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Performance Measurement of 2.4 GHz WLAN Channels for Overlapped and Non-overlapped Wi-Fi Direct Channel Activity

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***Abstract*- This paper presents an experimental performance analysis of 2.4 GHz wireless local area network (WLAN), while the nearby Wi-Fi Direct users communicate with the same channel. Structured WLAN APs were considered as primary users (PUs) and the smartphones as secondary users (SUs) for this study. At present spectrum saturation problem is a critical issue due to a large number of users join every day to this fix band of network. To support more users in a specific area needs more WLAN access points (APs) to avoid saturation. 2.4 GHZ WLAN only has 13 separate mutual channels, among them only 3 channels are non-overlapped with each other. As a result interference may often occur during the time of transmission. Wi-Fi Direct technology uses the same channels as the WLAN AP to communicate within smartphones (SUs). If the SUs use the same overlapped channel with the nearby APs, it interferes to the PUs and increase bit error rate (BER) for both users. In this paper, we studied the performance of PU channels while the SUs use the same overlapped channel and non-overlapped channel. The result shows the throughput performance degrades up to 12.5% during the period of SU activities over same channel.**

I. INTRODUCTION

WLANs have already 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 system is divided into 13 different mutual channels with 22 MHz of channel bandwidth. Among 13 channels, only 3 channels are found non-overlapped with each other as shown in Fig. 1, to avoid interference. Nowadays a practical roll-out 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 channels [3].

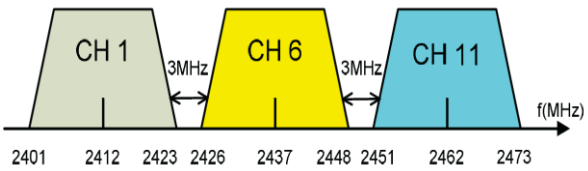


Fig. 1. Non-overlapped channel combination [3]

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 WLAN channel interference with Wi-Fi Direct activity, especially when both of them operate in the same channel.

A number of studies already had been done so far on channel assignment that captures interference at the client level in IEEE 802.11 WLAN [3] - [7]. In a research [3], the authors proposed a throughput enhancement approach based on separation of distance between WLAN APs, who are using overlapped channel. They experimentally analyzed the density of WLAN APs and obtained the separation distance of 3m for 11b; separation distance of 4m for 11g and 11n to guarantee stable throughput of WLAN APs.

In [5], the authors proposed a greedy algorithm which is able to deal both with the frequency assignment association control for WLAN channels between two nearby APs. The simulated results show the algorithm performed well than traditional approach to avoid interferences. Finally they claimed this algorithm maximizes the downlink throughput and avoid interference.

The authors in [6] proposed some approaches for avoiding neighbour interfering APs. They used artificial intelligence (AI) algorithm to mitigate partially or fully overlapped channels from nearby APs to avoid interferences. They expected to robust transmission and gain efficiency for all 802.11 WLAN systems.

Research work in [7], the authors presented a cross layer traffic separation scheme to improve WLAN performance over conventional WLAN. The authors focused on the characteristics of traffic in MAC layer and presented their proposed scheme performance through computer simulations. The presented result shows the system throughput increased up to 250% both in uplink and downlink compared to conventional LAN system.

All the recent works [3] – [7] proposed some unique techniques to improve channel throughput and avoid inter-channel interference. Among them, most of the methods used computer simulations, some work also reported based on experimental analysis. Moreover, all these studies analyzed interferences and throughput problems for more than one WLAN APs. But the throughput or interferences may also affect to nearby WLAN APs if one or more pair of Wi-Fi Direct SUs communicates with the same channel with those APs, which was not considered in any of the researches. Considering this research gap, we present this experimental analysis of throughput and BER of 802.11 WLAN APs users while Wi-Fi Direct operates in the same channel with nearby APs, and suggested a method to overcome this problem. This paper is organized as, Section II. System model, III. Experimental setup, IV. Results and discussions, and finally V. Conclusion.

