sciendo International Conference KNOWLEDGE-BASED ORGANIZATION
Vol. XXVIII No 3 2022

WEB SOLUTIONS FOR REMOTE CONTROL AND VISUALIZATION OF THE ELECTROMAGNETIC SPECTRUM PROVIDED BY SENSORS BASED ON SDR

Mirela ȘORECĂU*, Emil ȘORECĂU*, Annamaria SÂRBU, Paul BECHET****

***Technical University of Cluj-Napoca, Romania**
****"Nicolae Bălcescu" Land Forces Academy, Sibiu, Romania**
mirela.doicin@gmail.com

Abstract: *In this article, we present the implementation of a Software Defined Radio (SDR) remote sensor management solution for electromagnetic spectrum monitoring using web interfaces. The proposed sensor is developed on an SDR platform - USRP-2932 with LTE standard specific signal monitoring capabilities. Two solutions have been implemented for remote control and visualization of the sensor parameters: by using VNC (Virtual Network Computing) software for full remote access and by implementing in GNU Radio the Bokeh python library, which allows visualization of graphs and charts directly through a web GUI. For accessing the sensor via the backbone network of an Internet Service Provider (ISP), in both cases a Virtual Private Network (VPN) was set up using the Point-to-Point Tunnelling Protocol (PPTP) solution.*

Keywords: SDR, LTE, VPN, electromagnetic field monitoring, remote access

1. Introduction

The deployment of sensors in areas such as healthcare, national defense, industry, infrastructure, smart homes has seen impressive growth recently. In mobile communications, the design and deployment of sensors with real-time electromagnetic spectrum monitoring capabilities brings many benefits, such as: determining interference and intrusions, determining spectrum occupancy, identifying unauthorized emissions, monitoring emissions for possible spectrum sharing, monitoring mobile coverage. Monitoring data should be statistically analyzed by implementing supporting applications so that, by exploiting present and past information, judicious and intelligent resource allocation planning can be achieved [1]. To achieve all these goals, the National Telecommunications and Information Agency (NTIA) pilot program proposes that spectrum monitoring should be conducted on a permanent basis [2].

In recent years, there has been a growing concern to replace high-volume, high-cost measurement equipment with devices based on open-source software and applications [3] that meet the following performance criteria: small size, low cost, high bandwidth, commercial off-the-shelf (COTS) hardware; flexibility [4], with the possibility of remote control. Such a solution requires the implementation of a flexible real-time monitoring network composed of software-defined sensors [5]. Software-defined radio platforms are efficient solutions for implementing spectrum monitoring algorithms. A popular platform compatible with the GNU Radio programming environment is the Universal Software Radio Peripheral (USRP)

DOI: 10.2478/kbo-2022-0093
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platform [6].

Although there are many initiatives to build such monitoring networks using SDR sensors [7, 8, 9], very few address the possibility of remote control of them, especially for sensors that have implemented supporting applications in the GNU Radio programming environment [10]. A flexible way to achieve remote access to the monitoring system using the Internet can be implemented by establishing a VPN connection. Virtual Private Network allows remote access through secure and encrypted connections between a private network and different users via a service provider [11]. Various remote-control applications such as VNC can be used to control the sensor. This management tool provides intuitive operation and compatibility between different operating systems [12]. The present work is in line with these concerns to implement a solution for remote access and control of spectrum monitoring sensors via server-client applications and VPN connections.

2. Materials and Methods

The proposed LTE channel-specific monitoring sensor includes: a USRP-2932 SDR platform connected to the OmniLOG 70600 antenna and the software application in GNU Radio environment running on a Rapberry Pi 4 minicomputer. Data display was achieved using a 7-inch touch screen

