SMART IOT STREET LAMP

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Abstract – In Sri Lanka, traditional streetlamps currently consume 150 Gigawatt-hours of electricity every year. This is a significant amount of electric energy that has been wasted. To overcome this problem Multifunction Smart IoT Streetlamp system introduces as the viable solution. The system is designed to save electric energy. This system can be monitored and controlled remotely. For that, the traditional streetlamp system is replaced by using modern smart streetlamps. In this streetlamp system, lights can be turned on when needed off when not needed. In addition, the brightness of the lights can be controlled according to the requirements which increase the lifespan of the light, and the color temperature of the lights also can be controlled according to the requirements for ease of public. The proposed smart streetlamp is also equipped with a defect detection program that notifies the management dashboard of any defects. The smart streetlamp which will be introduced will communicate via the network and connect to the cloud through metropolitan Wi-Fi. Also, this system will ensure public safety by controlling the behavior of the streetlamp according to the environment surrounding conditions.

Keywords: smart streetlight, remotely, IOT, energy, brightness, Municipal Wi-Fi, cloud.

INTRODUCTION

In Sri Lanka, traditional streetlamps currently consume 150 Gigawatt-hours of electricity annually. This significant amount of electric energy wasted is being the one of main issues in concern. Apart from that main issue, if a traditional streetlamp is not light up or burned due to a fault, there is no proper method to determine until it is reported by someone. Due to this reason, road accidents can occur. Currently, most of streetlamps in urban areas are relayed together to the central location and daily switched on/off is done by human intervention. If the person who is responsible for turning off the lights falls sick or ill, sometimes it will also be turned on in the daytime. This consumes much unnecessary power and reduces the lifespan of the lamps. Also, the most used lamps are sodium lamps. So, the lighting in full brightness will reduce the lifespan of the lamp it will burn quickly. Because of these issues, the government needs to spend more on the repairs for the streetlamp replacement which is an additional cost. Also, based on the changing bad weather conditions (rainy, gloomy, misty) the traditional streetlamp is not effective to give good visibility to the drivers. It will again reduce the public safety. Additionally, if a sudden incident happens (vehicle accidents, fallen trees, broken pipes) until the official authorities arrive at the place to notify something happened with the road sign board and lights no guidance will be provided. So, there can be more accidents due to the unconscious of the other drivers or pedestrians. To overcome all these issues, the multifunctional smart IoT streetlamp system is proposed. This system is a high efficiency, cost-effective, and accurate system. Also, this system helps to save electric energy, light pollution, and ensure public safety. This system can be monitored and controlled remotely. For that, the traditional streetlight system is replaced by using modern smart streetlamps. This IOT Smart LED Street light system is one of the major technologies in developing a smart city.

LITERATURE REVIEW

Today, urbanization and the creation of smart cities are common in many countries. It is now being implemented in developing countries as well. One of the most important aspects of developing smart cities is street lighting, which illuminates roadways, pedestrian pathways, and other public places. As a result, high power consumption, public safety, and streetlamp quality (lifespan of streetlights) are all common challenges with this system. There are several projects for control and manage these problems. However, some projects could not have been given proper solutions. And compared to these projects, the clear idea could be got by us about how to solve our project problems and our project improvement.

In [1] Smart Street Lighting Control and Monitoring System is proposed. Main objective of this system is to reduce electrical power. As a solution, they developed a system that automatically shuts off the light in areas of the roadway where there are no vehicles and turns it back on in areas where vehicles are expected to arrive. This system used VANET to identify the presence of vehicles in real-time, as well as their speeds [1].

However, as technology evolves, conventional s suffers various technological difficulties, including decreased flexibility, scalability, poor connection, and insufficient intelligence. In our project Implemented a solution for it. When there are no movement of vehicles or people, the intensity of the streetlight is lowered, significantly reducing waste and light pollution. Intelligent streetlights only illuminate streetlights at sufficient levels when people or vehicles are detected, resulting in enhanced public safety. For monitoring the surrounding environment, a high-sensitivity LDR and a low-energy PIR were used.

