Competition: Tackling Cross-technology Interference using Spatial and Channel Diversity for Robust Data Collection

Mobashir Mohammad
School of Computing
National University of Singapore
mobashir@comp.nus.edu.sg

XiangFa Guo
School of Computing
National University of Singapore
xiangfa@comp.nus.edu.sg

Mun Choon Chan
School of Computing
National University of Singapore
chanmc@comp.nus.edu.sg

Abstract

Cross-technology interference is known to adversely affect the reliability of 802.15.4 communication. 802.15.4 competes with a lot of wireless technologies like IEEE 802.11 (WiFi), 802.16 (WiMAX), and Bluetooth for the shared 2.4 GHz ISM band. Common household appliances like the microwave and cordless phone further add on to the interference, making applications requiring data collection extremely challenging.

For this competition, we propose to use Oppcast, a robust, responsive, and energy efficient data collection protocol that carefully exploits a combination of spatial and channel diversity without the need for performing expensive channel quality estimation.

1 Introduction

Over a decade of research on designing data collection protocols for low-power wireless sensor network has resulted in numerous solutions. Many of which have been thoroughly tested on indoor WSN testbeds like Indriya [1] and FlockLab [8]. Because these deployments are found inside academic institutes, the nodes experience planned cross-technology interference (CTI) due to the usage of WiFi channels 1, 6, and 11 as shown in Figure 1. This allows 802.15.4 to coexist by using channels 15, 20, 25, and 26. However, coexisting in urban environments like residential complexes, shopping malls, cafeteria, etc. becomes particularly challenging due to non-availability of CTI-free channels. Such deployments suffer from harsh unplanned-CTI as shown in Figure 2.

Many approaches have been taken to mitigate the impact of CTI on the communication reliability. Broadly speaking, the approaches can be classified into the following five types: (1) Identifying the CTI source and taking necessary actions [6], (2) Exploiting spatial diversity through opportunistic routing [3], (3) Exploiting channel diversity through channel hopping [2], (4) Adding redundancies and error correction capabilities [7], and (5) Interference cancellation using MIMO [5].

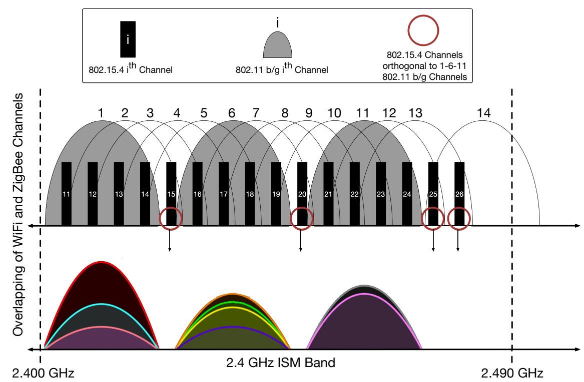

Figure 1. Coexistence of ZigBee and WiFi in the 2.4GHz ISM band having planned-CTI. WiFi scan illustration from inside an academic institute.

In this competition, we use Oppcast [9], a robust data collection protocol that carefully exploits a combination of spatial and channel diversity. In contrast to other works in the literature, we position Oppcast as shown in Figure 3. We discuss the design of Oppcast to match the competition requirements in Section 2 and conclude in Section 3.

2 Design

Oppcast is inspired from receiver-initiated protocols where nodes broadcast periodic PROBE requests. Every PROBE is followed by a short radio-on duration (7.8125ms in our implementation) to listen to response packets from neighbors who have DATA to be delivered to the SINK. Every successful DATA reception is followed by an ACK which completes the transaction (PROBE-DATA-ACK). However, unlike traditional receiver-initiated protocols like [10, 4], Oppcast incorporates the following features to achieve robust, reliable, and responsive data delivery without consuming a lot of energy. Refer to [9] for a more detailed description.

2.1 Channel Diversity

The competition involves harsh interfering RF signals. In order to be resilient to the ambient CTI, Oppcast incorporates the use of channel diversity. For efficient use of multiple channels, the following scheme is adopted:

International Conference on Embedded Wireless Systems and Networks (EWSN) 2017
20–22 February, Uppsala, Sweden

ISBN: 978-0-9949886-1-4

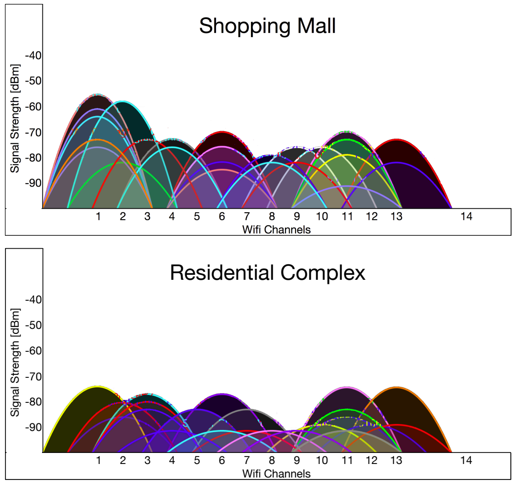

Figure 2. Severe interference due to unplanned-CTI.

