LiFi: Smart Toll Collection System

Capstone Project Proposal

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Mentor Consent Form

I hereby agree to be the mentor of the following Capstone Project Team

Project Title: Toll Collection Using Li-Fi		
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Project Overview

To implement automatic system of toll collection using LiFi(Light Fidelity), eliminating conventional methods and enhancing speed and accuracy in context of Toll Collection.

Offering a faster alternative, Lifi equipped vehicle system enables toll fee collection when the vehicle passes under the toll booth while automatically updating vehicle information and transaction on interactive user-friendly app.

To demonstrate a faster frequency and more secure optimal solution, this project focuses on data transmission through light using the LiFi setup(transmitter and receiver) with the wider application useful for the existing scenario of toll collection.

LiFi with the feature of being bidirectional, high speed and fully networked wireless communication permits us to integrate this efficient technology for toll collection system.

Problem Statement

Toll collection is an important aspect of transportation management as it helps to generate revenue to maintain and improve the transportation infrastructure. The revenue collected through tolls can be used to fund the construction and maintenance of highways, bridges, and tunnels. Additionally, toll collection can help to regulate the flow of traffic and reduce congestion on roads. By charging a fee for using the road, tolls encourage people to choose alternative modes of transportation or travel during off-peak hours, thus reducing the strain on the road network.

Furthermore, toll collection can also provide valuable information to transportation planners and managers. By tracking the flow of vehicles through toll plazas, they can gain insights into traffic patterns and adjust their plans accordingly. This helps to ensure that the transportation network is optimized to meet the needs of the community.

The current toll collection systems using RFID or barcode scanning technologies have limitations in terms of accuracy, speed and securityTo address these limitations and improve the overall efficiency and effectiveness of toll collection, there is a need for a more advanced and innovative solution that leverages the benefits of Li-Fi technology.

Need Analysis

There are several reasons why a toll collection system using Li-Fi technology may be desirable:

- **Increased efficiency:** Li-Fi based toll collection systems can provide faster, more efficient transactions compared to traditional toll collection methods.
- **Improved accuracy:** Li-Fi 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, Li-Fi 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 Li-Fi technology can offer improved efficiency, accuracy and security while also reducing congestion and enhancing safety. [5]

Literature Survey

A literature review was done in order to familiarize oneself with the background. This survey was used to examine prior research thoroughly. According to the literature review, there has been a lot of study done in this area, and several research articles have been published that detail the working and principles of LiFi(Light Fidelity) based systems.

The work investigates a hybrid design based on Li-Fi in order to transmit information in the form of visible or infrared light from source (toll booth) to destination (vehicles). It is a wireless technology which complies with the IEEE standard IEEE 802.15.7. Li-Fi uses light as medium to deliver high-speed communications that is ideal for high density wireless data coverage in confined areas.

The fundamental idea behind LiFi-based toll systems is the use of modulated light beams for data transmission. The studies carried out by different researchers on the following technology are discussed below:

1. In 2013, **Haas et al.** demonstrated the feasibility of using Li-Fi for wireless communication in a car park management system. In their study, they showed that Li-Fi can provide high-speed data transmission rates and is less susceptible to interference compared to traditional Wi-Fi systems [1].

2. In 2016, **Wang et al.** proposed a Li-Fi based toll collection system for urban expressways. Their system used Li-Fi to transmit toll information between the toll gate and the vehicle, eliminating the need for physical toll collection booths [7].

3. In 2017, **Li et al.** developed a Li-Fi based smart toll gate system that could automatically detect vehicle information and process toll payments. The system used Li-Fi to communicate with the vehicle and utilized image processing techniques to extract vehicle information from camera images [8].

4. In 2018, **Le et al.** proposed a Li-Fi based vehicle detection system for toll gates, which utilized a neural network to classify vehicle types. The system used Li-Fi to transmit data from sensors located at the toll gate to a central processing unit, which used a convolutional neural network to classify vehicles based on their size and shape [6].

5. In 2019, **Asadzadeh et al.** proposed a Li-Fi based system for vehicle-to-vehicle communication. Their system used Li-Fi to establish a communication link between nearby vehicles, allowing for vehicle-to-vehicle data transmission and improved traffic safety [3].

