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Eliminating the Problem of Coexistence Between Zigbee and Wifi Using EDCA Synchronization and Multi Header Transmission

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Abstract: ***In modern wireless world both wifi and zigbee play a pivotal role in infrastructure less communication system. Thus in order for both to work it is necessary to use some advanced techniques because of the overlapping of the bands of wifi and zigbee. This research paper examines the problem under the perview of EDCA model and alongside multi header zigbee transmission. Based on the above two techniques matlab simulation shows promising results.***

Keywords: WiFi , Zigbee , multi header , EDCA , contention window.

1. Introduction

Recently, the cyber-physical system (CPS) has drawn increasing attentions [1]; it aims at integrating computing, communication and storage capabilities with monitoring and or control of entities in the physical world. In the design of CPS, various wireless communication technologies have been witnessed, such as WiFi, ZigBee and Bluetooth [2,3]. Given the scarce availability of RF spectrum, many of these technologies are forced to use the same unlicensed frequency bands. For example, IEEE 802.11 (WiFi), IEEE 802.15.1 (Bluetooth) and IEEE 802.15.4 (ZigBee) all share the same 2.4 GHz ISM band. Sharing the same frequency band definitely leads to cross technology interference. It will cause intermittent network connectivity, packet loss and ultimately result in lower network throughput and higher communication latency. Specifically, ZigBee and WiFi networks are very likely to be colocated within the interfering range of each other. However, because of the lower transmit power and some other disadvantageous parameter settings (eg. Shorter back off time slot), ZigBee is affected more severely by WiFi networks.

With the growing popularity of WiFi, the situation will be even worse. Thus, under the existence of WiFi interference, how to improve communication performance of IEEE 802.15.4 is becoming a crucial issue. There have been some studies about how to avoid WiFi interference in IEEE 802.15.4 network [4,5]. The conclusion of those studies was that the only way to mitigate such interference for the 15.4 network is to avoid the channels occupied by 802.11. Furthermore, there are mainly two ways to achieve interference avoidance: global channel assignment and local channel assignment. In a global channel assignment scheme, all sensor nodes share the same channel (planed or not planed) to communicate with each other. This scheme has a fatal drawback: because of spatial locality of WiFi interference, some of the local areas may suffer severe degraded performance, thereby degrading the entire network performance. Moreover, with the increasing WiFi deployment, it's almost impossible to find the globally unoccupied channel. In local channel assignment schemes, different nodes in a sensor network, or the same node over different time, will use different 15.4 channels to avoid interference from nearby WiFi sources. Apparently, local schemes comply with the locality of WiFi deployment naturally. However, these schemes face two main challenges: (1) How to assess the severity of WiFi interference. Sometimes, there is no need to avoid interference when it is mild and acceptable. But when it suffers severe WiFi interference, a node has to choose a new channel to avoid interference and the new channel should be relatively clear in its vicinity. All these decisions require a node to know the given channel's degree of interference. (2) How to coordinate channel selection among 15.4 senders and receivers. Local WiFi environment changes will lead to channel switch, some kind of coordination is needed to ensure that senders and receivers are still able to communicate properly.

2. Introduction to EDCA

Medium access-control (MAC) represents a set of control functions designed to coordinate which station is allowed to use the shared communication medium at a given time. These MAC functions represent an essential part of the data link layer and very often, as in the case of all IEEE 802 standards, they form a separate sublayer. Most of the LAN technologies use competition-based distributed MAC functions. It is also the case of the 802.11 WLAN technologies.

II(A). MAC functions in 802.11 a/b/g

The first WLAN specification, standardized by IEEE in 1999 introduced two MAC methods, which were implemented in the same form also in later standards, like 802.11b (1999), 802.11a (2001) and 802.11g (2003) [2], [3], [4]. These MAC methods are called Distributed Coordination Function (DCF) and Point Coordination Function (PCF). PCF represents a centralized solution, where the access point (AP) regularly polls all the registered stations to ask them if they have data to send. This coordination function was mainly designed to give preferential treatment to stations with multimedia data.

