Interference Problem between ZigBee and WiFi

Wail Mardini[+], Yaser Khamayseh, Reem Jaradatand and Rana Hijjawi

Computer Science Department, Jordan University of Science and Technology, Irbid 22110 Jordan

Abstract. There are different wireless technologies that share the same 2.4 GHz frequency band. Such technologies usually operate in proximity and have to co-exist with each other. For example, WiFi uses the same frequency band that is used by ZigBee, however, WiFi uses higher power levels compared with ZigBee. When the ZigBee and WiFi use the channel at the same time, an interference problem appears which causes loss of the data packets being transmitted. This will result in retransmission in both WiFi and ZigBee until a successful transmission is achieved. This, in turn, causes delay and mitigation in the delivery ratio for both technologies. Moreover, ZigBee would wait longer to get free medium for transmission, and with the expected packet loss and retransmission, faster draining of the sensor battery is expected.In this paper we studied the mutual impact of WiFi interference on ZigBee channels by using QualNet Simulator and computed the Packet Delivery Rate (PDR) for bothZigBee and WiFi nodes. The obtained results show that ZigBee has little impact on WiFi Packets, and WiFi affects ZigBee packets with different degrees based on the traffic intensity and number of nodes.

Keywords: ZigBee, WiFi, co-existence, interference.

1. Introduction

The continuous emerging of wireless technologies, in addition to the increasing demands for mobile applications, combined with the wide spread of new human–computer interaction models, such as ubiquitous computing, paved the way for the emergence of new networking frameworks and new applications.

Nowadays, users are equipped with more powerful, small, wireless mobile devices such as mobile phones, PDAs and sensors, these devices generate substantial amount of various data. Moreover, to support the new generation of situation–aware applications, there is a real need for new networking paradigms to support the exchange of information between these devices.

Personal mobile devices are typically of a small size and with limited processing, communications and energy capabilities. Thus, the new networks should support low power and low data rate transmissions. Several technologies were developed to satisfy the above mentioned prospects. A successful example of these technologies is IEEE802.15.4 networks, which is known as ZigBee networks. ZigBee is designed to be cost effective to guarantee a successful commercial spread. To reduce the cost of these networks, they were designed to work in the crowded and overloaded 2.4 GHz ISM commercial band with different technologies such as IEEE802.11 known as WiFi. The coexistence of different wireless technologies causes interference and packets collision, then packet retransmission. Which in turn, cause delay and reduce the delivery ratio. Moreover, ZigBee packet loss and retransmission leads to faster draining of the sensor battery.Therefore, the need to design analytical model to depict the impact of mutual interference between ZigBee and WiFi.

2. Related Work

Several studies have been conducted using analysis and simulation to evaluate the effect of WiFi on ZigBee and vice versa.

[+]Corresponding author. Tel.: + 962-777306646; fax: + 962-7201000.
E-mail address: *mardini@just.edu.jo.*

In [1], the authors derived an analytical model to determine the impact of ZigBee network on the WiFi-bnodes. They experimented and shown that ZigBee network usually have little to no impact on the WiFi-b nodes performance, unless WiFi-b STA is located very close to ZigBee high activity clusters then the result may change.

Authors in [2] have conducted several test-bed experimentsto measure the mutual effects of coexistence between networks that operate in the 2.4 GHz ISM band, such as, ZigBee, Bluetooth, WiFi-b and microwave. The conducted experiments comprise a scenario of 5 test cases that shows that ZigBee is affected by WiFi-b, WIFI, Bluetooth, and microwave. The result of this test shows that when running ZigBee and WiFi-b together, 90% of ZigBee-frames are corrupted and no impact from ZigBee on WiFi-b.

In [3], authors focus on measuring the PER, RSSI and the run lengths distribution for real environments to evaluate the ZigBee MAC protocol by simulation. The authors conducted several experiments to determine the impact of the existence of WIFI and ZigBee networks. Experiments were being conducted using NS-2 simulator. Results show that ZigBee operation has no effect on WIFI packet transmission, whereas careful measures should be taken in order to maintain successful transmissions for ZigBee's packets.