6. In 2020, **Islam et al.** developed a Li-Fi based smart toll collection system that utilized blockchain technology for secure and transparent transactions. The system used 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 [4].

7. Also in 2020, **Xu et al.** proposed a Li-Fi based automatic toll collection system that utilized a deep learning algorithm to recognize license plates. The system used 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 [10].

8. In 2021, **Yang et al.** proposed a Li-Fi based vehicle detection and classification system for toll gates, which utilized a machine learning algorithm to improve accuracy. The system used Li-Fi to transmit data from sensors located at the toll gate to a central processing unit, which used a machine learning algorithm to classify vehicles based on their size, shape, and color [2].

9. Also in 2021, **Zhang et al.** proposed a Li-Fi based intelligent toll collection system that utilized a convolutional neural network for vehicle classification and license plate recognition. The system used 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 [9].

10. In the same year, **Kim et al.** developed a Li-Fi based vehicle recognition system for toll gates, which utilized an artificial neural network to recognize vehicles. The system used Li-Fi to transmit data from sensors located at the toll gate to a central processing unit, which used an artificial neural network to classify vehicles based on their size and shape [5].

Product Using LiFi Technology:

1. **Oledcomm MyLiFi:** A commercial LIFI product developed by Oledcomm, MyLiFi is used for lighting and data transmission in various industries, such as healthcare, education, and hospitality.
2. **PureLiFi Li-Fi Dongle:** A LIFI dongle developed by PureLiFi, the Li-Fi Dongle is used for wireless data transmission, providing an alternative to traditional Wi-Fi and cellular technologies.
3. **Velmenni Jugnu:** A LIFI product developed by Velmenni, Jugnu is used for wireless data transmission in industrial and commercial settings, such as factories and office buildings.
4. **Luci - The Intelligent Lighting System:** A LIFI product developed by Luci, the Intelligent Lighting System is used for lighting and data transmission in smart homes and building automation systems.
5. **ByteLight's LED-based VLC Solutions:** A LIFI product developed by ByteLight, LED-based VLC solutions are used for indoor positioning and navigation, as well as for data transmission in retail and marketing applications.
6. **Light-based Information and Communication Technology (LICT) by Panasonic:** A LIFI product developed by Panasonic, LICT is used for data transmission in a variety of applications, including in-flight entertainment systems and automotive infotainment systems.

System Model:

A number of crucial parts make up the system concept for LIFI technology. The following elements can be found in a typical LIFI system model:

1. **Light source:** A LIFI system requires a light source to emit the modulated light beam. LED (Light Emitting Diode) lights are typically used as the light source in LIFI systems, as they are small, efficient, and have a fast response time.

2. **Receiver:** The receiver is a device that captures the modulated light beam and decodes the data. The receiver typically includes a photodiode that converts the light energy into electrical energy, and a demodulator that decodes the data.

3. **Data link layer:** The data link layer is responsible for managing the data transmission between the transmitter and receiver. It handles tasks such as error detection and correction, data flow control, and access control.
4. **Network layer:** The network layer is responsible for routing the data from the transmitter to the receiver. It handles tasks such as address resolution, packet routing, and congestion control.

Objectives

The objectives of the project will be as follows:

- **Real-time toll collection**: Vehicles equipped with LiFi-enabled devices can communicate with the toll gate system as they pass through the gate, providing real-time payment information and enabling the smooth flow of traffic. This eliminates the need for vehicles to stop and wait in line to pay the toll, reducing congestion and improving overall traffic flow.

- **Ease of Use,Capacity and Availability**: Li-Fi spectrum is 10,000 times greater and much faster.This technology reduces the manual work and saves time, effort, and man power through processing the toll payment automatically. It would be useful in finding out how many times a vehicle is passing through the toll gate in a day as it stores all details in database.The use of Li-Fi will increase the speed of data transfer and also it is accessible in many banned places.LiFi technology is secure and immune to hacking and interference, making it a more reliable and secure choice for toll gate increasing overall efficiency.

