# Demo Abstract: Cost-effective Crowdsensing: Spectrum Monitoring with Sitara

Phillip Smith[1], Anh Luong[2], Shamik Sarkar[1], Harsimran Singh[1],
Neal Patwari[1,3], Sneha Kasera[1], Kurt Derr[4], Samuel Ramirez[4]
[1]University of Utah, [2]Carnegie Mellon University, [3]Washington University, [4]Idaho National Labs

***Abstract*—We demonstrate the spectrum-monitoring capabilities of Sitara, a portable, compact, narrow-band software-defined radio (SDR). We developed Sitara as a platform targeting experiments in crowdsensing and general spectrum measurement. As such, Sitara fills a niche between fully-featured off-the-shelf solutions such as the USRP products and the more cost-effective but tethered options in the RTL-SDR family of devices. Sitara is capable of transmitting and receiving common waveforms or capturing raw IQ samples for further processing. A mobile application interfaces with the Sitara over Bluetooth 5 for control and receipt of measurement data during experiments. Sitara operates in standalone mode, controlled locally by a user or as a remotely-managed node, controlled by our cloud-based framework. Here we demonstrate operation of the Sitara in both these functions in a spectrum monitoring scenario.**

***Index Terms*—Mobile Systems, Spectrum Monitoring, Wireless Networks, Crowd-sourcing, Software-Defined Radio**

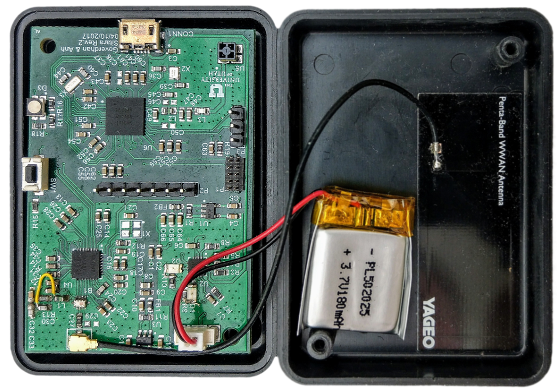

Fig. 1: Sitara SDR in an open enclosure

## I. Introduction

Experimentation in distributed, mobile sensor architectures continues to drive the development of portable, efficient, commodity-priced sensors. Our SDR, Sitara, continues this trend by offering a practical option for such research on a large scale. While many existing devices, such as the USRP and RTL-SDR, offer an assortment of capabilities, they remain less than ideal for large-scale crowd-sourced RF measurement studies [1]. A researcher may not possess the budget, or risk tolerance, to purchase and loan-out dozens of USRP E312s for such a study. Recruiting and convincing volunteers to carry around an RTL-SDR tethered to their phone for an extended period of time may prove equally challenging. An alternative to these may permit the researcher to instead carry out some limited set of experiments by controlling radios on a user's phone itself, but even in the best case, assuming firmware and software APIs permit the necessary functions, this could be disruptive to the user. We present Sitara as a solution to these sorts of challenges.

Initially envisioned as a testbed for research focusing on crowd-sourced spectrum sensing and monitoring, our SDR possesses utility beyond this specific application; Sitara's capabilities also make it suitable for sensor network architecture development or environmental propagation and channel modeling. Sitara can be a valuable tool for generating large quantities of distributed real-world RF measurements. Inherent in the crowd-sourced aspect of the design is the incorporation of user mobility information–an important feature in many related applications. In this demonstration we show how Sitara's strengths deliver an effective testbed for crowd-sourced spectrum measurements.

## II. System Description

*Sitara SDR*: Sitara comprises a low-power RF transceiver (TI CC1200), serving as the radio, paired with a Bluetooth 5 SoC (Nordic Semiconductor nRF52840) for command and control and data transport. The SoC firmware controls the CC1200 through a SPI interface while providing a communication channel to a paired mobile gateway (e.g., cellular phone) over Bluetooth. In its current implementation, a connection to a central Bluetooth device is required for operation. Key features that distinguish Sitara from other SDR offerings include its compact form factor, long battery life and cost.

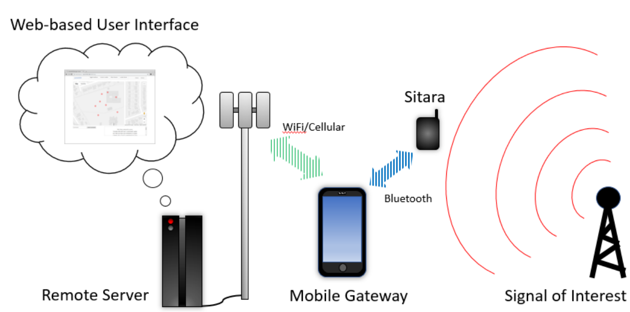


Fig. 2: Typical system deployment for remote operation

*Mobile Gateway*: The gateway runs our Crowdsourcer mobile application to manage the Bluetooth connection with the phone and provide geographic coordinates during measurements. These commands are generated through direct user input on the mobile gateway (in the case of local operation) or sent through a wireless backhaul (in the case of remote operation). During remote operation, the Crowdsourcer application runs as a background service, requiring no input from the participant while processing incoming server commands from the server.

