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NON WI-FI DEVICES INTERFERENCE TESTING IN A 2.4 GHZ WI-FI HOME

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ABSTRACT

Operating in probably the most crowded radio frequency bandwidth, the 2.4 GHz Wi-Fi is still common in the majority of living environments. Besides having to face problems regarding co-channel and adjacent channel influence, Wi-Fi often coexists with other radio technologies operating in this bandwidth which makes it ideal for interference testing.

In this article authors propose the use of freely available mobile applications to measure Wi-Fi signal spreading within a residential home as well as to quantify Wi-Fi performance in the presence of some commonly available interferers. A complete analysis of spectrum use is also provided by using a spectrum analyzer. We have found that Wi-Fi throughput degradation due to Bluetooth technology operated in the immediate vicinity of a mobile client is on average 26,5 % and decreases with distance from the Wi-Fi client. The presence of an active video baby monitor leads to a 7,5 % throughput degradation, but its functionality in heavy Wi-Fi traffic environment is however limited. The use of spectrograms in interference analysis is essential for a better understanding of the measured results.

KEYWORDS: Wi-Fi, interference, RSSI, throughput, Bluetooth, baby video monitor

1. Introduction

Over the last decade, Wi-Fi technologies are being deployed all over the world. Nowadays, Wi-Fi networks are widely spread across a variety of environments including outdoor public markets, hotels, restaurants, office buildings as well as home networks. As a technology for wireless local area networking, Wi-Fi devices are built according to the IEEE 802.11 standards.

The early developed 802.11b standard uses the 2.4 GHz bandwidth, direct-sequence spread spectrum (DSSS)

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modulation scheme and provides the users a maximum data rate of 11 Mbits/s. The later 802.11g version of the standard was developed in the same 2.4 GHz bandwidth but uses the Orthogonal Frequency Division Multiple (OFDM) access scheme offering a maximum theoretical bit rate of 54 Mbit/s. 802.11n is an amendment that improves the previous 802.11 standards by adding both spatial multiplexing (MIMO) as well as operation in the 5GHz bandwidth (IEEE, 2012a). The newest 802.11ac version includes wider channels (80/160 MHz compared to previously 20/40 MHz), eight spatial streams as well as higher order modulations (IEEE, 2012a). Engineers are continuously trying to find solutions to respond to users expectations for higher data rates and increased capacities in Wi-Fi networks. High order modulation code schemes (MCS) like quadrature amplitude modulation (ranging from 4 QAM up to 256 QAM) along with the use of complex spatial multiplexing techniques as Multi-user MIMO have led to theoretical data rates of 1300Mbits/s.

It is clear that the future of Wi-Fi networks lies in the less crowded 5 GHz bandwidth with increased channel width offering higher data rates. However, 5 GHz Wi-Fi network devices are still expensive compared to 802.11 b/g/n and because of that the majority of domestic users operate in the 2.4 GHz Wi-Fi bandwidth. The Federal Communication Commission (FCC) site lists over 480 licensed appliances in the 2.4 GHz frequency range including microwave ovens, wireless networks, Bluetooth, car alarms, cordless phones and baby monitors (FCC ID Applications, 2018).

The 802.11 standards divide the 2.4 GHz bandwidth into 13 channels with 20/22 MHz width, spaced 5 MHz apart from each other and a 14th channel spaced 12 MHz apart from channel 13 (IEEE, 2012b). Channel 1 central frequency is 2.412 GHz and channel 13 is centered on 2.472 GHz which leads to only 3 non-overlapping channels (1, 6 and 11) in this spectrum (IEEE, 2012b). This settings allow for both co-channel interference as well as adjacent channel interference in Wi-Fi networks. In addition there is another type of interference occurring from other non-Wi-Fi devices operating on these frequencies and competing for medium access. In order to control their susceptibility to interference, 2.4 GHz Wi-Fi devices use DSSS or OFDM technologies to access the radio environment. However, because Wi-Fi performance is directly affected by radio interference it became important to assess the degree of interference and to quantify and discuss the effects on measured traffic data rates.

