LiFi-based Smart Toll Collection System

Capstone Project Report

END-SEMESTER EVALUATION

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December-2023

ABSTRACT

The LiFi-based Toll Collection System presents the development and implementation of a Data Transmission Mechanism which leverages LiFi technology for efficient and secure toll collection processes. The objective of this system is to enhance the speed, accuracy, and overall efficiency of toll collection.

The methodology includes the design and deployment of LiFi Transmitter in the vehicle headlight and LiFi Receiver at the toll gate, coupled with software for seamless communication and payment processing. Extensive testing and optimization has been conducted to evaluate system performance under various conditions, ensuring reliability and robustness.

The findings reveal that the LiFi-based Toll Collection System significantly reduces wait times, minimizes errors, and enhances data security. It also offers the potential for cost savings through reduced maintenance of physical infrastructure. Moreover, the system contributes to a more streamlined and convenient toll collection experience for users.

This report discusses the practical implications of implementing LiFi technology in toll management, highlighting its potential to revolutionize traditional toll collection systems. The successful deployment of this system demonstrates its feasibility and its potential to improve toll collection operations across transportation networks.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled
LiFi-based Smart Toll Collection System is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr Sharad Saxena during 6th-7th semester (2023).

Date: 19/12/2023

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ACKNOWLEDGEMENT

We would like to express our thanks to our mentor, Dr. Sharad Saxena. He has been of great help in our venture, and an indispensable resource of technical knowledge. He is truly an amazing mentor to have.

We are also thankful to Dr Shalini Batra, Head, Computer Science and Engineering Department, entire faculty and staff of Computer Science and Engineering Department, and also our friends who devoted their valuable time and helped us in all possible ways towards successful completion of this project. We thank all those who have contributed either directly or indirectly towards this project.

Lastly, we would also like to thank our families for their unyielding love and encouragement. They always wanted the best for us and we admire their determination and sacrifice.

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LiFi	Light Fidelity
DFD	Data Flow Diagram
ER	Entity Relation
WiFi	Wireless Fidelity

1.1 Project Overview

LiFi is a wireless communication technology that uses light to transmit data. It utilizes the visible light spectrum to transmit data at high speeds, offering a faster alternative to traditional radio wave-based communication systems. LiFi has the potential to revolutionize the way we use wireless networks, particularly in environments where radio frequency interference is a concern, such as in hospitals or aircraft cabins. With its potential to transform the way we connect to the internet, LiFi is gaining increasing attention from researchers and businesses worldwide.

In the context of toll collection, LiFi could be used to implement a system for collecting toll fees with faster speed and reduced congestion. In a LiFi-based toll collection system, a vehicle equipped with a LiFi enabled device would pass under a LiFi enabled receiver toll booth. The LiFi receiver would then receive the vehicle number from the booth via light leading to payment transaction. The automatic transaction would be notified to the vehicle owner. Every vehicle equipped with a microcontroller and a memory connected to it will allow transmission of data via LED. The LiFi receiver (Admin) is present in the middle of the road at the tollbooth. An intelligent processor will be there at the receiver side, which will automatically process the toll tax payment on the payment portal linked with the vehicle number. The technology will be helpful in preserving the fuel consumption of vehicles and will create an eco-friendly environment.

The use of LiFi in toll collection has several benefits, including increased efficiency and accuracy in the collection of toll fees, reduced toll booth congestion and wait times and improved safety. Our approach consists of integrating LiFi technology into the toll collection system. The LiFi module is integrated with the vehicle of users. Another LiFi module (Receiver) is integrated into the toll booth. Additionally, as LiFi operates on a different frequency spectrum than traditional wireless

communication methods, it is less prone to interference and has a higher potential data transmission rate.

Overall, the use of LiFi in toll collection is an innovative solution that has the potential to improve the efficiency and accuracy of toll fee collection, with enhanced safety.

1.2 Need Analysis

There are several reasons why a toll collection system using LiFi technology may be desirable:

- **Increased efficiency:** LiFi-based toll collection systems can provide faster, more efficient transactions compared to traditional toll collection methods.
- **Improved accuracy:** LiFi technology enables real-time monitoring of toll fees, which can help reduce errors and increase accuracy in toll fee collection.
- **Reduced congestion:** By eliminating the need for physical toll booths, LiFi based toll collection systems can help reduce congestion and wait times, leading to smoother traffic flow and a more pleasant driving experience for motorists.
- **Increased safety:** This system will also reduce the risk of accidents and incidents at toll plazas, making them safer for motorists, toll collectors, and other personnel.

Overall, a toll collection system using LiFi technology can offer improved efficiency, accuracy and security while also reducing congestion and enhancing safety.

1.3 Research Gaps

- **Scalability and Reliability:** While LiFi technology shows promise, there is a need for research into its scalability and reliability in large-scale toll collection systems. Investigating how LiFi performs under heavy traffic conditions and in various environmental factors is crucial.
- **Interference Mitigation:** Addressing potential interference issues with LiFi signals, such as external light sources or obstacles obstructing the line of sight

between transmitters and receivers, requires further study. Developing effective interference mitigation techniques is essential for the robustness of the system.

- **Security Measures:** Research should focus on enhancing the security of LiFi-based toll collection systems. Exploring encryption methods, authentication protocols, and measures to prevent hacking or fraudulent transactions is vital to protect sensitive payment data.
- **Standardization and Compatibility:** Developing industry standards and ensuring compatibility with different vehicle types and hardware configurations is essential. Research should aim to create a standardized framework that promotes interoperability among LiFi-enabled devices.
- **Cost-effectiveness:** Investigating the cost-effectiveness of implementing LiFi technology compared to existing toll collection methods is crucial for the widespread adoption of this technology. Research should evaluate the initial setup costs, maintenance expenses, and potential cost savings over time.
- **User Acceptance and Behavior:** Studying driver and passenger acceptance of LiFi-based toll collection systems is important. Understanding user behavior, preferences, and any potential challenges in transitioning to this technology can guide system design and implementation.
- **Energy Efficiency:** Evaluating the energy efficiency of LiFi enabled devices, especially in vehicles, is necessary to assess their impact on vehicle batteries and overall energy consumption. Research on optimizing energy usage is essential for sustainable implementation.
- **Data Privacy:** Investigating data privacy concerns associated with LiFi-based toll collection systems is crucial. Research should explore methods for anonymizing and securing user data while still facilitating efficient toll payment processing.
- **Real-world Deployments:** Conducting real-world pilot projects and deployments of LiFi-based toll collection systems can help identify practical challenges and gather feedback from users and stakeholders.
- **Regulatory and Policy Considerations:** Research should address regulatory and policy frameworks governing LiFi-based toll collection systems, including issues related to data protection, user rights, and legal requirements for implementation.

1.4 Problem Definition and Scope

Problem Definition:

Toll collection is a crucial component of transportation management, serving as a primary source of revenue for the maintenance and enhancement of transportation infrastructure, including highways, bridges, and tunnels. It also plays a significant role in traffic regulation, alleviating congestion on road networks by implementing tolls, which influence travelers' choices of transportation modes and travel times. However, existing toll collection systems relying on RFID or barcode scanning technologies face limitations concerning accuracy, speed, and security. These limitations hinder the efficiency and effectiveness of toll collection processes, necessitating the exploration of an advanced and innovative solution.

Scope:

The scope of this challenge encompasses addressing the deficiencies in current toll collection systems by introducing a more sophisticated and efficient solution leveraging LiFi technology. LiFi offers a promising avenue for revolutionizing toll collection by utilizing visible light communication to enhance accuracy, speed, and security. This innovative solution aims to improve the overall toll collection process while contributing to better traffic management. Additionally, the implementation of LiFi technology opens opportunities for data collection and analysis, enabling transportation planners and managers to optimize the transportation network based on real-time traffic patterns and user behavior. Thus, the scope extends beyond merely addressing existing limitations to embracing the potential benefits of LiFi technology in toll collection and traffic management.

1.5 Assumptions and Constraints

1.5.1 Assumptions

S. No.	Assumptions
1.	There is sufficient LiFi coverage at toll booths and on vehicles to enable seamless communication.
2.	Vehicles using the system are equipped with LiFi receivers or transceivers to facilitate communication with toll booths.
3.	Clear line of sight is maintained between LiFi transmitters at the toll booth and LiFi receivers on vehicles for data transmission.
4.	Environmental factors, such as ambient lighting conditions, do not interfere significantly with LiFi signal quality.
5.	The system has the capability to process toll payments in real-time to minimize wait times at toll booths.
6.	Vehicles using the system comply with the LiFi-based toll collection requirements and have the necessary hardware and software components.
7.	LiFi technology ensures secure and encrypted data transmission to protect payment and user information.
8.	The system adheres to data privacy regulations and relevant legal requirements for toll collection.
9.	Sufficient support and maintenance resources are available to address system issues and updates.
10.	The implementation of LiFi technology for toll collection is financially viable and cost-effective in the long term.
11.	The LiFi-based system contributes to better traffic management by reducing congestion and wait times at toll booths.
12.	The use of LiFi technology in toll collection has positive environmental implications, such as reducing fuel consumption and emissions.
13.	The LiFi-based system can be effectively integrated with existing toll booth infrastructure and management systems.

1.5.2 Constraints

S. No.	Constraints
1.	LiFi technology relies on a clear line of sight between transmitters and receivers, which may be constrained by physical obstacles, weather conditions, or other factors.
2.	The installation of LiFi transmitters and receivers at toll booths and on vehicles requires a significant upfront infrastructure investment.
3.	The system's effectiveness depends on the adoption of LiFi enabled hardware in vehicles, and not all vehicles may have this technology.
4.	The system's performance is contingent on reliable network connectivity, and interruptions or network failures could disrupt toll collection.
5.	Bright ambient lighting conditions, such as sunlight or strong artificial lighting, can interfere with LiFi signals and impact data transmission.
6.	Compliance with data privacy regulations, such as GDPR or HIPAA, may impose constraints on the collection and handling of user data.
7.	Users may require education and training to understand and use the LiFi-based toll collection system effectively, and some users may be resistant to adopting new technology.
8.	Environmental factors such as extreme weather conditions (e.g., heavy rain, fog) may affect the reliability of LiFi communication.
9.	Ongoing maintenance and support costs for LiFi infrastructure and hardware may be significant, impacting the system's long-term feasibility.
10.	LiFi technology typically has a limited range compared to other wireless communication methods, which may require more frequent installation of LiFi transmitters.
11.	Integrating LiFi-based toll collection with existing toll booth systems and management infrastructure may pose compatibility challenges.
12.	Deploying the LiFi-based system may require a significant amount of time and effort, potentially causing delays during the implementation phase.
13.	The introduction of new technology for toll collection may require regulatory approvals and compliance with transportation authorities, which can be a constraint in some regions.

14.	The financial viability of implementing LiFi technology should be carefully assessed, as it may involve initial capital expenditures that need to be recouped over time.

1.6 Standards

1. **Data Transmission:** Standardization ensures consistent data transmission protocols, defining how information is encoded, modulated, and transmitted using visible light signals. It establishes reliable communication methods, data rates, error correction techniques, and modulation schemes for interoperability across LiFi-enabled devices.
2. **Hardware Setup:** Standardized hardware specifications encompass the design and components of LiFi-enabled devices. This includes LED transmitters, photodetectors, and associated circuitry. Standardization ensures uniformity in device form factors, power requirements, connectivity interfaces, and optical characteristics, facilitating seamless integration and compatibility.
3. **Integration:** Integration standards focus on the interoperability of LiFi systems with existing infrastructure and technologies. They address challenges related to integrating LiFi with WiFi, cellular networks, and IoT ecosystems. By defining protocols for seamless handovers, roaming, and coexistence, integration standards enhance the user experience across various communication environments.
4. **Software UI/UX:** Standardizing software user interfaces (UI) and user experiences (UX) ensures consistency and ease of use for LiFi-enabled applications. Guidelines for user interactions, connectivity indicators, and configuration interfaces streamline user engagement. UI/UX standards contribute to user-friendly experiences across different LiFi-enabled devices and applications.
5. **Database Updation:** Standardized protocols for database updating involve the synchronization and management of device information, connectivity status, and user profiles. These standards define methods to securely update databases, enabling efficient tracking of LiFi-enabled devices, user preferences, and access control lists for authorized communication.

Standardization in LiFi technology is crucial for widespread adoption, ensuring interoperability, reliability, and user-friendly experiences. Establishing these standards fosters a cohesive ecosystem that drives the advancement of LiFi-enabled communication systems.

1.7 Approved Objectives

The objectives of the project are as follows:

- **Detailed Literature Survey and Research :**

  To conduct an in-depth study of existing literature and research related to LiFi technology and toll collection systems, to gain insights into the technological advancements, challenges, and potential applications of LiFi in real-time toll collection.

- **Fast Efficient Data Communication and Data transfer :**

  To implement real time data transmission using LiFi enhancing efficiency and accuracy. To establish seamless transmission and reception of data to utilize high speed communication.

- **Implementation of Efficient Payment Transaction:**

  To integrate an efficient payment transaction mechanism within the LiFi system and develop a user-friendly online portal for secure payment processing and optimize performance.To conduct thorough testing and validation to ensure seamless operation and user satisfaction.

1.8 Methodology

The methodology for a toll collection system using LiFi technology could involve the following steps:

- **Research and gather information about LiFi technology and its implementation in various fields:** Before starting the project, it is essential to have a good understanding of the technology involved. Information about LiFi

technology and its implementation in various fields is researched and gathered to understand its potential and limitations. Academic research, industry publications, and other sources are explored to gain insights into the latest developments in this field. This research helps in the identification of the components required for the project, their specifications, and how to integrate them to create a functional system.

- **Identify the components required for the toll gate system:** The components required for the toll gate system are identified. These components include LED bulbs, LCD display, photodiodes, microcontrollers, communication modules, power supplies, and sensors. The specifications of each component are identified based on the project's requirements and budget.

- **Design the circuit diagram and layout for the system:** The circuit diagram and layout for the system is designed. The layout shows the physical arrangement of the components on the toll gate.

- **Assemble the hardware components and test them:** The hardware components are assembled and tested for functionality and compatibility. This step involves soldering components onto a circuit board, connecting wires, and mounting the components on the toll gate. Once assembled, the hardware components are tested to ensure they are working correctly.

- **Develop the software for controlling and monitoring the system:** The software for controlling and monitoring the system will be developed. This software will run on the microcontroller and communicate with the LED bulbs, photodiodes, and other components. A programming language such as C++, Python, or Java can be used to develop the software. The toll gate barrier will be controlled based on the data received from the LED bulbs and communication with the payment gateway will be established to process transactions.

- **Integrate the hardware and software components:** The hardware and software components will be integrated to create a functional prototype. This involves connecting the microcontroller to the LED bulbs, photodiodes, and

other components. The integration will be tested to ensure that the system is working as expected.

- **Test the prototype in a controlled environment:** The prototype will be tested in a controlled environment to evaluate its functionality, reliability, and security. Different scenarios should be simulated and tested to ensure the efficiency of the model.

- **Optimize the system based on the feedback received from field tests:** The system will be optimized based on the feedback received from tests. This step involves identifying the areas where the system needs improvement and making the necessary changes. The cost-effectiveness of the system will also be evaluated and ways to reduce the cost of the components and the overall system will be identified.

- **Document the entire design:** The entire design, development, and testing process will be documented in detail. This documentation will include the circuit diagram, layout, software code, and testing procedures used.

1.9 Project Outcomes and Deliverables

- The final outcome of this project is the successful implementation of Toll Collection Mechanism through the secure and fast data transfer in the LiFi module system.
- Data transmission and reception through light and implementation of data communication.
- Safe and efficient payment transaction system integrated with LiFi Module system for real time toll collection.
- User friendly and solution oriented deliverable product with optimized design and scope.

1.10 Novelty of Work

The novelty of implementing LiFi technology in toll collection lies in its transformative potential to address the limitations of traditional toll collection systems. Here are the key aspects of novelty in this work:

- **LiFi Technology Integration:** The adoption of LiFi technology as the primary communication method for toll collection is a novel approach. Unlike RFID or barcode scanning, LiFi uses visible light for data transmission, offering faster, more accurate, and secure communication between toll booths and vehicles.
- **Enhanced Efficiency:** The proposed LiFi based system promises significant improvements in toll collection speed and accuracy. This enhanced efficiency reduces wait times at toll booths, benefiting both commuters and toll operators.
- **Improved Data Security:** LiFi technology introduces a higher level of data security due to its unique properties. Data transmitted via visible light is less susceptible to interference and eavesdropping, enhancing the security of financial transactions and user data.
- **Real-time Traffic Insights:** The system's ability to monitor and analyze traffic in real-time provides transportation planners and managers with valuable insights. This novel capability enables data-driven decisions for optimizing traffic flow and infrastructure planning.
- **Environmental Impact:** The use of energy-efficient LiFi technology aligns with environmental sustainability goals. This novel approach reduces energy consumption compared to traditional RF-based toll collection systems, contributing to a greener and more eco-friendly transportation system.
- **User Convenience:** LiFi based toll collection offers a contactless and seamless experience for users. With automatic toll payments, users can pass through toll booths without stopping, improving convenience and reducing congestion.
- **Scalability and Future-Proofing:** The system is designed with scalability in mind, allowing for future expansion and adaptation to evolving transportation needs. This forward-looking approach ensures the system's longevity and relevance.
- **Compliance with Industry Standards:** The proposed system adheres to industry-specific security and privacy standards while also meeting local,

regional, and national regulations for toll collection, ensuring both security and legal compliance.