Another concept that is comparable to the proposed street lighting system, specifically for monitoring streetlamps, is given in [2]. The major goal of the proposed system is to provide a proactive monitoring system with providing warnings for effective [2] maintenance assistance andreduce energy waste by lowering or turning off on request. They utilized an embedded intelligent energy meter to measure energy consumption, and it provided a platform for government officials to examine periodic reports created depending on the status of usage, the performance of illumination, and operating times. Used a solution which is if a streetlight is not lit up or burned due to a fault, new bulbs can be replaced as soon as possible. because we implemented

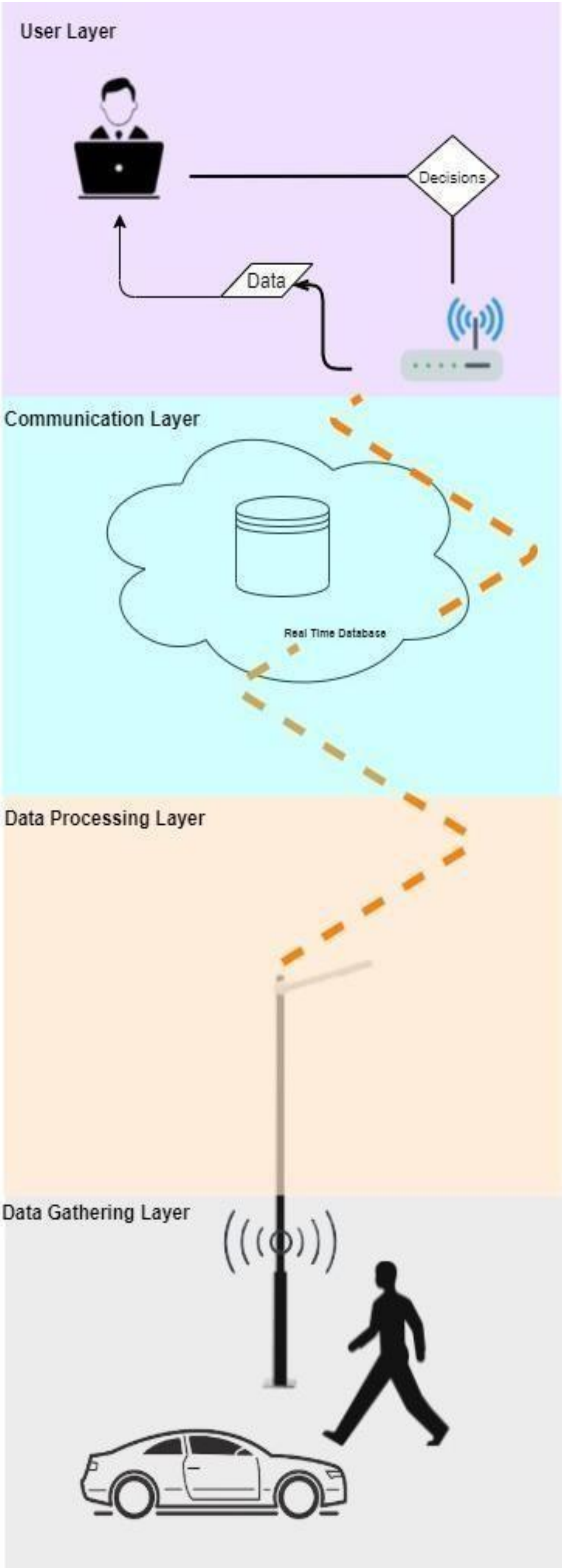

Figure 1: Overview Diagram

a system to monitor the streetlights remotely. The data gathered from this procedure will be used as an input for the remote monitoring procedure to display on the dashboard. In this procedure, analogue input pins of the microcontroller will be used to identify the voltage levels across the bulbs. Inputs will be processed by software to decide the defect whether the bulb is working or not.

Another method is proposed in [3] to minimize high power usage. In this project, the main aim was to introduce a new system for energy saving instead of traditional expensive electronic ballasts which have been electronically wasted and pollutant for many years. For solution of energy saving, in this proposed system an electromagnetic ballast is used which have a long lifetime, recyclability of iron chokes, high reliability and immunity [3]. The electric energy wasted issue can be avoided using the proposed Multifunctional Smart IoT LED Street Lamp system. This proposed system used LEDs which are high efficiency and cost-effective blubs. Therefore, these LEDs help to save electric energy and light pollution. This LEDs also provides change its intensity dependent on the necessity to replace high intensity discharge lights.

A remote-control system for road illuminating is proposed in [4]. The technology is based on the handling of wireless network, which can monitor lighting in real time. The proposed system uses the Zigbee wireless networks and GPRS standard to monitor the bulb status [4]. The aim is to ensure central monitoring of the condition of the road lighting terminals, including a wireless controller and a ballast to remotely connect or disable the terminal. In addition, all the terminals may be switched in a half-power status at some point to save energy. This system has numerous restrictions. To begin with, its difficulty and expense: every unit or endpoint requires a microprocessor controller, and wireless interface. This can significantly raise the system cost, preventing it from being widely deployed. Furthermore, it is employing a new system for road lighting control and administration rather than the old site. Finally, the system is not self-contained. The system is configured at a certain time to dime the terminals. The system does not consider whether vehicles are present. So, the maximum power savings cannot be achieved.

