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Research Article

# Design and Implementation of a Novel IoT Carbon Monoxide Detection System Using IP-based WiFi Location

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**Abstract.** Throughout the world and more particularly in Algeria, Carbon Monoxide (CO) poisoning is one of leading cause of death and taking worrying proportions. Colorless, odorless, non-irritating, this silent killer is responsible for more than 100 deaths each year, for several thousand hospitalizations, especially during the winter period when the cold sets in and the demand for heating homes increases. However, the protection of human lives becomes a top priority and consequently the CO leak location will have to be done as quickly as possible to provide first aid in record time. In this paper we present the design, development and a case of use of a novel Internet-of-Things (IoT) carbon monoxide detection system using IP-based WiFi location. Once the CO leak occurs, a notification alert message is sent to civil defense containing the detected CO amount and the public IP address used to extract the real location address of the CO leak by sending a request to a database provided by an internet service provider and therefore provide the necessary assistance in a timely manner by contacting the nearest unit.

**Keywords.** WiFi location; Carbon monoxide; Wemos D1; Internet of Things; Civil protection

**Mathematics Subject Classification (2020).** 68M10; 68M11; 68M15



## 1. Introduction

The increase in deaths caused by carbon monoxide throughout the world [19, 25, 29], and more particularly in Algeria, is taking worrying proportions. In recent years, hundreds or even thousands of people have died, some of them members of the same family. These deaths are

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usually attributed to water heaters, stoves, ovens, clothes dryers, charcoal grills, generators, power tools, gas and wood fire burners, wood stoves, furnaces, etc. [6].

Carbon monoxide is readily absorbed through the lungs. The quantity absorbed depends on the concentration of CO in the inspired air, the alveolar ventilation and the duration of the exposure [20]. Exposure to a high concentration for a short period of time is less of a consequence than exposure to a lower concentration but for a long period of time. Once absorbed, CO diffuses through the alveolar-capillary membrane and dissolves in plasma [30]. It undergoes only a very slight metamobilization (less than 1% of the CO is oxidized to $CO_2$). It binds to the hemoglobin of red blood cells to form carboxyhemoglobin, a form that is non-functional for oxygen transport. CO has about 250 times more affinity for hemoglobin than does oxygen [15]. The endogenous metabolism of certain xenobiotics can also lead to the production of endogenous CO: methylene chloride, dibromomethane, diiodomethane and bromochloromethane. The elimination of CO takes place mainly by the pulmonary route in unchanged form and the rate of CO elimination is directly related to the partial pressure of oxygen in the inspired air [17], [22].

During winter when carbon monoxide emissions from heaters increase incredibly, Algerian news is dominated almost daily by dramatic news related to often fatal incidents due to asphyxiation by this gas. In recent years, in fact, the very cold season in Algeria has been synonymous with death by this odorless and very dangerous gas. The reports point to a real massacre and the figures refuse to go back despite large and insistent awareness campaigns. In 2016, carbon monoxide killed 117 people. According to a civil protection report, which covers the period from January 1 to December 31, 2016, 1300 people were rescued after being inconvenienced or poisoned by carbon monoxide from heating devices. In 2017, the civil protection services recorded 128 deaths and 2400 interventions that saved 2928 people. During the period from January 1 to December 31, 2019, 145 deaths were recorded nationally in Algeria by asphyxiation with carbon monoxide emanating from heating appliances, compared to 131 deaths recorded in 2018.

It is undeniably a threat to the lives of Algerians whose magnitude and dangerousness should be reconsidered. The targeting of "Taiwan" heaters and the measures taken to ban them from the market, as well as the outreach effort, appear to be ineffective given the results. The design of house interiors should also be subject to strict rules and downstream control. The causes are also due to non-compliance with equipment installation standards, and to ventilation conditions that are not always correct. The majority of Algerian households never resort to an annual check of their installations. Incorrect installation of devices, as well as the lack of monitoring of the condition of the technical ducts only increases the risk of domestic accidents. Most of the time, users underestimate the risk of carbon monoxide poisoning and, through unconsciousness and ignorance, do not respect the installation and operating conditions of the devices. The main circumstances of carbon monoxide poisoning are related to heating appliances that are improperly used, poorly maintained and improperly installed. The prevention of poisoning is best achieved through regular maintenance and inspection of combustion appliances, proper ventilation of the premises and the proper use of space heaters. New natural gas appliances must have the CE mark and, for certain high-end cooking appliances, the NF GAZ Selection mark.

