Use of Different Acknowledgement Policies for Burst Transmission in Fiber-fed Wireless LANs

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Abstract—**The IEEE 802.11e Medium Access Control (MAC) for Quality-of-Service (QoS) support in 802.11 networks defines burst transmission and new acknowledgment (ACK) operations as optional mechanisms for increasing channel utilization. In this paper, we evaluate the performance of these new features in high speed Wireless LAN (WLAN) over fiber networks. It is shown that the negative effect of the fiber delay on the throughput performance of the MAC protocol can be significantly reduced when burst transmission is used with the Block or the No ACK policies.**

Index Terms— **IEEE 802.11e, medium access control, Radio over Fiber, wireless LAN**

I. Introduction

THE recent success of the IEEE 802.11 Wireless LAN (WLAN) standards [1] has drawn the attention of the radio over fiber (RoF) community, in constructing low-cost, WLAN over Fiber networks. The feasibility of inserting an optical path in 802.11 WLANs has already been reported in the literature [2], [3]. However, since the extra delay that the fiber inserts in the propagation time might violate some of the MAC timing boundaries [4]-[6], there is concern regarding the performance of the protocol in the wide range of scenarios where these systems might be used.

Recent studies have shown that the performance of the Distributed Coordination Function (DCF) will fall with an increase in the inserted fiber length due to the extra time needed for the acknowledgment (ACK) procedure and also due to the increase in the number of collisions [4], [5]. One of the mechanisms of the original DCF which can reduce the number of collisions, and therefore benefit WLAN over fiber, especially when hidden nodes are present, is the Request-to-Send/Clear-to-Send (RTS/CTS) exchange [6]. However, compared to conventional (non-RoF) WLANs, the channel utilization still remains low for in WLAN over fiber systems for very long fibers and high contention levels. Therefore, it is necessary for RoF networks to exploit new MAC features in order to enhance their performance.

The IEEE 802.11e extension for Quality of Service (QoS) [7] has emerged not only as a contribution to the QoS provisioning for different services, but also as an effort to allow the MAC to keep pace with the dramatic increase in the data rate that the Physical Layer (PHY) technologies can achieve [8]. The Enhanced Distributed Channel Access (EDCA), which is the contention based access mechanism of the 802.11e extension, supports the increase in the system's efficiency by the definition of new transmission operations: burst transmission and its different ACK policies (block ACK and no ACK). Compared to the extensive research on the QoS provisioning [9] the new transmission operations have received less attention. Nevertheless, through their use, channel utilizations of up to 85% have already been reported for conventional 802.11b networks [10]. Clearly the decrease in the contention overhead due to burst transmission and also in the number of ACK packets necessary contribute to this increased efficiency. However, to-date there has been no study on the effect of these new transmission operations on the performance of 802.11 over fiber networks.

In this paper we compare the performance of data transmission bursting with different ACK policies in an EDCA over fiber network. The new transmission operation concepts introduced in the 802.11e extension are given next. Then we present the results of our simulation study on the application of these new mechanisms in an 802.11g over fiber network, and finally, draw conclusions.

II. IEEE 802.11e EDCA Transmission Operations

EDCA supports differentiated channel access and increased system efficiency by enhancing the former DCF access. In this paper we focus only on the latter aspect of the enhancements that the EDCA provides.

Similarly to DCF, EDCA is based on a carrier sense multiple access with collision avoidance (CSMA/CA) scheme where nodes can transmit to the common channel, following exponential backoff rules, only after sensing the medium as idle continuously for a specified Interframe Space (IFS) interval. Differently to DCF, where after winning the contention a node gains the right to transmit on the channel an entire MAC Service Data Unit (MSDU), under EDCA, a node gains a transmission opportunity (TXOP), which is an interval whose maximum duration is limited by the *TXOP limit* threshold parameter. During a single contention win a node

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may transmit within a TXOP a burst of MAC Protocol Data Unit (MPDU) frames which are separated by the short IFS (SIFS) and might belong to different MSDUs.

EDCA also introduces new rules on how or whether the frames received at the destination will be acknowledged. Under DCF, on successful reception of a frame, after a SIFS the destination will respond immediately with an ACK packet. Only after reception of the ACK will the source continue with the next frame, otherwise a retransmission will occur. In order to reduce wasted time, the EDCA defines two new optional ACK operations: the block and the no ACK policies. The block ACK policy allows a specified number of frames to be transmitted, separated by a SIFS interval continuously, without being acknowledged immediately. Only when all the frames in the block are transmitted and after an explicit request from the source, will the destination acknowledge the transmissions with a block ACK packet, transmitted at the same rate as the data frames. The block ACK frame contains information about the reception status of each of the individual frames contained in the block transmitted, and any corrupted frames will be retransmitted in another burst. The No ACK procedure requires no MAC level acknowledgments. In order to reduce the probability of collisions during the TXOP, a protective mechanism such as RTS/CTS should be used [7].