METHODOLOGY

System Overview

The device implementation consists of 4 main layers. There is a ‘Data Gathering Layer’ (DGL), ‘Data Processing Layer’ (DPL), ‘Communication Layer’ (CL), and ‘User layer’ (UL). From here onwards, these layers are represented by these abbreviations in this paper. An admin interacts with the real-time database through UL. Through the UL, admin can monitor the system as well as control the system using manual override feature. When the admin enables manual override and controls the system, that control data flows from UL to CL. User layer consists of Administration dashboard. Dashboard is developed using React Js JavaScript library.

All the lights are connected to the CL via their DPL. Therefore, for each change admin does on the dashboard, CL triggers a message to all the lights connected to the system informing the change. The received information will be processed by the DPL and the light will be controlled accordingly. All these procedures happen in real-time. To implement the delay-sensitivity of the system, CL is developed using Google Firebase Realtime Database.

When the system is in ‘Automatic Mode’, the light system is controlled by solely by the DPL. DGL gathers data from its sensors and those data will be processed and fed to DPL as the input for ‘Automatic Mode’. According to the information received from DGL, DPL controls the light. It also updates the status of the light to CL. These layers are implemented with a NodeMCU development board and printed circuit boards specially designed for this purpose.

Admin can add a new light to the system by UL choosing the light mode whether if it to trigger human motion or vehicle light intensity. When adding a new light, the longitude and the latitude will be given to the CL. Default light will be put to automatic mode. A weather API is used to get the sun set time and sun rise time to the DPL. The system clock will run from a NTP server in the DPL. When the sun rises time and sun set time equals the lights will be turned on and off automatically without human intervention. Every day the light will be turned on in the sun set time and the light will be turned off in the sun rise with the algorithm that is implemented. Weather API call will be called in every morning to get the sun rise time and the sun set time of each day. So based on the location the sun set time and the sun rise time will be fetched from the open API to control the light accurately.

In the operation of the LDR mode the vehicle light intercity will be captured and the brightness of the light will be controlled based on the surrounding environmental light conditions. This option will be used to save the power of the streetlamp. If the light mode put to detect the human motion the lamp will be controlled based on the human motion. Streetlamp will be working on 25% brightness. Human motion triggered the lamp brightness will increase to 75% to give a good visibility and decreased back to 25% no human motion triggered via the DPL.

A warning light feature is implemented which can be used as a notification light to the drivers when and accident occurs according to the accident light can be configured to give a visible warning to the drives and the pedestrians by color. Red light warning can be given if a severe damage occurs on the road. If a minor damage occurs yellow light warning can be given on each lamp. Whatever the operate mode is warning light has a high priority. It can be turned on from the UL. From the UL a light list can be obtained, and the admin can override the warning light one by one. After the warning light off the light will go for the previous assigned state and execute the rest of the operations that has been instructed to do the execution.

Once DPL updates the CL with the light information regarding automatic controlling, UL access that information from the CL and displays on the dashboard. So, admin can monitor the status of the system via UL.

The lights also have a defect identifying procedure implemented in the DGL and DPL. If there are any defective operation occurs the DPL will send and update to the CL and notify the defectiveness on the dashboard. Admin can view what are the defective lights and notify the responsible authorities to do the repairs. It identifies defects in the light and informs to admin via the same procedure. Defect monitoring will also have a higher precedence in the mode of operation.

```
void setup{
        Connect to WI-FI;
        Connect to RTDB;

}
void loop{
//Manual override
if((mode == 1) and (on == 1){
            warningLights();
            doDefectMonitor();
            control brightness;
            control temperature;
            read brightness and color temp from the RTDB;

        if((brightness == 1) and (colorTemp == 1)){
                //1500k temperature with 10% brightness
                Control;
        }
        else if ((brightness == 2) and (colorTemp == 1)){
                //1500k temperature with 25% brightness
                Control;
        }
        else if ((brightness == 3) and (colorTemp == 1)){
                //1500k temperature with 50% brightness
                Control;
        }
        else if ((brightness == 4) and (colorTemp == 1)){
                //1500k temperature with 75% brightness
                Control.
        }
        else if ((brightness == 5) and (colorTemp == 1)){
                //1500k temperature with 100% brightness
                Control;
        }
}
//Automatic mode
else if ((ldrMode == 1){
                warningLights();
                doDefectMonitor();

                if( systemTime.equals(sunSet)){
                Light on;
                Control;
                }
                else  if ( systemTime.equals(sunRise)){
                Light off;
                Control;
                }
        }
 else if ((pirMode == 1){
                warningLights();
                doDefectMonitor();

                if( systemTime.equals(sunSet)){
                Light on;
                Control;
                }
                else  if ( systemTime.equals(sunRise)){
                Light off;
                Control;
                }
        }
}
```