- **User Adoption and Education:** The novel implementation includes comprehensive user education and training programs to facilitate user adoption, ensuring a smooth transition to the LiFi based toll collection system.

2.1 Literature Survey

2.1.1 Theory Associated with Problem Area

In the exploration of LiFi-based toll gate systems, this study is underpinned by several relevant theoretical frameworks that shape the investigation of this innovative technology. One primary theoretical foundation is the Technology Acceptance Model (TAM). TAM, a well-established theory in the field of technology adoption, emphasizes factors influencing users' acceptance of new technologies. In the context of LiFi based toll gate systems, TAM suggests that the ease of use and perceived usefulness of the technology are pivotal in its successful integration. Researchers have ensured that the LiFi systems proposed for toll collection are user-friendly and provide tangible benefits, such as improved toll processing and communication, aligning with the principles of TAM.

Furthermore, the Diffusion of Innovations Theory provides valuable insights into the adoption and integration of LiFi technology into existing toll gate systems. This theory delves into how new technologies spread through society. By proposing LiFi-based solutions for vehicle recognition, toll collection, and communication, the studies align with the process of innovation diffusion. This theoretical lens accentuates the studies' contributions to understanding how LiFi can be effectively integrated into existing toll gate systems to enhance efficiency and functionality.

By grounding the research in the principles of these established theories, this study aims to provide a comprehensive understanding of the theoretical underpinnings that drive the adoption and implementation of LiFi based toll gate systems in modern transportation infrastructure.

2.1.2 Existing System and Solutions

1. Radio-frequency Identification (RFID) technology based Toll Systems:

RFID based toll systems use radio frequency identification technology for automated toll collection:

Drawbacks:

- The Radio-frequency Identification (RFID) technology used for automatic toll payment is not consistently fast and the transceiver location varies.
- Transceiver placement varies, positioned ahead or next to boom barriers in different toll booths.
- Only vehicles with RFID tags can use the system, necessitating a separate lane for them.

Proposed System:

All vehicles are registered by manufacturers with government authorities, having vehicle registration plates and certificates. Microcontrollers within vehicles store these details, transferred via LiFi to toll plazas. Upon approaching a toll gate, IR sensors detect vehicles and LiFi transceivers communicate as gates close. The system will be using DRL (Daytime Running Lights) here . The receiver section will accept the signals from the DRL.

By leveraging LiFi technology, the proposed system aims to overcome the drawbacks of the existing RFID based toll payment method. It ensures seamless data transfer of vehicle details, enabling quicker and efficient toll payment processing. Additionally, the need for separate lanes for RFID-tagged vehicles can be eliminated, enhancing overall traffic flow and user convenience. [9]

2. Global Positioning System (GPS) technology based Toll Systems:

GPS-based toll systems rely on satellite navigation to track vehicle locations and calculate toll charges.

Drawbacks:

- GPS accuracy can be affected by signal blockages, leading to inaccuracies in toll calculation, especially in urban environments and tunnels.
- GPS signals can be susceptible to jamming and spoofing attacks, compromising the system's reliability.
- GPS signals can experience multipath reflections and signal blockages in urban settings, leading to reduced accuracy.

Proposed System:

In the proposed future system, the combination of GPS and LiFi technologies is envisaged to address the drawbacks of both standalone systems. By integrating GPS with LiFi, the system aims to mitigate inaccuracies caused by GPS signal blockages, especially in urban environments and tunnels. Additionally, the use of LiFi for data transfer at toll plazas enhances reliability by reducing susceptibility to GPS signal jamming and spoofing attacks. This integrated approach can provide more accurate and robust toll calculation while ensuring consistent communication between vehicles and toll infrastructure, thus improving the overall efficiency and effectiveness of the toll collection process.

2.1.3 Research Findings for Existing Literature

S.No.	Roll Number	Name	Paper Title	Tools/ Technology	Findings	Citation
1	102003130	Arpit Sagar	Li-Fi for wireless communication in a car park management system	Demonstrated the feasibility of using Li-Fi for wireless communication in a car park management system	Showed that Li-Fi can provide high-speed data transmission rates and is less susceptible to	4

					interference compared to traditional Wi-Fi systems	
2			A study on the application of Li-Fi technology in toll collection systems	Investigated the application of Li-Fi technology in toll collection systems	Proposed a Li-Fi based toll collection system for urban expressways	17
3			Vehicle-to-vehicle communication using visible light communication (VLC) technology	Proposed a Li-Fi based system for vehicle to vehicle communication	Used Li-Fi to establish a communication link between nearby vehicles, allowing for vehicle-to-vehicle data transmission and improved traffic safety	14
4	102003171	Manpreet Singh	Vehicle recognition system using visible light communication	Developed a Li-Fi based vehicle recognition system for toll gates	Used an artificial neural network to recognize vehicles based on their size and shape	8
5			Smart toll gate system based on Li-Fi and image processing	Developed a Li-Fi based smart toll gate system that could	Used Li-Fi to communicate with the vehicle and	16

				automatically detect vehicle information and process toll payments	utilized image processing techniques to extract vehicle information from camera images	
6	102003177	Sanchita Bora	Li-Fi based vehicle detection system for toll gates	Developed a vehicle detection system for toll gates using Li-Fi technology.	Demonstrated the potential of Li-Fi technology for toll gate applications, and proposed a system design that improves detection accuracy compared to traditional systems.	5
7			Vehicle-to-vehicle communication using Li-Fi technology for intelligent transportation systems	Proposed a Li-Fi based system for vehicle-to-vehicle communication in intelligent transportation systems.	Utilized Li-Fi to establish a communication link between nearby vehicles, allowing for vehicle-to-vehicle data transmission and improved traffic safety.	2

8			Smart toll collection system using Li-Fi and blockchain technology	Developed a Li-Fi based smart toll collection system that utilized blockchain technology for secure and transparent transactions.	Utilized Li-Fi to transmit toll information between the vehicle and the toll gate, and blockchain technology was used to ensure the security and transparency of toll transactions.	12
9	102003183	Anshika	Automatic toll collection system based on Li-Fi and deep learning	Proposed a Li-Fi based automatic toll collection system that utilized a deep learning algorithm to recognize license plates.	Utilized Li-Fi to transmit data from a camera located at the toll gate to a deep learning algorithm, which was trained to recognize license plates and process toll payments.	6
10			A Review of LiFi Technology	LiFi Module, LEDs, Visual Light Communication (VLC), Micro-LEDs, Electric Bulbs, Illumination	LiFi technology offers secure, efficient wireless data communication using visible light,	13

				sources.	holding potential for a faster, greener, and safer communicati on future.	
11			Intelligent toll collection system based on Li-Fi technology	Proposed a Li-Fi based intelligent toll collection system that utilized a convolutional neural network for vehicle classification and license plate recognition.	Utilized Li-Fi to transmit data from cameras and sensors located at the toll gate to a central processing unit, which used a convolutional neural network to classify vehicles and recognize license plates for toll payment processing.	7
12	10200318 8	Medhan sh Singh Verma	A vehicle recognition system for toll gate based on Li-Fi technology	Developed a vehicle recognition system for toll gates using Li-Fi technology and deep learning algorithms.	Demonstrate d the feasibility of using Li-Fi technology for toll gate applications, and proposed a system design that achieves high accuracy in	15

					vehicle recognition and classification.	
13			Vehicle recognition using a Li-Fi sensor for toll systems	The proposed system used a Li-Fi sensor to capture the light signal reflected by the vehicle passing through the toll gate and extracted vehicle features from the signal and used ANN for vehicle recognition.	The proposed system can recognize vehicles passing through the toll gate using a Li-Fi sensor, which eliminates the need for physical toll collection booths and reduces the time and cost of toll collection.	8

2.1.4 Problem Identified

Problems in various types of existing toll gate systems:

1. **RFID-based Toll Systems:**
   - *Inconsistent Speed and Transceiver Placement*: RFID-based systems suffer from varying transaction speeds due to inconsistent technology performance. Transceiver placement ahead of or next to boom barriers differs across toll booths, impacting transaction efficiency and vehicle flow.
   - *Exclusive RFID Tag Requirement*: Only vehicles equipped with RFID tags can use these systems, leading to separate lanes for tagged and non-tagged vehicles, causing congestion and inconvenience.
   - *Transceiver Line-of-Sight Dependency*: RFID technology relies on direct line-of-sight communication between transceivers and tags, resulting in failed transactions if not properly aligned or obstructed.

2. **GPS-based Toll Systems:**

- *Signal Inaccuracies in Urban Areas and Tunnels*: GPS accuracy can be compromised due to signal blockages, resulting in incorrect toll calculations, particularly in urban environments and tunnels.
- *Susceptibility to Jamming and Spoofing*: GPS signals can be vulnerable to jamming and spoofing attacks, undermining system reliability and security.
- *Multipath Reflections in Urban Settings:* In urban areas, GPS signals can experience multipath reflections and signal blockages, leading to reduced accuracy in toll calculations.

3. **Camera-based Toll Systems:**
   - *Limited Weather Resilience:* Camera-based systems may struggle in adverse weather conditions like heavy rain or fog, potentially affecting image quality and recognition accuracy.
   - *Privacy and Data Security Concerns:* Captured images raise privacy concerns, as license plate data can be misused or exposed without adequate security measures.
   - *Dependence on Image Quality:* Recognition accuracy heavily depends on image quality, making the system susceptible to errors in low-light or high-glare conditions.

4. **Manual Toll Collection:**
   - *Human Error and Delays:* Manual toll collection involves human operators and manual cash handling, leading to potential errors, long queues, and delays during peak hours.
   - *Operational Costs and Inefficiency:* Manual collection requires employing toll booth operators and additional infrastructure for cash handling, resulting in higher operational costs.

2.1.5 Survey of Tools and Technologies Used

Hardware Tools and Technologies: A deep study of available components like LEDs for transmission, LDRs for receivers and optimization of complete setup.

- **LiFi Transmitter :** A unique module to transmit light which is encoded with the message to be sent.
- **LiFi Receiver :** Receiver side module to detect light and decode the message and print it on a given display. The survey and study includes the programming, dry runs and procedural input/output trials to use the LiFi technology.
- **Integration Module:** Utilized to establish a connection between LiFi toll booth hardware components and the payment portal, enhancing project accessibility and scalability.

Software Tools and Technologies:

- **PHP for Backend:** Utilized for server-side scripting and handling dynamic data processing in the project.

- **SQL for Database:** Implemented for efficient data storage, retrieval, and management in the project.
- **HTML and CSS:** Employed for creating interactive and visually appealing user interfaces in the project.

2.2 Software Requirement Specification

2.2.1 Introduction

2.2.1.1 Purpose

The purpose of a LiFi-based Automatic Toll Collection System is to revolutionize toll collection by enhancing efficiency, accuracy, and security. By utilizing LiFi technology, this system streamlines the toll payment process, reducing wait times and traffic congestion, while ensuring precise fee calculations and secure data transmission. It contributes to cost savings for toll authorities, improves traffic flow, and offers environmental benefits through reduced energy consumption. Additionally, it provides valuable data for traffic analysis, enhances user convenience, and promotes the adoption of innovative technology in the transportation industry, ultimately contributing to economic growth and sustainability.

2.2.1.2 Intended Audience and Reading Suggestions

Intended Audience:

The intended audience for a report on a LiFi-based Automatic Toll Collection System includes:

- **Transportation Authorities:** Officials and decision-makers responsible for managing toll collection operations on highways, bridges, tunnels, and other roadways.
- **Infrastructure Planners:** Professionals involved in the planning and development of transportation infrastructure, including toll booth placement and technology integration.
- **Toll Collection Operators:** Individuals responsible for the day-to-day

management of toll booths and collection procedures.

- **Government Regulators:** Regulatory bodies overseeing transportation and toll collection, who may need to assess the system's compliance with standards and regulations.
- **Technology Providers:** Companies and experts in LiFi technology and intelligent transportation systems seeking opportunities for system deployment and innovation.
- **Researchers and Academics:** Scholars and researchers studying transportation systems, emerging technologies, and their impact on traffic management and infrastructure.

Reading Suggestions:

To gain a deeper understanding of LiFi and LiFi based Automatic Toll Collection Systems and related topics, the intended audience is encouraged to explore the following resources:

1. At TED Global, Harald Haas demonstrates that by flickering the light from a single LED, a change too quick for the human eye to detect, he can transmit far more data than a cellular tower -- and do it in a way that's more efficient, secure and widespread [3]
2. A Review of LiFi Technology [11]
3. Comparison between LiFi and Wifi [9]
4. Smart Toll Collection Using Li-Fi Technology [1]

By delving into these resources, the intended audience can acquire a comprehensive understanding of LiFi-based Automatic Toll Collection Systems.

2.2.1.3 Project Scope

The scope of the LiFi based Automatic Toll Collection System project encompasses the design, development, implementation, and evaluation of an innovative toll collection system leveraging LiFi (Light Fidelity) technology. The project objectives include the following key components:

1. **System Design and Architecture:** Define the architectural framework for the LiFi-based toll collection system, including the placement of LiFi transmitters at toll booths, integration with vehicles, and network infrastructure.
2. **Hardware and Software Development:** Develop and deploy LiFi-enabled hardware components, including transmitters and receivers, and design the software necessary for secure and efficient data communication, payment processing, and user interface.
3. **LiFi Network Deployment:** Install and configure LiFi networks at designated toll collection points, ensuring comprehensive coverage and reliability under varying environmental conditions.
4. **Real-time Data Exchange:** Establish a seamless and real-time data exchange mechanism between LiFi transmitters and receivers, allowing for accurate toll fee calculation and secure payment transactions.
5. **User Registration and Authentication:** Implement user registration and authentication processes to ensure secure and authorized access to the toll collection system, incorporating methods such as biometrics or vehicle identification.
6. **Data Analysis and Reporting:** Develop mechanisms for collecting and analyzing data on traffic patterns, usage trends, and system performance, with the goal of optimizing toll collection operations and infrastructure planning.
7. **User Education and Training:** Develop educational materials and training programs to familiarize users with the LiFi-based toll collection system, ensuring effective and smooth adoption.
8. **Compliance with Standards:** Ensure compliance with relevant industry standards and protocols, as well as local and regional regulations governing toll collection and data privacy.
9. **Testing and Optimization:** Conduct rigorous testing, simulation, and optimization phases to validate system performance, accuracy, and reliability under various operational scenarios.
10. **User Experience Enhancement:** Continuously seek opportunities to enhance the user experience, such as minimizing wait times, improving accessibility, and providing real-time transaction notifications.
11. **Environmental Impact Assessment:** Evaluate the environmental benefits of

the LiFi-based system, particularly in terms of reduced energy consumption and its contribution to sustainability goals.

12. **Maintenance and Support:** Establish protocols and resources for ongoing maintenance, support, and updates to ensure the system's long-term functionality and reliability.
13. **Documentation and Reporting:** Maintain detailed documentation of system components, processes, and performance metrics. Generate periodic reports for stakeholders, including transportation authorities and regulatory bodies.

2.2.2 Overall Description

2.2.2.1 Product Perspective

The LiFi-based Automatic Toll Collection System represents an innovative and transformative solution within the broader context of intelligent transportation systems (ITS) and toll collection technologies. From a product perspective, it can be viewed in the following context:

1. **Integration with Existing Infrastructure:** The system should seamlessly integrate with existing toll booth infrastructure, toll management systems, and traffic management solutions. It complements and enhances the capabilities of traditional toll collection methods.
2. **Interoperability:** The LiFi-based system should be designed with interoperability in mind, allowing for compatibility with a range of LiFi-enabled vehicles, transmitters, and receivers. It should also facilitate integration with emerging connected vehicle technologies.
3. **Complementary Technology:** This product perspective recognizes that the LiFi-based system is part of a broader ecosystem of ITS technologies, including RFID, DSRC, and GPS-based systems. It should coexist and collaborate with these technologies as needed.
4. **User-Centric Design:** The system places a strong emphasis on user convenience and experience. It should be user-friendly, ensuring that drivers and vehicle owners can easily adopt and utilize the system for toll payment.

5. **Data Insights:** Beyond toll collection, the product perspective includes the use of data generated by the system for traffic analysis, infrastructure planning, and policy decisions. It contributes valuable insights into traffic patterns and usage trends.
6. **Security and Privacy:** Ensuring the security of payment transactions, user data, and system integrity is a central aspect of the product perspective. It aligns with industry standards and best practices for data privacy and security.
7. **Environmental Considerations:** Recognizing its potential to reduce energy consumption compared to traditional toll collection systems, the product perspective acknowledges the system's role in contributing to sustainability goals and reducing the environmental footprint of transportation infrastructure.
8. **Maintenance and Support:** The product perspective includes provisions for ongoing maintenance, updates, and customer support. It ensures that the system remains operational and effective throughout its lifecycle.
9. **Regulatory Compliance:** The system adheres to local, regional, and national regulations governing toll collection, data handling, and transportation. It remains adaptable to evolving regulatory requirements.
10. **Cost-Effective Solution:** As a product perspective, it acknowledges that the system should demonstrate cost-effectiveness over time, considering factors such as initial implementation costs, operational efficiency gains, and long-term sustainability.
11. **Scalability and Future-Proofing:** The product perspective anticipates future growth and scalability needs, allowing for the expansion of the system to accommodate increasing traffic volumes and emerging technologies.
12. **Continuous Improvement:** It envisions a commitment to continuous improvement, where user feedback and technological advancements are incorporated into the system to enhance its performance, security, and user experience.

2.2.2.2 Product Features

1. **Real-Time Toll Collection:** Enable swift and real-time collection of toll fees as vehicles pass through toll booths, reducing wait times and traffic congestion.
2. **LiFi Data Communication:** Implements successful transmission and reception

of data through LiFi Modules and through a potential range without interference.