III. Performance Evaluation

In our simulations we investigate a WLAN over fiber network which uses the 802.11g PHY, operating in ideal channel conditions. The mobile stations (MS) transmit at 54 Mbps via an Access Point. The frame sizes are distributed uniformly in the range of [1000, 2000] bytes. All MSs operate in the saturated regime and have the same channel access probability.

A. Burst Transmission

WLAN over fiber systems are expected to benefit from burst transmission for the same reasons as conventional WLANs: the reduction in the contention overhead (the time wasted due to the channel access procedure and due to collisions which might occur due to simultaneous transmissions).

Indeed, the results in Fig. 1(a), which plot for a single MS the variation of throughput with fiber delay for three different TXOP limit threshold values, show that with the increase in the TXOP limit, due to lower contention overhead, the efficiency does in fact increase. As an example, compared to the DCF access, for a TXOP limit of 6.016ms and fiber delay of 4.5µs (i.e., 900m fiber) there is a 14% increase in the system's efficiency whereas this falls to 9.1% for the longer fiber delay of 45µs (i.e., 9km fiber). The apparent deleterious effect of fiber delay in this case is due to the increase in the time needed for the ACK procedure to be performed, as the delay the fiber inserts increases. The results also show that basic DCF gives similar performance to the EDCA for a TXOP limit chosen such that only 1 MSDU frame can be transmitted during its duration.

The improvements are more significant for higher numbers

TABLE I
DATA DROPPED DUE TO COLLISIONS (BITS/SEC) FOR 5 CONTENDING MS

TXOP	Fiber Delay (µs)						
	0	1.5	4.5	9.0	45	90	147
1 MPDU	4853	1991	6051	61239	477246	797189	948277
1504 µs	2123	2001	2703	23143	206651	436949	585895
3008 µs	0	0	0	11709	137730	260289	359462
6016 µs	0	0	0	5977	70116	119632	216804

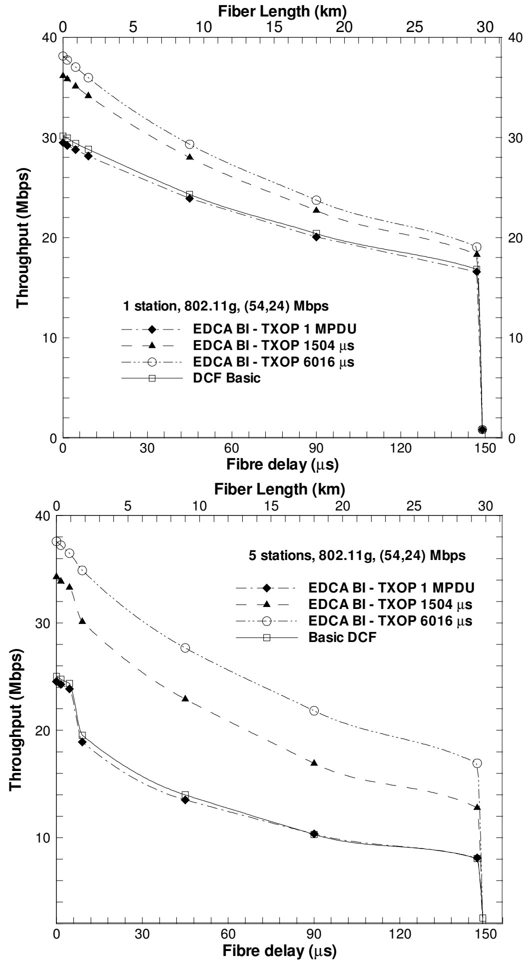

Fig. 1. Variation of throughput with fiber length using Basic access burst transmissions with Immediate ACK (BI) (a)1 MS (b) 5 MSs