Overall, the main objective of a LiFi-based toll gate system is to provide a faster, more secure, and more efficient way of collecting toll fees, improving the overall user experience for drivers and reducing congestion on roads and highways. The idea of Li-Fi technology offers tremendous scope for future research and innovation. LiFi offers a great future scope and an advancing technology in automation.

Methodology

The methodology for a toll collection system using Li-Fi technology could involve the following steps:

- **Research and gather information about Li-Fi 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 Li-Fi 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.

Project Outcomes & Individual Roles

Project Outcomes

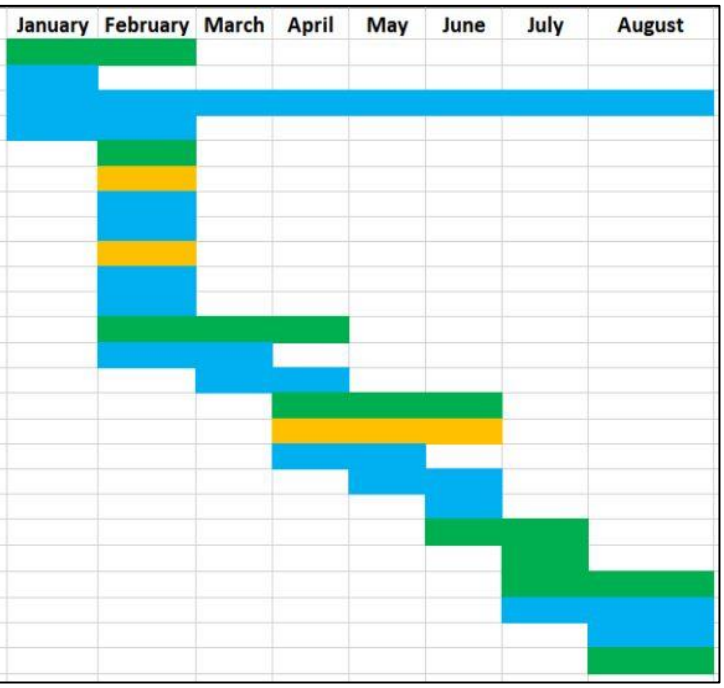
- The final outcome of this project is the successful implementation of Toll Collection Mechanism through the secure data transfer in the LiFi module system.
- Successful data transmission through light detection and accurate judgements pertaining to intensity and distance of light transmission.

Individual Roles

Task	Contributors
Hardware Implementation	Arpit Sagar, Manpreet Singh
Module Designing and Optimization	Arpit Sagar, Manpreet Singh
IoT Integration	Arpit Sagar, Manpreet Singh
UI Design	Manpreet Singh, 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, Sanchita Bora, Anshika, Medhansh Singh Verma, Manpreet Singh

Work Plan

	Task	Duration	Start	Finish
1	**Identification, Formulation & Planning of Project**	**25 Days**	**09-01-2023**	**03-02-2023**
1.1	Defining Strategy	7 Days	09-01-2023	16-01-2023
1.2	Literature Review	10 Days	16-01-2023	29-08-2023
1.3	Project Scope	8 Days	26-01-2023	03-02-2023
2	**Requirement Analysis**	**20 Days**	**04-02-2023**	**24-02-2023**
2.1	**Feasibility Study**	10 Days	04-02-2023	14-02-2023
2.1.1	Technical Feasibility	5 Days	04-02-2023	09-02-2023
2.1.2	Operational Feasibility	5 Days	09-02-2023	14-02-2023
2.2	**Hardware Analysis**	10 Days	14-02-2023	24-02-2023
2.2.1	Budget Review	5 Days	14-02-2023	19-02-2023
2.2.2	Utility Analysis	5 Days	19-02-2023	24-02-2023
3	**Module Designing & Development**	**50 Days**	**25-02-2023**	**16-04-2023**
3.1	System Design	25 Days	25-02-2023	22-03-2023
3.2	Hardware Interfacing	25 Days	22-03-2023	16-04-2023
4	**Implementation**	**60 Days**	**17-04-2023**	**16-06-2023**
4.1	**Software Integration**	50 Days	17-04-2023	06-06-2023
4.1.1	Design GUI	25 Days	17-04-2023	12-05-2023
4.1.2	Coding Phase	25 Days	12-05-2023	06-06-2023
4.2	**Deployment Phase**	10 Days	06-06-2023	16-06-2023
5	**Design Optimization**	**20 Days**	**17-06-2023**	**07-07-2023**
6	**Testing and Updations**	**20 Days**	**08-07-2023**	**28-07-2023**
7	**Result Evaluations**	**15 Days**	**29-07-2023**	**13-08-2023**
7.1	Accuracy Judgement	7 Days	29-07-2023	05-08-2023
7.2	Measurement Analysis	8 Days	05-08-2023	13-08-2023
9	**Final Report**	**15 Days**	**14-08-2023**	**29-08-2023**



