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# Impact of device unavailability on the reliability of multicast transport in IEEE 802.11 networks

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ABSTRACT

Multicast transport is an efficient solution to deliver the same content simultaneously to many receivers. This transport mode is mainly used these days to deliver real-time video streams. However, multicast transmissions support over IEEE 802.11 networks does not provide any feedback policies, which implies a definite loss of missing packets. This impacts the reliability of the multicast transport and the application employing it. An alternative to improve the reliability of multicast streaming over 802.11 networks is to prevent packet losses. In this perspective, it is necessary to identify the loss causes and to perform the required prevention actions. It is well known that collisions and path loss are two fundamental sources of transmission failures. Their impact can be eliminated by means of collision prevention and data rate adaptation. However, several works show that the loss rate of multicast packets may be considerable even in collisions-free environments and using an appropriate transmission rate. Particularly they show that losses may have a bursty nature which does not correspond to the bit error rate model of the PHY layer as defined by the chipset manufacturers. Therefore, in this paper, we carry out a thorough investigation of the loss causes in wireless networks. We show that device unavailability may be the principal cause of the significant packet losses that occur and their bursty nature. Particularly, our results show that the CPU overload may incur a loss rate of 100%, and that the delivery ratio may be limited to 35% when the device is in the power save mode.



## 1. Introduction

Packet losses in a WLAN may occur due to many factors. These losses reduce the network throughput, impact the reliability of the wireless link, and increase the transmission delays. This is because missing packets are considered as wasted transmission time, and retry-based protocols require additional delays to send data again. Besides, the losses reduce the delivery ratio of multicast and even unicast transmissions. Therefore, it is necessary to identify the factors that cause losses and perform the required actions so as to avoid transmission failures. This will enhance the reliability and the latency of multicast transport, and will improve network throughput. Interferences (including collisions) and path loss are two fundamental loss factors in wireless networks. Efficient mechanisms exist and are used to eliminate their impact. For instance, interferences are avoided by means of good planning of the available channels. Multicast packets are typically protected against collisions using CTS-to-Self [1] or Busy Symbol [2]. On the other hand, several rate adaptation schemes have been defined to select the appropriate transmission rate for multicast flows [3,4] to control the path-loss effect.

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However, many studies show that the loss rate can be significant even in the absence of interferences and when using an appropriate transmission rate. They also show that losses may occur in bursts. This loss pattern does not fit with the bit error rate model of the PHY layer as defined by the chipset manufacturers (see Figs. 14 and 15 of [5] for examples). Based on our hypothesis that transmission failures should occur individually and randomly, and our observation that the loss rate sometimes depends on the device itself, we argue that the device performance may be the main cause of the significant yet unexplained losses and their burstiness nature. It is worth noting that if losses are bursty due to the wireless channel, even the unicast transport becomes unreliable. This is because a packet and its retransmissions may be lost within a burst. This casts doubt on the reliability of the 802.11 unicast transport.

In this paper we carry out a comprehensive analysis of the loss factors in wireless networks using an experimental test-bed. We particularly focus on the case of multicast transport. We identify a new loss factor termed device unavailability. We show that the device is unable to process any packet when: (1) it is sleeping according to the Power Save (PS) mode; and (2) the Control Processing Unit (CPU) is overloaded with tasks exceeding the processing capability of the device. As such, we show that the device is itself responsible for missing several multicast packets and that the loss rate due to device unavailability may reach 100%. We highlight that this factor is widely ignored particularly in the field of wireless communications where mobile devices have limited battery and CPU resources. Furthermore, we provide recommendations for avoiding such losses and thereby enhancing the reliability of multicast transmissions.

The remainder of this paper is organized as follows. Section 2 discusses related work. Section 3 presents the PS mode and the evaluation of its impact on the delivery ratio and throughput of multicast flows. We introduce the CPU overflow issue and its impact on loss rate in Section 4. Finally, we conclude in Section 5.

## 2. Related works

There has been intensive work on analyzing the different causes of packet loss in wireless networks [6–24]. The underlying motivation is to understand the reliability of the wireless link and the variation of available bandwidth. Another motivation is to define rate adaptation algorithms at the sender that are aware of the loss sources and capable to decrease the transmission rate when necessary in order to maintain a reliable communication link with the receiver.

Most existing data rate adaptation algorithms [25–34] consider that losses in a WLAN occur either due to radio signal deterioration or due to collisions. The typical reaction to a reduced Signal-to-Noise-Ratio (SNR) is to decrease the transmission rate since a lower rate is always more robust. But if the rate adaptation algorithm believes that the transmission failure is caused by simultaneous channel accesses, it does not reduce the data rate and let the MAC layer increase the contention window in order to reduce the collision probability at the following transmission attempt.

In [6] the authors evaluated the impact of multipath fading and interferences on the loss rate of multicast packets. They deployed two networks operating at neighboring channels (namely, channels 10 and 11) in the same room. They showed that the loss rate varies between 2% and 7% in the presence of interferences from channel 10. Then they disabled the interfering network and they evaluated the impact of multipath on packet losses. They considered the scenario of a moving person in order to create reflections and showed that the average loss rate in this scenario is about 0.3%. Finally, they showed that the average rate falls to 0.1% in a static environment. The authors concluded that this variation is related to the multipath effect. However, we believe that a variation of 0.2% obtained using randomly chosen devices is not necessary enough to make important conclusions. Therefore it is necessary to prove that measurements are achieved using dedicated and precise equipment. Otherwise, the variation may be simply related to device unavailability. Therefore, the authors of [6] should show that the loss rate is not affected by the device unavailability, and should illustrate the variation of this rate over time to prove whether or not a variation of 0.2% is trustworthy and depicts the multipath effect.

In [7] the authors studied the correlation of packet losses as experienced by the receivers of multicast/broadcast streams. This is typically referred to as the spatial loss correlation. In their paper, the authors showed that closely located receivers loose the same packets almost all the time when the received signal is strong enough. This correlation decreases and the losses become independent when the radio signal deteriorates. In [34], the authors evaluated the loss rate as a function of the signal fluctuation. They introduced a new model to estimate the bit error rate of the wireless link based on the notion of effective SNR. Another experimental study was conducted in [8] where the loss rate of the multicast transport is measured, and the unfair sharing of the medium between unicast and multicast flows is evaluated. In this study, authors classified losses into three categories: "collisions", "queue overflow" and "others". However, they did not investigate the causes of transmission failures in the case of the third category. In [9] the authors collected loss traces from a real 802.11b network and studied their spatial correlation. They also evaluated the burstiness nature of the missing packets called temporal loss correlation. They showed that the loss rate varies between 4% and 30% from one receiver to another. In their testbed, the station with the highest loss rate (i.e., 30%) is the nearest one to the AP. This suggests that the device with the best link quality may experience the highest loss rate. Our work shows that device unavailability (PS mode and CPU overflow) may increase the loss rate significantly. Therefore, a receiver with good link quality but with bad configuration (in PS mode or with overloaded CPU) may experience high loss rate. We believe that this is the case in [9], where the device with the best link quality experiences the highest loss rate. The same observation is made in [10] where the authors confirm that identical devices perform quite differently in terms of