Mobile Low Cost System for Environmental Monitoring in Emergency Situations

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***Abstract*— Each year forest fires destroy large forest areas damaging the ecosystem they held. When these fires occur in residential areas, they also present a big danger to the inhabitants of the area, who must find a way to escape themselves from fire. Emergency services should also be able to determine possible access and evacuation routes. It is very difficult to have deployed networks that remain active, so in this paper, we propose the use of citizens' private vehicles to install sensor nodes capable of collecting data from the environment and send this data, through the telephone of their drivers to a database. This database can be consulted by citizens and emergency services. The system consists of a wireless sensor node equipped with several sensors that will communicate via Bluetooth with the Smartphone driver. A Smartphone 3G / 4G connectivity is used to send alarm messages, through Internet, to a central database. Finally, the system is tested in different conditions to check its effectiveness. With the use of this system, emergency services would be able to define escape routes for citizens who might be caught in a fire.**

Keywords-environmental monitoring; arduino; Android App; sensors; fire detection; mobile nodes; emergeny situations.

I. INTRODUCTION

Nowadays, the world is suffering from numerous wildfires. Year by year, thousands of hectares are destroyed. The consequences are terrible for the ecosystem and the economy of that area. In the most serious cases, forest fires cause the death of the inhabitants of the affected zone [1]. Active fires in California (USA), Portugal and Spain (EU) have killed more than 60 people [2][3]. Part of the people who died in those fires did so trying to escape from the fire by using rural roads. Unfortunately, the fire managed to trap them while they were on the road. This type of accidents is very hurtful for people as many of them could have been avoided. Detecting a fire on time and knowing the best escape routes to avoid it are of great importance in order to save the life of both citizens and fire fighters.

There are many systems that are employed for ambient and environmental monitoring [4]; however, most of them are developed for cities or are centered in measuring air pollution [5][6]. Cities allow an easy access and connection to the electricity grid for the devices employed for those purposes but, rural areas present more difficulties. Although there are many wildfire detection systems, they are based on image processing [7][8] or they require the deployment of Wireless Sensor Network (WSN) nodes over the expanse of the forest to obtain information on temperature and humidity [8]. These solutions are costly because they need a great quantity of nodes to be deployed over thousands of hectares in forest where access is very difficult. Moreover, the effort of charging the batteries of all nodes would be massive.

Deploying fire detection systems in vehicles can help to avoid accidents where the occupants of a vehicle get trapped by fire by alerting the driver. In this paper, a cooperative system for vehicles that measures ambient conditions and the state of the vehicle is presented. The system monitors air quality, the presence of fire, Global Positioning System (GPS) position of the vehicle and the state of the vehicle, meaning whether the vehicle is upside down, blocking the road or if it is functioning as it should. The information from all vehicles that get installed the system is then forwarded to a server in order to determine the best escape routes considering the roads of the area. This system can be employed by civilians and emergency responders in order to ensure their safety in light of extreme wildfire related circumstances.

The rest of this paper is structured as follows. Section II shows some previous works where previous proposals are presented. This system is composed by an electronic device based on an Arduino board, a smartphone and several software parts that control its operation. Thus, Section III shows the design of our prototype and it implementation. The results of our test bench to check the proper operation of our low-cost system are shown in Section IV. Finally, conclusion and future works are exposed in Section V.

II. RELATED WORK

The use of sensors for monitoring purposes is increasing constantly. Particularly, many are being employed as part of WSN to monitor environmental parameters. Ferdoush et al. employ in [10] Arduino and Raspberry Pi open source-hardware for environmental monitoring purposes. Their system includes a database and a web server to store and access the temperature and humidity data gathered by the sensor. Internet of Things (IoT), cloud computing and a GPS module are employed in [11] to monitor climate change and its effects. Another environmental monitoring system that employs WSN to gather data is presented in [12]. The presented sensing station costs around 900€ and employs a solar panel and two batteries as a power source.

