Design and Implementation of Wireless Communication System for Toll Collection Using LIFI

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Abstract – Automatic Toll Tax systems has reduced the heavy congestion caused at toll collection in the metropolitan cities. As the population is increasing day by day which results in high traffic congestion on roads. Most of the people find it difficult to be a part of long queue at toll for toll collection system. This causes high fuel consumption while waiting for a payment, which is going to extinct in coming years. The research is providing a great solution to this problem. LIFI is emerging technology in today's era. Here, we are using the power of LIFI for wireless communication to transmit user information from vehicle to toll. Every vehicle will be having a microcontroller and a memory connected to it. In addition, the setup will be used to send useful encoded data like vehicle number via LED. The LIFI receiver is present in middle of road at tollbooth. An intelligent processor will be there at receiver side, which will automatically process the toll tax payment according to the type of vehicle through a wallet linked with vehicle number. The technology will be helpful in preserving the fuel consumption of vehicle and will create an eco-friendly environment.

Keywords – Microcontroller; LIFI; Toll system; Wireless communication; Arduino; Proteus; Eagle.

I. INTRODUCTION

In today's time wireless communication has become the integral part of our life. There are many technologies that can be used for wireless communication. Wi-Fi is one of those. Undoubtedly, Wi-Fi is very eminent technology that has large applications in both our personal and professional life. One of its application is for wireless communication between vehicle and toll for toll collection. But due to tremendous use, RF bands are getting scarce and also they are restricted at airplanes and hospitals. Some of the issues related with Wi-Fi are its Capacity, Efficiency, Availability and Security. Also at tollbooth we require eco-friendly environment and a situation where there is no need for a vehicle to stop at tollbooth These issues led to development of a new concept called LIFI for short range communication, which can be used at tollbooth [1].

LIFI basically refers to light fidelity which means transferring the information with the help of light. In this technology the light waves are modulated according to the information which is to be sent. At toll booth we are using LIFI to decrease the stoppage time at toll and save fuel. Moreover it will be less costly than all other similar technologies. Its main components are LED, photodiode, amplifier and microcontroller. Wireless automatic Toll collection system has many advantages such as, shorter queue at toll plazas, faster and more efficient services, and minimization of fuel wastage and reduced emissions by reducing deceleration rate, waiting time of vehicles in queue, and acceleration, cost reduction in toll collection, expanding capacity without building more infrastructures.

II. BASIC COMPONENTS

A. LED

LED refers to light emitting diode. It is a p-n junction diode, which emits light when activated. When a certain voltage is applied to LED then energy, get released due to the combination of electron and holes in the form of photons. The color of the light depends on the band gap of the semiconductor used to make LED. This effect is called electroluminescence. It is used at transmitting end [1-2].

B. Photodiode

Photodiode is a device that converts light into current. The current is produced due to the breakage of bonds between electrons and holes when photons are absorbed by it. Small amount of current also flows through photodiode when no light falls on it which is called dark current. It is used as at receiving end [1].

C. Microcontroller

It is basically a small computer on a single integrated chip. It contains one or more CPU along with programmable memory and input/output peripherals. They are basically used for automation purpose like automatic engine control,

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remote sensing, robotics and other embedded applications In our paper it is used at both sender and receiving end.

D. Transimpedance Amplifier

The output current from the photodiode is very small which is difficult to detect. So to amplify it and to covert that amplified current into equivalent voltage we require a trans impedance amplifier.LM358 can be used for the same purpose.

III. RELATED WORK

Tremendous amount of research work is going on wireless communication system using, LIFI [3-10]. According to Noof Al et. al.[3] LIFI can be used for vehicle-to-vehicle communication to reduce road accidents. Each vehicle will contain a LIFI transmitter and receiver present at front and backside simultaneously. According to Zubin Thomas et. al.[4] LIFI can be used at shopping malls for automatic billing ,assuming that every good will have LIFI transmitter and the mobile have LIFI receiver integrated via On-The-Go (OTG) communication in shopping cart. RFID [5] can also be used for automatic toll collection. Each vehicle will be having a unique RFID tag that can be used for vehicle identification at toll. Amit Hatekar et. al. [6] suggested that toll collection can be done more efficiently by using GSM with RFID. In addition to the RFID tag, GSM technology can also be used to send the payment information back to the user. [7] The LED transmitter is placed for vehicle-to-vehicle communication and camera will be there at receiver end. The technology can be used to avoid collision with the help of the data transmitted from transmitter car. G. Vidhya Krishnan et.al.[8] explains the benefits and use of LIFI for vehicle-to-vehicle communication and its practical consideration. Paper[9-12] explains benefits of vehicle automatic toll collection and wireless communication. The spectrum will provide high data rates with low latency and high security [13-14] in Wireless communication. Our contribution in automatic toll collection technology is to have wireless communication between vehicle and toll using LIFI.

