CRUDE OIL PRICE PREDICTION

Project Report

Submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology

in

Computer Science Engineering

by

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CERTIFICATE

This is to certify that the report entitled "**CRUDE OIL PRICE PREDICTION**" is a bonafide record of the **Project** done by **PRACHI MISHRA** (*Roll No*.: **B200788CS**) under my supervision, in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Computer Science Engineering** from **National Institute of Technology Calicut**, and this work has not been submitted elsewhere for the award of a degree.

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ABSTRACT

Existing street lights in many nations use a tremendous amount of electricity because they are always on at night, regardless of how busy the route is. An ineffective lighting system that is unable to adjust to the volume of traffic is to blame for this high energy use. The energy consumption amount is equivalent to 0.8% of Japan's yearly electrical energy consumption, for instance, if there are 100 million street lights that each require 0.02 kW and are always on. In the USA, 5.1 106 kW power is consumed on a roadway per hour.

The massive energy consumption of highway lighting is the driving force behind the development of smart lighting, which is essential for better resource management. While previous literature concentrated on guaranteeing cost-effective illumination, a condition that is just as crucial—namely, the visual comfort of drivers—is all but ignored. In this article, a brand-new, Internet of Things-enabled system is suggested that can be intelligently managed in accordance with traffic demand. The key component that relies on the installation of lampposts with cyber capabilities to enable sensing-exchanging highway traffic data is cooperative relay-network architecture. Data accumulation is used to automate adaptive lighting switching ON/OFF and provide backtracking lamppost detection. From the standpoint of the service provider, we want to use extremely reliable, low-cost sensing and network components to drastically reduce operational costs. The relay network is seen through the eyes of the motorist, the relay-network is envisaged to provide a seamless driving experience where sufficient lighting is always perceived along the road.

The smooth driving experience is quantitatively evaluated using a critical analysis that takes into account the probability of outages, device malfunctions, and automobile arrival rate. Our proposed IeRN has been equipped with the capability of providing a backbone network for a smart highway lighting system, which can not only reduce the significant electricity cost but also maintain the service of the highway provider in terms of providing road comfort and safety to the drivers via seamless-turn- ON/OFF-lighting technology. A road occupancy-based cost estimation analysis demonstrates the effective cost reduction of the proposal compared to existing systems.

CONTENTS

LIST OF ABBREVIATIONS

IoT	Internet Of Things
CSU	Car Sensing Unit
LU	Lighting Unit
PU	Processing Unit
IFU	Information Forwarding Unit
GSM	Global System for Mobile Communication
IeRN	IoT-enabled Relay Network
UI	User Interface

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

In recent years, the Internet of Things (IoT) has become more widely used, which has made it possible to create a variety of smart applications as well as the cases involving public illumination developing or the ability to prototype a smart lighting system has been made attainable by new technologies are combining quickly, including light-emitting LEDs, sensors, tiny controllers (such as Raspberry Pi). Likewise, when numerous nations progress in the directionthe lighting system will have to incorporate green infrastructure, the mode in which energy is provided, as well as the the process of consuming energy.

Existing street lights in many nations use a tremendous amount of electricity since they are always on at night, regardless of whether or not traffic is present. An ineffective lighting system that is unable to adjust to the volume of traffic is to blame for this high energy use.

For instance, if there are 100 million street lights, and each one uses 0.02 kW and is constantly on, the energy consumption figure is equal to 0.8% of Japan's annual electrical energy usage. In truth, the numbers may be significantly higher in other nations. For instance, Spain, France, and Germany, respectively, have total annual power usage per street light of 116, 91, and 43 kW [4]. In the USA, power consumed is 5.1*10^6 kW is consumed on a roadway per hour.

Numerous research have been conducted to address excessive energy use in public lighting, which is the biggest energy user for outdoor lighting. Guaranteed to save a significant amount of energy while using efficient lighting it is used. There have been numerous attempts in recent years.

for creating street lighting that is both energy-efficient and attractive. The basic research mainly suggested converting luminaries to solid-state lighting with great efficiency in place of traditional metal, which is less effective, such as LED lights made of metal halides or high-pressure sodium (HPS) .Different forms of SLS are then used to follow this initially. Featuring only an ON/OFF lighting feature that detects daylight after which it was updated to planned adaptive dimming from dusk until daybreak combining Wi-Fi and wired.

Using modern technologies, a remote supervisory control can further increase the smart lighting system's efficiency, yet the performance is fragile since it depends on long-range wireless links that require a higher initial investment. The definition of a smart lighting system is described last changes as demand-based adaptive lighting powered by the Internet of Things and employing individually determined lowering percentages innovates.

While these elements unquestionably increase the energy economy of public lighting, the problem detection component is frequently ignored in most studies, raising concerns about the system's performance overall. However, frequent changes in the light's ON to OFF or vice versa are frequently criticized since they make driving less comfortable and increase the risk of highway accidents. In order to achieve smooth lighting, efficient problem detection, and energy conservation that would result in a secure and pleasurable highway driving experience.

1.1 Contribution of This Report

The article introduces an innovative solution for the complexities associated with implementing a smart lighting system, especially on highways. This challenge revolves around finding the right balance between energy efficiency and maintaining a smooth driving experience. The proposed solution, named IeRN, leverages IoT technology to establish a relay network that effectively manages highway illumination based on demand.

The key contributions of this solution are as follows:

1. The core structure of the network employs a linear bus topology, strategically aligned with the positions of lampposts along the highway. This design facilitates coordinated relay communication and restricted-range data transmission. As a result, the deployment of cost-effective network components becomes feasible.

2. Each highway section is anchored by a dedicated node that serves a dual purpose. Acting as a relay information coordinator, this node effectively manages data transmission. Simultaneously, it functions as a real-time fault detector for lampposts. A sophisticated backtracking detection mechanism is employed to promptly identify malfunctioning lampposts, streamlining maintenance efforts.

