Coexistence of ZIGBEE and WI-FI Frame Control Protocol Simulation Using HMM

Vishank Patel¹, Sunil Shukla²

¹Fourth Semester M.Tech, Oriental University, Indore
²Asst. Prof. Dept of E&C, Oriental University, Indore

Abstract— In the midst of the coexistence problems for the 2.4-GHz industrial, scientific, and medical (ISM) band, interference between Wi-Fi and IEEE 802.15.4/ZigBee networks in particular has become a dominant problem because of the wide installation of Wi-Fi access points (APs). However, the coexistence of such heterogeneous wireless systems is still an open challenge. Zigbee and Wi-Fi devices are increasingly located in the same environment which makes the coexistence problem more and more challenging and critical. In this paper, 1) We learn an HMM (Hidden Markov Model) based on the data traces of the network. With such an HMM model we can accurately characterize the dynamic distribution of the durations of white spaces in different times. 2) Based on the HMM model of the white space and the performance estimation we develop a novel Zigbee frame control protocol called HMM-driven White Space-aware Frame Control Protocol which can obtain the optimal trade-offs between link throughput and packet delivery (data traces).

Keywords—HMM, Wi-Fi, Zigbee, White Space

I. INTRODUCTION

As a less power and less cost communication technology, Zigbee is building its place on the market as an enabler for the emerging wireless personal area network (WPAN) [1]. As the Wi-Fi, Zigbee also uses the 2.4 GHz ISM band. Due to sustaining gracious application, they are very likely to be collect within the interfering range of each other and thus their ability to coexist need to be evaluated. Many such studies have done concerning coexist between the Wi-Fi and Zigbee thus by that there has a little impact on the performance of the two network. However the Wi-Fi during transmission can have a serious impact on the performance of Zigbee if channel selection and allocation is not done properly [1][2]. Infect the channel utilization if Wi-Fi based on network is quite low as shown in figure 1.

The existing terminology approaches does not uses the prominent channel white space which is not satisfactory. So Zigbee signals transmission is not visible to 802.11 transmitters even in presence of running Zigbee transmission. This issue can be resolve by adapting energy-based CCA; there are some other problems like timing of transmission and power. Zigbee have power that is typically 20db less then Wi-Fi. While Wi-Fi can easily sensed the Zigbee device. In wireless air transmission the Zigbee packet can be sensed by Wi-Fi device because Zigbee transceiver has 16 time longer response time. In this paper, we takes benefit of the channel white space and thus could decrease the effects of the interferences between Wi-Fi and Zigbee devices.

II. WHITE SPACE MODELING IN REAL-LIFE WI-FI

In this section, we study how to model the sequential white space of Wi-Fi networks. The white space model will be used to control the frame transmissions of ZigBee in presence of Wi-Fi blind terminals. General arithmetical analysis on data traces captured in real-life Wi-Fi networks was conducted. That showed in a channel shared by a group of 802.11 devices, the arrival process of aggregate Wi-Fi frame clusters has the feature of self-similarity. We then study in what time scale the temporal white space of Wi-Fi is model able. Finally we present a HMM model that accurately characterizes the white space.
**Wi-Fi Frame Clustering**: The arrival of Wi-Fi frames is highly bursty and clustered. We observe that frames are clustered together with short intervals typically less than 1 ms, while the idle periods between clusters are significantly longer. The short frame intervals are attributed to the MAC layer contention mechanism of 802.11, in which senders back off for a short random time before each transmission. According to 802.15.4 [3], the protocol header of ZigBee frame is 17 Bytes, which are transmitted at a rate of 250 Kbps. Thus the packet-in-air time of ZigBee is at least 544 $\mu$s. After accounting for the software in the clouds (e.g., the delay introduced by CPU and radio interaction), the minimum packet transmission time of ZigBee approaches the maximum backoff window size of 802.11. Therefore, it is very difficult for ZigBee senders to utilize the short Wi-Fi frame inter-arrival times for packet transmission. In the following, we will only focus on modelling the arrival process of Wi-Fi frame clusters where each cluster may include multiple frames spaced by intervals less than 1ms. We define the interval between frame clusters as *inter-cluster space* while the interval between the frames within the same cluster as *intra-cluster space*. Moreover, white space hereafter refers to inter-cluster space unless otherwise indicated. **HMM of WiFi White Space**: As discussed above, in a channel shared by a group of 802.11 devices, the arrival process of WiFi frame clusters has the feature of self-similarity. According to [19], the self-similarity is a feature of arrival process with heavy tailed or power law distributed inter-arrival time. Since the HMM process is used to adopt power law distributions, we chose HMM model to fit the arrival process of WiFi frame clusters. In the following, we first give the HMM model and then discuss the goodness-of-fit of it with respect to real Wi-Fi data traces. We assume the inter-arrival time of frame clusters within time window that fits HMM model.

**III. OVERVIEW OF ZIGBEE AND STANDARD**

IEEE 802.15.4 is a protocol designed for LR-WPAN defining the specification of PHY and MAC layers, while Zigbee is a protocol providing NET and APP layer specification and based right on top of the IEEE 802.15.4 specified layers. The complete ZigBee /IEEE 802.15.4 architecture is shown in Figure 2. The Zigbee standard provides the qualifications for the two basic lower network layers for WPANs which focus on less cost, less speed everywhere exchanges between devices. The emphasis of this standard is on very low cost communications of nearby simple devices with little infrastructure, limited resource and low energy consumption.

