Mesh Sensor Network for Atmospheric and Weather Data Acquisition

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Abstract-*The mesh sensor network can track the atmospheric and weather conditions on the campus are essential to informing and educating students about their environment. In this journal investigated a way to gather weather and atmospheric data using a mesh sensor network. This application the mesh network must fulfill the requirements of reliability, minimal latency, minimal bandwidth usage, and minimal power consumption. The network consisted of individual nodes and a central node or base station. Each of these nodes were designed gather sunlight, humidity, and temperature data. The base station gathers the same data as well as information about ozone levels. The base station also was designed to act as a relay to move the gathered data off of the mesh network and into an Internet accessible database. The system was tested using three nodes and a base station. Each node was one hundred to two hundred feet from either the base station or another node.*

Keywords: Mesh Network, Wireless, Solar Powered, Self-Sustaining, Sensors, Sensor Node, Weather Data, Atmospheric Data .Management, Measurement, Performance, Design, Reliability, Experimentations.

I. INTRODUCTION

To help in this effort, the chemistry, physics, and art departments have begun a paper to increase awareness about the air quality on the campus. They proposed and have begun work on a sculpture and accompanying electronics to monitor ground level ozone and display those levels in an informative and artistic way [2].

This journal sparked interest in not only monitoring ozone levels, but also in monitoring other environmental data such as temperature, humidity, and ultraviolet/sun light level. One way to educate students about sustainability and the environment is to engage them with a creative display detailing information about the environment where they live, work, and attend school.

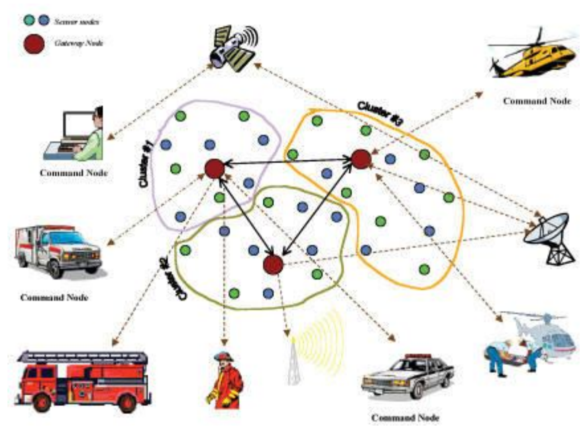

Fig 1: Wireless Mesh Sensor Network

The ozone paper understood this. They created an engaging piece of eye catching art intended to draw your attention and then educate you about ozone levels. Because they already had the sculpture in place, it was decided that augmentation to the existing system would be the best way to bring attention to the additional environmental data. Thus, the goal for this paper was to develop a system to collect temperature, humidity, and sunlight data and transmit it to a small computer located at the sculpture. This data could then be incorporated into the ozone paper's display at a later time.

II. SYSTEM CONSTRAINTS

The first step was to decide how, what, and where the additional data would be gathered. The question about where the data would be gathered influenced strongly the other two decisions. First of all, data was to be gathered from multiple points across the campus to allow for averaging differences in readings. Secondly, large installations were not feasible due to cost and space availability. Thirdly, in keeping with the sustainability principle these new data gathering stations needed to be solar powered. This meant they needed to be in a position that allowed them to get as much sunlight as possible. This also meant that the stations had to be small enough to be attached to the tops or sides of buildings or affixed to something like a light pole. Due to the limitation in size, the stations would only be able to generate a small amount of power. This limited the types of sensors and equipment that could be used to gather the data. Three data types were selected, ultraviolet/sunlight, temperature, and humidity.

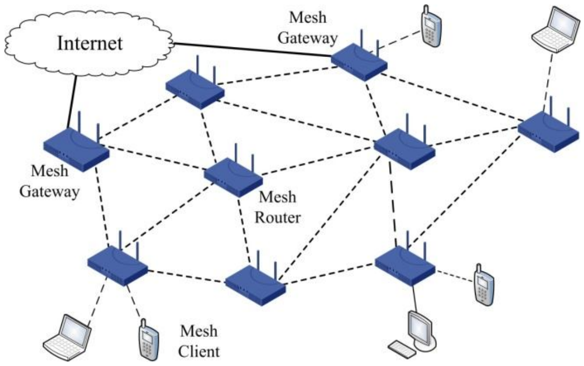

Fig 2: Wireless system constraints

Thus, the data was to be gathered as follows: a small station that was solar powered, using three small low power sensors to gather the ultraviolet/sunlight sensor, a temperature sensor, and a humidity sensor. These would be controlled by a low power controller that was paired with a small low power wireless transceiver. Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