3. The article outlines a practical approach to estimating the implementation cost of IeRN using a small-scale test environment as the basis. This projection underscores the potential of the proposed system to drastically curtail energy expenses associated with highway lighting.

1.2 Overview of IoT

The concept of the Internet of Things (IoT) involves linking physical objects to a virtual environment. Within this paradigm, these physical objects are embedded with sensors and actuators that enable them to perceive and control their surroundings. To facilitate the transmission of sensory data to a server, these sensors and actuators are integrated with a communication protocol. An IoT network is composed of the fusion of various components, including the integration of sensors and actuators, the establishment of connectivity, the processing of data, and the provision of a user interface (UI) for interaction. Fig 2 provides a visual representation of these four essential elements of IoT that collectively shape its functionality.

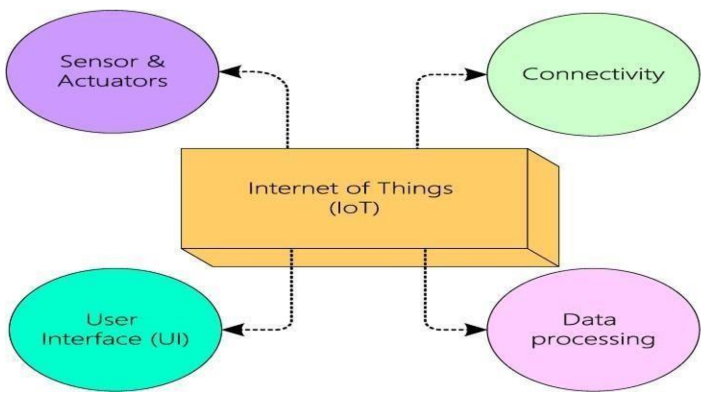

Fig 1. Components of IoT

As per forecasts provided by the GSM Association (GSMA) intelligence, it is expected that the worldwide count of Internet of Things (IoT) connections will attain 25 billion by the year 2025 [40]. The growth pattern of IoT devices from 2015 to 2025 is visually represented in Fig 2.

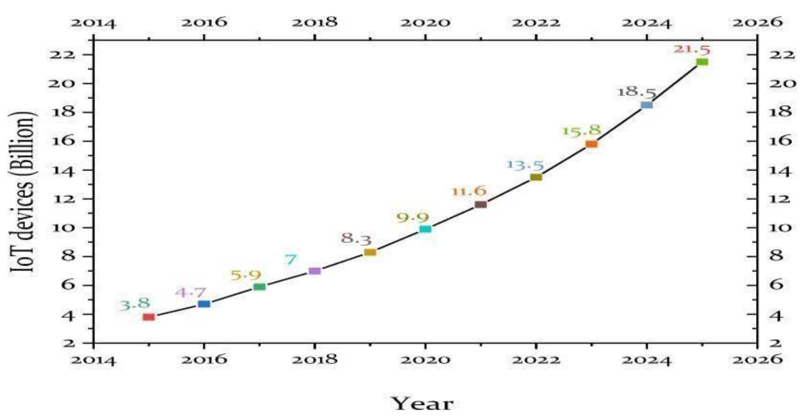

Fig 2. Growth of IoT devices

CHAPTER 2
RELATED WORK

A significant portion of existing research endeavors has been directed towards effectively managing energy consumption in street lighting. Many fundamental investigations have employed sensor-based methodologies encompassing real-time pedestrian and traffic sensing components. Pinto et al. evaluated planned and real-time dimming strategies, uncovering that traffic-based real-time lighting adjustments could lead to energy reduction. Leccese et al. employed ZigBee technology and local sensors for data collection within their interconnected lighting system. Similarly, Elejoste et al. implemented a smart lighting solution, incorporating multiple sensors for collecting traffic and weather data.

Both Leccese et al. and Elejoste et al. considered the concept of road sectorization to ensure seamless lighting provision. Research and simulations of traffic patterns have yielded various energy consumption reduction methods, particularly within the realm of timeline dimming for lighting. Marino et al., utilizing traffic prediction models, devised illumination control techniques. However, while the focus primarily centered on adequate illumination, considerations regarding driver comfort and fault detection were somewhat lacking.

Mustafa et al., employing a traffic probability model, segmented routes to address energy consumption. This method involves turning lampposts ON during vehicle engagement and OFF or dimmed otherwise. Nevertheless, the abrupt transitions between lampposts may overlook driver comfort, despite potential energy reduction benefits. Shahzad et al. proposed a combined traffic and vehicular mobility model to design a lighting system. They emphasized sensor-based adaptive lighting and low-energy wireless standards as energy-saving measures, compared to traditional MH lighting.

The development of a traffic-aware street lighting management network (TALiSMaN) by autonomously networked sensors represents a noteworthy direction. This approach, as highlighted in their work, could achieve energy savings ranging from 45% to 90% compared to existing systems. Particularly intriguing is the authors' implementation of a lighting pattern that continuously adjusts based on the distance from the recognized driver. It's worth noting that the article's limitation lies in its analysis of residential roads with light traffic, where ensuring driver comfort is relatively simpler than on busy interstate roads.

CHAPTER 3

RELAY NETWORK FOR HIGHWAY LIGHTING

An overview of our IoT-enabled relay network (IeRN) for highway lighting system is explicitly discussed in this section and is depicted in Fig 3.

