A Survey on Co-existence Mechanisms in WLAN and WPAN Devices

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***Abstract*----Wireless technologies have experienced an enormous growth in the last decades. The wireless personal area networks (WPANs) and wireless local area networks (WPANs) are heterogeneous networks which are used in different applications. Two networks, called Wi-Fi (IEEE 802.11 WLAN) and ZigBee (IEEE 802.15.4 WPAN), which operates in 2.4 GHz frequency. Spectrum sharing is an effective technique which is used to enhance spectrum utilization. However the coexistence and Interoperability is a critical problem in the case of heterogeneous networks. These critical problems will lead to occurrence of the crowd in the spectrum. Because of these reasons in which hosting of more number of heterogeneous networks, the shortage of ISM bands happens. The packet loss and less throughput problems happen in the network due to the insufficiency of the Wi-Fi channels in the ISM band. In this survey, different coexistence mechanisms are suggested to reduce the interference. Scheduling of frequency is one of the methods which are utilized to tackle the trouble of Zigbee Wi-Fi coexistence. However, this frequency planning method does not overcome the problem of burst collisions. This method only responds after the collision had occurred on the network. To develop the wireless personal area networks and wireless local area networks coexistence, the spectrum-survey technique is utilized which regulates the power level of transmission. This method is applicable for static networks and accomplishes the long-term throughput between the heterogeneous networks. But the drawback in this method is short-term performance factors such as collision rate, end-to-end delay is not considered. Specifically, in this survey different coexistence mechanisms are analyzed that how to reduce the interference.**

***Index terms*---WLAN, WPAN, Industrial, Scientific and Medical (ISM) band, Spectrum sharing**

I. INTRODUCTION

Recently, a huge number of wireless networks are developed and deployed in the market [15]. The incessant promising of wireless technologies and also the increasing demands of mobile applications, integrated with the extensive spread of new human–computer interaction models, such as ubiquitous computing, paved the way for the appearance of new networking frameworks and new applications. Based on the communication range, wireless networks can be categorized into wireless personal area networks (WPANs), wireless local area networks (WLANs), wireless wide area networks (WWANs), and Wireless metropolitan area networks (WMANs). The wireless personal area networks (WPANs) are a sophisticated technology which presents a data rate of hundreds of Mbps at a distance of less than 10 meters. In the wireless technologies, the wireless local area networks (WLANs) and wireless personal area networks (WPANs) are two emerging wireless technologies which are utilized in numerous applications.

A. WPANs and WLANs

Wireless personal area networks: Wireless personal area networks (WPANs) are one of the wireless communication technologies, which is used to communicate and transfer the data between the connected devices [15]. The communication range of the wireless personal area network is within 10 meters. The standard for wireless personal area networks (WPANs) is IEEE 802.15. The two significant technologies in WPANs are Bluetooth and Infrared data association. The operating frequency of WPANs is 2.4 GHz. The main target of WPAN is to provide a faultless connection among the interconnected devices. In the WPAN each and every device capable to plug into any other device and easily communicate with other devices. The other significant feature of every device is capability to lock out other devices selectively, so that it avoids the interference and permits the unauthorized persons. The important technology of wireless personal area network is Bluetooth and Zigbee. Bluetooth is a short range communication wireless technology, which is used to transfer the data. The communication range of Bluetooth is 10 meters. Bluetooth devices are pointing devices, printers connected to personal digital assistants, cell phones and computers are connected wirelessly.

II. BACKGROUND STUDY

A. Overview of 802.11

Wi-Fi networks [13] are mostly utilized in office buildings, homes, and even outdoors in urban areas. Consider that 802.11b, 802.11g, and 802.11n utilize the similar frequency 2.4 GHz ISM band with 802.15.4, 802.11 transmissions, then it can blocked with positioning of 802.15.4 networks. In the United States, only 15.4 channels are used where 25 and 26 do not overlie with Wi-Fi and even these channels are enclosed in other parts of the world. Most of the Wifi networks utilize channels 1, 6, and 11, 15.4 channels 15 and 20 can also be interference-free. The probable for 802.11 transmissions to overcome 15.4 receivers is augmented by the fact that 802.11 radios broadcast at 10 to 100 time's superior influence than 15.4 radios.

IEEE 802.11 gained huge popularity because of the cost effectiveness and easy deployment. It is used in broadly arranged wireless network technologies in the world.

