EXTENDING INTERNET TO POWERLESS AREAS

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Extending Internet to Powerless Areas

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Literature Review

The lack of internet in undeveloped countries and other rural areas is detrimental to the development of the area. Access to internet can have many profound effects on developing countries such as creating economic opportunities for small and medium sized businesses (Meltzer) and improving education (Purdue). In many of these rural areas and developing countries, such as Africa, children do not have up to date education (The Economist), people struggle to find jobs (ACET), and the infrastructure is lacking (The World Bank).

The lack of internet in areas that have been affected by natural disasters is also a large problem that our society faces. Areas where the cellular towers and power generators were knocked out would benefit greatly from connectivity because it would allow the affected community to communicate with outside help. One example of when internet needed to be extended to an area affected by disaster is Puerto Rico after Hurricane Irma knocked out over 90% of their cell service (Fiegerman).

Some companies have attempted to create solar powered wi-fi hotspots, but none of them are implemented in the way that we plan to solve the problem. No product exists that can provide internet without cellular coverage nor a power grid. However, there are a couple of products that are in our area of research. The company Soluxio has created a solar powered wi-fi extender/LTE wi-fi hotspot. This is primarily for creating outdoor wi-fi networks in places with an existing internet connection or for resorts and city parks in developed areas where LTE data is available (Soluxio). The company Moja has created a microserver that also connects to LTE data. This device has the option to be solar powered, but it also has the same limitation as the Soluxio device in that it relies on LTE data which does not cover a large portion of the globe (Moja).

Thesis Statement

Design a system/device that can provide internet to areas that do not have reliable power or cellular coverage.

Project Description

The purpose of this research is to test the viability of extending the reach of the internet to rural areas that do not have access to consistent electricity or cellular coverage with a device that can provide internet without connection to a power grid. Many people in developing countries currently do not have access to the internet. If this research is successful, we will be able to supply developing countries with reliable internet access which will potentially improve education, infrastructure, and the economy.

DEDICATION

We are dedicating this paper to Gale, Daisy, and Cloud. We are also dedicating this paper to our parents, Curt and Jiulian Doerfler.

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I would like to thank my professor Dr. Gwan Choi for his amazing guidance and support throughout the course of this research. He took us in when no one else would.

Finally, thanks to my mother and father for their encouragement and to my wife for her patience and love. She is also working on this research so thanks to my husband as well.

KEY WORDS

GHz	Frequency, Gigahertz, 10^9 Times/second
KWH	Kilo Watt Hour, measurement of energy
Wi-Fi	Wireless Fidelity, IEEE 802.11

INTRODUCTION

This report will consist of a comprehensive synopsis on our research on bringing internet and connectivity to areas that lack power and internet. Internet connectivity is quite crucial to growing a community, from bringing new information to everyone to communicating information to distant people. There are many areas in the world that do not have or have very sparse internet connections; some areas may even lack reliable power. There seems to be no device on the market that can provide an area with 24/7 internet connection and be self-sufficient. That is why we have taken on the task to design a system/device that can provide internet to areas that do not have reliable power or cellular coverage. Currently the best solution to bringing internet where little to no coverage exists is by using Google's Project Loons which extends 4G and LTE coverage from a balloon. Numerous balloons were deployed to Puerto Rico after the hurricane hit. The connection speed is also not even sufficient to make phone calls. (Verger) This type of coverage does not solve a few significant problems. Most of the Puerto Ricans did not have power. Their mobile devices were useless after a day or two; also, many people's electronics/laptops do not have LTE or 4G capabilities. Sending all those balloons and covering 70% of the Puerto Rican population with LTE did not solve their communication problem.

CHAPTER I

ELECTRICAL DESIGN

Design Requirements

Based on the lack of a well-rounded system/device that can provide internet to an area without power or cellular coverage, we have come up with several design requirements. Our device needs to be able to power itself, and maybe even provide some excess power to the client. The device also needs to have an on time of 24 hours a day and have a product lifespan of roughly 10 years. When selecting electrical components, we must also consider the weight of the components to keep installation simple and easy. Below, in Figure 1, is a more concise and visual representation of the requirements that need to be met by our self-sufficient internet system.