As a result of the increasing cases of wildfires, the number of wildfire detecting and wildfire fighting systems are on the rise. Many of them employ cameras to detect when a fire has started. Bosch et al. present in [13] a system that employs thermal imaging to detect wildfires. They use a

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WSN with sensors composed of a visible and a thermal camera and a motor, in order to be able to cover wider areas. The cameras do not need to be high resolution nor does the system require knowing the temperature. When a fire is detected, the system sends an alarm. It also sends an alarm when the wildfire is increasing in size or when it is persistent. This technique is also used to determine the presence of anomalies as diseased in grapes and/or its leaves [14]. Other solutions are employed after the fire detection and progress monitoring, such as the one proposed in [15]. The system is a co-operative control framework for Unmanned Aerial Vehicles (UAV) and Unmanned Ground Vehicles (UGV). It employs a hierarchical structure and It can design mission plans, allocate tasks and manage the activities of all the vehicles.

The concept of using cars as a source for sensing, data transfer and storage, computing, location and providing information and entertainment is getting more popular nowadays. Abdelhamid et al. name it in [16] as Vehicle as a Resource (VaaR). They also introduce the challenges of such technologies such as privacy, data quality or redundancy. One of its applications is monitoring different aspects in a car. In order to do so, sensors are being highly employed. Specifically, avoiding, assessing and aiding emergency situations are some of the most researched topics. A system that detects fatigue in drivers is presented in [17]. The system employs several sensors that measure movement, pressure, temperature, proximity and shocks to determine when the driver could be tired. If the system detects fatigue in the driver, a sound alarm, that the driver must disable pressing a button, is generated. A system that detects and estimates the severity of road accidents is proposed in [18] by Fogue et al. They consider vehicle and impact speed, state of the airbag and vehicle type. Impacts, high temperatures and water inside the cabin are detected by the sensors deployed inside a car on the system designed in [19]. In case of accident, the system forwards a message to a police station or hospital, and a family member. The message contains the location of the vehicle and its registration number.

Although systems that monitor the environment, detect fires and help drivers in emergency situations exist independently, there is no other system that combines all three applications into one system that helps drivers to detect when a wildfire has started and provides an escape route.

III. System Description And Implementation

This section explains the architecture that includes our mobile low cost system for environmental monitoring in emergency situations. It also includes a detailed explanation of system and its main parts.

A. *System description and propodsed architecture*

In a forest fire near to residential areas, one of the main goals is to ensure the evacuation of people through a secure way. For this reason, it is mandatory to establish a set of parameters to be monitored and shared along the network. After analyzing the last forest fires in Portugal and Spain, with fatalities, we have established the following parameters:

- GPS position and vehicle tracking.
- Vehicle status, i.e., if it has suffered an accident or it is blocking an escape routes.
- Presence of fire.
- Presence of Carbon dioxide or a poor quality of air that difficult the breathing.
- The system must be installed in a vehicle, without having to make any type of modification in its manufacture.

The proposed architecture is based on a set of mobile nodes provided with a set of sensors. These mobile nodes are connected via 3G / 4G technology (since we use the smartphone to transmit the data) to the Internet in order to send data to the central database unit (CDBU). CDBU contains the data from all vehicles that compose the cooperative network and provides data to a web site that dynamically changes as a function of the received data. To tag a route as available, the system has to consider the number of vehicles is driving along this route. In a scenario where all vehicles have this system, it is easy to obtain this parameter. Furthermore, the system should provide some alternative route to facilitate evacuation. The information is easily accessible by emergency/rescue services and citizens. There, we can see in different colors the possible available routes. The data gathered by sensors is locally stored in each node and shared through Internet. Finally, these data should be stored in a CDBU. The proposed architecture is shown in Figure 1. Although, the system is currently based on 3G / 4G networks since they are nowadays standardized and extended among users, it can be easily migrated to 5G technology when it will be standardized, deployed and extended among users. Additionally, the system should be able to send some alarm message (as a broadcast message or similar) in order to quickly inform about the problems in the escape route or rescue way. To process this alarm, we have developed a control algorithm that takes into account the data from all sensors (see Figure 2). As one can see, the node sensor is waiting to receive some connection request. When a user, through his smartphone requests to connect to it, the node accepts its connection. At this point, the node is ready to receive the location and current time. Data are directly extracted from the smartphone and locally stored on the node. Periodically, the node checks that the Smartphone is still available. If not, the node will log an error and return to the initial state. If any of the measured parameters exceeds the established security thresholds, the system saves the data and creates a text message with the detected event information.