There are numerous studies related to Wi-Fi interference (Fuxjager, Valério, & Ricciato, 2007; Sui et al., 2016; Kokkinos et al, 2016; Golmie et al, 2003; Taher et al., 2008; Lee et. al, 2017; van Bloem et al., 2012; Mahanti et al, 2010; Soldo Malaric, 2013). Much of the available public literature related to Wi-Fi interference is focused either on co-channel or adjacent channel interference (Fuxjager, Valério, & Ricciato, 2007; Sui et al., 2016; Kokkinos et al, 2016) or on specific devices such as Wi-Fi Bluetooth (Golmie et al, 2003) and microwave ovens (Taher et al., 2008). Experiments conducted in (Lee et. al, 2017) show severe impact of audio/video transmitters which causes significant overall QoS degradation of Wi-Fi communication in contrast to microwave and Bluetooth interference. Authors in (Mahanti et al, 2010) provide an accurate measurement study of interference from six common devices that use the 2.4 GHz bandwidth in both controlled and uncontrolled campus environments. In (Soldo & Malaric, 2013) a simple user available app tool is used for a quick measurement setup in order to reveal the influence of a limited number of factors on Wi-Fi signal and upload and download data rates.

In this article authors propose the use of available mobile applications to measure and quantify Wi-Fi performance in a residential home. A set of mobile applications were used to study Wi-Fi signal spreading within the home. Upload and download data rates were measured for various experimental settings. A baby video monitor and paired Bluetooth devices were plugged in, in the proximity of the wireless mobile client and used to conduct non Wi-Fi interference measurements. For a complete interference analysis a spectrum analyzer was also used.

2. Materials and Methods

The tested router was a TP-Link model operating in the 802. 11b/g/n mixed mode in the 2.4 GHz frequency band. Router settings made it possible to control the channel number the router is working on as well as the channel bandwidth. After a quick scan of the area, in order minimize co-channel interference as well as adjacent channel interference, the router was set to work on channel 1 (2412 MHz) using a bandwidth of 20 MHz. The router was located in a fixed position during all measurement scenarios. The location of the router was chosen arbitrary to ease access without taking into consideration any coverage optimization.

Two types of interferers were considered: Bluetooth and baby video monitor. The baby video monitor operates in the 2400-2483.5 MHz frequency band with a maximum emitted power of 17dBm using a Gaussian Frequency Shift Key (GFSK) modulation and adaptive frequency hopping (AFH) algorithm to access the radio environment. Bluetooth also operates in this frequency band and uses frequency hopping spread spectrum technology. Two paired mobile phones with only Bluetooth connections enabled exchanging a video file were placed in the proximity of the Wi-Fi client. Experimental setup is presented in Figure no. 1 but several cases were considered:

1. Mobile phone Wi-Fi connected to the router, no interferers presents (Several other Wi-Fi neighboring networks were present in the environment, as shown in figure 2b but signal strengths were low compared to the tested network).
2. Mobile phone Wi-Fi connected to the router with baby videophone monitor active and placed in the proximity of the mobile device (< 1m).
3. Mobile phone Wi-Fi connected to the router with paired Bluetooth devices exchanging a file in the proximity of the mobile device.
4. Mobile phone Wi-Fi connected to the router with both considered interferers active and placed in the proximity of the mobile device.

Figure no. 1: Experimental setup

Signal strengths measurement were conducted with a freely available mobile application Wi-Fi Analyzer. The mobile application makes it possible to measure interest network signal strength (Figure no. 2a) as well as neighbor Wi-Fi network signal strengths based on network RSSI (Received Signal Strength Indicator). Moreover it can graphically display available networks by showing both signal strength and operating channel (Figure no. 2b) for all the in range available Wi-Fi networks.

Figure no. 2:

a. Wifi Analyzer user interface – network view
b. Wifi Analyzer user interface – channel view
c. WiFi Speed Test – user interface

With the help of "Wifi Analyzer" application signal strength was measured along the ground floor at a high of 1,5 m and mapped according to Figure no. 3.