Thus, not all of the active stations must be registered for this polling. In fact, PCF is quite clumsy in practical use, which together with the fact that it is only an optional feature resulted in a minimal practical interest. DCF represents the main WLAN MAC function. This is a fully distributed contention-based algorithm, involving all the active wireless stations of the WLAN which have data to send. According to DCF, the station having data to send must win a competition with other stations to gain access to the shared radio channel. The competition is based on the combination of time constants and a random waiting period.

Time constants represent minimum waiting periods between two frames immediately following each other. These constants are called InterFrame Spaces (IFS) and there are three types of them.

- Short InterFrame Space (SIFS), as the name suggests, represents the shortest waiting period, which corresponds with the respective priority level. The highest priority level is strictly bounded by control frames like Acknowledgement frame (ACK), Request-to-Send (RTS) or Clearto- Send (CTS).
- If DCF operates in combination with PCF, the access point has to wait for the PCF InterFrame Space (PIFS) to start polling the registered stations. PIFS ensures midlevel priority.
- Most often stations have to send user data. In this case the stations must wait for DCF InterFrame Space (DIFS) before they can initiate data transmission. If the access point has data to forward to wireless stations, it also acts in this medium-access competition as a simple station.

To avoid simultaneous access from all the competitors after DIFS has expired, each station has to wait for an additional random period. This random waiting time, called Contention Window (CW), is generated from the set $\{0, 1, . . . , CW\min\}$, where $CW\min = 15$ for 802.11a and 802.11g and $CW\min = 31$ for 802.11b. The random number generated by each station is decreased by the end of each Slot Time (9 μs for 802.11a and 20 μs for 802.11b and 802.11g). When the zero value is achieved, the station can access the medium. After the winning station has started transmitting, all the other stations should detect that the medium is occupied, stop their countdown and save the recent value. In the next competition, these stations will continue to count down from the value stored. The data frame sent by the source must be acknowledged by the destination node. Only the acknowledged frame is considered to be successfully transmitted.

Sometimes two or more stations can choose the same random value, which means that they will gain access to the shared medium and start to transmit data at the same time. This situation is called collision and it is identified by the absence of the ACK frame from the destination node. In such a case the contention window is increased in order to reduce the probability of the selection of the same random number during the next attempt. The contention window will be increased according to the formula $CW\text{new min} = 2(CW\text{old min} - 1) + 1$. The contention window can be increased up to the $CW\max = 1023$ for all three WLAN standards mentioned above. With increasing number of stations in the WLAN the possibility of collision is also increasing. This means that the stations have more often to choose a random value from a larger contention window. This leads to longer waiting times and lower throughput of the system. The decreased throughput affects all stations equally, but can influence various network services differently.

II(B). MAC functions in 802.11e

The aim of the IEEE 802.11e standard is to overcome the limitations of the original MAC algorithm by allowing traffic flows to be classified into several service classes and to offer differentiated treatment of these classes. The differentiation is achieved by assigning a different set of MAC parameters to the Access Categories (AC). There are four access categories defined in the 802.11e standard:

- AC VO – for real-time, voice-based, conversational services,
- AC VI – for video services,
- AC BE – for standard best-effort services, covering the majority of network applications,
- AC BK – for background services for which a priority lower than the one assigned to the standard network applications is sufficient.

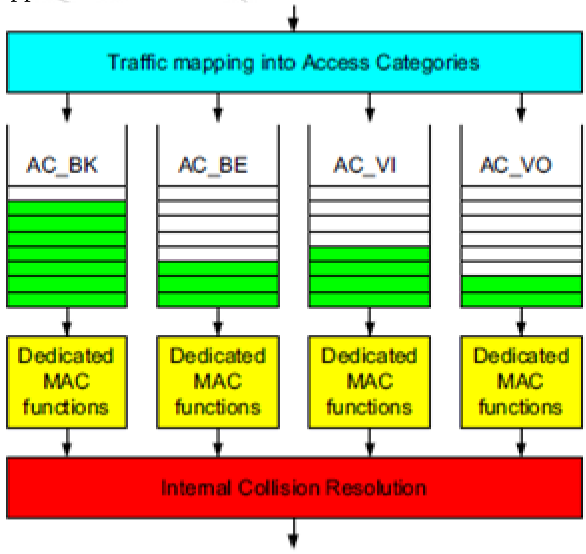

Figure 1: EDCA Functional Block Diagram

3. Simplified Model of IEEE 802.11E and its Probabilistic Analysis

The aim of our mathematical analysis is to derive a mathematical formula expressing the degree of mutual prioritization between two access categories in relation to the interframe spaces and contention windows assigned to these categories. The analysis is made for a lightly loaded WLAN network, in which case the number of collisions is considerably low. In such a case we can assume that a station will generate a random value from the default contention window only. This simplification leads to a more transparent mathematical derivation but, on the other hand, it constrains the relevance of the final results. The number of the access categories considered is limited to two.

