SNE-ISMTV: VESNA wireless sensor node expansion for cognitive radio experiments

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***Abstract*—This demonstration shows how VESNA wireless sensor nodes can be used for cognitive radio experiments involving wireless sensor networks. SNE-ISMTV is a radio front-end that has been developed for this purpose. Spectrum sensing capability in the TV white-spaces and 2.4 GHz ISM band is demonstrated by running receivers in a swept-tuned spectrum analyzer configuration and displaying measured spectrograms on a laptop PC. Analogue signal transmission simulating a wireless microphone is demonstrated by executing a direct digital synthesis algorithm on the sensor node microprocessor, transmitting the modulated signal using a narrow-band sub-1 GHz transceiver and monitoring the transmission using an USRP.**

I. Introduction

Current research in cognitive radio is mostly focused on high-bandwidth applications like broadband Internet access, video streaming and mobile services. Hence hardware used in such research traditionally includes an expensive, high-bandwidth software-defined radio device, from the popular Ettus Research USRP series to custom implementations like the IMEC sensing engine[1]. These front-ends are then usually coupled with a mid-to-high range personal computer to form a reprogrammable terminal where experiments with various parts of the networking stack can be performed.

However cognitive radio also has a future in low-bandwidth applications like wireless sensor networks. Growth in the number of deployed sensors and smart objects show that the already crowded ISM bands might not be enough to support growing number of devices in the future, even if individual bandwidth requirements stay low. Cognitive radio might also improve reliability of such networks.

Migrating experiments from a laboratory to a more realistic environment for a sensor network is difficult with existing solutions. Sensors are often deployed in inaccessible places that are not well suited for delicate laboratory equipment. Devices usually have to survive harsh environments. Size and power requirements are often a concern as well. Sensor networks can also comprise of a large number of devices, so price of an individual sensor node is an important factor.

VESNA is an embedded system with a IEEE 802.15.4 radio used as a wireless sensor network platform[2]. LOG-a-TEC, part of the CREW federation[3], is an outdoor sensor network testbed that comprises of 50 VESNA devices mounted on street lights, wirelessly connected into a mesh network[4]. It serves as an infrastructure enabling experimentation with communication protocols and spectrum sensing. Experimenters can run cognitive radio stacks on the sensor nodes themselves, use the network as a distributed spectrum sensor or use individual nodes to provide controlled interference.

When designing LOG-a-TEC, a second radio front-end was needed for VESNA that would be separate from the built-in radio used for testbed management and data collection. It had to be capable of operating in three frequency bands of interest (TV broadcast part of the UHF band, 868 MHz European SRD band and 2.4 GHz international ISM band) and flexible enough to enable various user scenarios. Existing solutions proved impractical to integrate with VESNA, hence a new front-end, called SNE-ISMTV, was designed to address these requirements.

This demonstration will include several VESNA sensor nodes equipped with different versions of the SNE-ISMTV hardware. Nodes will be connected to a laptop computer running Python scripts to demonstrate different capabilities:

Some nodes will be operated as a swept-tuned spectrum analyzer in the UHF and 2.4 GHz ISM bands to demonstrate how VESNA nodes can be used to detect DVB-T multiplexes or studio microphones in the vicinity of the demonstration area and also Wi-Fi networks and other transmissions from ISM band consumer devices brought in by the visitors. In an experiment this data could be used for example to compute real-time channel occupancy tables for cognitive terminals.

A node operating as a controlled interferer will also be shown simulating an analogue UHF wireless microphone transmission according to IEEE simulation method[5]. Wireless microphones are a common target device when developing spectrum sensing methods for TV white-spaces. The possibility to simulate their transmissions on VESNA nodes allows for remote spectrum sensing experiments to be performed on the testbed without the need to manually handle equipment. In the demo a USRP device connected with a coax cable to the node will be used to show the spectrum envelope of the transmission on a laptop computer.

