Cerberus: A Novel Alerting System for Flood, Fire, and Air Quality

Satvik Dasari

Westwood High School, Austin, Texas, USA
*Corresponding Author: Email: srdasari2@gmail.com

Abstract

According to the NHTSA, an average of 384 fatalities occur annually in the United States due to drowning while driving. The California wildfires in 2017 caused a property loss of $13 billion, 46 lives, and injuries to hundreds more. Most of the current alerting mechanisms are expensive and deficient in features for detecting floods at road crossings, wildfires, and air quality. The current fire alerting systems cost thousands of dollars, but they are not multi-purpose and compatible with smart city infrastructure. Also, the current flood alerting systems cost tens of thousands of dollars, are radio frequency-based, and require large antennas, but only provide a limited range. This paper proposes an innovative system, Cerberus, to provide early warnings for fires, floods, and air quality using an IoT device, sensors, cloud, and mobile technologies. The solution provides a Red-Yellow-Green light system for local alerts and a mobile app to alert users about unsafe water levels, fire, and air quality. All the data collected by Cerberus is stored in the cloud and used for other types of alerts such as voice calls, text alerts, and emails. The Cerberus warning system is low-cost, accurate, easy to maintain, and scalable to thousands of locations. The warning system is also integrated with an analytics platform that shows trends and historical data. The prototype was validated in the field using real data. The results show that Cerberus is a viable solution for providing accurate and reliable alerts for floods, wildfires, and air quality.

Keywords: fire, flood, alert, air quality

Introduction

In California, in 2020, there were 8,486 wildfire incidents which caused 8 fatalities, burned 4,105,786 acres, and damaged 5,491 structures [1]. According to the National Highway Traffic Safety Administration, an average of 384 deaths [2] were reported in the US alone due to drowning while driving. The current fire alerting systems are neither multi-purpose devices nor compatible with smart city infrastructure. One of the most common ways to detect fires is using video cameras and analyzing the video to determine fire patterns [3]. This solution is expensive as it uses high-end cameras. There is also a thermal imaging method using a satellite, but it is the most expensive way to detect fires. Most recent proposals include using Arduino based Long Range (LoRa) technology with low-power wireless communication [4]. This solution is not a multi-purpose device and not suitable for smart city use cases. Similarly, the current flood alerting systems cost tens of thousands of dollars, are radio frequency-based, require large antennas, and are not easily scalable [5]. Primarily due to the high cost of these alerting systems, they are not deployed at all critical creek-crossings. For example, only 1.6% of creek crossings in central Texas have water level measurement and alerting systems.

This paper proposes a low-cost fire, air quality, and flood alerting system, Cerberus. Cerberus is also a reliable, scalable, and accurate measurement and alerting system. It also provides a way to monitor and maintain each device remotely. The contributions of this paper are to provide the following: (1) a multi-purpose device with fire, flood, air quality, humidity, temperature sensors, and an IoT microcontroller, (2) code that processes data from each of these sensors and sends data to the cloud through a 3G or Wi-Fi mechanism, (3) a mobile app that shows the current status and provides appropriate alerts, (4) integration with an IoT analytics platform to show the historical trend, and (5) remote maintenance and monitoring of the device.

System Architecture

The proposed system comprises multiple components. The first part is the Cerberus node with various sensors – fire, temperature, humidity, air quality, and ultrasonic. A combination of temperature, humidity, air quality, and fire sensors detect fires and send alerts. In contrast, the ultrasonic sensor detects water levels to provide flood alerts. The Cerberus node also has a microcontroller that is capable of reading data from all of these sensors, process the data, and send it to the cloud. The second part of the solution is the cloud, which allows the solution to be scalable. Though this paper proposes that the microcontroller sends the sensor data to the cloud through 3G or Wi-Fi, any other communication mechanism can be used. The third part of the solution is the dissemination mechanisms such as email, text, voice call, and mobile app. Finally, the solution also manages Cerberus devices remotely. Due to the usage of the cloud, various analytics can be run on the sensor data, including generating trends. The overall architecture of the Cerberus system is illustrated in Fig. 1.

