Demonstration Abstract: Enabling Robust Data Collection in Unplanned Cross-Technology Interference of Urban Environments

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***Abstract*—It is widely known that cross-technology interference (CTI) adversely affects the reliability of 802.15.4 (ZigBee) communications. With the 2.4 GHz ISM band getting increasingly congested because of multiple wireless technologies like IEEE 802.11 (WiFi), 802.16 (WiMax), and Bluetooth and common appliances like a microwave and a cordless phone sharing it, data collection becomes exceedingly challenging especially in unplanned CTI prevalent in urban environments.**

This demonstration presents Oppcast, a robust and energy-efficient data collection protocol which carefully exploits a combination of spatial and channel diversity to eliminate the need for performing expensive channel estimation in advance. By exploiting multiple routes over multiple channels, packets can be reliably communicated to the sink even in severely interfered environments.

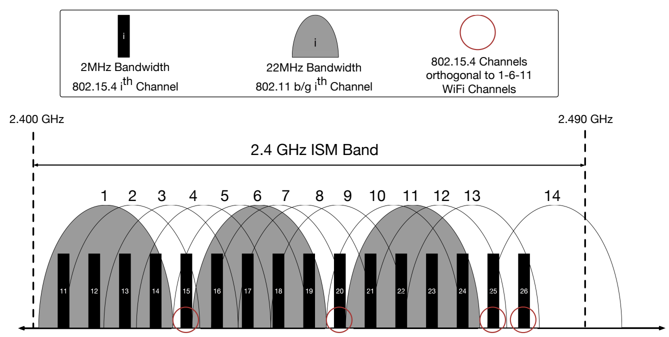


Fig. 1. Coexistence of ZigBee and WiFi in the 2.4GHz ISM band leading to CTI under different WiFi AP channel assignment strategies.

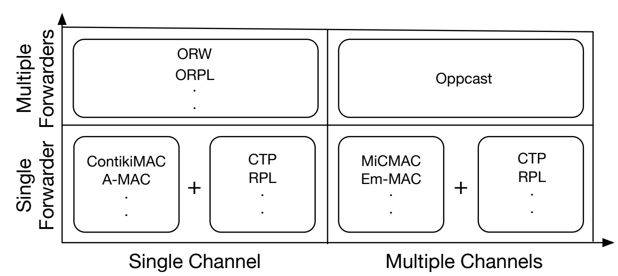


Fig. 2. Positioning Oppcast among other protocols.

I. Introduction

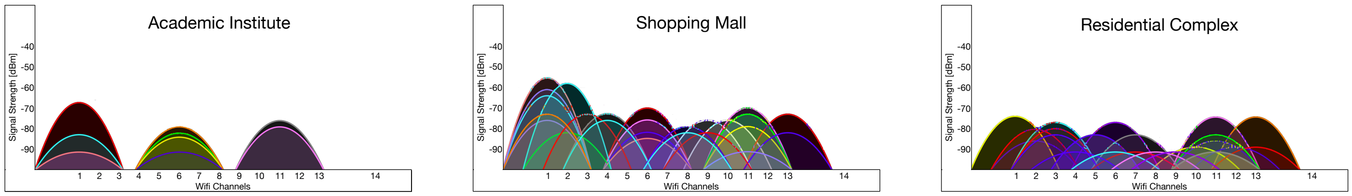
Numerous data collection protocols for low-power wireless sensor networks have been designed and thoroughly tested in various deployments like indoor WSN testbed such as Indriya [2], FlockLab [5], Twist [4], and MoteLab [7]. Since all these deployments are inside academic institutes, they experience planned cross-technology interference (CTI) because of the presence of a single network administrator who is responsible for the setting up of the WiFi Access Points (APs). In such planned CTI environments WiFi channels 1, 6 and 11 are mostly occupied, making at least 4 ZigBee (802.15.4) channels (e.g., Channels 15, 20, 25 and 26) available, which lie orthogonal to WiFi interference as shown in Figure 1. Figure 3(a) illustrates the WiFi analyzer's output inside an academic institute. However in urban places like residential complexes, shopping malls, cafeterias, etc., where there is a lack of a centralized control and the APs are set up by different entities, CTI is more dynamic as illustrated in Figure 3(b and c).

Data collection in WSN deployments in such urban environments is particularly challenging because of the following reasons:

- Due to dynamic CTI, it may not be possible to select a "good" channel that remains usable for an extended period of time.
- At times, there might not be any "good" channel at all.