III. MESH NETWORK

Wireless technologies allow for flexible device placement. Wireless communication comes with its own problem though: power requirements. Wireless technologies like Wi-Fi and cellular radios require massive amounts of power. This meant that the existing Wi-Fi infrastructure on the campus was infeasible. Low power point to point transceivers provided a viable alternative.

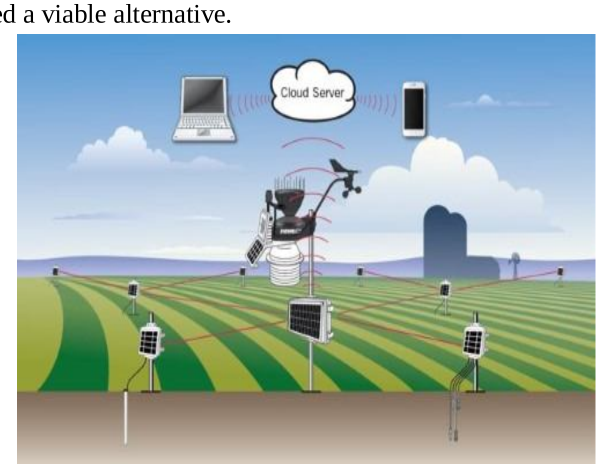

Fig 3: Flexible data weather accessing

The difficulty with lower power receivers is the distance at which they can communicate. For instance a sensor station on one side of the campus would not be able to communicate with one on the other side of the campus.

One way to resolve this is to use a network organization scheme known as mesh networking. In a mesh network every transceiver acts a relay, and every node is not necessarily connected to every other node. In order to get a message to node C, node A has to find a node or a series of nodes that can reach Cnode A can reach node B, and node B can reach node C. So if node A gives the message to node B, node B can then pass that message on to node C. Through the use of a mesh network configuration, low power radios can be used to send messages over distances that would normally not be achievable due to their limited range. In this research a wireless mesh network system was built to provide a reliable way to aggregate data gathered on a set of distributed nodes. The reliability of such a mesh network was investigated by examining its ability to provide consistent service.

IV. METHODLOGY

Materials

In order to investigate the reliability of a mesh network as a system for gathering weather and atmospheric data, a prototype system was necessary. It was decided that a custom built system would be used for two reasons. Using a custom system allows for an exact understanding of how the system components would affect the results. In addition, a custom system allows for direct programmatic control enabling modifications to improve the system performance according to the environment. The design and specifications of this system are described below.

Nodes

node is composed of four major components, a controller, a wireless module, a set of sensors, and a solar panel based power source. These components are either placed inside or affixed to the exterior of a hard-plastic, water tight enclosure. When deployed these nodes are placed outdoors in an area where they receive optimal sunlight for power generation. The controller chosen was an Adafruit Feather M0 Basic Proto - ATSAMD21 Cortex M0.

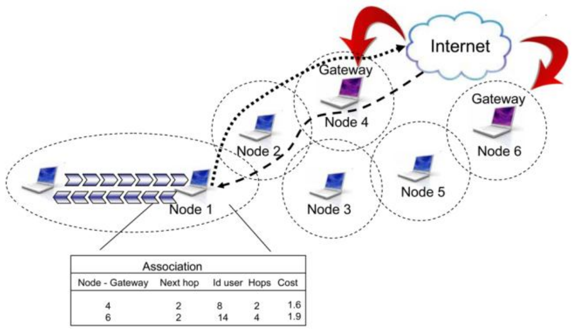

Fig 4: Mesh Network node connection

This controller was an ideal solution because it possessed the necessary sensor interfaces, was compatible with the selected wireless module, and had the necessary circuitry for charging a battery using a solar panel. There were a number of challenges that had to be addressed while selecting a wireless module. Power consumption and operating frequency were the most challenging. Originally the plan had been to use a module called the ESP8266. This module operated using Wi-Fi in the 2.4 GHz band. After consideration this module was ruled out because it could consume as much as 170ma. Also the network administrators in the area where these nodes would be deployed did not want devices broadcasting in the 2.4 GHz band.