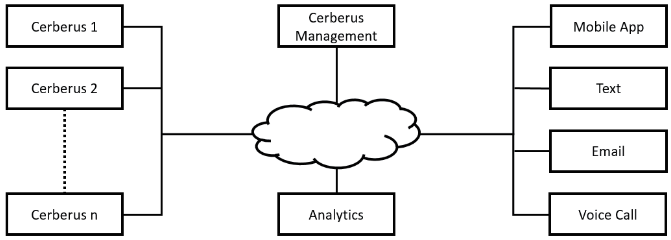

Fig. 1 Cerberus system architecture.

The Cerberus device consists of a microcontroller, various sensors, a communication mechanism, and LEDs. The circuit diagram of the Cerberus device is shown in Fig. 2. The ultrasonic, temperature and humidity sensors are connected to digital inputs of the microcontroller. In contrast, the fire and air quality sensors are connected to the analog inputs of the

ISBN: 978-1-7281-8060-1

microcontroller. Green, yellow, and red LEDs are also connected to analog outputs of the microcontroller.

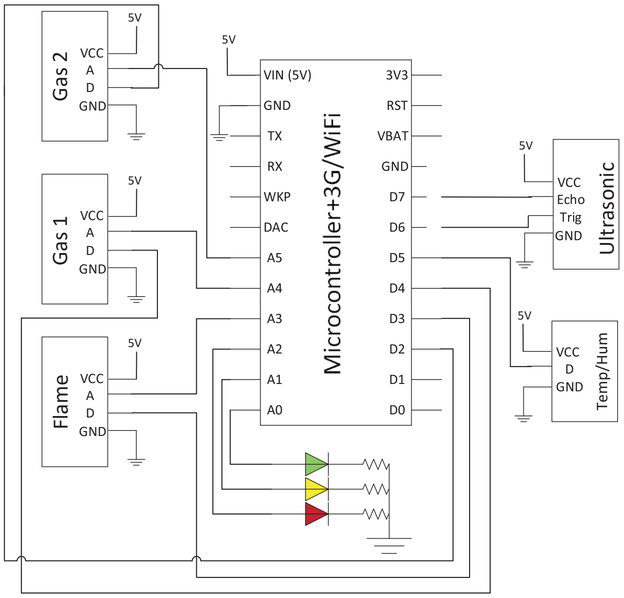

Fig. 2 Circuit diagram of the Cerberus device.

The microcontroller reads and processes the data from different sensors, and sends it to the cloud using 3G or Wi-Fi. Figure 3 shows the flow of the code running on each of the Cerberus devices. The Cerberus system supports various remote alerting mechanisms such as text, email, and a mobile app. In addition to the remote alerting, a local alerting mechanism is also supported using green, yellow, and red LEDs. When sensor readings are at a safe level, a green LED is turned on. When any of the sensor readings are at a warning level, a red LED is turned on. The yellow LED indicates a level between safe and warning.

Any of the commercial cloud services can store the data sent by each one of the Cerberus devices. The use of the cloud in the solution enables a wide variety of dissemination mechanisms, including a mobile app.

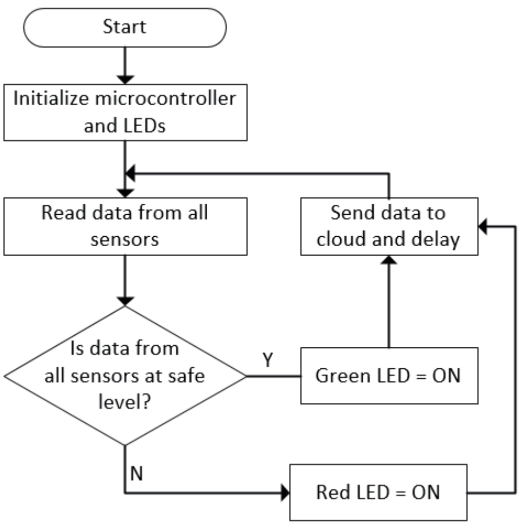

Fig. 3 Flowchart of Cerberus device program.

