HMM Driven White Space for IEEE 802.11

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Abstract—

Wi-Fi has been adopted more and more extensively in various applications such as wireless patient monitoring in hospitals, herds monitoring in pastures, smart control in home networking and game remote controllers. Most of these applications are performance-sensitive so the throughput and packet delivery ratio should be guaranteed for Wi-Fi system to work properly. However, since Wi-Fi operates in unlicensed ISM spectrum. White spaces between frame clusters in time domain observed in Wi-Fi its advantage should be taken to improve the performance of the system. In this paper, we propose a novel approach that ensures high performance of Wi-Fi data trace to time keep the Wi-Fi performance almost unaffected. First we learn an HMM (Hidden Markov Model) based on the data traces of the network. With HMM model we can accurately characterize the dynamic distribution of the durations of white spaces in different times. Second, we estimate the data trace of the Wi-Fi in time domain. Thus based on the HMM model of the white space and the performance estimation we develop a novel frame control protocol called HMM-driven White Space for Wi-Fi.

Key words: Wi-Fi, HMM, White Space

INTRODUCTION

As seen in the past decade witness huge advances in wireless communication technologies. These advances have fostered the development of international standards aiming to manage with the increasing demand for wireless solutions. In this situation, the IEEE published a set of standards for wireless local area network (WLAN) communication, known as IEEE802.11 or Wi-Fi [1]. Since its publication, the IEEE802.11 has been quite popular and today it is ordinary for both home and office networking. Owing to its low cost, easy set up and deployment, most current mobile and portable devices are currently empowered with Wi-Fi capabilities, allowing users to connect to nearby access points for Internet connection or alternatively. This connection is common to all the Wi-Fi users but there are many alternatives for the Internet connection and the problem arises to keep the continuity of packet while transfer of information on a same wireless medium. Thus Hidden markov model (HMM) has been used to find the probability of the white space arrival which is developed randomly during the packet through.

WIRELESS FIDELITY (Wi-Fi) IEEE 802.11

Wi-Fi networks are almost everywhere in office buildings, homes, and even outdoors in urban areas. Considering that 802.11b, 802.11g, and 802.11n share the same 2.4 GHz ISM band with 802.15.4, 802.11 transmissions can interfere with co-located 802.15.4 networks. In practice, since most Wi-Fi networks use channels 1, 6, and 11, 15.4 channels 15 and 20 can also be interference-free [3,2]. The potential for 802.11 transmissions to overwhelm 802.15.4 receivers is amplified by the fact that 802.11 radios transmit at 10 to 100 times higher power than 802.15.4 radios. The protocol also specifies the SIFS and DIFS intervals when nodes should defer using the medium. A time period, called the contention window, follows the DIFS as shown in Fig 1. This window is divided into different slots Nodes .The node that selects the earliest slot wins while others defeat.

Nodes initialize their contention window (CW) to 31 slots and double it every time they fail to access the medium, until CW reaches a maximum size of 1023 slots. Table 1 summarizes the duration of the DIFS, SIFS, and back off slots for 802.11b and 802.11g. Also shown are the maximum and minimum packet sizes for 802.11b, 802.11g, and 802.15.4. It is worth noting that for many 802.11b and 802.11g packets, the entire air time is smaller than WSN slot time. Based on the relatively small time intervals between 802.11 transmissions, one can easily see that a backlogged 802.11 sender can potentially corrupt the vast Majority of Zigbee packets.

Fig1: Messages and delays defined in the 802.11MAC protocol. Durations of packet transmissions and time intervals depend on the 802.11 variant used. The leading RTS/CTS exchange is used only for large packets.

[Diagram of 802.11MAC protocol showing messages and delays.]
WHITE SPACE for Wi-Fi

White Space refers to the unused broadcasting frequencies in the wireless spectrum. Television networks leave gaps between channels for buffering purposes, and this space in the wireless spectrum is similar to what is used for 4G and so it can be used to deliver widespread broadband internet. the Federal Communications Commission (FCC) recently agreed to evaluate the legal operation of unlicensed devices in “white spaces”, i.e., portions of the licensed TV bands that are not in active use by incumbent users, such as the TV broadcasters [4], [5]. Sub-GHz spectrum has many properties suitable for data communication. Radio frequency (RF) has long distance communications and RF waves have good incursion property in the lower bands compared to the higher ISM frequency bands. System must have a robust scheme for determining the white-spaces, and second, these systems must have a spectrum-aware MAC protocol that utilizes white-spaces of various bandwidths.

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. 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.

HIDDEN MARKOV MODEL

We will first study the Pareto Model of WiFi white space proposed in [6], and then we’ll propose our advanced HMM model of Wi-Fi white space. earlier proposed Pareto Model of Wi-Fi white space based on the fact that the arrival process of Wi-Fi frame clusters has the feature of self-similarity and according to [6], the self-similarity is a feature of inception process with heavy-tailed inter-arrival time. Proposed model says that all white space within sliding window follows Pareto distribution i.e.

\[ P_r(x > t) = \begin{cases} \frac{\alpha}{t^\beta}, & t > \alpha \\ 1, & \text{otherwise} \end{cases} \]

Hear \( \alpha \) and \( \beta \) are the scale and shape of Pareto model and \( x \) is the time of the white space. They set \( \alpha \) to 1 millisecond. In Pareto model, \( \beta \) is set by \( \lambda / (\lambda - \alpha) \), where \( \lambda \) is the average inter-onset time of frame cluster.

Fig. 3 shows an example of HMM. In an HMM, there are a set of states say \{S1,S2,S3,...,ST\}, each state has an initial state probability \{P01,P02,P03,...,POT\} that determines which state would be more likely to be the first state. And each state has a probabilistic distribution of its observation vectors. We adopt \{θ1,θ2,θ3,...,θT\} to describe the parameters of the states distributions. The transition probability matrix \( M \) where \( M_{ij} = \Pr(S(t+1)=S_j \mid S(t)=S_i) \) determines how a state could transit to another state.
CONCLUSION

In this paper we develop HMM Driven White Space for Wi-Fi that can show the unused band of Wi-Fi channel. We can see that exploiting the Wi-Fi channel white space is very useful for the Wi-Fi receiver and the other channels during interference. We propose the HMM model of the channel white space that get rid of the invalid assumptions and thus further improves the performance of that obtained in [6]. More over this unused white space can be used in the coexistence of different ISM band are Zigbee, Bluetooth, Wi-Max.

Reference


