

Demo: LoRea: A Backscatter Architecture that Achieves a Long Communication Range

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ABSTRACT

We present LoREA an architecture consisting of a backscatter tag, a reader and multiple carrier generators that overcomes the power, cost and range limitations of existing backscatter systems such as Computational Radio Frequency Identification (CRFID). LoREA achieves this by: *First*, generating narrow-band backscatter transmissions. *Second*, by mitigating self-interference without the complex designs employed on RFID readers by keeping carrier signal and backscattered signal apart in frequency. *Finally*, by decoupling carrier generation from the reader and using devices such as WiFi routers and sensor nodes as a source of the carrier signal. LoREA's communication range scales with the carrier strength, and proximity to the carrier source and achieves a maximum range of 3.4 km when the tag is located 1 m from the carrier source while consuming 70 μ W at the backscatter tag. We present various ultra-low power and long-range features of the LoRea architecture.

KEYWORDS

Battery-free, Backscatter, CRFIDs, WISP, Moo, RFIDs

1 INTRODUCTION

Backscatter communication enables wireless transmissions at a power consumption orders of magnitude lower than traditional radios. A backscatter transmitter modulates ambient wireless signals by selectively reflecting or absorbing them, which consumes less than 1 μ W of power [9]. This makes backscatter communication well-suited for applications where replacing batteries is challenging [11] or where extending battery life is important [4]. In the past few years, significant progress has been made to advance backscatter communication. Recent works demonstrate the ability to synthesise transmissions compatible with WiFi (802.11b) [7], BLE [6] and ZigBee [6, 12] at μ W of power using backscatter transmissions.

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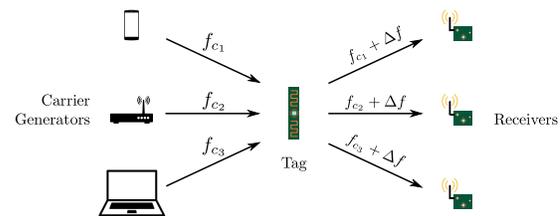


Figure 1: Overview of our architecture. One or more devices (sensor nodes, WiFi devices, etc.) provide the carrier that the tag reflects, and is received by one or more receivers.

Other works leverage ambient wireless signals like television [9] or WiFi [8, 16] for communication. On the other hand, the design of traditional backscatter readers and tags, e.g., CRFID systems, has not seen major improvements despite their continuing significance and the widespread deployment.

To understand the reason for the poor performance of existing CRFID systems, we see how these systems operate: CRFID tags require an external device (the reader) that generates a carrier signal, provides power, queries and receives the backscatter reflections from the tags. In most CRFID readers, a single device performs all of these operations. The readers receive backscatter transmissions at the frequency of the carrier signal [3, 15]. As energy delivery is combined with communication, the readers generate a strong carrier signal (~ 30 dBm/ 1 W), which significantly increases their power consumption making applications such as mobile backscatter readers very challenging. The backscatter reflections are inherently weak, hence separating them from the strong carrier requires complex techniques which increases both cost and complexity [4]. The readers also suffer from poor sensitivity (-84 dBm [5]) due to leakage of the carrier signal into the receive path [10] reducing range [2].

If we could overcome the above limitations, and design an inexpensive backscatter platform that achieves long communication range, we would significantly help applications conceived using CRFIDs. Further, such a platform could enable new battery-free applications that are challenging right now. For example, sensors embedded within the infrastructure. We demonstrate an architecture that provides such capability.