Carbon monoxide has established itself as one of the leading causes of death in Algeria. It thus becomes the duty to examine this phenomenon and to plan responses commensurate with the threat. To do this, we thought of designing and producing a prototype based on the Internet of Things to detect carbon monoxide and then locate it via WiFi. The growth of the Internet of Things means that we are at the start of a new era of data [2]. The two main components of an "IoT object" are its ability to collect data through sensors and transmit it over the Internet. The reduction in the price of sensors since the turn of the new millennium has been a major driver of the rise in IoT. In short, sensors are cheap today. Currently, the notion of the Internet of Things is exploding as the existence of smart objects makes it easier for us to achieve our goals in everyday life. Thus, the fields of application of the IoT are multiple; we cite for example transport [5], healthcare [1], connected homes [31], smart machines [27], smart cities [10], commerce, industry, public safety [18], etc.

The rest of the paper is organized as follows: related work will be presented in Section 2. In Section 3, a description of the software and hardware implementation of the proposed solution to fight against carbon monoxide has been discussed. Lastly, Section 4 concludes this paper and presents suggesting future research opportunities in this field.

## 2. Related Work

Following carbon monoxide (CO) poisoning from natural gas water heaters is a common household accident in Taiwan, Chen *et al*. [4] proposed a wireless and battery-less smart CO sensor to improve the operational safety of natural gas water heaters to alert users and their family members inside and outside their homes when the level of carbon monoxide reaches a dangerous level.

In the context of the fight against air pollution in the Philippines, which is a serious problem especially for city dwellers, Caya *et al*. [3] designed a system combining two types of sensors: an MQ-7 gas sensor and a dust sensor. The Raspberry Pi-based system detects air pollution and fine particles and sends an email notification to a monitoring center. Our health can deteriorate when the air quality is poor or a smog warning (presence in the air of a yellowish haze made up of gases and particles) is in effect. The effects of air pollution vary depending on how sensitive a person is. Saha *et al*. [23] deal with how to prevent to prevent air pollution and noise pollution. For this, they use some sensors to detect air pressure, temperature, Ultra Violet radiation, Air quality, Smoke, Nitrogen Dioxide in air and Carbon Monoxide in air, noise level etc.

The city of tomorrow will be connected and smart. This is the promise that a majority of metropolises around the world have been embracing for some time. Beyond the vision of a simple connected and technological city bewitched by "data", it was necessary to have tools and support systems to promote a more sustainable definition of the city of tomorrow, integrating environmental requirements and preservation of air quality. Among the air pollutants is carbon monoxide. In this context, Parachuri *et al*. [16] present a survey of methods to measure the emission of carbon monoxide in the air using a network of wireless sensors. Authors in [24] design an air quality monitoring system from a Smartphone connected to ESP8266 module. The air quality is checked in real time and each change will be reported on the Smartphone.

Estrada *et al*. [7] design and manufacture a system for the detection of carbon monoxide if the amount of CO exceeds a threshold of 25 particles per million. The system consists of an ESP8266 board, an MQ7 gas sensor, and a loudspeaker. The display of the amount of carbon monoxide on his Smartphone is done by the Blynk application. The Internet of Things refers to the exchange of digital information and data between objects in the real world and the Internet. IoT collects user data to interact between connected objects generally via WiFi or Bluetooth. Miles *et al*. [11] have exploited the advantages of this technology to alert civil protection services in the event of carbon monoxide detection. The proposed solution is based on the Publish-subscribe mechanism and communication is provided by the MQTT communication protocol.

Monitoring the carbon dioxide environment is a major concern for the majority of countries and global environmental organizations. In this context, Ming *et al*. [12] provide a solution to monitor the environment for the effects of carbon dioxide by making the most of Internet of Things and cloud computing technologies. This solution allows generating, accumulating, storing and visualizing the concentration of carbon dioxide using the MQ135 carbon dioxide sensor, the ESP8266 WiFi module, the Firebase cloud storage service and the Android Carbon Insight mobile app for data visualization.

