Hybrid Backscatter Sensors for Low cost Precision Agriculture Applications

Spyridon Nektarios Daskalakis, *Student Member, IEEE*, George Goussetis, *Senior Member, IEEE* and Apostolos Georgiadis, *Senior Member, IEEE*

Fig. 1. Agricultural backscatter communication setup in bistatic architecture. An emitter sends a pure carrier signal and a low-cost reader receives the modulated reflections of each tag.

***Abstract*—This report summarizes the main outcomes of the proposed work presented in the 2019 IEEE MTT-S Graduate Fellowship. This work describes a novel wireless tag that utilizes Bluetooth 2.4 GHz signals for backscatter communication. The proposed tag comprises of an ultra-low-power MCU and two RF front-ends for wireless communication. The MCU can accumulate data from multiple sensors through an ADC, while it transmits the information back to the receiver through the front-end by means of backscattering or using directly the Bluetooth technology.**

***Index Terms*—Backscatter communication, internet-of-things (IoT), radio frequency (RF) identification (RFID) sensors.**

I. Low-cost and Low-power WSN

THE explosive growth of agricultural applications has required the design of low-cost and ultra-low-power wireless sensors; backscatter communication has been introduced as a cutting-edge technology that could address the above constraints [1]. Thus, networking cost of 100 plants becomes prohibitive, the solution on this problem is based on reflection principles and it's called backscatter communication. In backscatter (RFID systems), the sensor node/tag receives a radio frequency (RF) wave from an emitter and sends its information back to a reader wirelessly by reflecting and modulating this incident RF signal [2]. By deploying backscatter sensors to monitoring the micro climate conditions (temperature, soil moisture, etc.) the farmers could stop make decisions based only on their own practical experience and optimize their daily tasks.

Our project discusses the implementation of a low-cost and low-power wireless sensor network for agricultural applications. Each sensor node have a super capacitor instead of battery thus the idea is to create a low maintenance batteryless system. Each sensor node also includes environmental sensors of pheromone, humidity, temperature, atmospheric pressure, leaf sensing and an accelerometer. an It is able to send data wirelessly to a low-cost base station via Bluetooth Low energy (BLE) or backscatter technology. It is noted that all the proposed tags can be a part of a backscatter WSN, transmitting data to a reader as shown in Fig. 1.

The deployment of the network is outdoors and a small solar panel provides energy autonomy to each sensor node for two days. In order to maximize the energy autonomy, every node is kept in sleep mode for most of the time. When an event occurs, the device wakes, takes the data from its sensors and a short message is advertised to a nearby base station.

The sensor node includes also integrated NFC technology for interaction with the farmer's smartphone. The farmer can securely read device's identification (ID) number or upload configuration parameters without moving the node from its installed position. The NFC can be also used for powering the sensor in parallel with solar panel offering a additional wireless power transfer capability. For example, in a extreme cloudy weather scenario (dark for more than four days), the farmer could activate each sensor using his smartphone. We have developed a power harvester for our sensor node using circuits necessary to combine the output of a solar cell and an NFC electromagnetic harvester [3]. The circuit is depicted in Fig. 2 and includes an NFC antenna, an NFC rectifier, the solar panel and a commercial boost converter working all together in order to charge a super capacitor.

The Texas Instrument BQ25570 IC was chosen as our power management unit with a boost charger, and a nano power buck converter at the output. The converter includes maximum power point tracking (MPPT) with minimum cold start voltage and typical input power of 330 mV and 10 uW, respectively. The BQ25570 was connected at the output of the rectifier in order to boost the output voltage of the charge pump and store the dc power in the super capacitor.

The architecture of the tag is based on the nRF52832 system on a chip (SoC) which supports BLE and NFC technology for communication. The cost of the chip is around 3 USD and it is ideally suited for BLE communication thus BLE technology has a slightly different modulation technique than classic Bluetooth technology.

