(Mobile Radio Network)

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ITMT-492 Embedded Systems

Mobile Radio Network

Technology has brought the benefits of incorporated multi-sensor equipment to the masses, and although the application of sensors and their associated systems has increased and transformed the world forever, the fundamentals of the main sensor types and how they work has not. These types of sensors can range from temperature, IR, Ultrasonic, Touch, Proximity, Pressure, Level and, Air/Smoke/Gas Sensors. Today, this enables us to set up various different systems that can better our lives being more efficient, more reliable, with less time consumption. As for this project we will focus on, an Arduino along with multiple Bluetooth transmitters called XBee 802.15.4 will be utilized for a median ranged, low power operation.

Temperature is one of the most common of all physical measurements. We have temperature measurement-and-control units, called thermostats, in our home heating systems, refrigerators, air conditioners, and ovens. Temperature sensors are used on circuit boards, as part of thermal tests, in industrial controls, and in room controls such as in calibration labs and data centers. Though there are many types of temperature sensors, most are passive devices: Thermocouples, RTDs (resistance temperature detectors), and thermistors.

When deciding in what course of direction we would take our project in, I recalled a similar project that was organized and executed by a group of graduate students at Purdue Calumet. These students wanted to make their university operate more efficiently in their power consumption. In reviewing the Universities’ financial records, it was revealed that an exceptional amount of money was spent the operation of one the industrial buildings. In order to tackle this issue, they had to figure a course of action that would enable them to determine what the cause of such waste in efficiency, without physically entering the system and disrupt production. In reviewing their options, it was determined that a wireless system of sensors would be best to obtain the best representation of data for the air flow in the vents.

This system is similar to our setup, except their main concept is utilizing Bluetooth frequency, rather than our inclusion of radio frequency to collect the data. In reviewing their collected data, they realized that the air flow in the ventilation system shift entirely to one side rather than utilizing the whole space. This caused for the system to over work itself in order to compensate for the lack in air flow for the other side of the building. Once this problem was addressed, they constructed a 3D simulation of the best fit for a slit to help distribute the directional flow of the air. Once they had completed their project, the institution was able to save $250,000.00 per year in utilities and the group of graduate students was rewarded with $1,000.00 (Chicagotribune, 2011).

In viewing this outcome, a small and inexpensive system played a large contribution saving a large sum of money for the institute. Not only can this concept be use to just demine irregularities in utilities usage, but it can be applied to many other areas. A setup like this can be brought to even a wider scale to not only save money, but even save the lives of many people. The possibilities of this type of system are endless.

The essential concept that our project surrounds is creating a system that would gather the temperature and transmit the data to an intermediate router and then to our main base that is connected to our Arduino to record and display the results. The simulative environment that we will create is applying the temperature radio system to a vacant house and determining in what area is there an escape of warm air that also lets in cold air. This will help determine what area needs better insolation that will help lower cost and energy used to warm up the house. The question now was how exactly would we go about in collecting and transmitting the data of the temperature? How could we prevent the radio endpoints from collecting mixed results in a average temperature of the house. Not only that, but where would we exactly place each endpoint to make full use of them?

Once face with this dilemma we decided to do some research and decided accordingly of how exactly we were going to address each of these issues. When transmitting the data, we had already set out to use the Xbee radios were used in a previous lab from class. When fully observing them, they have many perks to using them. Unlike Wi-Fi that goes off on 802.11, the XBee consumes an exponentially less amount of power, allowing it to run for days on end. When it comes to connecting many devices together Wi-Fi is limited to 32 devices and Bluetooth is limited to 7, while the XBee is able to just add on with very little restriction. Now while Wi-Fi and Bluetooth are able to transfer data at a larger size and rate, the XBee will be more than enough to transfer the data the temperature. Not but last least the distance that the XBee covers is generally greater than that of the coverage of Wi-Fi and Bluetooth without going too much into the budget. We also had to take a better look at how exactly we would create the environment to obtain the most accurate results without interfering with one another (digi, 2016).

When trying to collect the exact pattern of temperature in each room/area we decided upon isolating each room/area to maintain its own climate. With each room we decided to pad the doors with Styrofoam and padding to keep the temperature of that room to itself. Then to distinguish the main floor from the basement, we boarded up the entrance to the stairs. This allowed us to see a great distinguish between the both levels.