The authors in [4] aims to analyze and calculate the impact of mutual interference on the performance of both WiFi-b and ZigBee networks. The study assesses the performance by means of PER, transmission delay, and throughput. Experiments were conducted using OPEN simulator. Experiments conclude the following: distance and the center frequency offset between WIFI-b and ZigBee are important factors, if the distance is large enough between ZigBee and WiFi devices (about more than 8 meters), then the PER of ZigBee is reduced. However, if the distance is more than 4meters, then the PER of WiFi is reduced. However, for larger values than 7 MHz, the PER of ZigBee is reduced.The work in [5] examines the common interference impacts of 2.4 GHz nodes usually deployed at home, by applying both analysis and real experiments. A theoretical analysis model is conducted to estimate the PER of Radio Frequency (RF) metric of networks operating in the ISM band. The model is tested by applying a series of experiments. The experimental results show that WiFi-b wireless networks can strongly affect ZigBee.

In [6], the authors evaluated the impact of channel hopping on interference mitigation on the 2.4 GHz ISM band in the SunSPOT platform. They used experimental evaluation building in SunSPOT to measure the indoor interference mitigation for both WiFi and WSN; and proposed channel hopping model to reduce the interference between WiFi and ZigBee protocols. The proposed model manages the frequency used by the SunSPOTplatform; it classifies the channels into dense and sparse channels and hop from the dense to sparse channel.

In [7], the authors used three parameters to evaluate the impact on the interference: Received Signal strength indicator (RSSI) to measure the signal strength of THE received packets. Link Quality Indicator (LQI) measures the quality of the received packets, and the CORRelation value (CORR) is used to measure the average correlation value.

Experimental works on interference in the 2.4GHz band and reveal that [8] channel hopping can improve the performance of WSNs when deployed in WiFi collocating environments and [9] among the different parameters, the received signal strength indication (RSSI) is the most relevant for WSN performance evaluation in collocating WiFi environments..

3. Methodology and Experiments Setup

A set of experiments are performed in different environments with different parameters to test the effect of WiFi on ZigBee and vice versa. Different network sizes including changing the number of WiFi nodes and the number of ZigBee nodes along with different traffic rate for each set of nodes were tested.Simulation experiments were conducted using QualNet v 5.2[12].The topology of the network used is simple two stars of each technology with different number of nodes. The simulation parameters used are shown in Table 1.

Table. 1: General Scenario Properties

Parameters Name	Values
QualNet Version	5.2
Simulation Time	1000 sec
Scenario Dimension (x,y)	(25,25)
No. of Channels	1
Channel Frequency	2.4 GHz
Path Loss Model	Two ray model
Battery Model	YES
Distance Unit	Meter
No. of Sensor Nodes	3, 6 and 9 nodes
No. of WLAN Nodes	3, 6 and 9 nodes

Table. 2: WLAN and ZigBee Parameters

	WLAN	ZigBee
Beacon Mode	NA	None
Radio Type	802.11b	802.15.4
Data Rate	2 Mbps	250 kbps
Transmission Power (dBm)	15	3
Packet Reception Model	PHY 802.11b Reception Model	PHY 802.15.4 Reception Model
Mac Protocol	Generic Mac	802.15.4
Channel Access Mode	Slotted CSMA/CA	CSMA
Slot Duration	10ms	NA
Retry Limit	10	0
Routing Protocol	AODV/Direct to base station	NA
Traffic Generator	VBR	CBR
No. of VBR/CBR	2, 5 and 8	2, 5 and 8
Items to send	Unlimited (covers the simulation	Unlimited (covers the simulation
Item Size	Exponential with mean 512 Bytes	51 Bytes
Average packet interarrival	Exponential with mean 0.125,	1 sec
Start Time	Uniform[5,15] Sec	Uniform [15, 15.5] sec

4. Simulation Results

The following are three sets of experiments to evaluate the performance of each technology separately and with the existence of the other.

### 4.1. Results of individual technologies

The following set of results presents the performance of each technology without the existence of the other.In Fig. 1(a) we can see as the number of WiFi nodes increases from 3 to 9, the delivery ration decreases from 95% down to 73% due to more collision of packets. This will result in increasing the end to end delay as can be seen in Fig. 1(b) from 0.03 at 3 nodes to around 0.5 seconds 9 nodes.Fig. 2(a) displays the original result for ZigBee nodes in a clear site environment. Since ZigBee operates with the PAN coordinator according to predefined schedule, then ZigBee nodes don't affect each other for any number of nodes. However, as it can be seen in Fig. 2(b) as the number of nodes increases, the average end to end delay will increase.