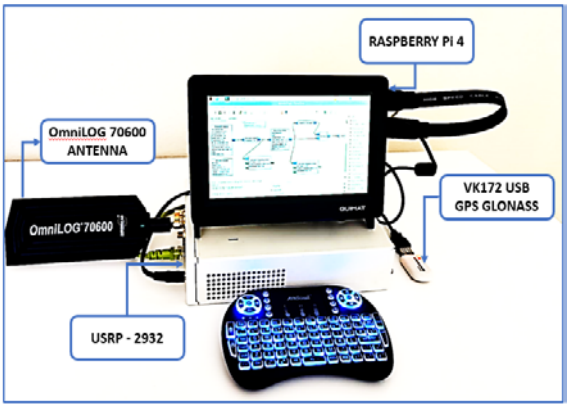
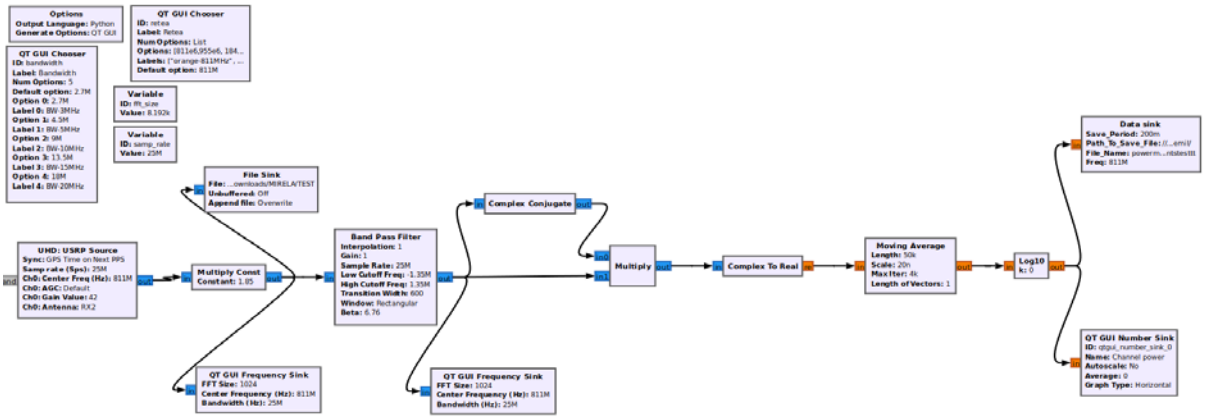


Figure 1: LTE monitoring sensor components

connected directly to the Raspberry Pi 4. The platform chosen for implementation, the USRP-2932, is a high-performance SDR with real-time wideband channels measurement capabilities, characterized by: instantaneous acquisition frequency band up to 40 MHz, 14-bit analog-to-digital converter resolution, noise Figure: 5 dB - 7 dB, acquisition cost of about 6200 $. The sensor components are shown in Figure 1.

As for the application running on the SDR sensor, it has been implemented in the free and open-source programming environment, GNU Radio Companion. The application includes both blocks from the default GNU Radio library and signal processing blocks created to handle additional functions. The application uses the Python programming language, and the connections between the blocks that perform signal processing are implemented



in the C++ programming language.

Figure 2: GNU Radio flowgraph for LTE monitoring

The link for remote Internet connection between the management computer and the sensor was achieved in both test situations by creating a virtual private network using the public internet provided by a service provider. To connect the sensor to the internet, a Wi-Fi 6 router was chosen to ensure the best possible transfer rate and offering high security and performance VPN capabilities.

A VPN is an IP-based tool that relies on encryption algorithms and tunneling protocols, and the entire connection can be viewed as a secure conduit that carries encapsulated data over a public network [13], e.g., the internet. The router we chose offers two options for establishing a VPN connection: OpenVPN and PPTP (Point to Point Tunneling Protocol) VPN. In our tests we set up PPTP VPN because it's much faster, compatible with the majority of operating systems and supports mobile devices. For the server setup, we set a pool of IP addresses to be leased by the server and a user with a strong password that users will need to enter when they want to connect to it.

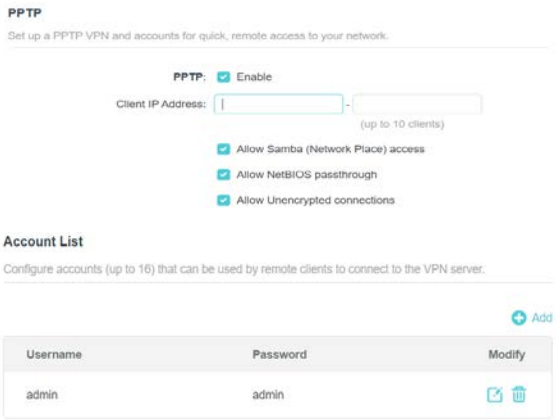


Figure 3: PPTP VPN server configuration

To connect the management laptop to the VPN server we had to set up a new VPN connection where we entered the public IP of the router provided by the ISP and then the user and password conFigured on the server.

Once the VPN connection has been made, the management computer and the sensors we are accessing act as they are connected to the same LAN. But to control the sensor from another PC we need a new software implementation. The VNC software solution was chosen for this. It is a desktop sharing software that uses the Remote Frame Buffer (RFB) protocol [14] for remote control.

VNC applications use a client-server model: a server installed on the device we connect to and a client running on the management devices. The RealVNC server comes pre-installed with some Raspberry Pi operating system. It is very reliable, convenient and secure. On the management computer we would normally install a VNC client and access the server with it. But in our case, we want to be able to access the sensor from a web interface. For this we installed on the Raspberry Pi noVNC, a web server application working next to VNC server. Both have been conFigured to start automatically when the operating system boots. With this configuration we can remotely access the sensor by entering in the internet browser only the IP and port conFigured on the server (Figure 4).



