Light Bharat–A Smart Lighting Solution

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Abstract: ***Now-a-days energy efficiency play crucial role in almost all smart systems. Smart Street Lighting forms the important and a valuable asset for the city's infrastructure that improves the efficiency of the lighting systems and reduces the overall energy consumption in the city. This paper presents the implementation of street lighting system for smart cities. In addition to vehicle detection based street light control, the setup includes a cloud based remote monitoring system for fault detection. The setup uses Amazon Web Services (AWS) through MQTT protocol for street light management system.***

Keywords: Smart Street lighting system, Internet of Things (IOT), MQTT, Cloud

I. INTRODUCTION

Conventional street lights consume 30% to 40% of the world's power generation and the statistics increase continuously. The consumption of power by the street lighting system can be improved and controlled by introducing smartness to the system. Light-emitting diode (LED) based lights have become popular as it is digitally controllable, small, highly efficient, and cheap to manufacture. The intelligent lighting methods will give the best power savings and lesser cost. It cuts the cost of Highways, Communities, and Street lighting systems. Various street lighting systems are implemented using LED lamps[10]. Many researches have implemented adaptive smart LED street lighting for energy optimization and proved to be efficient [1], [2], [4], [5].An application based remote monitoring street lighting are also proposed with LED lamps [3].A wireless based intelligent lighting systems are developed to control and monitor each street light poles remotely[1],[6]. The smart lighting control nodes are installed in each pole and communicate with the gateway node. All gateway nodes consist of microcontroller along with the various sensors. If the street lighting systems are made smart enough to work without any human intervention, then energy can be saved considerably. To connect the devices with each other and for communication with each other, fast and reliable protocol is required.

MQTT does all the required things with less time to communicate and with very less footprint of data. MQTT is one of the IOT protocols used nowadays on wireless and low-bandwidth networks. The MQTT protocol is lightweight in the sense that clients are small, and it uses network bandwidth efficiently [7],[8],[9].

This paper proposes smart street lighting system which illuminates the streets in the presence of objects and will be in OFF mode otherwise. The smart lighting system will detect the motion of vehicle and group of lamps are turned on using AWS services, considering as a single unit. A PIR motion sensor is used to detect the vehicle. This sensor detects the presence of the vehicle passing through and the information is reported to the microcontroller. Ambient light sensors help to detect the different light intensity levels of the surroundings. Based on the intensity of the light, the street lights are automatically turned on thus avoiding manual operations.

II. SYSTEM DESIGN

A. Sensors

1. Ambient Light Sensor: The OPT3001 Ambient Light Sensor is for controlling the smart lighting system based on the outdoor illumination. The sensor works based on I2C communication between smart controller light node and sensor. An ambient light sensor senses luminance in Lux (Lumens per square meter).The OPT3001 is the single chip Lux meter based sensor, measuring the intensity of the light.

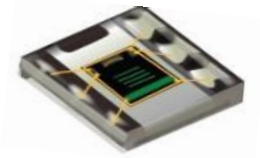

Fig. 1 ALS sensor

2. PIR Motion Sensor: The PIR (Passive Infrared or Pyroelectric) sensor is for detection of motion by humans or vehicle. It detects infrared radiation in the spectrum of 10µm wavelength, which was emitted by the human movement. The EKMC6101111 Panasonic PIR sensor is a high industrial grade, very reliable and accurate sensor.

Fig. 2 EKMC1601111 sensor

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The EKMC1601111 sensor will detect the length of up to 12 meters range in different angles based on the projection of the sensor. The sensors are able to detect the temperature changes from object as small as three degrees.

B. Smart Controller Board

The smart controller board is custom made on-board Wi-Fi ESP8266 module. Mainly this controller board is used for a controller node to communicate with the gateway. The ALS and PIR sensors are connected to the controller board.

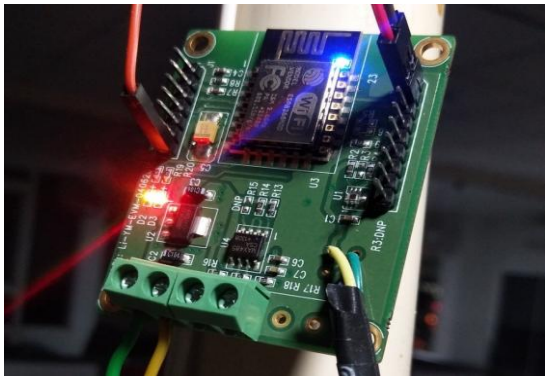

Fig. 3 ESP8266 Wi-Fi Smart Controller Board

Each smart controller has a unique node ID and it is specified for identification, which is generated by the Node MCU of the gateway node.