3. **LiFi Technology Integration:** Utilize LiFi technology for secure, high-speed data transmission between toll booth transmitters and vehicle receivers, ensuring accuracy in toll fee calculation.
4. **Contactless Payments:** Offer contactless toll payments, eliminating the need for physical currency or manual toll booth operators, enhancing convenience for users.
5. **User Registration and Authentication:** Implement user registration and authentication processes to ensure secure and authorized access to the toll collection system, protecting against fraudulent use.
6. **Environmental Efficiency:** Contribute to environmental sustainability by reducing energy consumption compared to traditional RF-based toll collection systems.
7. **Compatibility:** Ensure compatibility with a variety of LiFi-enabled vehicles, transmitters, and receivers, promoting widespread adoption and system interoperability.
8. **User-Friendly Interface:** Provide an intuitive and user-friendly interface for drivers and vehicle owners to register, manage accounts, and receive real-time transaction status.
9. **Maintenance and Support:** Offer comprehensive maintenance and support services to ensure the system's continuous operation and address any technical issues promptly.
10. **Continuous Improvement:** Commit to ongoing system enhancements and updates based on user feedback, technological advancements, and changing industry standards.

2.2.3 External Interface Requirements

2.2.3.1 User Interfaces

There are various user interfaces involved:

1. Vehicle Interface:

- User with a secure authenticated login and owns a vehicle with the transmitter installed.

2. Payment Portal:

- Login/Registration: Users can log in to their accounts or register if they are new users. They can also use a guest checkout option.
- Dashboard: After logging in, users are directed to a dashboard where they can view their recent transactions, account balance, and payment history.
- Make Payment: Users can initiate a payment by selecting the toll booth location and vehicle details. The system calculates the toll amount and prompts the user to confirm the payment.
- Transaction History: Users can access a comprehensive history of their toll transactions, including timestamps and toll booth locations.

Toll Booth Operator Interface:

- Authentication: Toll booth operators log in to their accounts with secure credentials.
- Vehicle Detection: When a vehicle approaches, the system identifies the vehicle using its LiFi transmitter and toll gate receiver. The operator's screen displays vehicle details.
- Toll Amount Display: The screen shows the toll amount owed by the driver based on their vehicle type and the distance traveled.
- Transaction: After the payment is done, the portal confirms the transaction.

Administrator Control Panel:

- System Overview: The administrator's dashboard provides an overview of all toll booths, transaction statistics, and system status.
- User Management: Administrators can manage user accounts, review and approve new registrations, and handle account-related inquiries.
- Toll Booth Configuration: Configurable settings for each toll booth, such as toll rates, payment methods, and operating hours.

2.2.3.2 Hardware Interfaces

1. Vehicle Hardware:

LiFi Transmitter: Installed on vehicles for unique data transmission.Comprises of array of LED Lights for visible light transmission and light encoded with unique code.

Microcontroller unit: Programmed control unit of buggy and driver motor with its programming unit.

2. Toll Booth Hardware:

LiFi Receiver: Installed at toll gates for data reception and detection.

Integration Unit: To successfully transmit the received data for user to pay the tax.

3. Design Setup:

Interfaces with complete software and prototype designing and installation.

2.2.3.3 Software Interfaces

1.User Portal Software:

- *Front-End:* Developed using web technologies for user-friendly interaction.
- *Back-End:* Manages user accounts, transactions, and interfaces with the database.

2.Payment Processing Software:

- Portal to view and manage toll tax transactions.

3.Database Management System:

- Stores user profiles, transaction history and toll booth data.
- Enables efficient retrieval and management of data.

4.Administrator Software:

- Manages user accounts, system configuration and analytics.
- Provides administrative control over the entire system.

2.2.4 Other Non-Functional Requirements

2.2.4.1 Performance Requirements

Performance requirements are a set of specific and measurable criteria that outline how a system or software application should perform in various aspects. These requirements are essential for ensuring that the system meets its intended objectives and delivers a satisfactory user experience. Here's a brief description of performance requirements:

1. **Transaction Speed:** Performance requirements define the speed at which the system should process transactions, such as payment processing, data retrieval, or data transmission. Faster transaction speeds lead to reduced wait times and improved efficiency.
2. **Throughput:** Throughput requirements specify the system's capacity to handle a certain number of transactions or requests per unit of time. This metric is crucial for systems with high user loads or heavy data processing demands.
3. **Network Latency:** Network latency requirements focus on minimizing delays in data transmission over a network. Lower latency ensures real-time communication and responsiveness.
4. **Availability and Uptime:** These requirements dictate how often the system should be available for use and how much downtime is acceptable for maintenance and updates. High availability and uptime are crucial for uninterrupted service.
5. **Reliability and Error Handling:** Reliability requirements ensure that the system operates consistently without unexpected failures. Robust error-handling mechanisms are defined to address and resolve issues promptly.
6. **Data Processing Efficiency:** These requirements focus on optimizing the speed and efficiency of data processing operations, such as calculations, transformations, and data storage.
7. **Data Storage Performance:** Performance requirements for data storage systems ensure that data can be retrieved and stored quickly, enabling rapid access to information.
8. **Scalability:** Scalability requirements specify how well the system can adapt to

increased loads or user volumes. Scalable systems can grow to accommodate expanding user bases without a significant drop in performance.

9. **Security Performance:** Security requirements outline the system's ability to maintain high performance levels while implementing security measures such as encryption and authentication.
10. **User Experience:** User experience requirements define the responsiveness and usability of the system's user interface, ensuring that users can interact with the system efficiently.
11. **Reporting and Analytics:** These requirements detail the system's ability to generate reports and analytics within specified timeframes, supporting data-driven decision-making.

2.2.4.2 Safety Requirements

Safety requirements for a LiFi-based Automatic Toll Collection System are essential to ensure the system operates securely and does not pose risks to users, operators, or the environment. Here are key safety requirements:

1. **User Data Protection:** The system must safeguard user data, including personal information and payment details.
2. **Access Control:** Implement robust access control measures to prevent unauthorized access to the system, ensuring only authorized personnel can manage and operate it.
3. **Authentication and Authorization:** Utilize strong authentication methods and role-based authorization to ensure that only authorized users can perform specific actions within the system.
4. **Data Integrity:** Guarantee the integrity of data during transmission and storage, preventing data corruption or manipulation by unauthorized entities.
5. **Physical Security:** Secure toll booths and LiFi infrastructure against physical tampering or vandalism to prevent disruptions to toll collection operations.
6. **User Safety Information:** Provide clear safety instructions and information to users, such as how to use the system safely and what to do in case of emergencies.

7. **Environmental Impact Mitigation:** Minimize environmental impact by ensuring that system components are energy-efficient and environmentally friendly, and that they comply with environmental regulations.
8. **Training and Certification:** Ensure that personnel responsible for operating and maintaining the system are adequately trained and certified in safety protocols and procedures.

2.2.4.3 Security Requirements

Security requirements for a LiFi-based Automatic Toll Collection System are essential to protect sensitive data, prevent fraud, and ensure the integrity and confidentiality of transactions. Here are key security requirements:

1. **Secure User Login:** Implement secure login mechanisms for user access, ensuring that only authorized individuals can access the system.
2. **Authorization and Access Control:** Enforce role-based access control (RBAC) to restrict users' permissions and actions within the system, preventing unauthorized access to sensitive functions.
3. **Secure Communication :** LiFi system should ensure secure communication and data transfer without any bit loss or external interruption.
4. **User Session Management:** Implement session timeout mechanisms to automatically log users out after a period of inactivity, reducing the risk of unauthorized access.
5. **Secure User Registration:** Ensure that user registration processes are secure, including identity verification and validation to prevent fraudulent account creation.

2.3 Cost Analysis

Cost Categories:

1. Hardware Costs
2. Software Costs
3. Miscellaneous Costs

Total Cost Estimation: ₹8000

Hardware Cost Structure:

Hardware	Cost
Components: • (Basic Structure) • Microcontroller(5 Arduino Uno Boards) • Sensors(2 Pair IR Sensors) • Connection equipments(breadboard, jumper wires, connecting wires)	₹3000
Module: • LiFi Transmitter • LiFi Receiver • Wifi Module (ESP8266) • LDR Module	₹2000
Setup Cost: • Installation • (Gantry, Track, Buggy Car)	₹1000
Testing: • LCD,I2C Modules • Power Supply Battery (9V/12V) • Calibration Components(Solder, Solder Plate, PCB)	₹1000

Adding overhead miscellaneous costs: Approx. ₹1000

[Networking, LEDs, LDRs, Mounting and enclosures]

Total Potential Hardware Cost: ₹8000

Software Cost Structure:

Based on development approach, Software WebApp for Payment Gateway to facilitate Transaction with user login and in-house centralized database. Maintenance: Bug fixes and feature enhancements for updates requiring technical support or online domain names and synchronization with hardware structure using Wifi module can range from ₹500 - ₹1000.

2.4 Risk Analysis

Risk analysis for a LiFi-based Automatic Toll Collection System involves identifying potential threats, assessing their impact, and outlining mitigation strategies. Here's a risk analysis for such a system:

- **Unauthorized Access:** Unauthorized individuals gain access to the toll collection system, potentially compromising user data and financial transactions.
    - Impact: Data breaches, financial losses, reputation damage.
    - Mitigation: Implement strong authentication, access controls, and encryption. Regularly monitor and audit system access. Conduct security training for employees.
- **System Downtime:** System failures or technical issues result in extended downtime, disrupting toll collection operations.
    - Impact: Revenue loss, traffic congestion, user dissatisfaction.
    - Mitigation: Implement redundancy and failover mechanisms. Schedule maintenance during off-peak hours. Develop a robust disaster recovery plan.
- **Data Breach:** Sensitive user data, including payment information, is compromised due to security vulnerabilities.
    - Impact: Legal and regulatory penalties, reputation damage, financial losses.
    - Mitigation: Encrypt data in transit and at rest. Regularly update and patch system components. Conduct security assessments and audits.
- **Environmental Factors:** Environmental factors such as extreme weather or natural disasters damage toll booths and infrastructure.
    - Impact: Disruption of toll collection, infrastructure damage, safety risks.

- Mitigation: Design infrastructure to withstand environmental challenges. Implement monitoring and alert systems for adverse conditions.

- **Hardware or Software Failures:** Hardware or software components fail, leading to system outages or performance degradation.
  - Impact: Disruption of toll collection, maintenance costs.
  - Mitigation: Implement quality hardware components. Regularly update and maintain software. Plan for hardware redundancy.
- **Regulatory Non-Compliance:** Failure to comply with local, regional, or national regulations and standards related to toll collection and data privacy.
  - Impact: Legal penalties, fines, operational disruptions.
  - Mitigation: Stay informed about relevant regulations. Conduct compliance audits. Adjust systems and processes to ensure compliance.
- **Insider Threats:** Insiders with access to the system misuse their privileges for malicious purposes.
  - Impact: Data breaches, financial losses, reputation damage.
  - Mitigation: Implement least privilege access controls. Monitor user activities and conduct background checks on personnel with access to sensitive systems.
- **Lack of User Adoption:** Users may resist adopting the new LiFi-based toll collection system due to unfamiliarity or inconvenience.
  - Impact: Reduced system utilization, financial losses.
  - Mitigation: Provide user education and training. Offer incentives or discounts for using the system. Ensure a seamless and user-friendly experience.

3.1 Investigative Techniques

Descriptive:

The investigative approach employed in this project is predominantly descriptive, focusing on understanding and documenting the fundamental components and processes underlying the LiFi-based smart toll collection system.In the context of this project, a descriptive investigative technique enables a comprehensive exploration of the LiFi technology, Arduino programming for the light-based transmitter and receiver, integration with WiFi modules, and the subsequent data transfer to associate vehicle numbers with user accounts. By adopting a descriptive approach, the project seeks to provide a thorough understanding of each component's functionality, their interplay, and the overall architecture of the smart toll collection system.

- **Understanding Complex Interactions:** The LiFi-based smart toll collection system involves intricate interactions between various elements, such as optical communication, Arduino programming, WiFi integration, and data management. A descriptive approach allows for a detailed examination of these interactions, aiding in the identification of dependencies and potential challenges.
- **Formulating System Models:** The project's goal includes designing a new system model and prototype to facilitate seamless communication and toll deduction. A descriptive technique is well-suited for formulating and documenting this scenario , providing clarity on the logical and functional aspects of the system.
- **Cataloging Novel Concepts:** As the project explores innovative concepts, programming , and methodologies, a descriptive investigative technique allows for the systematic cataloging of these novel elements. This documentation serves as a valuable resource for future development and research in the field.

- **Ensuring Reproducibility:** Descriptive investigations contribute to the reproducibility of the project by providing detailed records of the processes and methods employed. This transparency is crucial for peer review, validation, and the potential replication of the system in similar contexts.

Methodology:

The methodology for the descriptive investigation involves the following key steps:

- **Literature Review:** Conducting an extensive literature review to understand existing LiFi technologies, Arduino programming techniques, WiFi integration methods, and smart toll collection systems. This forms the foundation for the project's design and implementation.
- **Component Analysis**: Thoroughly analyzing each component of the LiFi-based smart toll collection system, including the light-based transmitter and receiver, integration module,connection setup and buggy designing. This involves dissecting the functionalities, constraints, and potential enhancements of each element.
- **Prototyping and Testing:** Developing prototypes of the system to validate the theoretical concepts and assess the practical feasibility. Rigorous testing ensures that the designed models and algorithms perform effectively in real-world scenarios.
- **Observation and Recording:** Systematically observing the interactions and behaviors of the components during various stages of operation. Recording detailed observations enables the creation of a comprehensive catalog of system behaviors, potential issues, and areas for improvement.
- **Documentation:** Creating detailed documentation of the project, including system models, algorithms, observations, and any modifications made during the development process. This documentation serves as a valuable reference for future iterations and contributes to the project's overall transparency.

By employing this methodology, the project aims to not only develop a functional LiFi-based smart toll collection system but also contribute valuable insights to the

broader field of intelligent communication technologies.

3.2 Proposed Solution

The proposed solution for a LiFi-based Automatic Toll Collection System is a comprehensive and innovative approach designed to enhance efficiency, security, and user convenience in toll collection operations. Here are the key components and features of the proposed solution:

1. **LiFi Technology Integration:**

- Description: Implement visible light communication technology (LiFi) at toll booths and in equipped vehicles. LiFi transmitters at toll gates communicate with LiFi receivers on vehicles to enable real-time, secure data exchange via visible light.
- Benefits: Faster and more reliable data transmission, reduced congestion at toll booths, and enhanced security.

2. **User Registration and Account Management:**

- Description: Users can register their vehicles and create accounts in the system. Each vehicle is linked to a payment portal for toll payments. Users can manage their accounts, view transaction history, and set up payment preferences.
- Benefits: Convenient user experience, simplified toll payment management.

3. **Contactless Toll Payments:**

- Description: Toll fees are deducted from the user's account as the vehicle passes through the LiFi-enabled toll booth, eliminating the need for physical payment and reducing wait times.
- Benefits: Contactless and efficient toll collection, reduced traffic congestion.

4. **Environmental Efficiency:**

- Description: LiFi technology is energy-efficient, contributing to reduced power consumption compared to traditional RF-based toll collection systems. This aligns with sustainability goals and reduces the environmental footprint.
- Benefits: Reduced energy costs, eco-friendly toll collection.

5. **Scalability and Future-Proofing:**

- Description: The system is designed to scale to accommodate increasing traffic volumes and emerging technologies. It can adapt to evolving traffic demands and toll collection needs.
- Benefits: Accommodates future growth, maintains system relevance.

6. **Continuous Improvement and Maintenance:**

- Description: The system includes provisions for ongoing maintenance, updates, and customer support. Regular user feedback and technological advancements are incorporated to enhance performance and security.
- Benefits: System reliability, user satisfaction, and responsiveness to changing requirements.

7. **Compliance with Standards and Regulations:**

- Description: The system adheres to local, regional, and national regulations governing toll collection, data handling, and transportation. It complies with industry standards for security and privacy.
- Benefits: Legal compliance, regulatory adherence, and user trust.

The proposed solution leverages LiFi technology to revolutionize toll collection, offering a secure, efficient, and environmentally friendly alternative to traditional methods.

