CSE 477 Capstone *D.R.E.W.* Final Report

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ABSTRACT
With global energy consumption at an all-time high, minimizing energy waste has become more important than ever. Our product D.R.E.W (**D**ramatically **R**educe **E**nergy **W**aste) attempts to solve this problem by creating a proximity based energy management system. Our product comes in the form of a wristband with accompanying zone modules for each room of a house and a USB module to manage the entire system. Through our product, users can connect to electronics in their home via Bluetooth and setup rules to perform various actions when a user leaves or enters a room. With this control, it becomes easy to reduce energy waste by turning off electronics in the house that don't need to be on when someone is near them. To evaluate our system, we setup a simple environment consisting of multiple wristbands, a single zone module and a Bluetooth-controlled outlet connected to a lamp.

Categories and Subject Descriptors
B.4.m [**Input/Output and Data Communications**]: Miscellaneous; B.7.m [**Integrated Circuits**]: Miscellaneous; D.2.m [**Software Engineering**]: Miscellaneous

General Terms
Digital System Design

Keywords
Wearable, wireless communication, home automation, proximity, energy waste prevention

1. INTRODUCTION AND RELATED WORK
Home automation is becoming an increasingly popular trend in many houses. As the ability to control electronics in the home increases, creating systems to reduce energy consumption becomes a much easier task. D.R.E.W. is our attempt to create an energy management system to hook into smart electronics or an existing home automation system. By using proximity, our system is able to turn off devices in a room when no one is nearby and on when someone enters. Additionally, since our system measures proximity, it can be extended in the future for other applications, such as tracking children or pets in a home for safety purposes.

Figure 1: The D.R.E.W. hardware

The D.R.E.W. system consists of several components:

- Wearable, rechargeable *wristbands* (one per user)
- *Zone modules*, to be placed in every room of the house where user proximity should be measured
- A single *USB dongle*, which is used by the *desktop application* for communicating with the rest of the D.R.E.W. system

Based on the proximity of a wristband to any zone module, users can setup rules for electronics in their home to turn on, off or any other controllable action via Bluetooth. These rules are managed in the *D.R.E.W. System Tool*, a Python application that must be running at all times for D.R.E.W. to operate.

1.1 Competitors
Currently, there are other competitors on the market that utilize similar proximity technology. The Apple iBeacon is the most popular of these technologies. The iBeacon utilizes Bluetooth low energy proximity sensing technology, primarily to help stores promote products and sales based on the

location of the user in the store. By using an ID sent from the iOS device, the iBeacon can lookup the ID over the internet and find the physical location of the device in the store. Then based on that location, the iBeacon can trigger a specific event or push notification on the iOS device. The primary use of the Apple iBeacon technology is for advertising, unlike D.R.E.W.

A more relevant competitor and implementer of iBeacon technology is the Airfy Beacon. The Airfy Beacon uses Apple iBeacon technology to communicate with a smartphone to turn on or off devices in your home when you enter a room. Each beacon is the equivalent of a zone module in D.R.E.W. The main difference between D.R.E.W. and the Airfy Beacon is that D.R.E.W. uses 915 MHz wireless communication instead and also has a separate wearable piece instead of using a phone.

By having a separate wearable, we ensure that users will be wearing the device at all times instead of carrying a phone (which many people don't always have on them). The wearable also has a longer battery life than the phone and won't waste phone battery life which could be used for other smartphone functions. By minimizing the amount of energy D.R.E.W. consumes, we ensure that there will be a net positive reduction in energy waste.

1.2 Recommended Use

The target users for D.R.E.W. are those with a home automation system already in place or devices throughout their homes that are easily controllable via Bluetooth. Although D.R.E.W. uses wireless communication in the 915 MHz ISM band for measuring proximity of the user to a zone module, all communication between D.R.E.W. and devices in the home is done via Bluetooth. This is done to ensure that new devices can be easily integrated with the D.R.E.W. System Tool.

Although D.R.E.W. currently does not natively support any external electronic devices aside from Plugable Bluetooth outlets, the use of Bluetooth makes adding new devices simple, only requiring modifications in the Bluetooth message format being sent from D.R.E.W. We believe that incorporating D.R.E.W. into existing home automations will not only make it easier to reduce energy, but also minimize user interaction with everyday electronics.

2. THEORY OF OPERATOIN

Wireless communication is carried out via manipulations of electromagnetic waves. By modulating the phase of an electromagnetic wave, binary data can be encoded and sent through the air. D.R.E.W. utilizes the RFM12b wireless transceiver module, which operates in the 915 MHz ISM band. For communicating with electronics in the home, it utilizes Bluetooth which operates in the 2.4 GHz ISM band.