Carbon monoxide is a poisonous gas produced by any incomplete combustion (by lack of oxygen) of a carbon compound. These fuels are most often: fuel oil, coal, and derivatives of natural gas, gasoline, wood or synthetic products such as plastic. It is a serious, life-threatening poisoning. Securing people against carbon monoxide is of the utmost importance because everyone is at risk of being poisoned by this gas. Nandi *et al*. [14] discuss the design and implementation of an effective real-time carbon monoxide detection and control system for living environments such as air-conditioned rooms, factory spaces and automobiles using integrated intelligent control mechanisms.

With the increase in the number of vehicles in Indonesia, fumes from vehicles are also increasing and polluting the environment because they produce carbon monoxide (CO), sulfur dioxide (SO2) and other substances. Rival *et al*. [21] have developed an air pollution monitoring system based on Internet of Things (IoT) technology, in particular for CO and SO2 gases using the electrochemical gas sensors CO-B4 and SO2-BF, the ESP8266 Node MCU development board, and the Blynk application on Smartphone.

Carbon monoxide is the cause of extremely common, sometimes fatal, household poisonings. The macabre balance that carbon monoxide makes during the winter season is often due to the use of heating devices and bathroom heaters without the slightest precaution of use or installation in accordance with current safety standards. To face this deadly scourge, Irid *et al*. [9] designed and produced a prototype firstly to detect carbon monoxide-related leaks, and secondly to provide possible solutions. These solutions allow a ventilation system to be activated first to ventilate the area where the leak occurs, and then to notify the civil protection services by sending them alerts in the form of notifications.

The prototype remains useful even for households without Internet; that is to say, it is content only to ventilate the place of the leak. The prototype produced is made up of a Wemos D1 mini type card, to which a gas sensor is connected. The Wemos card is a prototyping card that includes an ESP8266 module that allows you to connect to the Internet in order to alert the authorities concerned. The work carried out in this paper is an extension of the work done by Irid *et al*. [9]. The authors were content only to capture the amount of carbon monoxide and then send it to an IoT server as a notification. The question that can be asked is the following: What is the point of receiving a message whose source cannot be located?

## 3. Proposed Prototype

Throughout the world and more particularly in Algeria, one of the leading cause of death from accidental poisoning is carbon monoxide. This colorless and odorless gas with the chemical formula CO, appears in the environment as soon as combustion is incomplete, and is accentuated by a poor supply of fresh air or poor evacuation of combustion products (ventilation). This gas is virtually undetectable by humans. It is therefore necessary to have a carbon monoxide detector.

It thus becomes the duty to look into this phenomenon and to plan responses commensurate with the threat. This article aims to design an Internet of Things-based prototype to locate the carbon monoxide leak after it is detected and sent to a monitoring center.

Realizing a carbon monoxide detection system seems an easy thing to do, especially with the presence on the market of gas sensors and microcontroller-based boards such as Arduino boards and their derivatives. With the advent of the Internet of Things, each quantity captured or measured can be saved at any time at a remote site for possible or future processing. Locating the information coming from an IoT system does not pose any problem if the system is deployed in an outdoor environment thanks to a GPS module connected to the system that provides us with the coordinates in terms of longitude and latitude. On the contrary, location becomes difficult if the IoT system is placed in an indoor environment such as our system placed near heaters, because the use of a GPS module becomes inefficient.

To solve this problem, we thought of detecting carbon monoxide and then locating it using the WiFi protocol. The location is based on the public IP address of the access point used for sending the notification. This public IP address associated with the alert message is sent to a monitoring center (civil protection). It will later be useful for extracting the real address of the leak location by querying a database provided by an Internet service provider as shown in Figure 1. Once the address is obtained, the civil protection officer contacts the nearest unit to leak site to provide the necessary assistance in a timely manner.

