Electrosense: Crowdsourcing Spectrum Monitoring

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***Abstract*—We present Electrosense: a distributed, collaborative and low-cost wireless spectrum monitoring solution which is deployed on a large scale. The proposed framework provides tools to enable and promote a crowdsourced open spectrum monitoring platform for wide area deployments. The collected spectrum data is stored and processed in the backend which can be easily retrieved by the users through an open API. The framework also allows using various signal processing algorithms deployed on the sensors as well as in the backend. These algorithms provide statistics on spectrum usage, collaborative spectrum data decoding, help in applications like anomaly detection and localization. The goal of the demo is to introduce the framework, show the infrastructure already deployed, how to join the network and demo a few built-in applications.**

I. Introduction

The vision of shared spectrum instead of dedicated fixed licenses requires much more reliable and widespread spectrum monitoring solutions to allow interference management. Spectrum interruptions should be detected and solved in a timely manner, reducing their negative impact on deployed wireless systems. Advanced algorithms for anomaly detection, source identification and spectrum usage monitoring are required. These algorithms must be combined with a large scale dataset to fulfill the wireless spectrum sharing dream.

A few spectrum monitoring solutions have been proposed in literature. For example: Microsoft Spectrum Observatory [1] allows to sensing the spectrum using expensive devices, Google spectrum [2] for measurements on TV whitespaces and IBM Horizon [3] project that proposes a generic decentralized architecture to share *IoT* (Internet-of-Things) data. Albeit several attempts, the research community has not been successful in deploying large scale spectrum monitoring infrastructure. One of the main reasons that prevents the realization of such a system is the integration of various technologies which should take into account the (a) variability and cost of the used sensors (b) large spectrum data management (c) sensor reliability and (d) security and privacy concerns. Motivated by the success of the OpenSky Network [4], which became one of the largest air traffic surveillance networks, we designed Electrosense [5]. Electrosense, that it also follows the crowdsourcing paradigm for spectrum monitoring, enables the collaborative approach among sensors like distributed spectrum data decoding [6].

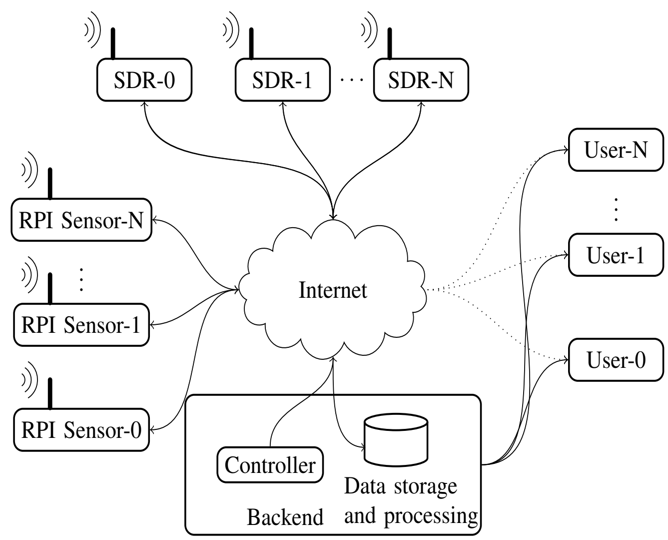

Fig. 1: Electrosense network comprising of various type of sensors.

The aforementioned issues are effectively solved by supporting:

(a) Wide area deployments through crowdsourcing.
(b) Software modules for low- and high-end sensors.
(c) Flexible big data architecture designed and tuned for spectrum data management.
(d) Secure sensor deployment via proper registration process.
(e) Privacy concerns addressed through proper data access settings.
(f) Free and Open API.
(g) Readily available and easy to use data analysis applications.

The project is mature enough with around thirty sensors already deployed and a hundred more sensors planned for deployment in the coming months. We expect more users to join the network once the framework is made public. In the following section the details of the framework are explained. Finally, an overview of the demonstration is given.

II. Demonstration Overview

The demo will showcase each part of the framework in detail and how the network scales for a large number of users along with some applications.