Data System	Able to handle at least 20Mbps
	Provide IEEE 802.11 ac/b/g/n (Wi-Fi) signal
	Able to handle at least 20Mbps
	Remote bandwidth control
	Remote reboot functionality
Power System	Able to be to function 24/7 majority of days
	Needs to be able to power everything
	Possibly even provide excess power to client

Figure 1. Electrical system requirements

Power System Design

Power for the system is the most crucial aspect of our design. Looking at our system's power requirements, which needs to include, and power simultaneously, a router, modem, satellite communication dish, inverter, microcontroller, fans, and various sensors at the same time, the power source would need to be quite reliable and powerful. After extensively researching possible energy sources, we have determined that solar energy is the most viable and widespread renewable energy source. Because of this, solar power is a very viable source of energy for our system. Areas from the top of the United States of America all the way to the bottom of South America have at least 2.5-3 average hours of full intensity sunlight over one year. That is also the case with areas south of Russia and France through South Africa and Australia. (Figure 2) Anything above 2.5 hours of full intensity sunlight is plenty of sunlight to power our device. Full intensity sunlight is regarded as 1000 watts per square meter. When a solar panel is advertised as 100 watts for example, that panel can produce 100 watts when there is 1000 watts of solar power per square meter shining directly on the panel. This does not mean that 2.5 hours of full intensity sunlight will generate 250 watt-hours of energy because there are other hours of less intense solar power throughout that day.

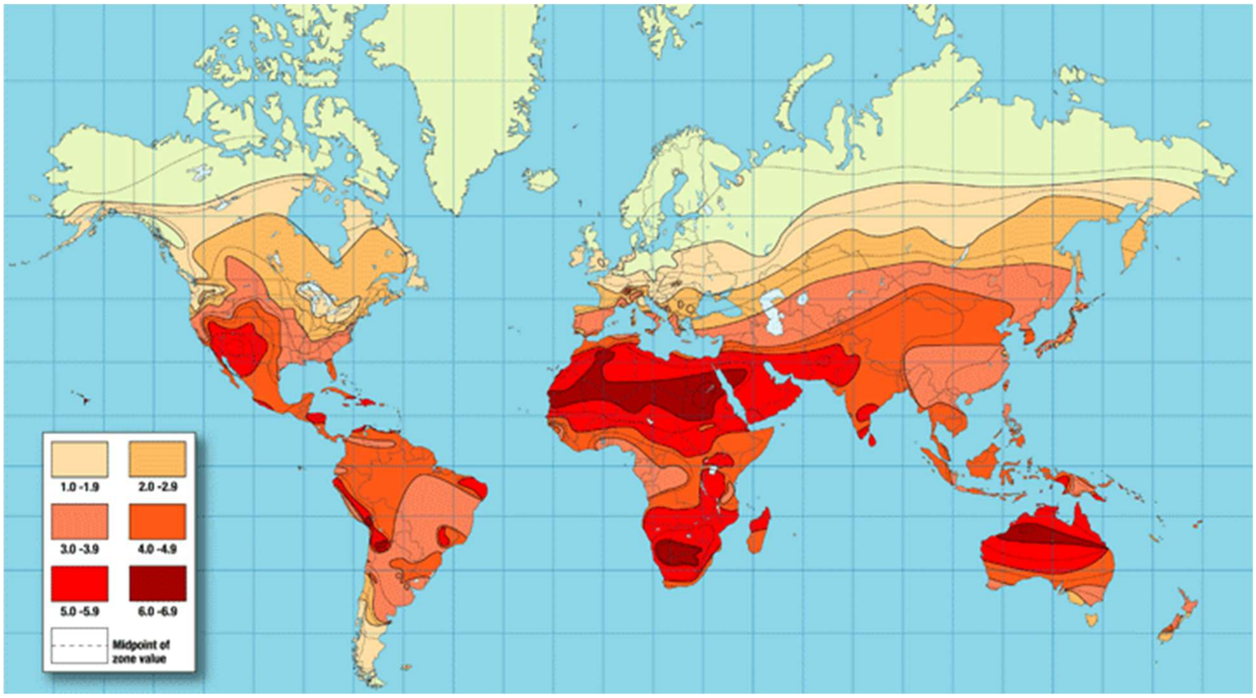

Figure 2. World map with average number of hours of daylight by region

Many people assume there will be 8 hours of sunlight each day, but based on what we have stated above, that is incorrect. A safer assumption would be 3 hours of sunlight per day, so that is what we will assume for the scope of this research paper. This assumption aligns with the main goal of the device, which is to provide internet access to those affected by natural disasters such as hurricanes. Based on the world map of natural hazards by region (Figure 3) and the world map of average number of hours of daylight by region (Figure 2), the areas that are most often affected by hurricanes receive more than 3 hours of sunlight per day. If the device will be deployed in an area that receives less sunlight, more solar panels can be added to accommodate the lack of sunlight.