A. Notation and Goal of Analysis

A discrete random variable *X* with a uniform distribution in the interval between integers *a* and *b* will be denoted $X \sim \mathrm{Ud}(\{a, \ldots, b\})$. A subscript going with the variable name means that the set of admissible values is shifted by that number, e.g. $X + c \equiv X_c \sim \mathrm{Ud}(\{a + c, \ldots, b + c\})$; specifically $X \equiv X_0$. A graphical representation of the above described model is given in Fig. 3. There are two access categories, AC1 and AC2, with their respective interframe spaces N_0 and M_0, and with their respective contention windows of sizes *N* and *M*.

During the derivation, the basic properties of the probability function will be used, together with well-known formulas for arithmetic progressions. Because the two stations do nothing during the common part of the interframe periods N_0 and M_0, we can simplify the situation by introducing the difference term $d = N_0 - M_0$. Thus, in the case of $d \le 0$ we can write

$$P^{\mathrm{C}}_{\mathrm{coll}} = P(X_{N_0} = Y_{M_0}) = P(X = Y_{-d}) = P[(X = 1 - d \wedge Y = 1 - d) \vee \ldots \ldots \vee (X = M - d \wedge Y = M - d)] = \cdot$$

$$P^{\mathrm{D}}_{\mathrm{win}} = 1 - [P(X < Y_{-d}) + P(X = Y_{-d})] = 1 - \left[1 - \frac{(M-d)(M-d+1)}{2MN} + P^{\mathrm{D}}_{\mathrm{coll}}\right] = \frac{(M-d)(M-d-1)}{2MN}.$$

4. Multi Header Zigbee

In dynamic channel assignment schemes, different nodes in a sensor network, or the same node over different points in time, will use different 15.4 channels to avoid interference from nearby WiFi sources. These mechanisms face two challenges: detect the presence of 802.11 traffic [6, 18] and coordinate channel selection among 15.4 senders and receivers [28]. In addition to the coordination complexity, interference avoidance mechanisms leave large portions of the spectrum unused even when there is little 802.11 traffic in them. This inefficiency is especially damaging for large and dense sensor networks that cannot support the desired application throughput using a single 15.4 channel [16, 30]. Instead of trying to avoid interference from 802.11 traffic, the goal of this paper is to improve the coexistence of 15.4 and 802.11 networks that operate in the overlapping frequency channels. Our approach is based on insights derived from a thorough examination of the interactions between the two radio technologies. In particular, we make several key observations that previous work has overlooked: (1) In the time domain, 802.11 packets are typically much shorter than 15.4 packets, so they cause bursty bit errors in 15.4 packets. (2) A large percentage of dropped 15.4 packets are due to corruptions in the packet headers, especially when the 15.4 transmitter is close to an 802.11 transmitter. (3) We experimentally found that when a 15.4 node is close to an 802.11 transmitter, a 15.4 packet can actually cause the 802.11 transmitter happens, 802.11 only corrupts the 15.4 packet header (which causes frequent packet losses), but the remainder of the 15.4 packet is left unaffected. Depending on how 802.11 and 802.15.4 transmitters interact, we partition the interfere domain of the two radios into symmetric and asymmetric regions. In symmetric regions, a 15.4 transmission can cause nearby 802.11 transmitters to back off, so the receiving bit corruption happens mainly in 15.4 packet headers. We employ a simple yet effective header redundancy mechanism, called Multiple-Headers (MH), to address this packet header corruption problem. MH sends the header multiple times in a single 15.4 packet. The first (corrupted) header will cause the 802.11 transmitter to back off, ensuring that the second header can be correctly detected by the 15.4 receiver. In asymmetric regions, the 15.4 signal is too weak to affect 802.11 behavior. In this case, we use a forward error correction (FEC) code to correct bit errors that occur across the entire 15.4 packet. We examine Hamming and Reed-Solomon (RS) codes and find that RS code is particularly effective against the bursty error patterns we observed.

