LoRa BASED SMART STREET LIGHT MANAGEMENT FRAMEWORK

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Abstract— The idea of outlining a new framework for streetlights is to reduce the power consumption involved in the present lighting system which consumes about 80% of the world's electricity. Smart lighting provides remote control mechanism that can be adjusted dynamically on the basis of environmental conditions. This can ensure longevity of the application and economic usage of power. This research aims to develop energy-efficient street lighting systems. In this research, a novel solution that utilizes the new upcoming technology known as Long-Range (LoRa) for communication and Arduino microcontroller for processing, is proposed. Light Dependent Resistor (LDR) and current sensor are used to sense the presence of illumination intensity based on which the switching ON/OFF of street light is performed automatically. LoRa technology supports communication upto 18 km when compared with the other traditional systems, namely Bluetooth, WLAN, and ZigBee. Due to this the usage of cloud support can be eliminated. In this research, a prototype is developed to analyze the performance of the proposed work in real time scenario.

Keywords: LoRa, Smart lighting, Current sensor, LDR, real time scenario.

I. INTRODUCTION

The traditional designing of streetlight system lacks adequate maintenance, leading to consumption of large amounts of energy and financial resources. It also lacks reliability. Streetlight is found to be one of the major components in the power consumption worldwide [1]. Hence, it is essential to give more attention to improve the efficiency of power consumption by saving energy. Thus the objective of this research is to design and develop an autonomous streetlight management system to enhance the power usage.

Existing systems consist of a monitoring center, a monitoring node which is interfaced with sensors and may or may not include a connection with the Internet. Most systems today use Bluetooth, ZigBee and Wi-Fi technology for wireless communication. The disadvantage of using Bluetooth is that it has a very short range (10m) while ZigBee and Wi-Fi systems also provide only upto 100m range [2]. Traditional lighting systems can be made intelligent with the incorporation of sensors [3] that can be used to interpret the surrounding environmental conditions. They are termed as smart streetlight system which exhibits adaptive behavior by turning ON/OFF the street light on the basis of surrounding illumination conditions [3].

In order to increase the battery's lifetime, a framework that utilizes much lower data rate with reducing power consumption needs to be developed. The proposed system uses LoRa technology which offers a very low data rate, thus lowering the power consumption and increasing the battery's lifetime to around 20 years .It supports star topology which ensures scalability and fault tolerance to the network. Each device can independently communicate with the hub and provide a means of centralized management to monitor the network. It offers a very long range of communication, i.e., 5 km in urban, 18 km in suburban and 48 km in rural area. This is more than 50 times the range offered by the previous technologies. It uses chirp spread spectrum in the 868 MHz band.

The rest of the paper is organized as follows: Section II discusses the state-of-the-art related to the proposed work. Section III describes the proposed work. The performance of the developed work is analyzed in section IV. Finally, section V concludes the paper with direction for the future work.

II. MATERIALS AND METHODS

Noriaki Yoshiura et al. developed a sensor network based smart street light system [6] which resembled the traditional Street Lights system. It turned ON/OFF on the basis of the outcome of the motion sensor which detected the presence of moving objects, namely pedestrians and vehicles. The brightness of street lights was dynamically adjusted on the basis of the information obtained from the pictures captured by the surveillance camera fixed on the streetlight pillar. The future plan of this research was to develop an algorithm to enhance the accuracy of ON/OFF control.

Huang-Chen Lee and Huang-Bin Huary designed a low cost and non-invasive system [7] to measure and detect faulty streetlights. A special equipment known as hitchhiker was commissioned in a mobile vehicle to collect information about the intensity of streetlights. An illumination maps (IMaps) was created using these collected data to determine faulty streetlights. Each hitchhiker consisted of a light meter and a GPS module. The significant advantage of this system was networking modules and additional sensors were not needed be installed in every streetlamp. Further, the designed system could be extended to detect faulty streetlights in the town by creating town sized IMAP. This could ensure road safety.

Abinaya et al. developed an IoT based smart and adaptive street light system [8]. The lighting condition in this system was controlled on the basis of the light intensity. Further, the developed system was also used for surveillance applications. The camera placed on top of the street light tracked the road activity and stores the footages in a server. The developed system also had a panic button placed on the poles; the person in danger could press this button to raise an alarm. It also had cloud accessibility. This developed system was reliable, cost effective, and prevented wastage of energy.