3.3 Work Breakdown Structure

Work Breakdown composing of hardware and software components as following:

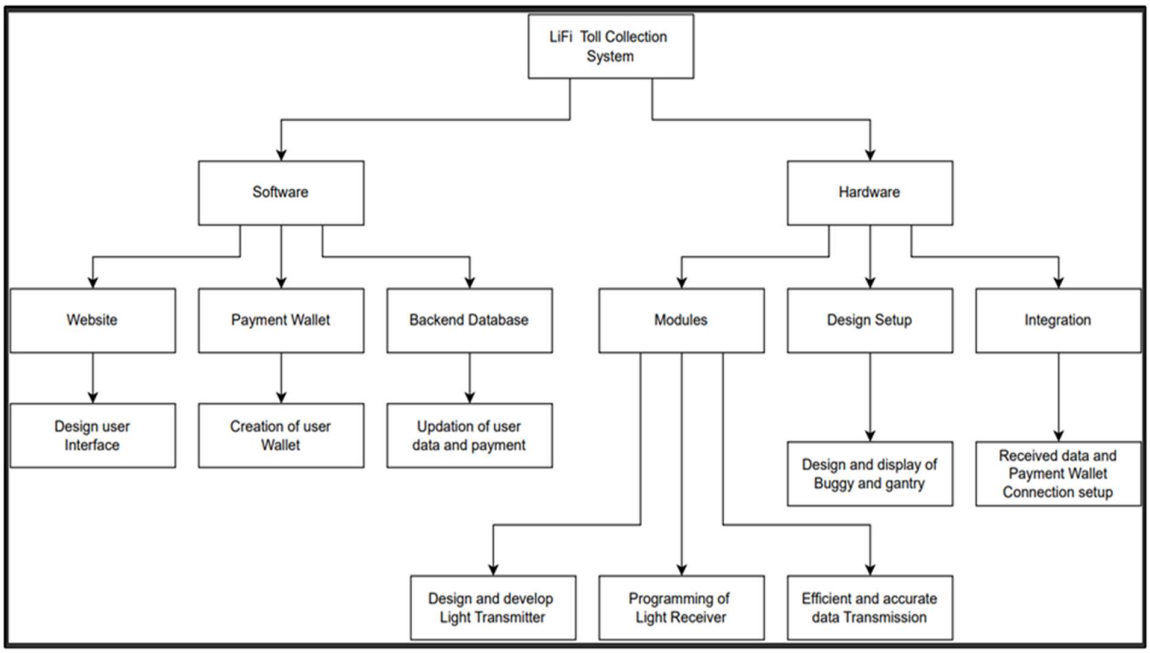

Figure 3.3.1: Work Breakdown Structure for the entire system clearly describing the segments and blocks for hardware component and software structure for the working of the suggested prototype.

Gantt Chart:

Task	Duration	Start	Finish
1 Identification, Formulation & Planning of Project	**30 Days**	**09-01-2023**	**08-02-2023**
1.1 Defining Strategy	15 Days	09-01-2023	24-01-2023
1.2 Literature Review	Project Duration	09-01-2023	11-12-2023
1.3 Project Scope	15 Days	24-01-2023	08-02-2023
2 Requirement Analysis	**30 Days**	**09-02-2023**	**11-03-2023**
2.1 Feasibility Study	**15 Days**	**09-02-2023**	**24-02-2023**
2.1.1 Technical Feasibility	7 Days	09-02-2023	16-02-2023
2.1.2 Operational Feasibility	8 Days	16-02-2023	24-02-2023
2.2 Hardware Analysis	**15 Days**	**24-02-2023**	**11-03-2023**
2.2.1 Budget Review	7 Days	24-02-2023	03-03-2023
2.2.2 Utility Analysis	8 Days	03-03-2023	11-03-2023
3 Module Designing & Development	**90 Days**	**12-03-2023**	**10-06-2023**
3.1 System Design	45 Days	12-03-2023	26-04-2023
3.2 Hardware Interfacing	45 Days	26-04-2023	10-06-2023
4 Implementation	**90 Days**	**11-06-2023**	**09-09-2023**
4.1 Software Integration	**45 Days**	**11-06-2023**	**26-07-2023**
4.1.1 Design GUI	15 Days	11-06-2023	26-06-2023
4.1.2 Coding Phase	30 Days	26-06-2023	26-07-2023
4.2 Development Phase	**45 Days**	**26-07-2023**	**09-09-2023**
5 Design Optimization	**30 Days**	**09-09-2023**	**09-10-2023**
6 Testing & Updations	**30 Days**	**10-10-2023**	**09-11-2023**
7 Result Evaluations	**15 Days**	**10-11-2023**	**25-11-2023**
7.1 Accuracy Judgement	8 Days	10-11-2023	18-11-2023
7.2 Measurement Analysis	7 Days	18-11-2023	25-11-2023
8 Final Report	**15 Days**	**26-11-2023**	**11-12-2023**

Figure 3.3.2: Gantt Chart explaining the workflow division with corresponding timelines.

3.4 Tools and Technology

- **Hardware:** The hardware components used are
  1. Light Transmitter
  2. Light Receiver
  3. Buggy Motorcar
  4. Integration Module (ESP8266-NodeMCU)
  5. Arduino Uno Microcontroller
  6. Pair of IR Sensors
  7. Driver Motor
- **Software:**
  1. Frontend technology used : HTML, CSS, Javascript
  2. Backend technology used : PHP
- **Integration:**

  Wifi Module(ESP8266-NodeMCU)

4.1 System Architecture

The Block Diagram can be used to accurately illustrate the system's design as shown in Figure 4.1.1:

4.1.1 ***Block Diagram***

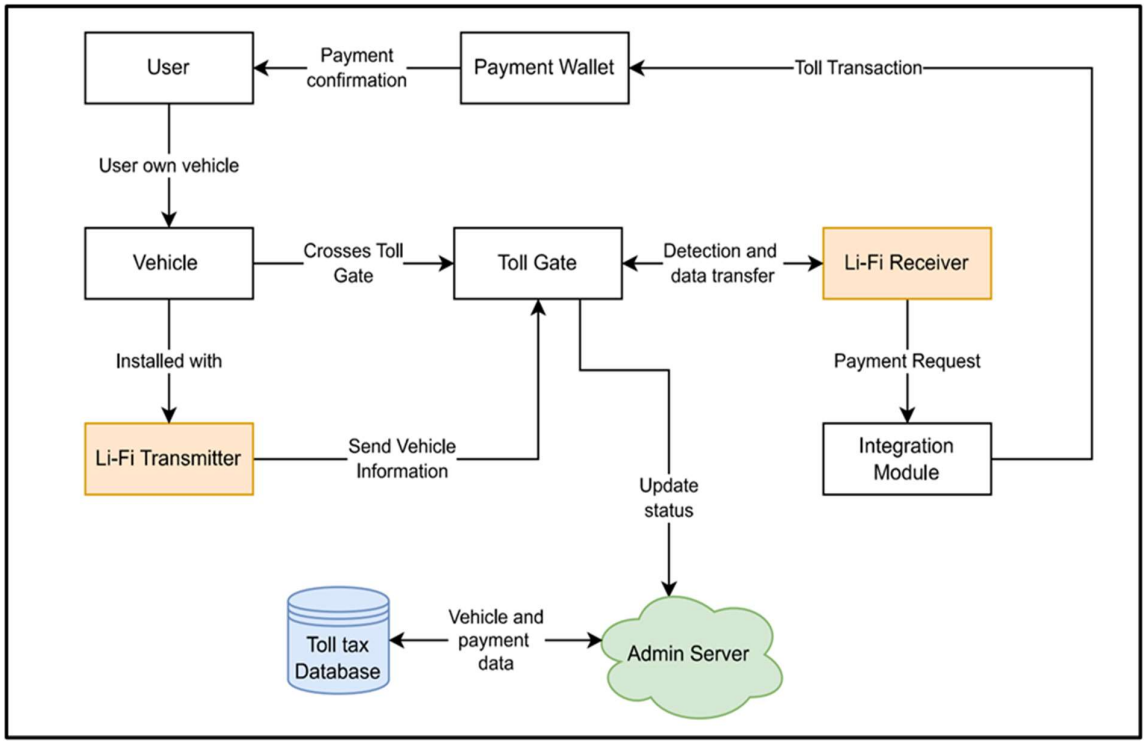

Figure 4.1.1 Block diagram

Figure 4.1.1 refers to the block Diagram of LiFi Smart Toll Collection System. In this, user owns a vehicle which is installed with a unique LiFi Transmitter. This vehicle passes a Toll Gate where this transmitter sends vehicle information to Toll Gate installed with LiFi receiver which detects the user information and the amount is deducted from the user account and successful payment confirmation is made to the user.

4.1.2 Activity Diagram

An activity diagram depicts the sequential flow of control from an initial point to a final point, while also highlighting the various decision points that may arise during the execution of the activity.

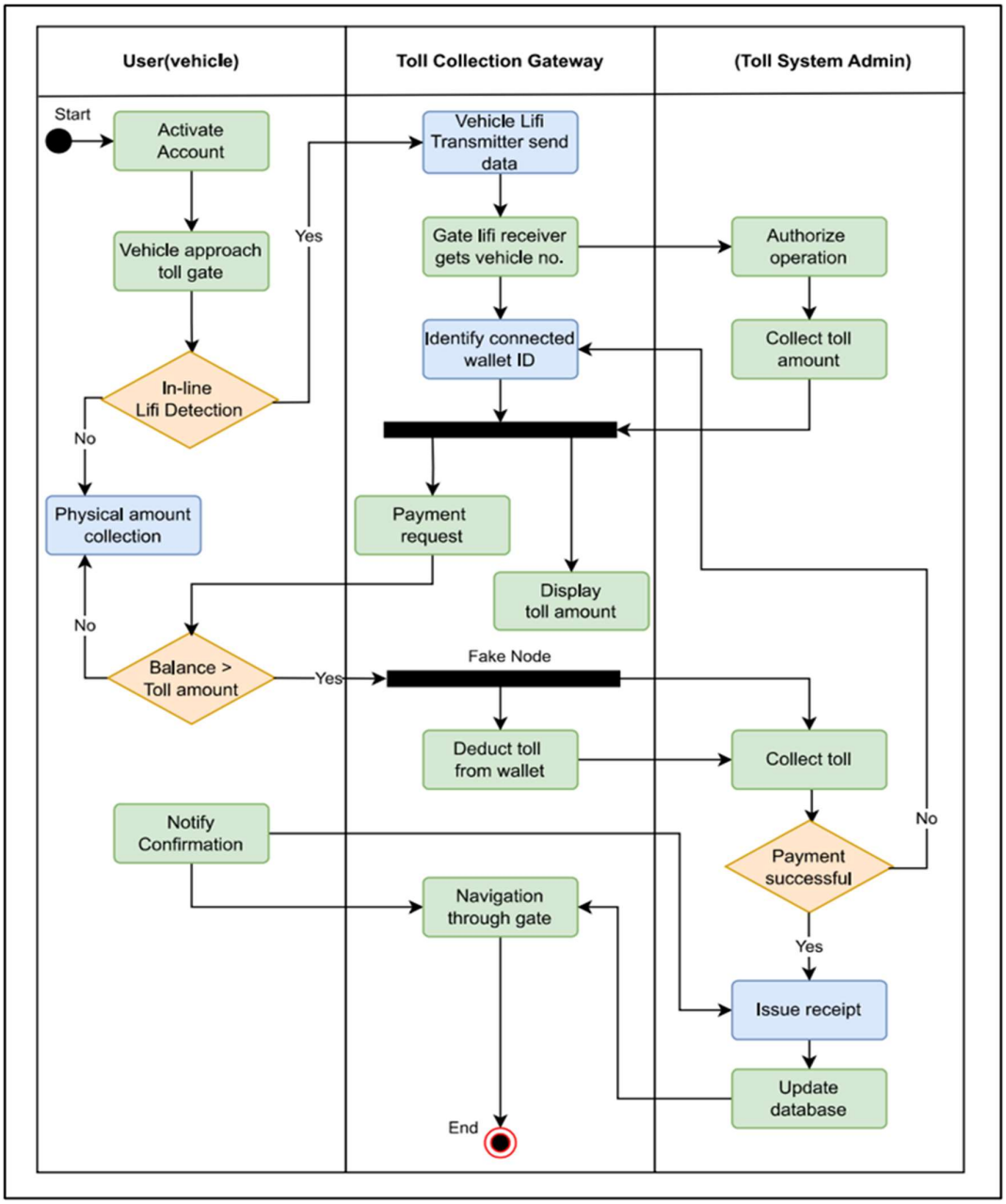

Figure 4.1.2 Activity Diagram

Figure 4.1.2 refers to the Activity Diagram of the project which begins with the start

node showing the initiation of the project with the creation of the user account. It further involves the in-line detection of the transmitter when the vehicle approaches the toll gate.The decision points arise to check the balance and also to check if the payment was successful. The flow of processes and functions are shown between the three sections of user(i.e the vehicle),Toll Collection Gateway,and the system Admin to achieve the operational procedure of entire project.

4.2 Design Level Diagrams

The following Data Flow Diagrams (Level 0 and Level 1) show the changes and transformations in data flows among all processes.

4.2.1 Data Flow Diagram (DFD):

4.2.1.1 LEVEL 0

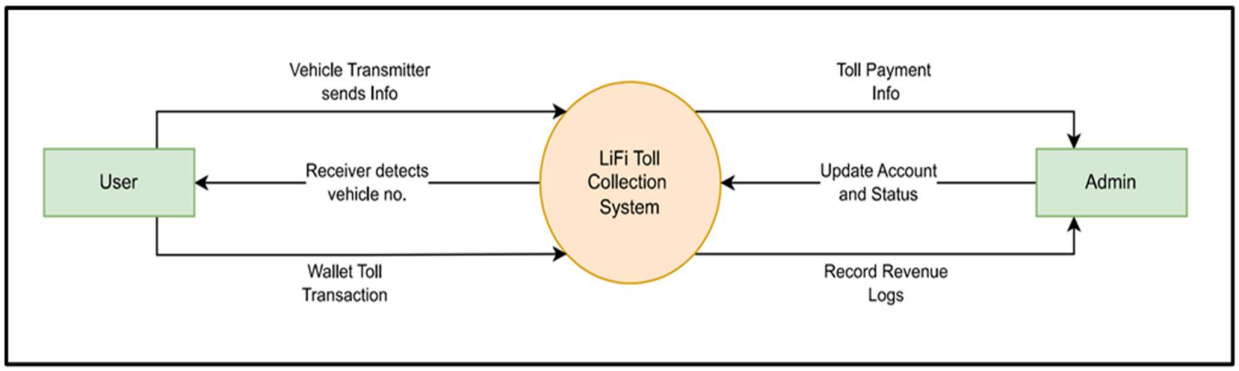

Figure 4.2.1.1 DFD (Level 0)

Figure 4.2.1.1 refers to the level 0 of the Data Flow Diagram.The components include User, LiFi Collection System and the Admin. The overview provides the functionalities between the user and the system including transmission and reception , between the admin and the system including payment updation, transaction and revenue records.

4.2.1.2 ***LEVEL 1***

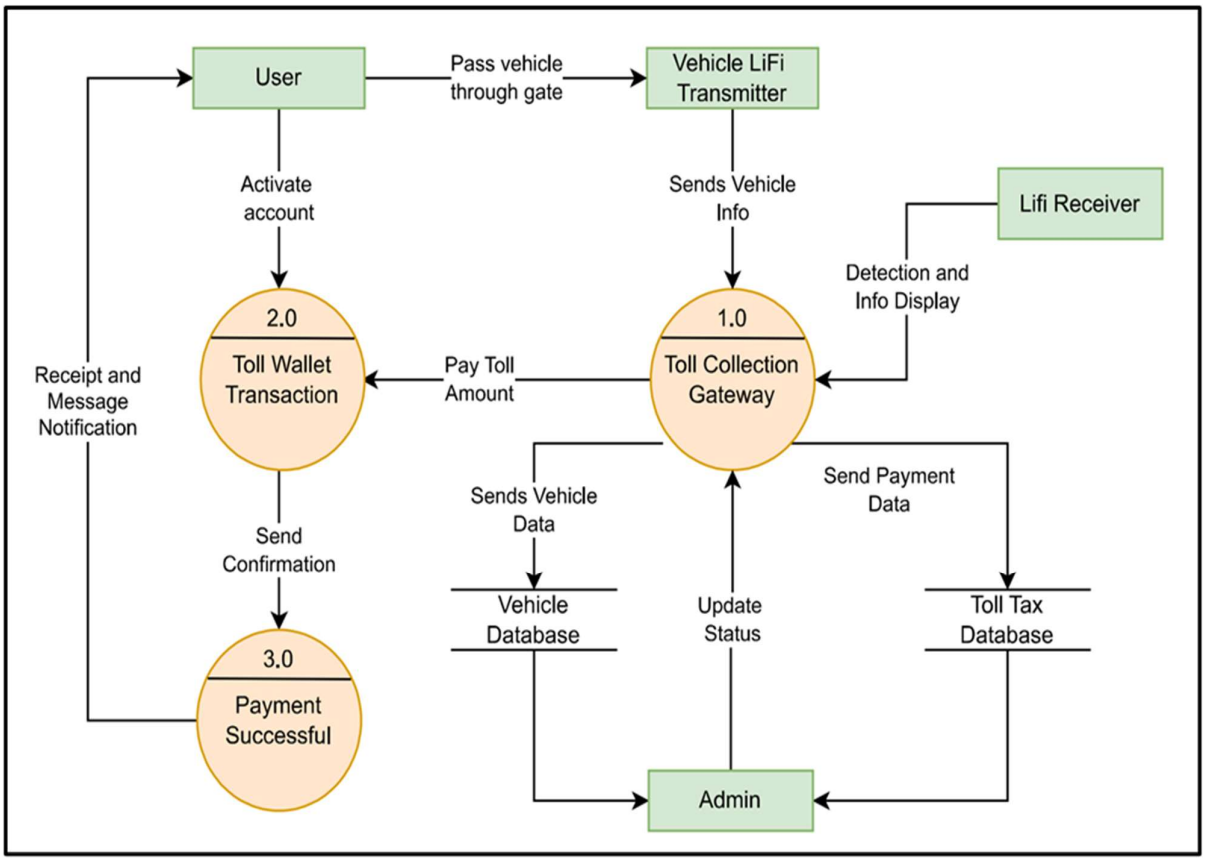

Figure 4.2.1.2 DFD (Level 1)

Figure 4.2.1.2 refers to the level 1 of the Data Flow Diagram which delves deep into the various operations of transmission,reception and payment transactions.The system involves two database i.e Vehicle database storing vehicle information (user and vehicle details) and Toll Tax Database (containing payments and transactions info).Further the display of information at LiFi Toll Gate receiver and admin status updation are also depicted through this diagram.