5. Simulation and Results

A graphical user interface as shown in figure below has been constructed using MAtlab , the GUI models the exact probabilistic analysis as given in [2] , then the boxplot of frequencies winning is displayed as shown below . Also in this particular case if the no of header in the zigbee system turns out to be less then 2 then collision occurs as per discussed earlier. Also the system shows the probability of winning and losing as per EDCA probabilistic model given in [2]. All the above results are shown below for ready reference :-

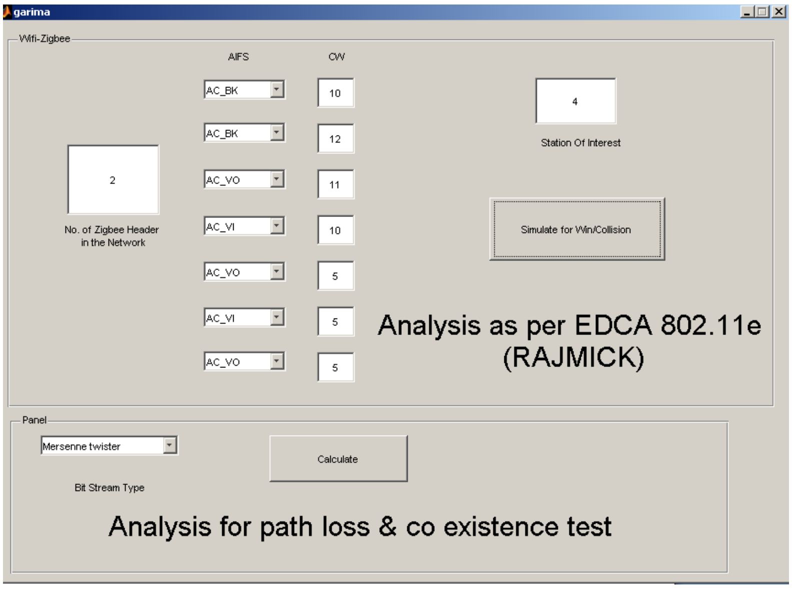

Figure 2: Graphical User interface built using Matlab

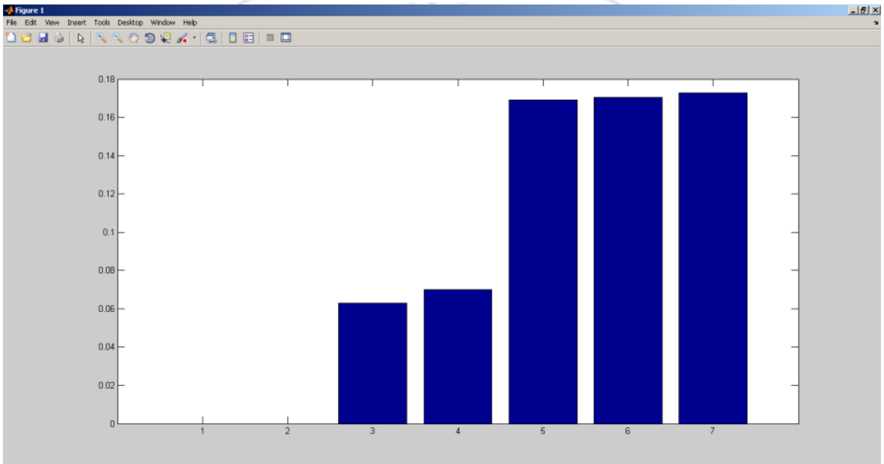

Figure 3: Graph showing various stations and their probability of winning as per EDCA