Figure 4: Web connection to the VNC server

Another implemented method to access the remote monitoring sensor from a web interface that allows to view and modify GNU Radio application parameters is provided by the gr-bokehgui module. This module was first developed by Kartik Patel [15]. After installing it in GNU Radio we have access to various sinks and widgets to allow interaction with applications running in GNU Radio via web interfaces using the python Bokeh library. This solution also involves making a VPN connection for access over public internet.

3. Results and Discussions

The first method of sensor control using VNC, gives us the possibility to have full control over the Raspberry Pi and implicitly the possibility to develop and run applications in GNU Radio or other applications for radio spectrum monitoring.

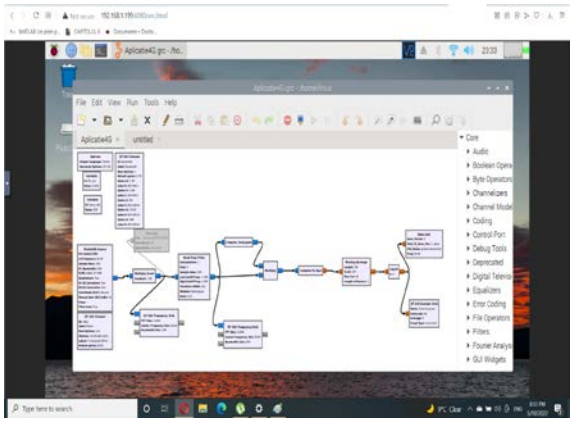


Figure 5: Remote control of Raspberry Pi using VNC

Figure 6 shows the spectrum in the frequency domain and a filtered LTE channel to which we measured the power on a given center frequency that can be remotely changed. Another parameter that can be changed remotely is the bandwidth (for the LTE standard we have the possibility to choose different bandwidths: 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz).

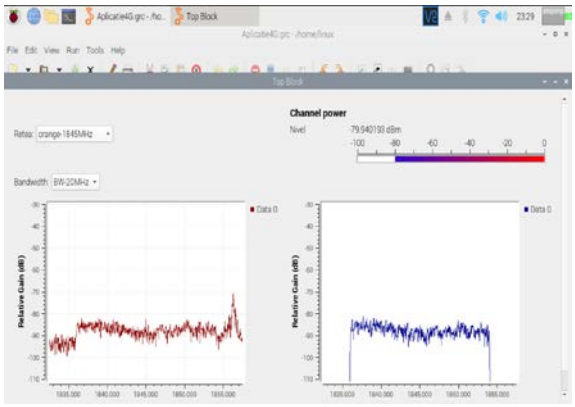


Figure 6: Spectrum visualization and SDR parameters control using VNC

When we choose to use remote-control, the person accessing the sensor after authentication can also make various changes to the block configuration, add or delete certain blocks or configurations.

The second method tested was using gr-bokehgui. To use this library, it is necessary after installation to replace and conFigure in GNU Radio all QT GUI Sinks and variables with the new Bokeh GUI Sink and widgets blocks (Figure 7). This method no longer requires the installation of VNC and noVNC applications. When running an application conFigured with Bokeh GUI in GNU Radio, it will automatically start the Bokeh server and the command prompt will display the port and IP with which it can be accessed from the web browser (Figure 8).