4.2.2 ER Diagram

The given below ER Diagram shows the conceptual model of our LiFi system defining the relationship between different entities of our project.

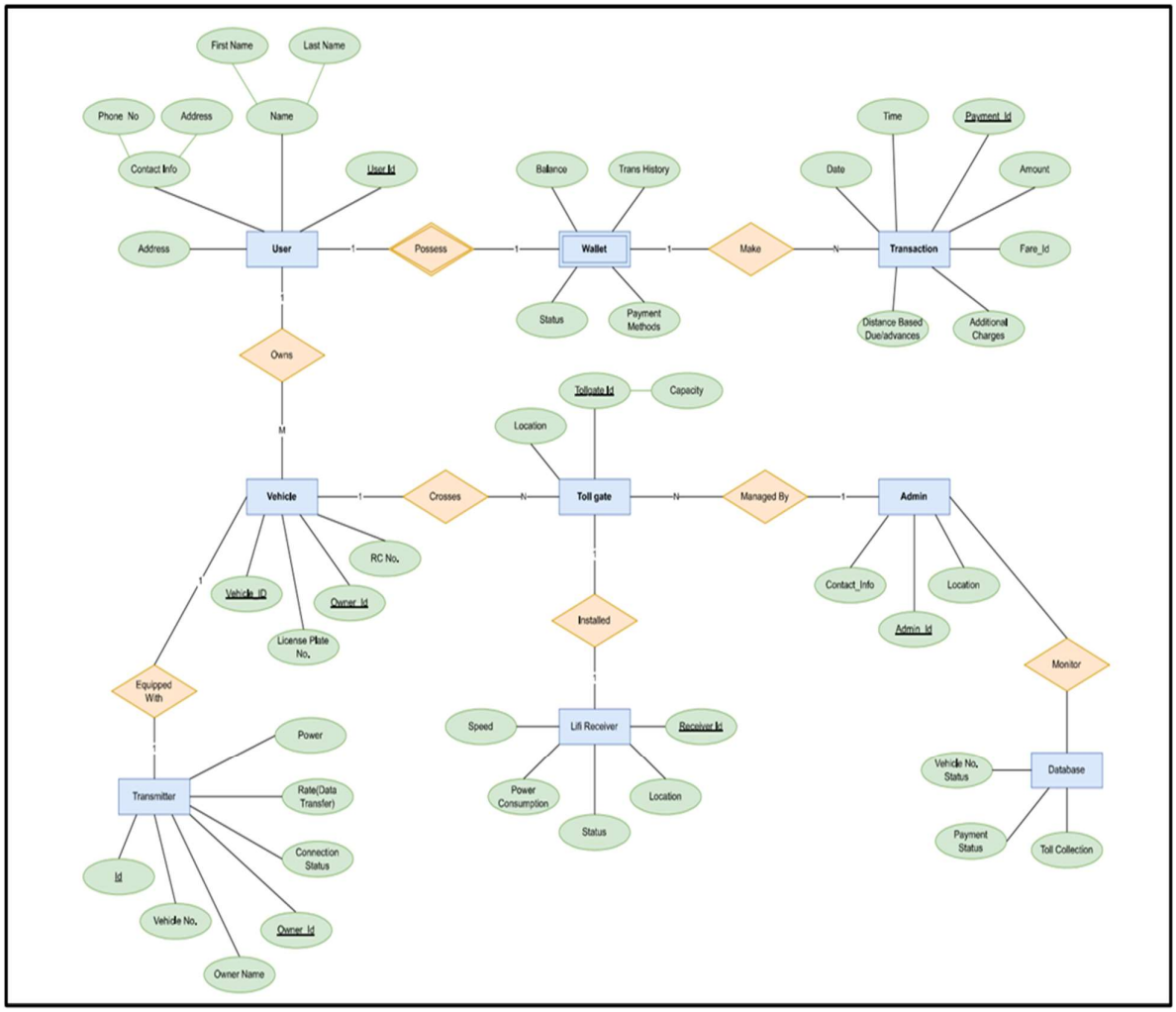

Figure 4.2.2 ER Diagram

Figure 4.2.2 refers to the ER diagram showing the connections between all entities. The entities, characteristic attributes and relationships interact to describe the entire system of the project. User owns a vehicle and has an account used for making the transactions. The 1:N relationship between the admin and the Toll gate describes the mechanism of toll collection. Admin monitors the entire database with the Toll Gate installed with LiFi receiver and User Vehicle Equipped with LiFi transmitter.

4.2.3 Class Diagram

The given Class Diagram represents the various aspects of the system and their corresponding functions.

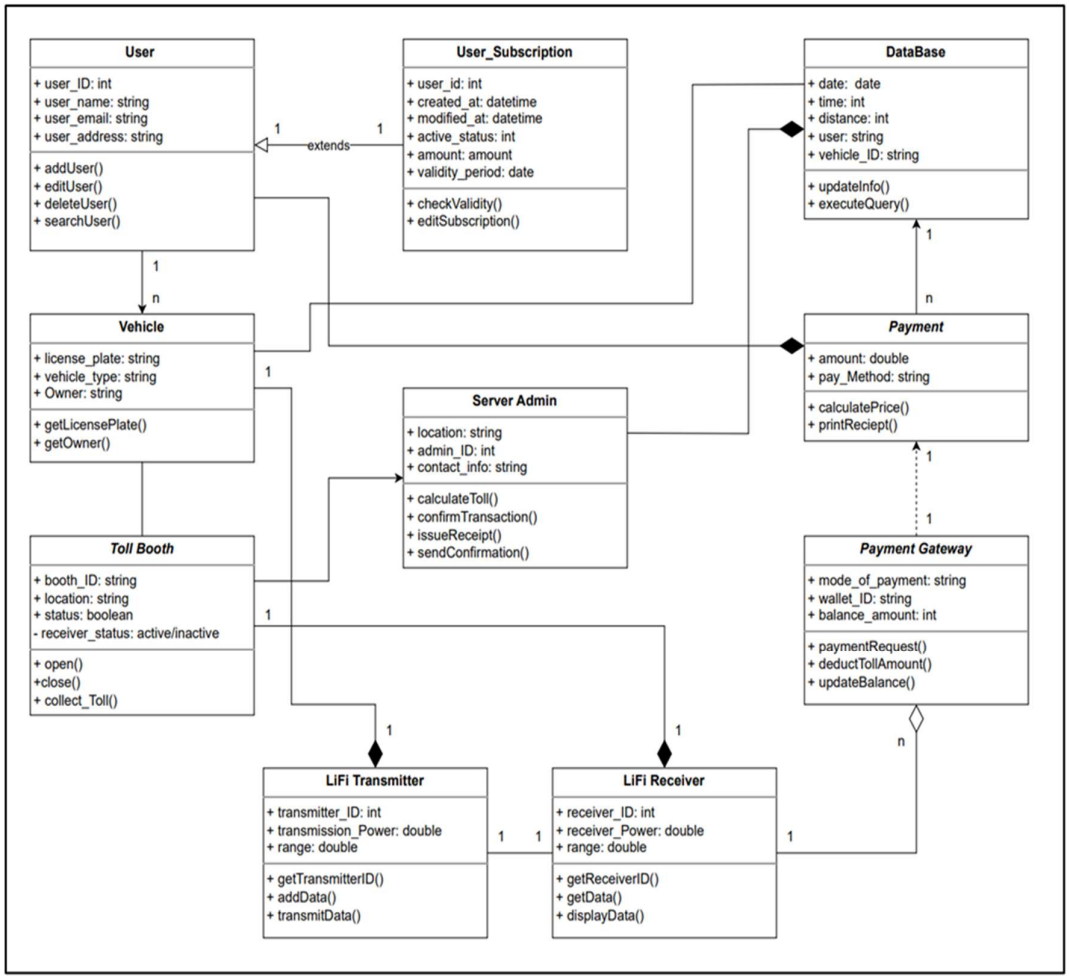

Figure 4.2.3 Class Diagram

Figure 4.2.3 refers to the Class diagram of the project. The dependencies at various levels are shown and through this visualization all the objects and classes used in the entire project are clearly depicted. Each class has some attributes and related operations and each class possesses some relationship with other classes to maintain the sync between all components. There is dependency between the LiFi Transmitter and the vehicle and one to one aggregation between toll booth and LiFi Receiver which further integrates with the Payment Gateway.

4.3 User Interface Diagrams

4.3.1 Use Case Diagram

The following use case diagram serves to illustrate the various ways in which use cases interact and engage with the system.

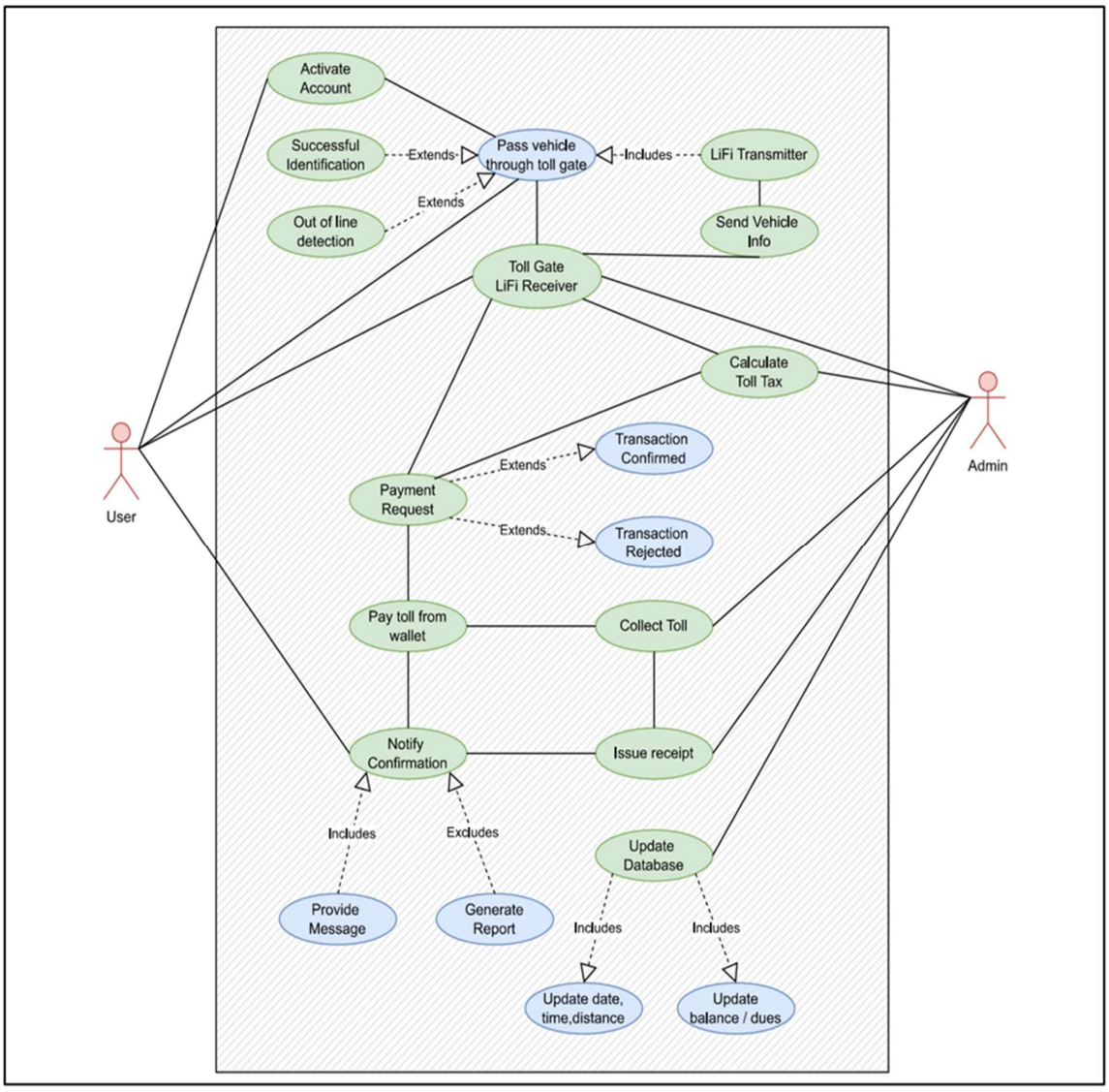

Figure 4.3.1 Use case Diagram

Figure 4.3.1 depicts the Use Case diagram for the LiFi data transmission .The actors involved are the registered user and end admin. The operations and functions involved are mentioned as the respective use cases and the unique interaction of transmission and reception as well as the function of payments are explicitly mentioned. The payment request mentions the two cases of transaction accepted or rejected. Through this system of transmitter and receiver, successful data communication leads detection of vehicle no. and deduction of payment from user account.

4.3.1.1 Use Case Template

The Use Case Templates are discussed below:

Use Case #1 (LiFi System on Vehicle and Id = 1)

Table 4.3.1.1.1: Use Case template for LiFi System on Vehicle

Use Case ID	2
Use Case Title	Automatic Payment System
Actors	User, Admin
Description	With this facility the user can carry out automatic toll payment at the toll gate.
Preconditions	The user should have an account and the LiFi system installed
Task Sequence	1. The user's vehicle has to be at the appropriate distance from toll gate 2. On successful transmission of vehicle information, the received information is sent to cloud-based database. 3. The money is deducted from the user's account using the information present in the database.

Postconditions	1. The user will have a cashless payment which will be time efficient. 2. User can keep track of the money deducted. 3. The user can view the payment history.
Alternative Flows	1. When the receiver is unable to detect the information, the user have to do manual transaction. 2. In absence of account the user will have to create an account for the same.

1. User Activation:

The user logins into the account as they approach the toll gate, initiating the transaction process.

2. Data Reception and Identification:

The toll collection gateway receives data transmitted by the vehicle's LiFi transmitter and identifies the connected account, enabling the system to recognize the user's account.

3. Transaction Confirmation:

The system displays the toll amount to the user for acknowledgment.

4. Database Update:

The system records and updates the transaction details in the database for future reference and auditing purposes.

This workflow illustrates the seamless process facilitated by LiFi technology in a smart toll collection system, ensuring efficient transactions.

IMPLEMENTATION AND EXPERIMENTAL RESULTS

5.1 Experimental Setup

- For this project we are relying on LiFi transmitter and LiFi receiver module combo for data transmission i.e. car number plate and then a website to deduct the toll tax amount.
- Hardware Specifications: Light Transmitter, Light Receiver , Buggy Motorcar, Integration Module (ESP8266-NodeMCU), Arduino Uno Microcontroller, Pair of IR Sensors, Driver Motor
- Software Specifications: PHP, SQL, HTML, CSS

5.2 Experimental Analysis

5.2.1 Data

The vehicle number is collected using the LiFi receiver at the gantry and this data is fed to the ESP8266 module, which is used to collect the toll tax corresponding the vehicle user and provide the receipt.
Database of user account and corresponding vehicle number is mapped for toll collection.

5.2.2 Performance Parameters

- **Accuracy:** Data transmission accuracy of signal bits is one of the most important performance measure of LiFi communication.
- **Range:** Data Transfer speed and detection in LiFi depends strongly on the range i.e the maximum distance at which the receiver can detect the transmitted light.
- **Payment Deduction:** Efficiency and robustness of the payment portal to successfully deduct the correct transaction and user account mapping is a performance metrics for the entire system software.

5.3 Working of the project

5.3.1 Procedural Workflow

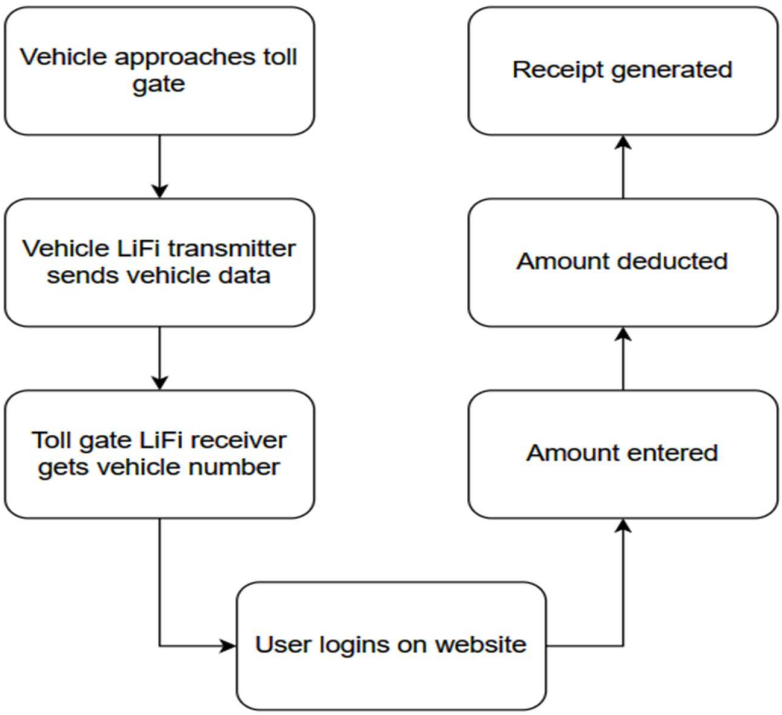

Figure 5.3.1.1 Workflow Diagram defining the entire process till toll collection.