Umber Noreen et al. investigated the characteristics of LoRa under three basic parameters, namely spreading factor (SF), code rate (CR) and bandwidth (BW). The conclusions drawn were that LoRa could offer the code rates (4/5, 2/3, 4/7, and 1/2) for FEC and higher spreading factor to provide long range communication. Each spreading code corresponding to each SF was considered orthogonal. Thus, multiple frames could be exchanged at the same time. Also, an increase in CR and SF values decreased the effective data rate and increased time-on-air of LoRa packet.

Philip Tobianto Daely et al. designed a smart LED streetlight system along weather monitoring smart city [9]. The centralized web-server received both weather information and real-time sensed data from each of the LED streetlights which were provided with a web interface for authorized users. Unlike the existing systems this system helped in mitigating the chance of traffic accident that might happen due to low visibility.

Jha Ashish et al. developed a Smart Street Light Management System using LoRa Technology [10] to automate the operation of the street light, meeting out the requirements of vehicles and travelers. They used Light Dependent Resistor (LDR) for day light saving, Passive Infrared Resistor (PIR) for motion detection. LM35 to sense temperature, MQ-7 to check the pollution caused due to carbon monoxide and hydrogen. Arduino microcontroller was used for data processing while ESP8266 was used for data transfer. It was found that deploying smart streetlight system using LoRa helped in saving energy, detecting faulty streetlamps and also in reducing manual surveillance on each pole.

Juha Petajajarvi et al. analyzed the performance of low power wide area network based on LoRa technology, namely doppler robustness, scalability and coverage [11]. They showed that with a transmit power of 14dBm and a spreading factor of 12, more than 60% of packets could be received for a distance of 30 km. Similarly, they measured the performance of LoRa in mobile scenarios and found that the performance was degraded drastically when the distance was around 40 km/h.

The following observations are made from the above cited in [6] the literature. The work mentioned in is cost-effective and reliable. However, it is not validated in real time. The work [10] provides an energy saving technique through adaptive lighting. The work cited in [9] uses ZigBee based communication, range offered is very poor, it is prone to attack from outside environment and replacement cost is found high.

To overcome these limitations, a communication protocol that provides longer range, higher security in transmission is needed. Thus, LoRa based street light monitoring addresses the above requirement. Added to that, it is also cost-effective and reliable in transmitting packets at lower power with low data rate. The works [3] and [11] provide basic understanding on LoRa technology.

The proposed framework consists of three modules, namely automatic ON/OFF, LoRa communication, and event processing with alert generation module as illustrated in Figure 1.

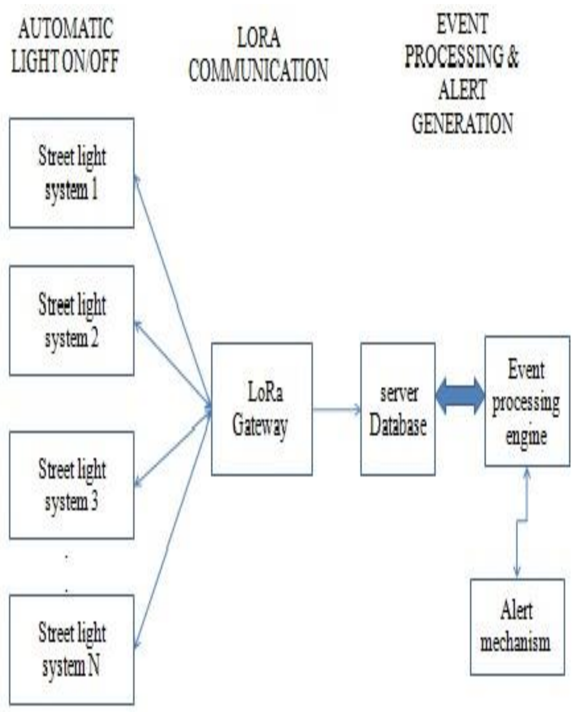


Fig.1- Proposed LORA based streetlight management framework

Automatic ON/OFF

This module consists of LDR (light dependent resistor), processing unit and LoRa transceiver as shown in Figure 2. The LDR detects the presence of environmental illumination. Whenever the illumination is dull, the sensed signal of LDR enables the process to trigger the relay circuit connected to the lamp to switch ON. The reverse condition will switch OFF the lamp. Thus automatic ON/OFF is realized on the basis of the environmental illumination.

