IOWA STATE UNIVERSITY

Remotely Controlled Advanced IoT Smart Lights Hub Prototype

Senior Design December 2021 Team 20

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Motivation

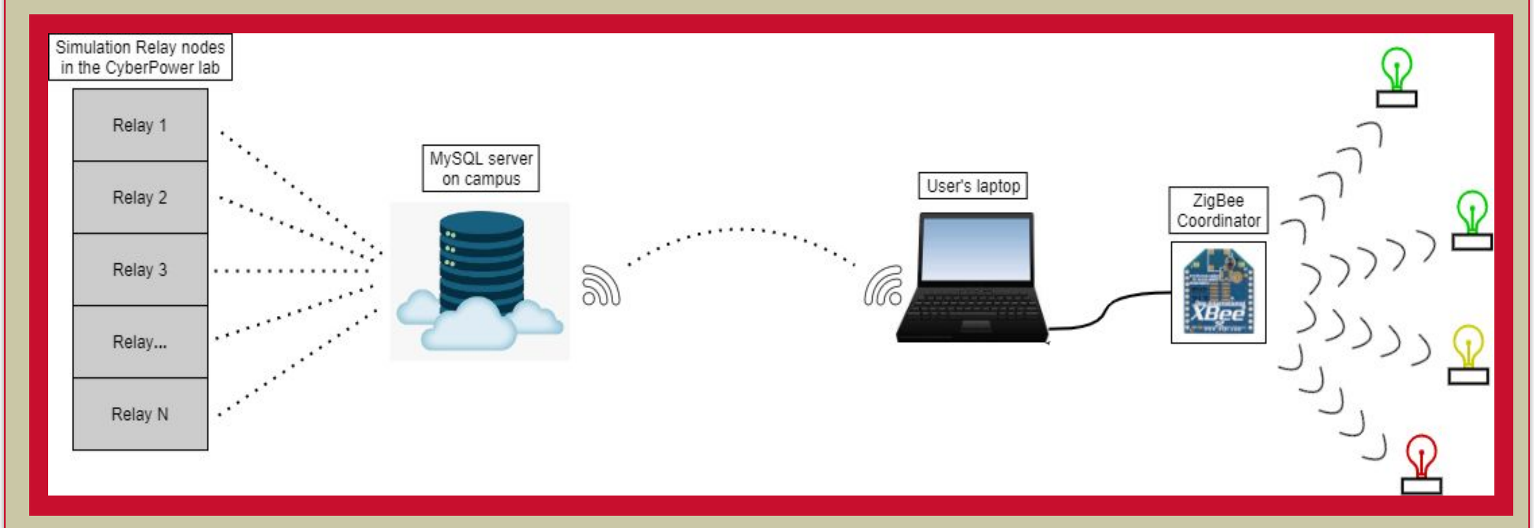
Iowa State's Power Cyber Lab is an automated system that performs simulations using a variety of control systems, PLCs, and communication systems. Because of the frequency of cyber security on infrastructure, the PowerCyber lab was integrated with Iowa State's ISEAGE security analysis system to evaluate vulnerabilities in SCADA control systems.

Currently the PowerCyber lab utilizes several server mounted lights to represent relays or PLCs from within the simulation, However this doesn't allow for scalability or transportability. A prototype to absolve these problems was created by a previous team, however the hardware lacked the ability to communicate with the simulation two ways. Senior Design team 20 has been designing a system to allow the simulation to interact with a database that will then update physical smart lights accordingly, with the smart lights being able to also send information back to the database.

Design Requirements

- Core Requirements
  - IOT Light Device shows the state of the simulation at the desired node using an LED.
  - Able to configure the IOT Smart Lights on Host PC to represent nodes on the simulation.
  - Light Devices battery powered, with a duration of 8 hours or more.
  - Light Devices communicate with Hardware Coordinator.
  - Hardware Coordinator communicates with Host PC.
  - Host PC communicates with PowerCyber Lab Simulation.
  - Light Devices are able to trigger an attack on their respective Relay.
- Non Functional Requirements
  - Aesthetically pleasing, Relatively small.
  - Access to WhiteBoard or magnetic board of some sort.
  - Light Devices Update to reflect the simulation in <1 second.
  - Light Devices are Magnetically Mountable, portable, and scalable to large simulations.
- Operating Environment
  - The cyber-attacks simulation running at the PowerCyber Lab located in the Coover Hall.
  - The Lights could be demonstrate in or outside of the lab environment depends on the events.
- Relevant Standards
  - This system uses the Zigbee (IEEE 802.15.4-based) wireless communication protocol for communication between the smart lights and the Zigbee controller.
  - IPC-2221B, a generic standard on PCB designs.

System Diagram



System Components

Simulation

- Simulation hardware in the Power Cyber lab.
- Simulates cyber attacks on power grids.
- Connects to a server in the lab.

User's Laptop

- Connects to a Linux Virtual Machine that runs all the software, including the GUI and light control software.
- Connects to the ZigBee Coordinator via serial cable.
- Can be transported anywhere.

