Tackling Self Interference, Cross-Technology Interference and Channel Fading in Wireless Sensor Networks

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ABSTRACT

Recently with a push towards "IoTification", the world foresees a sharp rise in the number of devices with wireless networking capabilities. It is inevitable to anticipate an enormous increase in both self and cross-technology interference leaving a very challenging wireless communication medium at one's disposal. Maintaining robust data transmission in this increasingly hostile 2.4GHz band without incurring significant additional energy consumption is a basic concern. Towards this end we propose a suite of protocols (Syncast and Oppcast) exploiting capture effect over multi-channels and a careful knit of spatio-temporal and channel diversity to provide robust data transmission for multiple communication paradigms (Collection and Dissemination).

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design—*Wireless communication*

Keywords

data collection; synchronous transmissions; capture effect; spatio-temporal diversity; channel diversity

1. INTRODUCTION

When it comes to Wireless Sensor Networks, data collection and dissemination are two important services. Be it real-time urban environment monitoring (data collection) or pushing updates to already deployed devices (data dissemination), reliability is a necessity. Over the last decade, the research community has contributed enormously to make these services not only reliable but also energy efficient. However most of these efforts are either non-scalable due to severe self-interference (SI) [5] or assume the availability of sufficient channels free from cross-technology interference (CTI) [1]. In today's world these assumptions are becoming less plausible specially because of the deployments becoming denser due to "IoTification" leading to increased SI or deployments starting to move out from research labs to urban areas where CTI starts to dominate.

Recently a lot of interest has been shown to tackle CTI by successfully classifying the different sources based on fast channel sampling followed by taking necessary remedial actions. However because of extremely dynamic behavior of CTIs, channel assessment becomes exceedingly expensive since it has to be periodically repeated for the entire spectrum. Moreover protocols are usually evaluated on testbeds deployed in research labs or within academic institutions like Indriya [2] where WiFi AP (major CTI source) is configured by the organization to operate on fixed orthogonal channels (1, 6 and 11), thereby allowing ZigBee to coexist. In contrast to the above "organized" WiFi deployment, a typical urban outdoor environment is quite "unorganized" with no single CTI free ZigBee channel available to use. Thus making SI and CTI increasingly important issue to address.

In this research we propose a Syncast, a data dissemination protocol leveraging Synchronous transmissions [5] for speed and Capture effect over multi-channels to mitigate SI by sparsifying the network. Next we study the impact of CTI on the performance degradation of the state-of-the-art data collection protocols in an urban outdoor deployment and propose Oppcast, a robust data collection protocol for such challenging environments. Instead of complex CTI source classification and then taking corresponding remedial actions [6], our approach leverages a careful blend of spatio-temporal and channel diversities to look for transient opportunities for reliable data transmission. Oppcast deviates from previous work by eliminating the need to perform expensive link quality estimation to identify the least interfered channel. Our contributions are as follows:

- To the best of our knowledge we are the first to study the effect of Capture effect over multi-channels on synchronous transmission based protocols and used it to design Syncast which makes them scalable.
- We studied CTI in different settings and could classify the environment into "Organized" and "Unorganized" categories having different protocol requirements.
- The above observation motivated us to design Oppcast to eliminate expensive channel quality estimation and still ensure high packet reception reliability by making use of spatio-temporal and channel diversities.

The rest of the paper is organized as follows. In Section 2 and 3, we motivate the need for and present Syncast and Oppcast, followed by ongoing future work and conclusion.