5.3.2 Project Deployment

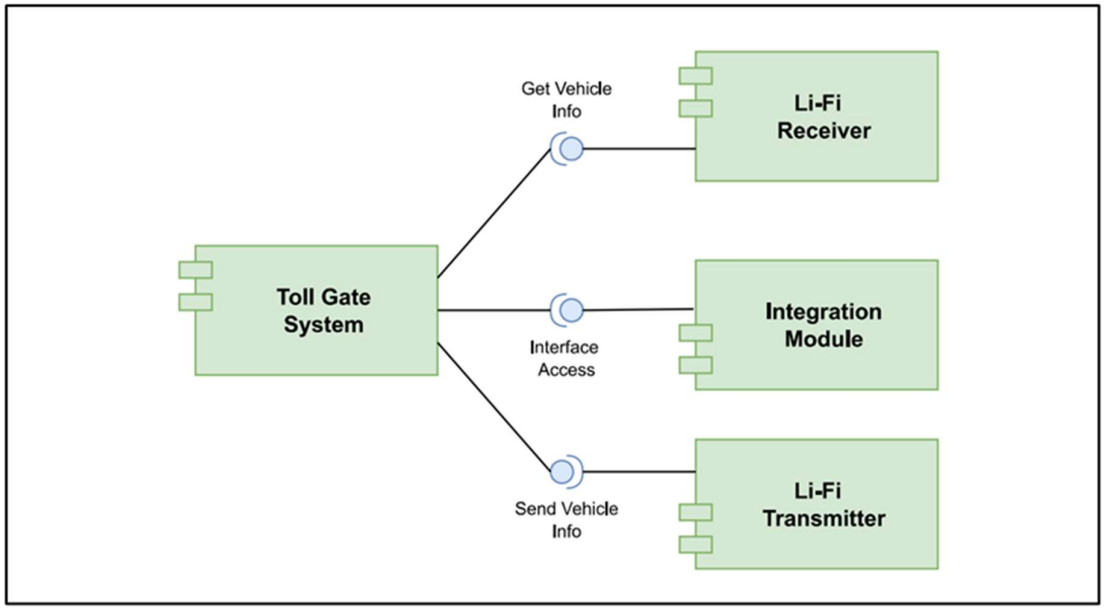

Figure 5.3.2.1 Component Diagram (Hardware)

Figure 5.3.2.1 depicts all the components used for the hardware section of the project. The payment is being initiated with the LiFi receiver capturing the vehicle number via the LiFi transmitter. The receiver receiver sends the details to the integration module (ESP8266-NodeMCU).

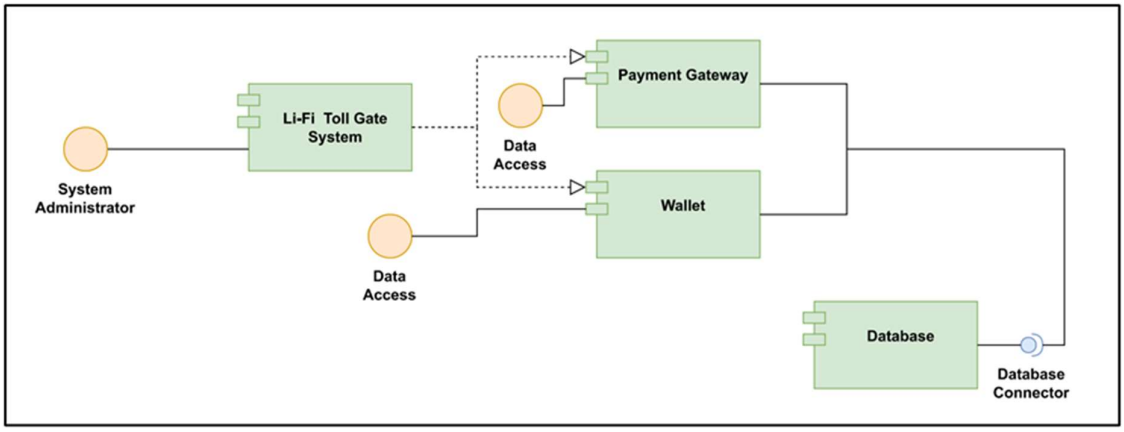

Figure 5.3.2.2 Component Diagram (Software)

Figure 5.3.2.2 depicts all the components used for the software section of the project.

The information from the integration module helps the amount to be deducted from the user's account corresponding to vehicle number. The acknowledgement is sent to the user along with the required changes being made visible in the database.

5.3.3 System Screenshots

Hardware Component:

Following screenshots show the various work progress and developments made to achieve the goal of data transmission using LiFi in the hardware component :

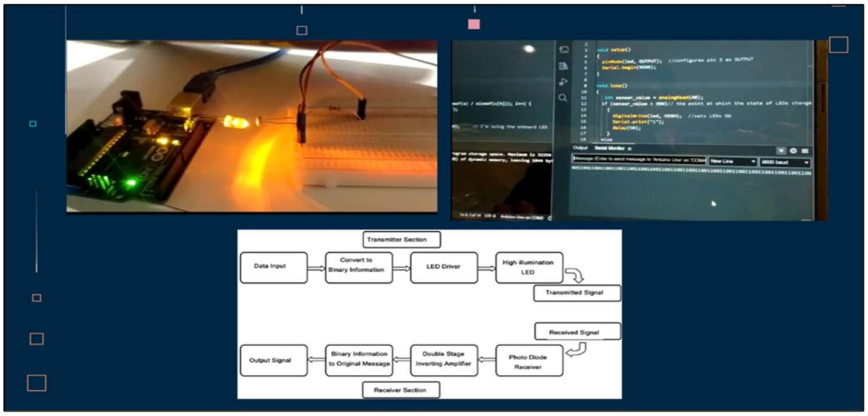

Figure 5.3.3.1 Initial working prototype using LDR showing bitwise data transfer of 0 and 1.

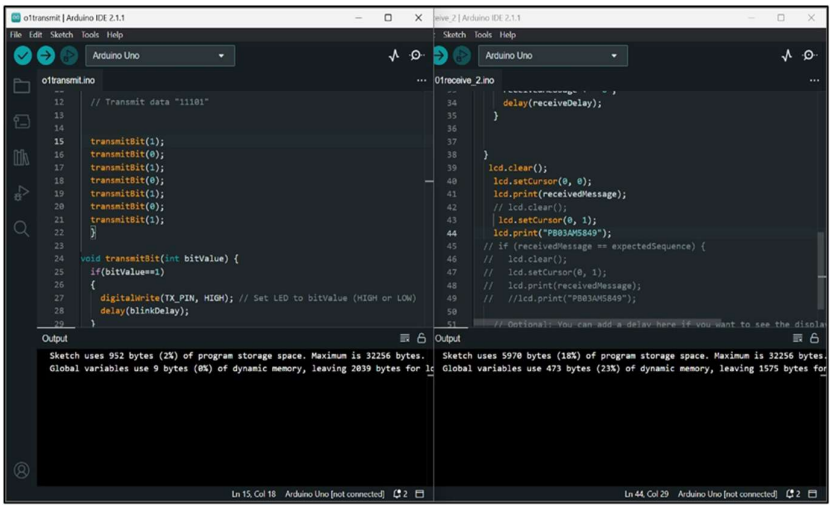

Figure 5.3.3.2 Working Code of LiFi Module (To transmit and receive a user message)

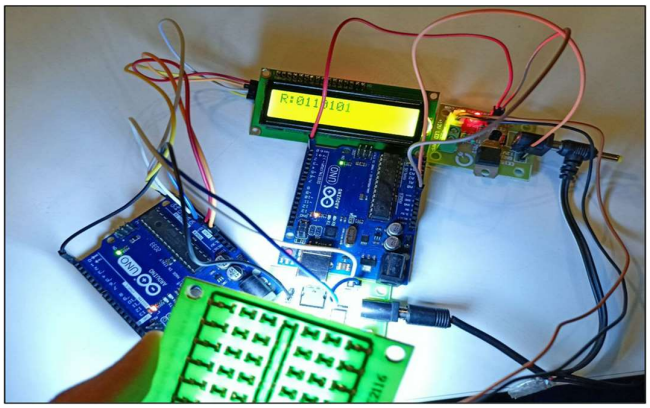

Figure 5.3.3.3 Initial 0-1 binary bits data transfer

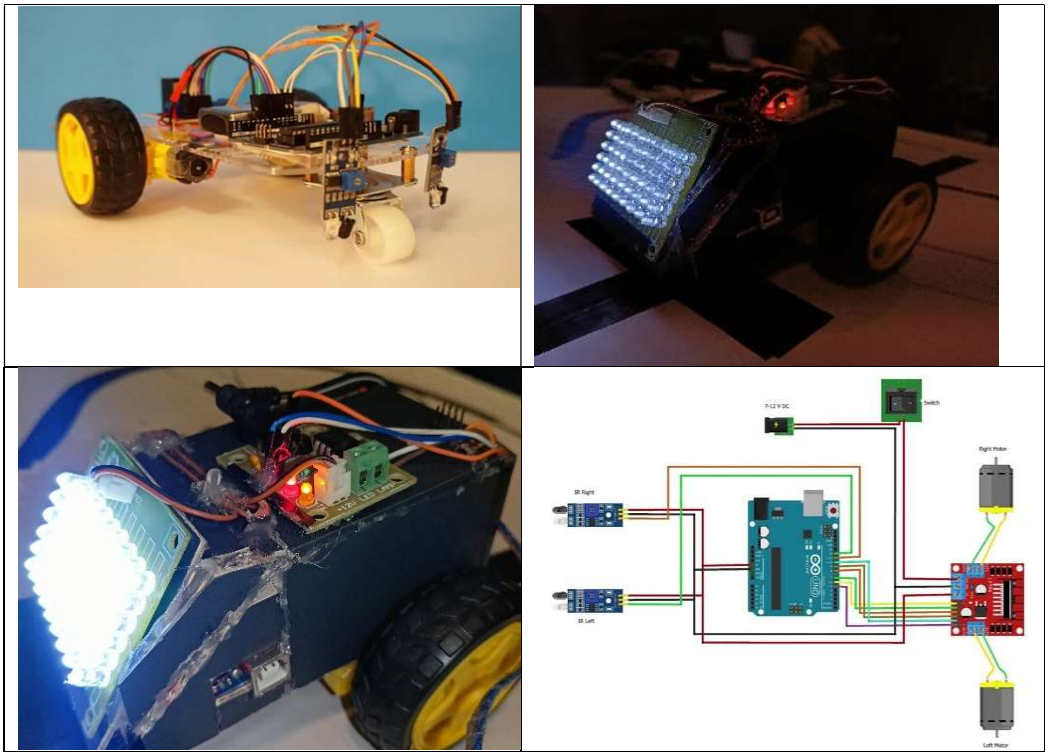

Figure 5.3.3.4 Design of Buggy Motor car installed with transmitter

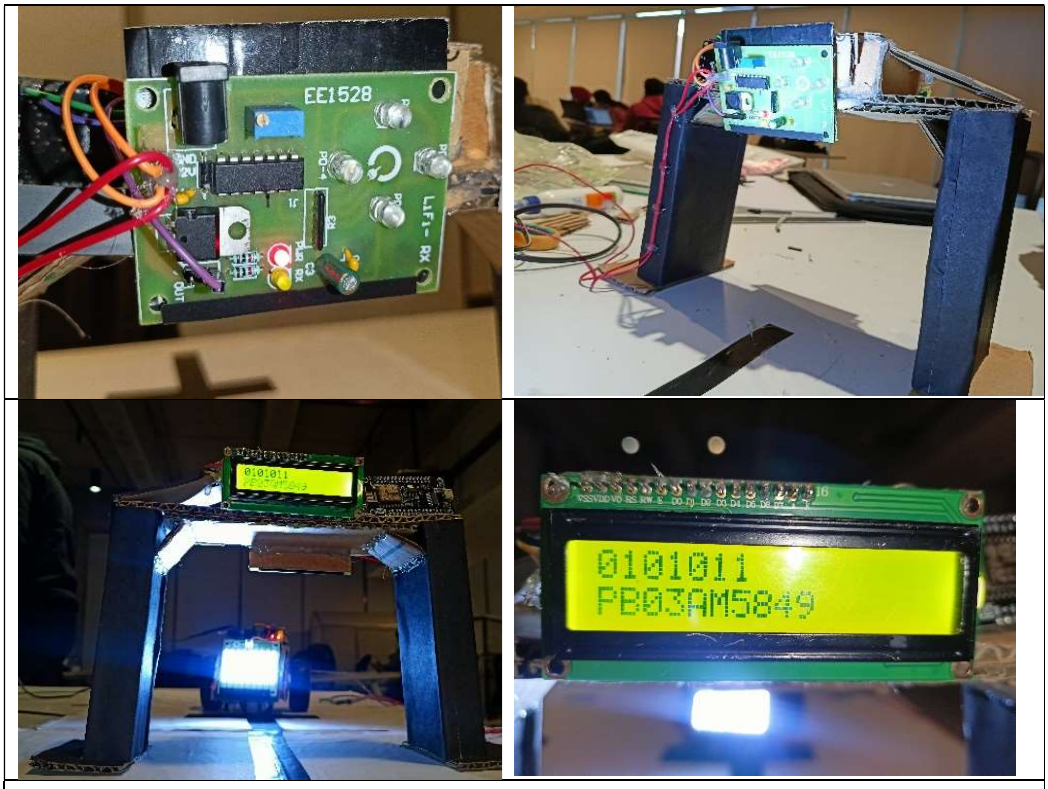

Figure 5.3.3.5 Detection of vehicle number at the receiver on the toll gate

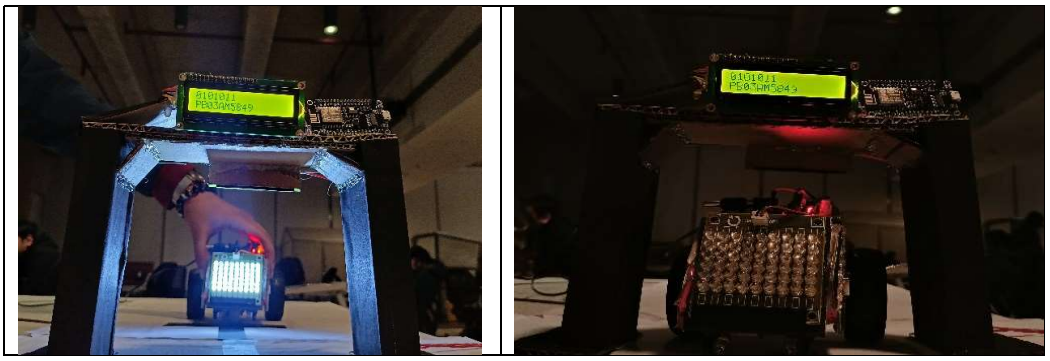

Figure 5.3.3.5 Detection of vehicle number at the receiver on the toll gate

```
const int right_motor_1 = 7;
const int right_motor_2 = 8;
const int left_motor_1 = 9;
const int left_motor_2 = 10;
int EN1 = 6;
int EN2 = 5;

#define ir_right 11
#define ir_left 12

void setup()
{

    pinMode(EN1, OUTPUT);
    pinMode(EN2, OUTPUT);
    pinMode(right_motor_1, OUTPUT);
    pinMode(right_motor_2, OUTPUT);
    pinMode(left_motor_1, OUTPUT);
    pinMode(left_motor_2, OUTPUT);
    pinMode(ir_right, INPUT);
    pinMode(ir_left, INPUT);
    Serial.begin(9600);
}
```

```
void loop()

{
    int speed = 50;
    analogWrite(EN1, speed);
    analogWrite(EN2, speed);
    digitalWrite(right_motor_1, HIGH);
    digitalWrite(right_motor_2, LOW);
    digitalWrite(left_motor_1, HIGH);
    digitalWrite(left_motor_2, LOW);

    int rightIRSensorValue = digitalRead(ir_right);
    int leftIRSensorValue = digitalRead(ir_left);


    if (rightIRSensorValue == LOW && leftIRSensorValue == LOW)
    {
        digitalWrite(right_motor_1, HIGH);
        digitalWrite(right_motor_2, LOW);
        digitalWrite(left_motor_1, HIGH);
        digitalWrite(left_motor_2, LOW);
    }

```

```
    else if (rightIRSensorValue == HIGH && leftIRSensorValue == LOW)
    {
        digitalWrite(right_motor_1, LOW);
        digitalWrite(right_motor_2, HIGH);
        digitalWrite(left_motor_1, HIGH);
        digitalWrite(left_motor_2, LOW);
    }

    else if (rightIRSensorValue == LOW && leftIRSensorValue == HIGH)
    {
        digitalWrite(right_motor_1, HIGH);
        digitalWrite(right_motor_2, LOW);
        digitalWrite(left_motor_1, LOW);
        digitalWrite(left_motor_2, HIGH);
    }

    else
    {
        digitalWrite(right_motor_1, LOW);
        digitalWrite(right_motor_2, HIGH);
        digitalWrite(left_motor_1, LOW);
        digitalWrite(left_motor_2, HIGH);
    }
}

```

Figure 5.3.3.6 Working code of line follower buggy

Software Component:

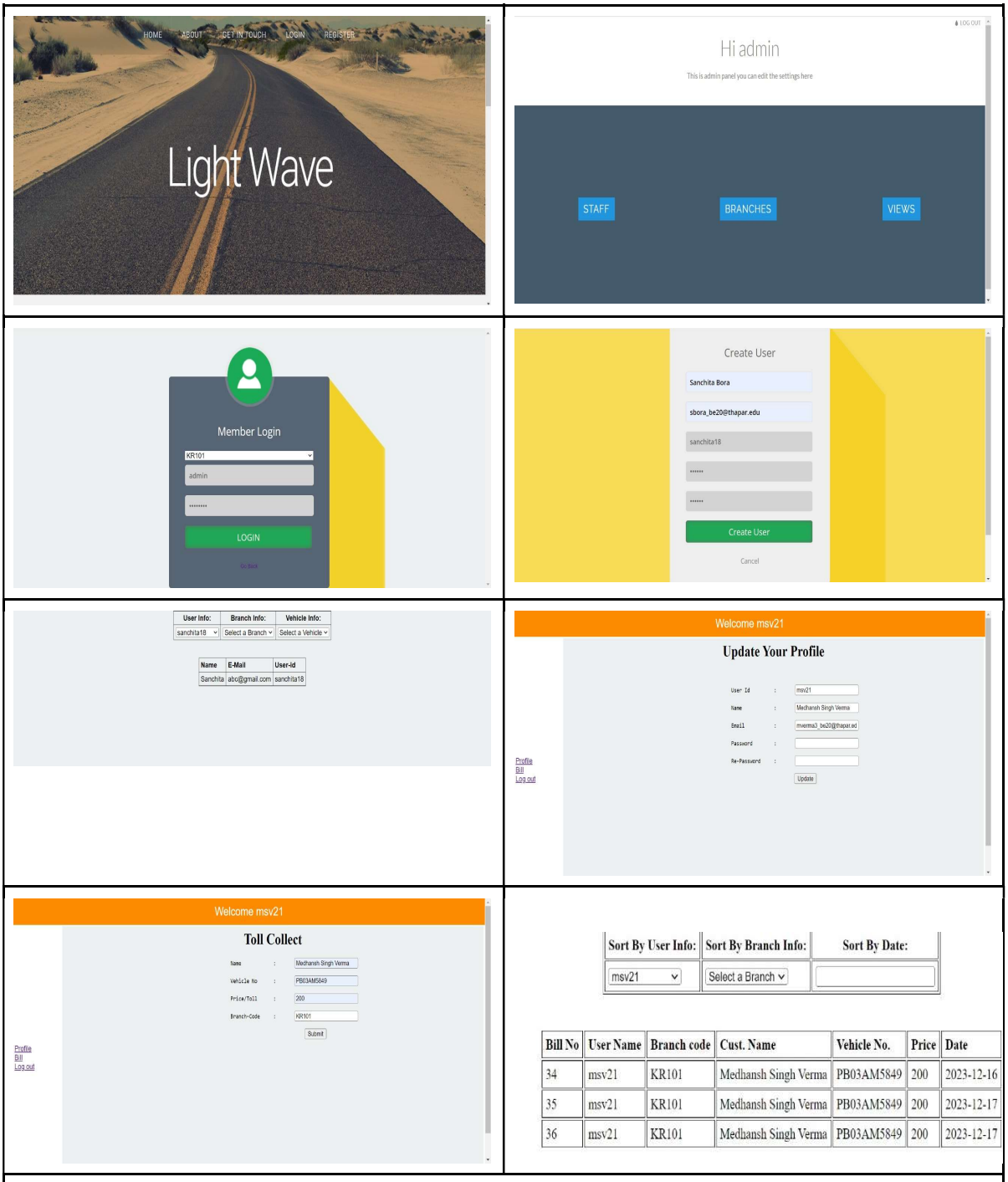

Figure 5.3.3.7 Implementation of system side software for toll payment

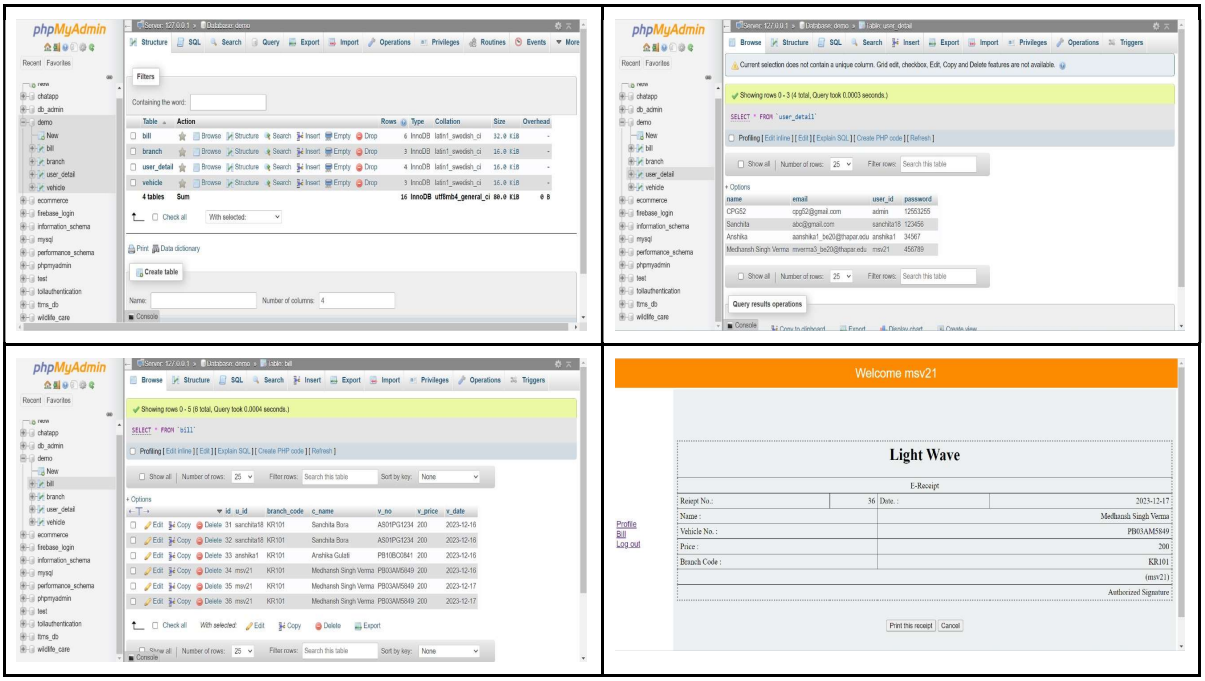

Figure 5.3.3.7 Implementation of system side software for toll payment

5.4 Testing Process

5.4.1 Test Plan

1. **Real Time Transmission**: Test the system for seamless data transmission and reception.
2. **Payment Transaction Mechanism**: Verify the flow of the payment transaction mechanism.
3. **User-Friendly Online Portal:** Evaluate the usability of the online portal for secure payment processing.
4. **System Integration Testing:** Verify the integration of LiFi technology with the toll collection system.
5. **Performance and Reliability**: Conduct stress testing to evaluate system performance under high loads.
6. **Resource Utilization:** Evaluate the efficient use of resources throughout the project.

5.4.2 Features to be Tested

Test 1: Real Time Transmission:

- Implementation of data transmission in real-time scenarios.
- Compare the results with expected values and industry standards.

Test 2: Payment Transaction Mechanism

- Test the system for seamless payment transaction.
- Identify and resolve any issues related to interruptions or delays.

Test 3: User-Friendly Online Portal

- Evaluate the usability of the online portal for secure payment processing.

Test 4: System Integration Testing

- Verify the integration of LiFi technology with the toll collection system.
- Ensure compatibility and functionality across all components.

Test 5: Performance and Reliability

- Conduct stress testing to evaluate system performance under high loads.
- Validate the reliability of the system through extended testing periods.

Test 6: Resource Utilization

- Evaluate the efficient use of resources (human, financial, and technological) throughout the project.

5.4.3 Test Strategy

1. Real Time Transmission

- Performance Test: Evaluates baseline data transmission speed under normal conditions.
- Stress and Volume Test: Assesses data transmission speed under high loads to ensure sustained performance.

2. Payment Transaction Mechanism

- Recovery Test: Verifies the system's ability to recover from interruptions, ensuring seamless data transmission.
- System Test: Ensures overall functionality, essential for uninterrupted data flow.

3. User-Friendly Online Portal

- User Acceptance Test: Validates portal usability from a user's perspective.
- System Test (Functionality): Verifies technical functionality to ensure a user-friendly payment process.

4. System Integration Testing

- System Test: Confirms the integrated functioning of LiFi with the toll collection system.

5. Performance and Reliability

- Performance Test: Assesses system performance metrics under standard conditions.
- Stress and Volume Test: Evaluates system reliability and performance under high loads.

6. Resource Utilization

- Documentation Test: Reviews resource allocation plans for effective utilization.
- System Test: Assesses specific functionalities related to resource management within the system.

5.4.4 Test Techniques

1. Performance Testing Techniques:

- Load Testing: Simulates normal and peak load conditions to assess system behavior. This would test how the system handles regular and high traffic,

ensuring consistent data transmission speeds.

- Stress Testing: Evaluates system performance under extreme conditions beyond regular capacity. Stress testing would assess how well the system copes with sudden surges in traffic or data transmission demands.

Comparison: These techniques help assess the system's data transmission speed and efficiency under various load conditions, crucial for LiFi-based toll gate systems to ensure uninterrupted data transfer during peak hours.

2. Recovery Testing Techniques:

- Interrupt Testing: Simulates unexpected interruptions (such as power loss) to evaluate how the system recovers. In LiFi toll gates, this tests the system's ability to resume data transmission after a disruption.
- Failure Testing: Intentionally induces failures to examine the system's response. For LiFi systems, this ensures the system quickly recovers from signal disruptions or node failures.

Comparison: Recovery testing ensures seamless data transmission post-disruption, vital for LiFi toll gates to swiftly recover from signal interruptions or technical issues.

3. Security Testing Techniques:

- Penetration Testing: Simulates attacks to identify vulnerabilities. For LiFi toll gates, this would verify the system's resistance to unauthorized access or data interception.
- Vulnerability Scanning: Automated testing to discover potential weaknesses in the system. In LiFi toll gates, this would identify points susceptible to security breaches.

Comparison: Security testing ensures the payment system's protection against data breaches or unauthorized access in LiFi toll gates, crucial for secure transactions.

4. User Acceptance Testing Techniques:

- Usability Testing: Evaluates the portal's ease of use. For LiFi toll gates, this ensures users can navigate and complete payments easily using the online

portal.

- User Feedback Surveys: Gathers opinions to improve user experience. In LiFi toll gates, this collects feedback on the payment process and portal interface.

Comparison: User acceptance testing focuses on ensuring a friendly and intuitive payment experience for users of LiFi toll gates, crucial for widespread adoption and ease of use.

5. Integration Testing Techniques:

- Interface Testing:

  Validates interactions between integrated components. For LiFi toll gates, this checks the seamless integration between the LiFi technology and the toll collection system.
- End-to-End Testing:

  Tests the entire system's functionality from start to finish. In LiFi toll gates, this ensures every aspect, from data transmission to payment processing, works cohesively.

Comparison:

Integration testing ensures that LiFi technology integrates flawlessly with the toll gate system, guaranteeing uninterrupted data transmission and payment processing.

6. Documentation Testing Techniques:

- Review of Resource Allocation Plans:

  Ensures efficient resource utilization i.e for LiFi toll gates, this evaluates the planned allocation of human and financial resources for optimal system performance.
- Cost-Benefit Analysis:

  Assesses the efficiency of resource usage against benefits gained. In LiFi toll gates, this evaluates the effectiveness of the resources employed in relation to the system's performance and revenue generation.

Comparison: Documentation testing ensures that resources in LiFi toll gate systems are utilized optimally, ensuring cost-effectiveness and efficient operation.

Each testing technique plays a crucial role in assessing specific aspects of the LiFi-based toll gate system, ensuring its performance, security, usability, integration, and resource utilization are optimal for smooth and secure operation.

5.4.5 Test Cases

Test Case: 1.0 **System:** LiFi-based Toll Collection System **Desgined By:** CPG 52 **Executed By:** CPG 52 **Short Description:** Receiver is able to capture transmitted signal.			**Test Name:** Receiver Signal Capture **Subsystem:** Receiver Signal Capture **Design Date:** 10-11-2023 **Execution Date:**10-11-2023	
Pre-Condition: Line of sight transmission between Receiver and Transmitter				
Steps	**Action**	**Expected Response**	**Pass/Fail**	**Comment**
1	Transmitter sending signal	Receiver is capturing the signal	Pass	
2	Vehicle number detection	Correct vehicle number detected	Pass	
3	Check post-condition		Pass	
Post-Condition: User balance details corresponding to the vehicle ID is visible in the database and wallet.				

Test Case: 1.1 **System:** LiFi-based Toll Collection System **Desgined By:** CPG 52 **Executed By:** CPG 52 **Short Description:** User and admin is able to sign in and log in through same portal			**Test Name:** User and Admin Portal Access **Subsystem:** User and Admin Portal Access **Design Date:** 12-11-2023 **Execution Date:** 12-11-2023	
Pre-Condition: User with some email ID x and password y				
Steps	**Action**	**Expected Response**	**Pass/Fail**	**Comment**
1	Login	System gives a form to input details and login	Pass	
2	Enter the details	Take input	Pass	
3	Click on "Login"	The corresponding account is made available without any conflict.	Pass	
4	Check post-condition		Pass	
Post-Condition: Show updated and correct details to the user or admin				

Test Case: 1.2 **System:** LiFi-based Toll Collection System **Desgined By:** CPG 52 **Executed By:** CPG 52 **Short Description:** User signing up with email that does not exist			**Test Name:** Invalid Email **Subsystem:** Invalid Email **Design Date:** 14-11-2023 **Execution Date:** 14-11-2023	
Pre-Condition: User with some email ID x				
Steps	**Action**	**Expected Response**	**Pass/Fail**	**Comment**
1	Sign Up	System gives a form to input details and login	Pass	
2	Enter the details	Take input	Pass	
3	Click on "Continue to Login"	System displays error that email-id does not exist and is not valid	Fail	
4	Check post-condition		Fail	
Post-Condition: No changes should be reflected in the database				

Test Case: 1.3 **System:** LiFi-based Toll Collection System **Desgined By:** CPG 52 **Executed By:** CPG 52 **Short Description:** Bill is generated against the vehicle number			**Test Name:** Bill Generation **Subsystem:** Bill Generation **Design Date:** 16-11-2023 **Execution Date:** 16-11-2023	
Pre-Condition: Vehicle details exist in the database				
Steps	**Action**	**Expected Response**	**Pass/Fail**	**Comment**
1	Details	The user details are being filled	Pass	
2	Toll Amount	Toll amount is being specified	Pass	
3	Click on "Submit"	The receipt for the toll amount is being created	Pass	
4	Check post-condition		Pass	
Post-Condition: The changes are being saved in the database				

5.4.6 Test Results

After running test cases, the system performed according to the implemented functionality and depending upon the correctness of vehicle number detected the corresponding toll is being deducted.

5.5 Results and Discussions

This project consists of data transmission using LiFi technology. We have used this technology in toll gate system to detect the vehicle number plate. Then the user creates an account on a website to input their details including the vehicle details. When the vehicle arrives at a toll gate, the LiFi transmitter placed on the vehicle, transmits data consisting of the vehicle number to the LiFi receiver placed on the toll booth. Then the user logs on to a website to complete the toll tax transaction and passes through the gate after a successful transaction.4

We faced some major challenges throughout the duration of this project. One of the challenges were the data transmission in our LiFi setup. It was a big challenge to fine tune this transmission in the presence of factors affecting the LiFi data transmission. Another major challenge in our project was integrating the hardware and software, getting the data on our database to be accessed by our website was a huge challenge and we could not successfully do it. Although in our website we were able to allow user to create accounts, login, do transactions and view their transactions.

5.6 Inferences Drawn

The work that has already been done in this idea and technology is pretty less and focussed in little areas. As this technology is in its early experimental phases but can be fine tuned to work with our particular application with time. Primarily, we faced two major challenges in this project which are data transmission using LiFi and the integration of hardware and software.

To successfully execute data transmission using LiFi, we need ideal conditions like power receiver and transmitter combo, zero or no extra light interference other than the transmitter lights, in between the transmitter and receiver. Also there should be no fog or any other kinds of obstruction between the receiver and transmitter combo.

In case of the integration part, the libraries supporting our particular application were very difficult to obtain or in some cases did not exist altogether. The WiFi module we have can be used to transmit sensor data but was not able to work in our application. At the software side it was very difficult to work with a dynamic database primarily because the libraries required were not available for LiFi receiver and transmitter combo.

5.7 Validation of Objectives

S. No.	Objectives	Status
1.	Detailed Literature Survey and Research	Successful
2.	Fast Efficient Data Communication and Data transfer	Successful
3.	Implementation of Efficient Payment Transaction	Successful

CONCLUSIONS AND FUTURE SCOPE

6.1 Work Accomplished

The approved objective is to successfully implement the automatic system of Smart Toll Collection using LiFi technology.

Hardware Implementation:

- In view of this, the work accomplished is the successful detection of light using a system of LiFi Transmitter and Receiver.
- Successful implementation of in-line data communication and data transfer.
- Logic and programming for encoding and decoding of light to transmit and receive data has been implemented.
- Calculations related to distance, range and intensity of light have been undertaken to achieve maximum accuracy.
- Interference of outside light has been measured to ensure optimal solutions.
- Successful installation of transmitter module on line follower buggy and installation of receiver on gantry for working prototype have been achieved.
- Receiver detection of signal and display of unique vehicle information for toll collection has been accomplished.
- Integration setup for deduction of toll from the signal of corresponding vehicle number has been set up with WiFi Module.

Software Implementation:

- The payments portal required for the transactions has been designed.
- The admin can manage user accounts as well staff information.
- The admin can manage branches associated with the system.
- The interface for login and database structure for user and payments window have been structurally designed.
- User can update the password and access their information.

- The user account where the payment will be generated and carried out has been developed and the required software needs have been met.
- The corresponding bill is generated after toll payment is carried out and the receipt is being made available which can be printed for future reference.
- The transaction details of a particular user can be seen in the database and admin account also gets synchronously updated.

