi-priority adaptive backoff mechanism for ATNs is described and analyzed in detail in [24].

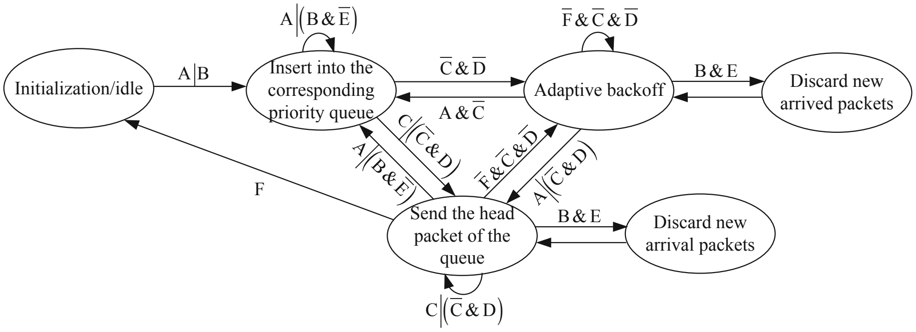
The node state transition in CTMA protocol is shown in Fig. 2. All nodes in the network work on the basis of the following state transition scheme. (1) In the state "initialization/idle", if the node receives a packet from the upper layer, the packet will be inserted into the corresponding priority queue. (2) When the packet is in head of the queue, the next state "send the head packet of the queue" or "adaptive backoff" will be judged according to the current channel occupancy state and the channel threshold of its priority. If the current channel load is lower than its channel threshold, it can enter the state "send the head packet of the queue"; otherwise, it will enter the state "adaptive backoff". (3) In the state "adaptive backoff" or "send the head packet of the queue", when new packets arrive, if the corresponding priority queue is not full, the packets will be insert into the queue, otherwise discard the packets. (4) After the state "send the head packet of the queue", the next state will be chosen in "send the head packet of the queue", "initialization/idle", and "adaptive backoff" according to whether all queues are empty and the current channel load.

2.2 Channel Occupancy Statistic Mechanism

For a fully connected network, all nodes can record the number of bursts received in the whole network during a period of time. As illustrated in Fig. 3, the current time is t_0, and the size of the statistic window is T_s. The number of bursts during $[t_0 - T_s, t_0]$ can be used to approximately represent the channel occupancy at t_0.

Define G_{total} as the number of bursts accessed to all channels. Since all nodes can record the number of bursts sensed in each channel, G_{total} can be obtained according to the total number of bursts sensed in all channel. Thus it is calculated as

$$G_{total} = \sum_{c=1}^{C} G_c, \tag{1}$$



A: Packets with priority 1 arrive; B: Packets with priority 2, 3, ···, P arrive;
C: The queue of priority 1 has packets; $\overline{C}$: The queue of priority 1 has no packets;
D: The channel load is lower than the channel threshold of the priority service;
$\overline{D}$: The channel load is equal to or higher than the channel threshold of the priority service;
E: The queue is full; $\overline{E}$: The queue is not full;
F: All queues are empty; $\overline{F}$: Not all queues are empty.

Fig. 2. Node state transition in CTMA protocol.

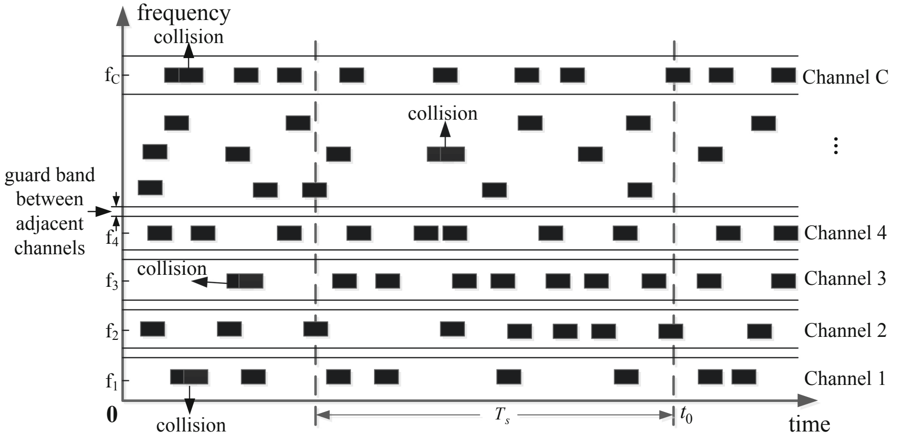


Fig. 3. Time and frequency state of multi-channel.

where G_c denotes the number of bursts sensed in channel c.

