A Survey on Interference Mitigation Techniques for 2.4 GHz ISM Band

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Abstract - **Wireless communication technologies play an important role in the design and implementation of Mobile Ad hoc Networks (MANET). This communication technology is mainly supported by Wireless Personal Area Network (WPAN) and Wireless Local Area Network (WLAN). Both WPAN and WLAN are operating in the 2.4 GHz industrial, scientific, and medical radio (ISM) band and this coexistence in the ISM band leads to interference and performance degradation in the MANET. The main objective of this paper is to make a survey on the existing interference mitigation techniques proposed by researchers in the domain of wireless communication technologies. This survey paper identifies that there are various interference mitigation techniques available and also aspecific interference mitigation technique is not applicable to all the interferences in the network. There is a wide scope for the researchers to concentrate on this interference mitigation techniques to improve the performance of the MANET environment. Though this work does not endorse any particular interference techniques, researchers would get benefit in knowing the existing techniques and selecting appropriate techniques for their study.**

Keywords: Interference, ISM, MANET, WLAN, WPAN

I. INTRODUCTION

In recent years, the emergence and advancement of communication technologies for flexibility among applications, virtual communities, and web services are increasing day-by-day. This technological development accelerated a lot in the mobile communication devices. These communication devices can be broadly classified into Wireless Personal Area Network (WPAN) devices and Wireless Local Area Network (WLAN) devices. Each device in WPAN and WLAN is having its own characteristics and restrictions. Both WPAN and WLAN relies on radio frequency to have a communication in the network. Use of radio frequency (RF) bands in the United States (US) is regulated by authorities such as the Federal Communications Commission (FCC), and in Europe by the European Telecommunications Standards Institute (ETSI).

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These regulators define part of the radio spectrum as license exempt (unlicensed) for private users, i.e. anyone can transmit as long as they meet certain requirements. The three main unlicensed bands suitable for sophisticated data transmission are industrial, scientific, and medical (ISM) bands, unlicensed national information structure (U-NII) and high-performance radio local-area networks (HiperLAN2). Specifications and allowable uses of these bands vary based on local regulations, so products must be certified to conform to the rules of the specified country, to be able to transmit. Among the three unlicensed bands, the 2.4 GHz ISM band is available globally, thus it supports and offers a rare opportunity for manufacturers to develop their products in the 2.4 GHz band for worldwide market. The Federal Communications Commission (FCC), originally required radios operating in the 2.4 GHz ISM band to apply spread spectrum techniques, if their transmitted power level exceeds minimum specified decibel units. Systems using these techniques, deliberately spread the message signal in the frequency domain, resulting in a much wider bandwidth and consequently in lower power density. When both WPAN and WLAN mobile communication devices co-exist in a particular environment there arise interference due to the usage of unlicensed ISM band of 2.4 Ghz. According to the Glossary of Telecommunication Terms - Federal Standard 1037C, "*interference is defined as a coherent emission having a relatively narrow spectral content*". Understanding the effect of interference and modelling interference-free protocols in wireless communication is essential, especially among WPAN and WLAN technologies in the 2.4 GHz unlicensed band for effective data transmission. Now-a-days, Cognitive radio technology is used to analyze the spectrum of WPAN and WLAN and it is also used for the detection of interference among WPAN and WLAN technologies under various dynamic conditions. The interference caused by wireless networks cannot be predicted. The duration of interference in this wireless adhoc network is from few minutes to several hours. This interference will cause a huge damage in the ad-hoc network. The interference could also make threats to functionality and security of the network. Effective mitigation of interference in MANET is still in nascent stage due to the divergent characteristic of devices and unlicensed band. This makes the researchers to build a specific interference mitigation techniques rather than a generalised technique to mitigate interference in the environment. From various study, it is found that usage of common spectrum suffers from interference and effective interference mitigation mechanism is needed for the co-existence of WPAN and WLAN [1] [2] [3]. In order to support the co-existence of WPAN and WLAN devices, various researchers have proposed various interference mitigation techniques. This paper aims to explore some of the notable interference mitigation techniques proposed by the researchers for the effective design and implementation of Mobile Adhoc Network.

The organization of the paper is as follows. Section II gives some of the notable existing interference mitigation techniques. Section III provides a brief discussion about the techniques surveyed and Section IV concludes the paper.

II. Existing interference techniques

When a narrowband signal is elaborated into a large or wide band spectrum, then the wide band spectrum is termed as spread spectrum. Nowadays both WPAN and WLAN techniques are using this spread spectrum. This spread spectrum can be classified into two major types called the Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS) which are used by WPAN and WLAN respectively. In general, the modulation process in FHSS is based on signal hopping in contrast; DSSS is based on signal chipping. Transmission in wireless mobile adhoc network for WPAN and WLAN can be initiated either by FHSS and DSSS. When the receiver detects the unwanted signal in the received signal along with original signal or it receives corrupted signal then it is termed as Interference or noise. When there is a best performance between data transmission among WPAN and WLAN devices then there is less interference. If there is interference among the devices then there might be need to resent data among the communications which leads to worst or poor performance. The negative effects of interference are, decrease in the wireless range between devices, decrease in data throughput, Intermittent or complete loss of the connection and difficulty pairing between device's discovery phases. This following section discusses briefly on the various existing interference techniques in the communication technologies of 2.4 GHz ISM band.