When looking at how to connect the XBee to the temperature sensor, we have two choices of either using a typical breadboard or soldering the XBee and sensor to a breakout board. At first we decided to just go with an ordinary board and wire everything together, but we soon realized that the mock up required very specific size capacitors and complete knowledge in where each pin of the XBee connects to. We then decided to go along with a simpler layout and solder the pieces together to ensure that they stay in place. The breakout board worked better with the setup as is was a smaller and slender size in comparison to that of a regular breadboard. This made it easier to place them where we wanted to without taking up too much space or looking too out of the ordinary. Originally we had positioned one in a single room, the basement, and the living room. We ran into an issue the old copper and steal piping in the basement that caused too much interference and irregularities in the results. Then with the living room, it was too exposed to the rest of the house that could not be closed off. This brought up some concerns in not being able to say for sure that this specific area is the cause for lower falls in the temperature. We later moved one to the bathroom and the garage. The one placed in the bathroom also had some irregularities and fadeouts. This was likely caused by the wall tiles, granite sink, and piping that caused for some distortion in the results. The one placed in the garage had better results, but was delayed in transmitting the data as older bricked wall of the house and garage caused for difficulty in the signal trying to reach the main base.

After looking at each area of the house the three rooms were the best place to position them. The three rooms proved to be easier in isolating from the rest of the rooms and this allowed for the XBees to be able to charge more efficiently with a solar panel. Having a great amount of room and access to a window, the XBees were placed in the center of the room with solar panel facing the room. This enabled for the XBee to record a more accurate representation of the room temperature and charge at the same time.

Once we started to incorporate the solar panels we have to solder a set of transformers with a capacitor to prevent the panel from over loading the lithium battery and shorting out or overheating the XBee. The other perk to using the XBee is its functionality to able to go into a sleep mode during the intervals of collecting the data, in order to conserve even more power from the battery. We tried to utilize that functionality, although it proved to be a difficult portion to try and code, so in seeing the deadline approach we concluded that it would be best to leave the program as it was to not cause for more issues in the code. Instead we decided on lengthening the intervals of data collection as it was not necessary to record every second or minute of data collection of the room temperature.

Ideally with that function and the setup of the battery and solar panel, the XBee could essentially run for months on end with little to no maintenance required. This adds on to making this a fully mobile, inexpensive, and efficient system in collecting most types of data. If anyone were to decide to place this in an outside environment, it would fully reach its efficiency in obtaining energy, granted that the device and setup is kept in an enclosed case.

In the planning of this setup an Arduino will be connected alongside the XBee that is set as the coordinator that together will make up the base station. The base station will wirelessly connect to the other XBee radios to collect data from temperature sensors that will record the information from the given area of the data we want to collect from the area. We decided to move the base station around to find the best fit and also test the distance of the radio frequency.

Now that the XBees and base were situated in their respected areas, it was now time to fully configure them to the system of endpoints, router, and base. The most difficult part was in trying to configure the XBees to communicate properly, where the endpoint work collect the data and relay it to the router and the router would relay it forward to the base to even further the distance covered. Many issues came across when the values given were not to what we had expected for it, or even worse when the shield or radio was bad. This caused for a lot of trouble shooting and adjustments that consumed a lot of time.

When it came time to write up the code we struggled a lot, as neither of us are proficient in trying to write out the logic in coding language to get exactly what we wanted. The first step was to trying to translate the given values of the XBees’ into a more user friendly output, such as Fahrenheit or even Celsius if it came to it. This took a few days in research in trying to understand the coding behind the logic. Once we understood that we looked at other tutorials in how the coding aspect is set up. Getting through that we were able to set up the if statements and the for loop to have the data printout again and again on the set delay for when the next interval was needed to take place. To get the data to come out to Fahrenheit, it was easier to first convert the raw data to Celsius and from there convert the Celsius data to Fahrenheit The coding and the configuring of the project had to have been the most difficult and stressful portion of the project.