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Recently, IEEE 802.211 is accessible in offices, campuses, airports, hotels, public transport stations and residential places.

The IEEE 802.11 standard defines two different architectures, one is BSS (Basic Service Set) and another one is IBSS (Independent Basic Service Set). In the Basic Service Set, the number of wireless channels are called STAs2, are related to an access point. By using the access point only, the communication takes place. An Independent Basic Service set has STAs2 access point which is a collection of number of wireless channels. It is fully involved in the communication process. STAs can change with them self and should be within the transmission range. In the absence of any network, STAs are allowed to build any type of wireless Ad Hoc network.

B. Overview of 802.15.4

Zigbee technology is an efficient wireless technology, which is a low data rate, low power consumption, low cost networks. This wireless technology is used in automation and remote control applications. IEEE 802.15.4 standard has also initiated working with low data rate applications. After that, ZigBee Alliance and the IEEE determined to connect forces and ZigBee is the viable name for this technology.

ZigBee is anticipated to provide low cost and low power applications so that to prolong the battery life. By using the mesh networks, Zigbee is developed which is larger than Bluetooth. ZigBee compliant wireless devices are anticipated to transmit 10-75 meters, based on the RF environment and the power output consumption requisite for a given application, and will function in the unlicensed RF worldwide. The data rate is 250kbps at the frequency 2.4GHz, 40kbps at the frequency 915MHz and 20kbps at the frequency 868MHz.

IEEE and ZigBee Alliance have been working intimately to denote the complete protocol stack. IEEE 802.15.4 focuses on the requirement of the lower two layers of the protocol. The Zigbee Alliance uses the upper layers of the protocol stack in multi-radio networks for improving their performance and also to build interoperable data networking. To develop the standard of protocol stack, enhanced security services, variety of wireless home and building control solutions, interoperability observance testing mechanisms and improved marketing schemes have been considered for Zigbee.

C. Contradictory coexistence of ZigBee with Wifi

Both production and research communities have been studied the interference between the Wifi and Zigbee. If there is less traffic in Wifi, Zigbee is known to suffer a smaller quantity conflict with Wifi and there is packet loss [4] [8]. On the other hand, under restrained to high Wifi traffic, the performance of the Zigbee is severely degraded.

Tan et al. [9] says that wifi may interfere the transmission of Zigbee even Wifi and Zigbee are positioned close to each other. Due to the propagation of Wifi devices and high data rate applications the quantity of Wifi traffic in a usual home or enterprise environment will keep growing, thus strictly disturbing the trustworthiness of ZigBee.

J. Huang et.al suggested a technique which is called WISE [12] modifies the ZigBee frame size adaptively based on the computation of the idle interval between Wifi transmissions. It needs to defer ZigBee transmissions in each Wifi burst, and is inappropriate for TDMA packets or delay-sensitive applications.

R. Gummadi [11] suggested a spectrum-based method for enhancing the WPAN–WLAN coexistence, by regulating transmit power and carrier sensing threshold. This method is appropriate for static networks. This method targets long-term throughput fairness between heterogeneous networks. On the other hand, this method does not consider the short-term performance metrics like delay and collision rate. Because these parameters are significant in the monitoring and control applications usually on the ZigBee networks.

X. Jing et.al suggested a simple reactive spectrum organization method which is used in multi-radio networks [5]. In these methods the nodes are reacting to interference and the channel conditions are altered by tuning the parameters like power level, data rate, and channels for reducing the interference. By using these methods complexity is reduced in multi radio networks and no extra equipment is required for processing. But the drawback in this method is less performance in the dense environment.

J. Zhu et.al suggested the heterogeneous radio technologies use the half of the spectrum in the multi-radio environment [7]. The interference problems are classified into two dissimilar categories: The interference occurred because of the co-located radios in the same platform. Another one is interference is occurring because of the close proximity of different wireless platforms. In the dense multi-user scenario, the interference problem is quite complicated and it is not easy for simple reactive methods to discover the gaps between spectrum-use bursts for interference avoidance.

S. Pollin et.al [6] suggested traditional approaches for coexistence of wireless devices which targets on the control of the transmission power level. For instance, the acceptable transmit power is decided in order to assure of a protected radius to primary users that should not be interfered with other devices. This is particularly helpful to facilitate spectrum allocation between systems with different levels of authoritarian status. This category of sharing is called vertical sharing whereas horizontal sharing considers the systems with equivalent authoritarian status. Pertaining to the horizontal sharing between homogeneous devices, game-theoretic concepts are used in to accomplish distributed transmit power allocations. If the operating conditions of the wireless networks such as Wi-Fi and Zigbee are very asymmetric, so

they can be considered as disadvantages of traditional approaches.