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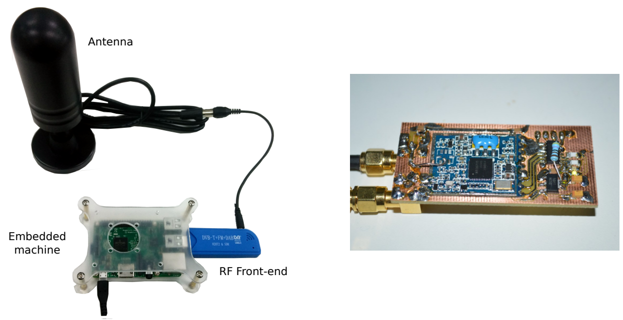

Fig. 2: [Left] Sensor based on a single-board computer (RPi) and RF front-end (RTL-SDR usb) device responsible for signal acquisition. [Right] Custom RF converter to enable spectrum scanning in 5-6GHz range.

A. Sensor hardware

The sensing nodes connected to Electrosense can range from cheap RTL-SDRs, connected to small embedded devices (as Figure 2 shows), to high end software defined radios such as the USRP. Most cheap SDR units have only a limited frequency range, for example, in case of the RTL-SDR, the maximum frequency is around 1.6GHz. To increase this, we will provide a low-cost custom RF downconverter that allows reception up to 6GHz. The software for connecting different sensors is provided by the Electrosense framework [5]. The software includes various algorithms for wideband spectrum scanning [7], signal pre-processing, frequency and time synchronization which are useful for collaborative spectrum sensing operations. Furthermore, measurements are averaged and only the squared magnitude FFT information is sent to the backend which saves bandwidth and storage and thus contributes to the cost-efficiency of the whole network.

B. Backend

Data collected by the sensors as shown in Figure 1 is forwarded to a central backend storage and processing system. Large and growing sensor deployments like these demand for scalable solutions. As such, the Electrosense backend is a state-of-the-art Big Data system built upon the Lambda Architecture [8]. This approach fulfills both analytical and real-time requirements for research purposes and describes a three-layered architecture consisting of (a) a batch layer for bulk analysis of large data sets, (b) a speed layer for enabling real-time capabilities and (c) a serving layer which handles data queries transparently. Apart from that, a controller is responsible for sensor coordination. It enables precise control of sensor signal processing algorithms and also helps to launch collaborative measurement campaigns.

C. Open API and Web frontend

Alongside with data processing it is important to provide the community with easy access to the data. An open API [9] serves this purpose for bulk or streaming data retrieval. The API also allows access to the output of algorithms running in the backend, for example the modulation classification algorithms or anomaly detector.

The web frontend features a visual waterfall display over the entire data set as shown in Figure 3. Furthermore, real-time spectrum monitoring is also possible through a streaming API in the backend or direct link from the user owned sensors.

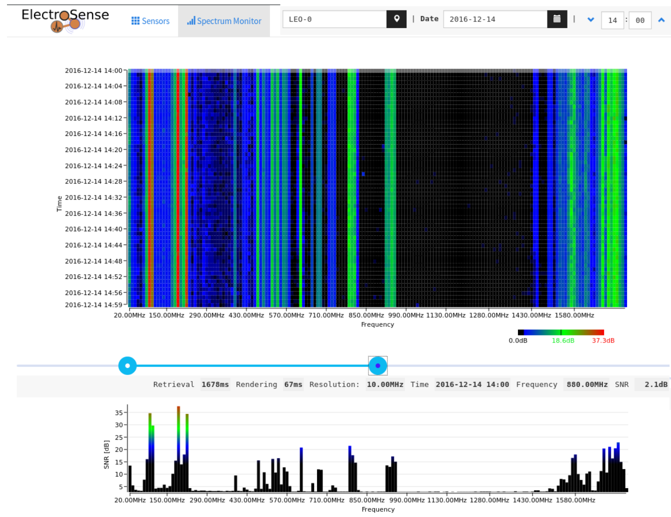

Fig. 3: Web frontend displaying waterfall plot.

D. Applications

Potential applications that can run on the electrosense framework include anomaly detection, interference detection, collaborative spectrum data decoding, localization and spectrum usage statistics. In order to showcase the full potential of the framework we select two applications for the demo.

1) Spectrum usage statistics: Spectrum usage over time, frequency and space can be easily visualized in real-time using the current framework. This part of the demo showcases the spectrum usage in Europe using the deployed sensors.

2) Technology/modulation classification: Modulation classification is one of the many ways in which anomalies in the spectrum can be detected. A modulation classifier can identify unwanted transmissions in a dedicated band. We employ state of the art deep learning based modulation classification algorithms [10] on the sensors and the backend to achieve high level of accuracy. For simplicity a simple usecase for distinguishing LoRa and Sigfox transmissions will be demonstrated.

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