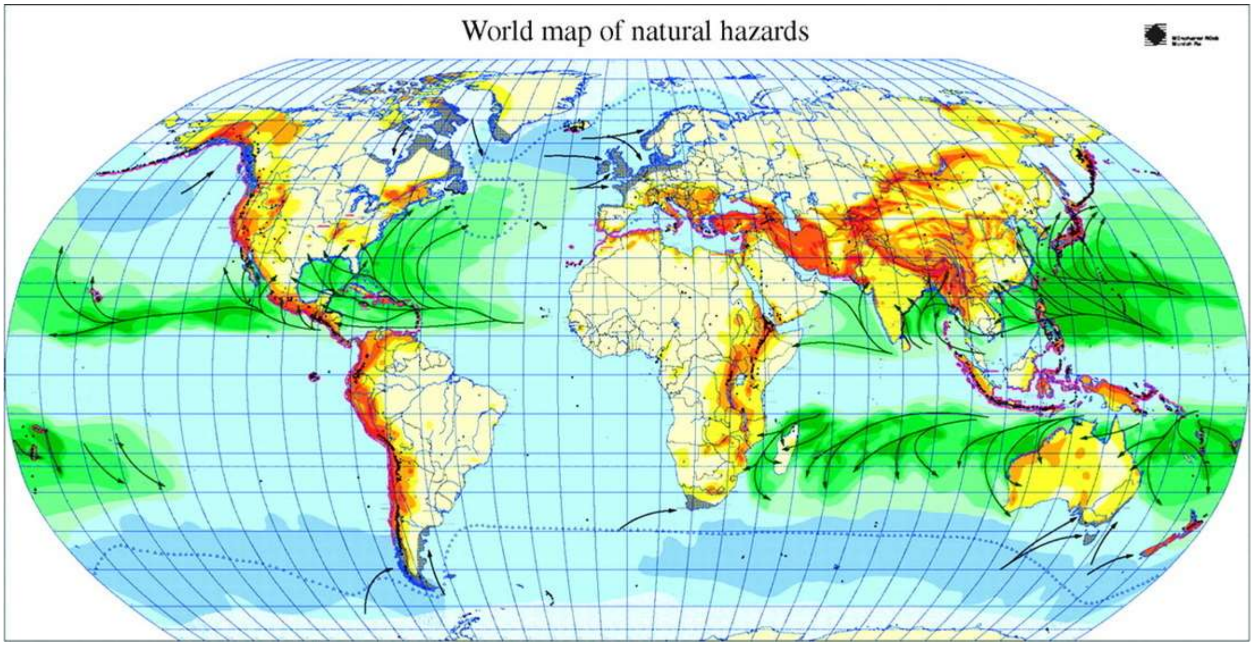

Figure 3. World map with natural hazards by region

The overall power system (Figure 4) receives power from the sun through solar panels which then goes through the charge controller to the Lithium ion Battery. The DC power output from the battery is converted to 120V 60Hz AC power with an inverter and then distributed to the satellite dish, router, modem, raspberry pi, and GPS.

