A Low-Cost Scalable Detection System for Forest Fires

Jahan Razavi and Norm Brennan

***Abstract*—**This paper presents a wildfire detection system to reduce chances of a large blaze. "PyroVision" detects the temperature and wirelessly transmits it to a receiver in the fire station. The transmitters are located on a grid system, enabling firefighters to know the location of the fire without using GPS. PyroVision transmitters consist of a temperature sensor, an Arduino board, and a Bluetooth module. The receiver consists of a Bluetooth module, another Arduino board, and a display. In our measurements, the transmission range was 170-250 feet (≈ 51-76 m) in an area with trees, and 290-400 feet (≈ 88-122 m) in a clear area. These measurements support the feasibility and scalability of our proposed system.

***Keywords*—** fire suppression, wireless system, Bluetooth transceiver, Arduino.

I. Introduction

FOREST, wild, and bush fires pose danger to humans, drain resources, and pollute the earth. The cost of wildfires in the U.S. alone (Fig 1) has been around 1-2 billion dollars per year, translating to about $200 per acre (≈ 0.25 hectares ≈ 4050 m^2 ≈ 64 m x 64 m) [1]. Similarly, bush fires in Australia cost about US$230 million annually [2], and forest fires in Indonesia cost approximately US$16.1 billion in 2015 [3]. By 2090, it is predicted that wildfire costs in Europe will go up by 200% [4]. Table 1 presents the number of hectares burnt across Europe, the Middle East, and North Africa in 2014, emphasizing the need for an efficient solution [5].

In creating a wildfire detection system, we face three challenges: detecting the fire, locating the fire, and transmitting the information over a long distance. This paper proposes a low-cost wildfire detection system that addresses these challenges and uses wireless technology along with an architecture that can be easily scaled to a large area.

II. Previous Solutions

There have been previous devices created to counteract the threat of wildfires. Those include the FireAlert MK1 [6] and the Wildland Detection Systems [7]. The FireAlert MK1 is an early-warning detection system that uses infrared to sense the fire. The disadvantages are that IR sensors are expensive and cannot see through trees. The Wildland Detection Systems consist of video cameras based on high vantage points to monitor flames and growth. The disadvantages are that the video cameras are expensive and they cannot see smoke at night. Neither solution meets all of the above challenges: detection, location, and transmission of information.

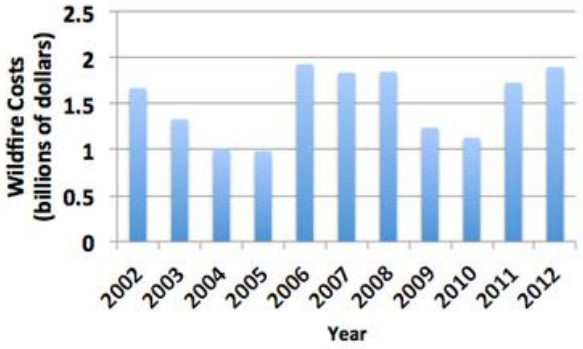

Fig. 1: Cost of wildfires in the US

Table I
Number Of Hectares Burnt And Number Of Fires With Areas Greater Than 40 Hectares In Europe, The Middle East, And North Africa In 2014

Country	Area (Ha)	Number of Fires
Albania	457.45	4
Algeria	63483.18	147
Bosnia and Herzegovina	3204.03	5
Croatia	304.73	2
Cyprus	435.85	2
France	4665.69	26
Greece	14813.97	31
Ireland	141.16	1
Italy	13250.53	78
Morocco	998.74	8
Norway	3335.85	6
Poland	54.43	1
Portugal	11573.71	35
Romania	2403.34	8
Spain	22053.32	62
Sweden	13630.76	12
Syria	2081.5	4
The Netherlands	395.95	1
Tunisia	11556.79	31
Turkey	7190.31	24
United Kingdom	85.17	1
TOTAL	***176116.45***	***489***

A third technique uses satellites to monitor forests and detect fires [8, 9]. This solution is extremely expensive and it requires complex algorithms to detect a fire automatically.