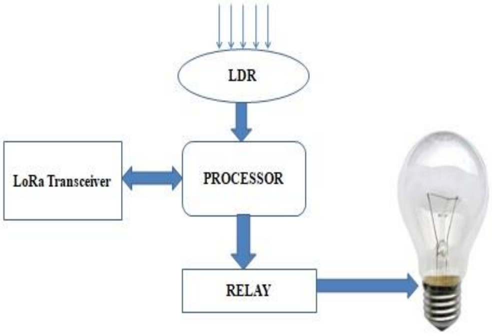


Fig.2-Automatic ON/OFF module

LoRa Gateway

The remote access of this application can be accomplished using wireless communication. As it is known from the literature, LoRa technology supports longer range of communication with limited transmitted power. Hence in this research, LoRa is employed. The processor transmits the status of the streetlight to the LoRa gateway using LoRa transmitter. From the literature, it is known that LoRa supports star topology and 65535 number of end devices.

Event processing with Alert mechanism

The processed information which indicates the status of streetlight can be stored in the cloud repository or local server as per the application requirement. In this research, it is made locally. Several events can be generated from the available Meta data as per the requirement of the application. They are energy consumption in the city due to streetlight, the faulty status which may demand periodic maintenance and finally, the illegal usage. Hence the event processing engine present in the server generates the above event. Based on the level of abnormality, the alert mechanism generates alerts.

III. RESULTS AND DISCUSSION

Figure 3 illustrates the customized automatic ON/OFF module developed. It consists of LoRa RF module (SX1272MB2XCS)[14] processor (Arduino Uno) [15], LDR (ACS712) [16] and relay of 5V [17].

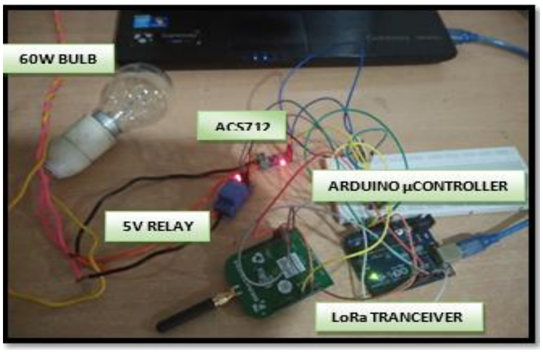
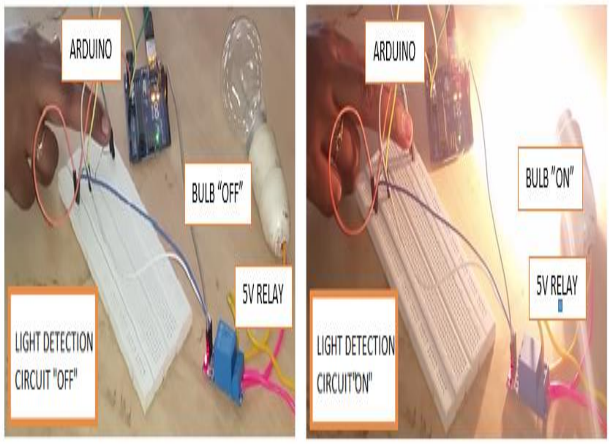


Fig.3- customized automatic ON/OFF module

Real time test bed

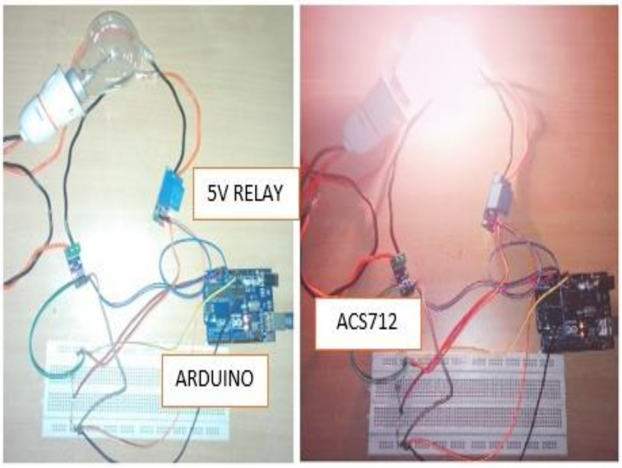
Light detection circuit shown in Figures 4 a and b forms the root system of the proposed framework. It provides the ON/OFF control over the streetlamp. It consists of an LDR (Light Dependent Resistor) whose resistivity is a function of the incident Electromagnetic Radiation. This circuit switches ON the streetlamp when it is dark and switches OFF when it is bright.