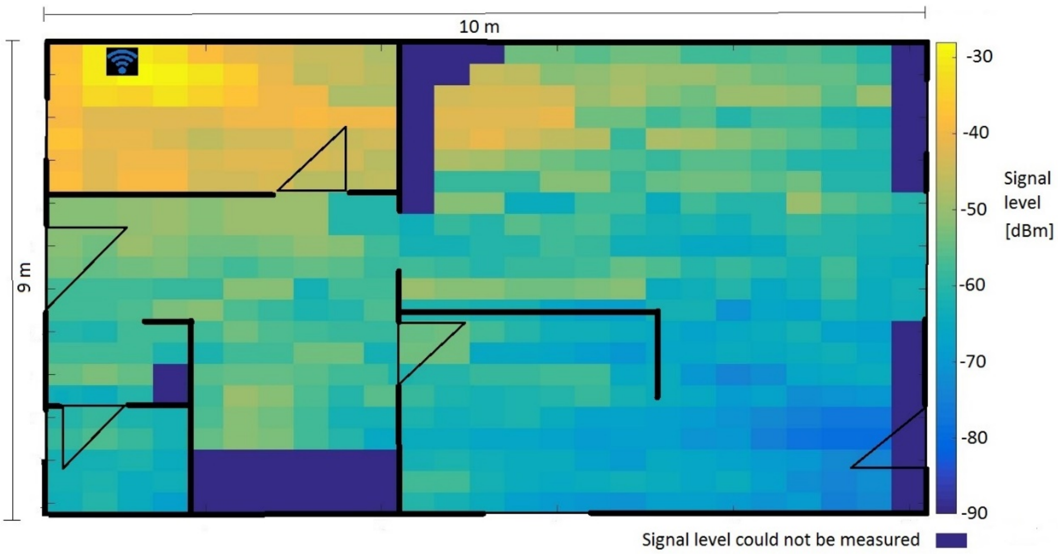

Figure no. 3: Measured signal strength across ground floor showing Wi-Fi router position

We have conducted a series of measurements in an attempt to quantify interferers influence on Wi-Fi network performance. Network performance was quantified by the help of the "WiFi Speed Test" mobile application. It is a freely available Android application that measures the network upload and download data rates. Measurements were made over the Wi-Fi network using a Transmission

Control Protocol (TCP) link with the computer used as a remote server and a test packet size of 80 Mb. 30 locations were chosen arbitrary within the house and tested for all the considered scenarios. The "WiFi Speed Test" has the option of storing results and export them to a csv file containing information about the upload and download data rates as well as the RSSI at each of the measurement point.

Aaronia manufactured Spectran HF-80120 V5 X spectrum analyzer equipped with OmniLOG 70600 Omni-Directional Antenna was used to measure the emitted signals and provide information about the spectrum occupancy during experimental scenarios.

3. Results and Discussions

In Figure no. 4 the measured download data rate is graphically represented as a function of the Wi-Fi network RSSI for all the considered cases. As theoretically expected, the measured download data rate decreases with signal strength degradation regardless of the considered case.

