Not Exactly the Internet of Things for Outdoor Lighting: Progress Report

Oregon State University CS Senior Capstone Group 22
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Client: Victor Hsu

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1 Abstract

Outdoor lighting seems like a simple problem to solve, but the solutions on the market today are less than ideal. The standard transformer/timer combos available in the big box stores are rudimentary and clunky at best (constantly needing to be adjusted for the changing sunset and sunrise times), but are reasonably priced. The new-generation smart apps for home automation are flexible and fancier, but are quite spendy and lock you into a specific protocol. So why not use an open platform running on commodity hardware? Easy to use, reasonably priced, and highly customizable–that is our goal.

Our system will consist of a wireless network of tiny "client" computers that each control up to 4 sets of lights and are controlled by a central "server" computer, which will automatically send out commands to the clients when it's time to turn on or off. The central node will run a control program that can be easily accessed via a touch screen, a web browser, or a mobile device, where the user can locally or remotely control each light individually. Want your lights to turn on at sunset and then dim gradually as the sun rises? Simple. Want your lights to flash when you're throwing a party? Just press a button. The control interface will allow users to easily set "rules" for what their lights do and when, depending on the time of day, the sun/moon position, and potentially even triggers such as weather conditions or calendar dates. This system will be easily extensible to potentially control other devices as well, such as garage doors, sound systems, and more.

Our group has made serious progress in the project to turn the Raspberry Pi and ESP8266 Wifi module into a "Not exactly IoT" device for controlling binary devices wirelessly. From project assignment to week five, our group produced a proof-of-concept for the final project, and planning the final software approach in the meantime. Despite all the writing requirements this term, we made excellent progress.

Throughout the term, our team moved between early prototyping and detailed documentation for the project. With regular communication through email and IRC, our group kept coordinated throughout the term, publishing progress reports to the Sharepoint site and code samples to our Github page. We will discuss our weekly progress and describe how the prototype and documentation unfolded over the course of the first term of the capstone project. This should provide an assessment on where our groups stands in preparedness to move forward with implementation next term.

2 Weekly Breakdown

2.1 Weeks 0/1

As we had not yet received our project or group assignments, we have little to report for weeks 0 and 1.

2.2 Week 2

Our first week of our capstone project, "Not exactly the Internet of Things for Outdoor Lighting", was relatively uneventful, as we had just received our project and group assignments. We met with our group promptly to create our draft of the Problem Statement, which was largely involved expanding upon our client's original project proposal with additional clarification, focus, technical details, and performance metrics.

2.3 Week 3

During week 3, we had another group meeting to brainstorm a list of clarifying questions to ask our client, Victor, about the project. Having met later in the week, we were able to get some answers:

- How is the system going to be controlled by phones? Is a dedicated app necessary, or can we provide a mobile-friendly website?
  Answer: A mobile-friendly website is acceptable.
- Are we just going to be controlling lights, or are we going to expand to other devices if we have time (e.g. sprinkler system, music players, garage door openers, alarm systems)?
  Answer: The control of other devices is currently outside the scope of this project, but can be a stretch goal.
- Will the code for this project be open source?
  Answer: Yes! The entire project is hosted on Github.com in a public repository.
- What hardware will we have access to?
  Answer: In addition to the hardware mentioned in the client's original project proposal, Victor agreed to order a 2.8" TFT Display with Resistive Touchscreen ¡http://www.adafruit.com/products/1774¿ for use with the Raspberry Pi in the control unit.

With the clarifications and direction provided by our client, we were able to finish our Problem Statement document.

2.4 Week 4

Having not received the hardware from our client yet, there was not much we could do on the physical side. We did, however, begin work on our Requirements Document, listing out several core requirements, as well as some stretch goals. Much of this work was simply listing out each individual piece of the system, all the while filling in assumptions with explicit requirements and providing examples to ensure the requirements cannot be misconstrued. For some of the aspects that we not yet sure of, we injected a little of our own vision, knowing that our client would be able to make the final decisions on details later. For organizational purposes, we decided to break up the requirements into three categories:

1. Device control
2. User interface
3. Rules

The "device control" section includes the bare essentials for booting each device, running the control programs, and ensuring that the devices are able to communicate with each other wirelessly.