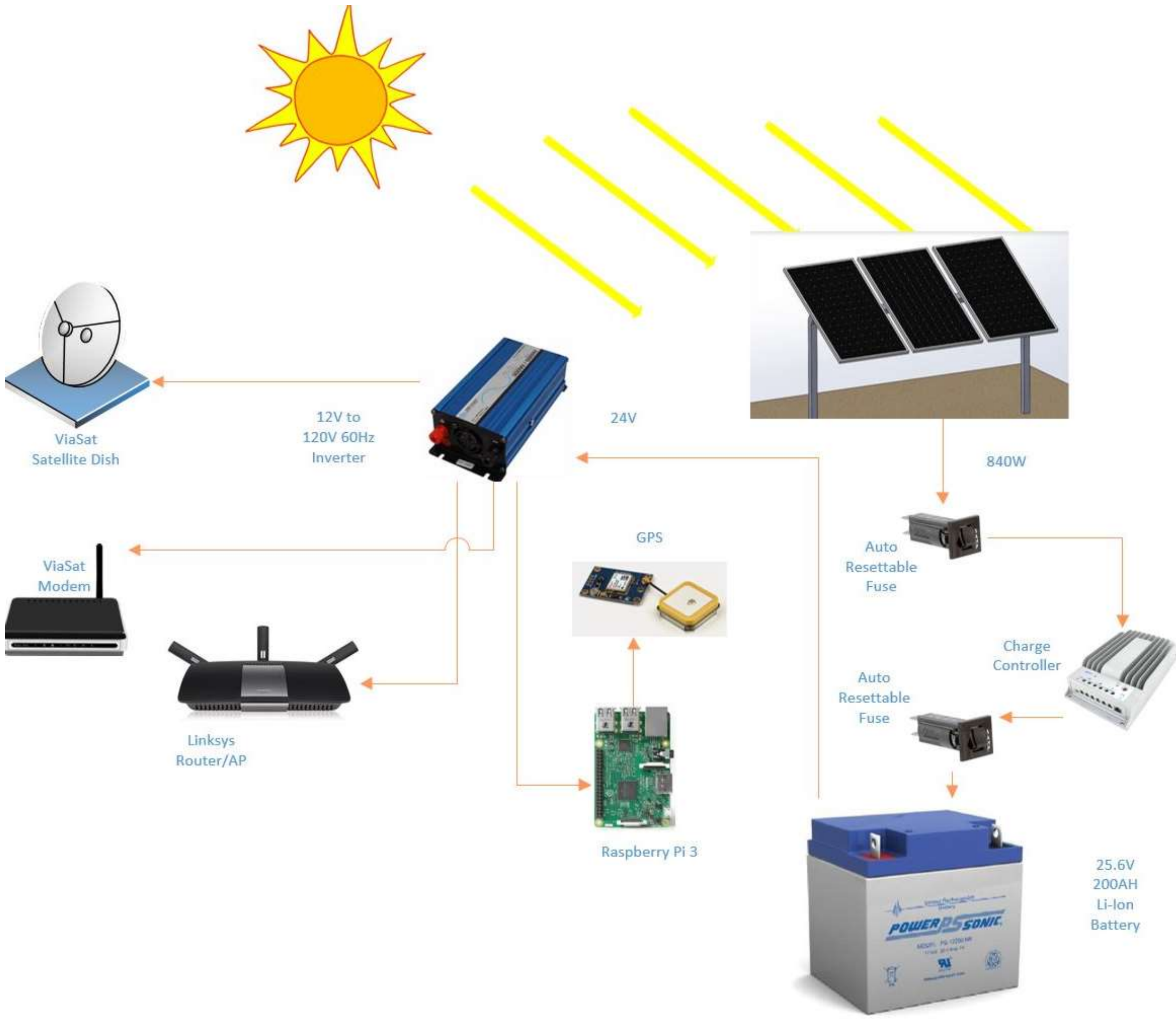

Figure 4. System power diagram

Data System Design

The overall data system (Figure 5) receives data from the satellite to the dish which then passed the data through the modem to the Wi-Fi router. The Wi-Fi router then passes the data to various user devices such as laptops. This dataflow also works in reverse with users being able to send data back to the satellite. The modem also connects directly to the raspberry pi which receives diagnostic data from the temperature sensor, GPS, and charge controller.

