IoT Based Street Light Controlling and Monitoring Webserver

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Abstract: The project has been aimed at achieving a solution for huge energy wastage by introducing a method to control and monitor the ON and OFF timings of street lights by both automatically and manually from a remote location using Internet of Things (IoT). Conventional street lights in most of the areas are turned ON and OFF manually in the evening before the sun sets and the next day morning after there is sufficient sunlight and do not have a controlling system.

The complete setup incorporates the use of Light Dependent Resistors (LDR) for sensing the light intensity in the environment and the sunlight falling on them to control the street lights. The lights will automatically glow once the sun goes down or at times when the intensity of light falling on the sensors diminishes due to stormy weather.

A major leap has been taken in the project by using ESP 8266 Wi-Fi module for integrating the sensor with the street light and also for monitoring and controlling the whole network in real time from any remote location through the internet. 04 Nos. of modules have been utilized for controlling, range extension and security. Mosquito broker in MQTT protocol has been utilized for the network set up. In the controlling module, the sensors will send the data to the modules which in turn will send it to the server through a chain of Wi-Fi modules configured as repeaters thus obtaining range extension to the network. Resilience in the network has been achieved by using a secondary ESP 8266 as a repeater since the network communication relies on the repeaters. Security to the network has been addressed by introducing a de-authenticator such that any intruder trying to access into the network will be interfered.

Keywords: Range extension, Resilience, Security

1. Introduction

Smart traffic light control systems and smart street light controls take the priority in transportation aspect. Street light systems can be developed to be automated and monitored in real time continuously without human intervention. The project has a scope of developing a smart street light controlling and monitoring system using IoT by integrating sensors and actuators through Wi Fi in order to control and monitor from a central location as well as from remote locations.

LDR (Light Dependent Resistors) sensors have been used to sense the intensity of light in the environment around streets. At night or in bad weather, streets have to be lighted. This has to be done accurately and efficiently for energy saving. For that, light intensity level is sensed by LDR and data is fed into an embedded system. ESP 8266 WiFi module is the embedded system used for controlling actuators and communicating information. LEDs and bulbs representing street lights are the controlled devices. Each street light pole is installed with a LDR, ESP 8266 module and the light. Whenever the module receives a signal of low intensity from LDR, bulb is lighted.

Wi Fi module which acts as both client and broker establishes a link for communication between each sensor node. The parent node is connected to a LAN or a public network to be connected to the internet. Thereby, the health of each street light can be monitored from a central station where the parent node is connected or from a remote location through the internet.

Graphical User Interface has been developed using Node Red. Indications are shown by publishing the update of status of each automatically operated street light. Controls

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have been included for each light to switch ON and switch OFF manually. Hence, indications have been set for light status in both automated and manual modes. A graph of status vs time is plotted in real time for each street light thus enabling to monitor past activities.

Since street lights expand for a longer distance from the central station, communication also has to be established to cover the range. Hence, the project scope is aimed to establish a long range communication through ESP 8266 modules. While street light is being controlled by Wi Fi module, an extra module has been used to establish the communication setup with modules connected to other street lights in such a way that data is hopped from one to other in cascading manner.

Meanwhile, redundancy and security aspects are also concerned to make the street light system more reliable and safe. Hence, a secondary ESP 8266 configured as another repeater is installed on each pole attached to primary repeater in order to increase the resilience. In a malfunction of a module, the controlling module is programmed to connect to the secondary WiFi router automatically. In addition, a fourth WiFi module is used to increase the security of the network. The controlling Wi Fi module is visible by devices as an open WiFi router or a hot spot. Hence, anybody can access into the wireless network through the module and attack the Street Light Network. The module utilized as the security device is programmed as a de-authenticator which will send continuous de-authentication packets such that Wi Fi seeking devices are blocked to connect to the network.

Remote monitoring and controlling are facilitated by A Graphical User Interface developed using Node Red. Separate indications are available for manual and automated status. Commands can be given using the plot buttons. Separate graphs are plotted for each light with respect to time to have history of operation.

As an expansion in the research, a private Local Area Network (LAN) also has been configured using a Raspberry Pi which is not connected to internet. Wireless network is connected to a router without internet access. Raspberry Pi acts as both broker and server to set up MQTT protocol. GUI is designed on Raspberry Pi using Python such that plot buttons with indications are located at respective places on a map for easy identification.