4.2. Effect of WiFi and ZigBee nodes on the performance of each other
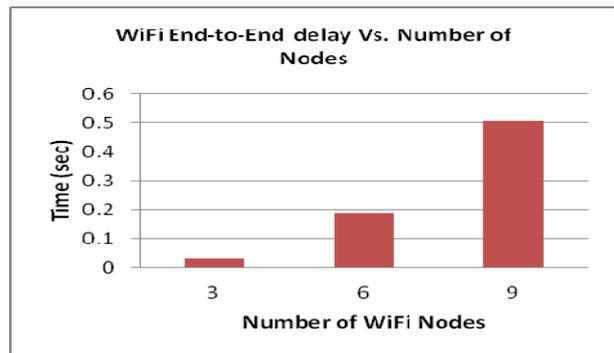
Fig. 3(a) displays the ZigBee delivery ratio for different number of WiFi nodes with fixed number of three ZigBee nodes. The delivery ratio for ZigBee is highly affected and the delivery decreased from 100% when no WiFi exists down to around 73% when 9 WiFi nodes present. As shown in Fig. 3(b)the WiFi delivery ratio for different number of WiFi nodes with fixed number of three ZigBee nodes; are decrease when increase number of WiFi nodes. In Fig. 4(a), we can see that the ZigBee average end to end delay is

not effected by increase the WiFi node, but the WiFi average end to end delay increased by increase the WiFi nodes as shown in Fig. 4(b).

In Fig. 5(a), display the results of ZigBee delivery ratio for three WiFi nodes with different number of ZigBee nodes; 3, 6 and 9 nodes. Apparently since the number of WiFi nodes is fixed, then the same effect is introduced in the three cases of 3, 6 and 9 ZigBee node, so the delivery ratio is almost has very small effect as shown in the three cases. In Fig. 5(b), we can see that the delivery ratio for the three WiFi nodes is affected by introducing more ZigBee nodes, WiFi nodes consider the ZigBee noise as error in packet transmission, as it interferes it's signal if the total activity of ZigBee nodes become bigger. The ratio decreases from around 96% when there are no ZigBee nodes to around 88% when there are 9 ZigBee nodes in proximity. The average end to end delay takes the converse behaviour, i.e. as the number of nodes increases the delay increases. And as a result the energy consumed is also increased. Details are omitted for page limitations.
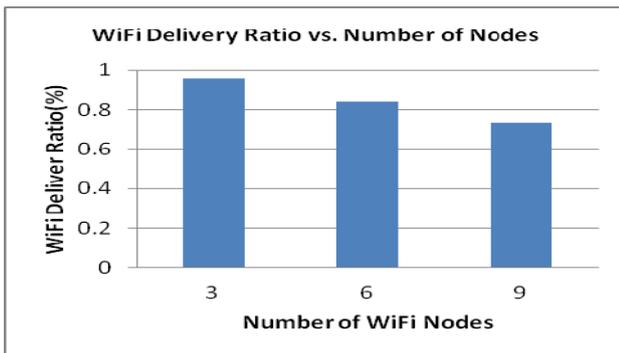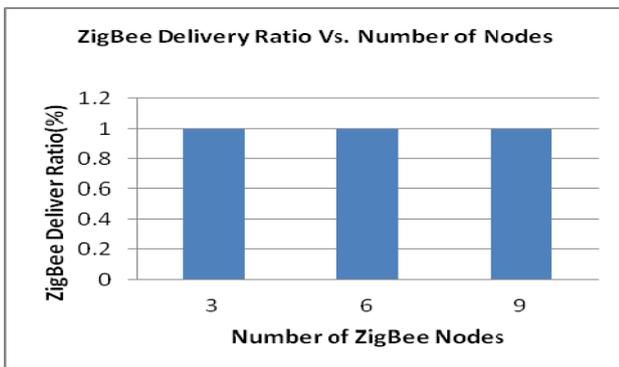

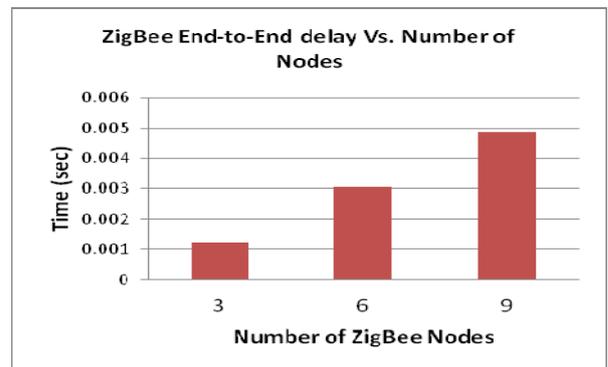(a) WiFi Delivery Ratio vs. Number of WiFi Nodes   (b) WiFi End-to-End delay vs. Number of WiFi Nodes