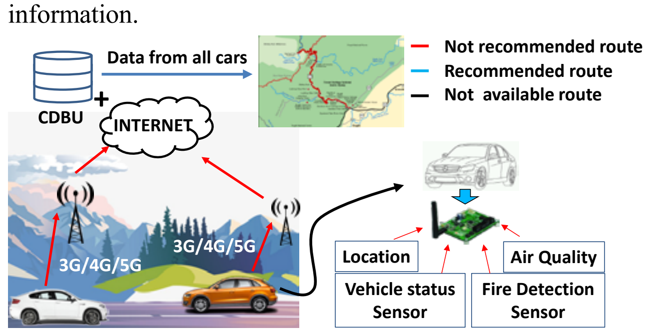

Figure 1. Proposed Architecture for the system.

B. *Design and implementation*

In order to design the system, we have set up some premises that this system should satisfy. The system should be:

- Cheap and easily installable in a vehicle.
- Versatile and should be independent from the vehicle brand.
- Able to take data on geographical position from the smartphone the driver has.
- The data exchange between drivers' smartphone and the system should be through permanent Bluetooth connection.

The whole system (see Figure 3) is composed by a microcontroller board and a Bluetooth module, which is connected to the Smartphone that drivers usually have. There are several possible commercial microcontroller boards but in our case, we have used an Arduino module since this platform is very cheap and easy to configure. The system works as follows. On the one hand, the smartphone receives the GPS positioning data from the satellites intended for it. This information is sent to our device via Bluetooth combined with the reference of the current time. In this way, our device can keep a record with the data from sensors and store the vehicle GPS position with and actual reference time in a Secure Digital (SD) card. On the other hand, when a sensor detects some anomaly in the sensors value, it sends an alarm code via Bluetooth to our mobile phone, which the Android application recognizes and acts accordingly.

The system is composed by a set of sensor that Table I summarizes. The connections schema of the system and the different modules used to compose our mobile low-cost system for environmental monitoring in emergency situations is shown in Figure 4.

C. *Android Graphical User Interface*

In order to carry out the communication between the Arduino module and the Smartphone, we have developed an application called *CarAppCident* for the Android platform with a simple user interface, prepared for future incorporation of new sensors.

After installing our application, we should run it. We will see the main screen (Figure 5a) where we can press *"Bluetooth Device"* to start the scan for available Bluetooth devices. After pressing it, we access to a black screen with a list of detected devices (Figure 5b). From this list, we can select our Arduino device, which is identified as *ArduinoR*.

If we click on the name of the device, we will be connected and prepared for sending and receiving information. Once connected, our Smartphone starts sending location and time data to our Arduino module since the application is running in the background. At this time, we could stop managing the application. However, if we want to know our position we can press the button "My Position" and the coordinates, i.e., latitude, longitude and height, of our position will appear. In addition, an approximate address to where we are is provided. This is a quick way to self-locate, if this information should be provided for requesting help or in any other situation (see Figure 6).

In addition, with the indicator of passengers (function that will be enabled in future versions), the system can save the data in regard to the number of vehicle's passengers. This information can be useful when emergency services should rescue a damaged vehicle and determine if all of the vehicle's passengers have been located and assisted.

To program the necessary code to gather data from sensors and establish the connection, the App Inventor application has been used. One of the main parts of the program is the Bluetooth connection (see Figure 7).

Before pressing "Bluetooth Device" button, the smartphone check if Bluetooth clients are available and displays them. If the connectivity with the Bluetooth client is lost or the device is no longer available, the system will shows us an error. After pairing both devices, the smartphone starts to send the time reference, GPS position and current address. As Figure 8 shows, each parameter is sent separately. Parameters are sent separated by a space since it is easy to be processed.