2. Literature Survey

Many researches and projects have been done on controlling and monitoring street light systems wirelessly. Advancing from conventional street light controlling system, IoT based smart street light monitoring and controlling gives power saving, less involvement of man power, smart system integrated with sensors and actuators and a user friendly system [1]. Techniques and protocols such as Bluetooth, LoRaFi, Zigbee, radio RF, GSM, WiFi, power line communication etc have been used for communication establishment [2].

Intelligent street light monitoring systems have been implemented using LDR and IR sensors for automating lights' intensity with surrounding light level and traffic [1][3]. Arduino boards have been used to interface the sensors and controlling. In addition, controlling is also achieved by vehicular ad-hock networks [5]. Here, transceivers have to be installed in both vehicles and street lights. Communication is established with the approach and departure of the vehicle and street lights will operate accordingly.

In addition to the wireless networks such as Bluetooth, Zigbee etc, long range communication and interfacing to internet have been achieved by using combined technologies of LoRa (Long Range Communication) and ESP 8266 Wi Fi module [4]. A combined embedded system called LoRaFi has been implemented from a research done in Malaysia. ESP 8266 Wi Fi module's limited range has made a requirement of integrating a long range wireless network with it. Hereby, LoRaFi has overcome range problem.

ESP 8266 Node MCU module has been utilized to achieve both range extension and connecting to cloud [6]. Here, an external antenna has been linked to the Node MCU module to increase the gain of antenna and thereby increasing range. Antenna type varies with the model of Node MCU. Either PCB or external antennas are connected to the module.

More researches have been conducted for the same purpose using ESP 8266 Node MCU module. But, any progress regarding range extension has not been included. There one Wi

Fi module has been interfaced with a particular street light network and the latter is controlled by the command of the Node MCU on arduino platform [6]. In addition, individual street light has been installed with independent Node MCU modules which can be accessed by mobile networks through internet using IoT Expressif mobile application [7].

In conclusion, range has been extended for the wireless network either by LoRaFi protocol or by using an external antenna with a higher gain [4][7]. Independent ESP 8266 Node MCU Wi Fi modules have not been utilized for a long range street light network.

3. Implementation

3.1 Introduction

A wireless network for controlling and monitoring street lights has been developed using ESP 8266 modules in Wi Fi protocol. Block diagram of the network is represented in figure 1. The initial setup required an integration of development boards (Node MCU), LDR sensors, copper board, diodes, resistors, opto couplers, transistors, relays, LEDs and bulbs.

The project accomplishes a complete Wi Fi transmission of light status (ON/OFF) and control command using a server-client-broker MQTT protocol.

3.2 Controller ESP 8266

Each pole of street light is installed with 04 Nos. of ESP 8266 modules, LDR sensor and the light. Wi Fi module configured as the controller is integrated with LDR sensor for sensing environmental light intensity and a light for lighting the street as depicted in circuit diagram in figure 2. Sensor and actuator parts are thus connected to the controller module.

LDR will send an analog signal corresponding to real time light intensity of the environment to analog input pin A0 of the modue. A threshold value is set in the program such that digital output pin D2 will be high to power the relay coil through an opto coupler used for protection of the module from HV AC supply. Thus, relay output will be latched to make the light glow. Secondary contacts of the relay are supplied with 230V AC/ 12V DC required by the street light. Manually control command is fed to digital output pin D0 such that light can be controlled from a remote location through IoT.

