Poster: Proactive ZigBee: a Novel MAC Mechanism Enabling Coordination between WiFi and ZigBee

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Abstract

In this poster, we aim at the coexistence problem of scenarios including WiFi and ZigBee devices. We propose that WiFi and ZigBee coordinate with each other proactively and explore how the coordination enabled by CTC may help achieve the fairness and performance of the whole network.

1 Introduction

As Garterner report shows, wireless technologies develop rapidly with more than 20 billion devices by 2020. With the emerging paradigm of Internet of Things (IoT), the dense deployment of various devices and pervasive connection between them make our everyday lives even more convenient. However, due to limited spectrum recources, the overcrowded unlicensed spectrum (e.g., ISM) has led to severe interference between different technologies, named cross-technology interference (CTI). In cross-technology scenarios where different technologies (e.g., WiFi and ZigBee) coexist, all the devices contend for channel for their own communication. Both WiFi and ZigBee devices adopt CSMA/CA mechanism to avoid collision to guarentee the whole performance of the network. But because WiFi and ZigBee cannot directly communicate with each other, they will not coordinate with each other. As a result, ZigBee is vulnerable to the interference of high power WiFi, which usually overlooks the ZigBee traffic and may decrease ZigBee's packet reception by 50% according to recent studies [**?**].

In traditional MAC protocols for WiFi networks or ZigBee networks, all the devices coordinate with others by observing common rules. In classical CSMA/CA mechanism, when a device detects ongoing transmission from some other devices, it defers its own transmission to avoid collision. All devices in the network obey this simple rule and in return, their own transmission will not be destructed by other devices. But in cross-technology scenarios including WiFi and ZigBee devices, the WiFi devices will not avoid collision with ZigBee transmission as they often overlook the ZigBee traffic due to power asymmetry. So despite the fact that WiFi and ZigBee both adopt CSMA/CA mechanism, WiFi devices still cause destructive interferences to ZigBee transmission. To generalize, in cross-technology scenarios, no coordination between WiFi devices and ZigBee devices due to power asymmetry leads to the unfairness and degraded performance of the whole network.

Based on the above fact, recent studies focus on how ZigBee survives in the shadow of WiFi traffic [**?**, **?**]. They propose that ZigBee predict white spaces free of WiFi traffic before occupying spectrum and then passively avoid the transmission of WiFi traffic. Such methods of *passive* avoidance are inherently prone to uncertainties from traffic dynamics. Fortunately, recent advances in cross-technology communication (CTC) [**?**, **?**, **?**, **?**], by enabling direct communication between disparate wireless devices, bring new opportunities into this scenario. For example, via message exchange among heterogeneities, the ZigBee devices may *proactively* communicate with WiFi devcies to enable the coordination between them. This coordination provides the potential to fundamentally resolve CTI and even further, achieve fairness in spectrum sharing and performance breakthrough of the whole network.

This work introduces Proactive ZigBee, a noval mechanism where ZigBee proactively communicate with WiFi and contend for spectrum resources. As a research in the early stage, we do not offer a specific and detailed protocol, but present a new design of MAC mechanism.

2 CTC Background

The recent rapid development of CTC enables the direct communication between devices with completely different phisical layers. For commuication from WiFi to ZigBee, FreeBee [**?**] and Wizig [**?**] enables CTC by encoding symbols into packet timing or packet energy. Recently, WEBee [**?**], as a physical-level CTC, achieves CTC from WiFi to ZigBee with higher date rate by emulating the time-domain waveform of a legitmate ZigBee packet. Both packet-level and physical-level CTC achieve the transmission of short controlling message from WiFi to ZigBee. As for communication of reverse direction, there are no existing physical-level CTC from ZigBee to WiFi. However, packet-level CTC is still available. ZigFi [**?**] enables CTC by piggy-backing

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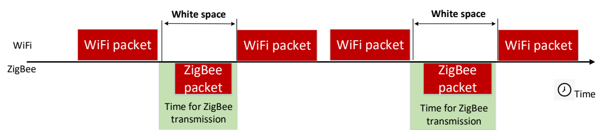

Figure 1. Mechanism of previous work

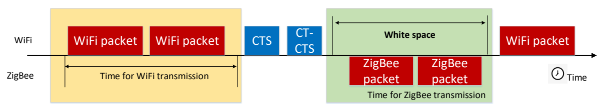

Figure 2. Design of ECC

on an existing WiFi transmission. Here we do not focus on the details of how to achieve CTC by packet-level encoding or physical-level emulation, but to leave an impression that state-of-art CTC techniques enable the exchange of short controlling messages between WiFi and ZigBee.