Once we were able to get the system to work and fully demonstrate it, we were able to hit upon each point of electricity, data collection, data transmission, and data presentation. In achieving electricity we demonstrated it in two different portions of the project. The first representation was with the main base which when plugged into the computer, the Arduino was powered up along with powering up the XBee that was connected to it. This was also demonstrated with the endpoints that were connected to a lithium battery that was being charged up by a solar panel that was being maintained by the transformer/capacitor. We demonstrated the data collection portion by implementing the temperature sensor to collect the temperature of the room that we checked to be reliable. The endpoint would collect the data and the router took the data and relayed it to the main base. The usage of the XBee radios were a great example of data transmission as it shows a better representation of how data is transferred through not just point a to point b, but also going through an intermediate as well. We tested the range of this set up from 15 feet to approximately 130 feet. We finally displayed the data presentation by implementing the Arduino to use the code that enabled us to convert the collected data to a readable output of Fahrenheit and display it to the user.

Upon final completion of the project, we had a feeling of satisfaction that didn’t last long as there was still much to have been improved upon. We thought about it thoroughly and saw many areas that could later be improved upon to make it into a more pleasing product that can be used by many. The main idea that we wanted to expand on is incorporating a lot more radio endpoints to further demonstrate and prove that radios have the capacity to far exceed Wi-Fi and Bluetooth devices in how many can connect to each other. This improvement will allow for more data collection and proved more accurate results that could lead to more discoveries in energy loss. We could also expand on the solar panels on making a longer cable that would enable the endpoints to not be so constrained to having being too close to the window for power. We could also implement a light signal or buzzer for when the temperature in the room drops to a certain point in order to better identify when and where a loss of temperature/energy is taken place. A final suggestion that would make this more suitable to a company is implementing the Ethernet shield to the Arduino that we used earlier in the course. This will enable the user to be anywhere they want to be and just connect to the internet to review the temperature of the given area and determine whether or not they would need to turn on the air conditioner or heater.

When looking at this project from a third perspective there are still many more implements that this system can be utilized in. In this project we mainly covered how it can be used to record the temperature of separate rooms in a household and see how to save money from it, but there is still much more to test this one. Being that this system is wireless and battery/solar powered, it does not have the drag of being anchored down in a set spot. Even though this is a cheaper solution to solve many issues, it would be pointless if it were limited to a stationary position. If it were stationary, then it would have to be bought and reconstructed all over again, costing a lot more money in the long run. If this system were to be expanded to a scale that cost a few thousands of dollars then it would be best to make it mobile, so when the stationary room is no longer in use, it would not take a long time or large amount of money to try and transfer everything. This is also bad in the fact that different portions of the system can be damaged or broken when being removed and transferred over to a new set location.

In the market right now there are many variants of a system that does a similar collection as this system. Although many of those are either too expensive, costing hundreds of dollars or even thousands of dollars. Many of them also implement only one sensor that has to be manually operated that, defeating the purposes of being efficient and accurate. Others that are more expensive that do consist of multiple endpoints are limited by the Wi-Fi 802.11. This limits their range, depending on the usage of g, n, ac, ad, etc. Also since it is Wi-Fi only a certain amount of endpoint can be utilized, limiting how much data can be collected and recorded. The implementation of a radio network for our system allows for as many endpoints as needed to be connected all at once collecting all the data needed. The cost is also greatly lower by at least half the cost. The basic set such as ours with the Arduino, radios, solar panels, and other parts cost roughly $250.00 to $300.00. When adding another endpoint to be implemented to the system it would only cost approximately $30.00 to $40.00 more dollars for each endpoint.

In the end the project proved to a be a good challenge that made us implement what we learned in class and our own skills into a real world situation and present an executable solution for it. Seeing as how we could improve on this project, we realized how all the small projects can greatly contribute to this system. No matter how much of a stress and bother it had put on us at times, we can add this onto our list of experiences and see how we can further implement this in the future.

# Works Cited

*adafruit*. (2016). Retrieved from www.adafruit.com: https://www.adafruit.com/

*arduino*. (2016). Retrieved from www.arduino.cc: https://www.arduino.cc/

*Chicagotribune*. (2011). Retrieved from http://articles.chicagotribune.com: http://articles.chicagotribune.com/keyword/purdue-university-calumet

*digi*. (2016). Retrieved from www.digi.com: https://www.digi.com/pdf/xbee-802-15-4-protocol-comparison.pdf

Faludi, R. (2010). Wireless Sensor Networks. In R. Faludi, *Wireless Sensor Networks* (p. 300). Sebastopol, CA: O'Reilly Media, Inc.