Demo: Electrosense - Spectrum Sensing with Increased Frequency Range

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Abstract

This demo introduces an expansion board for Electrosense, a system for crowdsourced spectrum monitoring and analysis. The first generation of Electrosense sensor nodes, was based on a low cost Software Defined Radio (SDR) dongle with a frequency range limited to 24 MHz - 1.7 GHz. The new generation adds a custom made down-converter that extends the capabilities of the SDR dongle, enabling spectrum monitoring from almost DC up to 6 GHz. The low cost of the proposed sensor nodes allows for a large scale deployment which generates a massive amount of RF spectrum data. A server backend performs storage and data analysis. All the data and the results are available through an public open API. The goal of the demo is to introduce the hardware platform and illustrate how a combination of the default sensor and the expansion board can be used to flexibly scan multiple frequency bands.

1 Introduction

In the last years, the number of devices transmitting wireless data increased at an incredibly high rate: up to x115 increase, between 2015 and 2024, according to [9]. More and more novel applications are emerging that require ultra-reliable wireless communication thus service interruptions, pirate sources and spectrum anomalies should be detected and removed quickly. Spectrum monitoring is crucial for flexible sharing of the spectrum beyond dedicated fixed and exclusive licenses. Flexible sharing allows to accommodate the increasing number of wireless devices because fixed licensing result in suboptimal spectrum usage leaving wide slices of spectrum under-utilized while user accessible bands (ISM, LTE, etc...) get overcrowded. Efficiently sharing the spectrum can be a solution to increase the channel capacity but requires reliable and widespread monitoring for access management and minimization of interference [12]. Spectrum sharing requires accurate information about the usage of the spectrum. This helps long term planning of the spectrum use, as well as interference management and QoS analysis at the short term. If spectrum sensing and analysis at large scale can be automated, we can envision a large set of use cases that will improve the robustness and efficiency of wireless communication. To bootstrap this research, a large and representative dataset of spectrum usage is needed.Some spectrum monitoring solutions have been proposed in literature like the Microsoft Spectrum Observatory [5], Google spectrum [3] and IBM Horizon [4]. None of them have been successful in large scale deployment because of cost or complexity reasons.

Figure 1. Prototype of the down-converter board

Electrosense, that follows the crowd-sourcing paradigm for spectrum monitoring, enables a collaborative approach among inexpensive sensors reducing the initial barriers of cost and complexity. A similar project is RadioHound [8] but at the moment Electrosense is more advanced in terms of hardware and software backend. An integrated frontend, like in [11], can be the final goal of Electrosense if massive deployment is reached. Figure 1 shows the prototype of the down-converter board.

In this work, we propose a frequency converter that extends the frequency range of the low end SDR and a demo

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of how it can be used in conjunction with the Electrosense framework. The following sections explain the hardware platform object of this demo and its interactions with the backend subsystem. Finally, an overview of the demonstration is given.

1.1 Sensor Nodes Hardware

The extended Electrosense sensor nodes consist of three main components:

1. Custom Down-converter board which includes also a small up-converter (Figure 1).
2. SDR Frontend: RTL-SDR v3 receiver [6].
3. Single board computer: Raspberry Pi model 3.

The node design is simple and completely modular. Each part is independent from the others and uses standard interfaces. Each component can be replaced as needed depending on the desired frequency, analysis and accuracy. High cost, difficulty to find components and complex user interaction are all potential barriers to the diffusion of the sensor nodes and are addressed by our cheap and simple design. The typical configuration that we propose costs less than 200€ in prototype phase and can go down to 120€ once produced in volume. The performance of the sensor node is deeply analyzed in [10].

1.2 Down-converter Design

The novel demonstrated down-converter board has three possible RF inputs operating at different bands:

Up-conversion input	0 - 30 MHz
Direct input	30 MHz - 1.6 GHz
Down-conversion input	1.6 GHz - 6 GHz

The output of the down-converter board has a bandwidth of 20 MHz, even though the RTL-SDR has only 2.4 MHz bandwidth. Higher quality SDRs can be used to take advantage of the extra bandwidth. For each band there is a dedicated antenna connector. The input selection is operated via an RF multiplexer. The up-conversion is performed using a double balanced mixer with 48 MHz or 72 MHz LO frequency. The direct input connects the MID antenna input directly to the RF multiplexer. The down-conversion input consists of two SMA connectors. The RF signal goes to a low noise amplifier and then to a diplexer followed by an RF switch. This stage is needed to convert the signal from DSB to SSB before going to the mixer itself. The switch can select between upper and lower band. After the mixer there is a SAW filter and another amplifier to boost the signal to the input range of the SDR frontend.

A microcontroller provides configuration and control of the board and a virtual serial port via USB for communication with a computer. The analog to digital conversion is performed by the RTL-SDR dongle which transmits raw I/Q data to the Raspberry Pi using a USB port. The GPU on the Raspberry Pi is used to perform the FFT and a custom module for GNU-Radio controls the sensing operation. The sensor node should be registered on the Electrosense network and connected to the internet to receive commands from the software controller running on the backend.

The schematic and layout of the down-converter board, the firmware of the microcontroller and the GNU-radio modules can be downloaded from GitHub [1] .

1.3 Software Components

All the data collected by the sensor nodes is transmitted via internet to a backend server which takes care of the analysis, storage and visualization through a web interface. Part of the analysis is in near real time while more complex tasks have more relaxed time constraints. All the results and the stored data can be accessed by a public REST API [2].The full software architecture is explained in [12].

2 Demo Overview

The Electrosense framework allows to perform several analysis like anomaly detection, interference detection, collaborative spectrum data decoding, localization and spectrum usage statistics [7]. The demonstration consists in showing how the sensor node can sense the WiFi bands (2.4GHz and 5GHz) and send the sensed data from the extended Electrosense sensor to the backend where a simple analysis will be performed. The presentation of the down-converter board will be the main focus of the demonstration with a full explanation of how it improves the capabilities of the simple RTL-SDR dongle and how it can be used in cooperation with the Electrosense framework.

3 References

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