In order to realize our prototype dedicated to the detection and sending of carbon monoxide, we chose a WeMos D1 mini card and a gas sensor. MQ sensors are physicochemical sensors that detect a wide variety of gases, pollutants and fumes in the atmosphere. In our setup, we used the MQ-2 sensor for availability reasons. The MQ-2 is a sensor that detects gas or smoke at concentrations from 300 ppm to 10,000 ppm. The unit ppm stands for parts per million.

After calibration, the MQ-2 can detect different gases such as LPG (LPG), i-butane, propane, methane, alcohol, hydrogen as well as fumes. It is designed for indoor use at room temperature. This is the only versatile detector; the others specialize in one or two molecules. Connecting the MQ-2 sensor consists of connecting the Vcc and GND pins of the sensor to the 5V power supply and to the ground of the WeMos D1 Mini. The analog output of the A0 sensor should not be connected directly to the A0 pin of the WeMos D1 Mini, as the latter does not tolerate more than 3.2V as the input voltage for the A0 pin. To do this, we have to use a voltage divider that

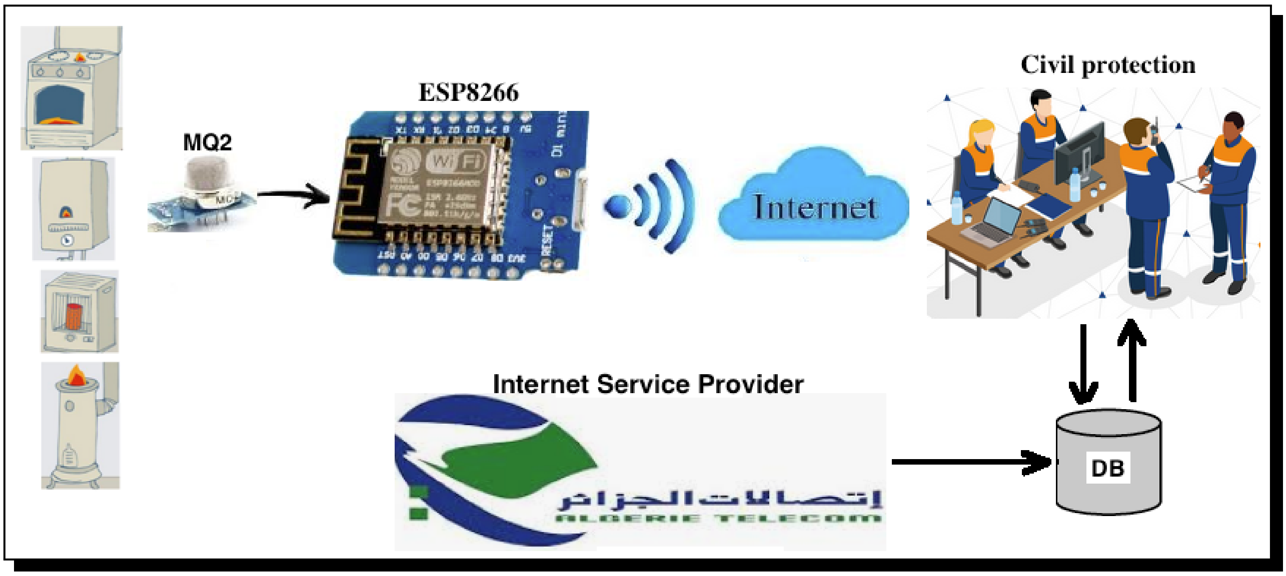


**Figure 1.** Schematic diagram of the proposed system

reduces the input voltage from 5V to an output voltage of 3.2V. We use open source software known as Fritzing [13] to produce the schematic diagram given by Figure 2.