IV. SYSTEM MODEL

In order to design the system, the "Line of sight" between receiver and transmitter is required to send the data. LIFI uses visible light communication or infrared and near-UV spectrum waves, which can be achieved by using LED (light emitting Diode). There is requirement of transmitter as well as a receiver so as to achieve the concept of wireless communication system, as the LIFI refers to the Light fidelity which is also a wireless communication system and it will transmit data using Electromagnetic wave(Light) therefore it requires a transmitter circuit and receiver circuit. Here, Vehicle is acting as a transmitter because the transmitter circuit i.e. LED and Intelligent controller is connected with the vehicle's Power system. As the vehicle is having the 12V battery to power the Electronic components present in the vehicle, also this power will be given to the transmitter circuit.

On the receiving end there will be a photo-detector to sense the change in light transmitted from LED, and so as to meet the requirement of "Line of sight" we are connecting the receiver circuit on the Road just under the car. As mention in Fig.1 there are five major components of transmitter i.e. memory, microcontroller, vehicle, Driver circuit, LED array. Data or Information of the user stored in the memory attached with the microcontroller, memory will contain the vehicle number, personal identification number and payment gateway password.

Microcontroller is an intelligent device which is able to process user's commands and gives the relevant output. Microcontroller will process the algorithm of sending the data from memory to LED in modulated form.

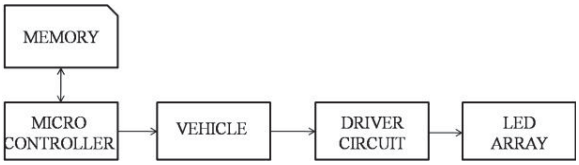

Fig. 1 Transmitter Block Diagram

During uplink and downlink setup of LIFI there is an "Interference" of sunlight with LED light. Sunlight is having a luminous value comparable to high intensity LED, which vary in the range of 1000-2000 Lux. This problem can be resolved by placing the array of LED under the vehicle, which will also resolve the problem of "Line of sight". Since, under the vehicle the luminous value is relatively low which prevents the unwanted interference of LED with sunlight. Array of LED is there to transmit the information to toll for payment.

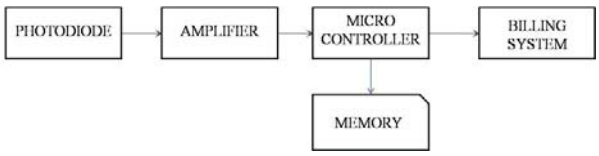

Fig. 2 Receiver Block Diagram

Fig. 2, shows the receiver block diagram with the five major components i.e. photodiode, amplifier, microcontroller, memory and billing system. The photodiode will receive the information sent by LED in form of current pulses. The strength of the signals will decrease as it travels through air, so as to convert these weak current pulses into equivalent voltage pulses we need to amplify these signals by

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transimpedance amplifier. The amplified signal requires a signal processing element which is a microcontroller. Data will forwarded to microcontroller for further processing, comparision of received data with existing database takes place, payment for toll, and notification regarding toll deduction will be sent to user via SMS.

Challenges and assumptions for system setup:-

i. The Interference of sunlight on photodiode which is minimized by placing transmitter under the vehicle.
ii. The distance between transmitter and receiver is minimized by placing transmitter under the vehicle.
iii. The billing system present at toll, which does all the billing work and sends the notification as well as receipt back to user's mobile.
iv. There is a wallet linked with every vehicle which is password protected.

V. IMPLEMENTATION

Light Fidelity gives the fastest rate for data transmission from transmitter to receiver. Consider a vehicle, with the transmission circuit with LED, Microcontroller, Memory device and driver circuit. As mention in the fig. 3, Sender circuit is connected with the car under the Bow-nut with LED connected to microcontroller. Receiver is placed on the road at Toll plaza. As the car reach to the toll, the car need not to stop for further process, directly car number and user detail will send to toll receiver. Receiver process the data and payment will be done at receiver side according to the user's data. Receiver side is connected to the internet for further process. Also, Cloud is interfaced at sender side to get notification in mobile app and save the data history on to the cloud.

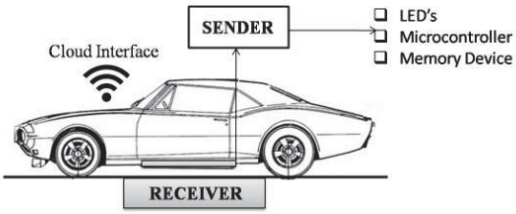

Fig. 3 Basic Vehicle Model side view

As can be seen in Fig. 3, is the side view of the vehicle and Fig 4, is the front View of the vehicle. According to traditional method, toll plaza requires high installation cost but after the implementation of the LIFI wireless system, there will be no need to put booth on the roads, therefore it reduces the installation as well as repair cost on toll plaza.