II. SYSTEM MODEL

We considered the structured WLAN APs as PU 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 connected and transfer data between them using Wi-Fi Direct at nearby location as shown in Fig. 2. We fixed the PU channel and changed the SU channel to observe the channel utilization and noise using Wi-spy device and Chanelizer 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 or partially overlapped

channel with the PU; Scenario 2, SU 1 and SU 2 communicates between them using non-overlapped channel with PU.

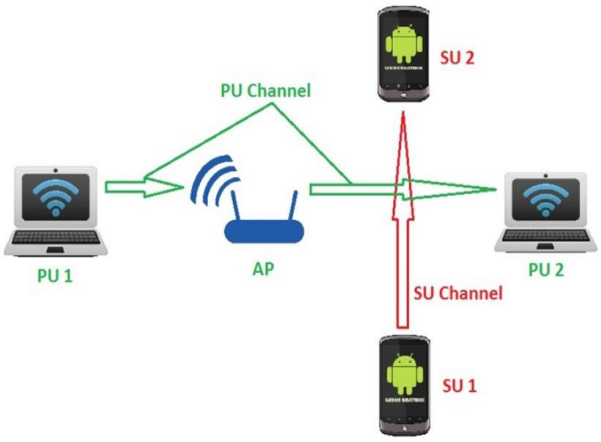


Fig. 2. System setup scenario for experiment

For SU Wi-Fi Direct activity, we used one Android smartphone and one Android tablet with specification detail as shown in Table 1.

Table 1: Smartphones and Tablet PC specifications

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

III. EXPERIMENTAL SETUP

During transmission over a wireless channel, there is a possibility of errors being introduced into the system. Such systems are wireless data links as well as fiber optic data systems, Ethernet, or any system that transmits data over a network of some form where noise and interference. It is necessary to assess the performance of the system, and BER provides an ideal way to decide. BER can be expressed from the following formula (1):

$$BER = \frac{TotalBit_{error}}{TotalBit_{sent}} \quad (1)$$

Where, $TotalBit_{error}$ = Total number of Error bit.
$TotalBit_{sent}$ = Total number of sent bit.

BER can be affected by a number of factors, i.e., Interference, narrow bandwidth, lower order modulation and transmission in low SNR environment. For this experimental case, we considered only the interference factors to measure the experimental BER for overlapped and non-overlapped channel.

To achieve our goal, we followed by a set of experimental steps. All the experiments were performed in lab/indoor environment. At first, we made sure no other WLAN channels, Bluetooth, cordless phones or IP cameras were present on that area to interfere the experimental results. The AP was fixed with channel 1and changed the smartphone's Wi-Fi Direct channels from channel 1 to channel 6 for testing the data throughput and BER consequently.

Two laptops were wirelessly connected to the AP as PU user through 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 [8] to visualize the activity. Chanalyzer turns data collected from a Wi-Spy (and a wireless network interface card) into charts and graphs that help users to determine about the interference level [8]. Fig. 3 shows the working block diagram for the experimental system setup.

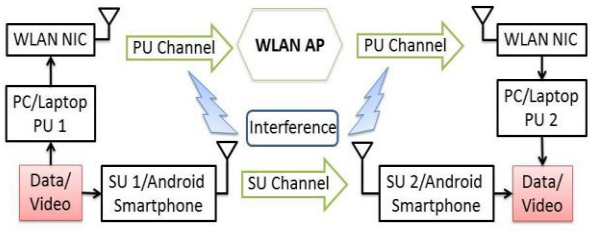


Fig. 3. Block diagram of the Experimental setup.