The "user interface" section includes requirements regarding the user's experience and access through the touch-screen and web site interfaces, including how they can view, name, group, toggle, and apply rules to lights.

The "rules" section, then, describes the rules that will be available for users to control their lights with. These include time-based rules (e.g. turning on at 8pm and off at 6am every weekday) and of course, the crowning feature, rules for toggling based on the sunset and sunrise, obviating the need to manually adjust the system when the sunset and sunrise times change with the seasons.

We also included a "stretch goals" category following the same 3-section layout as described above, where we filled in interesting ideas that we and our client had, but were not absolutely necessary for the proper functioning of the system and would only be implemented after the core requirements were complete, if time allowed.

In the device control section, stretch goals included potentially expanding the system to control devices other than lights, such as garage door openers, music players, holiday decorations, and sprinklers.

In the user interface section, we considered additional usability features, such as allowing the web interface to be accessible over the Internet (for remote control) or even external "cloud" hosting for the web interface to improve uptime and obviate the need for the user to port forward on their router.

The rules section included more complex rules, such as toggling based on weather/celestial conditions (which might require Internet access) or various attachable sensors, such as motion sensors, light sensors, moisture sensors, and sound sensors. These types of rules would require significant additional hardware, but would allow the system to, for example, turn on lights when you pull into the driveway. The usefulness of these rules would also greatly increase if combined with other stretch goals, like sprinkler system control, as the system could then be configured to stop sprinkling if the ground is already wet (e.g. due to rain) or to pause temporarily if someone is walking by.

2.5 Week 5

This week, we completed our requirements document and began researching the hardware once we had it in our hands. We picked up the Raspberry Pi and TFTLCD display from Victor and booted the device with the *fbtft* module for the device. This week was otherwise uneventful with everyone working on other projects and midterms, but there was still work done with regards to group logistics and future planning. We planned to continue our proof of concept project next week to get the firmware and relay online.

2.6 Week 6

Most of what we did on week 6 of our project involved trying to get a functioning proof of concept for our project, which turned out to be filled with more problems than anticipated. We began to investigate software packages and technologies that would help us meet the requirements outlined in our requirements document. The main problem that we ran into this week was with the wireless networking that we were planning on for the Pi.

We tested the devices with various wireless networking methods, including ad-hoc and access-point mode. While testing, we discovered that the ad-hoc system was not working as expected. This was due to the USB WiFi adapters we were using not being compatible with an ad-hoc setup. This was especially problematic because our main plan was to use ad-hoc for networking. After further investigation, it became clear that we would have to reevaluate our network implementation, as there would be no way to work around the issue and still use ad-hoc. We are now just using the Pi as a wireless access point that the plug nodes will connect to. This solves the problems caused by the compatibility issues with ad-hoc.

In addition to working on the proof of concept, we also made headway on some of the documents that we had due soon. We started an outline of our Technical Review document, and also started revising our Requirements Document as Kevin suggested. We asked our TA, Xinze, to see if he had any comments on it. His advice was to elaborate more on the requirements we already had and make them as specific as possible. Following his advice, we expanded on our current requirements by adding more detail and specifying exactly what we meant, rather than relying on assumptions.

Finally, we also wrote the first draft of our elevator pitch, a 30-second overview of our project that we will be presenting to the rest of the class later in the term.