6.2 Conclusions

The Report highlights the progress and significant developments of the project aimed to implement the smart toll collection system using LiFi technology. It also gives a detailed description of the tools and technologies used in the project and an overview of all the functionalities achieved.

With the analysis of product perspective, existing literature and functional and nonfunctional requirements, we have successfully identified the product scope , its purpose and features to fulfill the needs of the targeted audience and leverage an innovative solution to the masses.

The implementation of the LiFi smart toll collection system showcased the feasibility and effectiveness of using LiFi for data transmission in real-world applications. The technology exhibites remarkable advantages such as high data transfer rates, minimal electromagnetic interference, and enhanced security due to the confined nature of light signals. The successful integration of the payments portal with the vehicle detection mechanism streamlines the toll collection process, reducing traffic congestion and manual intervention.

The project not only addresses current challenges but also paves the way for innovative solutions with far-reaching benefits. Through continuous research, development, and collaboration, the potential of this technology can be fully harnessed to create smarter, more connected, and efficient transportation systems.

Proceeding ahead, we aim to give more enhancements and improvements in our existing work to provide better user experience with more accuracy and efficiency of

the proposed product.

With the progress of this project, we aim to fulfill all the objectives and wish to deliver the best product design and prototype which achieves the above goal. With this opportunity, we learn to overcome all the challenges that come forward and with relentless teamwork and collaborative efforts, we wish to make this a great learning experience for all of us.

6.3 Environmental(Economic/Social) Benefits

Economic Benefits

- **High Data Transfer Rates:** LiFi can provide significantly faster data transfer rates compared to traditional communication technologies like WiFi. This results in quicker transaction processing at toll booths, reducing wait times for drivers.
- **Reduced Infrastructure Costs:** LiFi can be integrated into existing LED lighting infrastructure, eliminating the need for separate communication infrastructure. This can lead to cost savings in terms of deployment and maintenance.
- **Improved Efficiency:** The high-speed data transfer capabilities of LiFi contribute to the overall efficiency of toll collection systems. Faster transactions mean increased throughput, reducing congestion and improving traffic flow.
- **Energy Efficiency:** LiFi operates using LED lights, which are generally more energy-efficient than traditional light sources. This can result in lower operational costs over time.

Social Benefits

- **Reduced Traffic Congestion:** Faster toll transactions lead to reduced wait times at toll booths, contributing to a smoother traffic flow and reducing overall congestion on roads.
- **Enhanced Safety:** Reduced congestion and smoother traffic flow can contribute

to improved road safety. The faster toll collection process minimizes the chances of traffic bottlenecks and accidents at toll plazas.

- **Convenience for Drivers:** Quick and hassle-free toll transactions provide convenience for drivers, enhancing their overall travel experience. This can be particularly beneficial for frequent travelers.
- **Integration with Smart Cities:** LiFi enabled toll collection can be part of a broader smart city initiative. It aligns with the goal of using technology to enhance various aspects of urban living, including transportation.
- **Digital Inclusion:** Implementing LiFi technology in toll collection can contribute to the digitization of infrastructure, promoting digital inclusion and aligning with the broader trend of incorporating advanced technologies into public services.

It's important to note that while LiFi offers several advantages, successful implementation would require addressing potential challenges, such as the need for line-of-sight communication and potential interference from ambient light. Additionally, the economic and social benefits may vary depending on the specific implementation and the broader context of the transportation infrastructure.

6.4 Future Work Plan

1. **Efficient Data Transmission:**
   - Develop advanced modulation techniques to maximize the data transfer rate of the LiFi system.
   - Investigate adaptive coding and modulation schemes to optimize data transmission based on channel conditions.
   - Explore methods to reduce latency and enhance the overall efficiency of data transfer.
2. **Optimization of Hardware Components:**

- Investigate measures to minimize hardware setup and space utilization.
- Explore miniaturization of components for seamless integration into various environments

3. **Robust Software:**

- Develop advanced error correction algorithms to mitigate data loss and ensure reliable communication.
- Implement adaptive link management strategies to maintain stable connections in dynamic environments.
- Explore software solutions for seamless handover between different LiFi access points.

4. **Fast and Secure Systems:**

- Implement low-latency protocols for real-time communication.
- Develop secure and efficient authentication mechanisms to prevent unauthorized access.
- Investigate Quality of Service(QoS) mechanisms to prioritize critical data traffic and ensure timely delivery.

5. **Security Enhancements:**

- Explore methods to detect and mitigate signal jamming and interference.
- To ensure no data loss and implement end-to end encryption to ensure confidentiality of transmitted data.

6. **Better User Experience and Diversification of Utility:**

- Diversifying the utility of this LiFi system to other domains like emergency response systems, industrial automation etc.
- By fostering collaboration and innovation to enhance user experience, the pursuit of continuous improvement and optimize intuitive design principles.

7.1 Challenges Faced

Hardware Segment Challenges

1. Range of Light Detection: Maintaining a stable and reliable communication link between the transmitter and receiver, and to configure a decent range of light was a task to be achieved.
2. Receiver Setup: Selection of a suitable receiving device which is economically compatible and the strategic designing of its installation on the gantry.
3. Connection Challenges for buggy: Buggy design and consecutive testing for the prototype was a challenge to ensure a scalable and compact system of communication.

Software Segment Challenges

1. Real Time Communication: Implementing real-time communication between the LiFi system and the toll collection backend is essential for seamless and quick toll deduction.
2. Database Updation: For every new user and new toll payment successful database update and connection had to be setup.
3. Fault Tolerance and Error handling: A major challenge faced was to handle errors such as data transmission failures, error bits received or the misreads. Building a Webapp to securely connect to user account for payment deduction was a critical step.

7.2 Relevant Subjects

The following course subjects are used for the successful execution of the project:

● **Electronics Engineering:**

The concepts of electronics engineering and IoT are used for designing the circuits and other hardware related components.

● **Computer Science:**

The team has developed a software that keeps a track of the financial transactions.

● **Optical Communication:**

The properties of light, including its spectrum, intensity, range of transmitter light as well as knowledge of optics and photonics were used for the development of the project.

● **Business and Database Management:**

- Financial management to manage the project and develop a business plan for the LiFi-based toll gate system.
- Applying project management principles to plan, execute, and monitor the progress of the project and ensuring effective collaboration among team members with different expertise.
- Designing databases for storing and managing user accounts, transaction history, and other relevant data. Ensuring data integrity and security in the storage and retrieval process.

● **Software Engineering:**

Software engineering concepts and the phases required for developing any system and its associated principles are used to build the entire prototype and for documentation.

7.3 Interdisciplinary Knowledge Sharing

The aim of this project is to provide our users with a toll management system that will enable them to carry out:

- Fast and efficient data transfer

- Efficient payment transaction

Our project embarked on a multifaceted journey aiming to revolutionize toll collection systems by harnessing the potential of LiFi technology. Our objectives were meticulously structured to unravel the complexities and potentials of LiFi technology while addressing the challenges in real-time toll collection.

The foundation was laid with an exhaustive exploration of existing literature and research on LiFi technology and toll collection systems. This detailed literature survey was instrumental in gaining profound insights into the technological advancements, challenges, and prospective applications of LiFi in the realm of real-time toll collection.

Implementing real-time data transmission using LiFi became the cornerstone of our project. By leveraging LiFi's capabilities, we sought to enhance the efficiency and accuracy of data transfer significantly. Our endeavor was to ensure seamless transmission and reception of data, harnessing the prowess of high-speed communication that LiFi offers.

Furthermore, our focus extended beyond data transfer, encompassing the integration of a robust and secure payment transaction mechanism within the LiFi system. The development of a user-friendly online portal for secure payment processing was integral to optimizing system performance. Rigorous testing and validation protocols were meticulously executed to ensure flawless operation, prioritizing user satisfaction at its core.

The hardware setup included a specialized buggy equipped with essential components:
1. Microcontroller Unit
2. LiFi Transmitter
3. LiFi Receiver
4. Integration Unit

In tandem, our software architecture relied on a blend of versatile programming languages and technologies:
HTML, CSS, JavaScript, and PHP formed the backbone of our software implementation. By applying the System Development Life Cycle (SDLC), we devised a sophisticated software solution complemented by hardware components. This interdisciplinary approach brought together hardware and software engineering, challenging us to synthesize knowledge from diverse engineering disciplines, particularly electronics and computer science. Our project not only sought technical excellence but also honed our professional skills, fostering teamwork, refining presentation techniques, and emphasizing meticulous documentation.

The amalgamation of our efforts culminated in a comprehensive solution poised to transform toll collection systems by harnessing the capabilities of LiFi technology, ensuring secure, efficient, and seamless operations in the realm of transportation infrastructure.

7.4 Peer Assessment Matrix

		Evaluation of				
		Anshika	Arpit Sagar	Manpreet Singh	Medhansh Singh Verma	Sanchita Bora
Evaluation By	Anshika	5	5	5	5	5
	Arpit Sagar	5	5	5	5	5
	Manpreet Singh	5	5	5	5	5
	Medhansh Singh Verma	5	5	5	5	5
	Sanchita Bora	5	5	5	5	5

7.5 Role Playing and Work Schedule

Task	Contributors
Hardware Implementation	Arpit Sagar, Manpreet Singh
Module Designing and Optimization	Arpit Sagar, Manpreet Singh
IoT Integration	Arpit Sagar, Manpreet Singh
UI Design	Sanchita Bora, Anshika, Medhansh Singh Verma
Backend and DBMS	Sanchita Bora, Anshika, Medhansh Singh Verma
Software Testing	Sanchita Bora, Anshika, Medhansh Singh Verma
Literature Review	Arpit Sagar, Manpreet Singh, Sanchita Bora, Anshika, Medhansh Singh Verma
Documentation	Arpit Sagar, Manpreet Singh, Sanchita Bora, Anshika, Medhansh Singh Verma

7.6 Student Outcomes Description and Performance Indicators (A-K Mapping)

SO	SO Description	Outcome
1.1	Ability to identify and formulate problems related to computational domain	Used Programming concepts and encoding algorithms to analyze communication.
1.2	Apply engineering, science, and mathematics body of knowledge to obtain analytical, numerical, and statistical solutions to solve engineering problems.	Applied existing knowledge of electronics and computer science to solve toll collection scenario application.
2.1	Design computing system(s) to address needs in different problem domains and build prototypes, simulations, proof of concepts, wherever necessary, that meet design and implementation specifications.	Successfully formulated constraints and assumptions for the prototype development.
2.2	Ability to analyze the economic trade-offs in computing systems.	Analyzed the economic constraints for the implementation.
3.1	Prepare and present variety of documents such as project or laboratory reports according to computing standards and protocols.	This project shows the complete documentation for LiFi and its research analysis.
3.3	Able to communicate effectively with peers in well organized and logical manner using adequate technical knowledge to solve computational domain problems and issues.	Collaborative approach with the peers for continuous advancement of the project and learning exposure.
4.1	Aware of ethical and professional responsibilities while designing and implementing computing solutions and innovations.	Responsible and careful assessments were conducted to compute solutions.
4.3	Evaluate computational engineering solutions considering environmental, societal, and economic contexts.	Strategic evaluations and considerations regarding social and economic benefits of LiFi were made.
5.1	Participate in the development and selection of ideas to meet established objective and goals.	Goals and objectives clearly identified and targeted aim achieved.
5.2	Able to plan, share and execute task responsibilities to function effectively by creating collaborative and inclusive environment in a team.	Effective execution and collaboration to include all plan outcomes.

6.1	Ability to perform experimentations and further analyze the obtained results.	Calculative experimentations and calculations regarding range and intensity of data were made.
6.2	Ability to analyze and interpret data, make necessary judgement(s) and draw conclusion(s).	Interpretations of data and conclusions were made.
7.1	Able to explore and utilize resources to enhance self-learning.	All resources were observed and carefully utilized.

7.7 Brief Analytical Assessment

Q1. What sources of information did your team explore to arrive at the list of possible project problems?
Ans: We brainstormed on the possible project problem in detail. We also discussed the problems with our mentor. We took the help of various research papers and journals to explore the problem. Internet also played a huge role as there were many articles and videos available.

Q2. What analytical,computational and/or experimental methods did your project team use to obtain solutions to the problems in the project?
Ans: Testing and calibrations on different conditions and edge cases, while various hit-and trial methods were also used to obtain solutions to the problems faced.Starting with the basic technology components and then further extending the scope of the project to get the best deliverable outcome.

Q3. How did your team share responsibility and communicate the information of schedule with others in team to coordinate design and manufacturing dependencies?
Ans: We had team meetings with our project members every alternate week to discuss about the project progress. All doubts and confusion were resolved. We had also clearly divided work equally among us. All team members knew their responsibility and worked together to achieve the given target.

Q4. Does the project make you appreciate the need to solve problems in real life using engineering and could the project development make you proficient with software development?
Ans: With the help of this project, we were able to solve the problem of congestion on roads and we were able to achieve fast and efficient data communication and transfer for the real life scenario of toll collection.

REFERENCES

[1] A. Ambika, M. Aswinkumar, M. Kamalesh and K. Naveen, "Smart Toll Collection Using Li-Fi Technology," 2019 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC), Melmaruvathur, India, 2019, pp. 236-239, DOI: 10.1109/ICCPEIC45300.2019.9082373.

[2] A. Asadzadeh, A. Rajabi, and M. A. Zamani, "Vehicle-to-vehicle communication using Li-Fi technology for intelligent transportation systems," in Proc. IEEE International Conference on Advanced Information Networking and Applications (AINA), 2019, pp. 617-623. DOI: 10.1109/AINA.2019.00109.

[3] H. Haas "Wireless Data From Every Light Bulb." TED. Internet: www.ted.com/talks/harald_haas_wireless_data_from_every_light_bulb/transcript, July, 2011 [Sep. 25, 2023]

[4] H. Haas, L. Yin, Y. Wang, C. Chen, and J. Wang, "Li-Fi for wireless communication in a car park management system," in Proc. IEEE Vehicular Technology Conference (VTC Fall), 2013, pp. 1-5. DOI: 10.1109/VTCFall.2013.6692266.

[5] H. Le, N. Le, and T. Hoang, "Li-Fi based vehicle detection system for toll gates," in Proc. International Conference on Green and Human Information Technology (ICGHIT), 2017, pp. 48-53. DOI: 10.1109/ICGHIT.2017.7915820.

[6] H. Xu, Y. Ma, W. Zhang, X. Cai, and S. Guo, "Automatic toll collection system based on Li-Fi and deep learning," in Proc. IEEE International Conference on Industrial Internet (ICII), 2020, pp. 407-411. DOI: 10.1109/ICII50041.2020.9306919.

[7] H. Zhang, D. Liu, and Y. Liu, "Intelligent toll collection system based on Li-Fi technology," in Proc. IEEE International Conference on Industrial Internet (ICII), 2021, pp. 267-272. DOI: 10.1109/ICII50948.2021.9506969.

[8] J. Kim, J. Ryu, D. Kim, J. Yoo, and J. Park, "Vehicle recognition using a Li-Fi sensor for toll systems," in Proc. International Conference on Ubiquitous Information Management and Communication (IMCOM), 2021, pp. 1-4. DOI: 10.1145/3430063.3430251.

[9] J. Sherman "Light bulbs could replace your Wi-Fi router." digitaltrends. Internet: https://www.digitaltrends.com/mobile/light-bulb-li-fi-wireless-internet/, Oct 30, 2013, [Sep. 25, 2023]

[10] K. Kim, J. Park, and D. Lee, "Vehicle recognition system using visible light communication," in Proc. International Symposium on Communications and Information Technologies (ISCIT), 2017, pp. 1-6. DOI: 10.1109/ISCIT.2017.8274251.

[11] K. T. Swami and A. A. Moghe, "A Review of LiFi Technology," 2020 5th IEEE International Conference on Recent Advances and Innovations in Engineering

(ICRAIE), Jaipur, India, 2020, pp. 1-5, DOI: 10.1109/ICRAIE51050.2020.9358340.

[12] M. S. Islam, T. H. Nguyen, S. S. Ahmed, and T. M. Pham, "Smart toll collection system using Li-Fi and blockchain technology," in Proc. International Conference on Advanced Technologies for Communications (ATC), 2020, pp. 609-614. DOI: 10.1109/ATC48436.2020.9225635.

[13] N.R. Sathis Kumar, T. Nirmalraj, "Smart Toll Collection Using Li-Fi Technology," International Research Journal in Global Engineering and Sciences (IRJGES), vol. 3, no. 3, pp. 51-56, Sep. - Nov. 2018. ISSN: 2456-172X.

[14] S. Asadzadeh, S. Talebi, and S. M. Banihashemi, "Vehicle-to-vehicle communication using visible light communication (VLC) technology," in Proc. IEEE International Conference on Communications (ICC), 2016, pp. 1-6. DOI: 10.1109/ICC.2016.7510831.

[15] S. Kim, S. Kim, S. Hwang, and S. Jung, "A vehicle recognition system for toll gate based on Li-Fi technology," in Proc. International Conference on Advanced Communication Technology (ICACT), 2021, pp. 74-79. DOI: 10.23919/ICACT51384.2021.9370480.

[16] Y. Li, Y. Liang, and Y. Li, "Smart toll gate system based on Li-Fi and image processing," in Proc. IEEE 3rd International Conference on Image, Vision and Computing (ICIVC), 2017, pp. 678-682. DOI: 10.1109/ICIVC.2017.7986232.

[17] Y. Wang, Y. Qiao, and H. Liu, "A study on the application of Li-Fi technology in toll collection systems," in Proc. International Conference on Information Science and Technology (ICIST), 2015, pp. 380-384. DOI: 10.1109/ICIST.2015.7288435.

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