The mobile app provides a convenient way to monitor fires and floods. The flowchart of the mobile app code is shown in Fig 4. The mobile app identifies all the Cerberus devices, reads sensor data from each of the devices through the cloud, uses an algorithm to determine whether any of the sensor data is outside of the pre-configured thresholds. It sends alerts that indicate safe or warning levels along with the real-time sensor data.

The Cerberus system also supports remote maintenance and monitoring of the devices. Using the management console, one can monitor all of the sensor data from each of the Cerberus devices. Also, the status of every Cerberus device is monitored. Besides, over-the-air firmware updates can be performed through the management console. Finally, the Cerberus system was also integrated with the ThingSpeak IoT analytics platform, which provides historical data and associated graphs. Though it has been integrated with this specific IoT analytics platform in this study, it can be integrated into any other commercially available solutions.

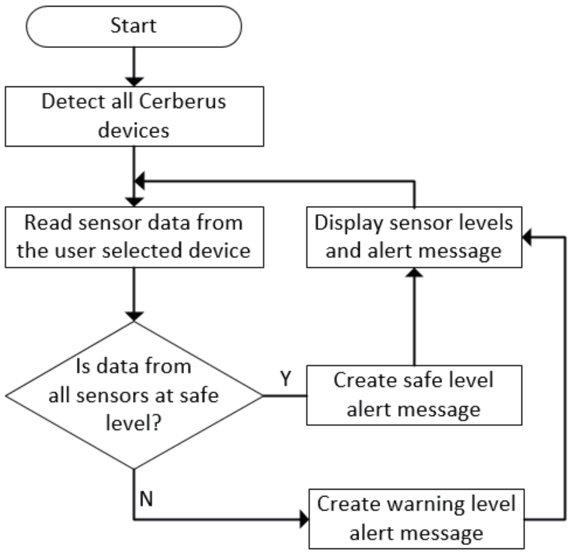

Fig. 4 Flowchart of mobile app code.

Experiments, Data Collection, and Analysis

Prototypes of Cerberus devices were built using a microcontroller, ultrasonic sensor (HC-SR04), temperature and humidity sensor (DHT11), flame sensor module (KY026), and different types of gas sensors modules (MQ-2). The prototype of the Cerberus device with all sensors connected is shown in Fig. 5.

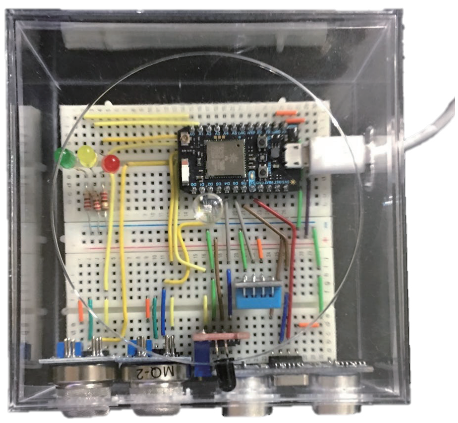
Fig. 5 The prototype of the Cerberus device.

ISBN: 978-1-7281-8060-1

The microcontroller has a built-in 3G or Wi-Fi system. The mobile app was developed to test data from different sensors. For validation, each of the sensors is tested to make sure the values reported are close to the actual values. For example, the ultrasonic sensor is validated by comparing the value reported in the mobile app with the actual value measured with a tape.

The data from the ultrasonic sensor is collected at a creek crossing over different days and weather conditions. The ThingSpeak capture of the data is shown in Fig. 6. The values are close to the actual water levels in a 1-inch range.