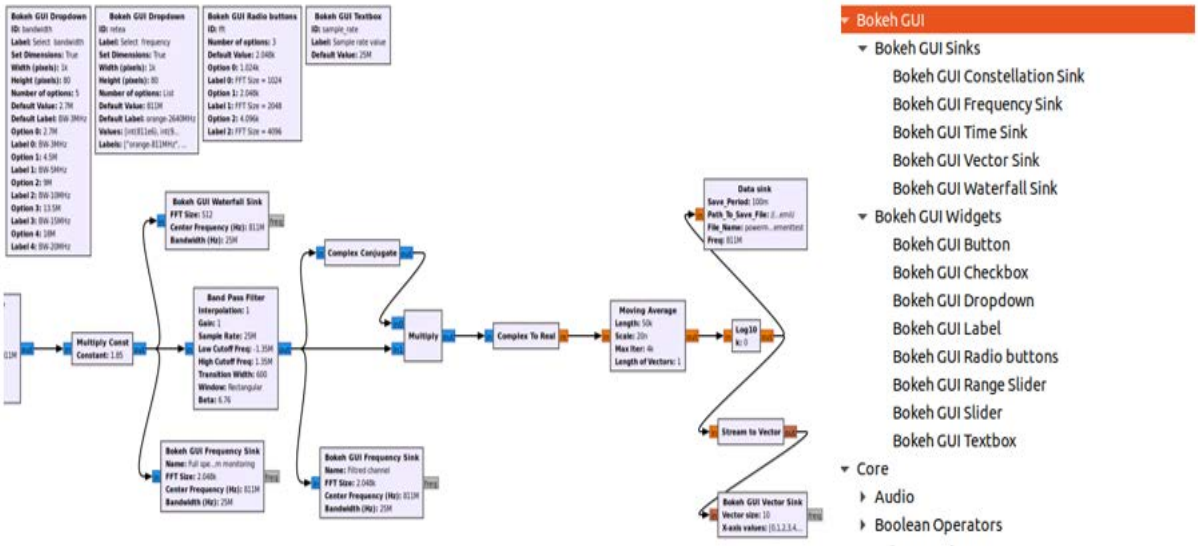


Figure 7: GNU Radio configuration using Bokeh GUI Sinks and Widgets blocks

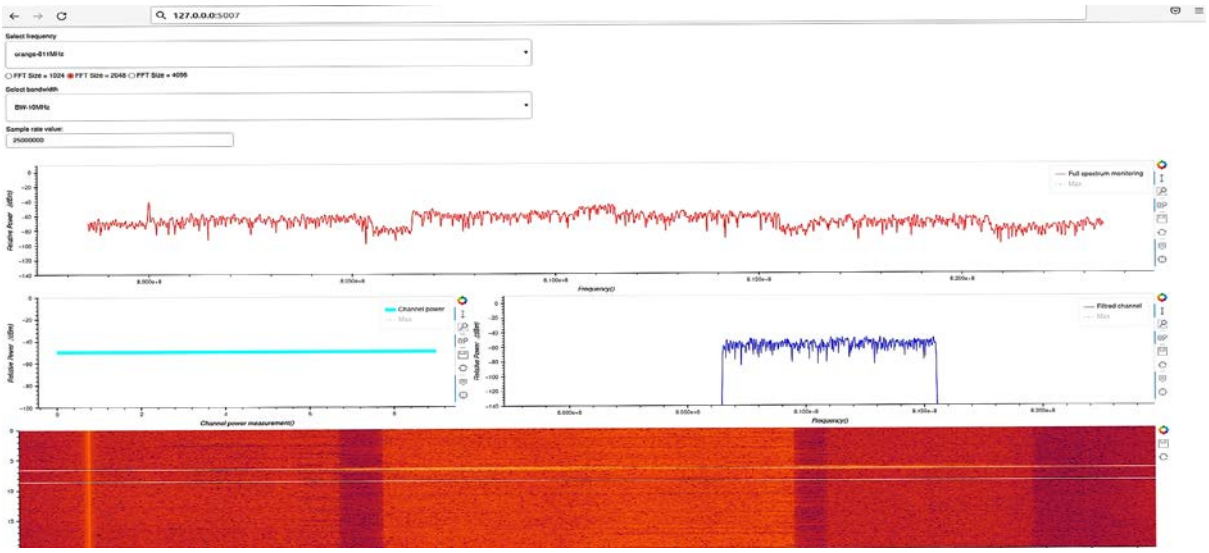


Figure 8: Spectrum visualization and SDR parameters control using gr-bokehgui installed on GNU Radio

Using this method you can limit access to the sensor, and those accessing it can only view and modify parameters in GNU Radio that have been conFigured with the Bokeh GUI.

In terms of security, the first method is more secure because it uses double authentication (VPN and VNC) and allows the sensor manager to have full control over the sensors.

The second method is secured only by VPN, but is easier to use when we want to give access to more users with limited access only to the data processed in GNU Radio. Both solutions depend on the internet connection and its speed in the installation locations. When other services were used at the same time, latency and image freezing was observed in sensor control.

4. Conclusions

The present work aimed to implement web-based remote-control solutions for sensors designed for electromagnetic spectrum monitoring. The sensor proposed in the paper is in line with the current trends of replacing high-performance, high-cost equipment with scalable and flexible devices.

The implementation of a solution for remote-control of monitoring sensors is particularly necessary when we talk about their deployment in hard-to-reach areas or in remote locations.

In the context of the further development of a wireless sensor network for electromagnetic spectrum monitoring, remote management is necessary. This is the most efficient way to deal with various sensor errors that may occur due to hardware or security (unauthorised access).

Thus, the study focused on the implementation of two ways of implementing remote management: one involving exclusively remote control, which is mainly required by the administrator, and a second, more flexible solution, which is mainly suitable for users interested in the field of electromagnetic spectrum monitoring. This method can easily be implemented when the administrator does not want certain users to modify the application flowgraph, but only to view the information and modify some parameters conFigured via the Bokeh graphic interface.

Acknowledgment

This work was supported by a grant of the Romanian Ministry of Education and Research, CNCS - UEFISCDI, project number PN-III-P1-1.1-PD-2019-0500, within PNCDI III.

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