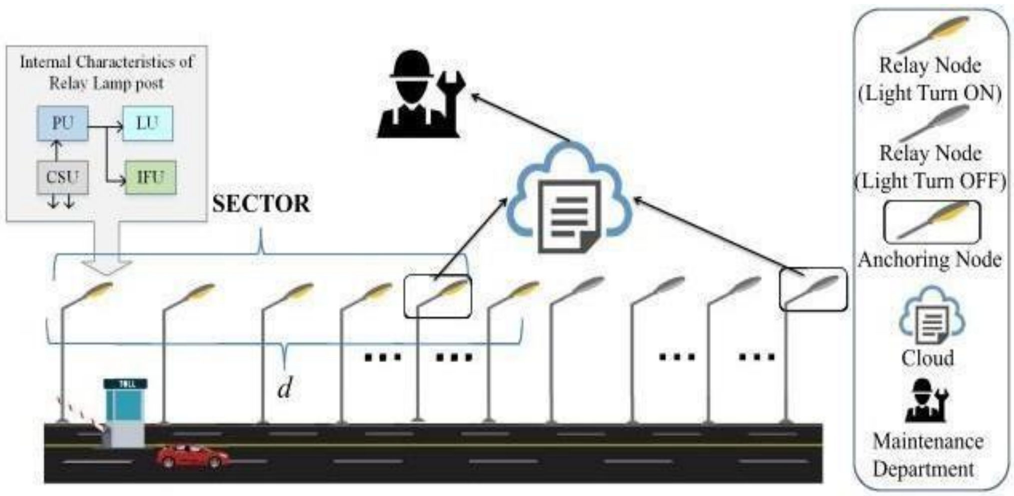

Fig 3. Architecture of IeRN

This network helps spread the knowledge of the vehicle's presence along the highway.

By taking advantage of this network, lampposts will illuminate in advance of cars, who won't be aware of the roads on/off behavior. This system is known as seamless- turn-ON/OFF lighting. Below, we continue with a step-by-step explanation of the system's architecture, data transfer, and upkeep procedure.

3.1 System Components

The IeRN consists of four components, i.e. toll lamppost, relay lamppost, anchoring node, and control center. The details of each component are described as follows

1) Toll Lamppost: The initial lamppost positioned at the highway's onset remains illuminated throughout the night, directly facing the toll booth. This lamppost is equipped with sensors, a controller, and a transmitter. As vehicles approach the toll lamppost for toll payment, they need to decrease their speed. The aforementioned sensors utilize the car's light and movement to validate its presence, subsequently transmitting this information to the next lamppost. Upon receiving this information, the subsequent lamppost activates its corresponding light. This data forwarding mechanism initiates an automatic switching sequence among successive lampposts. This continuous switching creates the illusion for the driver that the road is consistently well-lit during the night, thereby enhancing both driving comfort and safety.

Concurrently, the activation of lamppost lights is contingent on the road's occupancy level, a measure aimed at curbing energy consumption.

2) Anchoring Node: Sectors separate the entire highway. A sector is made up of a collection of lampposts, with the initial and last lampposts serving as anchoring nodes. This segmentation idea is essential for lowering total energy consumption as depicted in the next thinking about a freeway road off. If we turn on all of the highway's lampposts, we can travel about 100 km. It would be a waste of energy till the car pulled into the toll plaza because the vehicle will eventually arrive at the end of the route in 1 hour (i.e., assuming the vehicle is travelling at 100 km/h). If you want to effectively hence, in order to regulate the energy, we turn on the light from an the distance from one anchoring node to the following anchoring node plus the constitutes instead of one human eye's typical vision entire roadway The anchoring node serves as a barrier separating sectors, each of which indicates the separation between two successive lamppost anchoring A sector's distance is predetermined. Based on a human's N times human eye-vision to deliver seamless- turn-ON/OFF-lighting. Similarly, the anchor node outfitted as a lamppost for the toll. A second function of an anchoring node is to use GSM technology to send alerts to the control center about any damaged lampposts that are under its watchful eye. The toll lampposts are used to mark the beginning of the highway as the first anchoring node.

We provide the following measures for measuring seamless behavior, which correspond to the case in which a line of autos drives continuously past lampposts.

Average Bursty Period: This span is defined as the typical successive time interval during which it is dark outside but the lights are intended to be on.

Probability of System Outage: The proportion of OFF lampposts to all lampposts serves as the definition for this metric.

We want to know how the likelihood of a system failures (such as a broken lamppost) affects the likelihood of system outages as well as the average busty period. With the goal of capturing seamless behavior as the circumstance in which the driver of the vehicle does not encounter any darkness while operating it, we describe the smooth level as follows

Seamless Level: The values of infinity and 0 reflect totally seamless and non-seamless lighting services, respectively. This corresponds to the inverse of the average bursty period.

The seamless level, given an appropriate choice of sector size/length, depends on the likelihood that the gadget may malfunction. We go into further information about this seamless idea and the system outage.

3) Relay Lamppost: This lamppost serves as a network relay node. All lampposts within a sector—aside from anchoring nodes—are regarded as relay lampposts. This lamppost's goal is to turn on its light based on data propagated from a preceding lamppost or data it has collected through sensing. When it does, it will propagate the knowledge of the car's presence to the following lamppost.

The relay node serves a different purpose but is similarly outfitted to the toll lamppost (without the GSM technology). In contrast to the toll lamppost, the relay lamppost's light will decrease once the route is less crowded in order to conserve electricity.

4) Control Centre: This part can be compared to the department responsible for maintaining the roads, as it receives information about any broken lampposts from the anchoring nodes. It uses GSM technology sent by lampposts that are anchored to acknowledge the defective lamppost.

3.2 Network Architecture

Figure 3 depicts the IeRN's network architecture. Following the placement of the lampposts along the highway road, the graphic depicts a linear bus topology. With the help of Node ID, each lamppost represents a network node with transceiver functionality. Four essential building components make up each lamppost's internal architecture: the lighting unit (LU), the car sensing unit (CSU), the information forwarding unit (IFU), and the processing unit (PU). After a vehicle is detected, the CSUs are typically the sensors (a light intensity sensor and a proximity sensor) attached to the lampposts which provide sensing data to the PU or controller. To decide whether to turn on or off the light, the PU communicates data with the LUs.