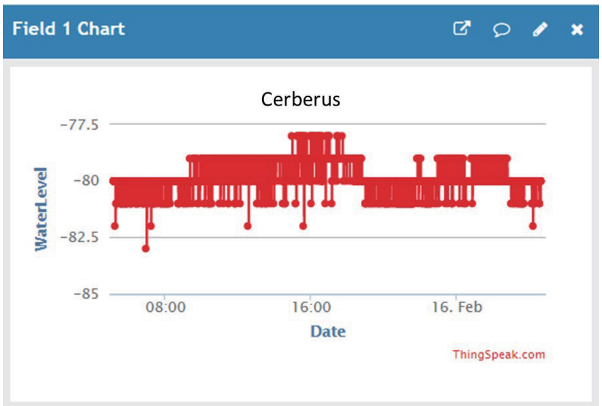

Fig. 6 Water level data from the Cerberus device.

The temperature and humidity are validated by comparing the values reported in the mobile app to those reported by a thermostat. They were within less than 1% error. Figure 7 shows the temperature graph from ThingSpeak, and Fig. 8 shows the humidity graph from ThingSpeak.

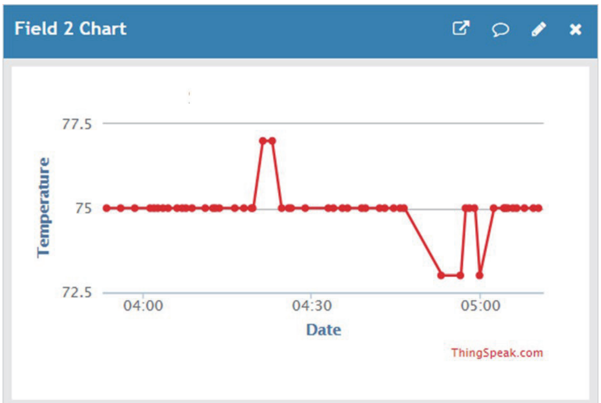

Fig. 7 Temperature data from the Cerberus device.

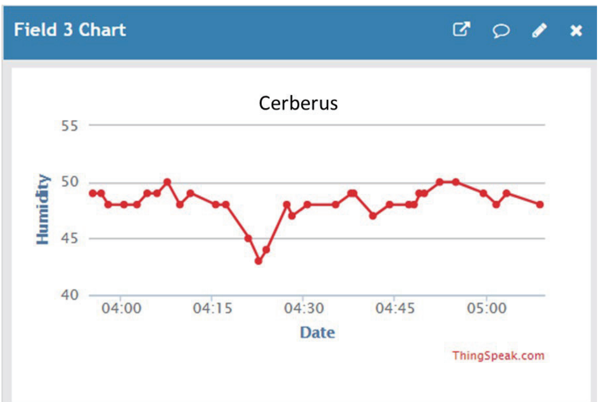

Fig. 8 Humidity data from the Cerberus device.

Fire is tested by igniting a flame and changing the distance between the flame and the sensor. Figure 9 shows the data from the fire sensor. The dip in the graph shows the detection of fire and results in a warning message on the mobile app.

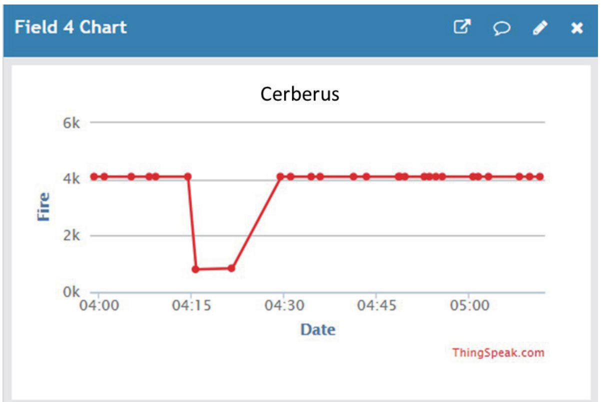

Fig. 9 Fire data from the Cerberus device.