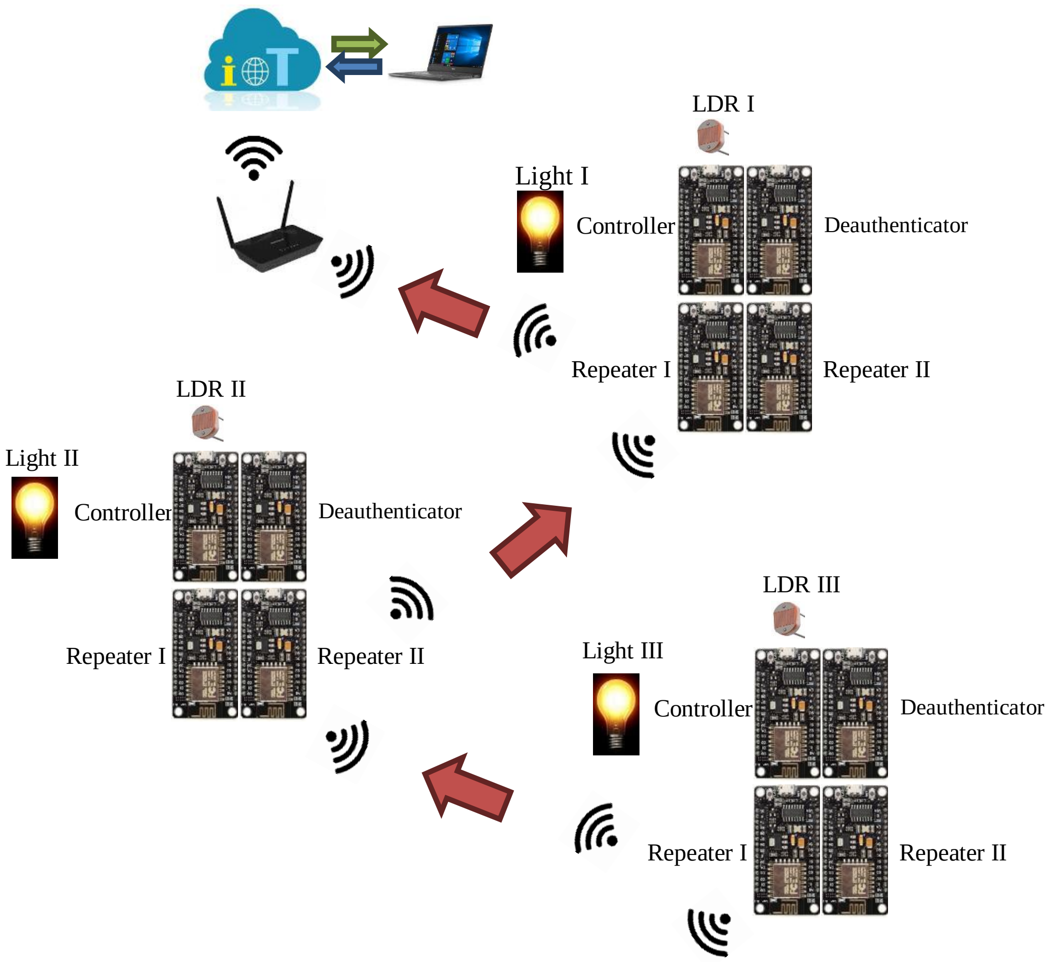

Figure 1 –Block Diagram of Wireless Network.

Since street lights need long range communication, data is transmitted using WiFi protocol using repeaters. Control module is connected to the repeaters installed alongside via Wi Fi. Control module is fed with main router's SSID and password in its program such that it will automatically connect to the network when it is within router's coverage.

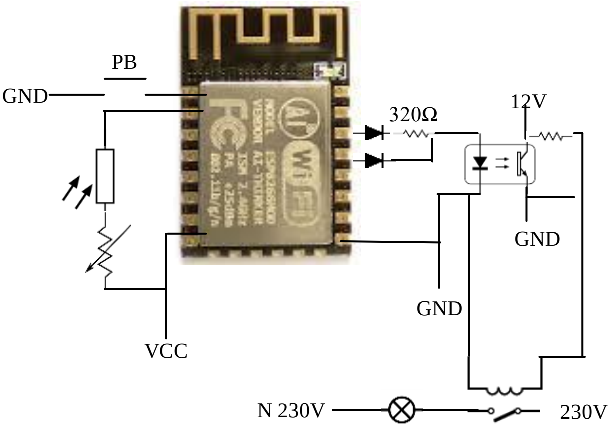

Figure 2 – Control Circuit.

3.3 MQTT Protocol

MQTT is a client server publish / subscribe messaging transport protocol. It stands for Message Queuing Telemetry Transport protocol. It is light weight, open, simple, and designed to be easy to implement. These characteristics make it ideal for use in many situations, including constrained environments such as for communication in Machine to Machine (M2M) or IoT based systems. The protocol runs over TCP/IP or over other network protocols that provide ordered, lossless, bidirectional connections. MQTT is a messaging protocol i.e it was designed for transferring messages and uses a publish and subscribe model. This model makes it possible to send messages to one or multiple clients. There is no direct connection between the broadcaster and the viewer. In MQTT, a publisher publishes messages on a topic and a subscriber must subscribe to that topic to view the message. All data published by a client is dumped in MQTT broker which in turn sends data to other clients as per their subscription.