C. Gateway Server (Raspberry Pi& NODEMCU)

The Raspberry Pi is a mini computer with Raspbian Operating System. The processor used in Raspberry Pi is of ARM family. It has 40 GPIO pins configured on the board. The Raspberry Pi extra peripherals are USB connectors, Wi-Fi module, Bluetooth module, and Ethernet connector. Raspberry Pi is easily connected to the internet using Wi-Fi and Ethernet port.

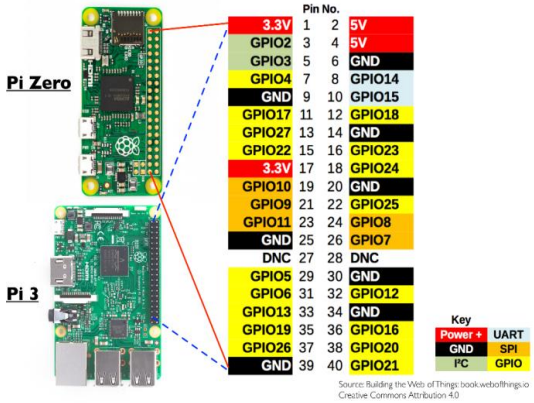

Fig. 4 Raspberry Pi Pin Configuration

The Raspberry pi and Node MCU are used as the gateway node.

D. FTDI Flasher

This FTDI flasher stacks up on the smart controller board. It serves a dual purpose. They are: Easy flashing of codes (Flash mode) and UART serial Monitoring.

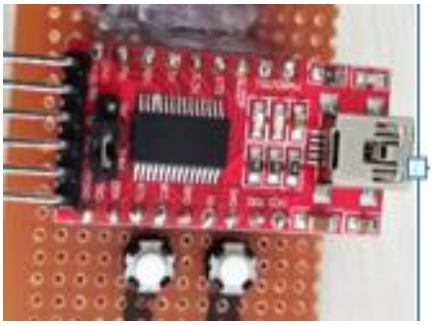

Fig. 5 FTDI ESP Flasher

In ESP 12E, Flash is controlled by pulling the GPIO0 to low. And Reset is carried out by pulling the nearest to low. In order to carry out UART flashing, i.e., in order to upload a program onto the ESP 12E chip, program mode is used. This mode requires GPIO0 to be low during power up.

E. Dimmable Driver Circuit

The dimmable driver circuit is used for changing the intensity of light according to the ambient light. The intensity levels will vary based on the brightness values coming from the gateway side. Using dimmable driver circuits, the LED lights lifetime will increase.

Fig. 6 Dimmable driver circuit

F. RTC Module

The DS3231 is an accurate I2C based real-time clock. It is connected to the I2C pins of gateway node (Raspberry pi).

Fig. 7 RTC Module

III. PROPOSED METHODOLOGY

A. System Overview

The proposed lighting system helps to reduce power consumption, manual operation and maintenance costs of lighting infrastructure in smart cities and industries. The overall system is a platform, extensible for monitoring and surveillance. The proposed lighting system consists of three stages: Gateway server (Raspberry Pi Microcontroller), Mesh server (NODEMCU Microcontroller), and ESP8266 smart controller node. Initially the communication will start from Raspberry Pi gateway to the mesh server, then data is sent to all nodes. The system flow diagram is shown in Fig.8.

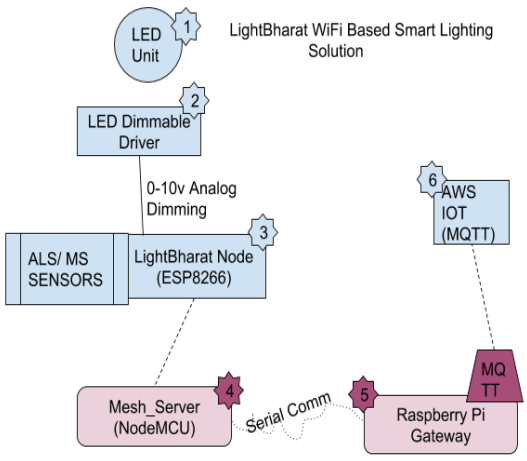

Fig. 8 System flow diagram

B. Communication Protocols

In this project three different types of communication protocols are used.

1. MQTT Protocol: The Message Queuing Telemetry Transport is an ISO standard publishes-subscribe based message passing protocol. It works based on the TCP /IP protocol. Mainly is designed for connecting things remotely. In this, the messages are exchanged between client and server with two types of operations: publishing topic and subscribe to the topic. MQTT is the lightweight message queuing and the transport protocol. MQTT protocol is used for communication between Raspberry Pi and Amazon Web Services (AWS).

2. Painless Mesh Networking Protocol: The smart controller uses the Painless Mesh library to create and participate in the mesh network. The mesh topology is formed based on signal strength. Each node (ESP12E) can be connected to a maximum of four other nodes. The network is formed in such a way that messages can be routed to any node through the mesh, and local loops are automatically avoided. Upon powering up of the mesh nodes, it may take anywhere between a minute to a few for the topology to form and stabilize. The library assigns unique node identification to each and every node in the mesh network.