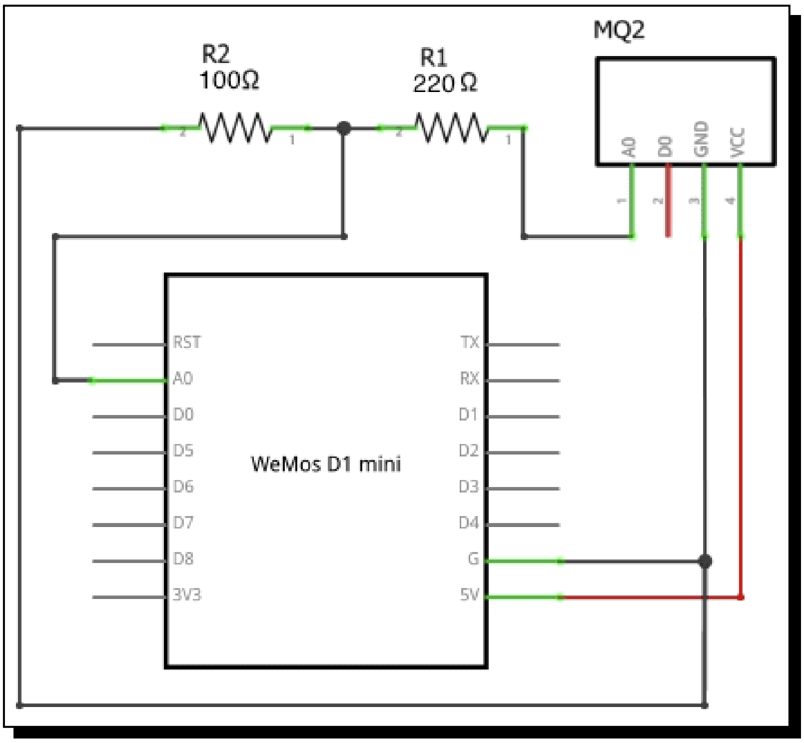


**Figure 2.** Wiring a Wemos D1 to MQ sensor

The electrical circuit of the connection is illustrated in Figure 3.

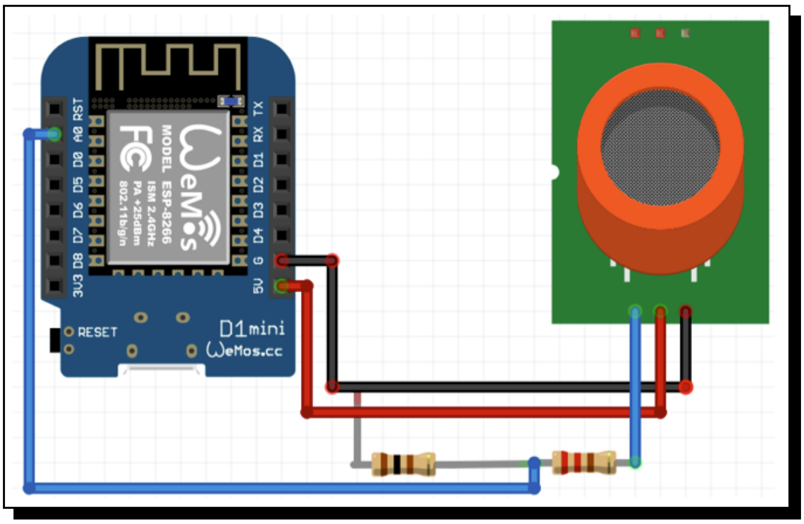


**Figure 3.** Electrical diagram of the connection of the D1 Mini with the MQ2 sensor

The implemented system based on the IoT using MQ-2 gas sensor connected to a WeMos D1 Mini, which is a WiFi development board based on the ESP-8266EX microcontroller to notify the civil protection services by sending them a notification containing the CO amount and the WiFi access point public IP address. Figure 4 shows a photograph of the realized prototype.