(a) (b)

Fig.4 Light detection circuit

Power monitoring circuit continuously senses the voltage across the street bulb, using ACS 712 current sensor. Further manipulations in the LoRa transmitter code yields power consumption. When this module is powered with Arduino and supplied with AC power, ACS712 sensor undergoes Hall Effect, RMS current and RMS voltage can be seen in the serial monitor of Arduino IDE. The power monitoring test set-up is shown in Figure 5.



(a) (b)

Fig.5-Power monitoring circuit

The target node consists of SX1272MB2xAS LoRa transceiver, Light detection circuit and Power monitoring circuit. When the LoRa radio shield is powered on, the device gets detected and it transmits the RMS current, RMS voltage, Power consumed by individual streetlamp to the LoRa gateway.

The output at target node is displayed on the serial monitor of Arduino IDE and this is shown below in Figure 6.

Fig.6- Output of the transmitting node when lamp is OFF and ON

The receiver node consists of SX127MB2xAS LoRa RF transceiver interfaced with Arduino microcontroller. As soon as the receiver end node is powered, it starts to detect the transmitted power values from the target node as shown in Figure 7

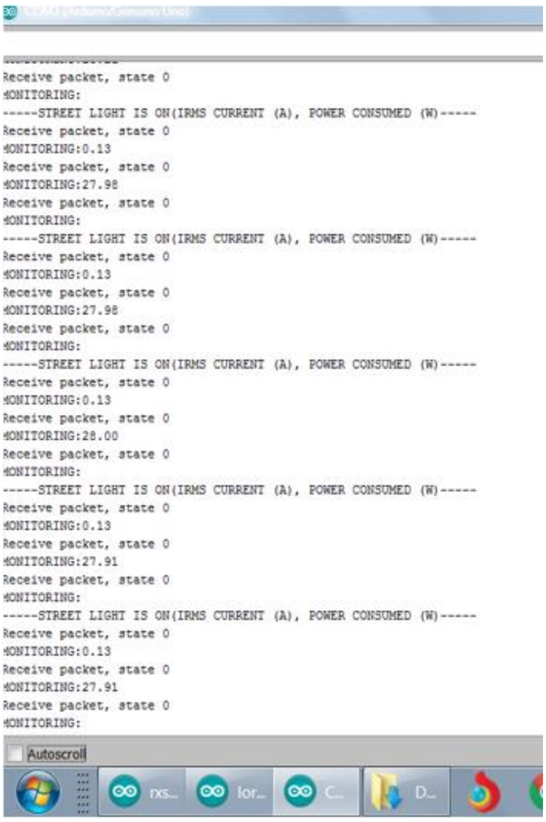


Fig.7- Output of the receiving node

Performance Analysis:

The performance of the proposed work is analyzed in terms of power consumption and communication range of LoRa.

Power Consumption Analysis:

Here the power consumed by lamps having different ratings is presented. The power consumption and RMS current are plotted at intervals of 1 minute.

RMS current and power consumption characteristics of 15W, 28W, and 60W bulbs are found. Here the RMS current and power consumption readings for bulbs of different ratings in the ON condition for 15 minutes are shown in Figure 8 and Figure.9 respectively.

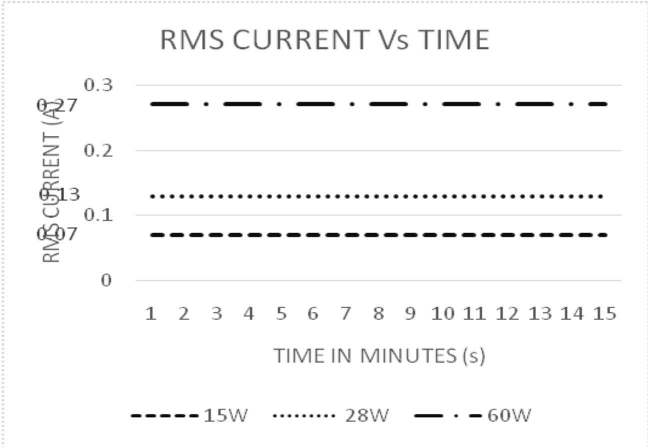


Fig.8- RMS current vs. time

In Figure 8, the RMS currents drawn by 15 W, 28 W, and 60 W bulbs have been observed over duration of 15 minutes. The time in minutes is considered along the X-axis and the RMS current is plotted along the Y-axis. After letting the bulb glow for 15 minutes, it can be observed that the current drawn by the 15 W, 28 W, and 60 W bulbs are 0.07A, 0.13 A and 0.27A respectively. Similar the power consumed by the corresponding bulbs was presented in Figure 9.