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Thus, there is a need for a system that can perform the three tasks in a cost-efficient manner.

III. Our Proposed System

Figure 2 is an illustration of our system, "PyroVision," in arge scale in the field. PyroVision consists of wireless transmitters, located on the corners of each acre, that send their information to the fire station. The distance between any two adjacent transmitters, ≈208 feet (or 64 m), plays a critical role in the design, which we will describe in Section 5.

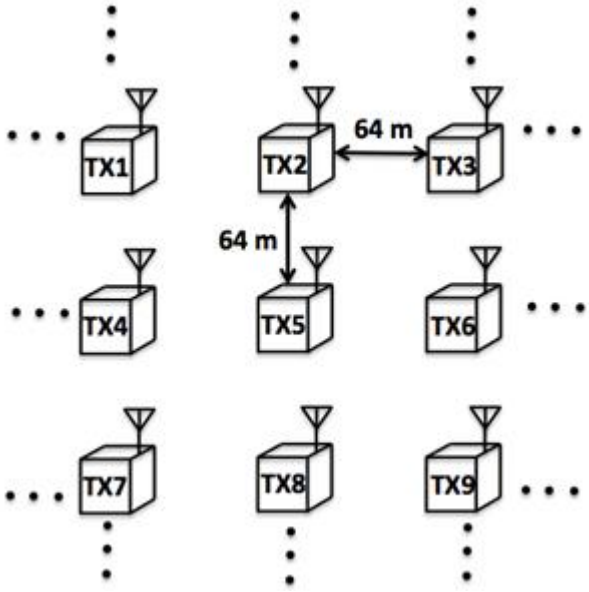

Fig. 2: PyroVision high-level diagram

Each PyroVision transmitter (TX), Fig. 3(a), consists of a temperature sensor, an Arduino Uno, and a Bluetooth transmitter. The system operates as follows. A TMP37 temperature sensor, manufactured by Analog Devices, detects the temperature, converts it to a voltage, and provides it to the Arduino, which is a small, low-cost, programmable computer. The Arduino converts the voltage to a digital output and gives it to an nRF24L01 Bluetooth transmitter along with an identification number. The Bluetooth transmitter wirelessly sends the data to a Bluetooth receiver in the fire station.

The PyroVision transmitter has several advantages over the previous solutions. It incorporates low-cost components and is easy to install. In an area of n^2 acres (an n x n array) in Fig. 2, the number of transmitters needed is $(n+1)^2$. We then find that for a large area, the number of transmitters is approximately equal to the number of acres. The total bill of materials for each PyroVision transmitter is about US$16, much less than the present suppression cost of US$200 per acre.

Each PyroVision receiver, Fig. 3(b), employs a Bluetooth receiver, an Arduino Uno, and a display. The PyroVision receiver functions as follows. The Bluetooth receiver receives the wireless information and sends the data, which consists of the temperature reading and the ID of the transmitter, to an Arduino. The Arduino compares the temperature to a custom threshold that represents the fire temperature. If the threshold is passed, there is a fire and the display corresponding to the PyroVision transmitter registers an alarm. The PyroVision receiver would be located in the fire station. Only one receiver is needed because the Arduino has the capability of supporting numerous transmitters.