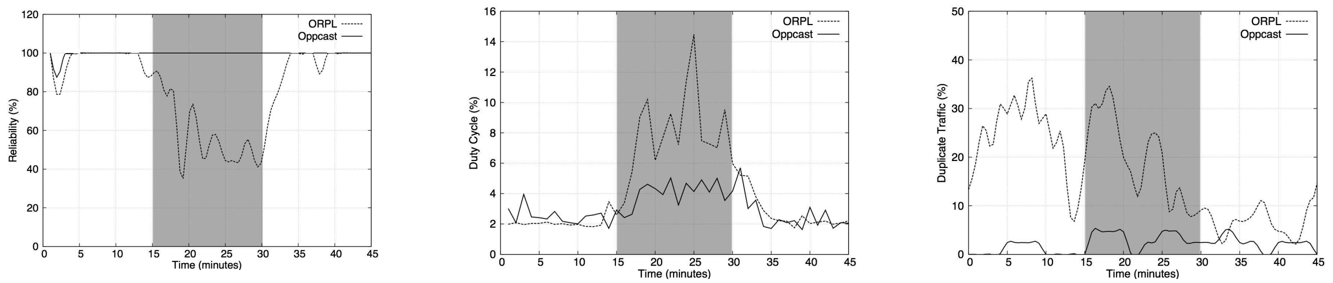
In this demonstration, we present *Oppcast*, a data collection protocol that is robust to unplanned CTI in urban environments. The key idea behind Oppcast is to exploit spatial and channel diversity at the same time unlike other protocols shown in Figure 2, so that by enabling opportunistic routing over multiple channels, the set of potential receivers can increase significantly. This provides a substantial improvement in end-to-end reliability with significantly lower energy consumption and reduced packet delivery latency.

Our extensive evaluation in [6] shows that Oppcast significantly outperforms state-of-the-art data collection protocols like ORPL [3] (a single channel opportunistic routing protocol) and MiCMAC [1] (a multi-channel MAC protocol that runs



(a) Academic Institute (b) Shopping Mall (c) Residential Complex

Fig. 3. Depiction of the extent of WiFi interference in different dynamic urban deployment environments.



(a) Reliability (b) Duty Cycle (c) Traffic Duplication

Fig. 4. Stress test: Oppcast is resilient to transient CTI, maintains high reliability without much increase in duty cycle, and has consistently lower redundant duplicate traffic.

over RPL) in terms of reliability, in particular, in the presence of CTI. For instance, when evaluated in urban areas with unplanned WiFi, Oppcast achieves reliability over 98.55% in all cases, while the reliability of ORPL varies between 68% to 100% depending on the environment. Figure 4 illustrates the performance of Oppcast on a 20 node testbed under the influence of a controlled source of interference (10 running Oppcast and 10 running ORPL in parallel) with ZigBee channels 11, 17 and 23 selected for Oppcast and channel 22 selected for ORPL. In the middle of the experiment, we introduce WiFi interference by continuously flooding UDP packets for 15 minutes on WiFi channel 11 which interferes with the two adjacent ZigBee channels 22 and 23. In the interfered duration, Oppcast shows resilience to CTI by maintaining reliability continuously at 100% and consuming significantly lower energy due to the use of multi-channel and generation of reduced duplicate traffic.

II. Demonstration

This is a demo of an associated paper presented at IPSN 2016 [6] which contains a more detailed description of the system. In this demonstration, we deploy a small TelosB network at the venue with an implementation of Oppcast running. Each node periodically senses the ambient light and transmits the sensed data with an inter-packet interval of 1 minute over the underlying DODAG (direction oriented directed acyclic graph) towards the sink. To illustrate Oppcast's performance in the real-time, we show various metrics like network topology, end-to-end packet reception reliability, average duty cycle, channel utilization, etc. on a web-based dashboard. In order to reflect the impact of CTI, we select only those ZigBee channels that are interfered by the deployed WiFi at the venue.

III. Conclusion

We present a real-time demonstration of Oppcast, a multi-channel probe-based receiver-initiated opportunistic routing protocol which uses opportunistic unicast transmissions to improve reliability with reduced duplicate transmissions in the presence of highly dynamic CTI which characterizes an urban environment. Due to the lack of expensive channel estimation and exploitation of multiple routes over multiple channels, Oppcast promises to be a practical and extremely robust data collection protocol with reliability consistently maintained above 98.55% in multiple real deployments.

IV. Acknowledgement

This work was supported in part by the Agency for Science, Technology and Research (A*STAR), Singapore, under SERC Grant 1224104049.

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