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Developing an Open-Source, Low-Cost, Radon Monitoring System †

Alberto Alvarellos * and Juan Ramón Rabuñal

RNASA-IMEDIR, Computer Science Faculty, University of A Coruna, 15071 A Coruña, Spain; juan.rabunal@udc.es
* Correspondence: alberto.alvarellos@udc.es
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Abstract: The United States Environmental Protection Agency (USEPA) and the International Agency for Research on Cancer (IARC) have declared Radon gas a human carcinogen. Spain has several regions with high radon concentrations, Galicia (northwestern Spain) being one with the highest Radon concentration. In this work, we present the development of an open-source and low-cost radon monitoring and alert system. The system has two parts: devices and the backend. The devices integrate a Radon sensor, capable of measuring Radon levels every 10 min, and several environmental sensors capable of measuring temperature, humidity, atmospheric pressure, and air pollution. The devices send all the information to the backend, which stores it, exposes it in a web interface, and uses the historical data to predict the radon levels for the following hours. If the radon levels are predicted to overpass the threshold in the next hour, the system issues an alert via several channels (email and MQTT) to the configured recipients for the corresponding device, allowing them to take measures to lower the Radon concentration. The results of this work indicate that the system allows the radon levels to be greatly reduced and makes the development of a low cost and open-source radon monitoring system feasible. The system scalability allows a network of sensors to be created that can help mitigate the health hazard that high radon concentrations create.

Keywords: radon monitoring; IoT; radon alert system; open source; Arduino; Node-RED; open-source

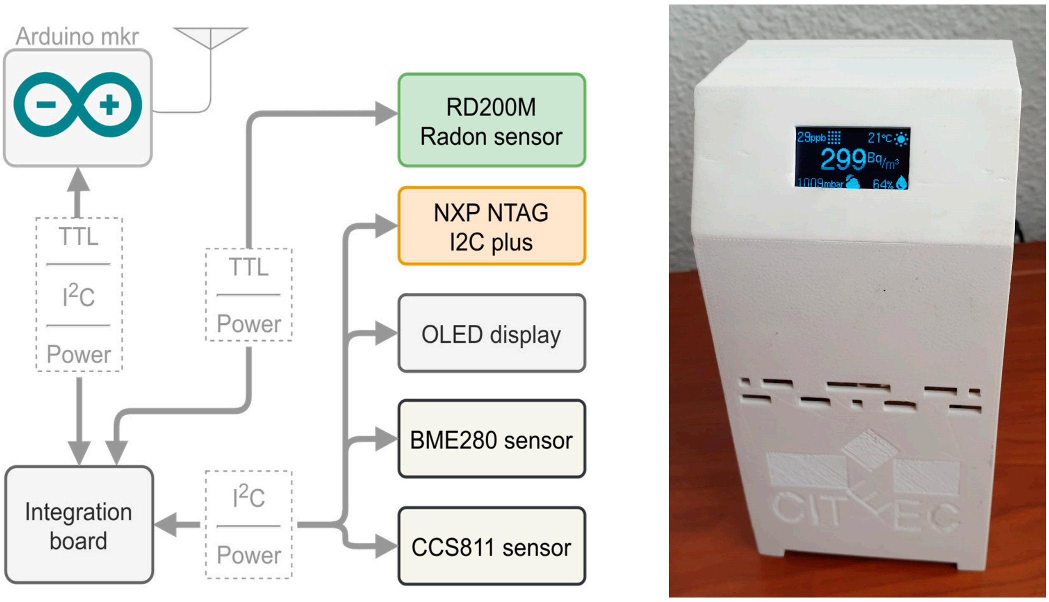
1. Introduction

Radon gas levels are generally high in Spain, and more so in Galicia, caused by its strong links to granite geology, granite being the principal source of radon emissions [1,2]. Several studies carried out in the 1980s highlighted these high radon concentrations [3].

The European Union (EU) has indicated in its guidelines (E2013/59/EURATOM [4]) that annual average radon levels in homes and worksites should not exceed 300 Bq/m^3. These guidelines also indicate the need for member states to include in their Technical Building Codes information regarding radon detection and mitigation. Using a system that can measure radon levels and help mitigate high values, or even better, avoid future high radon levels via predictions, could meet these requirements. In this work, we present the development of the said system. It comprises several monitoring devices and a backend that stores the data, predicts radon levels, and issues alerts.