Rahul et al. [10] proposed an interference-nulling approach to enhance the performance. This method forces the wideband devices to assign the idle spectrum for narrowband devices. This method needs hardware alteration to complete customized signal processing. Furthermore, the devices must be capable to intellect each other so as to decide which part of the spectrum should be nulled.

III. Different Co-existence Mechanisms

A. Distributed adaptation methods

Sofie Pollin et.al [6] suggested distributed adaptation methods for WPAN devices, to reduce the effect of the WLAN device interference. Because the main significant problem is heterogeneous networks in Interoperability and coexistence. So, to reduce the interference new adaptation methods are suggested. The idea is to initiate distributed algorithms to enhance the 802.15.4 performance under varying 802.11 interference patterns. The sensor network is indeed dangerously exaggerated by the coexistence, because its output power is much lower than that of 802.11 networks. The proposed algorithms should be fully distributed to progress scalability (since sensor networks are large), robustness (which is an important requirement for sensor network applications) and adaptability.

B. Multiple Access Control Methods

In [1], **Tobagi and Kleinrock** suggested a method which utilizes a busy tone to overcome the hidden terminal problem. The protocol which is called busy tone multiple access (BTMA) protocol is a centralized network operation. i.e., a network with base stations. In this scheme, if the base station senses the transmission of a terminal, a busy tone signal is broadcasted to the entire terminals keeping them from accessing the channel. The original busy tone multiple accesses were suggested to be used in a network with a base station and the scheme utilizes the busy tone in a centralized manner. Even though this protocol could be used in ad hoc networks with distributed control, to the knowledge, but the performance has not been investigated for this scheme in such networks.

Tobagi and Kleinrock suggested and analyzed the Split-channel Reservation Multiple Access (SRMA) scheme for reducing the interference [2]. In this scheme, there are number of terminals and one central station. The entire channel is divided into two sub-channels for transmitting the messages and transmitting the control messages. Otherwise the three sub-channels are used for transmitting the messages and transmitting the request messages and answer-to-request transmission. A node sends the request message to the central station on the particular requested channel in an ALOHA or CSMA manner. The central station acknowledged for the successful requests will be acknowledged before the data packet is transmitted.

The Receiver-Initiated Busy-Tone Multiple Access scheme (RI-BTMA) was suggested by **Wu and Li** [3]. In this method, a packet preamble is sent to the intended receiver by the transmitter. Once the receiver receives the preamble accurately, the receiver sets up an out-of-band busy tone and waits for the data packet. After that, the transmitter senses the busy-tone transmits the data packet to the destination. The main functionalities for the busy-tone: to acknowledge the channel access request and to evade transmissions from other nodes. This method is used in the slotted manner. The accurate process of Receiver Initiated Busy Time Medium Access (RI-BTMA) depends basically on the synchronization of slots, which is typically complex to accomplish globally in a distributed ad hoc networking environment, particularly of the mobile type.

C. Scheduling mechanisms

Xinyu Zhang et.al [14] suggested Cooperative Busy Tone mechanism which is used to enable the consistent coexistence between two such networks, which is called ZigBee and Wifi. This cooperative busy tone mechanism facilitates a separate ZigBee node to schedule a busy tone concomitantly with the preferred transmission, so that it improves the visibility of ZigBee devices to Wifi. Its core components contain a frequency flip scheme which avoids the mutual interference between cooperative ZigBee nodes, and a busy tone scheduler that reduces the interference to Wifi, for both CSMA and TDMA packets. To optimize CBT, an analytical framework can be established which is associated with its key design parameters to performance and cost.

The frequency flip make use of the intrinsic spectrum heterogeneity between ZigBee and Wifi. In the WPAN networks, a unique coordinator schedules a mixture of TDMA and CSMA slots occasionally. At every scheduling period, a beacon signal is initiated, followed by a number of CSMA slots and TDMA slots.

Cooperative Busy Tone mechanism sustains the inheritance scheduling protocol, but it needs the signaler to transmit the busy tone at a fitting time, such that: i) it minimizes the Wifi preemptions of ongoing or approaching ZigBee transmissions and ii) it reduces the potential influence on Wifi performance. The busy tone scheduler is intended to address this tradeoff. It facilitates both the TDMA and CSMA mode of ZigBee to coexist with Wifi.