IV. RESULTS

After the programming the system, we need to check its correct operation. To do it, the different sensors have been tested. This section shows the results obtained during the test bench.

A. *GPS position*

The first test is focused on determining the geographical position of our vehicle. To do so, the vehicle where the system has been installed has performed a trip.

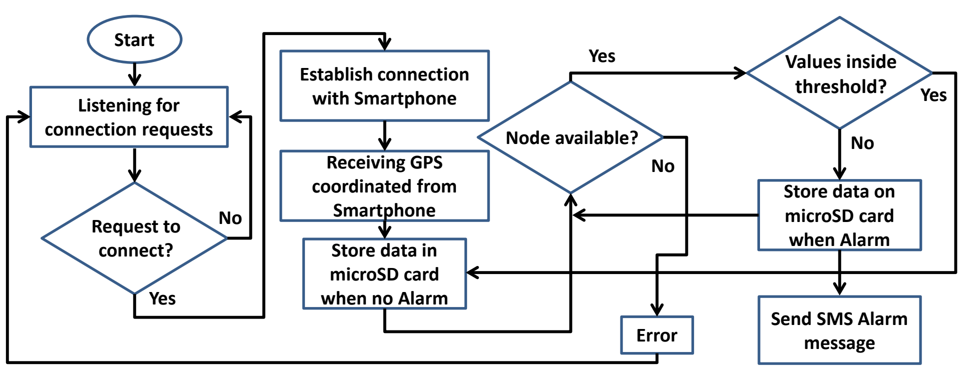

Figure 2. Operation Algorithm.

TABLE I. COMPOMENTS USED BY THE SYSTEM

	Components used by the system					
Function	*Data Processing*	*Air Quality*	*Fire presence*	*Gyroscope*	*Bluetooth*	*Data Storage*
Component	Arduino UNO. rev. 3	MQ-2 Sensor	KY-026 sensor	MPU-6050 GY-521 sensor	HC-06 Module	MicroSD module and MicroSD Card
Price ($)	25	3	7	2	7	10

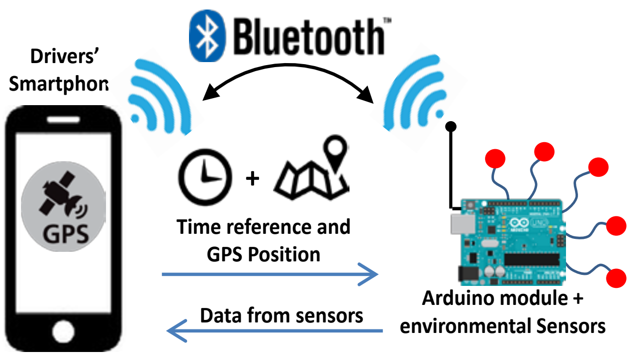

Figure 3. Schema of connection for the system.