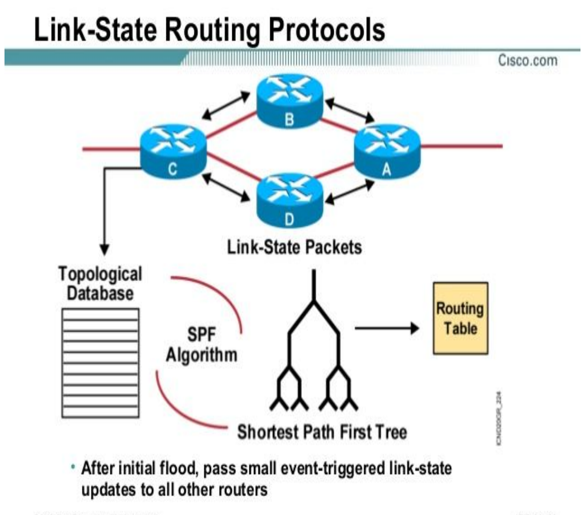

Fig 5: Routing Protocols

The second module considered was an XBee Pro 900. This module solved the operating frequency dilemma. It operated in the 900 MHz band, one that the network administrators were not using and thus did not cause any problems. However, it made the power problem even worse. This second module could consume as much as 210ma. The third module considered, and the one selected for use, was a HopeRF RFM22B-S2. This module met the needs of the paper, using only 87ma and operating the 900 MHz band. Three sensors were selected: a temperature sensor, a humidity sensor, and an ultraviolet/light sensor. These sensors were selected to gather basic weather data and atmospheric data. The specific sensors – the Waterproof DS18B20 from Adafruit, the DHT11 from Adafruit, and the SI1145 from Adafruit – were selected because of their ease of integration with the selected controller. The power component of each node is a combination of the charging circuitry built into the controller, a 2200mAh lithiumpolymer battery, and a 5V 2.5W solar panel. This combination allows the solar panel to charge the battery when it is receiving enough sunlight. The battery allows the system to run at night and on days when there isn't enough sunlight to power the system.

The components were assembled using a hard-plastic, water-tight sensor box and two custom 3D printed parts. The sensitive controller and wireless module components, were sealed inside the sensor box. The solar panel is affixed to the top of the sensor box. The light sensor is attached to the sensor box using one of the custom 3D printed parts. The humidity sensor is located inside a large grey plastic wedge. The waterproof temperature sensor is also located inside the 3D printed wedge. Each of the components outside of the sensor box are fed back to the controller through a series of sealed ports in the sensor box. The red box is the water-tight portion. The grey wedge houses the sensors and the solar panel on top feeds power into the system through the lid of the box.

Base Station

The base station is a modified version of a sensor node. In addition to acting as a sensor node the base station also acts as a relay, moving data from the mesh network into a system that is able to put it in an Internet accessible database. The controller and the wireless module are the same ones that are used in sensor nodes. It is also important to note how the base station is powered. The base station is part of the collaborative ozone data sculpture. Because it is part of the sculpture it made sense from a design point to use the power that the sculpture generates rather than having the base station generate its own power. The power is drawn from the sculptures batteries that are charged using a much larger 180W solar array. This means that power is not a major concern for the base station.

V. RESULTS AND ANALYSIS

The base station and nodes were placed in testing configuration, emulating the configuration they were to be placed in on the campus, the power sources were connected, and each was turned on. The output form the base station was monitored, but no data was being received. All of the nodes and the base station were brought back to the lab for diagnostics. The nodes and base station were powered on and everything appeared to be working. The nodes were transmitting data and the base station was receiving and relaying the data back to the computer. Upon further investigation and examination of the data it was found that the signal strength between the nodes and the base station was very weak. The RSSI (Received Signal Strength Indicator), in the lab with the nodes and base station only a few feet apart, was between -70 and -80. Preliminary tests had shown RSSI at approximately two hundred feet to be between -65 and -75. Since high values are stronger signals the current RSSI values indicated something was causing a severe decrease in signal strength from what was measured in the preliminary tests. Three aspects of the design were examined in an attempt to determine what had caused the degradation in signal strength.