1. Salam Akoum et al. [4] have proposed spatial interference mitigation at the transmitter for multiple input single output adhoc networks. They have applied zero forcing beam forming at the transmitter, and have analyzed the corresponding network throughput and transmission capacity. By assuming a network with Poisson distributed transmitting nodes and spatially independent Rayleigh fading channels, they have applied mathematical tools from stochastic geometry to derive a lower bound on the probability of outage. Their approach has increased residual interference at the receiver.
2. SofiePollin et al [5] proposed a distributed adaptation method to mitigate interference between WLAN and WPAN devices. In this method, the author proposes an algorithm to adapt WLAN and WPAN devices in the environment based on the power consumption and distribution in the network. This work demonstrates and increases the performances of 802.15.4 under the coexistence of 802.11.The major setback of this work is range of distribution to have a better performance.
3. Santi [6], proposed a topology construction mechanism based on energy to mitigate the interference.The proposed work can be exercised by reducing the transmission range of all the nodes in the network by the same minimum amount, or the minimum transmission range for each node. From various literature survey it is observed that the assumptions are valid but they are costly and not easy to implement.
4. Kleinrock and Tobagi [7]**,** have proposed interference mitigation technique based on Split Channel Reservation Multiple Access (SRMA). This is one of the earliest methods proposed to handle interference in the communication. In this technique, the author suggested to split the channels into two-three sub channels between the transmitter and receiver node. Based on the division, nodes in the network can use this sub-channels to transmit and receive the messages in the network. The major drawback of this proposed technique is centralised station to monitor the network.
5. V. Haghighatdoost et al. [8] have proposed a general algorithm called Apln for finding the spanning tree of separate nodes in the plane. Their Apln algorithm presents an iterative routine for minimizing the maximum interference of the resulting spanning tree. At the beginning the resulting tree has only one edge, which is the smallest edge in the input graph, until all input nodes are not connected together, their algorithm adds a new edge to the resulting tree. For adding a new edge to sub graph the best edge, which imposes minimum increase on the interference of all nodes from all available edges is selected. The Apln is a general algorithm for any two dimensional distribution and it has no limit or special conditions for the input distribution.
6. Chiasserini, Carla-Fabiana, and Ramesh R. Rao [9], have proposed co-existence of WPAN and WLAN devices with reduced interference based on the traffic scheduling algorithm. This traffic scheduling algorithm was supported with V-OLA scheme and D-OLA scheme to avoid overlapping between WPAN and WLAN packets. The major setback of this algorithm is delay in packet delivery .
7. Zhang, Xinyu, and Kang G. Shin [10], have proposed Cooperative Busy Tone (CBT to mitigate the interference issues between 802.15.4 and 802.11. This work employs legacy scheduling protocol to monitor the 802.15.4 networks and pre-empts when 802.11

signal influence the network thereby avoiding the packet loss and interference in the network. This work advocates for centralised system to monitor and mitigate the interference among the devices.

8. Fredrick Awuor et al., [11] have proposed coupled interference network utility maximization (NUM) strategy (i.e. CIN) for rate adaptation in WLANs that is solved using "reverseengineering" based on Karush-Kuhn-Tucker (KKT) conditions. According to their approach, the users determine data rates based on their local observations (i.e. coupled interference). Both pricing and limited message passing mechanisms are employed in the NUM wherein pricing restrict users from selfinterest behaviors while limited message passing assist users to announce their prices and transmit powers.
9. R. Gummadi [12] proposes conventional spectrum based method to support the coexistence of WPAN and WLAN devices. The major drawback of this proposed model is its support for the static network and not for the dynamic and mobile network. This work advocates that the carrier sensing and transmission power support to mitigate the interference.
10. Burkhart et al [13], have proposed a topological graph based interference mitigation mechanism among the WPAN and WLAN devices. This model supports sender-centric interference measure and mitigation which is the major drawback of this system. This model suggested a graph with less sparseness will have a less interference than the graph with more connectivity.
11. NouhaJaoua et al. [14] have proposed an approach based on Bayesian estimation using particle filtering. They have proposed their approach to estimate jointly the multicarrier signal and the noise parameters. Based on sequential Monte Carlo (SMC) methods, their proposed scheme allows the online estimation using a Raoblackwellized particle filter.
12. D'mello, Sejal, and ZahirAalam [15] have classified interference mitigation based on Adaptive Frequency Hopping (AFH) techniques for the co-existence of WPAN and WLAN devices and argues that AFH are robust in interference mitigation. This work addresses effective interference mitigation for Bluetooth devices and not to support the WLAN devices.
13. Guinian Feng et al.,[16] have proposed a topology control algorithm called minimum interference algorithm (MIA), to minimize the overall network interference. They have formulated the pair wise interference condition between two links, and showed that the interference conditions for the minimum-transmit-power strategy and the equal-transmit power strategy are equivalent. Based on the pair wise definition, they have further investigated the "typical" interference relationship between a link and all other links in its surrounding. They have defined a new metric called the interference coefficient to characterize the extent of the interference between a link and its surrounding link.
14. Moaveni et al. [17], have suggested a model called "coverage model" to mitigate the interference in the communication. This work considers interference arises based on the number of nodes in the environment and its communication link. This model considers interference from the sender perspective rather than the receiver. The other major drawback in this model is the adhoc connectivity of nodes in the network.
15. Suseendran, G., and E. Chandrasekaran., [18] have proposed Interference Reduction Technique in Mobile Adhoc Networks using Mathematical Prediction Filters.This paper proposed an interference reduction technique for mobile adhoc network (MANET) using mathematical prediction filters. This technique uses Hidden Markov Model (HMM) for predicting the interference of nodes. Initial transmission power is set by comparing the received signal power with minimum and maximum values. During data transmission, RTS and CTS messages are exchanged at initial transmission power values and they include the interference values of the source and destination, respectively. The source uses the interference value of the destination to transmit data packet. On the other hand, the destination uses the interference value of the source to transmit the ACK message. Thus, this interference calculation at both ends reduces the interference.