The broker used in MQTT is "mosquito". Each controller module acts as a client while main router connected to the internet is the server. Hence, each client is given an ID for addressing individually.

3.4 GUI Webserver

A graphical user interface (GUI) shown in figure 3 has been developed using Node Red. It is the dashboard of Node Red GUI development software. The GUI includes buttons to give commands to switch lights On and Off by addressing to individual street light. An indication is provided to notify light status in Red (Off) or Green (On) in manual mode which is operated by the user at a remote controller through commands. In addition, separate indications are available to represent light status controlled automatically by the LDR sensor at each light post. A graph is plotted to indicate light status vs time and capable of accessing to operation history.

Figure 3 – GUI Webserver.

At each MQTT node, Mosquito broker is used as the server with address "test.mosquito.org". Each LED and LDR representing street light is addressed with a unique client ID. "LED" is subscribed by the server to glow or not as per the command signal. In turn, "LDR" node publishes light status controlled by the LDR sensor.

3.5 Repeater ESP 8266

A dedicated module is configured as a repeater of the router from which the network is connected to the internet. Thereby, each repeater enhances the coverage of the router along the street. ESP 8266 is flashed as a repeater with same SSID and password of the main router. Bin file containing repeater program is flashed into the module using ESP 8266 flash download tool. Once flashed, repeater is discoverable as "MyApp" open WiFi device. Repeater can be then logged in through internet using IP address 192.168.4.1. Webpage corresponding to repeater configuration is thus obtained. App SSID and password is fed as same as that in main router. After setting App SSID and password, module is discoverable in the name of SSID given. Next log in will allow to feed main routers' SSID and password such that the repeater will seek for the same within router's coverage.

Resilience has been addressed in the project by adding an additional repeater to each street light. A third Wi Fi module is also configured in same manner to act as a repeater. Since network of all clients beyond each repeater rely on the health of the specific repeater which next nearby client is connected to, an issue was aroused. Hence, additional repeater has been connected for redundancy. Anytime when a repeater at a light post fails, the other will automatically takes charge and sets up the network.

A separate GUI has been developed in Raspberry Pi for the private LAN which is not connected to the internet. As shown in figure 4, GUI consisting with location marking of street lights on a map has been designed based on Python programming language.

Figure 4 – LAN GUI on Raspberry Pi.

3.6 De-authenticating ESP 8266

The Wi Fi module configured as the controller is visible as an open Wi Fi device and can be connected by any intruder. Thereby, access is granted to outsiders into the network. If control of street lights in smart cities, remote areas etc is hacked by an intruder easily, it can lead for illegal deeds. Hence, security in the network has to be certified. A fourth ESP 8266 module is configured as a de-authenticator which will send continuous de-auth packets in the name of the SSID of controller. Thereby, any intruder is not allowed to connect to the network.

De-authenticator is configured using ESP 8266 de-auth flashing tool. Bin file of the de-auth is compiled into the tool and flashed to the board. After flashing, the device is discoverable as a secured WiFi device with SSID "pwned" and password "DEAUTHER". Once the device is connected, webpage with IP address "192.168.4.1" has to be accessed. Available WiFi networks nearby are thus shown after scanning. SSID of the specific controller Node MCU has to be selected and attack has to be clicked so that continuous de-auth packets are sent from the de-authenticator.

Figure 5 represents the model of the attacker. Once a client sends authentication request, any device can connect to the network through the open client. Once authentication response is sent by the user by accessing into the client, the de-authenticator sends de-auth packets continuously such that the user will continuously receive them except the information from the client since the information is thus blocked. Thereby, security of the network is assured.

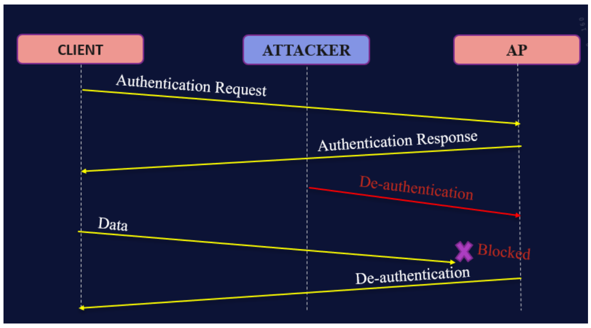

Figure 5 – De-authenticating Model.

