Demo Abstract: Implementing SNOW on Commercial Off-The-Shelf Devices

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Abstract—**The recently proposed Sensor Network over White spaces (SNOW) has gained interest due to the availability and advantages of TV spectrum. SNOW is the first highly scalable Low-Power Wide-Area Network (LPWAN) over TV white spaces technology providing reliable, asynchronous, bi-directional, and concurrent communication between numerous sensors and a base station (BS). In this demonstration, we introduce our SNOW design and showcase the communication between multiple SNOW nodes and the BS.**

I. Introduction

Recently, Low-Power Wide-Area Network (LPWAN) has gained interest. For many application, which require to connect thousands of sensors over long distances such as civil infrastructure monitoring [1] and oil field management [2] existing WSN technologies in the ISM band such as IEEE 802.15.4 [3] and 802.11 [4] cover a large area with numerous devices as multi-hop mesh networks at the expense of energy, cost, and complexity. One example is the applications in the agricultural domain (Figure 1). They require long-range communication due to the limited/lack of the availability of network infrastructure/coverage in such rural locations. In addition, using cellular-based technologies, in most cases, require recurring subscription fee to provide services, which introduces additional cost. These limitations can be overcome by deploying LPWAN.
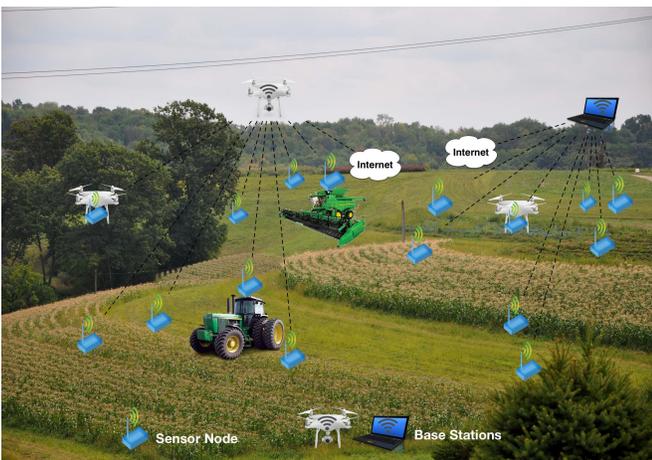

Fig. 1. Sensor network deployed in farm.

Accordingly, we propose *Sensor Network Over White Spaces (**SNOW**)* [5], an LPWAN technology with potentials to overcome the scalability limitation of existing LPWAN

technologies. SNOW operates over the unlicensed TV white spectrum. Thanks to their lower frequencies, white spaces have excellent propagation characteristics over long distance and obstacles. Compared to IEEE 802.15.4 or Wi-Fi, they offer a large number of and less crowded channels, each 6MHz wide. White spaces are available in both rural and urban areas, with rural (and suburban) areas tending to have more [6], [7]. SNOW presents a novel design eliminating the scalability limitation existing in LPWAN technologies. Hence, the number of supported nodes in SNOW increases with the spectrum availability. In this demonstration, we showcase the communication between several SNOW nodes and a BS. We show the capabilities of SNOW BS to decode packets from multiple asynchronous Commercial-Off-The-Shelf (COTS) transmitters (TI CC1310) simultaneously.

II. SNOW: Model and Design

SNOW is an asynchronous, long range, low-power platform operating over the TV white spaces [5], [8]. Each sensor node is equipped with a single half-duplex narrow-band white space radio. The white space spectrum provides excellent long transmission (Tx) range, hence, nodes are directly connected (with a single hop) to the BS and vice versa. The BS and its associated nodes thus form a star topology as shown in Figure 2. The nodes are power constrained and not directly connected to the Internet. They do not do spectrum sensing or cloud access. The BS uses a wide channel split into orthogonal subcarriers, each of equal spectrum width (bandwidth). It determines white spaces by accessing a cloud-hosted database through the Internet. In SNOW the assumption that the BS knows the locations of the nodes through manual configuration or some existing localization technique such as those based on ultrasonic sensors or other sensing modalities [9]. The BS selects white spaces available at its own location and at the locations of all other nodes. SNOW BS uses two radios, both operating on the same spectrum one for only transmission (called ***Tx radio***) and the other for only reception (called ***Rx radio***). Such a dual-radio of the BS allows concurrent bidirectional communication in SNOW.

