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Performance analysis and modeling of errors and losses over 802.11b LANs for high-bit-rate real-time multimedia

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Abstract

Inherent error-resilient nature of multimedia content renders two high-level options for wireless multimedia application design. One option is to employ (semi-) reliable wireless Medium Access Control (MAC) functions in conjunction with the traditional User Datagram Protocol (UDP). The other option is to employ a less-reliable MAC and transport layer protocol stack that passes corrupted packets to the application layer, which consequently achieves a "higher throughput". This "higher throughput" traffic, however, could contain many "useless" corrupted packets. In this paper, we address key questions regarding the viability of the above two options for the support of high-bit-rate wireless multimedia applications over 802.11b LANs. First, we study the level of throughput improvements realized by the less-reliable protocol stack at 2, 5.5 and 11 Mbps data rates using actual measurements that mimic realistic home or business settings. Second, we analyze and model the error patterns within the "higher throughput" corrupted packets to evaluate their potential impact on multimedia applications. Third, we compare the amount of overhead that is needed at the application layer to achieve different levels of lost- and corrupted-packet recovery for the two (reliable and less-reliable) protocol stack scenarios. Major conclusions of our study include: (1) Either protocol-stack is viable at 2 Mbps while neither of them is viable at 11 Mbps under realistic settings; and (2) Some benefits of the "higher throughput" corrupted packets can be realized at 5.5 Mbps when combined with a joint erasure-error protection algorithm at the application layer.

Keywords: High-bit-rate multimedia; Wireless channel modeling; 802.11b networks; Protocol design; UDP Lite

1. Introduction

The advent of wireless networks has advanced real-time multimedia communication into a novel realm. The wireless medium, due to its inherent vulnerability and physical characteristics, is more error prone than most of the contemporary (wired) media. Nevertheless, migration of technologies from the wired to wireless domain is currently underway. One of the key challenges in this context is the delivery of real-time content

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over the wireless medium. The promise of real-time multimedia over the wired Ethernet is often attributed to the simplicity and pragmatism of User Datagram Protocol (UDP)/IP protocol suite. However, this protocol suite was designed for considerably low error-rate environments as opposed to wireless networks. In this regard, a positive aspect of real-time applications is their inherent tolerance to a certain level of corrupted and/or dropped packets. This characteristic of real-time applications motivated the development of new methods and protocols for wireless networks. For example, a new transport layer protocol which is tailored for real-time applications over error-prone networks has been proposed recently [1–3]. This protocol, known as UDP Lite, relies on the premise that multimedia applications can tolerate, and therefore should, receive corrupted packets. Naturally, this UDP Lite-based framework makes it necessary for the Medium Access Control (MAC) layer to forward corrupted packets to the higher layers. Consequently, developers of wireless multimedia applications are faced with two (high-level) options: (1) Employing current wireless MAC functions, which include dropping of corrupted packets and attempting to recover these packets through retransmissions, in conjunction with the traditional UDP protocol; or (2) Allowing the MAC layer to pass corrupted packets to a UDP Lite-type transport layer which in turn relies on the application layer to handle the corrupted data. A key advantage of the second option is the increase in the, potentially corrupted, throughput of the end-to-end transport layer packets. However, these "high-throughput" packets contain corrupted data.

Therefore, and based on the above two options, three key questions can be raised: (1) How much improvement in the "throughput" is actually being gained by using the new UDP Lite-based framework? (2) How badly corrupted these "high-throughput" packets are? In other words, how much and what type of error patterns are observed in these packets? (3) As a consequence of the first two questions, what level of application layer loss-protection, error-concealment and/or error-correction would be required to achieve acceptable quality under the two protocol-stack variants? In this paper, we address the above questions in the context of high-bit-rate[1] multimedia applications[2] over 802.11b wireless LANs.

At this point, it is important to outline how we intend to answer these three questions. The first question, which has been addressed partially by previous studies (see, for example, [3,4]), can be answered through a set of experiments and related analysis that is presented in this paper. Our analysis of packet throughput is conducted at the 2, 5.5 and 11 Mbps data rates using actual measurements that mimic realistic home or business settings.[3] Answering the second question requires a thorough analysis and some modeling of the error patterns at the MAC layer (i.e., errors that are not corrected by the physical layer). In addition to presenting our experimental results and analysis for byte-level[4] error patterns at the MAC layer, we propose a new hierarchical Markov-based model for representing these error patterns. As shown later in the paper, the proposed model captures the observed errors more accurately than the traditional two-state Markov chain.

Addressing the third question is naturally more challenging than the first two questions, as it depends on a wide spectrum of objective and subjective evaluations of a variety of multimedia applications and corresponding error protection and concealment algorithms. For example, some applications targeted for wireless networks may take advantage of better error resilience features, such as Reversible Variable-Length Coding (RVLC) that is supported in the MPEG-4 video standard [5]. Other examples include a range of (video) error concealment algorithms and/or Forward-Error-Correction (FEC) methods [6,7]. Due to this wide spectrum of methods and algorithms, which can influence the answer to the above third

[1] In this work, we conducted our study and analysis at the full-rates provided by the different modes at the physical layer. Consequently, our definition of "high-bit-rate" follows the 2, 5.5, and 11 Mbps bit-rates supported by 802.11b.

[2] An example of real-time multimedia is MPEG-4 video [5], which we use occasionally in this paper to illustrate some visual simulation results in support of our findings.

[3] We believe that a minimum criterion for a "realistic" setting is a wireless transmission between two rooms. This is explained further later in the paper.

[4] In order to develop a thorough understanding of the channel, we performed analysis of error traces at two levels of granularity, i.e., bytes and packets. Respectively, it is referred to as byte-level and packet-level analysis.