The IFU then transmits the data to more lampposts in the hope that the relaying nodes will transmit the data packets to the final sink. In case of a problem, the control center observes and manages all system components. The anchoring lamppost will use GSM connectivity to send the control center the faulty notifications.

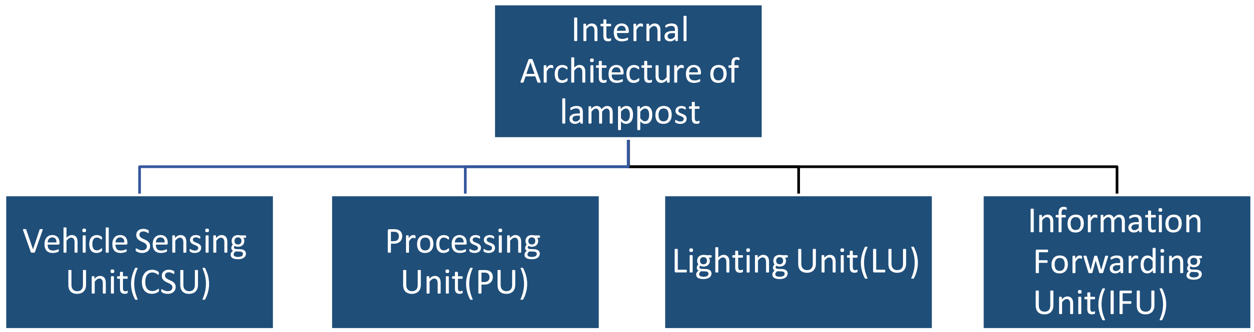

Fig 4. Internal Architecture of Lamppost

3.3 Data Transmission

The operational foundation of our data transmission is rooted in the system's defined logical rules. Breaking down the processes aids in comprehending the functionality of our lighting control system. The Control System Unit (CSU) situated at the toll booth or the initial lamppost plays a central role in detecting the presence of vehicles. The Principal Unit (PU), which acts as the network's main controller, is directly linked to the CSU.

A preconfigured software with embedded instructions governs the controller's operations. These preprogrammed instructions assess the logic state of each lamppost before making decisions. It's important to note that only the PU has the capability to generate data packets in our system. Other network components act as transmission relays, forwarding packets to their final destinations. As a result, the PU contains information about newly detected vehicles and issues instructions to the Lamp Unit (LU) and Interface Unit (IFU) on appropriate actions.

For the LU to activate the LED lights, data must be received by the CSU connected to the PU for each lamppost. The IFU then forwards the data to the relay lamppost. In scenarios where data is unavailable from the preceding node due to malfunction, the intermediate lamppost relies on its own sensors to detect vehicle presence. In such cases, it transmits data through its transceiver to activate the LED lights.

In practical settings, when sensors at the first lamppost detect vehicle presence (sensor status = YES), communication initiates. Subsequently, the IFU dispatches network information to all relay lampposts within a specified range, leading to the illumination of lights. The range's distance "d," as depicted in Figure 2, is determined by the sector's length (distance between anchoring nodes) along with the typical range covered by human vision.

This continuous communication process ensures a seamless driving experience with consistent lighting. The system's adaptability to traffic volume ensures that drivers won't perceive lighting fluctuations (ON/OFF) as they move through different road sections. In scenarios where no vehicles pass through the toll lamppost (sensors status = NO), all subsequent or connected lampposts remain unlit to conserve energy.

The collaborative operation of the relay network's components leads to reduced energy consumption. The implementation of multihop relay capability in specific sectors maintains signal integrity as wireless signal strength diminishes with increasing distance. This energy-efficient transmission approach facilitates data transfer hop by hop, thus preserving relay lifespan. The nearest lamppost, as determined by destination-oriented directed acyclic graphs (DODAG), acts as the recipient of data packets, serving as a candidate relay.

3.4 Maintenance Process

Given the primary focus of our IeRN project on highway road applications, ensuring the continual functionality of both lampposts and network components is of paramount importance for the highway service provider. This assurance is critical to ensure the safety and satisfaction of drivers. Beyond the seamless activation and deactivation of lights, the concept of sectorization embedded in our network offers a strategic approach for efficient maintenance procedures. A key distinction is that all anchoring nodes possess the capability to communicate with the maintenance department, unlike the scenario where only the final transmitting node notifies about a malfunctioning lamppost.

This strategic approach facilitates more efficient utilization of electrical power, particularly when the road is divided into distinct sectors. The rationale behind this lies in the extended duration required for data transmission from the toll booth or the initial lamppost to the terminal lamppost. This prolonged transmission interval consumes greater device power. Consequently, segmenting the road into sectors reduces power consumption and augments overall operational efficiency.

