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Non-overlapping Channel Utilization and Noise Floor Measurement of 2.4 GHz Wireless LAN Based Cognitive Radio Network

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Abstract

This paper presents channel utilization and noise floor measurement of IEEE 802.11n 2.4 GHz wireless local area network (WLAN) for standalone channel and non-overlapped channel in a cognitive radio network. Spectrum is getting saturated day by day with a huge number of increasing application as well as increasing number of smartphone users. Most of the case, the smartphone users get connected with nearby WLAN access points (APs) for real time audio or video streaming, playing games, social networking, stock market updates and so on. As a single AP has limitations to the total number of users, so it may necessary to use more than one AP to cover this increasing number of devices specially in office, universities, student hostel areas. Recently in an experimental survey, we found there are 1193 different APs are using among 8 student residential hostels at Universiti Malaysia Perlis. In this paper, we investigated the utilization and noise floor level of a channel while nearby smartphones use Wi-Fi Direct to communicate between them using non-overlapped channels. In the results, we found an interesting outcome, i.e., even a non-overlapped channel used by nearby smartphones, increased the noise floor level up to 3.5 dBm and channel utilization level up to 3% of WLAN channels.

Keyword: IEEE 802.11n, Noise floor, channel utilization, WLAN

INTRODUCTION

WLANs have been widely deployed during the last decade and hence are the source of prime interference within the industrial scientific and medical (ISM) radio band. For instance, France Telecom alone has deployed more than two Million WLAN systems for domestic and industrial use in the last decade in France until 2007 [1]. Telekom Malaysia (TM) has deployed more than 17,000 WLAN site nationwide in Malaysia until 3rd quarter of 2015 [2].

2.4 GHz WLAN is divided into 13 different mutual channels with 22 MHz of channel bandwidth. Among 13 channels, only 3 channels are non-overlapped with each other as shown in Figure 1, to avoid interference. A practical roll-out is nowadays confined to the usage of a few channels only, e.g. the channels numbered 1, 5, 9 and 13 in Europe and also in Korea, so as to limit interference between adjacent cells [3].

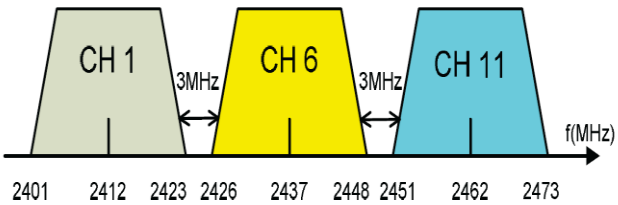

Figure 1: Non-overlapped channel combination [3]

2.4 GHz WLAN APs became much familiar because it is cheap, easy to install and can use with desktop PCs, laptops and smartphones to access internet, share files or videos between devices etc. Recently a project conducted by School of Computer and Communication Engineering, Universiti Malaysia Perlis (UniMAP) and found 1193 number of 2.4 GHz access points are using at 8 residential hostels among 7000 students in the hostels. So, on average every 6 to 7 students are using a single AP. The channels using by that APs were also measured and the following Figure 2 shows the percentage of total used channels according to channel number.

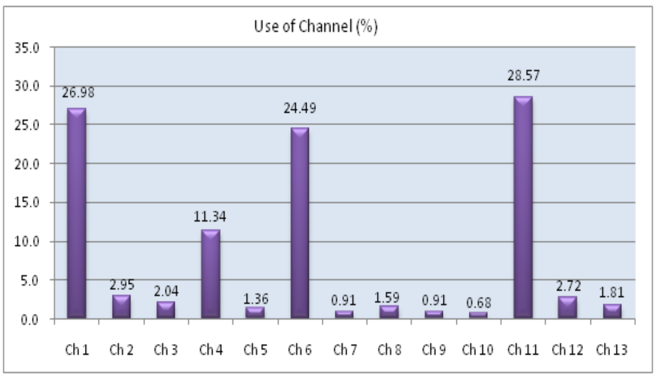

Figure 2: Percentage of used channels at UniMAP hostels

Wi-Fi Direct is a new technology defined by the Wi-Fi Alliance aimed at enhancing direct device to device communications in WLAN. Wi-Fi Direct devices communicate by establishing P2P groups, which are functionally equivalent to traditional WLAN infrastructure networks. The device implementing AP-like functionality in the P2P group is referred to as the P2P group owner (P2P GO), and devices acting as clients are known as P2P clients [4]. These roles are dynamic, hence a Wi-Fi Direct device has to perform both the roles of a client and AP (sometimes referred to as Soft-AP). In this paper, we presented an experimental analysis of 802.11n WLAN channel utilization and noise floor level with Wi-Fi Direct activity, especially while they operate in non-overlapped channels. This paper has organised as, section II. Previous works, III. System Model, IV. Experimental Methods, V. Result and Discussion and finally VI. Conclusion.

