Are 802.11 Link Quality Broadcast Measurements Always Reliable?

[Extended Abstract]

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ABSTRACT

This paper describes an unexpected finding concerning link quality measurements carried out through broadcast frames. We found out that, with experimental equipments/drivers widely used by the scientific community (Atheros WLAN cards with MADWiFi driver), broadcast-based link quality measurements seem to be affected by a NIC-proprietary power saving mode. The striking conclusion is that some packet losses, typically attributed to bad channel characteristics, rather may depend on the broadcast measurement methodology. Unicast measurements are shown to be exempt from such a problem. A very simple test is furthermore proposed to verify whether measurement results are affected by the described phenomenon.

1. INTRODUCTION

Literature work reports several measurement studies devised to assess the link quality performance in various 802.11 WLAN scenarios (indoor vs outdoor, infrastructure vs ad hoc, Mesh networks, etc). In order to test specific mechanisms/protocols and thoroughly assess their performance by means of duly customize experiments, the scientific community needs to rely on somewhat flexible/configurable equipments (such as Atheros and Prism NICs, LinkSys APs, etc) as well as highly configurable and programmable open source drivers (such as MADWiFi, rt2x00, HostAP, etc).

While several early studies used 802.11b Prism NICs with the open source HostAP driver [1, 2, 3], a recent trend is to rely on 802.11a/b/g Atheros NICs [3, 4, 5] driven by MADWiFi (http://madwifi.org), a highly configurable and programmable open-source Multiband Atheros Driver for WiFi. This chipset/driver pair not only supports part of the recent QoS extensions (specifically, the Wireless Multimedia Extension), but it is indeed extremely useful to perform link quality measurements, due to the very detailed information provided at both transmission and reception of frames.

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2. MEASUREMENT APPROACH

We developed an experimental trial to collect measurements devised to assess the quality of 802.11b/g outdoor links. The results gathered, and documented in a companion paper [6], relied on unicast frames. However, an additional set of measurements, not presented there for the striking reasons that will come out later in this paper, were taken on broadcast frames. The testbed implementation was based on 802.11 b/g Atheros NICs driven by MADWiFi, with basic access mode and automatic rate fallback algorithms disabled, i.e. with fixed configured physical rate. In order to fulfill the per-frame measurement goals that motivated [6], we have modified the MADWiFi driver in order to bypass the native Exponentially Weighted Moving Average (EWMA) filtering provided by the driver on the per-frame Signal-To-Noise Ratio (SNR) measurements[1], and we have provided our own filtering outside the driver and with smoothing parameters explicitly configured by ourselves.

3. THE FINDING

The following results are presented for 802.11b at 11 Mbps rate, but the same analysis applies to any other rate as well as 802.11g. Traffic has been generated through ICMP Echo broadcast packets of size 1500 bytes, generation rate set to 100/second, and disabled ICMP Echo reply (to avoid traffic on the opposite direction). Figure 1 reports measurement results gathered on 90 seconds. The plot reports two performance figures. The first is the Delivery Probability Ratio (DPR), i.e. the probability that a MAC layer frame is correctly received. The label in the Figure reports also the DPR mean (η=0.50) and standard deviation (σ=0.06) taken along the whole measurement time. The second performance figure is the measured RSSI - Received Signal Strength Indicator, i.e. the SNR measured by the NIC. In the specific case of Figure 1, the DPR as well as the SNR were computed over 800 ms windows, yielding 1 sample every 0.8 second[2]. The Figure suggests that the considered link exhibits an intermediate performance (neither good nor bad), with 50% of the frames being corrupted in correspondence to a somewhat stable SNR (mostly in the range from 13 to 16 dB).

[1]An EWMA filter is defined as $y_n = (1-\alpha)y_{n-1} + \alpha x_n$, where y_n is the running average, x_n is the current measurement, and α is the filter weight. For what concerns SNR measurements, MADWiFi uses a default weight set to $\alpha = 0.1$, whose effect, roughly speaking, is somewhat analogous of taking a running average over the latest 10 samples.

[2]We remark that our measurement setting does not rely on the native driver filtering, but smoothing mechanisms and parameters are explicitly provided outside the driver.