3 Motivation for Proactive ZigBee

In this section we characterize the cross-technology scenario in a more intuitive way, show how the state-of-art works [**?**, **?**] deal with CTI and then represent the requirement for new design. As shown in Figure 1, in the precious work, the ZigBee devices try to survive the WiFi traffic. Specifically, by modeling the interval between WiFi packets, a ZigBee device carefully predicts and utilizes the white space left by WiFi traffic to send its own packets. This is not so efficient, as the white space left by WiFi traffic is dynamic and may not be long enough for one ZigBee transmission.

In order to solve this problem, recent work named ECC [**?**], proposes that WiFi aggregate the scattered white space by injecting WiFi CTS message, and then explicitly notifies ZigBee nodes via a cross-technology CTS (CT-CTS) packet in Figure 2. In this situation, the performance of ZigBee nodes has been improved as they now obtain a larger white space to send packets. However, ZigBee still stays passive as it waits for white space left by WiFi. In other words, the WiFi still dominates the channel and ZigBee only contends for channel when permitted by WiFi. As a result, ZigBee transmission faces delay, inflexible duty cycle and potential problems about energy saving.

To deal with the above problems and achieve fairness in the cross-technology scenario, we suggest Proactive ZigBee, where ZigBee proactively contend for channel.

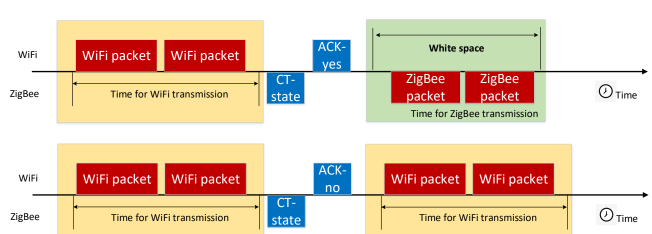

Figure 3. Design of Proactive Zigbee

4 Design of Proactive ZigBee

In this section, we introduce our design of Proactive ZigBee. By using CTC from ZigBee to WiFi, a ZigBee device sends a packet named CT-state to WiFi devices before accessing the channel. By this packet the ZigBee device notifies the WiFi devices that it wants to occupy the channel for a certain duration. When a WiFi device receive CT-state, it determines whether it leaves the requested white space based on its own transmission requirement and then responds to the ZigBee device with a ACK of Yes/No. If the answer is no, the WiFi device refuses to make room for ZigBee and may continue its own transmission. And the answer of yes means that the WiFi device is willing to stay silent in the next duration defined by ZigBee. The ZigBee device then transmits packets in the white space whose length is defined in the CT-state packet.

Note that it is quite tricky for ZigBee to decide how long to request WiFi to leave the channel. Here we propose the packet CT-state for CTC, which contains several-bit controlling information concerning with the requested duration. The bits in CT-state represent different levels, which correspond to different duration of white space. And when WiFi knows the requirement of ZigBee, it determines whether to accept the ZigBee's request and then give away the spectrum resources based on its own requirement.

There are still many open problems like how to select levels of CT-state and whether WiFi accept ZigBee's request. Moreover, the scenario will become more complicated with more WiFi and ZigBee devcies considered and various requirements of these devices. We leave these problems to the future work.

5 Conclusions

In this poster we propose our design of Proactive ZigBee by providing a mechanism where WiFi and ZigBee coordinate with each other proactively. We explore how the coordination enabled by CTC may help achieve the fairness and performance of the whole network.

6 Acknowledgments

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