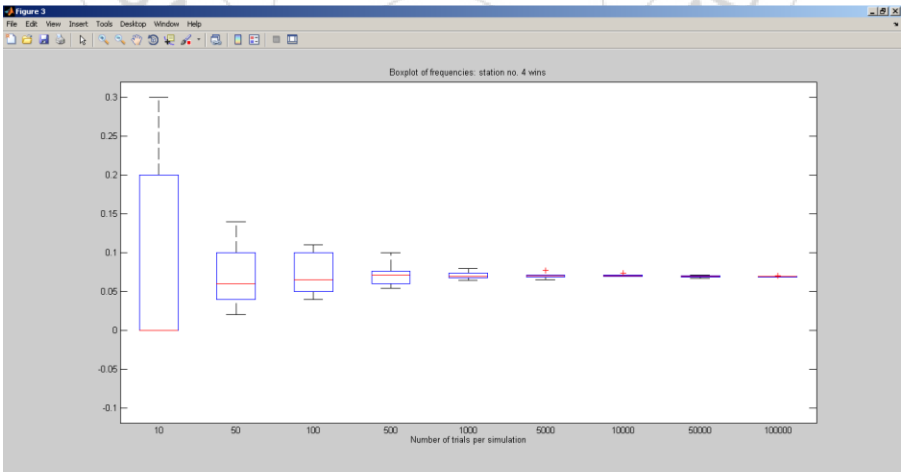

Figure 4: Box plot of frequencies which shows the value for the selected station

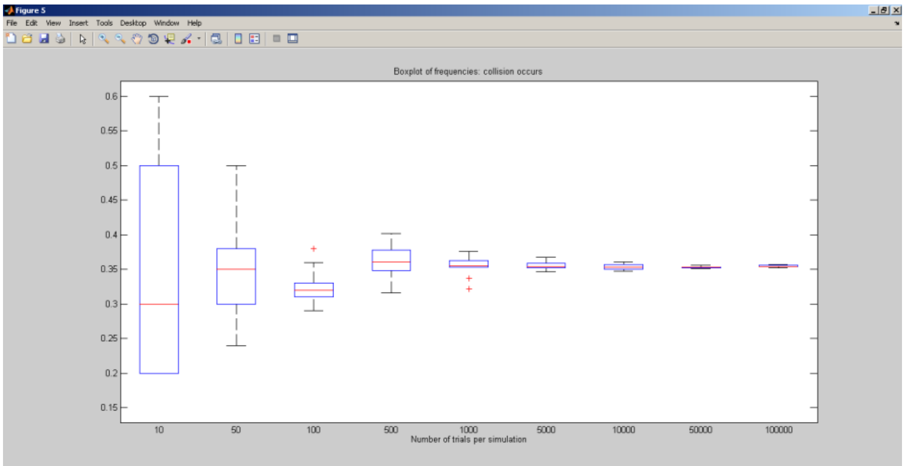

Figure 5: Box plot in case of collision when the no. of headers is less than one

6. Conclusion

This paper presents a careful analysis of the IEEE 802.15.4 and 802.11 interference patterns at 2.4 GHz ISM band. We examine these interference patterns at a bit-level granularity, and we explain how a 15.4 node may change the behavior of nearby 802.11 transmitters under certain conditions. The paper introduces an algorithm allowing fast computation of the IEEE 802.11 contention-related characteristics and outcome in terms of probabilities associated with the respective wireless stations. This model and algorithm helps understand the nature of the contention process in terms of two parameters per station , and allows evaluating the effect of different WLAN MAC parameters on the probability of gaining access to the shared wireless medium for the corresponding IEEE 802.11-2012 access categories. The suggested method was evaluated in a demonstration scenario and the obtained results agree with the simulations, as well as with the empirical expectations. We are aware that the model does not yet reflect some of the important characteristics of real network traffic first of all, the model does not capture the interrupted attempts to access the medium, with reactions to collisions, and we also did not consider variable traffic intensity for different access categories. However, dynamic network behavior could be modeled with our tool, which would have to be applied round-to-round, where our algorithm would be the lowest-level computing routine. In such occasions, the exactness achieved by our algorithm has to be paid by some memory and computational load. Imagine that in a realistic scenario, a huge Markov chain (involving several contentions and repetitions caused by collisions) could be generated by using our algorithm, but it would be much more complex and computationally expensive to evaluate in comparison to the models originating in Bianchi's work.

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