

Modeling and Performance Analysis of Statistical Priority-based Multiple Access Protocol

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Abstract—As the rapid development of wireless communication, a growing number of communication systems generate multi-priority traffic, and different priority traffic has different requirements on delay and loss rate. Statistical priority-based multiple access protocol (SPMA) can be applied to these systems by virtue of its high-reliability and low-delay characteristics. In this paper, we propose a non-preemptive M/M/1/K queuing model to analyze the performance of different priority traffic in SPMA in terms of the average packet loss rate and the average packet delay. Firstly, we take no account of threshold of channel occupancy. Through analyzing the process of state transition, we can get the steady-state probability of the model. The loss rate and delay can be obtained based on the steady-state probability. Then, we extend to the case in consideration of threshold. Extensive simulations demonstrate that loss rate values and delay values obtained from our analytical model closely match the simulation results under various offered loads. More importantly, our model can enable designers to obtain a better understanding of the effect of protocol parameters on the performance of SPMA.

I. INTRODUCTION

The statistical priority-based multiple access protocol (SPMA) is designed for long-range, high-speed, large-capacity, high-dynamic communication system, such as U.S. military Tactical Targeting Network Technology (TTNT) or flying ad hoc network (FANET) [1]. In contrast with classic MAC protocol, for instance, time division multiple access (TDMA), carrier sense multiple access (CSMA), SPMA can support multi-priority traffic, and guarantee high first-time success rate and low delay for high-priority traffic [2]. Therefore, SPMA is gaining more and more interest as the rapid development of the tactical network communication.

Recent years, there are various related studies on SPMA. In [2], channel occupancy statistic was replaced by traffic statistic, which can effectively control the actual channel load in a reasonable level. Based on the proposed algorithm, the theoretical formula of success rate and access delay was derived. In [3], Wei, Zhang et al. proposed a priority threshold and conflict backoff algorithm for SPMA, which can maintain an optimized network traffic under high load. In [4], Markov model and queuing theory were used to deduce the protocol performance expressions of modified SPMA protocol. However, the theoretical analysis in previous researches had some assumption which were not suitable for standard SPMA. For instance, last in first out (LIFO) queuing model was used in [2], and [4] assumed that the arrival rate of high-priority traffic was far less than low-priority traffic and the queuing model

was preemptive. Thus, building an accurate model for SPMA has become an attractive task.

In this paper, we propose a non-preemptive M/M/1/K queuing model to analyze the average packet loss rate and the average packet delay of different priority traffic in SPMA. Our theoretical model is validated by simulations. It shows that the loss rate obtained from our analytical model matches simulation results within 5%, and the delay obtained from the analytical model matches simulation results within 5%. Our model can be used to evaluate the performance of SPMA under various offered loads, and provide a better understanding of the effect of protocol parameters on the performance of SPMA, which can help designers to optimize SPMA protocol and configure parameters of that.

The rest of the paper is organized as follows. In section II, we introduce SPMA protocol and overview the queuing model for SPMA. We then present theoretical analysis on performance of SPMA details in section III. The simulation results are presented in section IV to verify our model. Finally, Section V wraps up the paper with conclusions.

II. SYSTEM MODEL

A. SPMA Introduction

SPMA can be viewed as a generalization of CSMA for spread spectrum systems. SPMA is similar to CSMA in that the state of the channel is sensed [1]. However, it has some different characteristics from CSMA. In SPMA, the channel may take on many different states depending on the amount and characteristic of the traffic that is sensed on the channel, not only busy or idle state.

In SPMA systems, one individual priority queue and a predefined threshold value are assigned for each priority traffic. Because SPMA supports full-duplex mode, a node can receive packets anytime. When a packet enters the data link layer, it will be put into the corresponding priority queue. When the queues are not empty, it will choose the highest priority packet in all priority queues to transmit. The packet will be discarded if it expires. Then the current channel occupancy statistic (COS) is compared against the threshold of this priority. The value of COS is the ratio of the busy time in the statistic time interval. If COS is below the threshold, the packet will be transmitted immediately. Otherwise, the node will wait a random backoff interval, which is related to the priority, and recheck COS when backoff is finished. During this backoff interval, if the node receives a packet with lower priority,

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