Define η as the mean channel occupancy rate, meaning the mean ratio of the total channel transmission time of all bursts received in T_s. So η can be calculated as

$$\eta = \frac{G_{total}}{C} \cdot \frac{T_{packet}}{T_s}. \tag{2}$$

2.3 Multi-priority Multi-queuing and Scheduling Mechanism

The priority of services in the network is denoted by p, where $p = 1, 2, \cdots, P$. $p = 1$ denotes the highest priority, and $p = P$ denotes the lowest priority. The arrival rate of the priority p packet is λ_p, and the time to transmit a priority p packet has a general distribution with mean $\bar{X}_p = E\left[X_p\right]$ and secondary moment $\overline{X_p^2} = E\left[X_p^2\right]$. If the time to transmit a packet has an exponential distribution, the queueing system is changed to a multi-priority M/M/1 queueing system. Let the service rate be μ, and it satisfies that $E\left[X_p\right] = 1/\mu$ and $E\left[X_p^2\right] = 2/\mu^2$. If the packet size of each priority is fixed, the service time for each packet is a fixed value, and thus the queueing system is changed to a multi-priority M/D/1 queueing system. In this case, it satisfies that $E\left[X_p\right] = 1/\mu$ and $E\left[X_p^2\right] = 1/\mu^2$. We define $\lambda = \sum_{p=1}^{P} \lambda_p$ as the aggregate arrival rate of all packets, $\rho_p = \lambda_p E\left[X_p\right]$ as the utilization of the server by the priority p packets, and $\sigma_k = \sum_{p=1}^{k} \rho_p$ as the utilization of the server by the priority 1 to k packets. Let W_p be the waiting time of priority p packets, and let T_p denote the total time that a priority p packet spends in the system, namely the sojourn time.

Due to the backoff mechanism, before the service for a priority p $(p > 1)$ packet, the node needs to judge whether it can be served immediately according to the current channel state. If it does not satisfy the service condition, the server will start a vacation. After the vacation, the node needs to judge once again. If it still does not satisfy the service condition, another vacation will be started. The process is repeated until the service for the packet is started. For the priority p $(p > 1)$ packet, the probability of server's vacation is denoted as P_p^{vac}. Obviously, it satisfies that $P_2^{vac} < P_3^{vac} < \cdots < P_P^{vac}$. For any priority p $(p > 1)$ packet, the server's vacations are denoted as $V_1, V_2, \cdots, V_m$, where V_i is an independent and uniformly distributed random variable on interval $[0, W]$ with mean $\frac{W}{2}$. For a priority p $(p > 1)$ packet, the number of times of server's vacation is represented by m_p, where $m_p = 0, 1, 2, \cdots$. Obviously, the expected value of m_p can be expressed as

$$E\left[m_p\right] = \sum_{i=0}^{\infty} i\left(P_p^{vac}\right)^i\left(1 - P_p^{vac}\right) = \frac{P_p^{vac}}{1 - P_p^{vac}}. \tag{3}$$

Every priority service adopts the nonpreemptive policy. That is to say, if a higher priority packet arrives when a lower priority packet is being transmitted, the arriving higher priority packet will wait until the lower priority packet's transmission is completed. Thus, any packet that enters for transmission will complete the transmission without interruption.

According to the multi-priority queueing theory, without considering the server's vacations, the mean waiting time of the priority 1 packet is given by

$$E[W_1] = \frac{E\left[R_{pac}\right]}{1 - \rho_1}, \tag{4}$$

where $E\left[R_{pac}\right]$ is the expected residual service time for all priority packets. From renewal theory we know that

$$E\left[R_{pac}\right] = \frac{1}{2}\sum_{p=1}^{P}\lambda_p E\left[X_p^2\right]. \tag{5}$$

For the highest priority packets, the server's vacations could not influence the service for them obviously. Thus, the mean waiting time of the priority 1 packet is invariable, i.e.,

$$E[W_1] = \frac{\sum\limits_{p=1}^{P}\lambda_p E\left[X_p^2\right]}{2(1-\rho_1)}. \tag{6}$$