For the backscatter communication the MCU collects the information from the sensors through the analog-to-digital converter (ADC) and creates a modulated signal with the information in order to control the RF front-end part. The front-end uses binary FSK modulation and the hardware has been be implemented using an ADG902 RF switch and a

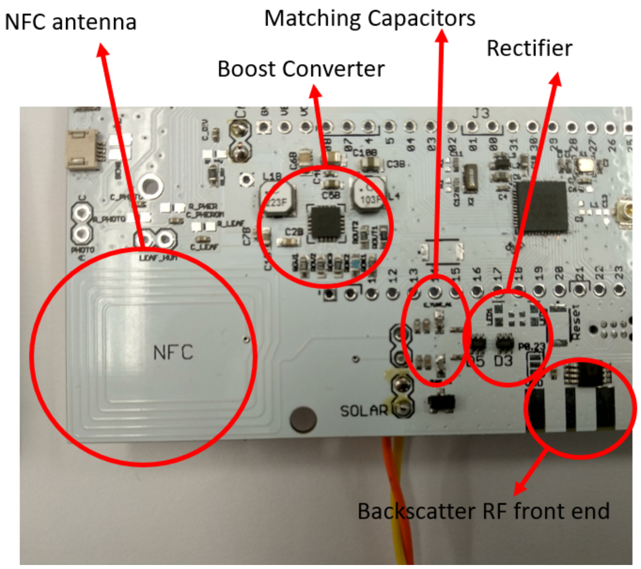

Fig. 2. The fabricated rectifier, boost converter and NFC antenna on the same printed circuit board.

dipole antenna. The tag can communicate remotely using two low-cost 2.4 GHz commercial transceivers using bistatic backscatter architecture. One transceiver can be used as a carrier emitter and the second as a reader of the reflected waves.

The sensor node is also able to send data directly to a low-cost base station via BLE technology. Then the base station can upload the information to the cloud. The base station will be in the middle of the facility and will consist of an access point a with BLE connectivity. The access point is inside a waterproof box and will be powered by the facility power lines or a bigger solar panel. The BLE modulation differentiation offers a communication range of up to 500 meters with a 10 dBm radio chipset. In order to extend the range of the sensor, a small efficient antenna has been designed without the need of an extra amplifier. The average, current consumption for BLE is less than 25 uA and for backscatter communication, is less than 5 uA. The active power consumption is reduced to a tenth of the energy consumption of classic Bluetooth.

The final tag circuit consists of the nRF52832, the two RF front ends, the sensors, the NFC antenna with the rectifier, the matching network and the boost converter. All the above were fabricated on low cost FR-4 substrate as depicted in Fig. 3.

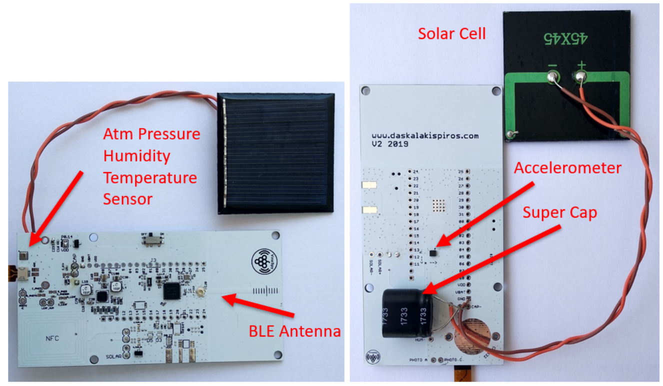

Fig. 3. The proposed sensor node printed circuit board. The board also includes a small solar pane and a super capacitor intend of a battery.

Professional Career Plan

I am currently working toward to finish my PhD degree in School of Engineering and Physical Sciences from Heriot-Watt university. My research interests include low-power, low-cost wireless sensor networks and energy harvesting. During this period, I am at the finals to complete my research on ambient backscatter systems and more generally, on a new, novel modulation technique that is going to extent the communication range over a hundreds of meters. After my PhD graduation, I would like to find an academic position as Post-doctoral researcher and remain in the microwave community. Working as a researcher, is my passion and the IEEE MTT-S Fellowship motivated me to actively take part of the microwaves world and gave me the confidence to interact with other scientists from all over the world.

IMS Impressions

I had the opportunity to attend the IMS2019 conference that represents the leading event of the RF/Microwave Community. Also I had the chance to participate as co-organizer in Backscatter Radio Student Design Competition and I had the opportunity to increase my network, learn news and research trends from both academia and industry. What's more, I was able to transform the enthusiasm generated by such a big event to renovated energy for my experimental activity.

Acknowledgment

I would like to thank IEEE MTT-S community for selecting me for this prestigious award. I also would like to thank my supervisors Apostolos Georgiadis and George Goussetis for encouraging me to apply for this fellowship and for supporting me during my research life. I would also like to thank Lloyd's Register Foundation (LRF) and the International Consortium in Nanotechnology (ICON).

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