Impulse Radio UWB for the Internet-of-Things

A Study on UHF/UWB Hybrid Solution

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Abstract

This dissertation investigates Ultra-Wideband (UWB) techniques for the next generation Radio Frequency Identification (RFID) towards the Internet-of-Things (IoT). In particular, an ultra-high frequency (UHF) wireless-powered UWB radio (UHF/UWB hybrid) with asymmetric links is explored from system architecture to circuit implementation.

Context-aware, location-aware, and energy-aware computing for the IoT demands future micro-devices (e.g., RFID tags) with capabilities of sensing, processing, communication, and positioning, which can be integrated into everyday objects including paper documents, as well as food and pharmaceutical packages. To this end, reliable-operating and maintenance-free wireless networks with low-power and low-cost radio transceivers are essential. In this context, state-of-the-art passive RFID technologies provide limited data rate and positioning accuracy, whereas active radios suffer from high complexity and power-hungry transceivers. Impulse Radio UWB (IR-UWB) exhibits significant advantages that are expected to overcome these limitations. Wideband signals offer robust communications and high-precision positioning; duty-cycled operations allow link scalability; and baseband-like architecture facilitates extremely simple and low-power transmitters. However, the implementation of the IR-UWB receiver is still power-hungry and complex, and thus is unacceptable for self-powered or passive tags.

To cope with μW level power budget in wireless-powered systems, this dissertation proposes an UHF/UWB hybrid radio architecture with asymmetric links. It combines the passive UHF RFID and the IR-UWB transmitter. In the downlink (reader-tag), the tag is powered and controlled by UHF signals as conventional passive UHF tags, whereas it uses an IR-UWB transmitter to send data for a short time at a high rate in the uplink (tag-reader). Such an innovative architecture takes advantage of UWB transmissions, while the tag avoids the complex UWB receiver by shifting the burden to the reader. A wireless-powered tag providing -18.5 dBm sensitivity UHF downlink and 10 Mb/s UWB uplink is implemented in 180 nm CMOS. At the reader side, a non-coherent energy detection IR-UWB receiver is designed to pair the tag. The receiver is featured by high energy-efficiency and flexibility that supports multi-mode operations. A novel synchronization scheme based on the energy offset is suggested. It allows fast synchronization between the reader and tags, without increasing the hardware complexity. Time-of-Arrival (TOA) estimation schemes are analyzed and developed for the reader, which enables tag localization. The receiver prototype is fabricated in 90 nm CMOS with 16.3 mW power consumption and -79 dBm sensitivity at 10 Mb/s data rate. The system concept is verified by the link measurement between the tag and the reader. Compared with current passive UHF RFID systems, the UHF/UWB
hybrid solution provides an order of magnitude improvement in terms of the data rate and positioning accuracy brought by the IR-UWB uplink.

Key Words
Ultra-Wideband, impulse radio, IR-UWB, RFID, asymmetric links, UHF/UWB hybrid, wireless sensing, energy detection, low power, radio receiver, positioning, Internet-of-Things