The waiting time of the priority 2 packet contains the residual service time of the packet receiving service when it arrives, the time to serve the priority 1 packets which are in queue, the service time and backoff time of the priority 2 packets which are in queue, the time to serve those priority 1 packets who arrive while the tagged priority 2 packet is waiting to be served, and the backoff time of the tagged priority 2 packet. Thus, its mean waiting time is

$$\begin{aligned} E[W_2] = E[L_1]E[X_1] + E[L_2]E[X_2] + \lambda_1 E[W_2]E[X_1] \\ + E[L_2]E[m_2]E[V] + E[m_2]E[V] + E\left[R_{pac}\right] \end{aligned}, \tag{7}$$

where $E[L_1]$ and $E[L_2]$ respectively represents the expected number of priority 1 packet and priority 2 packet waiting in queue when the tagged priority 2 packet arrives. From Little's formula we have $E[L_1] = \lambda_1 E[W_1]$ and $E[L_2] = \lambda_2 E[W_2]$. This gives that

$$E[W_2] = \frac{\rho_1 E[W_1] + E\left[R_{pac}\right] + E[m_2]E[V]}{1-\rho_1-\rho_2-\lambda_2 E[m_2]E[V]}. \tag{8}$$

According to (2) and (6), we can obtain that

$$E[W_2] = \frac{2E\left[R_{pac}\right] + W(1-\rho_1)E[m_2]}{(1-\rho_1)(2-2\rho_1-2\rho_2-W\lambda_2 E[m_2])}. \tag{9}$$

Following the same approach used for the priority 2 packet, for a priority 3 packet, we have that

$$E[W_3] = \frac{2(1-\rho_1)E[W_2] + W(E[m_3]-E[m_2])}{2-2(\rho_1+\rho_2+\rho_3)-W\lambda_3 E[m_3]}. \tag{10}$$

By continuing in the same way, we can obtain the mean waiting time of a priority p ($p \geq 3$) packet as

$$E\left[W_p\right] = \frac{2\left(1-\rho_1-\cdots-\rho_{p-2}\right)E\left[W_{p-1}\right] + W\left(E\left[m_p\right]-E\left[m_{p-1}\right]\right)}{2-2\left(\rho_1+\cdots+\rho_p\right)-W\lambda_p E\left[m_p\right]}. \tag{11}$$

The mean sojourn time of a priority p packet is

$$E\left[T_p\right] = E\left[W_p\right] + E\left[X_p\right]. \tag{12}$$

The mean sojourn time of all priority classes is

$$E[T] = \frac{\sum\limits_{p=1}^{P} \lambda_p E\left[T_p\right]}{\sum\limits_{p=1}^{P} \lambda_p}. \tag{13}$$

The mean queue length of priority p is

$$N_Q^k = \lambda_k E[W_k]. \tag{14}$$

2.4 Channel Threshold Based Admission Control Mechanism

In the channel threshold based admission control mechanism, the key problem is to acquire the optimal channel threshold for each priority service (except the highest priority service).

Let λ_c^{in} denote the burst access rate in channel c, and k denote the number of burst transmitted in channel c during the unit time σ. According to the Poisson Equation, the probability that k bursts are transmitted in channel c during σ is

$$P_c^{in}(k) = \frac{e^{-\lambda_c^{in}}\left(-\lambda_c^{in}\right)^k}{k!}. \tag{15}$$

According to the principle of CTMA protocol, if G_c is lower than the channel threshold T_p^{ch} of the priority $p(p > 1)$ service, the bursts of priority $p(p > 1)$ can be accessed to channel c. Thus, the probability that the burst can be accessed to channel c is

$$p_p^c = P\left\{G_{\alpha-pre}^m < T_p^{ch}\right\} = \sum_{k=0}^{T_p^{ch}} P_c^{in}(k). \tag{16}$$

Therefore, the probability that the burst of priority $p(p > 1)$ chooses channel c to be accessed is

$$p_r^p = p_p^c \cdot C_{C-1}^S \prod_{r \in G(r,S)} \left(p_p^c\right)^S \frac{1}{S+1} \cdot \prod_{r \in G(r,C-1-S)} \left(1 - p_p^c\right)^r, \quad S \in [1, C-1], \tag{17}$$

where $G(r, S)$ indicates the set of S channels (not including channel r) to which the burst can be accessed, and $G(r, M - 1 - S)$ indicates the set of $M - 1 - S$ channels (not including channel r) to which the burst cannot be accessed.