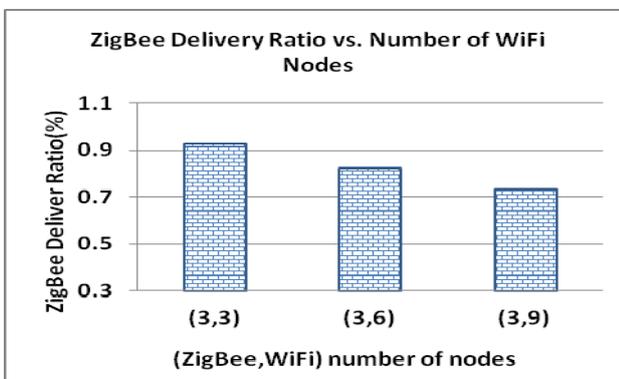Fig. 1: Effect of Increasing the WiFi Nodes in Clear Environment

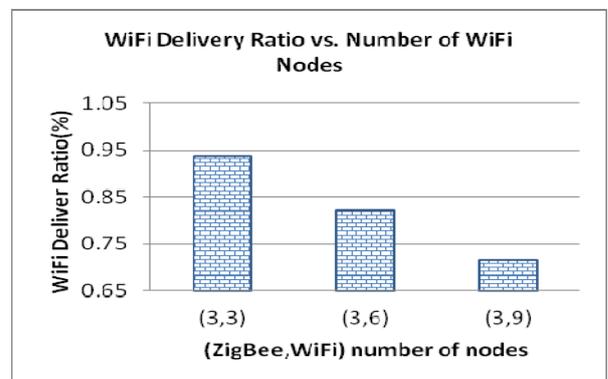(a) ZigBee Delivery Ratio Vs. Number of Nodes   (b)ZigBee End-to-End delay vs. Number of Nodes

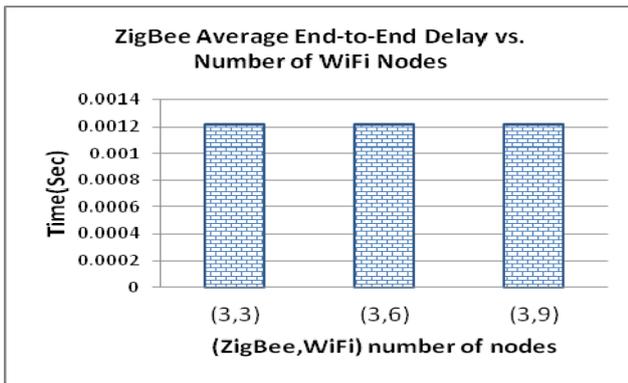Fig. 2: Effect of Increasing the ZigBee Nodes in Clear Environment

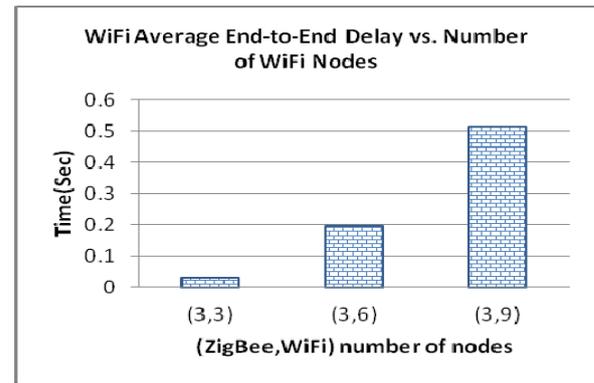(a) ZigBee delivery ratio for different number of WiFi nodes   (b) WiFi delivery ratio for different number of WiFi nodes

Fig. 3: WiFi and ZigBeedelivery ratio for different number of WiFi nodes with fixed number of ZigBee nodes

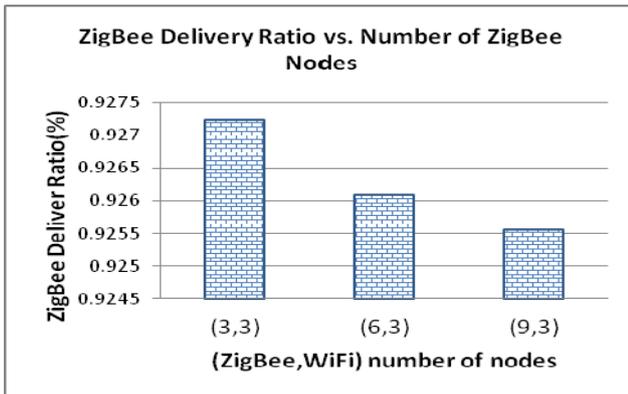(a) ZigBee End-to- End Delay for different number of WiFi nodes