IV. ANALYSIS OF METHODS

S. No	TITLE	AUTHORS	METHODS	ADVANTAGES	DISADVANTAGES
1	The hidden terminal problem in carrier sense multiple-access and the busy-tone solution [1]	F. A. Tobagi and L. Kleinrock,	Floor acquisition multiple access (FAMA)	Performs better than ALOHA and CSMA protocols in the presence of hidden terminals	End to end delay are much larger than propagation delay
2	Avoiding RF Interference Between WiFi and Zigbee[4]	Crossbow technology	Analysis of avoiding RF interference	When wifi and Zigbee are properly configured RF interference can be avoided	When MICAz's ZigBee and the Stargate's WiFi channel are overlap together packet loss ratio reduced from 100%
3	Reactive Cognitive Radio Algorithms for Co-Existence between IEEE 802.11b and 802.16a Networks[5]	X. Jing, S. Mau, D. Raychaudhuri and R. Matyas	Common Spectrum Coordination Channel (CSCC) protocol	Overall system throughput is improved	Delay and control overhead is not considered
4	Distributed Cognitive Coexistence of 802.15.4 with 802.11[6]	S. Pollin, M. Ergen, M. Timmers, L. Van Der Perre, F. Catthoor, I. Moerman, and A. Bahai	Co-existence Model based on power and timing	Contention window remains the same size in the case of busy time also.	IEEE 802.15.4 nodes may still suffer from the IEEE 802.11 interference due to the interference of wireless devices.
5	Multi-Radio Coexistence: Challenges and Opportunities[7]	Jing Zhu, Alan Waltho, Xue Yang, and Xingang Guo	Media independent coexistence service (MICE) layer	Achieves up to 50% improvement of the transmission efficiency	Co-existence bottleneck is bottleneck
6	ZigBee – WiFi Coexistence[8]	Gilles Thonet, Patrick Allard-Jacquin, and Pierre Colle	Co-existence of Zigbee layer	Real time wifi traffic doesn't have any impact on Zigbee transmission	Increased wifi duty level and power level can lead to the packet loss.
7	Harmful Coexistence Between 802.15.4 and 802.11: A Measurement-based Study[9]	S. Pollin, I. Tan, B. Hodge, C. Chun, and A. Bahai	Analysis of co-existence between IEEE 802.11 and IEEE 802.15.4	Interference doesn't affect the routing path. No need to change the routing path.	It cannot guarantee about the location of group of adjacents.
8	Learning to Share: Narrowband-Friendly Wideband Networks[10]	Hariharan Rahul, Nate Kushman, Dina Katabi, Charles Sodini, and Farinaz Edalat	SWIFT	Acheives higher throughput and greater range	Decoding a packet requires an exact knowledge of agreed bins
9	Surviving Wi-Fi Interference in Low Power ZigBee Networks[13]	Chieh-Jan Mike Liang, Nissanka Bodhi Priyantha, Jie Liu, and Andreas Terzis	BuzzBuzz Solution, TinyRS	Increased packet reception rate	Smaller packets can be demodulated due to the corrupted length field
10	High-Speed Wireless Personal Area Networks: An Application of UWB Technologies[15]	H. K. Lau	Ultr wide band (UWB) in WPAN	1. Provides high band width for small communication range 2. More Robust to interference	High power consumption

V. CONCLUSION

This survey presents a successful investigation of the IEEE 802.15.4 WPAN (Zigbee) and 802.11 WLAN (Wifi) interference patterns at 2.4 GHz ISM band. These two networks are used in different applications. But the interference is an important consideration which reduces the system performance. This survey focuses on different coexistence mechanisms to tackle the problem. The mechanisms like Distributed adaptation methods, Multiple Access Control Methods, Scheduling mechanisms are suggested and analyzed. Busy-tone-based signaling mechanism is one of the mechanisms are recommended to improve the performance of CSMA for ad-hoc and sensor networks. Also, cooperative busy-tone mechanism is used which can be recognized by utilizing off-the-shelf ZigBee devices. The intention of CCS will be different from preceding busy-tone mechanisms in that it facilitates the coexistence between heterogeneous MAC protocols. At the end of this survey, conclude that an effective mechanism is proposed to reduce the interference in the heterogeneous networks.

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