**IV. OVERVIEW OF WIFI STANDARD**

The Wi-Fi standard provides wireless connectivity to devices that require rapid system. It defines PHY and MAC layer specifications as well as the communication protocols handling data transfer at each layer [4]. Powered Wi-Fi station starts by scanning accessible channels to detect active networks in areas where beacons are located for transmitting.
But on the other hand Wi-Fi is more convenient when transmission of data is required for long range and power consumption is not an issue. Within the 802.11 family of standards, the three that have found prominence today are 802.11a, 802.11b, and 802.11g. It can be considered that 802.11a and 802.11b are distinct protocols within themselves and that 802.11g is a fusion of those two standards molded into one. This is because 802.11g encompasses the more attractive traits of 802.11a, which is the speed, and the broad compatibility of 802.11b. One interesting similarity to note is that all three protocols instantiate the same MAC (Medium Access Control) layer defined by the 802.11 standard and it is only how the PHY (Physical) layer is implemented that distinguishes the protocols from one another.

V. RELATED WORK

1. Based on an empirical study of Zigbee and Wi-Fi coexistence, we reveal that Wi-Fi nodes are often blind terminals of Zigbee nodes due to inadequate carrier sensing mechanism of 802.11 and transmit power asymmetry between Zigbee and Wi-Fi. A Wi-Fi blind terminal fails to detect Zigbee signals and hence can easily corrupt ongoing Zigbee packet reception, which is a major cause of poor Zigbee performance in coexisting environments.

2. Extensive Simulated analysis of data traces captured in real-life Wi-Fi networks was conducted. To that, in a channel shared by a group of 802.11 devices, Wi-Fi frames are highly clustered and the arrival process of clusters has the feature of self-similarity. Then a HMM was presented that accurately characterizes the white space between Wi-Fi frame clusters and penetrate the Zigbee frame cluster one by one in the white space of Wi-Fi to avoid the co-existence.

VI. COEXISTENCE ISSUES BETWEEN ZIGBEE AND WIFI

Considerable amount of research work has been performed in recent years to investigate Coexistence issues between different types of networks which operate in the same frequency band, such as IEEE 802.11a/b WLAN and Zigbee WPAN. The IEEE 802.15.2 standard is one of the earlier noteworthy efforts for addressing the coexistence issues of Zigbee and Wi-Fi. Specifically, it describes the coexistence of WPANs with other wireless devices operating in 2.4 GHz band, especially Wi-Fi. In the following sections, the coexistence issues between IEEE 802.15.4 WSN and IEEE 802.11b/a WLAN are discussed, followed by a comprehensive review of recent research Work in this area.

Study of Co-existences issue: The 2.4 GHz Industrial, Scientific, and Medical (ISM) unlicensed band is used by lots of wireless technologies, such as Wi-Fi, ZigBee, Bluetooth, etc. Due to the low power, ZigBee is potentially liable to the intrusion introduced by these wireless technologies. Therefore, in this paper we focus on the coexistence between Zigbee and Wi-Fi. Between two adjacent channels in the 2.4GHz band Wi-Fi standard defines 14 channels with 5MHz distance. The bandwidth of every channel is 22MHz [5]. Figure 3 shown Wi-Fi channels in Europe and the overlap channels between Wi-Fi and Zigbee. As we can see, the channels of Zigbee and Wi-Fi are mostly overlapped.

![Figure 3: Channel of Zigbee and Wi-Fi](image)

While in [6] [7], a obvious Zigbee and Wi-Fi coexistence model is already presented. Taking in the account the transmission power and timing difference between Zigbee and Wi-Fi.

VII. EXPERIMENTS

In this section we see the difference among the two networks in the power of predicting the upcoming white spaces. In our experiment we use HMM hidden states for both the training and test data which is artificially synthesized by a communication tool and Hmm tool in matlab by the use of artificially generated Zigbee and wifi frames in data and time consent. This frames are generated for the same time as given by the user and randomly generated frame are generated as the time given by user is same or different as seen in the simulation output. We had taken a random time of 300 millisecond for first test bed we get Zigbee frame cluster in figure 4, and for same time Wi-Fi frame cluster in figure 5.
The above frame cluster are for the same time for Zigbee and for Wi-Fi now by the use of the HMM technique the probability of white space is find and the Zigbee frames are coexist in the white space of Wi-Fi.

Hear the penetration is done frame by frame first frame of Zigbee will start entering the white space of Wi-Fi from last bit of Wi-Fi it will be coexist until completely in same white space as seen frame by frame coexistence of Zigbee and Wi-Fi in figure 6 for first frame, in figure 7 for second frame, and in figure 8 for third frames of Zigbee. The same experiment has been performed for different number of time and for different frames which are randomly generated.
VIII. CONCLUSION

In this paper we develop coexistence of Zigbee and Wi-Fi frame control protocol simulation by the use of HMM that can have a capability to resolve the interference problem in Wi-Fi. Here in this we had observed that by exploiting a white space in the Wi-Fi channel has become very useful for the coexistence of Zigbee and Wi-Fi. Our outcome results are little bit based on the previous work done in [3], but it had some invalid assumptions which had overall affect the system performance. From the above assumption and use of HMM this invalid assumption can be rid of and thus can make the better coexistence of data frame in same set of time without interference. Some more robust and difficult mechanisms such as the Segmental Hidden Markov Model may further improve the performance. And also by putting loops of frame an continuous Zigbee frames can be fed in Wi-Fi white space in the currently running frame.

REFERENCES

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