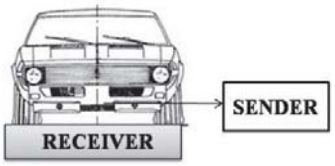

Fig. 4 Basic Vehicle Model Front view

As seen in the Fig. 5, the circuit diagram to send data at transmitter side. Circuit diagram is having 5V to power up the circuit with optimum current and having four LED's connected to the four output digital pin of the microcontroller. At the time of sending the information from user the data will move to microcontroller and then directly pass to LED via Driver circuit. LED works on the range of 2.2-4.5V.

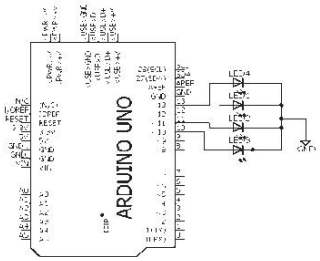

Fig. 5 Schematic of Transmitter circuit

At receiver side (Fig. 6), the photo-receiver is there to sense the change in LED and it will detect low voltages. As the voltage is very less and is in Milli Volts, it will get amplified using a transimpedance amplifier so that controller can read the information. As the controller is working in the range from 0V to 5V so that information also should be in the range from 0V to 5V. After receiving, the information is shown on to the 2x16 LCD.

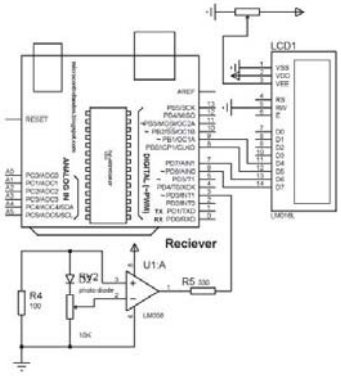

Fig. 6 Schematic of Receiver Circuit

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VI. SIMULATIONS

Noof Al Abdul Salam et. al. [3] had discussed simulation results for communication using LIFI. These are simulations for sending data using Light fidelity. These simulations are helping to learn basic optical communication.

A. Transmitter Circuit

Initially the simulation of basic transmitting and receiving circuit is done on proteus. The main purpose of this simulation is to understand the basic concepts of optical communication.

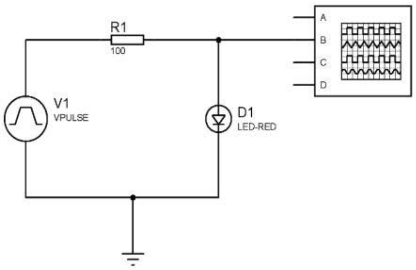

Fig. 7 Basic Transmitter circuit

In Fig. 7, the square pulse is given as input to LED and corresponding output is as shown in Fig. 8, which confirms that LED blinks according to the signal.

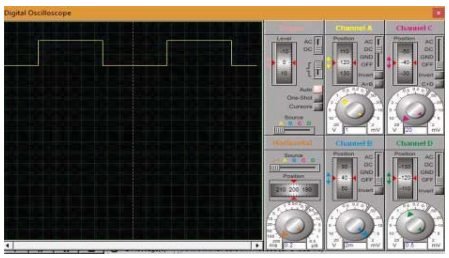

Fig. 8 Output of Transmitter circuit

B. LED Driver Circuit

Fig.9 shows the LED Driver Circuit. It is used to provide proper operating conditions to the LED. Driver circuit can be used as voltage regulator or current regulator. Here we are using it as a current regulator.

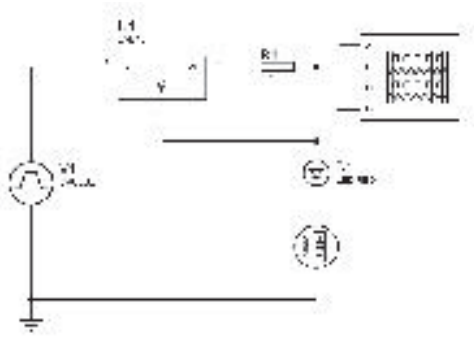

Fig. 9 Driver circuit simulation

Fig.8 shows the simulation output of the driver circuit with the voltage provided to input in the range of 0V to 5V.

