Detecting Wildfires with the Internet of Things Wireless Sensor System

(Technical Report)

Preventing Wildfires, Mitigating Natural Disasters, and "Avoiding the Inevitable"

(STS Research Paper)

A Thesis Prospectus Presented to the

Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree

Bachelor of Science in Computer Engineering

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Fall, 2020

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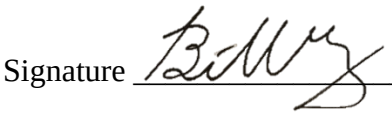
On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Signature  Date 11/02/2020

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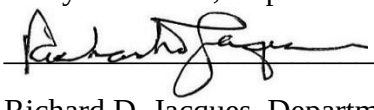
Approved  Date 12/01/2020

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Introduction

The recent phenomenon known as the Internet of Things (IoT) shows us a glimpse into a future where people rely on smart connected devices to solve various problems. However, people have only used IoT devices primarily in dense, urban areas and homes because they rely on existing electronic network technologies such as Bluetooth, short-range WiFi, and Ethernet, transmitting data based on proximity. With the emergence and ubiquity of novel wireless technologies such as Zigbee and LoRa and ultra-low-power hardware, it is now possible to use IoT devices remotely in rural locations to gather data from a broader geographical area. The emergence of these new technologies enables engineers to solve an even more comprehensive range of problems due to wireless technologies' increased capabilities and reliability.

Natural disasters, namely wildfires, have become an increasingly trending topic of the news lately. Beyond their immediate devastations, the enormous amount of smoke and ashes produced buries the surrounding areas, and the desolation of the ecosystem takes years, if not decades, to revive. The sensor system that we will design is a distributed IoT network that monitors and detects hazardous conditions, such as wildfires, remotely to help humans better respond to these significant threats, preventing large-scale fires and invaluable economic damages. Alongside the technical sensor system that we will be designing, I will further examine the implications of wildfires today. My STS research will dive into detail on wildfire's causes, ties to climate change and other catastrophes, and how humanity can rise to the challenge of combating natural disasters as such.

Technical Project

The 2019-2020 bushfire season in Australia destroyed an estimated 46 million acres of land and nearly 6000 buildings in a few months. Similarly, countless wildfires ravaged the California areas, causing millions of dollars in damages while displacing numerous families and calling for massive evacuations. A fast and reliable fire detection network can save countless lives and prevent millions of dollars in damage. The many current satellite-system forest fire detection implementations are prone to limitations, such as the lack of "omniscient coverage," often leading to delay in detection speed and failure in quality. Meanwhile, other methods utilizing automatic smoke detection usually run up maintenance and detection costs way too high (A. A. Alkhatib, 2017).

Our team aims to build a robust and smart monitoring system for monitoring wildfires by creating an IoT wireless network that utilizes sensors to collect and transmit data to existing web technologies. These web technologies, which consist of databases and data visualization dashboards, can visualize the data and provide meaningful feedback quickly and efficiently. We attempt to perform all the tasks listed above while prioritizing low-power and high-efficiency.

This project's inspiration came from the news in recent years due to climate change (Gary, 2019). It is also worth noting that Aeris and LADSensors have implemented a similar implementation of our solution in the past. Where metrics such as temperature, ambient CO2 levels, humidity, wind direction, and speed were measured to detect wildfires in early stages and predict their potential spread (Fight Forest Fires with Tech, n.d.). Furthermore, wireless sensor networks have been used to monitor plants, such as in aquaculture monitoring, which means that the project's technical nature is within the realm of possibility (Xiaoman & Xia, 2016). Our team intends to deploy this sensor system and data acquisition pipeline in regions, such as forests,

prone to dry climate or extenuating weather conditions to aid in the early detection of wildfires. If both technically and economically viable, this system would help first responders and/or other human operators go a long way. It will do so by providing early alerts to improve response time, ultimately leading to the prevention of such hazards, enacting prompt and appropriate responses (A. A. A. Alkhatib, 2014).

Our team will be building software, hardware, and firmware, using SDKs from Texas Instruments, CAD programs such as KiCad, National Instruments Multisim and Ultiboard, and editors Visual Code Studio and Code Composer Studio to aid our design. The building and testing will take place in the NI Lab, and throughout the developing phase, we will be working on the software, the firmware, and the hardware all in parallel. Under the supervision of professors Harry C. Powell and Adam Barnes, our team plans to finish the principal building and unit testing by Thanksgiving and complete the technical report by the start of December.

STS Research Paper

In May 2017, policy-makers and disaster management experts from over 180 countries gathered in Cancun, Mexico, to discuss ways to counter the ever-increasing trend of natural catastrophes. And in the middle of the Cancun summit, news arrived that large parts of Sri Lanka were devastated by floods and landslides, killing at least 150 and displacing almost half a million people (Eriksen et al., 2017). Calamity has been around since the earliest records of history, and the biblical Great Flood in the Book of Genesis is a prominent example. But in recent years, storms have grown wilder, and the weather has become more erratic. More and more of these cataclysms occupy the news, and we have grown accustomed to them over time. In the past few decades, rapid industrialization and modernization have resulted in tremendous growth in society and generated welfare beyond measure. But have we been developing in our best interests, have we been doing so in sustainable ways, have we exploited the Earth in irreversible ways, and do our deeds play a part in mother nature's disaster calls? These are all questions essential to humanity because natural disasters are perhaps the most devastating events in history, much more so than warfare. It is paramount that society strives to "do our part" and endeavor to eliminate technological disasters and reduce natural catastrophes.