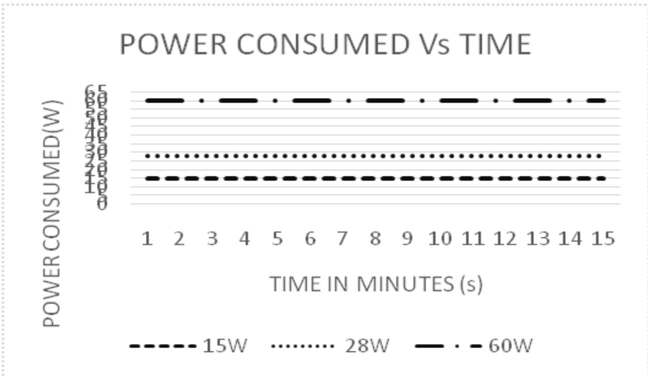


Fig.9- Power consumed vs. time

Fig.10- Serial monitor output showing RMS current and power consumed at transmitter and at receiver

From the above results, it can be observed that the expected values agree with the measured values. The monitoring of RMS current and power consumed helps to identify any anomalies that would occur in the case of leakage or faulty streetlights.

Range Analysis: Transmission and reception were observed at different ranges in different types of areas with and without obstacles. A graph of the throughput vs. range has been plotted and is shown in Figure 11.

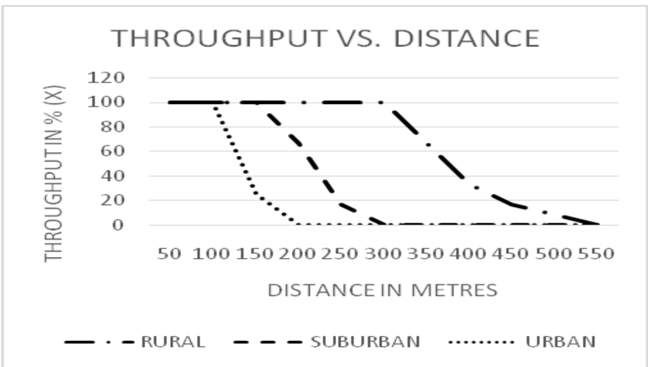


Fig.11- Throughput vs distance in rural, suburban, and urban areas.

From the above results, it is inferred that the range increases from urban area to suburban area to rural area. When considering an urban area, the throughput is found to decrease drastically after 200 m. In a suburban area, it is after 300 m while in rural area it is at 550 m. Maximum throughput of 100% is attained at 110km, 170km and 320 km respectively for the above three terrains. Hence from the investigation, it is concluded that deployment can be limited to the above obtained coverage distance if maximum throughput is expected or demanded.

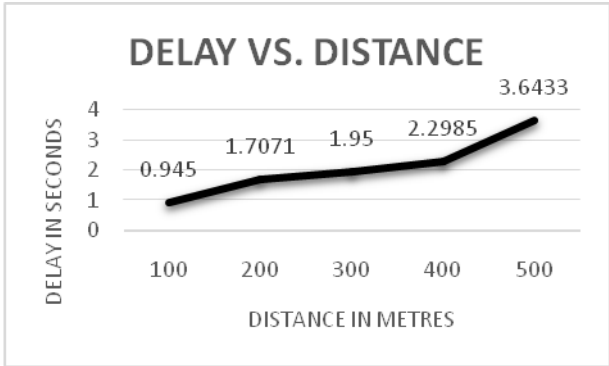


Fig.12- Delay vs. distance graph

Delay between transmission and reception has also been analyzed and a graph has been constructed between delay and distance as shown in Figure 12. From the above results, it can be inferred that as the distance increases, the delay between transmission and reception also increases. The delay is dependent on both distance and obstacle density. As the number of obstacles between the nodes increases, the delay also increases.

IV. CONCLUSION AND FUTURE WORK

In this paper, the LoRa based smart streetlight management framework is developed. A method for autonomous switching and power monitoring has been designed which enables the detection of leakage and faultiness of streetlights. This research also provides efficient transmission of data packets from each streetlight to the control station. Parameters like RMS current drawn, power consumed are also obtained and analyzed. Range testing has been performed for locations of various densities. Delay between transmission and reception has also been calculated and interpreted. The scope of this research can be broadened to include various other sensors, cloud support, enhancing memory capacity of the module by installing Raspberry Pi at the receiver end and including an inference engine.

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