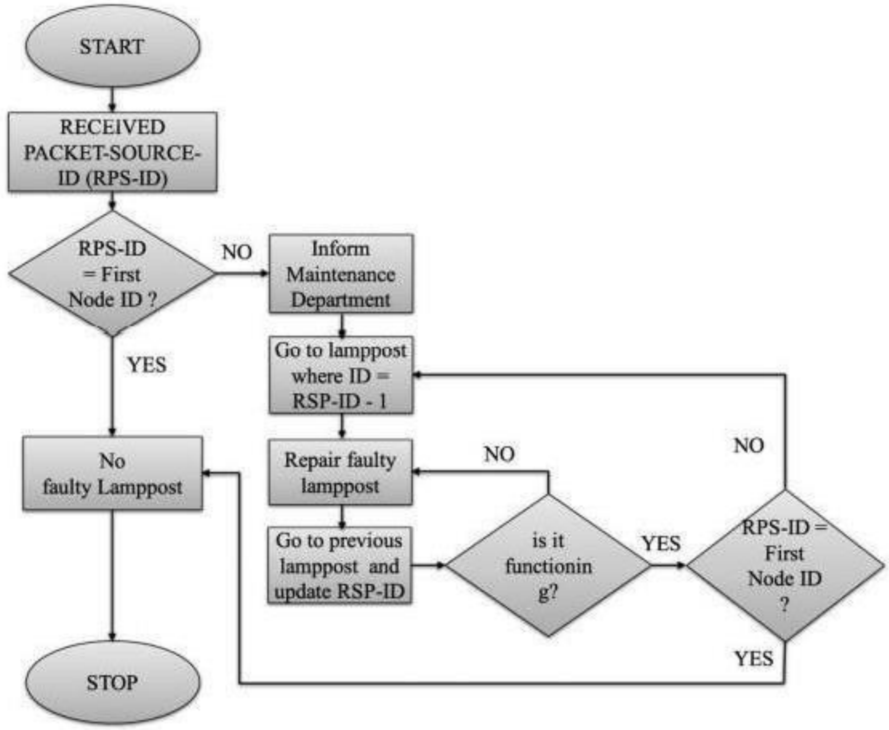

Fig 5. Flow-chart of the lamppost maintenance process

Built upon the principle of NodeID detection within each sector, this technology effectively addresses issues arising from malfunctioning lampposts. It's worth recalling from the network architecture that NodeID serves as a unique identifier for every node, which corresponds to each lamppost within the network. When defective lampposts are present within a specific sector, a solution is devised using the anchoring node situated at the sector's end (final node as illustrated in Fig.3's Flowchart).

It's important to highlight that when the Received-Packet-Source-ID (RPS-ID) aligns with the FirstNode-ID, it indicates the absence of malfunctioning lampposts in the sector. Conversely, if they do not match, a notification is relayed to the control center. Subsequently, the maintenance division is prompted to identify the problematic lamppost through the RPS-ID. The SourceID of the lamppost comes into play here. In the event of a lamppost failure, the subsequent middle lamppost after the defective one detects the presence of a vehicle using its internal sensors. Subsequently, it starts utilizing its own NodeID as a SourceID. Upon locating the faulty lamppost, swift repair action is undertaken by the maintenance division.

The maintenance process involves backtracking to the preceding lamppost when the current node's RPS-ID matches the First-Node-ID. This procedure is conducted to inspect the remaining malfunctioning lampposts within the sector. Leveraging GSM technology, the maintenance team receives lamppost status updates from the anchoring lamppost. Subsequent to receiving this notification, the maintenance team promptly identifies the malfunctioning lamppost, facilitating quick intervention and rectification. The continuous availability of adequately functioning lampposts is crucial for driving safety.

CHAPTER 4

VALIDATION OF THE PROPOSAL VIA COST ANALYSIS

4.1 Assumption and Calculation

We conducted an evaluation of the energy consumption of lampposts while considering varying levels of road usage. Unlike some prior studies that employed an on-board power metering subsystem, we opted for calculations based on the lamp's specifications and certain assumptions. The entire electricity consumption cost for each lamppost, accounting for three operational modes—ON, OFF, or dim—is determined using the formula:

$$\mathbf{Ppm = (PF \times \beta) + (PD \times (1 - \beta))}$$

Where PF stands for the cost of power consumption in full illumination, for the fraction of the road that is lighted, and PD for the cost of power consumption in dim illumination.

For illustrative purposes, we assumed that the power for full light is 0.5 kW and for dim light is 0.05 kW. As a result, the power required for full light PF is 5 kWh, and for dim light PD is 0.5 kWh. At a unit price of RM 0.164 or USD 0.04, the daily costs for PF and PD were calculated to be 0.2 and 0.02 USD, respectively. We obtained these values using the Tenaga Nasional Berhad (TNB)-Tariff G street lighting tariff for all kWh (including maintenance) in Malaysia.

This allowed us to determine the average energy cost i.e., Ppm for varying degrees of road occupancy, employing the values of PF and PD. Furthermore, for a comprehensive cost analysis, we calculated Ppm for a single lamppost per night and for 100 lampposts per month.

It's worth noting that while the proposed IeRN has the potential to replace the existing highway lighting system, this transition would entail additional expenses, including the electricity costs of the new devices. Table I provides an overview of the overall device cost and the supplementary device electricity consumption on a monthly basis for 100 lampposts.

In our analysis, we determined the device energy consumption (DEC) for a random lamppost over a month, utilizing the specifications of each device. The total device costs TcD = 6370 USD and total device electricity costs TcDE = 0.5514 USD were derived for 100 lampposts. As the additional devices are less costly, the energy savings from the IeRN implementation are expected to outweigh these additional expenditures.

TOTAL DEVICE COST AND ELECTRICITY CONSUMPTION PER MONTH FOR 100 LAMPPOSTS

System Components	Quantity	TcD/Item [$]	TcD for 100 [$]	DEC [W]	DEC/ Month [KW/m]	TcDE/Item [$]	TcDE for 100 [$]
1. Arduino Uno	100	24.95	2495	0.25	0.075	0.003	0.3
2. 802.15.4	100	30.48	3048	0.132	0.0396	0.001584	0.1584
3. Proximity Sensor	100	1.06	106	0.075	0.0225	0.0009	0.09
4. LDR	100	0.21	21	0.0025	0.00075	0.00003	0.003
5. Other accessories	100	5	500	-	-	-	-
6. Installation cost	100	2	200	-	-	-	-
Total device cost [TcD]			6370	Total electricity cost of device of 100 lampposts for 1 month [TcDE]			0.5514

Table 1. Total device cost and electricity consumption per month for 100 lampposts

4.2 Comparison between the Proposed and Traditional Systems

Using the calculation and supposition mentioned before, we compare the proposed IeRN- based system and the conventional street lighting system in terms of energy costs. We think that three typical instances of nighttime traffic and road use, the following: 10% (poor utilisation), 40% (lower medium utilization), 70 percent (upper medium usage) and 100 percent (full utilization).