There exist plenty of voices and theories which go against such effort. Many indeed think that mankind cannot and should not stand "against" mother nature, those disclaiming climate change. But whether "climate change is a hoax" is a political point of view that people are free to support, its real-world implications are needless to argue. Climate change is a likely significant cause of natural disasters, even without direct connections, since it affects our planet in several different ways. It increases ocean temperatures, which in turn brews stronger storms. It also leads to an increased probability of droughts as the average temperatures have risen, setting optimal

conditions for wildfires (Ritchie & Roser, 2014). It ultimately rests on the government's shoulders to lead its people towards greener lifestyles, which will, in turn, lighten the intensity of climate change and ease its effect on the increasing number and intensity of natural disasters. Of course, the people have to answer the call, but no individual nor group is capable of the assembly. If society can implement technology to maximize the effort to help counter such catastrophes, countless lives and an invaluable amount of losses can be saved.

While my project is one specific implementation that targets combating and preventing wildfires, my research will discuss wildfire prevention and awareness and elevate to the broader scheme of coping with natural disasters, confronting mother nature. To answer such a question of "how to mitigate natural disasters," we need first to understand the issue itself, these catastrophes, and how and why they occur. We need to examine the affected regions closely to learn their geography, climate, and culture to better assess situations. Finally, to fully interpret the root cause and propose plans, we will need knowledge from the engineering fields across to the humanities, math, physics, economics, politics, sociology, and many more. But of course, no expertise is required in any field; the basics and the interactions between these contrasting areas are sufficient to govern in the right direction. And luckily, in today's age of the Internet, knowledge has never been more accessible, and we need not start from "Ground Zero" and master every subject. Reading the journals, marking the articles, and analyzing the data and numbers are the best ways to internalize information and externalize thoughts.

The general topic area for my research is "coping with natural disasters." And in response to my technical project, I hope to answer the question of "how to monitor and prevent wildfires efficiently" and "how to mitigate natural disasters with technological advancement and avert natural disaster's adverse effects" by the end.

Conclusion

Although the research is still cultivating, my team has a concrete technical project to work on and present. By the end of the project, we will have a wireless sensor system capable of communicating and transferring data through the WiFi. Should we succeed in developing a low-power and high-performance sensor system, not only will we be able to monitor forests but also in parks, preserves, and virtually any extensive "woody areas" prone to wildfires. On the other hand, my research will complement the project aptly as it explores wildfire prevention's social and political aspects while raising its awareness. Above all, it will also expand wildfire prevention into a broader scope of natural disaster mitigation and shed some light on how our society can strive to "avoid the inevitable."

References

Alkhatib, A. A. (2017). Forest fire monitoring. *Forest Fire*. https://doi.org/10.5772/intechopen.72059

Alkhatib, A. A. A. (2014). A review on forest fire detection techniques. *International Journal of Distributed Sensor Networks*, *10*(3), 597368. https://doi.org/10.1155/2014/597368

Eriksen, C., Roth, F., & Prior, T. (2017, June 27). *Understanding the root causes of natural disasters*. The Conversation. http://theconversation.com/understanding-the-root-causes-of-natural-disasters-80017

Fight forest fires with tech: How forest fire-prone regions leverage iot to limit wildfires and mitigate destruction. (n.d.). Aeris. Retrieved October 7, 2020, from https://www.aeris.com/news/post/fight-forest-fires-with-tech-how-forest-fire-prone-regions-leverage-iot-to-limit-wildfires-and-mitigate-destruction/

Gary, E. (2019, September 10). *Satellite data record shows climate change's impact on fires*. Climate Change: Vital Signs of the Planet; NASA's Earth Science News. https://climate.nasa.gov/news/2912/satellite-data-record-shows-climate-changes-impact-on-fires

Lone, R. I., & Subramani, Dr. S. (2016). Natural disasters: Causes, consequences and its preventive role in sustainable development. *The International Journal of Indian Psychology*, *3*(3), No. 4.

R., B., A., W., & D., G.-S. (2009, October). *Disaster category classification and peril terminology for operational purposes | centre for research on the epidemiology of disasters*. https://www.cred.be/node/564

Ritchie, H., & Roser, M. (2014). Natural Disasters. *Our World in Data.Org*. https://ourworldindata.org/natural-disasters

Xiaoman, L., & Xia, L. (2016). Design of a ZigBee wireless sensor network node for aquaculture monitoring. *2016 2nd IEEE International Conference on Computer and Communications (ICCC)*, 2179–2182. https://doi.org/10.1109/CompComm.2016.7925086