While no dedicated mobile application was developed for local operation, any application compatible with the appropriate Bluetooth Uart service can communicate with the Sitara. One such application is the Nordic Semiconductor nRF Uart application.

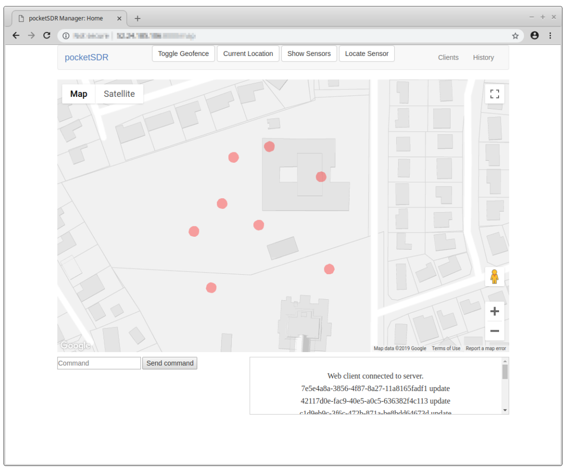


Fig. 3: Server homepage showing user interface and locations of participating Sitara sensor nodes

*Remote Server*: For remote operation, depicted in Fig 2, a cloud-based server maintains a connection with each Sitara via the mobile gateway using a network socket over WiFi or cellular service. The server hosts a web-based GUI to display Sitara node location, status and provide a user interface for issuing commands. The backend consists of a Gunicorn server running a Flask application paired with a database for processing and storage of received measurement data. This design provides a convenient interface to manage experiments in real-time and lends itself to adaptation with changing user needs. For example, a complex experimental interaction between a set of nodes can be quickly added as a python function by leveraging the existing framework. Additionally, further processing or localization algorithms can also easily be added as a backend function which operates on live or previously recorded measurements.

Additional implementation and design details can be found in our accompanying paper in this conference and our GitHub repository [2]

## III. Demonstration

We will present the Sitara SDR with its optional control framework and discuss some of its capabilities and operational concept. Additionally, we present two use-case scenarios which demonstrate how Sitara can be address real-world problems.

### A. Transmitter Localization

Here we present a hypothetical scenario in which Sitara nodes are deployed to locate a malicious actor carrying out unauthorized transmissions (i.e., a spectrum offender). For our purposes, and so as not to become ourselves a spectrum offender, we will configure a Sitara to transmit in the ISM band between 902 to 928 MHz. Other Sitaras will serve as participating "crowdsensors" to locate the offender in coordination with others.

We will first use the server side user interface to command the participant nodes to locate the offender. We will then demonstrate how the same, with more effort on the part of the participant(s), can be accomplished using the local user mode.

During remote management, the server (researcher) issues commands which request participant node locations paired with RSSI measurements at the target frequency. With three or more participants–or fewer participants but repeated measurements–transmitter localization is possible. During operation, the server displays sensor locations on a map overlay. Additionally, the server can generate a map with recorded RSSI measurements filtered by sensor and timestamp. A researcher may also configure a script to run a localization algorithm on the same set of data to generate a transmitter location estimate.

### B. Spectrum Monitoring

In addition to transmitter localization for an observed signal, this system can also perform spectrum monitoring to alert authorities of a detected out-of-band, unauthorized transmission. We will demonstrate this capability by configuring participant nodes to receive on different bands and provide information to the server when RF activity is detected in the target bands.

Depending on the desired outcome and importance of the spectrum in question, varying spectrum monitoring schemes can be deployed which balance the cost of resources such as sensor battery life, quantity and node availability with detection latency and accuracy for different types of signals. For example, a single, continuous, high-powered transmitter may be detected (and localized) in a relatively short period of time with few resources. However, a frequency-hopping, mobile transmitter may require a coordinated effort with cooperative scanning among many nodes to locate the source of such a transmission. While the latter scenario may be possible on our system, we present a simpler user case.

## Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. 1564287.

## References

[1] Ettus Research. *Getting Started with the Ettus Research USRP E312 SDR*, March 2016. Rev 1.
[2] SPAN lab. Sitara. https://github.com/SPAN-WashU, 2019.