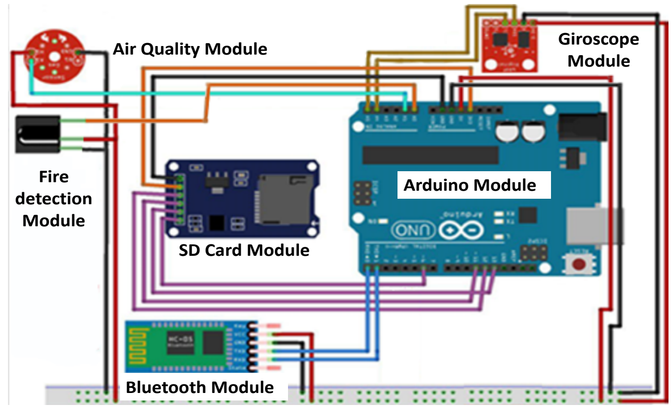

Figure 4. Microcontroller and sensors connection

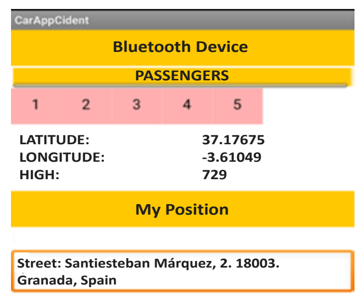

Figure 5. Position reception

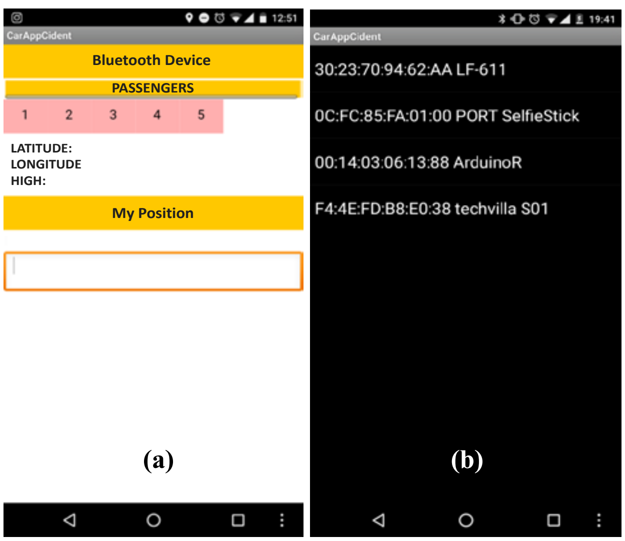

Figure 6. Main screens of CarAppCident application

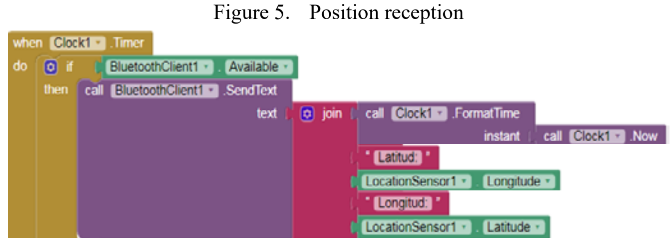

Figure 7. Program for sending GPS Position through Bluetooth

A smartphone with GPS connection has also been used to provide the data of latitude and longitude. Measurements are taken every 30 seconds. These data is sent to the Arduino module and stored as a file text in the microSD Card. An example of this text file is shown in Figure 9. Finally, the collected data has been placed on a map in order to see the path followed by the vehicle (see Figure 10).

B. Vehicle status

To check how the gyroscope sensor works, the system is installed in a platform which emulates the movement of a car when it dumps. We emulate that a car has suffered an impact and has undergone a turn until it is positioned on one of its sides. The sampling frequency is 4 samples per second. The results obtained are shown in Figure 11.

As one can see, up to 3 seconds, our vehicle is in the rest position. From this moment, the vehicle begins to vary its position, making a sharp turn toward the +X-axis. We establish an alarm threshold (20º), from which we consider that the car has overturned. This type of sensors does not have an immediate response. As we can observe, when 7 seconds have elapsed, the system has exceeded the specified threshold. When 12 seconds have elapsed, both axes have exceeded the threshold and therefore the alarm is generated. In this case, the system has taken 9 seconds since the vehicle begins to vary its position until it blows the alarm due to a dangerous position. These values have been selected only for the purpose of presenting how the alarm is generated as a function of the car movement. However, these values are easily adjustable.

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C. Fire detection

As we explained before, the system should be able to detect the presence of fire in the surrounding areas of our vehicle and activate the alarm. The results offered by the sensor are shown in Figure 12. During this test, we kept the sensing far from the fire during the first 8 seconds. From this moment, we have approached the fire and stepped back from it several times. We could observe that when there is no fire, the voltage value of the fire sensor is approximately 4.92 volts while lower values meant that there was presence of flames near the vehicle, and therefore, the place where we were cannot be considered as a safe escape route. It is easy to see that the voltage registered by the sensors decreases when fire is detected near the car. So, we establish the threshold at 4.5V. From this point, the system will consider a fire is detected.