Configure wireless module library Configure sensor libraries Read data from each sensor and store the result Using the stored values build the message to be sent to the base station Send the message to the base station. Pause execution for a set amount of time to save power .

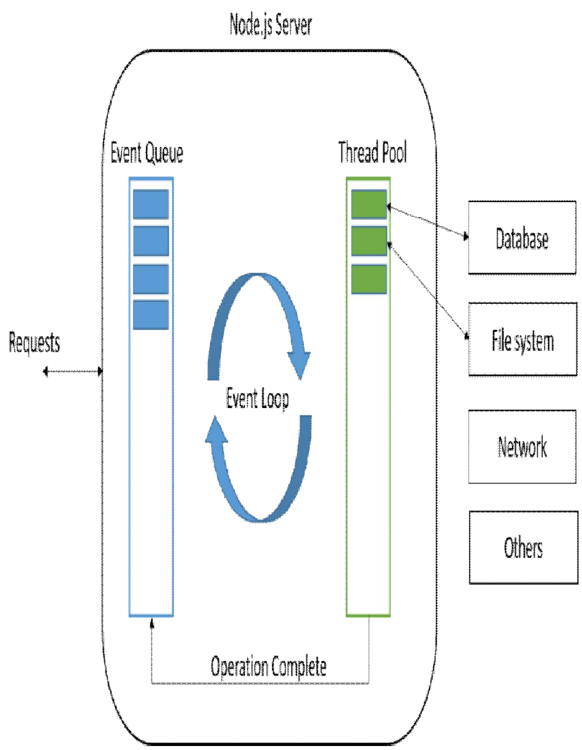

Fig 5: Node Code Loop

Configure wireless module library Configure the sensor libraries Set aside space for incoming messages. Check if message is received if not go to set . If message is received send it to the serial port . Repeat starting at set. Once every set amount of time read data from each sensor and send it to the serial port.

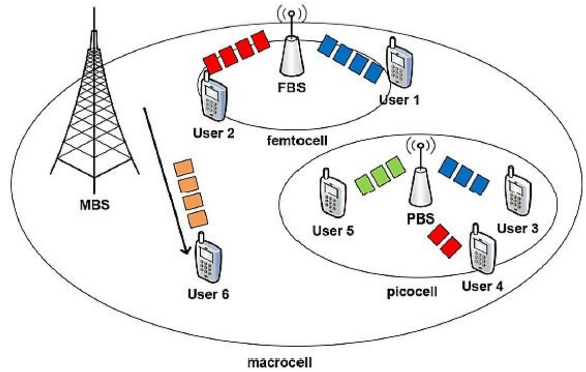

Figure 4 : Base Station Code Loop

The first attempt to diagnose the problem was to move the base station and the nodes to a new environment to ensure that there was no localized signal pollution. The nodes and base station were taken to a residential neighborhood rather than the university campus. This test showed no improvement in signal strength. After signal pollution was ruled out, the electrical integrity of the connection between the wireless module and its antenna was examined for problems. This was done by directly attaching the antenna to the wireless module rather than having it connected through the circuit board. This did not lead to an improvement in performance. After the connection to the antenna was determined to be intact a new antenna was tested. Using a more precise measuring tool and a solid copper wire, a new antenna was fashioned. This new antenna replaced the old antenna. The signal strength was measured again, and found to have no improvement. These results were not expected. They show that in the current configuration these modules are not suitable for this system. This avenue of inquiry should not be abandoned though. Preliminary results showed that power consumption of this system was within the required margins for self-sufficiency.

VI. CONCLUSION

It is the conclusion of this report that this particular configuration of hardware is not a suitable system for gathering weather and atmospheric data. The radio chosen for this system failed to meet the requirements of the specification. It is believed that this failure was the result of a failure in the electrical design of the system. As such, two modified systems may prove to be more viable and should be the focus of further study. The first of these systems would use the same components as the current design. The difference would be a strong focus on improving the electrical design. Instead of using a general purpose development board, a high quality application specific PCB should be designed for the system. The second suggested system would replace the current radio module with a module that is more selfsufficient. This module would remove the need to focus on difficulties of wireless electronics.

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