3.7 Power Circuit

A power circuit has to be designed to supply power to each ESP 8266 module and street light. Hence, 12V DC and 230V AC supplies are required. Street light posts have been already supplied with 230V phase voltage. Therefore, it was stepped down to 12V and rectified using a transformer and a rectifier bridge to be utilized by the ESP 8266 and opto couplers after regulating to 3.3V DC. Power circuit is shown in figure 7.

4. Prototype Setup

Prototype set up has been designed as shown in figure 6 with PCB and installed on street light posts at a distance of 75m (approx.) each as represented in figure 8. Network was tested and proven at Sri Lanka Naval Dockyard, Trincomalee.

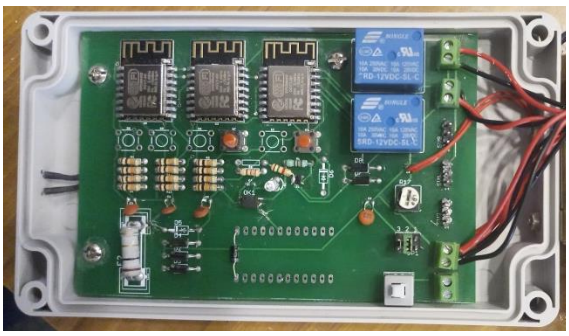

Figure 6 – Prototype Setup.

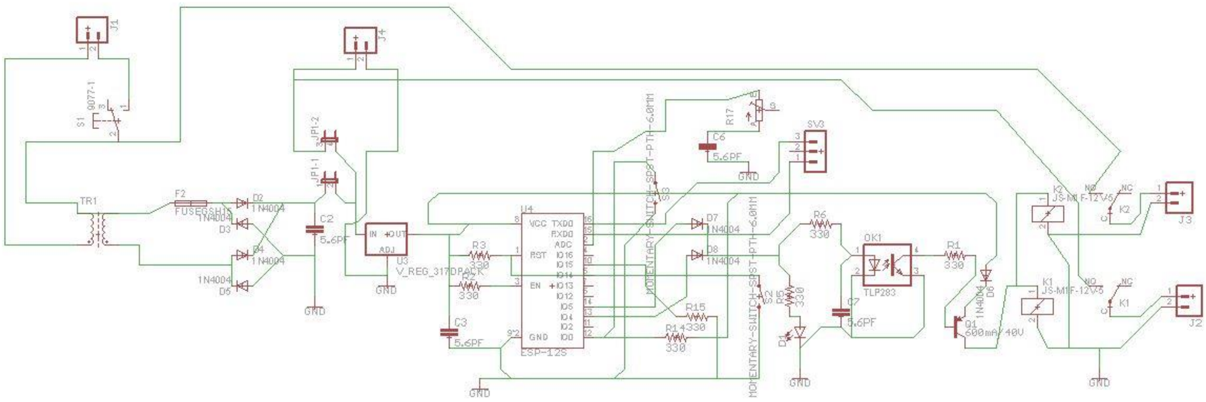

Figure 7– Power Circuit.

Figure 8 – Prototype Setup Installation.

5. Conclusions

The project was to implement an IoT based street light controlling and monitoring system. Already established street light controlling systems use conventional, power line communication, Zigbee, Bluetooth, LORA etc. A cost effective technique was to utilize ESP 8266 Wi Fi modules to form a network and get connected to a LAN or router to achieve the concept IoT.

The challenge of a street light system is long range communication. Range extension from Wi Fi modules has been achieved in this project. Clients have established a network and continuously connected to a broker. ESP 8266 modules communicate to the nearest client and then to the broker. Moreover, reliability has achieved by installing two or more ESP 8266 modules at each light. Once a module is malfunctioning, data will be transferred by the secondary module which automatically takes over the communication link. Hence, low cost ESP 8266 modules are kept for redundancy. LDR sensors are used to sense the light intensity of the environment. It will send a signal to ESP 8266 module to switch on street lights. Security aspect is achieved by introducing a de-authentication frame from an extra ESP 8266 which is connected to the broker. Network can be accessed through internet via a webserver GUI developed using Node Red which will allow user to control and monitor street lights individually. LAN which is not connected to internet is also configured with Raspberry Pi with a GUI based on Python.

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