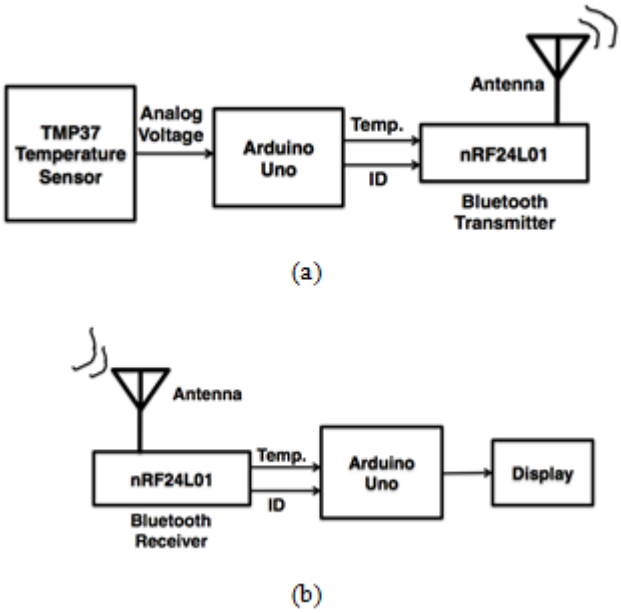

Fig 3: (a) PyroVision transmitter block diagram, (b) PyroVision receiver block diagram.

IV. Locating The Fire

As mentioned in Section 1, we face the challenge of locating the fire after it has been detected. The first obvious idea would be to use GPS in PyroVision, an expensive and power-hungry solution. To address this problem, we use a grid system (Fig. 4): each PyroVision transmitter has an ID based on the longitude and latitude of its location. The ID and the temperature are sent wirelessly to the PyroVision receiver in the fire station.

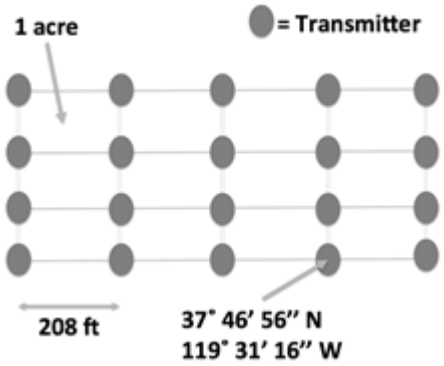

Fig. 4: Grid system for locating fires.

When the temperature passes the threshold, the receiver registers an alarm that shows the location of the fire based on the transmitter's ID. The fire station would have an online map that shows the approximate location of each transmitter.

V. Scalability

As discussed in Section 1, the third challenge is transmitting the data over a long distance. One possible solution would be

to use cellphone technology, but it is even more expensive and power-hungry than GPS. Bluetooth is a feasible solution that we employ but we are faced with the problem that Bluetooth cannot transmit information across a distance of over 140 feet (≈ 43 meters) with trees present (Section 6). To solve this issue, two measures are taken. The first is data hopping, which works as follows: TX1 in Fig. 2, for example, sends its data to TX2. TX2 packages the data with its own and sends it to TX3, and so on, until the result reaches the fire station.

In order for data hopping to successfully operate in Figure 2, the transmission range of the Bluetooth transmitters needs to be about 210 feet (≈ 64 m), which is quite larger than the 140-foot limitation. This limitation is caused by the poor transmission range of the nRF24L01 antenna [Figure 5(a)]. We addressed this shortcoming by replacing the Bluetooth receiver antenna with a dipole structure [9] [Figure 5(b)].

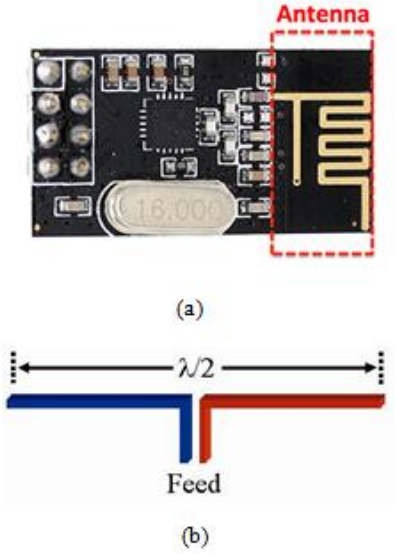

Fig. 5: (a) nRF24L01 antenna, (b) dipole antenna diagram, λ/2 ≈ 6.5 cm

The second measure is about the battery. The batteries in the field, if they stayed on all the time, would drain in about 1-2 days. To address this drawback, we turn each transmitter on for 0.1 second every few minutes. This enables a D battery to last several years. There is a delicate balance between the time the transmitter stays on and the time it stays off. If the PyroVision transmitter stays off for too long, the fire has the chance to spread over many acres before it is registered. On the other hand, if the transmitters stayed on for a minute, and off for the next, the battery would drain quickly.