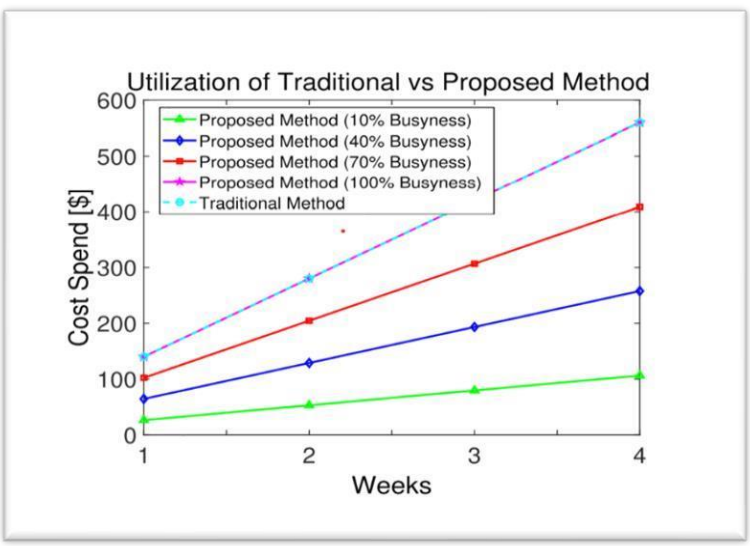

Fig 6. Cost Analysis

The proposed and traditional electricity cost expenses are displays various systems in fig4 (a). As can be seen, the proposed system's cost expenditure is directly correlated with the road traffic congestion Due to the fact that the road is congested, less likely than the recommended system is the entire night (100%) able to outperform the conventional system for the majority of the time. If worst comes to worst, where the road busyness is 100%, cost expenditure is same as traditional system.

4.3 Cost Reduction

The proposed system's potential for cost reduction is then assessed, taking into consideration the traffic volume on the road. To compute the cost savings, we consider an average period of 30 days (equivalent to one month) and assume the presence of 100 lampposts. The subsequent formula can be utilized to determine the cost reduction at a given road occupancy rate of X% (measured in USD):

Cost reduction (X %) = Cost at 100% road occupancy level - Total cost at X% road occupancy level (1)

For instance, considering 100 lampposts and applying formula (1), the calculated cost reduction values for road occupancy levels of 10%, 40%, and 70% are $486, $324, and $162, respectively. It's noteworthy that because the lights remain continuously active during the night, the cost associated with 100% road occupancy aligns closely with the expenses of a traditional lighting system. This study affirms that our proposed technology consumes minimal power, demonstrating the potential to significantly lower expenses for the highway service provider in terms of both electricity bills and power consumption.

4.4 Brake Even Point

According to the analysis above, the suggested lighting system is preferable to the conventional street lighting system in that it can significantly reduce energy consumption and the costs associated with it. It will take some time before the benefits of the suggested system can be realized due to the addition of new components to the system. The time needed to pay off the installation cost is specifically referred to as the break- even point (BEP).

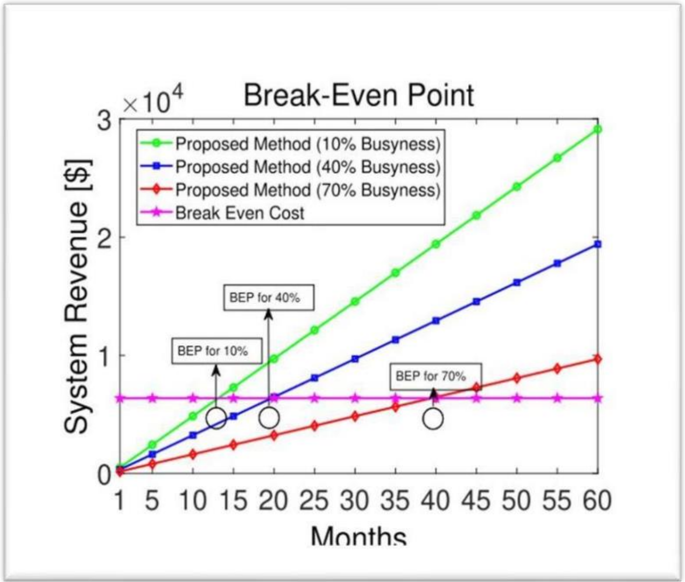

Fig 7. Break Even Point

CHAPTER 5

SIMULATION

5.1 Setups

To assess how communication protocols function in the suggested IeRN system, ran several simulations.

In the NS-3 environment, two distinct technologies—LoRA and 802.15.4—are employed to demonstrate which protocol performs better in various scenarios. The framework includes an

802.15.4 Or LrWPAN module, while [32] offers LoRA. While 802.15.4 (also used in ZigBee and Xbee) is chosen because to its dependable transfer rate (up to 250 Kbit/s) and widespread use in IoT environments, LoRA technology is chosen due to its long-range transmission potential.

As shown in Fig. 8, each sector is equipped with a low-cost, miniature PC with a LoRA/802.15.4 transceiver attached to start off our description of the simulation setup. The symbols used in the simulation setup are described in Table III. This device has the ability to receive and send packets to any other device nearby. The device detects and transmits the initial packet each time a car approaches the highway entrance. Sector 0 refers to the area where the initial anchoring node (A0) is located.