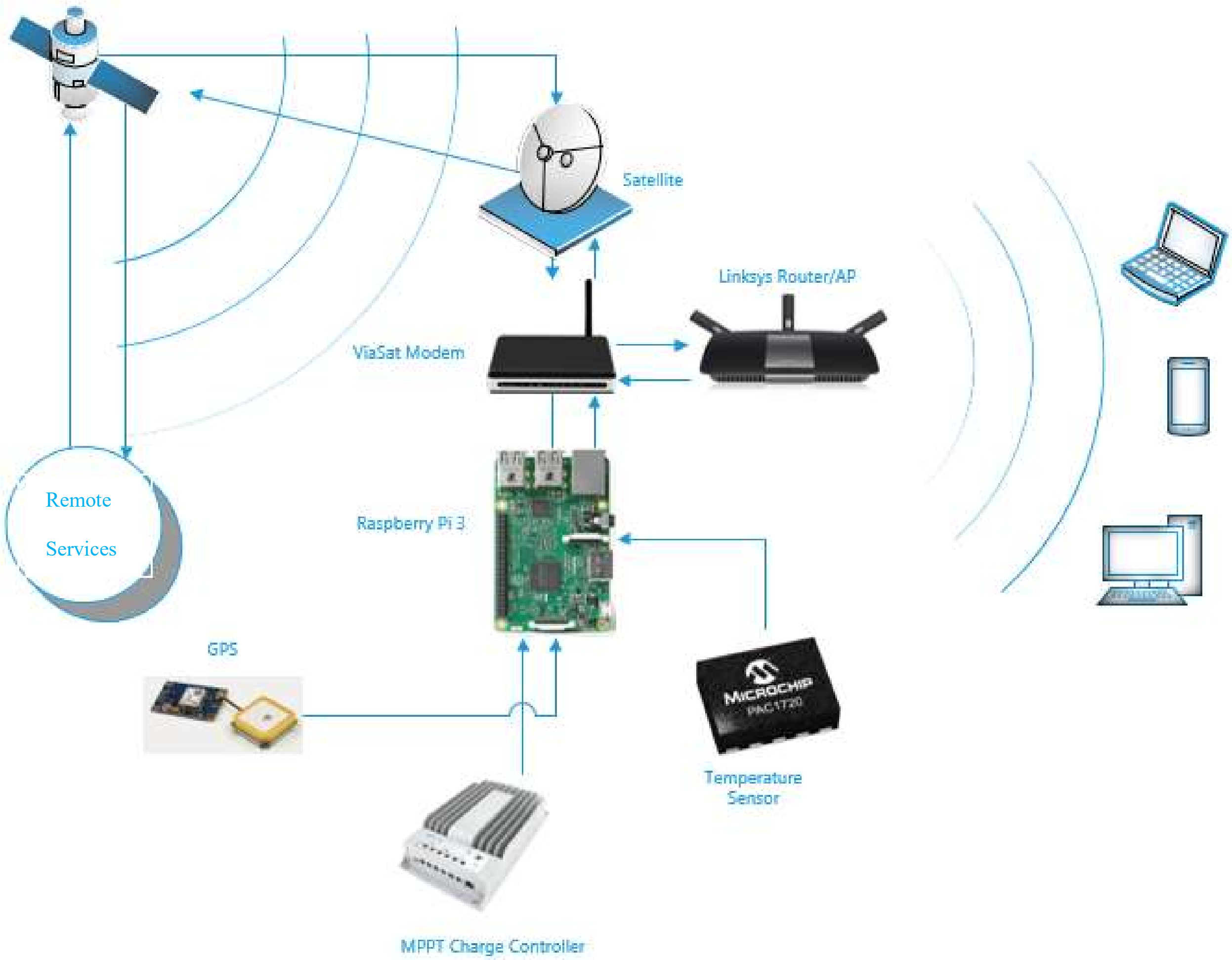

Figure 5: System data diagram

Parts

Based on the requirements listed above, we have chosen the following equipment listed in Figure 6 to go inside our system. The majority of these components are generic and not a specific brand. All of these components were picked to fulfill a requirement and are replaceable by other devices of similar function and formfactor. Each components' roles are explained in greater detail in the previous subsections of this section of the paper.

Item	Power Consumption	Purpose	Price
Raspberry Pi 3 with preloaded SD card	<1W	Information Processing	$41.98
GPS Receiver and resistor	<1W	Location monitoring	$9.55
Temperature Sensor and resistors	<1W	Temperature monitoring	$0.21
5KWh Li-Ion Battery	N/A	Power storage	$2350.88
3x280W Solar Panels	-840W	Power generation	$388.08
MPPT Charge Controller	~2% of power converted	Device safety	$137.50
300W Inverter	~5% of power converted	Power conversion	$74.00
Router	5W	Convert satellite to WiFi	$169.99
Satellite Antenna	75W	Sends and retrieves data (internet connection)	$140.00
Cooling Fans	0.25W per fan	Device safety	$1.57
			Total: $3313.76

Figure 6. Summary of parts required for the electrical design and their prices

Our device is designed to be able to power itself, be weather resistant, provide a IEEE 802.11b/g/ac (2.4 GHz and 5 GHz Wi-Fi signals), modular (easy to replace and repair broken parts), and even provide some excess power to the users. Since most of the Puerto Ricans do not have power or lights still, it would be imperative to have some sort of power source functionality. Our system is capable of producing its own power and sustaining itself and even some excess power to the client. Our system also provides the more widespread and accessible Wi-Fi signal as opposed to 4G/LTE.