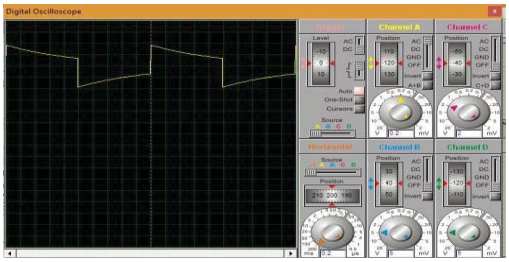

Fig. 10 Driver Circuit Output

C. Receiver circuit

Fig. 11, shows the simulation of receiver circuit and the corresponding output is shown in Fig. 12. The output is little distorted but we can clearly predict the digital 1 and 0.

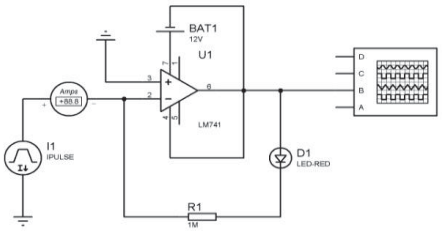

Fig. 11 Simulation of Receiver circuit

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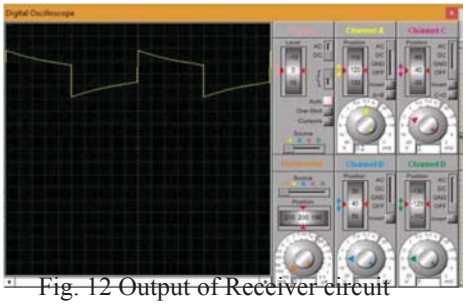

Fig. 12 Output of Receiver circuit

D. Transimpedance amplifier

Fig.13 is the circuit diagram of transimpedance amplifier, which contains the op-amp in inverting configuration, which converts the photodiode output current into equivalent voltage and amplify it.

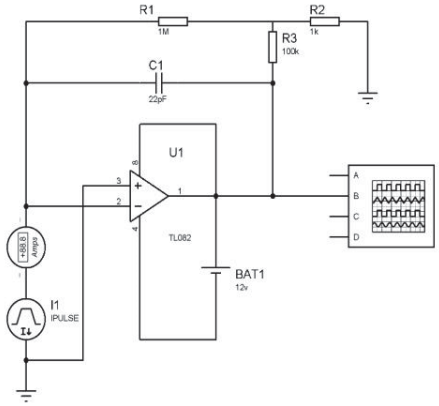

Fig. 13 Simulation of Transimpedance amplifier

During simulation, it is assumed that the photodiode will receive the signal, so it is depicted by constant current source.

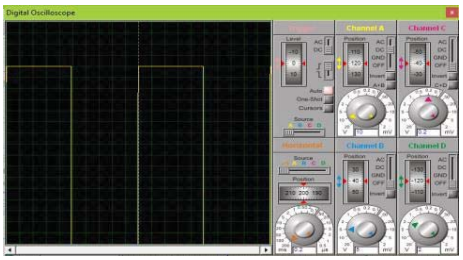

Fig. 14 Output of transimpedance amplifier

Fig.14 shows the output of transimpedance amplifier, which clearly shows that the signals got amplified.

VI. RESULTS

We have sent vehicle number "HP 31B 2779" using serial monitor, Arduino processes the input vehicle number and send it to the Led array via driver circuit. Information sent by the LED array and is received by photodiode at receiver side and is send to the Arduino for payment process and same number is printed on the LCD as shown below.

Fig. 15 Input from serial monitor

Fig. 15 is showing the input vehicle number given through serial monitor of Arduino coding environment.

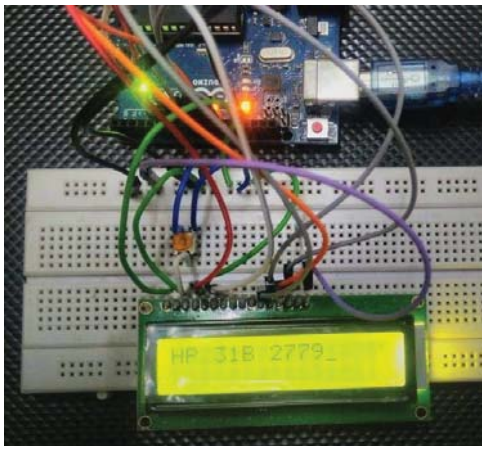

Fig. 16 Output of receiving circuit

Fig. 16, Shows that the number transmitted from the serial monitor is received at receiver side and is shown on 2x16 LCD.

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VII. CONCLUSION AND FUTURE WORK

The paper is successfully able to implement the Wireless communication system using LIFI technology. The vehicle number send from the vehicle is successfully received at toll side. The practical results are in accordance with simulation results.

In future, work on data transmission rate and billing system can be done.

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