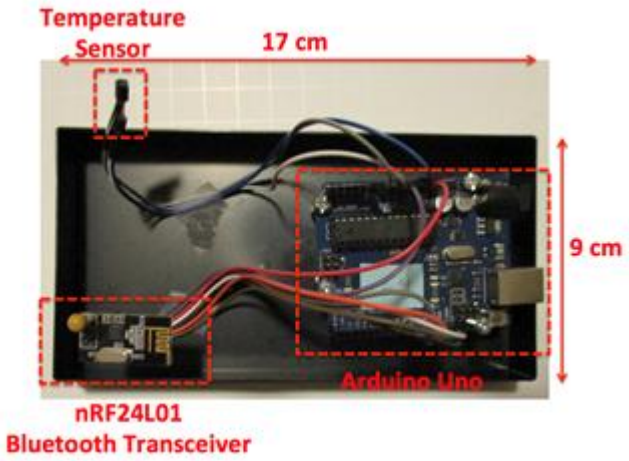

Fig. 6: PyroVision transmitter prototype

VI. Test Results

Our demo system consists of four transmitters, to simulate the four corners of an acre, and one receiver to simulate the fire station. The receiver constantly monitors the temperature readings sent by the transmitters. One PyroVision transmitter is shown in Fig. 6. The most important aspect of PyroVision is the transmission range, which needs to be at least 208 feet in our design. We tested the transmission distance between the transmitters and the receiver in two different areas in a park, one area with trees and one clear. The data for the transmission range is shown in Fig. 7. Our first measurements were with the original nRF24L01 antenna, resulting in a transmission distance of 150 feet in an area with trees. We then modified the receiver's antenna to a dipole. As seen in Fig. 7, the transmission distance increased to 170- 250 feet (≈ 51-76 m) in the same area. Finally, in a clear area with the dipole antenna, the range was about 290-400 feet (≈ 88-122 m).

In order to expand the range even further, we can also modify the transmitters' antennas and change them into dipoles. In the environments where the Bluetooth transmitters do not have enough range, the user can place the PyroVision transmitters in Fig. 2 more closely.

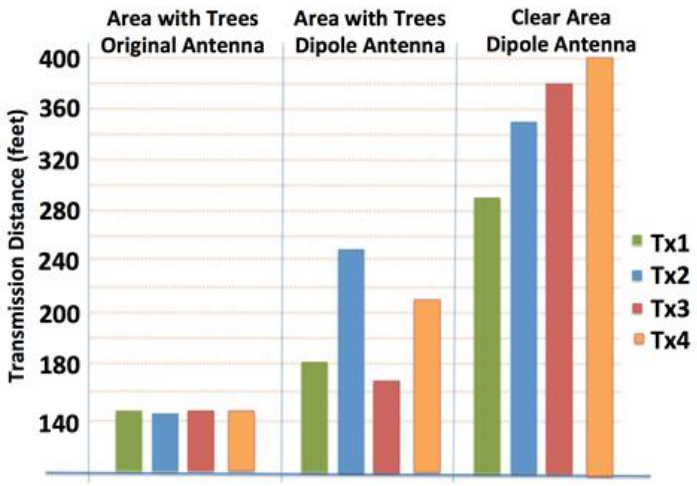

Fig. 7: Transmission range test data

VII. Conclusion

Forest fires are a major threat to humans and the environment. We have proposed a wireless solution to counteract wildfires that detects the fire, locates it, and transmits the information over a long distance. This low-cost system can be scaled to cover a large area. In our testing, we found that the transmission range in an area with trees reaches 170-250 feet while the range in a clear area reaches 290-400 feet, which suffice for our design. We have also proposed a grid system as well as data hopping for scalability.

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