ZigBee Coordinator Module

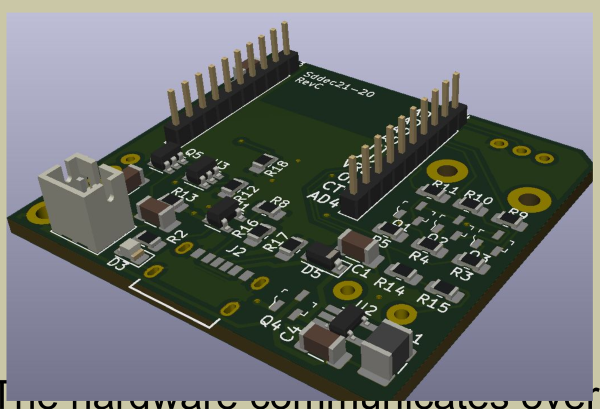
- Connects to the user's laptop via serial cable.
- Communicates with the wireless light modules, sending commands and receiving push-button interrupts.

Wireless Light Modules

- Can connect to the user's laptop via serial cable for initial configuration.
- Communicates wirelessly with the Coordinator module.

Technical Details - Module and Software

Hardware
The largest hardware task was designing the circuit and PCB of a new smart light module. The modules were extensions of the Xbee s2c, modules that were available to use through the PowerCyber Lab.
Each module is fitted with a battery charging circuit, Lithium battery, potentiometer, RGB LED, and a button to trigger callbacks to the software.
The PCB uses USB C as the charging interface, providing power to the Xbee as well as the battery.



The hardware communicates over the zigbee wireless protocol with a coordinator and the coordination software. The coordinator sits atop a serial conversion chip connecting to the computer host with USB.

Software

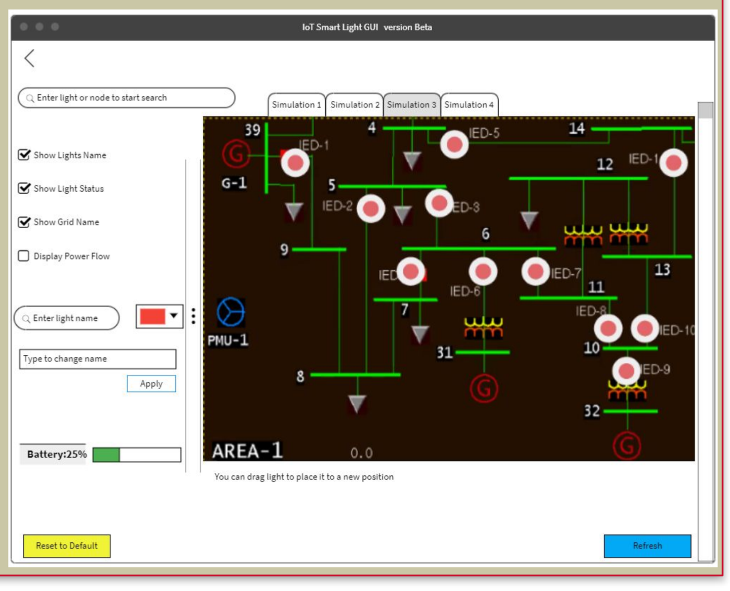
Programming Languages: Python, HTML,CSS

Tools and Libraries: Django, Visual Studio, Python sqlite, Github

Software contains two main components resides at User's laptop GUI and control software/database.

On the GUI, it shows graphical representation of the power grid simulation. Users are able to connect to the database that stores the relay status and lights data. Also, users are able to configure light devices (assign physical device a name or number). In addition, users are able to switch the light color by tapping the light icon. Users are able to switch between different simulation by uploading new simulation image and configuration.

Control Software/Database allows easy configuring setups, manipulating mySQL database, and interfacing with the Coordinator Module and APIs for GUI to store, retrieve and etc. data from database.



Intended use or users

This system is intended for use by members of the PowerCyber lab at Iowa State University to visually represent the status of relays in power grid simulations, though the system could be easily adapted to visually represent of the status of nodes in any graph-type system.

Testing

Hardware
Each node is tested with the following criteria in mind.

- Receives information from hardware coordinator.
- Triggers updates back to the coordinator.
- coordinator software communicates with the application program.

Software
Testing on GUI and Database.

- Runs Database on the background and launches GUI.
- Adds lights infos through GUI page and passes to Database.
- Retrieves the data from Database through GUI page.
- GUI displays the lights information.

Conclusion

What is done:
The prototype boards for the wireless light modules are designed, assembled, and capable of communication. However, they do not have a completed enclosure so to they are not completely ready for delivery. Assembly of the module also needs to be detailed.

The control software is fully functional and connected to the GUI.

The GUI is mostly complete. From the GUI, users can add light modules to the database and show all the light modules in the database. Users can also upload an image of the simulated power grid to be projected onto the magnetic mounting surface. The missing functionality is the ability to connect to the simulation via GUI and establish a data stream.

Some possible future extensions:
The GUI could use some beautification. It is currently pretty bare, prioritizing functionality over aesthetics. This could be easily improved in the future.

A robust enclosure design for the wireless light modules and the Coordinator module could also be added, either by 3D printing or by purchasing a pre-made enclosure from a third party.

Acknowledgements