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Dynamic and distributed packet aggregation to solve the performance anomaly in 802.11 wireless networks ☆

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Abstract

In the widely used IEEE 802.11 standard, the so-called *performance anomaly* is a well-known issue. Several works have tried to solve this problem by introducing mechanisms such as packet fragmentation, backoff adaptation, or packet aggregation during a fixed time interval. In this article, we present and thoroughly analyze PAS, a dynamic and distributed approach solving the performance anomaly problem. PAS is based on packets' aggregation using a dynamic time interval, which depends on the wireless channel occupation time perceived by each node. Since each station senses the medium independently, this makes PAS a totally distributed solution. Even more, PAS may coexist with standard IEEE 802.11 nodes without any particular adaptation, yet being able to improve performance. Our solution differs from other propositions in the literature because of its dynamic and distributed nature, which makes it suitable in the context of multi-hop networks. Furthermore, it allows increasing fairness, reactivity, and in some cases efficiency. In this article, we thoroughly analyze and emphasize the performance evaluation of our proposal.

Keywords: IEEE 802.11; MAC protocol; Anomaly; Algorithm

1. Introduction

Performance anomaly is a key issue in IEEE 802.11 multi-rate wireless networks. It decreases the network global performance because of bad time sharing between stations transmitting at high bit rate (fast stations) and stations transmitting at low bit rate (slow stations). This bad time sharing causes an unfair throughput, with slow stations throttling fast stations' traffic [4].

Several solutions have been proposed in the literature to solve this problem. Some of them are based on a static predefined time sharing between slow and fast stations, by shaping the MTU (maximum transmission unit) on a transmission rate basis.

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Other approaches set a maximum amount of time a station can hold the medium, like with the TXOP (transmit opportunity) introduced in the IEEE 802.11e standard. Finally, other approaches try to adapt the contention window size of IEEE 802.11, according to the transmission rate of the station.

The main problem of existing solutions is that they are static or centralized. In this paper, we tackle both issues, solving the performance anomaly with a dynamic and distributed approach. Our solution is dynamic because it introduces a transmission time, as the TXOP, that changes depending on the perceived channel occupancy, which evolves with the traffic load of the network. Our solution is a distributed approach because each node computes locally the maximal channel occupancy time. The carrier sensing mechanism provided by IEEE 802.11 natively allows this computation. Once a node gains access to the medium, it can send a burst of packets. The number of transmitted packets is limited by the computed transmission time, which depends on the maximal occupancy time perceived by the station.

In this article, besides presenting our solution, which we called PAS, we also propose an analytical evaluation in a classical scenario where all stations are within communication range. A detailed and careful simulation-based evaluation is also given. We evaluate our protocol both in terms of efficiency and of fairness on many configurations, not limited to single-hop networks. We also analyze the improvements provided by our approach on both UDP and TCP traffic. Furthermore, we compare our solution to three different approaches that belong to the three main classes of solutions solving the performance anomaly. This article is an extended version of [12], which includes more performance evaluation results, protocol details, evaluation using TCP traffic, and the impact of the RTS/CTS mechanism.

The remainder of the paper is organized as follow. We give a short overview on the IEEE 802.11 access function, and describe the performance anomaly in Section 2. In Section 3 we propose a review of the existing modifications of the IEEE 802.11 solving the performance anomaly. In Section 4 we describe PAS, our proposal. In Section 5 we propose an analytical evaluation for a specific topology while in Section 6 we carry out extended simulations to evaluate the performance of our approach. We also study the impact of the different parameters of PAS on various scenarios. Finally, we conclude the paper with the perspectives raised by this work in Section 7.

2. The performance anomaly

The IEEE 802.11 standard [11] provides a fully distributed medium access protocol, called the distributed coordination function (DCF). The DCF belongs to the carrier sense multiple access with collision avoidance (CSMA/CA) family of MAC algorithms. Basically, the emitters have to wait for the channel to become idle before sending a frame. This frame is also protected by a collision avoidance mechanism.

In particular, when a frame is ready to be emitted, the emitter first waits until it senses the medium idle for a fixed amount of time called DIFS (distributed inter frame space). Once this condition has been achieved, the emitter generates a random number called *backoff* within an interval called *contention window* (CW). This number indicates the amount of time to be waited before really transmitting the frame. The backoff is a simple collision avoidance mechanism, since it strongly reduces the probability of colliding transmissions for synchronized emitters. If, while the backoff is decreased, the medium becomes busy, the decrementing process is stopped. When the medium becomes idle again, the station waits for a DIFS time before restarting to decrease its remaining backoff. As soon as the backoff reaches 0, the frame is emitted. Since collision detection is not possible, each unicast frame has to be acknowledged. When a receiver successfully receives a frame, it waits for a SIFS (short inter frame space) time and then emits the acknowledgment. The SIFS is shorter than the DIFS in order to give priority to acknowledgments over data frames. The lack of the reception of an acknowledgment is considered as a collision. In that case, the CW size is doubled and the same frame is emitted again with the same process described previously. If another collision happens, the CW size is doubled again if it has not yet reached the maximum value defined by the standard. After a fixed number of retransmissions, the frame is dropped. The CW size is reset when a frame is dropped or after a successful transmission.

Heusse et al. [4] have shown that the presence of slow stations in a multi-rate wireless network slows down all other stations. During the transmission of a slow station the medium is busy for a longer period than during the transmission of a fast station,