Hence, the access rate of burst with priority 1 to channel c is $\frac{1}{\lambda_1^{-1}+E[T_1]} \cdot \frac{1}{C}$, and the access rate of burst with priority $p(p > 1)$ to channel c is

$$\lambda_c^{in} = \frac{1}{\lambda_1^{-1} + E[T_1]} \cdot \frac{1}{C} + \sum_{p=2}^{P} \frac{p_p^{in}}{\lambda_p^{-1} + E\left[T_p\right]}, \tag{18}$$

According to (15) to (18), λ_c^{in} and p_r^p can obtained. Here p_p^{in} is defined as the probability that bursts of priority p can be accessed to channel, and it is easy to acquire that

$$p_p^{in} = \sum_{r=1}^{C} p_r^p. \tag{19}$$

Assume that the time intervals of bursts obey exponential distribution with parameter λ_c^{in} in a single channel, so the probability density function of time interval on arbitrary channel is deduced as

$$f(t) = \lambda_c^{in} \cdot e^{-\lambda_c^{in} t}. \tag{20}$$

Define P_{bur_suc} as the burst successful transmission probability, and it can be calculated as

$$P_{bur\_suc}{=}e^{-2\lambda_c^{in} T_{burst}}. \tag{21}$$

Define P_{pac_suc} as packet successful transmission probability. According to RS-Turbo theory, only if M_{burst} bursts are successfully received, the original packet can be recovered by receiving terminals. According to the permutation and combination theory, the packet successful transmission probability can be calculated as

$$P_{pac\_suc} = \sum_{k=M_{burst}}^{N_{burst}} C_{N_{burst}}^{k} \cdot \left(P_{bur\_suc}\right)^k \cdot \left(1 - P_{bur\_suc}\right)^{N_{burst}-k}. \tag{22}$$

$T_{\max}^{ch}$ is defined as the maximum access rate of the whole network. Different thresholds for other priority services are set to guarantee the requirement of the highest priority service. Suppose the ratio of packet arrival rate of priority $1, 2, \cdots, P$ is $k_1 : k_2 : \cdots : k_P$, and thus T_p^{ch} can be calculated as

$$T_p^{ch} \left(\frac{\sum\limits_{r=1}^{p} k_r}{\sum\limits_{r=1}^{P} k_r} \right) = T_{\max}^{ch}. \tag{23}$$

3 Performance Analysis

3.1 Successful Transmission Probability of Each Priority

Let P_{suc}^{p} be the packet successful transmission probability of priority p. It can be easily acquired that

$$P_{suc}^{p} = p_{p}^{in} \cdot P_{pac\_suc}. \tag{24}$$

3.2 Mean Delay of Each Priority

Let $E\left[T_D^p\right]$ be the mean delay of priority p, defined as the during from a packet entering the buffer of sender to the receiver. $E\left[T_D^p\right]$ is composed of the mean sojourn time and the propagation delay of the packet with priority p. As discussed in Sect. 2.3, for the packet with priority 1, the mean sojourn time $E[T_1]$ only contains the mean queuing time and the transmission delay. For the packet with priority $p(p > 1)$, the mean sojourn time $E\left[T_p\right]$ contains the mean queuing time, mean backoff time and the transmission delay.

Define $E\left[T_{pro}\right]$ as the packet propagation delay, and its value is related to the communication distance. Let L' be the maximum communication distance in a single hop, and c is the speed of light. So $E\left[T_{pro}\right]$ can be calculated as

$$E\left[T_{pro}\right] = \frac{L'}{2c}. \tag{25}$$

Therefore, T_D^p can be expressed as

$$E\left[T_D^p\right] = E\left[T_p\right] + E\left[T_{pro}\right]. \tag{26}$$

4 Simulations

In this section, we will verify the performance of CTMA protocol through simulations in OMNeT++. The simulations are based on the following assumptions:

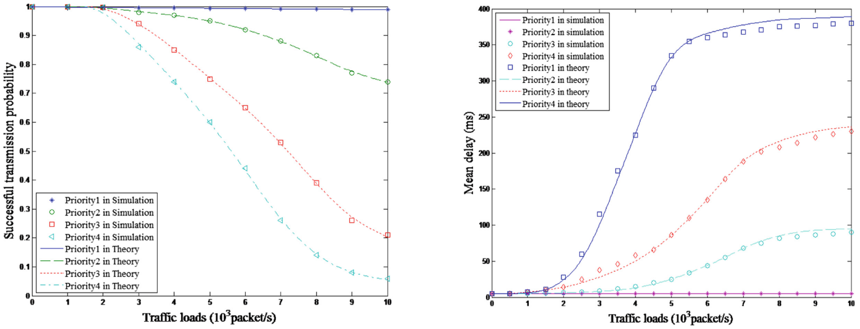
(1) All nodes are randomly distributed among the scenario in the beginning, and make uniform linear motions with the speed of 300 m/s and random directions in simulations. A fully connected ATN is formed by all nodes.
(2) Every node has a sending pathway and multiple receiving pathways as many as the channels. The receiving pathways are not blocked when packet are sending.
(3) The traffic in the network has 4 priorities. The arrival of packets obeys the Poisson distribution. All packets of any priority are of the same length and data transmission rate, and packets of the same priority are of the same packet arrival rate.
(4) When bursts are accessed to channels, the channel is chosen randomly among all channels.