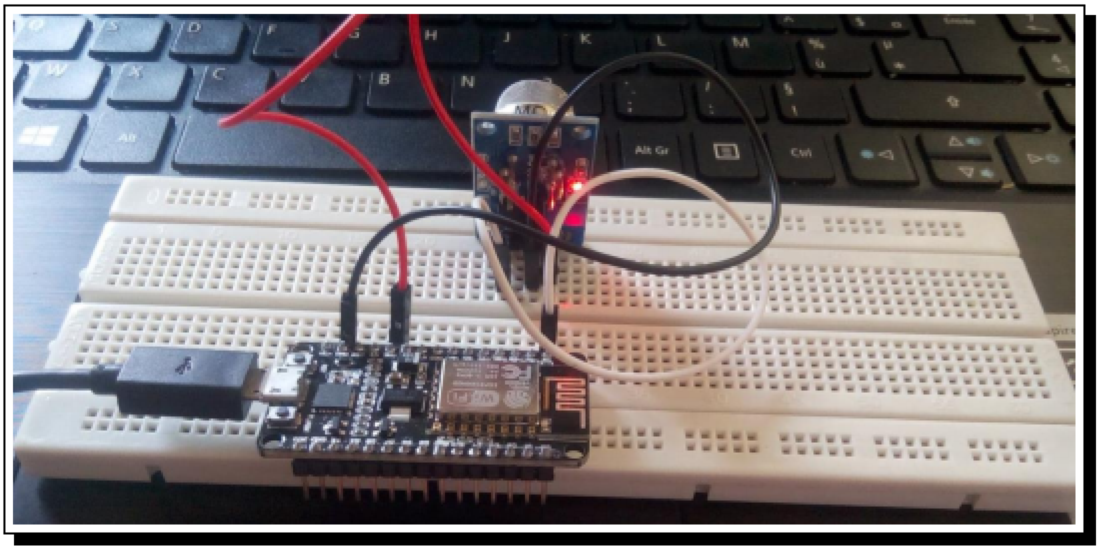

**Figure 4.** Photograph of the realized prototype

## 3.1 Proposed Algorithm

The proposed algorithm allows detecting the presence of carbon monoxide using the MQ2 sensor, the purpose of which is to prevent civil protection in the event of a leak. We have assigned a CO threshold-limit value (TLV) of 400 ppm, which causes a frontal headache within 1 to 2 hours, before the next level which is considered immediately dangerous to life or health. The symptoms and effects on healthy adults of the CO concentration of 800 ppm are; Headache, dizziness and nausea in 45 minutes, collapse and possible death in 2 hours [8], [28].

The operation of the proposed algorithm is described by the flowchart in Figure 5. Once the leak is detected, the amount of carbon monoxide and the public IP address are transmitted in the form of a notification to a monitoring center represented by civil protection.

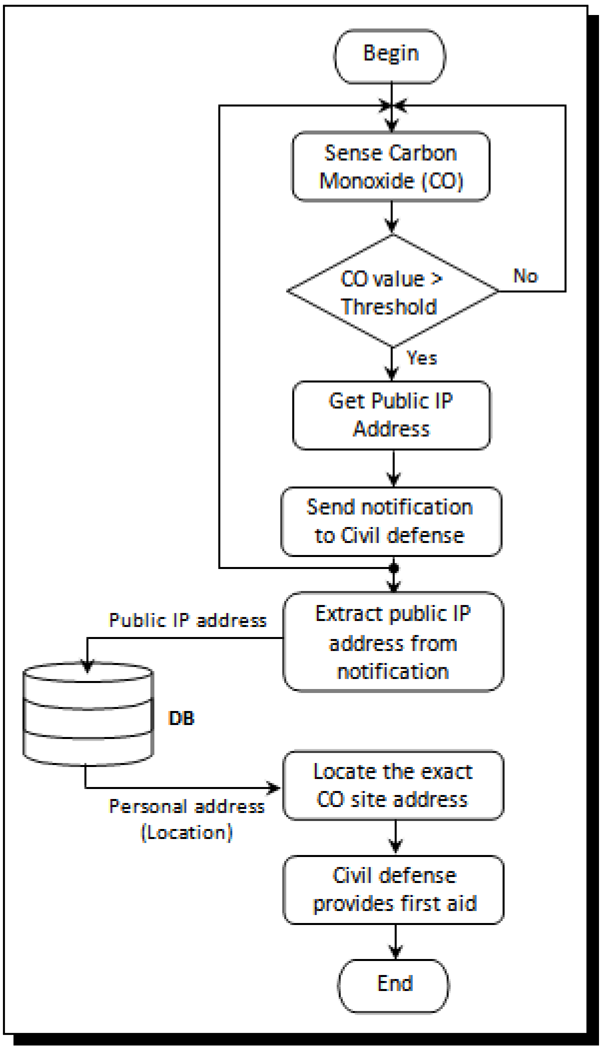


**Figure 5.** Proposed prototype flowchart

Notifications are sent using pushbullet / pushingbox IoT applications. The civil protection agent sends a request based on the public IP address to a database provided by the Internet service provider in order to obtain the personal address of the place of the leak and therefore call the unit nearest to the location of the leak to provide the necessary assistance in a timely manner. The database provided by the Internet service provider must contain information such as first name, last name, personal address, public IP address, and so on.