2. SYNCAST

Synchronous transmission has gained popularity recently for its ability to speed up data collection and dissemination by eliminating the need for channel contention [5]. The

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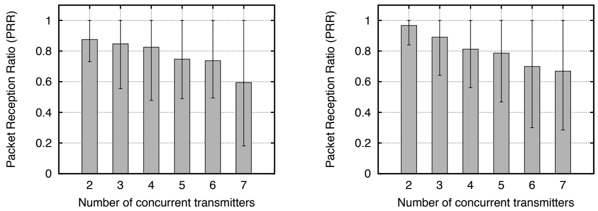

(a) Indoor Setup (b) Outdoor Setup

Figure 1: PRR vs. Number of Concurrent Transmitters for different deployments environments

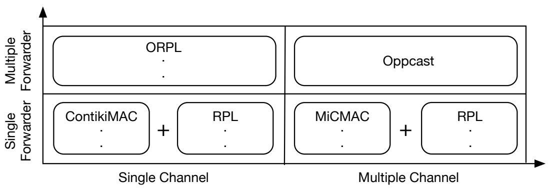

Figure 2: Positioning Oppcast among others

challenge is to maintain a synchronization accuracy of up to 0.5μs among synchronous transmitters. However due software, hardware and propagation delays synchronization error exceeds 0.5μs when the number of synchronous transmitters increases, resulting in the so-called *scalability problem* as shown in Figure 1 where on introduction of every additional concurrent transmitter, the packet reception ratio falls.

Approach: Syncast aims at scaling the synchronous transmission for large packet sizes and dense networks having large number of concurrent transmitters by exploiting capture effect to relax the timing constraint to 160μs and multichannels to make the network sparse. Real testbed evaluation of Syncast shows consistently high reliability with up to 92% energy savings in contrast to Glossy [5] whose reliability depends on SI, CTI and packet sizes.

3. OPPCAST

Since WSN link are highly dynamic [7], link quality estimations becomes unfeasible. Most of the protocol assume that there are at least four ZigBee channels available which are orthogonal to the most commonly used WiFi channels (1, 6 and 11). In today's time with every house having wireless connectivity, this assumption is becoming less likely. From our observations, we were able to identify two environment types based on the WiFi AP deployment:

1. *Organized CTI*: Found in places like educational institutions, libraries, corporate offices, etc. where a central administration handles WiFi AP deployment. Figure 3(top) illustrates a WiFi analyzer output of one such deployment where only WiFi channel 1, 6 and 11 has been used. Indoor testbeds like Indriya is a representative example.

2. *Unorganized CTI*: Found in places lacking central control over WiFi AP deployment like shopping malls, residential complexes, etc. as illustrated in Figure 3(bottom).

Approach: A lot of research effort has been put in the past along various directions of exploiting diversities like multiple channels or multiple forwarders in isolation as illustrated in Figure 2 [1, 3, 4, 8]. Oppcast aims at providing a unified solution to exploit spatio-temporal and channel diversities to achieve robust data collection. The research is in progress and the Contiki implementation of Oppcast is being tested on both indoor and outdoor environment with preliminary results proving its robustness to CTI.

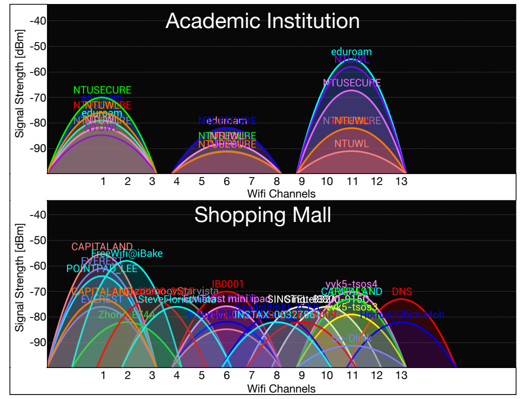

Figure 3: CTI in different deployment environments

4. CONCLUSION AND FUTURE WORK

In this research we address two important challenges to wireless communication in urban outdoor environment: SI and CTI. Towards this end we proposed Syncast, a synchronous transmission based protocol for robust data dissemination exploiting capture effect over multi-channels and evaluated it on real testbed. Later we motivated the need for specialized protocols for outdoor urban environment through comparative study of different environments and proposed Oppcast, a robust data collection protocol that eliminates expensive periodic link quality estimation over multiple channels. In future we would like to study the seriousness of packet losses due to channel fading in an urban setting and try to avoid packet loss due to sudden weakening of link because shadowing from obstacles by leveraging radio as a sensor instead of additional expensive sensor deployment.

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