CHAPTER II

MECHANICAL DESIGN

Design Requirements

The device needs to have a product lifespan of roughly 10 years. Since many use cases for our device involves disaster relief areas, the device also needs to be able to withstand very rough climates and weather conditions. Weight and size would also need to be factored in since Puerto Rico's recovery efforts are mainly limited to the physical transportation of aid supplies. (Robles, Mazzei) The device would need to be light enough to transport easily by vehicle or even parachuted in to the disaster areas via air planes. Installation would also need to be completable by a couple of people. Below, in Figure 7, is a more concise and visual representation of the requirements that need to be met by our self-sufficient internet system.

Physical Design	Under 300 lbs combined weight
	Withstand various climates and weather
	Not easy to steal or break into
	Lifespan: Minimum 5 years, target 10 years
	Assembly possible by locals

Figure 7. Mechanical System Requirements

Electronics Housing Design

The electronics housing must be able to protect the power and data components from the environment that the device is located in. In many disaster relief scenarios, there will be heavy rain as well as extremely strong and fast winds. Another concern is protecting the electronics from being taken by thieves. While we must focus on keeping the electronics safe from the climate and thieves, we must also focus on ensuring that the electromagnetic signals can properly propagate through the housing material.

Metals and other conductive materials will block or absorb wireless signals going to and coming from the wireless router inside. Therefore, the housing is composed of High Density Polyethylene (HDPE) (Figure 8). HDPE is recycled plastic, and it is an abundant and sustainable resource. Due to the wireless nature of our device, we need the material to have very low propagation loss. HDPE is quite strong and has a very low loss tangent. The housing design will also include special locking screws for security and PTFE filters to allow air to flow through while keeping water out (Figure 8).

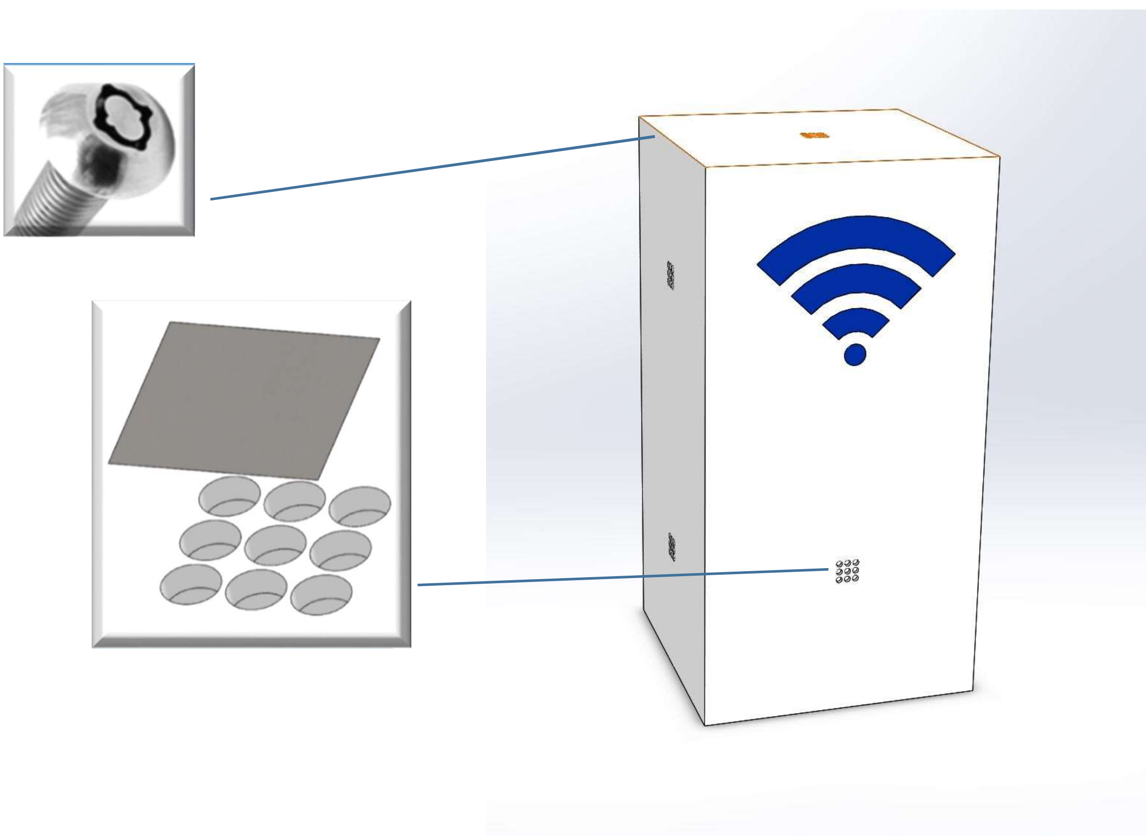

Figure 8. Housing Design

Solar Panel Mount Design

The only components that will not be kept in the HDPE housing will be the solar panels and satellite dish. These will be mounted on a roof (Figure 9) or on a pole (Figure 10) mount. The roof and pole mounts are constructed using rolled steel and built to withstand wind speeds of up to 75 miles per hour.