### 3.2 Send Notification using Pushbullet/Pushingbox IoT Applications

Cloud-based IoT applications PushingBox and PushBullet for Android/IOS devices are used to transfer notifications to Smartphones [26]. Pushbullet is a cross-platform application that is used to transmit files, links, photos, and notifications to different devices. Pushbullet acts as a bridge between devices and computers, providing users with a seamless experience by allowing them to view and reject their incoming notifications on their computers, send text messages from their PC, and easily move links and messages, files between all their devices.

PushBullet allows you to transmit to yourself, but also to your friends, files, links, messages and you can also write and read your SMS directly from your computer. PushingBox is a notification service that handles mails, Twitter, Karotz, Prowl, Pushme.to, Toasty, Notifry, Notify my Android, and Getnote. This service is free, complete, powerful i.e. notifications arrive quickly, easy to use, and has a neat interface. PushingBox is a notification service that brings together many services. The notifications appear on all devices with which you shared.

Figure 6 and Figure 7 show, respectively, notifications received on Desktop and Smartphone with three quantities of carbon monoxide and the Access Point public IP address. These notifications alert us when the CO value exceeds a predefined threshold.

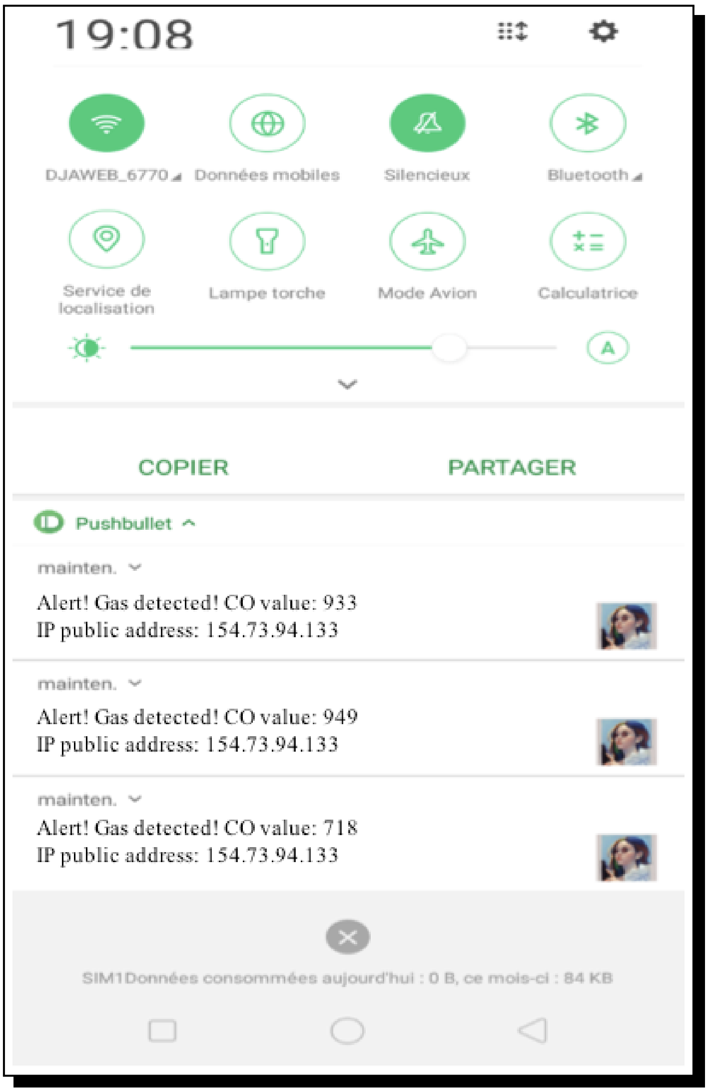


**Figure 6.** Notifications received on Desktop

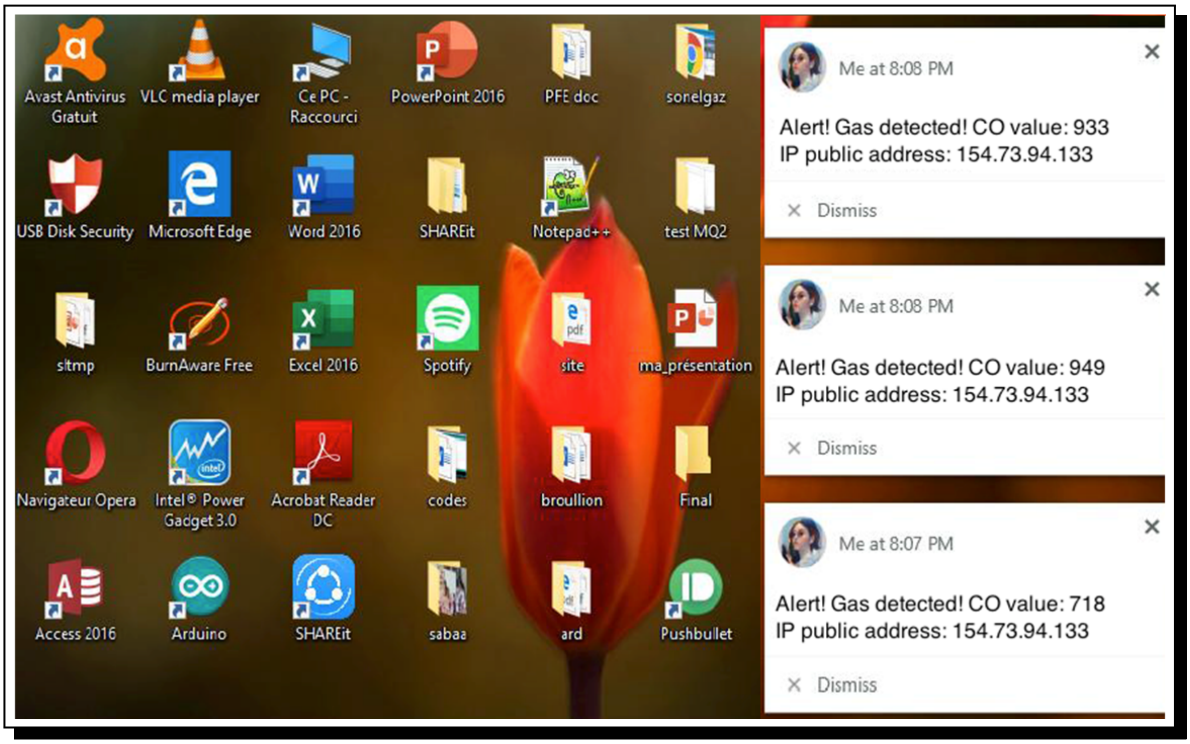


**Figure 7.** Notifications received on Smartphone

In our procedure, the civil protection agent checks the provided database to find out the real address. The location including the postal address (street or road, building name, floor/level, house/flat number, postal code and name of city) usually used to locate the vitctim's house for the given IP address. The location is also displayed using Google Maps as shown in Figure 8.


**Figure 8.** Showing location using Google Maps

## 4. Conclusions

In this paper, we have proposed a prototype for locating carbon monoxide leaks. As the prototype is deployed in an indoor environment, that is to say placed not far from heating sources, the location must be done by the WiFi protocol. The designed prototype consists of a simple Wemos card to which an MQ2 sensor is connected. Once the leak is detected, the amount of carbon monoxide and the public IP address are transmitted in the form of a notification to a monitoring center represented by civil protection. The civil protection agent sends a request based on the public IP address to a database provided by the Internet service provider in order to obtain the home address of the gas leak location and therefore call the unit closest to the location to provide timely assistance.

### Competing Interests

The authors declare that they have no competing interests.

### Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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