2. Monitoring Devices

In this work, we design and develop the monitoring devices. They use an RD200M sensor for measuring Radon levels, a BME280 sensor for measuring relative humidity, barometric pressure and ambient temperature, and a CCS811 gas sensor for monitoring indoor air quality. All these data (radon concentration, temperature, humidity, barometric pressure, and air quality) are collected and processed by a processing unit based on the Arduino MKR family (with an ARM Cortex-M0+ CPU). Figure 1a shows the schema of the devices. To integrate all the sensors and the devices' processing unit, we designed an electronic integration board and a 3D printed case (see Figure 1b). The processing unit samples each sensor, processes the data, shows it in a display, and sends it to the backend every 10 min (a sampling period recommended by the radon sensor manufacturer to obtain correct measures). The devices send the data using two different communication technologies: WiFi and Sigfox. We use the WiFi devices in locations where a WiFi network is available, and the Sigfox devices when WiFi is not available.

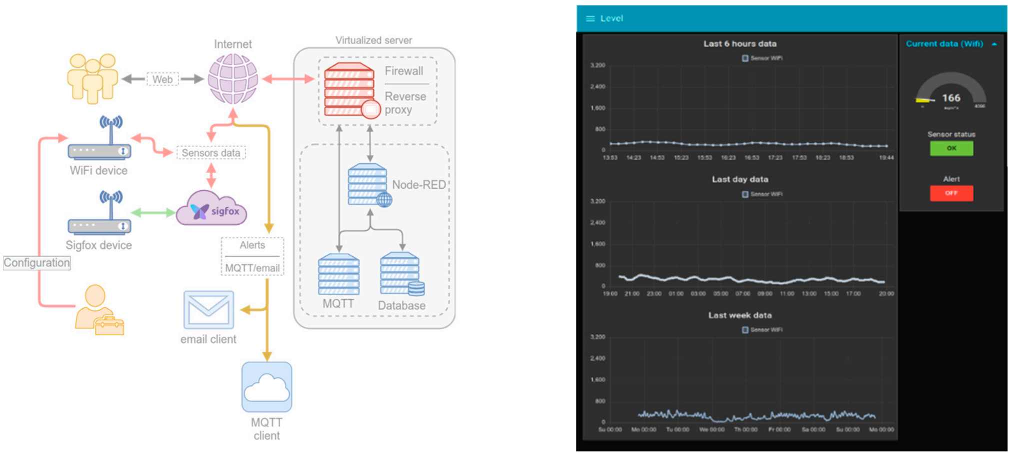


(**a**) (**b**)

Figure 1. (**a**) Monitoring devices sketch. (**b**) Final device assembled in a 3D-printed enclosure.

3. System Architecture

The backend stores the data sent by the devices, it exposes it in a web interface, and predicts the radon level for the next hours, for each device, using its historical data (see Figure 2). If the backend predicts a high radon level for a given device, it sends an MQTT message to an MQTT topic associated with the device, and an email to the addresses registered for the device.



(**a**) (**b**)

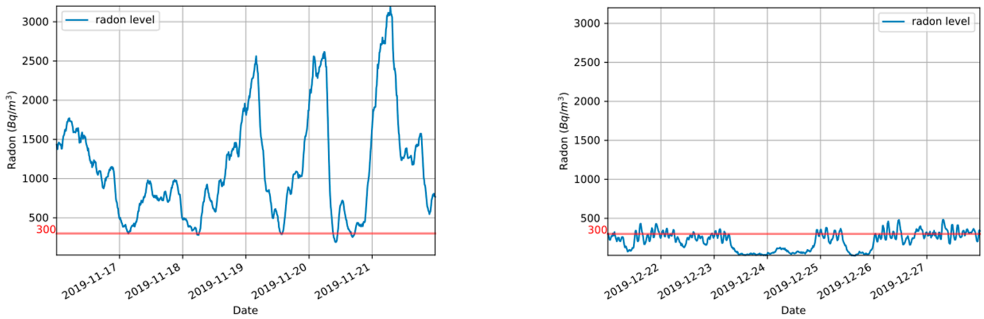
Figure 2. (**a**) Architecture of the radon detection and alert system. (**b**) System's web interface.

Once the radon concentration level is below the threshold, the backend sends a message indicating that levels are back to normal (also via MQTT and email). Currently, the system uses the threshold that E2013/59/EURATOM establishes for issuing the alerts (300 Bq/m^3), although it can be configured per device.

4. Results

We tested the system in a laboratory with naturally high radon levels in two scenarios. In the first scenario (Figure 3a), the alert system was not activated, showing the natural radon level of the testing site. In the second scenario (Figure 3b), the alert system was activated, and a human operator turned an airflow control system on or off with each alert/"back to normal" message.

Comparing these two scenarios, we can see that the system can satisfactorily be used to significantly lower the radon levels.



(**a**) (**b**)

Figure 3. radon levels for the same location: (**a**) alert system deactivated, (**b**) alert system activated, and airflow control system operated by a human.

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Conflicts of Interest: The authors declare no conflict of interest.

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