



## Experimental assessment of the effects of cross-traffic on Wi-Fi video streaming

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### ABSTRACT

Wi-Fi networks are the first and sometimes only choice for the video streaming in homes, airports, malls, public areas and museums. However, Wi-Fi networks are vulnerable to interference, noise and have bandwidth limitations. Due to the intrinsic vulnerability of the communication channel, and the large number of variables involved, simulation alone is not enough in the evaluation of the performance of wireless networks. Actually, there is a tendency to give experimental tests a central role in the assessment of Wi-Fi networks performance.

The paper presents an experimental analysis of the effects of cross traffic on the performance of video streaming over Wi-Fi, based on cross-layer measurements. Experiments are carried out in a semi-anechoic chamber, to prevent the results from being influenced by external factors. The experimental results permit to analyze the influence of cross traffic characteristics on cross layer measures and objective video quality metrics evaluated through a standardized approach.

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## 1. Introduction

Multimedia sharing, thanks to the progress of the video streaming technology underlying it, is rapidly spreading as an everyday practice. Nowadays, people want to access remotely stored videos from every part of their homes, on their own laptop or pocket PC. Access to multimedia contents via a PDA, a laptop or a pocket PC in airports, malls, public areas and museums is becoming more and more widespread, for entertainment purposes, public utility information, and ubiquitous commercial communication.

While being the first choice in home connectivity, thanks to their flexibility, low cost and quickness of installation, Wi-Fi networks, that are wireless local area networks (WLANs) based on IEEE 802.11 specifications, are the most practical technology solution for video streaming in public areas.

Despite such a huge development, the performance of Wi-Fi networks is sometimes hard to predict and to guarantee. This is mainly due to the poor stability and reliability of the radio link. In fact, while on wired channels signal integrity is assured by mechanical, electrical and protocol characteristics of the physical and data link layers [27], on wireless channels unpredictable and uncontrollable interference can severely affect data transmission, and ultimately degrade or even compromise the desired performance of the network [1]. The Wi-Fi standard exploits a scarce, shared, and noisy spectrum, i.e. the unlicensed

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2.4 GHz Industrial Scientific Medical (ISM) band, on which other devices may operate simultaneously [2–6].

Performance evaluation based on simulations can be of help, but is not sufficient, due to the great number of variables involved. In such a direction, useful information can be achieved through ad hoc laboratory and on-field measurements, exploiting proper test beds [7,8]. In the recent past, cross-layer measurements have come out to be a powerful option to assess and predict the performance of wireless and hybrid networks, as well as to troubleshoot them [9–16]. In the literature, a number of papers investigate on the feasibility of video streaming over Wi-Fi networks. In many cases, efficient solutions are proposed for improving the quality of video streaming. Nevertheless, only few of such contributions face the problem from an experimental point of view [15,16]. Experimental performance assessment is, indeed, very important under critical conditions, e.g. when noise, in-channel interference and/or cross traffic are present. In such cases, in fact, the complexity of the protocol makes it difficult to obtain reliable analytical and simulative results.

Extensive standardization related work has been undertaken on experimental measurement approaches for activities conducted at different layers of the network abstraction, however, these tend to be concentrated on a few layers only. For example, work has been undertaken to assess the quality of a video sequence at replay (e.g. Mean Opinion Score [29]; VQM [26]), this is essentially an Application Layer issue. Separate standards relate to network performance measurement at the middle layers [30]; yet other independent approaches consider RF measurement at the physical layer [31]. However, to the best of the author's knowledge, little work has considered the simultaneous measurement of multiple performance metrics at different layers of the network. Hence this paper presents an approach to the measurement of the effects of interference at different layers on a Wireless network supporting video transfer for which no single coherent measurement standard applies.

Regarding Wi-Fi video streaming quality, a related work was presented in Ref. [21], where the video performance over WLAN is experimentally assessed with a cross-layer approach. The paper is interesting and investigates the impact of distance, possible obstacles and motion on the video quality, considering different metrics, including the peak signal-to-noise ratio (PSNR), which is used as a quality indicator. It has to be noticed, however, that the choice of transmitting the cross traffic from the same source and to the same destination as with the video stream can raise some methodological concerns. In fact, more commonly bandwidth limitations are due to other hosts on the same wireless network rather than the same host, and the artificial cross traffic for the experiments should compete for the same wireless link, but should not at the same time represent an overhead for the host receiving the video, otherwise it could slow it down, and alter the results.

The authors have recently investigated the effects of Gaussian noise on the streaming time of the TCP (Transmission Control Protocol) connection [19]. However, UDP (User Datagram Protocol) is by far more adapt and widespread for wireless video streaming, due to its connectionless features.

Thus, in this paper the attention is focused on the experimental analysis of Wi-Fi video streaming quality over UDP, with regard to both a normal UDP connection (hereinafter, referred to as *normal mode*) and a quality-of-service-oriented one (*QoS mode*). In particular, the goal is to evaluate their performance in the presence of cross traffic. In fact, while the performance of Wi-Fi video streaming over UDP has already been studied with regard to noise and interference [17,18], an experimental study based on cross-layer measurements, including VQM (Video Quality Metric) [26], in presence of cross traffic, is not reported in the literature.

The paper is organized as follows: an overview of the IEEE 802.11x standards is given in Section 2; the measurement test-bed, tools and procedure are respectively presented in Sections 3–5; experimental results are shown and discussed in Section 6; finally, conclusions are given in Section 7.

## 2. IEEE 802.11x standards

The family of IEEE 802.11 standards concerns wireless connectivity for fixed, portable, and moving stations within a local area. It applies at the lowest two layers of the Open System Interconnection (OSI) protocol stack, namely the physical layer and data link layer.

The physical layer (PHY) essentially provides three functions. First, it interfaces the upper MAC sub-layer for transmission and reception of data. Second, it provides signal modulation through direct sequence spread spectrum (DSSS) techniques or orthogonal frequency division multiplexing (OFDM) schemes. Third, it sends a carrier sense indication back to the upper MAC sub-layer, to verify activity in the wireless channel. The data link layer includes the MAC sub-layer, which allows the reliable transmission of data from the upper layers over the PHY media. To this aim, it provides for a general controlled access to the shared wireless media, called carrier-sense multiple access with collision avoidance (CSMA/CA). It also protects the data being delivered through proper security policies. The IEEE 802.11 family currently includes multiple extensions to the original standard, which are based on the same basic protocol and are essentially different in terms of modulation techniques. The most popular extensions are those defined by the IEEE 802.11a/b/g amendments (also referred to as standards), on which most of today's manufactured devices are based. A further extension, namely IEEE 802.11e standard [20], has been emanated to support quality of service (QoS) in wireless environment. It defines specific MAC layer strategies to assure reliable performance on the wireless link for different traffic categories.

Nowadays, the IEEE 802.11g standard is the most widely accepted worldwide. It involves the license-free 2.4 GHz ISM band (2.4–2.4845 GHz), in the same way as the IEEE 802.11b standard, and supports a maximum data rate of 54 Mbps, in the same way as the IEEE 802.11a standard. IEEE 802.11g standard devices are backwards compatible with IEEE 802.11b ones. They use the OFDM modulation scheme for data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mbps, and revert to complementary code keying (CCK, as in the

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