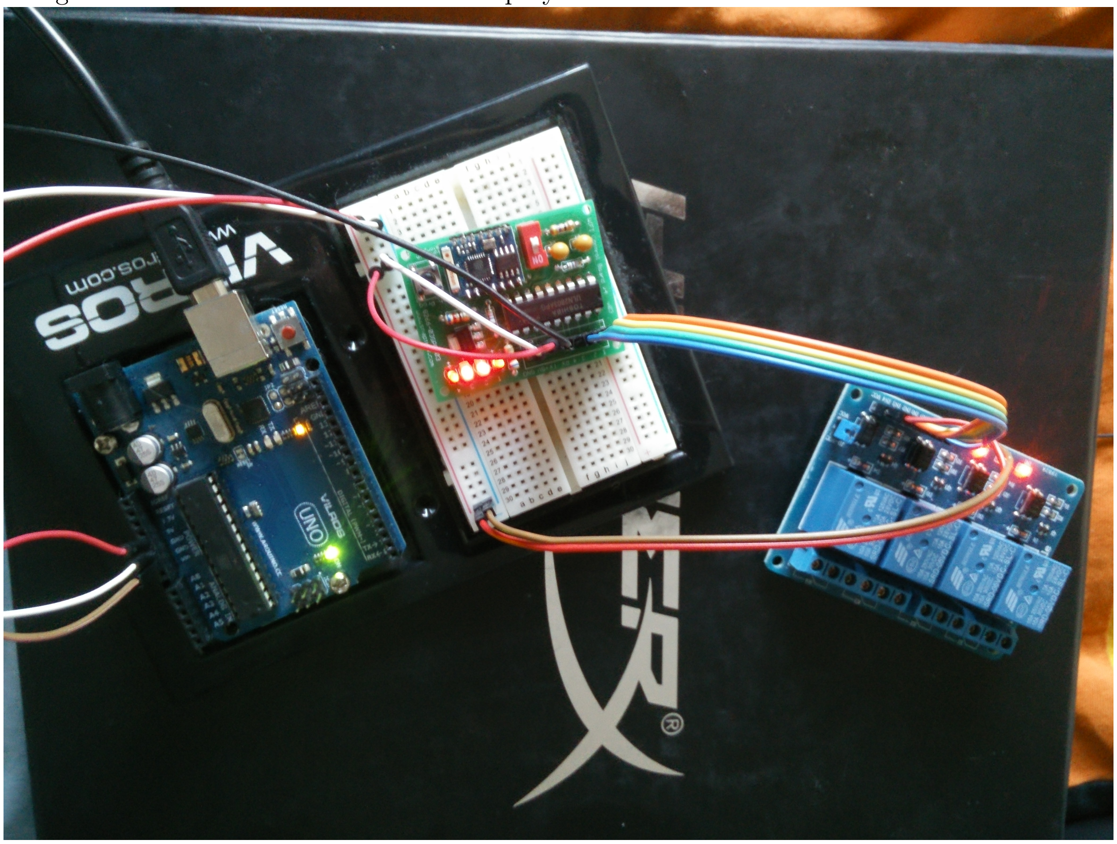
2.7 Week 7

After much delay, sweat, and tears, we finally had a functional proof of concept to demo and show off. The program was quite simple, but accomplished the bare minimum of what we would expect the program to do. Sending a basic TCP command to the ESP8266 module will cycle the lights through the device's Lua firmware, and will in turn flip the relays out of the board's GPIO once we wire it up too. The TCP commands are sent by the Raspberry Pi using a boot script on lxTerminal, using an execution sequence that looks like this:

1. Pi boots into the TFTLCD module, screen initialized
2. Pi loads lxTerminal, runs startup script in init.d
3. inid.d script connects to the ESP8266 module, gets an IP

4. After the connection is made, the inid.d script starts a Python script
5. The Python script cycles through TCP commands and send them to the device

For our next step, we planned to make sure that the Pi could reliably perform the discovery operation (the IP was hard-coded) and that the ESP8266 module could run as a client in the future, connecting to the Pi to take advantage of the Pi's DHCP server and to simplify future connections.



As far as documents go, we also finished revising our requirements document, fleshed out our technology review, and started on our expo poster this week. The expo poster largely involved filling out the provided template with the proper information from our existing documents in a more condensed and less technical format.

For our technology review, we chose to focus on four different main components of the system:

- OS for the control unit (the Raspberry Pi)
- Server program implementation
- Web site implementation
- Server/client communication

For each component, we reviewed 3 potential solutions and chose what seemed to be the best fit for the job, given our requirements for the project.

For the Pi's OS, we considered using an existing OS such as OpenWRT (designed for networking tasks) and Raspbian (designed for ease of use on the Raspberry Pi), but in the end, we decided to go with Yocto, as it will allow us to strip the OS down to just what we need, making the system more optimized and responsive. This is particularly important given the modest processing power of the Pi and the fact that it will be facing the user directly, making response time all the more important.