Table 1 summarises the existing interference mitigation techniques.

Table 1. Interference Mitigation Techniques

S. No.	Authors	Techniques Proposed	Interference Measured	Drawback
1.	Salam Akoum et al.	Spatial Interference Mitigation	Multiple Input Single Output Adhoc Networks	increased residual interference at the receiver
2.	SofiePollin et al	distributed adaptation	802.15.4 and 802.11	range of distribution differentiates the performance
3.	Santi	Topology construction	Nodes in the Network	costly and not easy to

				implement
4.	Kleinrock and Tobagi	Split Channel Reservation Multiple Access (SRMA)	Nodes in the Network	centralized System to monitor the network
5.	V. Haghighatdoost et al.	General Algorithm called "Apln"	Spanning Tree	considers only two dimensional distribution
6.	Chiasserini, Carla-Fabiana, and Ramesh R. Rao	Traffic scheduling algorithm.	WPAN and WLAN devices	increased delay in packet delivery
7.	Zhang, Xinyu, and Kang G. Shin	Cooperative Busy Tone	802.15.4 and 802.11	centralized System to monitor the network
8.	Fredrick Awuor	Coupled Interference Network Utility Maximization (NUM) Strategy (i.e. CIN)	WLAN	data distribution rates are determined by users
9.	R. Gummadi	Spectrum based method	WPAN and WLAN	considers only static network in the MANET environment
10.	Burkhart et al	topological graph	WPAN and WLAN	sender centric and considers only sparse graph
11.	NouhaJaoua et al.	Bayesian estimation using particle filtering	Multicarrier Signal and Noise Parameters	Noise parameters also considered as interference
12.	D'mello, Sejal, and ZahirAalam	Adaptive Frequency Hopping	Bluetooth interferences in WLAN	Wi-Fi interference issues are not considered
13.	Guinian Feng et al	Minimum Interference Algorithm (MIA)	Overall Network Interference	Not specific to WPAN and WLAN devices
14.	Moaveni et al	coverage model	Fixed nodes in the Network	Adhoc connectivity of irrelevant nodes are considered
15.	G.Suseendran et al	Mathematical Prediction Filters	Mobile Adhoc Network (MANET)	Initial transmission power plays a role in interference measurement

III. Discussion

WPAN and WLAN are considered the broadest classifications in the 2.4 GHz ISM band. One of the main challenges in this 2.4 Ghz ISM band is interference. Unfortunately, research in this area is so young that researchers have to investigate different ideas regarding the identification of a universal measure of network interference mitigation.Due to the increasing number of devices and systems that operate in the 2.4 GHz band, interference among these systems becomes unavoidable and complex in nature. From the above survey it is clearly observed that various interference mitigation techniques between WPAN and WLAN are existing to increase the performance of the systems throughput, packet delivery ratio and other notable parameters. Most of the work endorses that proximity and simultaneous operation of WPAN and WLAN devices are the foremost reason for interference. Almost all the interference mitigation techniques encourages for the coexistence of WPAN and WLAN devices. Most of the researchers specify that the creation of exact and lightweight models of common interference sources in the network isnot an achievable task.The researchers also deploys various scheduling algorithm to mitigate the interference in the network. Another notable technique to mitigate interference is changing transmission power among the nodes in the network and manipulating spatial data to enhance the performance of the network.

IV. Conclusion

Wireless Local Area Network (WLAN) and Wireless Personal Area Network(WPAN) are the two major classification in the 2.4 GHz ISM band. Role of these WPAN and WLAN devices in day-to-day applications are increasing enormously and coexistence of these devices reduces the performance of applications due to interferences.This paper representedvarious interference mitigation techniques for the coexistence of WPAN and WLAN devices in the 2.4GHz ISM band. Though various interference mitigation techniques are available, there is a plenty of opportunity for the researchers to address the issue of interference between WPAN and WLAN devices due to the emergence of various new gadgets in the 2.4 Ghz ISM band, Internet of Things(IoT) and Internet of Everything (IoE).

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