Figure 2: Device Firmware execution precedence.

Hardware Overview

A. Light Intensity Capturing Mechanism

According to the characteristic curve of the LDR when the environment gets dark the LUX level is very low comparing to the day light and the sunlight. So, this characteristic curve was used to build the automatic light control the light when the light put on automatic mode. When the LUX becomes lower brightness of the light must increase, and when the LUX is higher the brightness of light must decrease. This characteristic curve can be used to turn on and off the lamps automatically.

LDR will be used with a voltage divider circuit. LDR will be series with 10kΩ resistor. deceased, and when the light level decreases the resistance of the LDR will be increased. The resistance will be kept at constant. From the Ohms law

$$V = IR$$

If R is kept at constant V will be proportional to I. So, the Equation will be

$$V \propto I$$

When light meet the surface the I will be increased. Because V is proportional to V will be decreased. With this relationship the voltage references can be read through an analog pin of the microcontroller through a 0-1024 sampler. After the sampling based on the values read through the analog pin the light can be controlled based on the light intensity.

```
int analogVal=value of the analog pin;
if((analogVal  > 0) and (analogVal <98)){
                    brightness (75%);
else if ((analogVal > 102) and (analogVal <198)) {
          brightness (60%);
}
else if ((analogVal > 202) and (analogVal <298)) {
                    brightness (50%);


}
........................................................
else if ((analogVal > 902) and (analogVal <1024)) {
          brightness (0%);
}
```

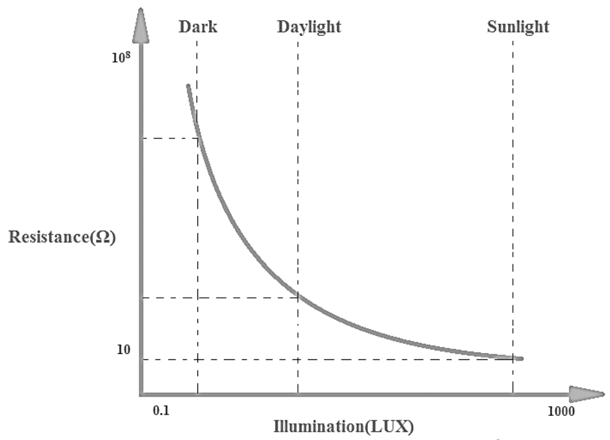

Figure 3: Luminance vs. Resistance of LDR

B. Human Motion Detection

To detect human motion there are mainly two mechanisms can be used. Industrial IR (Infrared sensors) or Industrial PIR (Passive Infrared Sensor). PIR is more intelligent than the IR sensor. Because the PIR sensor will give a digital output based on the heat energy detected basedon the movement with the pyroelectric sensor. There are two parameters that need to be adjusted to use the sensor in the most optimized manner.

1. The sensing distance of the sensor

Every sensor will come with some error. According to the datasheet the sensor can sense heat signals up to 8m, but with the surrounding conditions it can work up to 5m. (Figure 4) So, the sensor will be placed on the lamp in a manner it can detect the human motion and give the signal to the microcontroller.

2. The time that the trigger will stay high when the sensor detects a motion

The output of the HIGH signal was tested with time to find the most viable solution to trigger the increase the brightness of the streetlamp.

$$\text{Ontime} = \text{Signal High trigger time} - 0 \text{ ms}$$

Based on the calculations the parameters adjusted to keep the signal at logic level 1 for 5ms and then go for logic level 0. (Figure 5) After the parameter adjusted, the logic was implemented to control the streetlamp that will use human motion trigger as an input.

```
int pirVal = value of the pirPin;
if( pirVal == 1 ){
                    brightness (50%);
else (pirVal == 0) {
          brightness (10%);
}
```