Table 1. Simulation parameters.

Parameter	Value	Parameter	Value
Number of nodes	50	Number of channels	10
Data transmission rate on each channel	2 Mbit/s	Packet length	600 bits
Number of bursts that a packet is divided into (N_{burst})	30	Ratio of packet arrival rates of different priority (from high to low)	1:2:4:6
Minimum bursts needed to be recovery a packet (M_{burst})	15	Node communication range	250 km
Scenario size	600 × 600 km^2	Node speed	300 m/s

In simulations, the lower limit of the successful transmission probability for priority 1, 2, 3 is set as 99%, 80% and 60%, respectively. Hence, according to the mathematical model, the channel threshold T_2^{ch}, T_3^{ch} and T_4^{ch} can be obtained. The detailed simulation parameters are shown in Table 1.

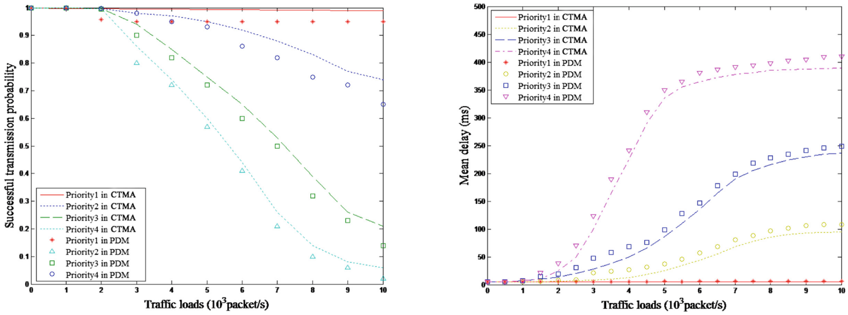
Firstly, we will show the comparison of theoretical results and the simulation results in the CTMA protocol. The effects of traffic loads on network performance of each priority in CTMA protocol is shown in Fig. 4. The theoretical results match well with the simulation results on the whole, which indicates the correctness of the mathematical model. As is depicted in Fig. 4, the performance of different priorities has a great difference, because of their different channel threshold. In light load condition, each priority has high successful transmission probability and low delay. However, in heavy load condition, the performance of low priority becomes worse with the increase of load, while that of the highest priority almost keeps stable. Furthermore, the mean delay for each priority tends to reach their life cycle under heavy load.



(a) Successful transmission probability. (b) Mean delay.

Fig. 4. Network performance of each priority in CTMA protocol.

In the following, we will compare the performance of CTMA protocol with that of the PDM protocol proposed in [21]. The simulation results are shown in Fig. 5, containing the successful transmission probability and the mean delay. As is depicted in Fig. 5(a), the successful transmission probability of the highest priority in CTMA protocol can maintain at 99% all the time with increase of the channel load, but that of PDM protocol can only reach 95%. As is shown in Fig. 5(b), the mean delay of the highest priority in CTMA protocol can maintain at 2 ms with increase of the channel load, but that of PDM protocol is about 7 ms.



(a) Successful transmission probability. (b) Mean delay.

Fig. 5. Comparison of network performance between CTMA and PDM protocol.

5 Conclusions

In this paper, we propose a novel multi-priority differentiated, multi-channel and distributed random contention MAC protocol based on channel awareness for ATNs. This protocol contains four main parts, i.e., channel occupancy statistic mechanism, multi-priority queueing and scheduling mechanism, channel threshold based admission control mechanism, and adaptive backoff algorithm. We further model the protocol mathematically, acquire its optimal channel threshold, and show its performance through simulations. The protocol can differentiate services for different priorities in ATNs according to the real-time channel state, and provide effective QoS guarantee for transmissions of various information. In the future, we will further improve and optimize the protocol, ensuring the QoS requirement of high priority, as well as enhancing the throughput of low priority as much as possible.

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