21.5 An LTE-Harvesting BLE-to-WiFi Backscattering Chip for Single-Device RFID-Like Interrogation

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Recent work in backscatter modulation has enabled very low-power communication between an IoT tag and commodity hardware such as WiFi or BLE transceivers [1-4], allowing a new set of exciting IoT applications such as on-body sensors or asset trackers that demand low power and low deployment cost via compatibility with existing standards. However, such backscatter approaches tend to require two external devices: a transmitting tone generator [3,5] or access point (AP) [1,2,4] and a receiving AP [1-5] in order to perform tone-to-WiFi [3,5], WiFi-to-WiFi [1,2,4] or BLE-to-BLE [4] communication without requiring power-expensive RF signal generation on the backscattering IoT tag (Fig. 21.5.1, top). Unfortunately, not all applications natively have multiple available APs, and deployment of additional infrastructure can be expensive.

Since there are few, if any, commodity devices that feature full-duplex communication or multiple radios operating concurrently with the same standard in the same band, a low-power backscatter IC that can be interrogated by a single device has not been demonstrated. In addition, most such backscattering IoT tags require either batteries or auxiliary energy harvesters, which can further increase deployment and/or maintenance costs.

This paper presents a backscattering IC that can enable wireless communication and battery-less operation with multi-standard inputs coming from only a single mobile device by: 1) harvesting power from LTE signals; 2) buffering this power onto a energy storage capacitor; 3) starting-up a duty-cycled WiFi wake-up receiver (WuRx) that has been previously tuned to detect the timing of BLE packets; and 4) transferring a low-power backscatter BLE packet into a single-side-band (SSB) OPSK modulated WiFi packet via a fully-reflective I/O backscatter modulator. As illustrated in Fig. 21.5.1 (bottom). In this manner, the energy harvesting source is directly coupled to the intent to interrogate, unlike other sources of energy harvesting that may or may not be available at interrogation time (e.g., PV, TEG) and therefore require an energy buffering battery. As a result, this approach enables a robust, low-cost, and scalable way to provide power and enable communication in an RFID-like manner, but in this case utilizing existing commodity mobile devices that feature separate LTE, WiFi, and BLE chips as a reader.

Inspired by [6], the incident tone for backscatter modulation can be generated by intentionally transmitting a BLE packet with either all 1s or all 0s. To avoid channel uncertainty due to frequency hopping, this work leverages only BLE advertisement packets on ch. 37, 38 and 39. The most basic way to perform DSSS backscattering for compatibility with 802.11b is to modulate the incident tone with baseband data that is multiplied with an 11MHz Barker code. However, doing so would cause the backscatter signal to land on the same frequency as the incident tone; since BLE and WiFi channels do not share the same center frequency, this is not possible within the confines of the two standards. This work demonstrates that an open-loop ring oscillator may have sufficient short-term stability to enable successful 802.11b backscattering [3]. Finally, backscattering is achieved via a fully reflective transmission-line-reflective reflector [4] and using the outputs of the baseband Barker code processor.

The proposed backscatter IC was fabricated in 65nm, occupying a core area of 0.43 mm². A micrograph is shown in Fig. 21.5.7. This work was supported in part by the National Science Foundation under Grant 1923902 and UC San Diego Center for Wearable Sensors. References:

Figure 21.5.1: Prior-art WiFi and BLE-based backscatter approaches (top); proposed self-sustaining single-interrogation-device backscatter system (bottom).

Figure 21.5.2: Frequency planning to enable translation from all possible BLE advertisement channels to up to 8 different WiFi channels (top); operation timing diagram (bottom).

Figure 21.5.3: Block diagram of the tag, including LTE energy harvesting and power management, WiFi wake-up, crystal oscillator, ring oscillator, and reflector stages.

Figure 21.5.4: Measured crystal oscillator startup transients and measured spectra showing frequency translation from three BLE advertisement channels to fully modulated WiFi signals at 8 different WiFi channels.

Figure 21.5.5: Photograph of the wireless testing setup (top); measured wireless charging time vs. input power level and distance (bottom).

Figure 21.5.6: Table of comparisons to other tone/BLE-to-WiFi works.
Figure 21.5.7: Die micrograph of the proposed single-device-interrogated LTE-powered BLE-to-WiFi backscattering chip.