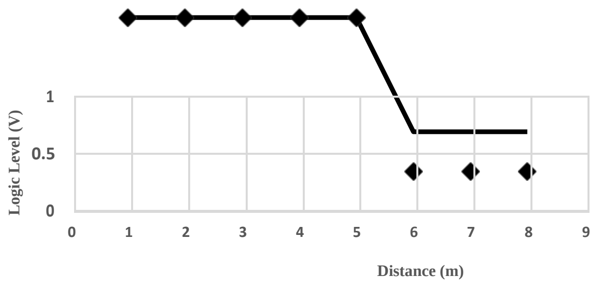

Figure 4: PIR Distance Test Results

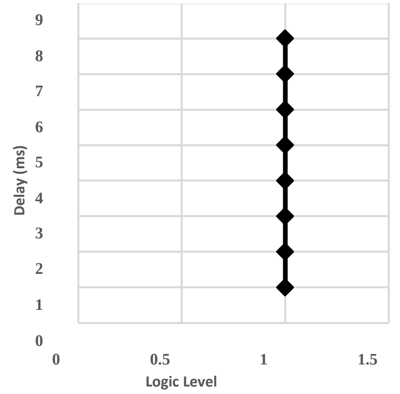

Figure 5: PIR Delay Test Results

CONCLUSION

Usually in Sri Lanka use traditional streetlamp systems in streets specially in urban areas which has lot of technical issues and failures. That system wastes huge amount of unnecessary electrical energy.

Existing streetlamp systems does not have proper automation switching system or light intensity control system which is helpful to save lifespan of the lights. To overcome above addressed local issues this project have proposed as a proper solution.

To avoided the electric energy wasted issue used LED blubs which are high efficiency and cost-effective blubs. Therefore, these LEDs help to save electric energy and light pollution. This system can be monitored and controlled remotely. For that, the traditional streetlight system is replaced by using modern smart streetlamps. The system monitors the defect on the streetlamps remotely. Therefore, new bulbs can be replaced as soon as possible. This will help to ensure the public safety to reduce the vehicle accidents and robberies happens in the street. This system is capable to reduce the intensity of the light whether the condition it is manually override or in automatic mode. The multifunctional smart IOT LED streetlamp can adjust the brightness and control the energy effectively. It will increase the lifespan of streetlamps. So, no regular replacements are needed. It will save the government budget on spending more on streetlamp replacements. Remote controlling monitoring will ensure that all lamps will be turned on and off at the correct time periods. It will save energy. The smart streetlamp is intelligent enough to say if it has a connection issue or the light is burnt. It can notify the dashboard in real-time when the event occurs. So, it can be repaired immediately to ensure the public safety of the drivers. This smart street can give the optimal color rendering for a defined weather condition (rain, misty, gloomy) condition compared to the sodium streetlamp which gives solid 1700K yellowish light. When there is an accident, or any incident occurs the streetlamps can be used as warning lights to ensure the safety of the others.

The streetlamp itself will be able to turn on and off if the light put in automatic mode without any human intervention which is a dramatic advantage comparing with the traditional street lighting system that is currently existing in Sri Lanka

In the future improvements solar power will be used rather that the traditions power lines to power up the streetlamps. As a consequence of the availability of solar-powered street lighting systems, it is widely predicted that smart lighting systems will have a significant influence in the future years. Today's world, economically developing countries are in the stages of enacting solar street light systems, which they have discovered to be an efficient way to save electric energy and Energy costs. As a result, it would be more suitable for countries such as Sri Lanka, which also spends a large portion of its electrical energy generated on streetlamps.

This Multifunctional Smart IOT LED Street Lighting system can be developed in the future so that city maps with the positioning of each streetlamp can be connected with the smart system. This will allow for real-time monitoring of the system, making it even more efficient. Because they are relatively simple to utilize for wireless modules.

Streetlamps will be networked with the ad-hoc network technologies for the management purposes. For a network of lights one main lamp will be connected to the communication layer and based on the instructions that will be received to the main lamp the rest of the lamps can be controlled via the main controller of the main lamp.

Furthermore, the lamps can adjust the color temperature and the brightness manually. In the future improvements an Ai engine will be implemented to make the decisions based on the surrounding environment. There are varies of whether conditions (cloudy, misty, rain, heavy rain, gloomy). Using an AI engine, the most optimal rendering can be implemented to be changed based on the current weatherconditions

Implementing the RTC modules to the light poles will be added to measure and keep the system time on every streetlamp rather than getting the time from an NTP server. With the RTC the embedded module can be optimized using the ROS. More optimization of the embedded module will be done via the ROS.

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