PREVIOUS WORKS

A number of study been done so far on 2.4 GHz WLAN in past recent years. Several analyses already have tried to find these parameters and evaluated their impacts. The authors in [5] experimentally studied how the 802.11n affects with several performances (throughput, packet loss and fairness) and interact with each other across a wide range of scenarios differing in channel and interference conditions. Finally they concluded with some inconsistencies between simulated and experimented works. But they did not consider about the noise floor level and channel utilization for any specific channel.

In the paper [6], the authors found some reasons to explain the inconsistency between the theoretical and experimental performances of 802.11n. They presented and covered the parameters behind this performance degradation in angular parameters such as the angular spread, the angles of departure and arrival. Also noticed an increase of the correlation coefficient and hence higher packet error rate (PER) for small angular values and vice versa, especially when the variation affects the first cluster of the D model.

The authors in [7] deployed a numerically model for CSMA/CA IEEE 802.11n MAC protocol with 4×4 MU-MIMO transmission adapted Markovian chain for modified control frames in non-ideal channel. They analysed the achieved saturation throughput and delay performance with respect to the number of active stations and frame error probability due to erroneous channel. Finally they concluded with the numerical results with the substantial impacts of channel error and the number of station involved transmission on the network performance.

This paper [8] investigated impacts of rate adaptation, bridging, batman-adv, and antenna orientation over a constructed WLAN link. They evaluate the link performance in terms of throughput, signal strength, packet loss and CPU occupancy and found that bridging reduces implementation complexity, and also consumes more CPU occupancy at the sender side and causes throughput degradation.

Analysing the previous works related to 802.11n WLAN performances [5]-[8], most of the experimental task considered channel throughput, channel error, packet loss, packet transfer rate and signal strength of the linked signal. None of them considered on channel utilization or noise floor level of surrounding environment also have impact on overall channel performance. Wi-Fi Direct is also using same channel range as WLAN APs, are not considered as well. However, taken these matters into consideration, we investigated the WLAN channel performance measuring the noise floor and channel utilization while nearby smartphones using a Wi-Fi Direct non-overlapped channel for data transfer.

SYSTEM MODEL

To conduct with the experiment, we considered the structured WLAN APs as PUs and Wi-Fi Direct enabled smartphones as SUs. To set up the experimental test bed, we used two laptops connected with a single AP using channel 1. Two smartphones were also used for SU activity and they were connected and transfer data between them using WLAN channels at nearby location as shown in Figure 3. We fixed the PU channel and changed the SU channel to observe the channel utilization and noise using Wi-spy device and Chanalizer Pro application software. We assumed the environment noise floor between-95 dBm to-100 dBm which is usual for a clean sunny weather. Two types of scenario may occur during communication; Scenario 1, SU 1 and SU 2 communicate between them using fully overlapping channel with the PU; Scenario 2, SU 1 and SU 2 communicates between them using partially overlapped channel; Scenario 3, SU 1 and SU 2 communicate between them using non-overlapped channel with PU. We considered scenario 1 and scenario 3 for this experiment and investigated results in the result and discussion section.

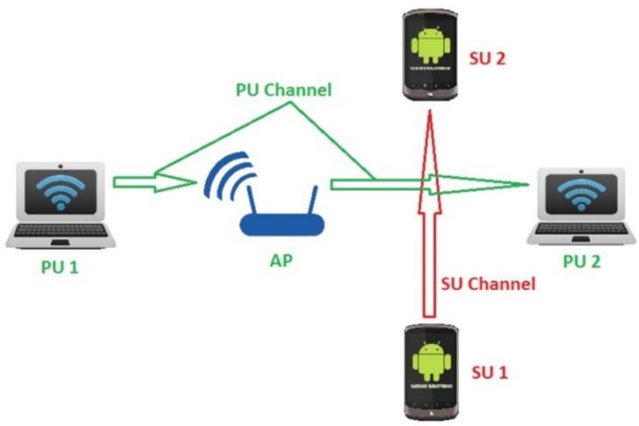

Figure 3: System setup scenario for experiment

EXPERIMENTAL METHODS

While data transmitted through a specific channel, the utilization of that channel as well as the mutual overlapped channels increased. Channel utilization is the ratio of the data throughput to the total capacity of that channel. The following formula expressed the utilization as Equation (1):

$$Utilization_{Channel} = \frac{Throughput}{Total\_Capacity} \qquad (1)$$

Noise floor is another important parameter to measure the performance of a channel. The lower noise floor level increases the channel performance even for a very low signal to noise ratio (SNR) environment. On the other hand a high noise level may decrease the channel performance in higher

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SNR level. The aim of this experiment is to measure how the channel utilization and noise floor level varies for standalone channels and non-overlapped channels.