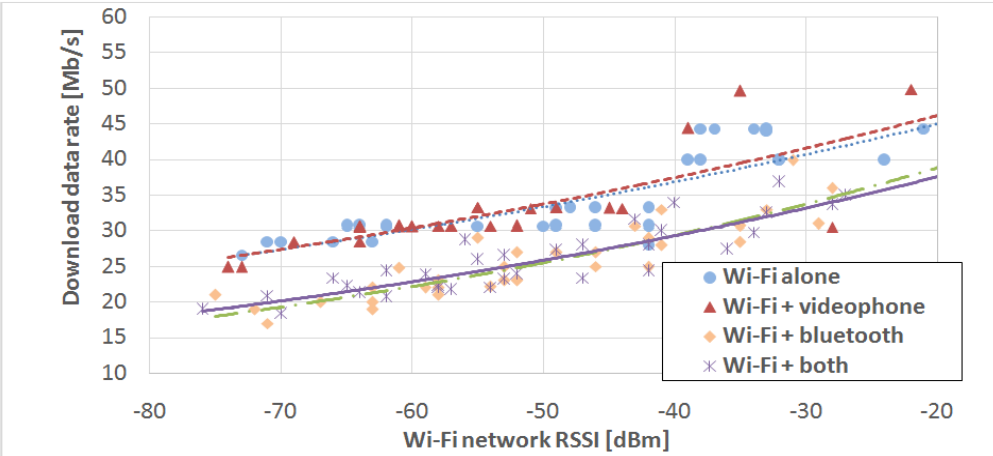

Figure no. 4: Download data rate as a function of network RSSI

The presence of the baby video monitor didn't have a remarkable influence on the download data rate with an average calculated decrease of only 5,9 %. No decrease was noticed for good signal strength measurement conditions, when the video monitor experienced even complete signal loss because of the Wi-Fi channel heavy occupancy during testing. By excluding the 20 MHz used by Wi-Fi channel 1, we have calculated that a 63 MHz bandwidth was left unoccupied for the baby phone to use. However, for this device, the AFH mechanism could not always adapt to use the less crowded frequencies of the entire operating bandwidth. This lead to the conclusion that intense Wi-Fi traffic can even interrupt communication for the baby video monitor placed in the proximity of a Wi-Fi client.

Because Bluetooth uses the same family radio access technology, with very low duty cycles we were expecting similar results for the third case considered. Because the FHSS technology used by Bluetooth is limited to a maximum of 2 MHz bandwidth we did not expect much influence on our Wi-Fi device. However degradation of the measured download data rate was notable when paired Bluetooth phones were exchanging a video file in the proximity of the Wi-Fi client. The calculated throughput degradation was on average 26,4 %, and decreased with distance increase. The observation is consistent with previous findings as reported in (Mahanti et al, 2010). When both interferers were active the results were similar to the previous considered case, and mainly due to Bluetooth influence.

Similar results were observed for the upload data rates, as graphically represented in Figure no. 5. The use of the baby video monitor influenced upload data rates only for weak signal conditions and the overall upload data rate degradation due to its use was calculated to be 8 %. The upload data rate degradation due to Bluetooth influence was on average 29,2 %, similar to download data rate influence.

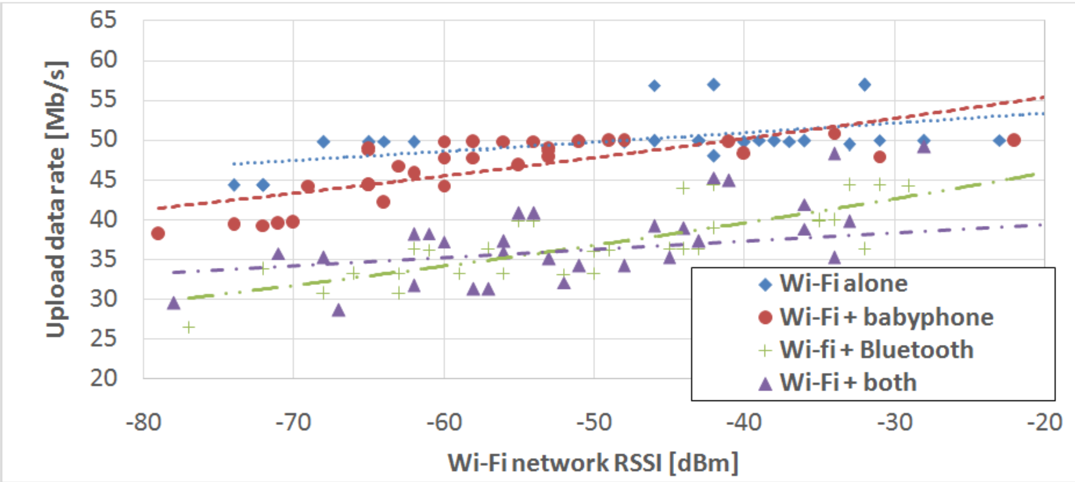

Figure no. 5: Upload data rate as a function of network RSSI

When trying to assess interference it is important to analyze signal in both time and frequency domain, thus the use of spectrograms is optimal. Figure no. 6 presents the measured spectrograms for the Wi-Fi channel active with no controlled interferers active and no traffic (a), the baby video monitor (b), Bluetooth paired devices (c), Wi-Fi channel and baby video monitor active during testing (d).