For the server program implementation, we considered writing it in a low-level language such as C for performance benefits. We also considered whether to use sysfs directly to interact with hardware devices, or whether to use the libmraa library to abstract them and make the interaction easier. However, in the end, we decided to go with Python for its ease of use and higher development speed. Since the ESP8266 can run MicroPython, using Python for the Pi as well made sense since we only have to focus on using one language.

For the website implementation, we considered several languages and frameworks, both for the backend and the frontend. For the frontend, there is probably no way to get around the standard HTML/CSS/JS stack, but for the backend, we condidered whether to write our own site from scratch using PHP/Ruby/Python, or whether to use a framework like Ruby on Rails for Django/Flask. In the end, we decided on using Flask, as it is a fairly simple yet powerful web framework written in Python, which will allow us to use Python almost everywhere for this project and communicate easily with the server control program.

Finally, for the server/client communication, we considered three architectures: ad-hoc, where every device would connect to every other device; central WAP, where the Pi would act as a central Wireless Access Point and server, with the ESP plug units connecting to it; and CAS, where every device connects to an external server that directs the entire system. In the end, we decided that the CAS system would rely too heavily on external resources and would be too difficult to maintain, while the ad-hoc system was not possible with the given hardware. Thus, we decided to use the central WAP method.

2.8 Week 8

We have accomplished the task of automatic communication between the control and plug units; booting the Pi connects it to the ESP automatically and cycles the lights on the relay. We also demonstrated our proof of concept to our TA, Xinze Guan, so he could see our progress.

As far as documents go, we also finished up our expo poster and got feedback from Kevin McGrath on our elevator pitch. Though he said he liked it personally, it was a bit too informal for a business presentation, so we reworked it a bit to sound more professional.

2.9 Week 9

During week 9, we continued to work on testing out our proof of concept. We managed to connect actual lights to our relay and verified that we can control them by toggling them on and off. This is a good step toward getting a fully working proof of concept working as it means we have most of the main parts done, and mainly need to start working on the UI of the touchscreen and web page.

We decided that we are most likely going to use Flask to implement the website. Flask is a micro-framework for Python that is designed for developing websites. The main reason we are planning on using it is that we are using Python for many of the other parts of the project, and so it would be easy to integrate this and also would make sense in terms of keeping the code consistent. To prepare for when we are ready to start implementing that, we have begun learning more about how Flask works, and how we might be able to use it to create our our website.

We also presented our elevator pitch on this week, which went decently well. There were no documents to turn in this week, and there was only class on Tuesday, so there is not much else to report. Next week, we planned to iron out the design document and work on the progress report.

2.10 Week 10

The final week of the capstone project was largely uneventful as our group began working on other final projects and studying for exams. However, we did get some work in with regards to some project details and the work on the design document. This week, we took our document to the TA to get some feedback regarding the design elements we focused on for the paper, and he was pleased with the overall result after some vocabulary changes. The hardware project itself didn't get much direct attention this week, but we did wonder about the usability of the final result, from a user perspective. How easy should the setup process be? Should the user have to worry about port forwarding on the home network? According to Victor, our project sponsor, there was no need to design an overly-simplified option. We will continue to investigate more networking options over break.

- Completed: Design Document
  The design document was reviewed by our group and a TA and turned in. we also had our weekly meeting with the TA at this time.
- How complicated does the user setup portion of the project need to be and are there restrictions on what they should be able to do?
  Answer: As of now, having to reconnect to the device to reconfigure it is acceptable. Victor imagines that we won't have to connect so often that investing time into developing a complex networking option is not necessary.

- What will the project do over break?
  Answer: Evan will be taking the hardware home to use in his network testing bench, which is pretty much just a dozen microcomputers plugged into an old Cisco 2960x networking together.

Over break, Evan will be experimenting with some networking strategies and working with the web serve to flip the relay. Sean suggested that Flask would provide a good framework, but as of now he's the only one with experience in it, so Malcolm and Evan will need to study it. An ideal goal for the start of Winter term would be having a working web interface that can flip the relay, built with the Yocto build server. Even better if we have the interface up on the TFTLCD screen, but we may save that until we get back together.