If the car runs constantly, the packet will be sent to the next sector continuously before the car gets there. Additionally, it will ensure the smooth operation of our lamp management system. For instance, a car passing one sector when another sector is already lighted up ahead won't notice the lamp turning ON before he gets there. This seamless aspect in our suggested system is ensured by the length of a sector taking human eye vision into account.

The end-to-end latency is then calculated by subtracting the matching packet's arrival time from its departure time. The length of the sector (d) has a considerable impact on end-to-end delay since more numerous single-hop communication occurs at lower d values. More anchoring nodes will be required for the packet to pass through, increasing propagation and processing time.

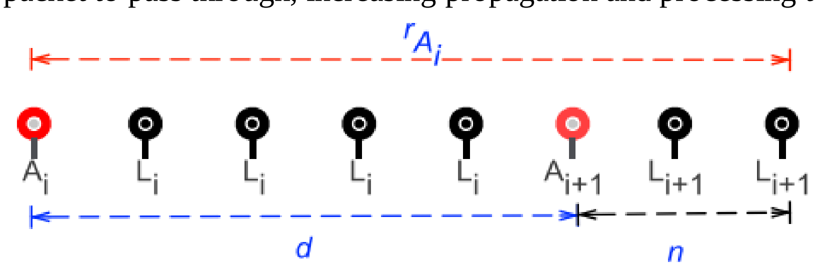

Fig 8. Device placement in simulation

5.2 Results

The spreading factor (SF), an adjustable quantity that controls the amount of bits that LoRa encodes, is specified by LoRA and ranges from 7 to 12 kilometers. There are M = 2SF potential starting frequencies that are a part of a chirp, a sinusoidal signal with linearly increasing frequency and fixed duration that is represented by SF using a symbol. We can find SNR values and bit rates for the range of SF. In urban and suburban regions, respectively, a transmission with SF 7 and 500 kHz modulation can achieve 2–5 and 15 km transmission ranges.

Our experiment uses a 125-kHz band, which results in a lower SF 7 radius. However, when channel considerations are taken into account, transmission with a larger SF can offer a reasonable delivery rate.

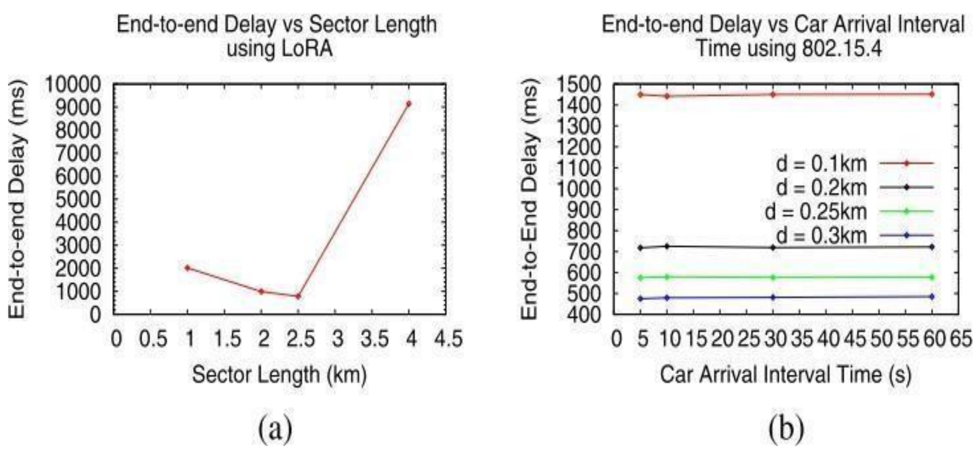

Fig 9. (a) LoRA performance. (b) 802.15.4 performance

LoRa WAN adoption necessitates users to be cautious with duty cycle. This policy limits the number of transmissions that a specific node is allowed to send. In other words, it establishes the hourly maximum "on" time states that three duty cycle settings are available: 0.1, 1.0, and 10%. These choices typically depend on geographical setup. With a duty cycle of 1 and 0.1%, this experiment employs the configuration for the EU Region. A LoRA protocol with a 1.0% duty cycle guarantees 36 transmissions per hour, while a 10% duty cycle caps 360 transmissions. With this configuration, LoRA can have a longer lifespan. As a result, packet transmission with a 120 s packet transmission interval per hour must be prevented based on the 1.0% standard. If not, the PHY layer will delay the packet

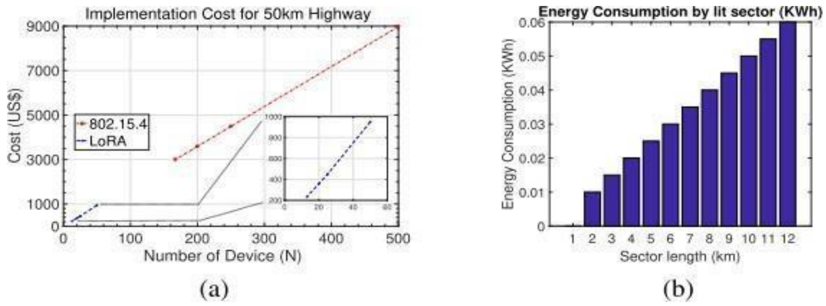

Fig 10. (a) Cost versus number of devices. (b) Energy consumption versus sector length