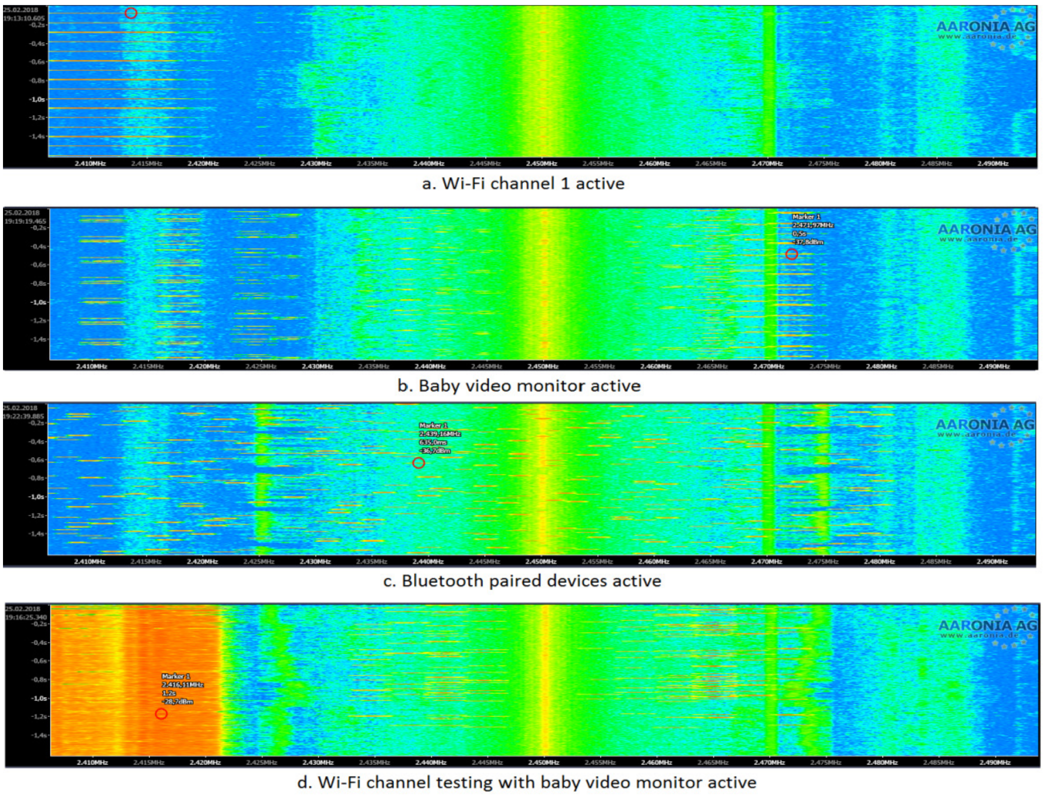

Figure no. 6: Spectrograms for different considered cases

In Figure no. 6a one can note the presence of the Wi-Fi beacon channel, visible every 100 ms as well as the existence of other radio emissions and week signals belonging to neighbor Wi-Fi networks working on different channels and other licensed devices operating in this band. In the spectrogram of the baby video monitor one can observe the presence of the frequency hopping algorithm used with low frequency variability (as compared to Bluetooth). This observation can explain why this type of communication was often interrupted when Wi-Fi channel occupancy was high, as seen in Figure no. 6d. Bluetooth channels of 2 MHz bandwidth are visible in Figure no. 6c together with a much more flexible frequency hopping algorithm.

4. Conclusions

We have demonstrated that Wi-Fi network interference characterization can be possible, to some extent, by using common available mobile applications. By making use of the described method authors found a significant influence of active Bluetooth technology, placed in the proximity of the Wi-Fi client, on network throughput for both uplink and downlink data rates. The use of a wireless baby video monitor doesn't have a remarkable influence on the parameters analyzed, but its functionality is however strongly influenced if placed in intense Wi-Fi traffic environment.

The use of similar mobile applications is recommended if limited information about Wi-Fi interference is desired, and very useful if co-channel or adjacent channel interference is of interest. However a complete evaluation of non-Wi-Fi device interference analysis require the use of a spectrum analyzer capable of measuring a signal in both time and frequency domain.

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