D. Smoke detection

The operation of the smoke/gas sensor is very simple. When it detects some type of gas, specifically Liquefied Petroleum Gas (LPG), propane, methane, alcohol, hydrogen or smoke, the internal system of the sensor begins to warm up and its temperature increases, which implies an increase in the reading of the analog value. In addition, the sensor needs few seconds since it is started up until it is able to reliably take measurements. In order to test the operation of the sensor, our sensor is subjected to various bursts of butane gas. The results obtained are shown in Figure 13. As one can see, the sensor needs approximately 10 seconds to stabilize its resting value, which is around 0.8 V.

When the gas/smoke concentration increases near to our sensor, the voltage also increases. One can see two peaks at 80s and at 135s. The values of output voltage of sensor in the presence of gases detected are higher than 1.1V. So, we can establish the threshold at 0.85volts.

E. Alarm messages

Finally, Figure 14 shows an example of a text message generated when fire is detected near to the car at a particular location. As noted, the message contains information about the event which generated the alarm, the time it was generated and the GPS location where this event was detected.

V. Conclusion and Future Work

In this paper, we have presented a mobile low cost system for environmental monitoring in emergency situations. The novelty of this system is that we use the private cars to have several nodes taking data from the environment. The system is composed by a sensor node, which is connected to a smartphone to take advantage of the 3G / 4G connectivity. According to our result, the system can be very useful to determine possible evacuation routes to rescue stranded citizens, in emergency situations, such as forest fires. In this way, many deaths of people who attempt fires along roads that are unaware of their condition could be avoided.

As future works, we would like to integrate some more sensors in the vehicle. These sensors will provide information to the emergency services about the vehicle status in order to better plan the rescue tasks

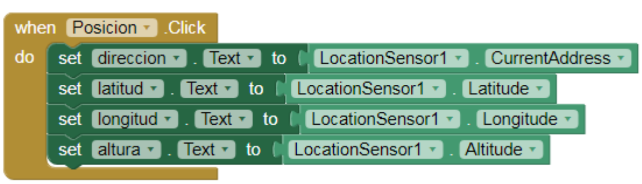
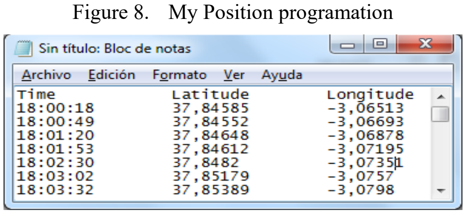


Figure 8. My Position programation



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Time	Latitude	Longitude
18:00:18	37,84585	-3,06513
18:00:49	37,84552	-3,06693
18:01:20	37,84648	-3,06878
18:01:53	37,84612	-3,07195
18:02:30	37,8482	-3,07351
18:03:02	37,85179	-3,0757
18:03:32	37,85389	-3,0798

Figure 9. Text file with GPS coordinate

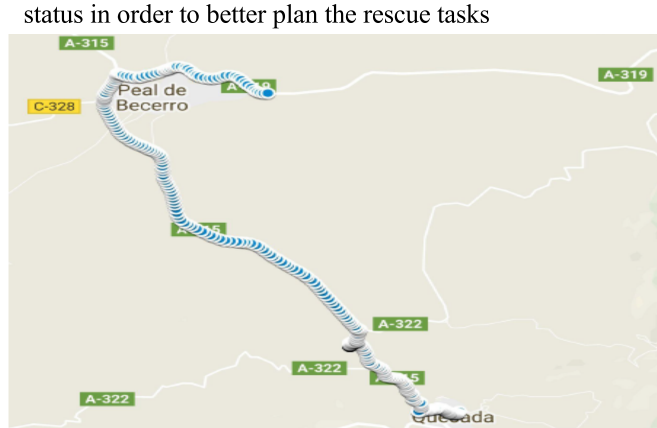

Figure 10. Position information placed on a map.