C. Message Formats

The message format from Amazon Web Service to the Gateway (Raspberry Pi) and responses of all nodes can be seen in AWS. The communication will happen between Gateway and cloud only after subscribing the topic and publishing the topic.

Status of all nodes in a Gateway

{“k”:0, “r”:121}

Table. 1 Get Status of all nodes in gateway

k	Packet Type
R	Unique Request Id generated by server

Status from specific node

{“k”:1, “r”:121, “o”:122223 }

Table. 2 Get Status from specific node

k	Packet Type
R	Unique Request Id generated on server
o	NodeId to which the requested command is directed

Command packet from cloud to all nodes

{"k":4,"b":25, “r”:12}

Table. 3 Packet from Cloud to all nodes

k	Packet Type for all recipients to set to dimming level b
b	Dimming level
-1	Switch to default policy
r	RequestId

Command packet from cloud to a specific node

{"k":3,"b":25, "o":2138510154, “r”:12}

Table. 4 Packet from Cloud to specific node

k	Packet Type for a specific recipient
b	Dimming level
-1	Switch to default policy
o	Node Mac Id
r	RequestId

Status packet from node to cloud

{"k":2,"b":25,"e":122,"ms":93,"ls":577,"f":211,"o":2138510154,"r":107, “ap_id”:232, “ap_t”: 233, “cp_id”:23, “cp_id”:23, “ap_t”:23232, “f_t”:22322, “ce”:343}

{"k":2,	Packet Type
"b":25,	current dimming level of LED Driver
"e":122,	Current Active Power Energy consumption watts
"ms":93,	Effective average motion value in last 5 minutes
"ls":577,	Effective ALS value
"f":211 ,	Fault Code
"o":2138510154,	Node macId
"r":121,	0 (If Sent by node on its own) | xxx (if responding to any gateway request for stats)
“ap_id”	Associated Policy Id
“ap_v”	Associated Policy versioned
“cp_id”	Current applied policy (0 in case of custom dimming or 1 in case of default policy or xx in case of custom policy)
“cr_id”	Current applied rule (0 in case of custom dimming or xx in case of rule)
“ap_t”	Time when the custom dimming applied or rule switch done
“f_time”	The timestamp when this fault happened. TS when node failed condition

D. The Way of Communication between Nodes

The Raspberry Pi (Gateway) and NODEMCU mesh network server are termed as peers. Observe the same protocol to listen and communicate with each other. And here the pin configuration is that the RX and TX pins are connected to the Mesh server RX and TX. Flag is available to make alert to listen from the peer.

IV. IMPLEMENTATION AND DISCUSSION

The proposed smart lighting system is having the ability to reduce power usage in all scenarios of lighting systems. The more energy consuming areas are on highways, communities and street lighting systems. The gateway node will communicate with AWS using MQTT protocol based communication.

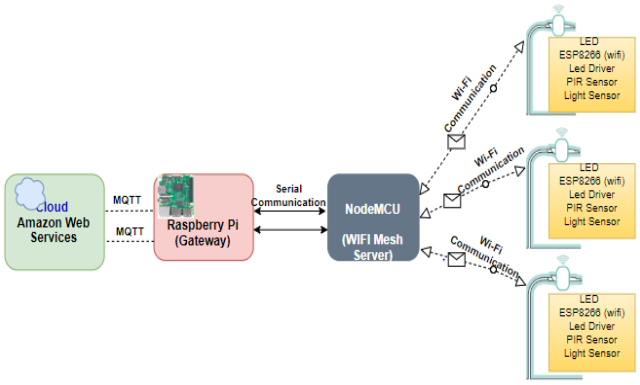

Fig. 9 System Communication flow diagram

After publishing the topic, the JSON based, the full length of packets will come to the gateway node (Raspberry Pi) by using MQTT protocol based communication. The gateway node will receive all packets from AWS and it will send it to the NODEMCU mesh server. It will receive all JSON packets from the gateway through serial and send it to the all smart controller nodes.

Fig. 10 Smart Light Pole Prototype

All smart controller nodes are communicating with the mesh server through Wi-Fi. Smart controller nodes will update the actual JSON packet parameters. After updating the values, it will send back responses to the NODEMCU mesh server then mesh server, send back the same packets through serial communication to the gateway node. The system uses time based lighting system and also senses various illumination levels based on the ambient light sensor values.

Fig. 11 Different test cases of smart light

V. CONCLUSION

The smart advance technology based smart lighting system is the future of the smart cities, highway lights and smart communities. The system design provides a proper and cost-effective solution for energy consumption problems. The upcoming future technologies are Wi-Fi and Lora based smart lighting systems. The implemented system is the least complex and more efficient reduction of manual operations. The system satisfies the core motive of power saving as the whole world consumes more power for lightning.

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