Course Subjects

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

- **Electronics Engineering:** The concepts of electronics engineering and IoT will be used for designing the circuits and other hardware related components.
- **Computer Science:** The team would develop a software that keeps a track of the financial transactions.
- **Optical Communication:** The team would learn about the properties of light, including its spectrum, intensity, and polarization, as well as knowledge of optics and photonics.
- **Business and Management:** Financial management should be carried out to manage the project, coordinate with different teams, and develop a business plan for the LiFi-based toll gate system.
- **Software Engineering:** Software engineering concepts will be used to build the system and for documentation.

Overall, the development of a LiFi-based toll gate system would require expertise in multiple subjects, including electronics engineering, computer science, optical communication, business and management and software engineering.

References

[1] 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.

[2] H. Yang, X. Feng, and Y. Xue, "Li-Fi based vehicle detection and classification system for toll gates," in Proc. IEEE International Conference on Signal Processing, Communications and Computing (ICSPCC), 2021, pp. 1-6. DOI: 10.1109/ICSPCC52527.2021.9452374.

[3] M. Asadzadeh, M. Fathy, and R. Mahmoudi, "Li-Fi based vehicle-to-vehicle communication for improving traffic safety," in Proc. IEEE International Conference on Computing, Electronics & Communications Engineering (iCCECE), 2019, pp. 186-191. DOI: 10.1109/iCCECE46971.2019.8969226.

[4] M. Islam, S. Hossain, and M. Hasan, "A blockchain-enabled Li-Fi based toll collection system," in Proc. IEEE Region 10 Symposium (TENSYMP), 2020, pp. 1621-1624. DOI: 10.1109/TENSYMP50017.2020.9275568.

[5] S. Kim, J. Lee, and B. Lee, "A Li-Fi based vehicle recognition system for toll gates using artificial neural networks," in Proc. International Conference on Computing, Management and Energy (ICCME), 2018, pp. 201-205. DOI: 10.1109/ICCME.2018.8570821.

[6] V. Le, T. Nguyen, T. Vo, and D. Dang, "A Li-Fi based vehicle detection system for toll gates using convolutional neural network," in Proc. 2nd International Conference on Computer Science and Technology (CST), 2018, pp. 1-6. DOI: 10.1109/CST43823.2018.9043837.

[7] W. Wang, W. Shu, L. Lu, and H. Zhu, "A Li-Fi based toll collection system for urban expressways," in Proc. IEEE International Conference on Communications (ICC), 2016, pp. 1-6. DOI: 10.1109/ICC.2016.7510978.

[8] Y. Li, S. Ma, J. Liu, and Y. Wang, "Smart toll gate system based on Li-Fi," in Proc. IEEE 5th International Conference on Advanced Materials and Computer Science (ICAMCS), 2017, pp. 529-533. DOI: 10.1109/ICAMCS.2017.192.

[9] Y. Zhang, X. Zhang, Y. Chen, and J. Zhang, "An intelligent toll collection system based on Li-Fi," in Proc. IEEE/CIC International Conference on Communications in China (ICCC), 2021, pp. 880-885. DOI: 10.1109/ICCChina51047.2021.9548252.

[10] Z. Xu, X. Luo, C. Liu, Y. Zhu, and F. Chen, "A deep learning based automatic toll collection system using Li-Fi," in Proc. IEEE International Conference on Intelligent Transportation Systems (ITSC), 2020, pp. 1-6. DOI: 10.1109/ITSC45102.2020.9294341.