2 LOREA ARCHITECTURE

We redesign CRFID-based systems and introduce a new architecture shown in Figure 1, and described in [13, 14]. We achieve a

significant improvement across key metrics like range, price and power consumption in comparison to the state of the art [1, 6, 7, 16]. Our architecture is based on the following design elements:

- (1) The tradeoff between bitrate and receiver sensitivity is well known. Recent ultra-low-power backscatter systems operate at high bitrates (thousands of kbit/s) due to the use of commodity protocols [1, 6, 7, 16] which limits their range and applicability. We deliberately operate at low bitrates (2.9 kbit/s) which allows us to use highly sensitive narrow-band receivers. Such a design is not detrimental to most sensing applications as they only send small amounts of information.
- (2) We keep the carrier and backscattered signals at different frequencies. This improves the SNR of the backscattered signal by reducing the interference from the carrier. As opposed to traditional readers that use complex solutions to reduce self-interference, we use the ability of transceivers to reject emissions on adjacent channels.
- (3) Finally, we employ a bistatic configuration where the carrier generator and the receiver are spatially separated. This has three advantages: First, spatial separation decreases self-interference, which improves the range owing to path-loss of the carrier signal. Second, when operating in the 2.4 GHz band, we can leverage commodity devices to provide the carrier signal. Third, decoupling helps to separate the energy-intensive carrier generation from the reader.

Design elements (2) and (3) have also been used in recent backscatter systems [6, 7, 16]. Combining the three design elements enables us to reduce self-interference without using the complex designs employed by current CRFID readers. This helps us to reduce the price of the reader to 70 USD, a drastic reduction when compared with the approx. 2000 USD that commercial RFID readers cost.

Design element (3) enables us to use an infrastructure of wireless devices as the source of the unmodulated carrier signal. While Interscatter [6] demonstrated that BLE radios can be used to generate carrier signals, we go a step beyond and demonstrate that 802.15.4 and WiFi radios can also generate carrier signals.

Keeping the carrier and backscatter signal separated in frequency, also introduces a new challenge in the design of the tag. We present a backscatter tag that can shift and frequency-modulate the carrier signal. The tag consumes $70 \mu\text{W}$ and $650 \mu\text{W}$ while operating at 868 MHz and 2.4 GHz respectively. We show the tag in Figure 2.

At the backscatter tag, we choose FSK as a modulation scheme over the conventionally-used amplitude modulation. We choose FSK since it provides several advantages: *First*, FSK is a constant-envelope modulation and offers robustness against fading. *Second*, FSK is more robust to noise than amplitude modulation since it can achieve a lower Bit Error Rate (BER) for the same signal-to-noise ratio. We employ a frequency deviation of 13 kHz and 190 kHz between the bit 0 and 1 for the 868 MHz and the 2.4 GHz respectively, which helps generate narrow bandwidth backscatter transmissions.

In our architecture, when operating in close proximity (1 m), and with the strength of the carrier signal close to the maximum permissible power, we achieve a range of more than 3.4 km in the 868 MHz band, and 225 m in the 2.4 GHz band with a carrier strength of 28 dBm and 26 dBm respectively. This range is an order

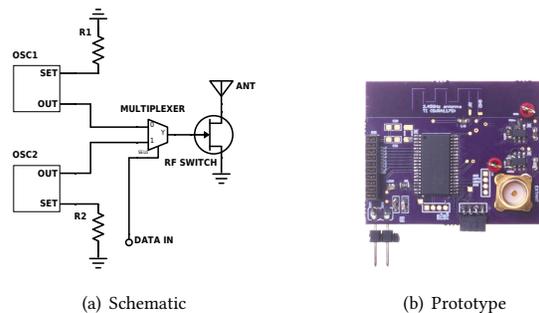


Figure 2: Backscatter tag schematic and prototype. The tag shifts and modulates an ambient carrier with microwatts of power.

of magnitude longer than what state-of-the-art systems achieve [6, 7, 16] when operating in similar settings.

3 DEMONSTRATION

We will demonstrate our prototype long-range backscatter tag, and the reader. We show that our prototype is capable of communication at long distances within the interfered environment of the conference venue. The demo works as follows: The backscatter device will periodically transmit information by reflecting ambient carrier signals. The carrier signal will be generated from an externally-powered device. These transmissions will be received and displayed. The tag will be placed as far as possible from the receiver to demonstrate the long-range capability of our design. Furthermore, to demonstrate ultra-low power, our tag operates on energy harvested from a small solar cell under indoor illumination. We would require a table, two power outlets, and a monitor.

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