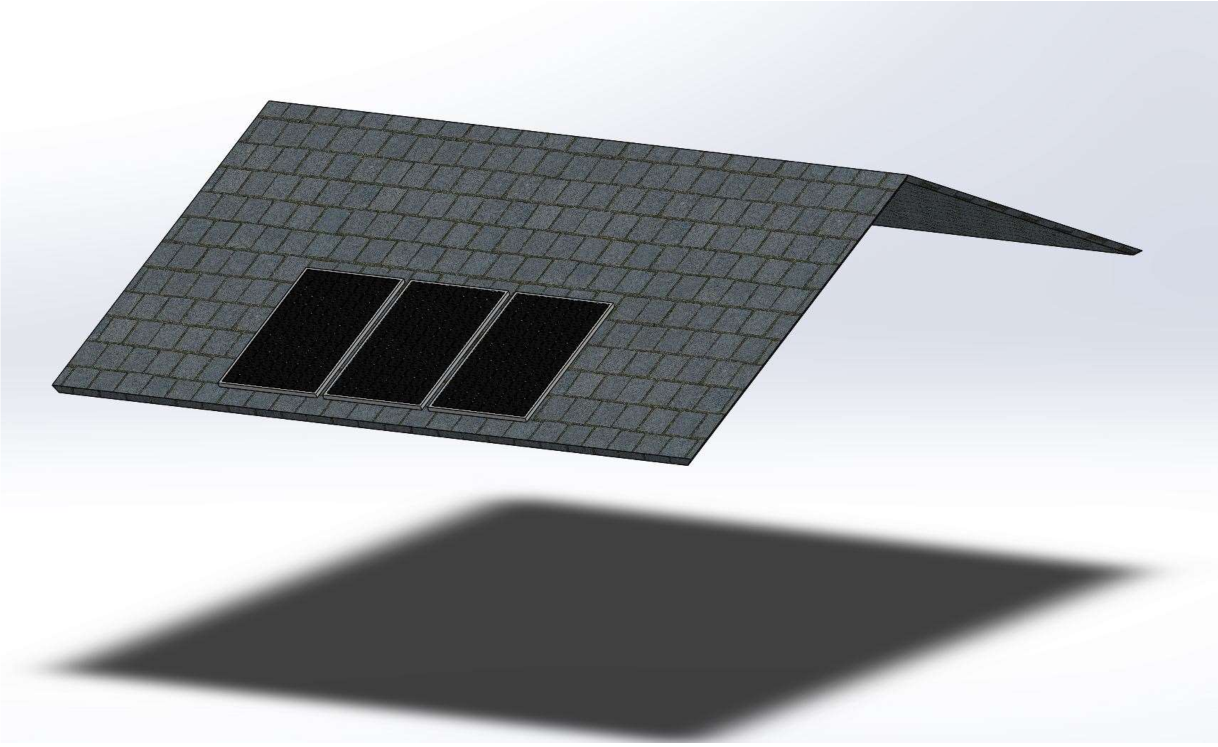

Figure 9. Solar Panel Roof Mount

The roof mount design is less expensive than the pole mount design, however it can only be used in areas with the proper infrastructure. The main advantage to the pole mount design is the fact that it can be deployed pretty much anywhere as long as it can be buried 3 feet in the ground. Concrete will add extra security, but it can actually be buried in dirt with no concrete and still withstand winds of up to 75 miles per hour.