The PHY layer of SNOW uses Distributed implementation of **OFDM** (Orthogonal Frequency Division Multiplexing) for multi-user access, called D-OFDM. In SNOW, the BS's wide white space spectrum is split into narrowband orthogonal subcarriers which carry parallel data streams to/from the distributed nodes from/to the BS as D-OFDM. A subcarrier
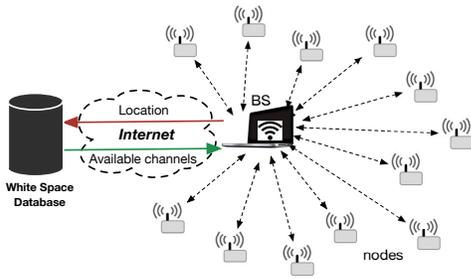
Fig. 2. The network structure of SNOW.

bandwidth can be chosen as low as 100kHz, 200kHz, 400kHz depending on the packet and expected bit rate. Narrower bands have lower bit rate but provides longer range, while consuming less power [10]. Thus, SNOW adopted D-OFDM by assigning the orthogonal subcarriers to different nodes. Each node transmits and receives on the assigned subcarrier. Each subcarrier is modulated using Binary Phase Shift Keying (BPSK).

While OFDM has been adopted for multi-access in the forms of OFDMA and SC-FDMA in various broadband (e.g., WiMAX [11]) and cellular technologies (e.g., LTE [12]) recently, its adoption in SNOW was novel for LPWAN design. For uplink communication in both OFDMA and SC-FDMA adopted in WiMAX and LTE, the BS uses multiple antennas to receive from multiple nodes. Taking the advantages of low data rates and short packets, the transceiver design of SNOW was much simpler. D-OFDM enables multiple packet receptions using a single antenna which is transmitted asynchronously from different nodes. It also enables different data transmissions to different nodes through a single transmission using a single antenna. The BS can exploit fragmented spectrum. If the BS spectrum is split into n subcarriers, then it can receive from n nodes simultaneously. Similarly, it can transmit n different data at a time.

Currently, the sensor nodes in SNOW uses a very simple and lightweight CSMA CA approach for transmission like the one used in TinyOS [13]. The nodes can autonomously transmit, remain in receive mode, or sleep. When a node has data to send, it wakes up by turning its radio on. The BS periodically sends a beacon. The nodes are aware of this period. Any node that wants to listen to the beacon can choose to wake up for the beacon. Since D-OFDM allows handling asynchronous Tx and Rx, the link layer can send an acknowledgment (ACK) for any transmission in either direction. Both radios use the same spectrum and have the same subcarriers, the subcarriers in the Rx radio are for receiving while the same in the Tx radio is for transmitting. Since each node (non-BS) has just a single half-duplex radio, it can be either receiving or transmitting, but not doing both at the same time.

III. IMPLEMENTATION

We have implemented SNOW [5], [8] in GNU Radio [14] using Universal Software Radio Platform (USRP) device for the BS [15] and Texas Instrument (TI) ultra-low power wire-

less micro-controller [16] as SNOW nodes. GNU radio is an open-source development toolkit provide signal processing blocks to develop software-define radio. USRP is a hardware platform designed for RF application. The BS USRP devices are B210, while the nodes are TI CC1310 [16] operating in operating on the Sub-GHz band. Packets generation, SNOW modulator, and decoder are implemented in GNU Radio. Figure 3 shows devices used for SNOW implementation.

TI CC1310   USRP B210

Fig. 3. SNOW node and BS.

IV. CONCLUSION

In this demonstration, we introduced the design of SNOW, the first highly scalable Low-Power Wide-Area Network (LP-WAN) over TV white spaces technology supporting reliable, asynchronous, bi-directional, and concurrent communication between numerous sensors and a BS. We demonstrated the communication between SNOW nodes and BS COTS devices as a proof of concept. SNOW is a promising LPWAN technology that overcomes the scalability limitations in existing LPWAN technologies and provides support for different future applications.

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