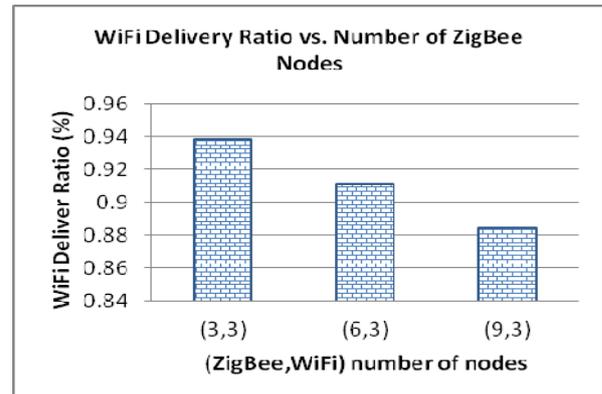(b) WiFi End-to- End Delay for different number of WiFi nodes

Fig. 4: ZigBee and WiFiEnd-to- End Delay for different number of WiFi nodes with fixed number of ZigBee nodes

4.3. Effect of change the interarrival time

Simulations were conducted to show the effect of different WiFi Interarrival time and the effect of different ZigBee Interarrival time on the performance. We omitted the results for page limitation. As a summary, the results concluded that as we decrease the WiFi Interarrival time (i.e. increase the traffic rate), which increase the amount of the channel busies period and reduce the available time for ZigBee to use the channel, the delivery ratio for both ZigBee and WiFi decreases.

(a) ZigBee delivery ratio for different number of ZigBee nodes

(b) WiFi delivery ratio for different number of ZigBee nodes

Fig. 5: ZigBee and WiFidelivery ratio for different number of ZigBee nodes with fixed number of WiFi nodes

5. Conclusions and Future Work

The ZigBee work in 2.4GHz band, this is free band and multi of networks have a high power, high data rate and high frequency work in this band. This networks have adversely effect on the ZigBee; interference problem. In this paper we studied the mutual interference effect between ZigBee and WiFi devices. In the future we can proposed scheme comes to reduce from one of the major problems facing the ZigBee; interference.

6. References

[1] Howitt, I, Gutierrez, JA. ZigBee low rate-wireless personal area network coexistence issues. Wireless Communications and Networking, 2003; (3): 1481- 1486.

[2] Axel S, Voicu FG. Coexistence of ZigBee with other Systems in the 2.4 GHz-ISM-Band. In IEEE Instrumentation and Measurement Technology' 2005 May, Ottawa: Canada.1786–1791.

[3] Marina P, Janne R, Petri M, Saverio L. Performance Study of ZigBee Using Measurements and Simulations. Proceedings of IEEE Wireless Communications and Networking Conference 2006 April ; Las Vegas, NV:USA; 487–492.

[4] Soo YS, Hong SP, Wook HK. Mutual interference analysis of ZigBee and WiFi-b. Computer and Telecommunications Networking 2007;(51) : 3338–3353.

[5] HUO H, XU Y, Mikael G, ZHANG H. Coexistence of 2.4 GHz sensor networks in home environment. China Universities of Posts and Telecommunications 2010; 17(1) :9-18.

[6] Antoine BB, Ashish M, Marco Z. Experimental Evaluation of Interference Mitigation on The 2.4 GHz ISM band Using Channel Hopping, Proceedings of the IEEE Wireless Days' October 2010; Venice:Italy: 1-5.

[7] Jun H, Guoliang X, Gang Z, Ruogu Z. Beyond Co-existence: Exploiting WiFi White Space for ZigBee Performance Assurance. The 18th IEEE International Conference on Network Protocols (ICNP)' October 2010; Kyoto: Japan. 305-314.

[8] Shahin F. ZigBee Wireless Networks and Transceivers. USA: Newnes; 2008: 339. ISBN: 978-0-7506-8393-7.

[9] Cirronet, Inc. ZigBee™ Wireless Transceiver Engineering Options. 2005. White Paper.

[10] Paolo B, Prashant P, Vince WC Chook, Stefano C, Alberto G, YFun Hu. Wireless Sensor Networks: A Survey on the State of the Art and the 802.15.4 and ZigBee Standards. Computer Communications. 2007; (30):1655-1695.

[11] William L, Lee W McKnight. Wireless Internet Access: 3G vs. WiFi Madrid. Telecommunications Policy 2003. 351–370.