The throughput data were collected from the Ixchariot log files and processed for further analysis. We Directly got the throughput in Mbps from this application. The throughput data for both overlapped and non-overlapped channel were collected and measured the BER from the following formula (2):

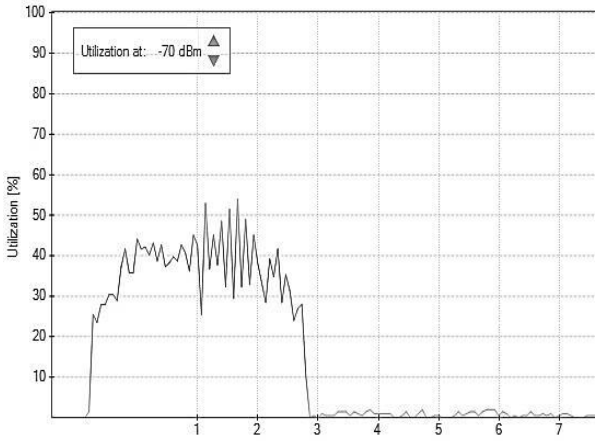
$$Throughput = (1 - BER) \times TotalBit_{sent} \quad (2)$$

Where, $Throughput$ is the total data throughput in Mbps.

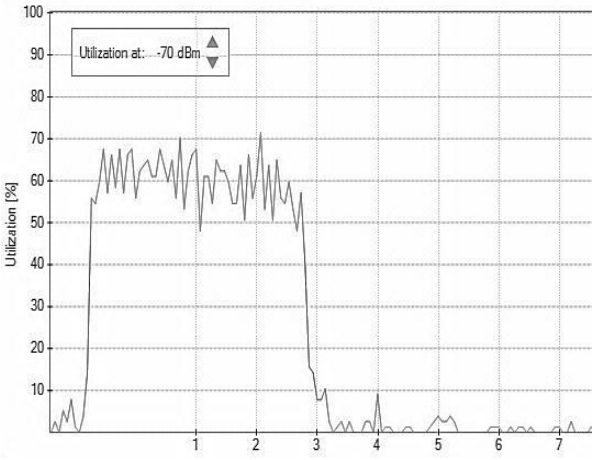
For PU video streaming, we used a 275 seconds long video file with full duplex communication mode; and transferred one 90.4 Megabytes of file from one SU 1 to SU 2 as SU activity. Finally, the throughputs were measured from PU nodes for both scenarios. Ixchariot and Chanalizer Pro application software were used to measure the performance for both scenarios. The findings are discussed in detail in the following section.

IV. RESULTS AND DISCUSSIONS

Fig. 4(a) shows the average channel utilization for channel 1 while only two laptops are streaming data between them through the AP, i.e., only PU is active. It is seen that the utilization is about 40% for PU activity. Fig. 4(b) shows the combine utilization for both PUs and SUs while they are transferring data using the same channel.



(a)



(b)

Fig. 4. Channel utilization with and without Wi-Fi Direct activity

It is seen that, after the SU data activity the total utilization increased for the channel around 60%, i.e., the Wi-Fi Direct activity increased the channel utilization around 20% than usual if no other external interfere to the same channel.

Fig. 5 shows both PU and SU activities while they were using non-overlapped channels. PU was set to channel 1 and SU is set to channel 6 and it is seen that the PU channel utilization is almost same as Fig. 4, and the value is around 40%, whereas, the standalone SU channel utilization is around 30%.

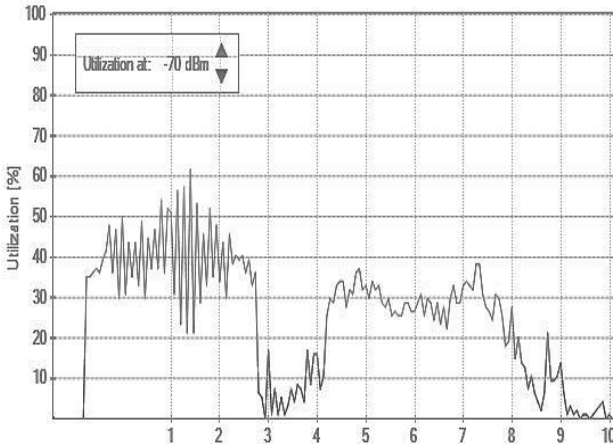


Fig. 5. Non-overlapping channel utilization for PU and SU

Fig. 6 shows the throughout performance of PUs during an on-going Wi-Fi Direct activities at the same channel to PU, and measured by Ixchariot software. We found the non-overlapped channel throughput was around 2.4 Mbps whereas for overlapped channel, it reduced to around 2.1 Mbps. So, it is clear that, there is a significant distortion of data streaming performance exactly at the period of SU activity, which is 12.5% less than the usual throughput. More number of SU activities may cause more interference to the PU WLAN activity.