We replicate a situation where cars are sequentially moving along the road at a constant speed in order to measure the end-to-end transmission latency. Determined recurring period t. Because it's easier, we'll assume that following the appropriate lights turn on as a car passes by the anchoring node will be activated for a duration of time, time being at least 60 seconds to guarantee a continuous ON period for each of the t values in Tables 2 and 3. Table 2 lists the performance of LoRA in several cars arrival elapsed time. According to Fig. 9(a), the sectorization with higher end-to-end delay is produced by d = 1 km than d = 2.5 km as a result of channel usage within the same coverage. In actuality LoRA can install nodes in less than an hour and transmit up to 4 kilometers than this number might influence the relay system. Any equipment that must calculate in order to receive the packet on the same frequency whether quick packet forwarding is possible. Sectorization requires greater air time and device resources when d = 4 km near to duty cycle policy active time. Considering our One-hop transmission in this sectorization demands experimentation 36-second delay causes the anchoring node to have to wait one hour to transmit the packet.

d (km)	End-to-end Delay (ms)				PDR (%)
	t=5s	*t*=10s	*t*=30s	*t*=60s	
1	2019	2019	2019	2019	100
2	989	989	989	989	100
2.5	783	783	783	783	100
4	9144	9144	9144	9144	100

Table 2. End-to-end delay and packet delivery ratio (pdr) using lora

d (km)	End-to-end Delay (ms)				PDR (%)
	t=5s	*t*=10s	*t*=30s	*t*=60s	
0.1	1449	1442	1450	1451	100
0.2	718	725	719	722	100
0.25	575	579	576	577	100
0.3	475	479	481	485	100

Table 3. End-to-end delay and pdr using 802.15.4

With no duty cycle policy and a higher transmission rate (250 Kbit/s) than LoRA, 802.15.4 has a smaller transmission range. With the performance metrics presented in Table V, sectorization using this approach can accommodate d = 0.1, 0.2, 0.25, and 0.3 km. As seen in Fig. 9(b), 802.15.4 results in a significantly lower end-to-end delay while relaying the packet via more hops than LoRA does. Fig. 10(a) illustrates the overall cost of various protocols' implementation.

5.3 Seamless Lighting

The highway lighting system must provide the driver with vision that is wider than the vehicle's field of view headlights. The suggested sectorization idea taking into the goal of human eye vision is to resemble the conventional highway a situation when the lights are on all the time. This choice of sector is what determines whether a feature is seamless length. The relationship between sector length and energy cost is shown in Figure 7(b) illustrates the linear behavior of increasing energy. When the sector length is, consumption versus the illuminated sections increased. The sector length for LoRA should be the minimum if we suppose that human eye vision n = 1 km, then 2n = 2 km.

To guarantee the lowest end-to-end costs and flawless lighting operation LoRA is delayed, but we succeed 2.5 kilometer long sectors. Herein, we can say that a 2-2.5 kilometer sector can accomplish Our IoT-based lighting system is operating almost optimally. For Due to the absence of a duty cycle in 802.15, the end-to-end latency remains steady. so the same sector length will be used where there is involvement also here. There are two additional elements that might be related to the suggested lighting system's smooth operation, notably the likelihood of a system breakdown and the typical bursty period. To illustrate the impact of them, we take into account three scenarios. Anchored node with LoRA support, and LoRA with 802.15.4, redundancy.

The system outage probability for LoRA and 802.15.4 is similar, as shown in Fig. 8(a). Due to the deployment of two LoRA modules in each anchoring node, the probability of device malfunction is cut in half, allowing LoRA with redundancy to outperform the other two scenarios. On the other side, the typical bursty period denotes the time when a device failure causes the system to go down. The average bursty period is displayed against the likelihood of a device malfunction in Fig. 8(b). Due to the lower sector length, IEEE 802.15.4 performs better than the other two LoRA situations.

CHAPTER 6

EXPERIMENTAL TESTBED

We created an experimental testbed employing the Xbee S2, ultrasonic sensor, and light sensitivity sensor on Arduino UNO platforms. We install four lampposts and particularly design a test infrastructure a little car is employed to indicate the presence of a car on a highway. Each lamppost has an embedded IoT box attached to it, which recognizes the presence of the car. The provision of seamless.

During the driving experience, the IoT box communicates the vehicle information to the sector's subsequent lampposts so that before the vehicle passes through, the light will be turned on each matching lamppost. We also think about upkeep using this testbed's processing. If any lampposts are broken, a short message service (SMS) will be used to alert the maintenance staff. By using this approach, the maintainer can examine and fix the broken lamppost in less time.

In less congested highway traffic conditions, LoRA modules can offer adequate performance and less expensive deployment costs. In contrast, 802.15.4 functions effectively in congested traffic conditions and has a significantly shorter end-to-end delay, although it has a higher deployment cost. It is important to note that the suggested system will cost more to integrate with the current lampposts. The energy-saving device will, however, make up for the added expense.

CHAPTER 7
CONCLUSION

The escalating need to manage energy efficiently in smart cities is driven by population expansion and the dwindling reserves of fossil fuels. Within smart cities, a notable energy consumer is the lighting system. This system primarily comprises streetlamps and lampposts. The shift towards a smart urban infrastructure occurs when a single lamppost incorporates cutting-edge sensing and communication protocols. This advancement empowers the individual lamppost to offer a multitude of services to residents, including real-time environmental data, Wi-Fi access, and electric vehicle charging stations, intelligent lighting, and more.

This study introduces an innovative architecture that operates on fog and edge computing principles, with IoT support, to implement intelligent lampposts. These lampposts offer a diverse array of practical applications. To ensure an uninterrupted driving experience, a rigorous assessment is conducted, considering variables such as outage probabilities, device malfunction rates, and the frequency of automobile arrivals. Our proposed solution, known as IeRN, has been devised to serve as a foundational network for a smart highway lighting system. This system not only significantly curtails electricity costs but also aligns with the highway provider's commitment to ensuring road comfort and driver safety through seamless lighting control technology.

Moreover, a comprehensive cost analysis based on road occupancy is conducted to demonstrate the cost- effectiveness of our proposal in comparison to existing systems.

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