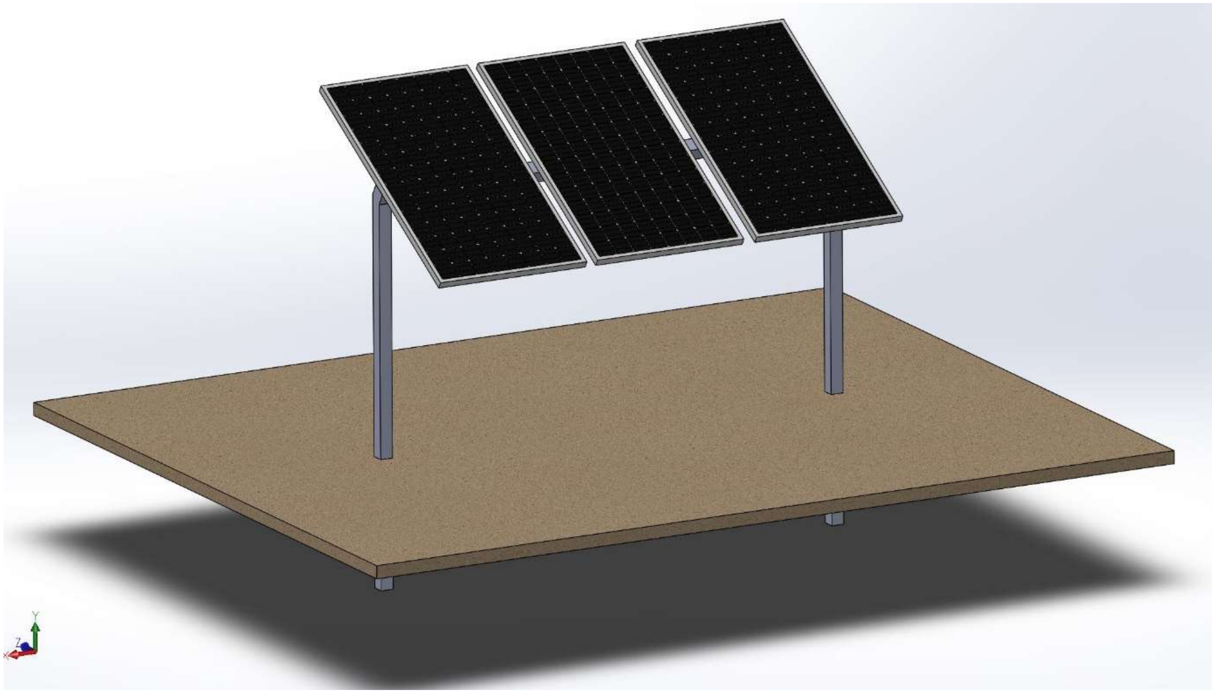

Figure 10. Solar Panel Pole Mount

Parts

Based on the requirements listed above, we have chosen the following equipment listed in Figure 11 to go inside our system. We have consulted several industry experts regarding the viability and pricing of our mechanical design. Each components' roles will be explained in later sections of this paper.

Item	Purpose	Price
HDPE Housing	Protest electronic components with minimal signal loss	$217.80
Pole mount kit	Protect solar panels while positioning them in such a way as to maximize solar energy received	$385.00
Wires	Connecting various electrical components over various distances	$13.20
Solar panel connectors	Connect solar panels to each other	$11.00
PTFE Filters	Allow for air to pass through the HDPE housing while maintaining watertight integrity of the system	$3.00
		Total: $630.00

Figure 11. Summary of parts required for the mechanical design and their prices

There is a slight variation in cost for the system that utilizes the roof mount. This is shown in Figure 12. The main difference between the two solar panel mounting choices are price and security. The roof mount is much cheaper than the pole mount.

Item	**Purpose**	**Price**
HDPE Housing	Protest electronic components with minimal signal loss	$217.80
Roof mount kit	Protect solar panels while positioning them in such a way as to maximize solar energy received	$110.00
Wires	Connecting various electrical components over various distances	$13.20
Solar panel connectors	Connect solar panels to each other	$11.00
PTFE Filters	Allow for air to pass through the HDPE housing while maintaining watertight integrity of the system	$3.00
		Total: $355.00

Figure 12. Summary of parts required for the mechanical design and their prices

CONCLUSION

Overall, the Solar Powered Wi-Fi Hotspot design has proven to be an extremely viable solution for both extending the reach of Wi-Fi to remote areas as well as providing internet connection and some power to those that have been affected by natural disasters around the globe. From its completely self-reliant power source to its more accessible IEEE 802.11 Wi-Fi signal, it fulfills the needs that no other commercial device can. In future iterations of this research, we will look at ways to improve the power efficiency of the system and further extend the area that the device can provide internet access to. One method we will explore is the possibility of utilizing a nodal design in which only one main node will have this design and other nodes will have wi-fi extenders instead of their own individual satellites.

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