The RFM12b module has several key features which make it ideal for D.R.E.W. Each module supports both receiving and transmitting of signals, allowing for each component of D.R.E.W. to have a handshake system to guarantee proper transmission of messages over the air. Additionally, each module can be easily daisy-chained to transmit messages further than just one zone module to the next (although

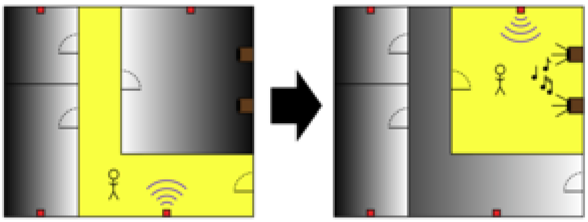

Figure 2: Example Use Case

not implemented yet), which is ideal in situations where the USB module is further away from certain zone modules.

The most important aspect of the RFM12b module is the ability to measure signal strength. Each module has the ability to measure the signal strength of incoming messages and output them in decibal units. This feature is key for measuring user proximity. By equating signal strength with physical distance between communicating devices, we can make a prediction about the users approximate distance from a zone module. However, one difficulty of using the 915 MHz band is that electromagnetic waves at 915 MHz can sometimes have trouble penetrating through walls, furniture or people.

This feature of the 915 MHz band is useful in the sense that it helps us ensure that each zone module represents a single room, since messages can't be send through walls from one room to the next easily. However, it also makes it a bit difficult if other objects, such as furniture or a person is between the wearable and the zone module. To solve these issues, we have implemented logic to better predict whether a user has left a room versus having an object suddenly move between them and the zone module.

The other component of the wireless communication is done via Bluetooth. Users of D.R.E.W. are required to have a computer with built-in Bluetooth. By sending specific messages from the computer running the D.R.E.W. System Tool to Bluetooth-enabled electronics in the home, the D.R.E.W. system can hook into any home automation systems and interface with devices throughout the home. Right now, D.R.E.W. only supports communication with Plugable Bluetooth outlets, but can easily support other devices.

3. SYSTEM IMPLEMENTATION DETAILS

The communication between each component of D.R.E.W. is rather simple in the sense that there is never a large quanitity of information being sent over the wireless network. All processing of data is done in the D.R.E.W. System Tool to conserve energy consumed by the D.R.E.W. hardware modules.

3.1 Wearable

The wearable is built using a custom PCB, the ATMega328 surface mount microprocessor and an RFM12b wireless transceiver. There is also a regulator and charging circuit for the 150 mAH lithium polymer battery contained in the case. These components together provide all the basic transmission functionality needed by the werable, which has the simplest

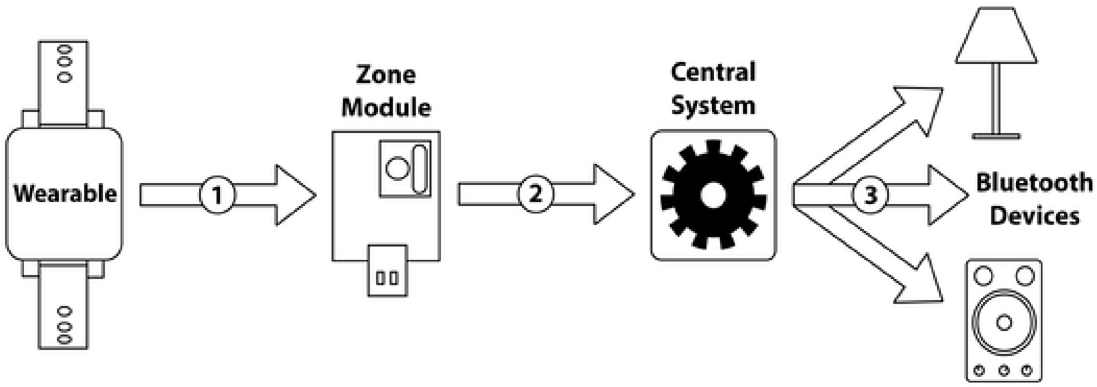

Figure 3: Wireless Communication Block Diagram

communication logic. Once every 0.5 seconds, the wearable sends two bytes of information:

- 1 byte indicating the message type
- 1 byte indicating the ID of the wearable

When not transmitting this message, the wearable enters a sleep mode to save energy. We estimate that it takes about 3 milliseconds to transmit a message. The wearable has no receiving logic and is only ever transmitting this message regardless of what the rest of the system is doing.

3.2 Zone Module

The zone module is constructed similarly to the wearable, except without the battery circuits. Instead it has a USB connector which provides power to the unit. This allows them to be easily placed and powered throughout the house with just a USB wall adapter. The zone module has the most complicated communication logic out of the the whole system. The zone module is constantly receiving, looking for both messages from the wearable and the USB module. When it receives a message from the wearable, it sends the following four bytes of information to the USB module:

- 1 byte indicating the message type
- 1 byte indicating the ID of the wearable it received the message from
- 1 byte indicating the ID of the zone module that received the message
- 1 byte indicating the signal strength of the message received

This is the minimum amount of information needed for the D.R.E.W. System Tool to be able to figure out which wearable is nearby which zone and to calculate whether or not the wearable is to be considered "in" the zone. This message is sent immediately whenever a zone module receives a message from a wearable.