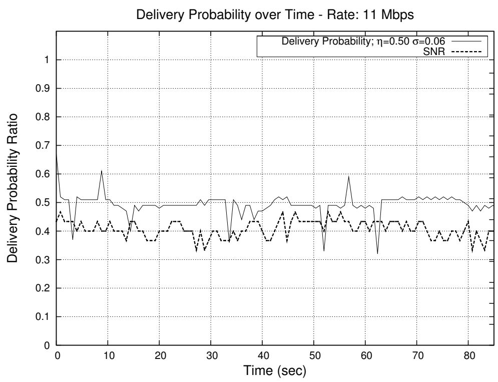

Figure 1: Delivery Probability Ratio and link quality for a selected link - 1 second windowing

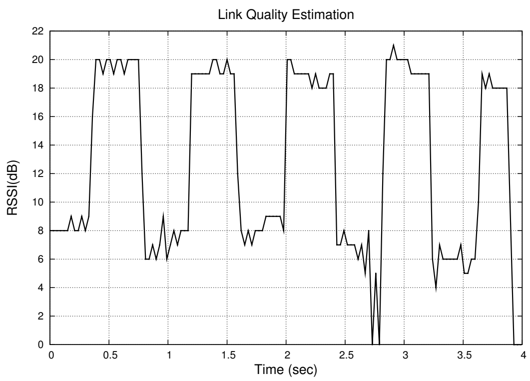

Figure 2: link quality for the same selected link - 40,96 milliseconds windowing

Now, Figure 2 replots the RSSI performance figure, but with a different smoothing parameter: the window size over which RSSI measurements are averaged is set to 40,96 ms (40 times the IEEE 802.11 1.024 ms Time Unit - TU). From the Figure it clearly emerges that, in a period of 800 TU (slightly greater than 800ms), the measured RSSI commutates between two 400 ms phases (i.e. 4 beacon intervals), one characterized by a high link quality, the other characterized by a poor link quality where the RSSI shows a decrease of about 12 dBs, and most frames are lost.

The regularity pattern in Figure 2 clearly raises the evidence that a power saving mechanism is adversely affecting the measurements. Specifically, without any power saving, the resulting 20 dB SNR would be above the receiver sensitivity for the specifically employed rate, and almost all frames will be successfully received. Conversely, in the 400 ms in which the power saving mechanism is active, the SNR drops down to about 8 dB, thus resulting in a very high loss probability for frames transmitted in this period, and yielding to a 50% average DPR (as measured in Figure 1). We mark that a large amount of outdoor links will happen to be in such "intermediate" conditions (this occurs whenever the SNR fluctuates above and below the receiver sensitivity for the considered rate). Note that the chipset vendor advertises[3] that there is a proprietary power-saving mode designed to reduce NIC power consumption by at least 60% with respect to competitors, thanks to low power operation and sleep mode. However, from the 802.11 standard it is not expected that a power saving mechanism should affect reception of broadcast traffic: the receiving card should in fact awake when broadcast traffic is expected following a DTIM - Delivery Traffic Indication Map - beacon. Indeed we verified that all beacons are DTIM in our experimental setting. Note also that the card does not enter a "true" sleep mode, but only a low power operation (most likely the lower gain of the low noise amplifier (LNA) just before the A/D converted and the 802.11 baseband, which is responsible for the decoding process and RSSI estimation), perhaps in this behavior circumventing the rules enforced by the standard.

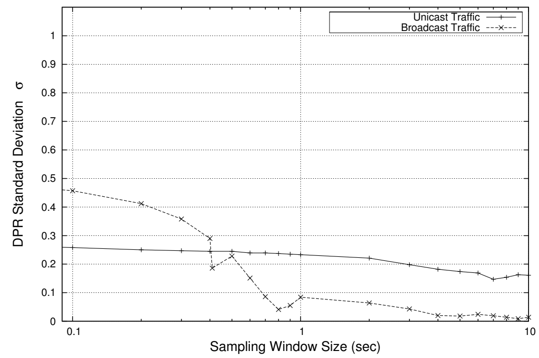

Figure 3: Standard deviation σ as function of the sample window size

4. MEASURE VALIDATION CRITERION

We propose a simple test to i) verify whether the above described phenomenon affects a measurement campaign or not and ii) understand whether the same problem affects unicast frames as well. The test consists in computing the DPR standard deviation σ for a varying size of the sampling window used (i.e. the window over which the DPR sample is locally computed). Figure 3 shows the σ value for different smoothing windows, and for the two cases of unicast and broadcast frames. It clearly shows that the σ values is loosely dependent on the window size for unicast frames (variations in the order of 10%), i.e. the smoothing time scale slightly affects the measurement results. Conversely, in the case of broadcast frames, σ starts from an high value (due to the power-saving induced fluctuations shown in Figure 2), significantly reduces of as much as 90% as the window size increases, and flattens after an 800 ms window size, as the smoothing effect of the window starts to include both awake and low power operation phases.

5. REFERENCES

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