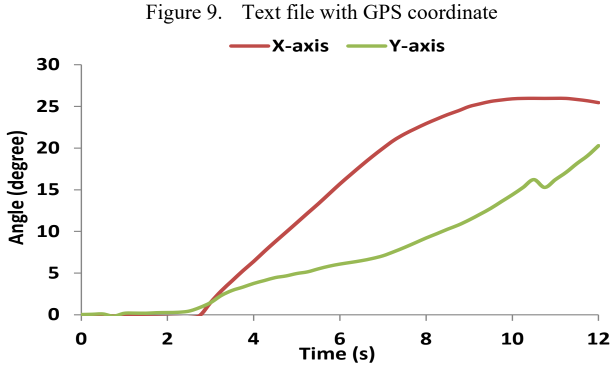

Figure 11. Measurements of vehicle position with measurements each 0.25s

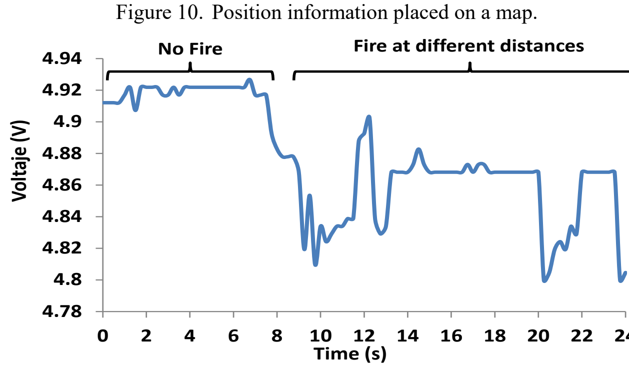

Figure 12. Measurements of fire detection

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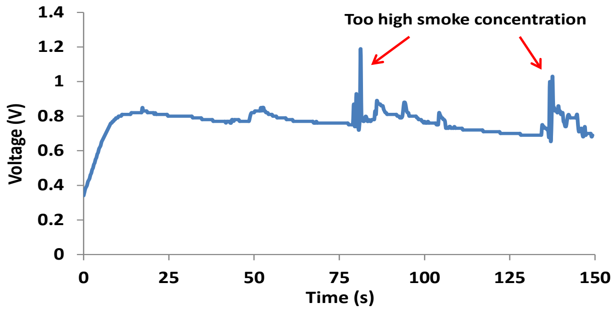

Figure 13. Measurements of smoke detection

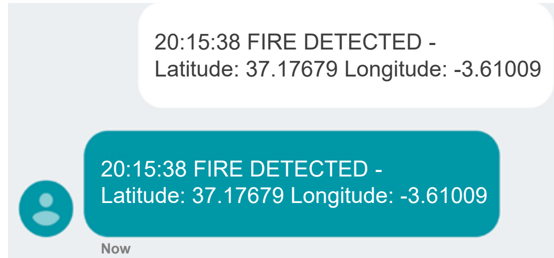

Figure 14. SMS reveived when fire is detected.

We would also ensure the security of data stored in the CDBU through the last techniques [20] to be sure that nobody uses them in a criminal way. Finally, the system is transmitting the data through 3G / 4G networks. As future actions, we would like change the connectivity to 5G networks [21].

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REFERENCES

[1] J. Lloret, M. Garcia, D. Bri, and S. Sendra, "A wireless sensor network deployment for rural and forest fire detection and verification", Sensors, vol. 9, no. 11, 2009, pp. 8722-8747.

[2] M Garcia, D Bri, S Sendra, J Lloret, "Practical deployments of wireless sensor networks: A survey", Int. J. on Advances in Networks and Services, vol. 3, no. 1-2, 2010, pp. 170-185

[3] CNN, "More evacuations ordered as deadly wildfires scorch Northern California". Available at: http://edition.cnn.com/2017/10/10/us/california-fires-napa/index.html (Last accessed: Oct. 26, 2017).

[4] El País, "Why wildfires in Portugal are so lethal?". Available online: https://elpais.com/internacional/2017/10/19/actualidad/1508410409_311317.html (Last accessed: Oct. 26, 2017).

[5] B. Manlio, D. Franca, F. Erina, and G. Alberto, "Environmental Monitoring for Smart Cties", IEEE Sensors Journal, no. 99, July 2017, pp. 1-8.