The zone module also has a discover functionality. In order to be configured in the D.R.E.W. System Tool, the zone module needs to send its information to the USB module. Whenever it receives a discovery message from the USB module (explained in the next section), it sends the following 2 byte response:

- 1 byte indicating the message type
- 1 byte indicating the ID of the zone module that received the discover message

This message is only sent when it receives a discover message from the USB module, which should only happen during the initial configuration in the D.R.E.W. System Tool.

3.3 USB Module

The USB module hardware is identical to the zone module hardware but it uses an ATMega32U4 microprocessor in order to allow for communication over the serial port of a computer with the D.R.E.W. System Tool. This module provides an interface to and from the other hardware modules with the D.R.E.W. System Tool and is always receiving messages. Whenever it receives a message from the wearable, it sends the following comma-delimited values across serial:

- 1 byte indicating the message type
- 1 byte indicating the ID of the wearable that sent the message

This is used for configuring wearables in the D.R.E.W. System Tool. When the D.R.E.W. System Tool needs to configure wearables, it sends a single byte over serial to the USB module which triggers the USB module to send a message

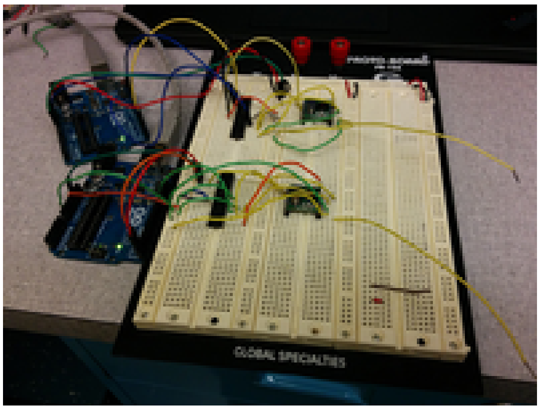

Figure 4: D.R.E.W. Prototyping Board

to the wearable containing 1 byte which indicates the message type. As described in the previous section, the zone module replies with a message containing its own ID, which the USB module receives and transmits over serial using the following comma-delimited values:

- 1 byte indicating the message type
- 1 byte indicating the ID of the zone module that sent the message

These two message formats sent over serial cover all hardware configuration needed in the D.R.E.W. System Tool. When the configuration is complete, the USB module is ready to receive messages from configured zone modules. When receiving a message from a zone module indicating that a wearable is in the vicinity, the USB module relays that information over serial to the D.R.E.W. System Tool using comma-delimited values in the following format:

- 1 byte indicating the message type
- 1 byte indicating the ID of the wearable it received the message from
- 1 byte indicating the ID of the zone module that received the message
- 1 byte indicating the signal strength of the message received

The D.R.E.W. System Tool then uses this information to calculate whether the signal strength is large enough for the wearable to be considered “in” the zone. The USB module does not carry out Bluetooth communication with any connected devices; that is done through the computer’s internal Bluetooth adapter and the D.R.E.W. System Tool.

3.4 D.R.E.W. System Tool

The D.R.E.W. System Tool is a desktop Python application built using the Qt application and GUI framework. This tool handles all hardware configuration and connected device configuration. Once each part of the hardware is configured, users can create rules determine how connected devices respond based on where the user is in relation to the zone modules. They can configure a threshold for at what value of signal strength a user is to be considered “in” the zone. The user then configures which connected devices correspond to which zone modules, and actions for the connected devices to perform when a user leaves and enters that zone. The actions are carryed out via messages sent from the computer’s internal Bluetooth adapter. For future releases, better support for multiple connected devices will be included.

4. CHALLENGES

The main challenge of this project was creating logic to accurately tell whether or not a user is in a zone. Because there are frequently objects between a user and a zone module, it becomes hard to ensure that the wearable message is successfully transmitted to the zone module. In the future, we plan on resolving this issue by having more complex logic for differentiating drops in signal strength from leaving a room versus having an object move between the zone module and wearable.

Another way to solve this issue would be to use Bluetooth instead which generally doesn’t have as many issues with objects obstructing communication between two modules. This is the approach of the Airfy Beacon. However, without testing it is hard to know whether or not this would remedy our issues.

5. CONCLUSION

In this project, we created a proximity-based home automation system called D.R.E.W. With this system comprised of a wearable, a zone module and USB module, we were able to control electronic devices throughout the home based on the user’s proximity to each room. Although we had issues with accuracy and obstacles blocking the path between the wearable and zone module, we were able to successfully measure promixity using wireless communication and signal strength.

The D.R.E.W. System Tool brings all the hardware components together, by providing a configuration tool so that users can easily tweak the parameters of their D.R.E.W. system. We hope that our work in proximity estimation using wireless communication will be beneficial for future home automation systems and believe that this technology is pivotal in reducing energy waste in the home.

APPENDIX

A. REFERENCES

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