All the experiments were performed in lab/indoor environment. At first, we made sure no other 2.4 GHz WLAN channels, Bluetooth, cordless phones or IP cameras were present on that area to interfere the results. We set channel 1 for the AP, and changed the smartphone's Wi-Fi Direct channels to channel 1, channel 6 and channel 8 and transferred data as SU activity.

Two laptops were wirelessly connected to the AP as PU activity through that WLAN, which is set to channel 1. Ixchariot software was used for UDP streaming between these laptops and the constant load was set to 2.4 Mbps. We also used the Metageek Channalizer Pro software and Wi-Spy device to visualize the WLAN channel activity. Wi-Spy is a fine-tuned hardware that also shows non-WLAN activity emanating from devices like microwave ovens, automation systems, Bluetooth, cordless phones, wireless security cameras, or anything else operating wirelessly in those frequencies. It also helps users determine a viable channel for network communications. Chanalizer Pro turns data collected from a Wi-Spy (and a wireless network interface card) into charts and graphs that will help users determine if they are experiencing interference [9]. Figure 4 shows WLAN channels look through Wi-Spy and Chanalizer Pro application:

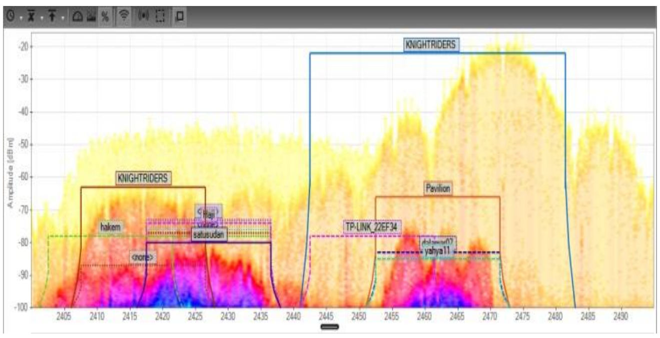

Figure 4: Available 2.4 GHz WLAN channels in Chanalizer Pro software

On the other hand, for SU Wi-Fi Direct activity, we used one Android smartphone and one Android tablet which support Wi-Fi Direct technology. The detail specification of the smartphone and tablet are in Table 1 as follows.

Table I: Smartphones and Tablet PC specifications

Device Name	CPU/Chipset	Operating System	WLAN Type	Wi-Fi Direct ?
Samsung Galaxy Tab P5100	Dual core 1.0 GHz, TI OMAP 4430	Android 4.1.2	802.11 a/b/g/n, dual band	Yes
Sony Xperia Smartphone D2403	Quad core 1.2 GHz, Qcom Snapdragon 400	Android 4.4.4	802.11 a/b/g/n, dual band	Yes

We transferred one 90.4 Megabytes of file from one mobile device to another as SU activity and measure the PU data throughput for scenario 1 and 2. Ixchariot and Chanalizer software were used to measure the performance of our desired parameters for PU. The findings are discussed in detail in the following section.

RESULTS AND DISCUSSIONS

Figure 5 shows the frequency amplitude of WLAN channels while PUs and SUs transfers data simultaneously using overlapped, mutual overlapped and non-overlapped channels. As PUs and SUs are located very nearby, so we received the total combination of amplitude for both PU and SU channels. From the results, it is seen that while both PUs and SUs were using the same channel (channel 1), the amplitude was in the highest level from others and the value is-73 dBm. On the other hand while SUs were using a non-overlapped channel (channel 6), the amplitude was increased for channel 1 and channel 6 and the values are-82.5 and-84 dBm respectively.

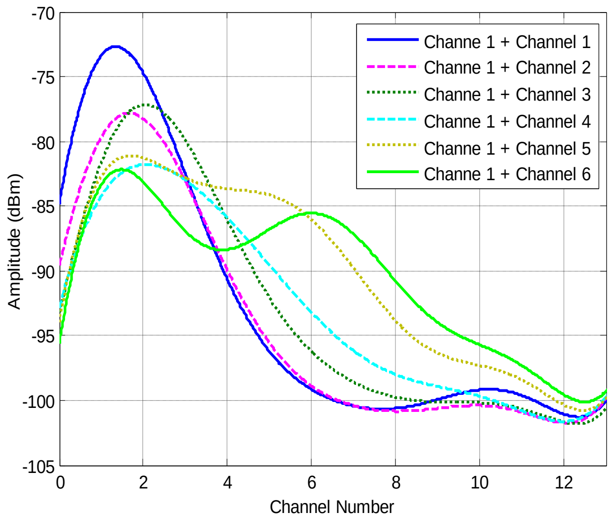

Figure 5: Frequency amplitude for overlapped, mutual overlapped and non-overlapped channels