II. Hardware

To keep complexity low, SNE-ISMTV was designed around of-the-shelf highly-integrated RF components. Where possible, signal processing has been left to the ARM CPU present on the VESNA sensor node core to provide flexibility. However, because of a relatively low processing power available compared to a modern personal computer, implementing a fully

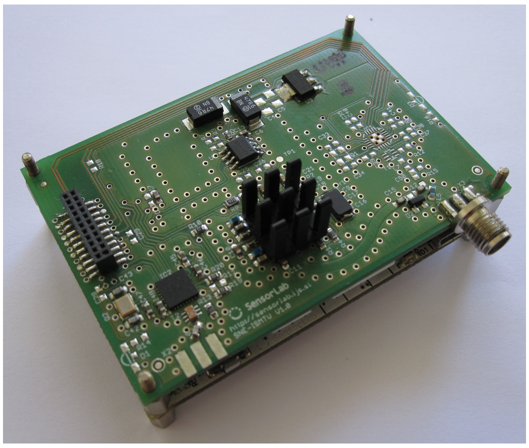

Figure 1. SNE-ISMTV-UHF (top) mounted on a sensor node (bottom).

software-defined radio architecture was not feasible. The CPU is capable of recording and generating signals up to 500 kHz in bandwidth with any additional signal processing further lowering the available bandwidth. Since requirements called for operation with signals of larger bandwidths, certain signal operations were left to hardware, with care taken that sufficient reconfigurability was available to cover all predicted scenarios.

Depending on the frequency band of interest, SNE-ISMTV offers three options for a radio front-end:

A. *Wide-band receiver for the UHF band*

The SNE-ISMTV-UHF is based on the NXP TDA18219HN silicon tuner and can receive signals from 470 to 870 MHz with channel filter bandwidths between 1.7 MHz and 10 MHz. Using an analogue detector with a logarithmic response it can be used for energy detection experiments with the resolution bandwidth identical to the channel filter setting and approximately 50 ms per channel sampling.

The detector is also coupled with an A/D converter optionally providing 1 Msample/s of the amplitude of the baseband signal. The samples can then be further digitally analyzed in software on the sensor node for more advanced spectrum sensing methods.

B. *Sub-1 GHz and 2.4 GHz narrow-band transceivers*

SNE-ISMTV-868 and SNE-ISMTV-2400 are based on the TI CC1101 and TI CC2500 integrated circuits respectively and are identical in design and operation except for the supported frequency band.

These transceivers contain software-reconfigurable radio front-ends operating from 780 and 930 MHz and from 2.40 to 2.48 GHz with channel bandwidths from 60 to 800 kHz and frequency-agile local oscillators with 75 µs settling time. They include an integrated logarithmic detector for energy detection and several modems that can be either connected to integrated packet handling hardware or provide a raw baseband digital stream to and from the CPU. This makes it possible to support experiments that require packet based as well as continuous transmissions.

Since the CPU can be used to generate a digital baseband signal up to 500 kbps, these transceivers can also be used to simulate analogue AM and FM transmissions by running a direct-digital synthesis algorithm on the CPU, albeit with a significant level of quantization noise.

III. Software

Since SNE-ISMTV does not provide a SDR architecture, its use can be complicated from the standpoint of a software developer. Supporting software has therefore been developed in a modular fashion to ease the experimenter's task. For code running on the sensor node, a hardware driver provides basic abstraction API for the spectrum analyzer and signal generation modes of operation. However exploiting full capabilities of the hardware still involves register-level access and knowledge of the front-end implementation details.

If remote control from a computer is desired, a Python module can be used that further simplifies the interface. It abstracts the connection between the computer to the sensor node, which can be for instance a RS-232 cable, TCP/IP connection or a remote IEEE 802.15.4 management mesh network in the LOG-a-TEC testbed.

Acknowledgments

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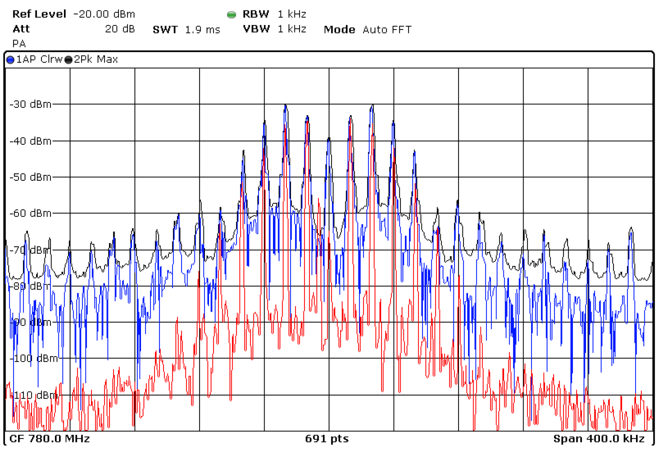

Figure 2. Spectrum of a simulated wireless microphone signal using an USRP (red trace) and VESNA with SNE-ISMTV-868 (blue trace).