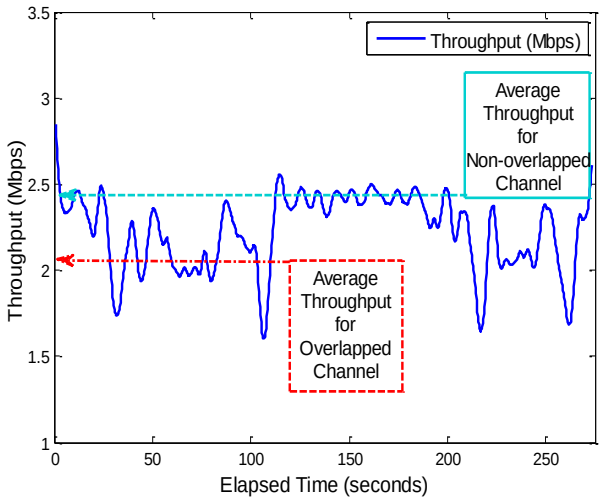


Fig. 6. Throughput interference caused by Wi-Fi Direct activity

Fig. 7 presents the BER for both overlapped and non-overlapped channel. It is seen from the figure that, BER curve for overlapped channel is non-linear and higher than the non-overlapped channel. As we used around 1 meter of distance between laptops for PU-PU and 0.5 meters for SU-SU communication, so the external channel noise due to associated environment is negligible sue to higher interference signal. This higher BER was occurred only due to channel interference with the SU transmission with that same channel. For the non-overlapped channel, the BER still occurs because of the small channel noise. Also, more SU activities at the nearby area may cause more interference than a single pair of SU activities.

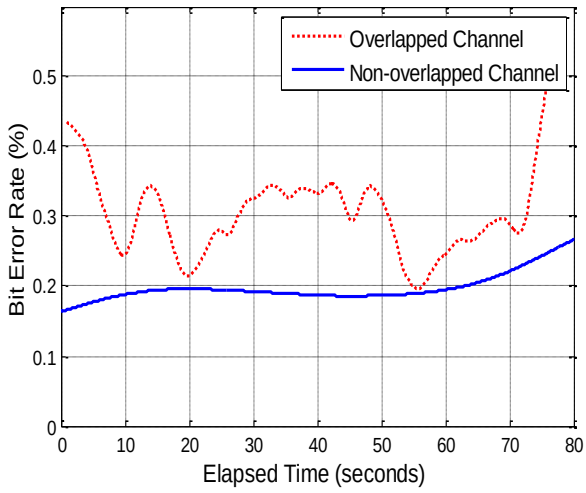


Fig. 7. BER for overlapped and non-overlapped channel

From this experimental study, it is clear that the higher BER can be occurred to WLAN AP users due to high signal interference to noise ratio (SINR) caused by the Wi-Fi Direct transmission at that same channel. This problem is increasing day by day due to higher increasing rate of smartphones and applications with the limited number of WLAN channels. In this experiment, we have used Wi-Fi Direct channel customization method to overcome the problem. It worked nicely with the current set of experimental setup described above to improve the performance significantly.

V. CONCLUSION

In this paper, we have presented an experimental analysis of WLAN channel with and without Wi-Fi Direct activity in terms of throughput and BER. The results show the performance degrades up to 12.5% than the usual throughput due to Wi-Fi Direct overlapped channel activities. Unlike all other WLAN activities, Wi-Fi Direct activities cannot be controlled imposing any rules or regulations. Its activities are also increasing every day with increasing demands of smartphones and applications. So, Wi-Fi Direct channel customization according to user demand may one of the solutions to reduce this channel

interfering issues. Future work may include the development of automatic channel customization according to SU users demand, so that the PU channel users can't be interfered by the SU activity.

ACKNOWLEDGMENT

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