Gas sensors were tested using smoke. Fig. 10 and 11 shows the ThingSpeak graph for both of the gas sensors.

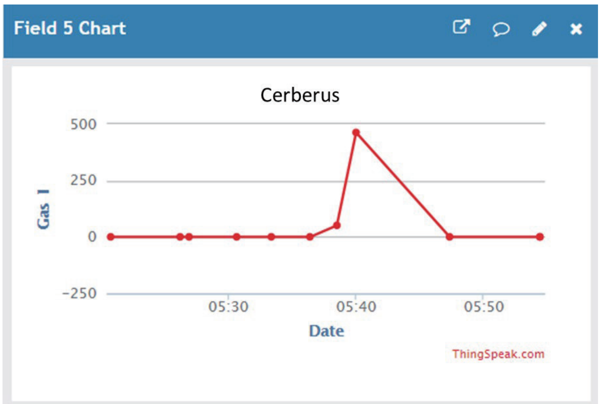

Fig. 10 Gas 1 data from the Cerberus device.

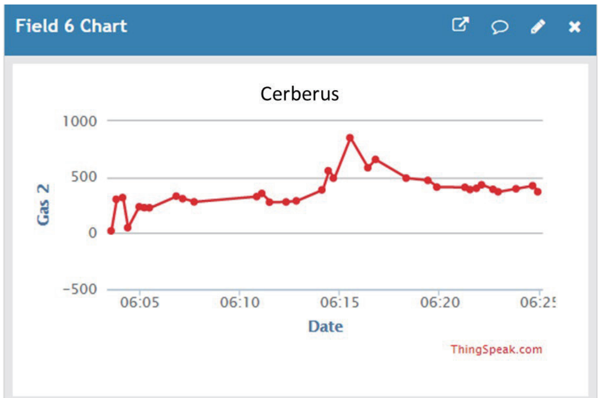

Fig. 11 Gas 2 data from the Cerberus device.

Conclusion

Cerberus is a low-cost and accurate solution for the measurement and alert of fires and floods. It supports multiple alert dissemination mechanisms, including a mobile app. Local alerting mechanisms provide a convenient way of knowing the live status onsite. The Cerberus solution integrates with the cloud enabling centralized monitoring, scalability, and remote maintenance. The system significantly

ISBN: 978-1-7281-8060-1

reduces the fatalities related to drowning while driving and wildfires. Also, Cerberus supports many other sensors for the city infrastructure. The limitations of the system include a short (180 inch) range of ultrasonic sensors and a few feet range of fire sensors. In further research, these limitations can be overcome by upgrading to more advanced sensors while keeping the overall solution the same.

References

[1] "2020 Fire Season | Welcome to CAL FIRE", Fire.ca.gov, 2020. [Online]. Available: https://www.fire.ca.gov/incidents/2020. [Accessed: 15- Oct- 2020].

[2] Testsite.autosafety.org, 2020. [Online]. Available: https://www.testsite.autosafety.org/sites/default/files/imce_staff_uploads/Drowning-Deaths-in-Motor-Vehicle-Traffic-Accidents.pdf. [Accessed: 15- Oct- 2020].

[3] A. Çetin, K. Dimitropoulos, B. Gouverneur, N. Grammalidis, O. Günay, Y. Habiboglu, B. Töreyin, and S. Verstockt, " Video Fire Detection Review", Digital Signal Processing, Elsevier , vol. 23, pp. 1827-1843, 2013.

[4] T. Blalack, D. Ellis, M. Long, C. Brown, R. Kemp and M. Khan, "Low-Power Distributed Sensor Network for Wildfire Detection," 2019 SoutheastCon, Huntsville, AL, USA, 2019, pp. 1-3, doi: 10.1109/SoutheastCon42311.2019.9020478.

[5] Assets.publishing.service.gov.uk, 2020. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/411184/Cost_estimation_for_flood_warning_and_forecasting.pdf. [Accessed: 15- Oct- 2020].

ISBN: 978-1-7281-8060-1