[6] F. Zeiger and M. F. Huber, "Demonstration Abstract: Participatory Sensing enabled Environmental Monitoring in Smart Cities", 13th Int. Symp. on Inf. processing in sensor networks, Berlin, Germany, 15-17 Apr. 2014, pp. 337-338.

[7] R. D. Labati, A. Genovese, V. Piuri, and F. Scotti, "Wildfire Smoke Detection Using Computational Intelligence Techniques Enhanced With Synthetic Smoke Plume Generation", IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 43, no. 4, 2013, pp.1003-1012.

[8] J. Park, B. Ko, J. Nam, and S. Kwak, "Wildfire Smoke Detection Using Spatio Temporal Bag-of-Features of Smoke", IEEE Workshop on Applications of Computer Vision, Tampa, Florida, USA, 15-17 Jan. 2013, pp. 200-205.

[9] A. R. Ulucinar, I. Korpeoglu, and A. E. Cetin, "A Wi-Fi Cluster Based Wireless Sensor Network Application and Deployment for Wildfire Detection", Int. J. of Distributed Sensor Networks, vol. 10, no. 10, 2014, pp. 1-12.

[10] S. Ferdoush and X. Li, "Wireless Sensor Network System Design using Raspberry Pi and Arduino for Environmental Monitoring Applications", Procedia Computer Science, vol. 34, 2014, pp. 103-104.

[11] S. Fang et al., "An Integrated System for Regional Environmental Monitoring and Management Based on Internet of Things", IEEE Transactions on Industrial Informatics, vol. 10, no. 2, May 2014, pp. 1596-1605.

[12] G. Barrenetxea, F. Ingelrest, G. Schaefer, and M. Vetterli, "SensorScope: Out-of-the-Box Environmental Monitoring", Int. Conf. on Information Processing in Sensor Networks, St. Louis, MO, USA, 22-24 April 2008, pp. 332-343.

[13] I. Bosch, A. Serrano, and L. Vergara, "Multisensor Network System for Wildfire Detection Using Infrared Image Processing", The scientific World Journal, vol. 2013, 2013, pp. 1-10.

[14] J. Lloret, I. Bosch, S. Sendra , and A. Serrano, "A Wireless Sensor Network for Vineyard Monitoring That Uses Image Processing", Sensors, vol. 11, no. 6, 2011, pp. 6165-6196.

[15] C. Phan and H. H. T. Liu, "A Cooperative UAV/UGV Platform for Wildfire Detection and Fighting", 7th International Conference on System Simulation and Scientific Computing, Beijing, China, 10-12 October 2008, pp. 494-498.

[16] S. Abdelhamid, H. S. Hassanein and, G. Takahara, "Vehicle as a Resource (VaaR)", IEEE Network, vol. 29, no. 1, Jan. 2015, pp. 12-17.

[17] S. Sendra, L. García, J. M. Jimenez, and J. Lloret, "Low-Cost Vehicle Driver Assistance System for Fatigue and Distraction Detection", Int. Conf. on Future Intelligent Vehicular Technologies, Porto, Portugal, 15 Sep. 2016, pp. 69-78.

[18] M. Fogue et al., "A system for Automatic Notification and Severity Estimation of Automotive Accidents", IEEE Transactions on Mobile Computing, vol. 13, no. 5, 2014, pp. 948-963.

[19] S. Chaklader, J. Alam, M. Islam, and A. S. Sabbir, "Black Box: An Emergency Rescue Dispatch System for Road Vehicles for Instant Notification of Road Accidents and Post Crash Analisys", Inte. Conf. on Informatics, Electronics and Vision, Dhaka, Bangladesh, 23-24 May 2014, pp. 1-6.

[20] R. Kamatchi, K. Ambekar, Y. Parikh, "Security Mapping of a Usage Based Cloud System", Network Protocols and Algorithms, vol. 8, no. 4, 2016, pp. 56-71.

[21] H. N. AL-Hashimi and W. N. Hussein, "PMIPv6 Assistive Cross-Layer Design to reduce handover latency in VANET Mobility for Next Generation Wireless Networks", Network Protocols and Algorithms, vol. 7, no. 3, 2015, pp.1-17.

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