2.1.1 *Channel Selection*

It is extremely important to identify which channels to use for any multi-channel protocol. It is quite common to base channel selection on popular Link Quality Estimators (LQEs) like PRR, ETX, RSSI, etc. However, in environments suffering from dynamic interference patterns, LQEs become extremely expensive and inefficient. Oppcast proposes the use of three random 802.14.5 channels with the constraint that they are far apart in the frequency domain. This eliminates the need for periodic link quality estimation. This scheme fails only if transmissions happen over all the three orthogonal WiFi channels simultaneously and continuously.

2.1.2 *Channel Switching*

To reduce the average radio on time which correlates directly to the energy consumption, Oppcast nodes performs a Fast Channel Hop (FCH) to the next one on every probe interval if no PROBES are received on the current channel. The challenge lies in avoiding the channel-chasing problem since a receiver and a transmitter might end up performing channel hop in the same sequential order and at the same rate. By reversing the channel hop sequence and relying on the fact that multiple neighbors exist in any typical deployment, channel-chasing is mitigated.

2.1.3 *Channel Biasing*

Because of the above FCH scheme, nodes can passively learn which channel out of the selected three performs the best in its vicinity. We include channel biasing into Oppcast such that every node begins probing from the least to the most interfered channels out of the three. The sequence dynamically adapts itself based on the most recent channel conditions and speeds up the node encounter.

2.2 Spatial Diversity

Besides reliability, another critical requirement for data collection is low end-to-end latency. Oppcast exploits two forms of spatial diversity, each having a different goal:

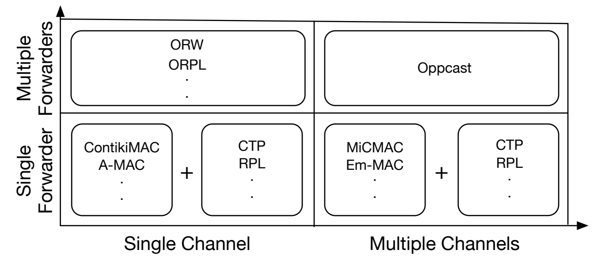

Figure 3. Positioning Oppcast among other protocols.

2.2.1 *Node Diversity*

The first technique enables opportunistic routing using opportunistic unicast transmissions. It not only reduces the end-to-end transmission delay significantly but also helps in lessening the generation of duplicate network traffic and minimizing the amount of time that the receiver and the sender occupy the wireless medium.

2.2.2 *Path Diversity*

The second technique aims more at improving the end-to-end reliability by utilizing multiple non-overlapping routes for data delivery towards the sink over a DODAG. Depending on how harsh the CTI is around the nodes, Oppcast may choose to create more and more replicates that take different routes towards the sink.

3 Conclusion

We propose Oppcast with channel biasing as a solution for a dependable network. It exploits channel and spatial diversity to achieve robust and energy-efficient data collection without the need of any expensive channel quality estimation.

4 References

[1] M. Doddavenkatappa, M. C. Chan, and A. L. Ananda. Indriya: A low-cost, 3d wireless sensor network testbed. In *TRIDENT*. Springer, 2012.

[2] S. Duquennoy, B. Al Nahas, O. Landsiedel, and T. Watteyne. Orchestra: Robust mesh networks through autonomously scheduled tsch. In *SenSys*. ACM, 2015.

[3] S. Duquennoy, O. Landsiedel, and T. Voigt. Let the tree bloom: scalable opportunistic routing with orpl. In *SenSys*. ACM, 2013.

[4] P. Dutta, S. Dawson-Haggerty, Y. Chen, C.-J. M. Liang, and A. Terzis. Design and evaluation of a versatile and efficient receiver-initiated link layer for low-power wireless. In *SenSys*. ACM, 2010.

[5] S. Gollakota, F. Adib, D. Katabi, and S. Seshan. Clearing the rf smog: making 802.11 n robust to cross-technology interference. In *SIGCOMM*. ACM, 2011.

[6] A. Hithnawi, H. Shafagh, and S. Duquennoy. Tiim: technology-independent interference mitigation for low-power wireless networks. In *IPSN*. ACM, 2015.

[7] C.-J. M. Liang, N. B. Priyantha, J. Liu, and A. Terzis. Surviving wi-fi interference in low power zigbee networks. In *SenSys*. ACM, 2010.

[8] R. Lim, F. Ferrari, M. Zimmerling, C. Walser, P. Sommer, and J. Beutel. Flocklab: A testbed for distributed, synchronized tracing and profiling of wireless embedded systems. In *IPSN*. IEEE, 2013.

[9] M. Mohammad, X. Guo, and M. C. Chan. Oppcast: Exploiting spatial and channel diversity for robust data collection in urban environments. In *IPSN*. IEEE, 2016.

[10] Y. Sun, O. Gurewitz, and D. B. Johnson. Ri-mac: a receiver-initiated asynchronous duty cycle mac protocol for dynamic traffic loads in wireless sensor networks. In *SenSys*. ACM, 2008.