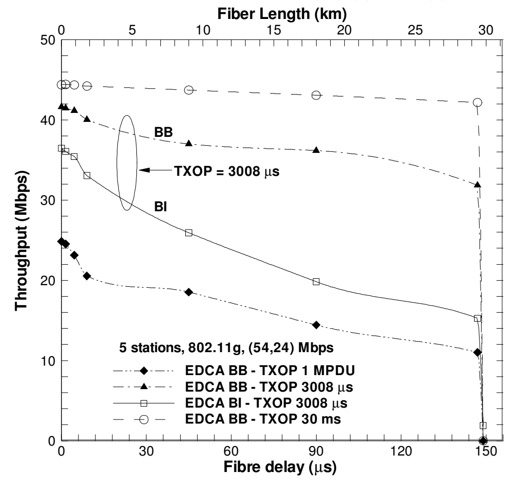

Fig. 2. Throughput vs. fiber length for Basic access burst transmission with Block ACK (BB) and immediate ACK (BI) policies for 5 MSs.

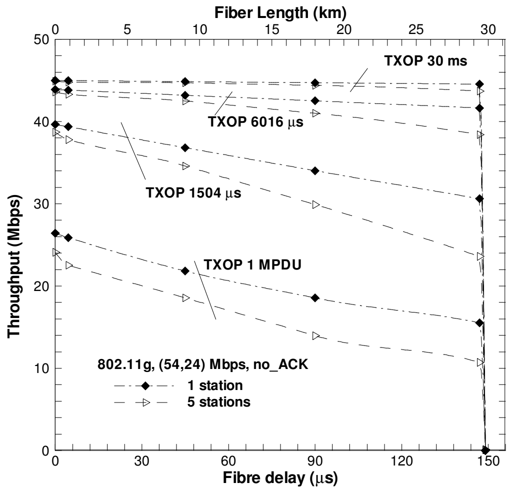

Fig. 3. Variation of throughput with fiber length for the no ACK policy for the single and multistation scenarios

of MSs where the larger TXOP limit values also lead to a reduction in the number of collisions, as the results shown in Table I for 5 contending MSs indicate. The corresponding throughput results plotted in Fig. 1(b) also indicate the increase in the system's efficiency. Specifically, for a TXOP of 6.016ms there is a 22% efficiency increase for 900m fiber compared to the DCF Basic Access case, whereas the efficiency increases by 26% for 9km of fiber.

B. Block and No ACK policies

Wasted channel time due to the ACK procedure is more severe in RoF networks due to the fiber delay. Therefore, it is expected that by using the block ACK operation, these networks will benefit more than conventional WLANs. In addition, since one of the reasons for performance degradation in WLAN over fiber systems is the increased risk of collisions because the medium might be sensed idle while an ACK signal is propagating in the fiber, further benefits are expected due to the decrease in the number of ACK packets circulating in the network.

These intuitive conclusions are verified by the results shown in Fig. 2, which for 5 contending MSs and different TXOP values plot the variation of throughput with fiber length when burst transmission is used with the block ACK policy. To show the extra benefits gained from the use of Block ACK, results are also plotted for one case when burst transmission is used with immediate ACK (i.e., for a TXOP of 3.008ms). Our results clearly indicate that for longer fiber lengths where the collision probability increases, the improvements are more significant. Specifically for TXOP 3.008ms there is a 31% increase in the system efficiency for fiber delay 4.5μs, whereas it improves to 48% for the 45μs delay. Probably the most interesting observation here is that for larger TXOP values, the fiber length no longer significantly affects the throughput.. Specifically, for a TXOP 30ms there is only a 5% efficiency decrease for 29 km of fiber.

The no ACK policy totally eliminates the wasted time due to the ACK procedure. Fig. 3, which plots the variation of throughput with fiber length for two different number of contending stations (1 and 5 MSs) and different TXOP values, shows that the use of the no ACK operation results in even further throughput increases for both single- and multi-station cases. Channel efficiencies of up to 83% can be achieved whereas the effect of fiber delay is further diminished. Specifically, there is only a 2.2% efficiency decrease for a TXOP of 30ms when 5 stations operate in the network.

The sudden drop in throughput in all scenarios presented (Figs. 1 - 3) indicates that the maximum fiber length is still limited by the ACK or the CTS timeout parameters [5, 6].

IV. Conclusion and Future Work

Burst transmission operation via definition of TXOP values can be beneficial in reducing the negative effects of fiber delay in 802.11 fiber-fed networks, especially when used with the block or the no ACK policy. However, channel errors might have an impact on the performance of these mechanisms, especially when the no ACK operation is used since it does not provide MAC level recovery and the traffic might have to rely on the error recovery mechanisms of the layers above. The effect of media error on the performance of the new transmission operations and the interlayer interaction will be the focus of our work in the future.

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