The following Figure 6 shows the channel utilization for PU channels and non-overlapped SU channels. Fully or mutual overlapped channel obviously increased the channel utilization of PU, beyond this, from this figure we found some interesting results for non-overlapped channel utilization. Standalone PU channel 1 utilize the channel up to 32% whereas, a non-overlapping channel using by SUs (channel 6), increased the channel utilization of channel 1 by 3% than the standalone channel activity. To make sure about utilization increasing by a non-overlapped channel, we used another non-overlapped channel 8 to justify the matter and found to be affect channel 1 as well.

To find the justification of the results in previous Figure 6, we focused on the noise floor level of those channels. Figure 7 shows the noise floor level measured by Chanalizer Pro application at the period of data transmission. We observed, the standalone PU channel 1 activity increased the channel noise up to-90 dBm. At the time while PUs and SUs were using non-overlapped channel (channel 1 and channel 6 respectively), the noise floor of channel 1 also increased than usual activity and the value is around 3.5 dBm more than the usual activity. The similar results were found while SUs are using channel 8 as well. So, it is clear that, the nearest non-overlapped channels affect the PU channel by increasing noise.

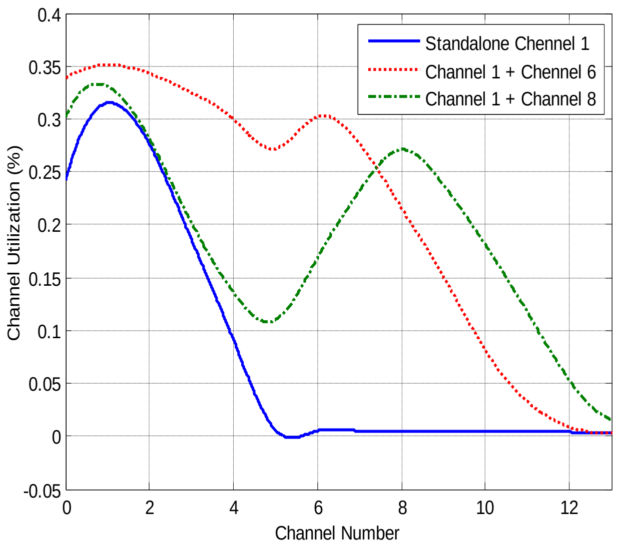

Figure 6: Channel utilization for standalone and non-overlapped channels

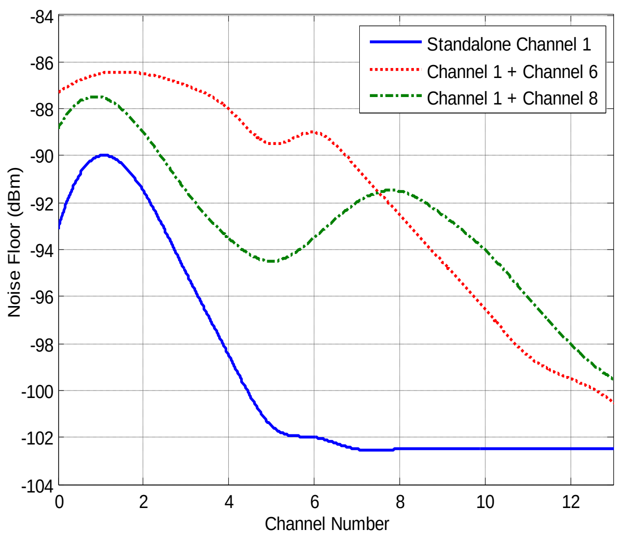

Figure 7: Noise floor for standalone and non-overlapped channels

CONCLUSION

This paper presented 2.4 GHz WLAN channel performance in terms of utilization and noise floor level for a non-overlapped Wi-Fi Direct channel activity. The results show that the non-overlapped channels increased the noise floor level of a WLAN channel up to 3.5 dBm and channel utilization up to 3% than the standalone channel activity. We experimented using one AP, 2 laptops and a pair of SU (smartphone) only. For a medium high crowed area, like office, universities, student hostels use hundreds of APs and thousands of PCs, laptops and smartphones using in peak time. So, the overall noise floor affects a lot to surrounding devices and decreases the overall system performances.

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