International Journal of Research in Engineering, Science and Management
Volume-2, Issue-6, June-2019
www.ijresm.com | ISSN (Online): 2581-5792

Li-Fi based Toll Collection System

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***Abstract*: Li-Fi is a wireless optical networking technology that uses light-emitting diodes (LEDs) for data transmission. Li-Fi stands for Light-Fidelity which involves transmission of data using visible light by sending data through an LED light bulb that varies in intensity faster than the human eye can follow. If the LED is on, the photo detector registers a binary one; otherwise it's a binary zero. Li-Fi is designed to use LED light bulbs similar to those currently in use in many energy conscious homes and offices. Currently, Li-Fi bulbs are outfitted with a chip that modulates the light imperceptibly for optical data transmission. Li-Fi data is transmitted by the LED bulbs and received by photoreceptors. Proposed system uses Li-Fi technology to improvise the conventional toll automation systems. Toll automation uses Li-Fi for communication between vehicles and the toll booth. There will be data transmitting LED array connected at the bottom of the vehicles. The data is read from a photoreceptor which is placed on a platform. The data which is a unique id is passed (to the internet) using IoT to a pre-registered database which is used to and the account details, vehicle info and owner details. After deduction, the balance is conveyed to the user through sms. After getting a confirmation from the server, the gates are opened for the vehicle to pass.**

***Keywords*: Access points, Li-Fi Database, Raspberry Pi, STM 32, VLC.**

1. Introduction

Li-Fi is high speed bidirectional networked and mobile communication of data using light. Radio frequency communication requires radio circuits, antennas and complex receivers, whereas Li-Fi is much simpler and uses direct modulation methods similar to those used in low-cost infrared communications devices such as remote control units. Li-Fi comprises of multiple light bulbs that form a wireless network. When an electrical current is applied to a LED light bulb, a stream of light (photons) is emitted from the bulb. LED bulbs are semiconductor devices, which mean that the brightness of the light flowing through them can be changed at extremely high speeds. This allows us to send a signal by modulating the light at different rates. The LED [1] [2] lights used to transmit Li-Fi signals are modulated at such a fast rate that the eye cannot perceive the modulation or flicker. As a comparison, the lowest frequency at which the lights are modulated is 1MHz and this is 10,000 times higher than the refresh rate of our computer screens [9]. The signal can then be received by a detector which interprets the changes in light intensity (the signal) as data. The intensity modulation cannot be seen by the human eye, and thus communication is just as seamless as other radio systems, allowing the users to be connected where there is Li-Fi enabled light. Using this technique, data can be transmitted from a LED light bulb at high speeds. LED is more advantageous than the existing incandescent in terms of long life expectancy, high tolerance to humidity, low power consumption, and minimal heat generation lighting. The Ministry of International Trade and Industry of Japan estimates, if LED replaces half of all incandescent and fluorescent lamps currently in use, Japan could save equivalent output of six mid-size power plants, and reduce the production of greenhouse gases. LED is not only used as a lighting device, but also to be used as a communication device. It is a kind of optical wireless communication that uses the visible white ray as the medium. This dual function of LED, for lighting and communication emerges many new and interesting applications. Li-Fi can operate in daylight and even in direct sunlight conditions, as the modulated light can still be detected. Li-Fi relies on detecting the fast changes in light intensity and not on the absolute or slowly varying levels caused by natural disruptions in daylight or sunlight. Li-Fi technology modulates the light at very high rates and sunlight is constant light and therefore can be filtered out at the receiver. Now, if all power to the light is turned off then there is no Li-Fi. However, Li-Fi technology can be enabled to dim low enough that a room will appear dark and still transmit data. There is consistent performance between 10 and 90 percent illumination [5] [6]. There are also other options for using invisible parts of the light spectrum such as infra-red, which is currently already being used for sending information back to the light bulb (uplink). Li-Fi is a complimentary technology that works alongside other wireless technologies such as Wi-Fi. If the light signal to a Li-Fi enabled device is below the receivers threshold then it will not receive data. In that instance, radio systems or cellular networks, if available, will continue to deliver data. However, the moment the device begins to receive light from a Li-Fi light bulb; the device will resume high speed communications using light as an additional communications medium. Li-Fi is significantly more secure than other wireless technologies because light can be contained in a physical space. Our doors and windows can be shut, and physical barriers and adjustments can be implemented to contain and protect the light. We can create the conditions that allow us to shut the door on our wireless data. It should be understood that the existing security protocols for encryption and authentication can be leveraged in Li-Fi systems to provide even more secure wireless systems.

2. Literature survey

Li-Fi technology is based on Visible Light Communication (VLC) technology. VLC is one of the advanced optical wireless communication technologies in which light in the visible region (375nm-780nm) is used as a medium for data transmission. This section of the paper discusses the so called Visible Light Communication and a fruitful application of it on which this paper is based, Li-Fi. Visible Light Communication [1] is a communication method where visible light within a particular frequency range is used as the medium of communication. The visible light frequency range for VLC is from 400 to 800 THz. VLC (Visible Light Communication) operates under the concept of transmission of data via light rays to send and receive messages in a given distance. Putting into use LED lighting; VLC can be used as a replacement for radio frequencies in areas where it cannot be applied. In addition, VLC has the upper hand over radio frequencies as it offers ultra-fast data transmission and also high bandwidth transmission. This has been most evident in traffic lighting, besides other sectors. The concept of VLC dates back as early as 1880.This was first put into use by Alexander Graham Bell, a Washington D.C resident when he invented the photo-phone. The method relayed speech over long distances via modulated sunlight. However, back then the idea was not applied much as it was centuries ahead of its time. Due to this, the technology paved way for slower communication media thus was never a big hit.

A. Overview

Given that light travels 186,000 miles in a second, communication via this source is virtually instantaneous. This makes VLC the fastest means of communication between all means available in the market. To function, VLC uses visible light between 780 to 375 nm which are visible to the human eye. Every form of data can be broken down into single units of ones and zeroes that can be deciphered as low or high signals. In VLC, this is achieved by fast turning of light on and off(also called on-off keying, OOK). However, this form of data transmission is dependent on how fast the light can go on and off. To achieve great results, LED lighting is well suited for the task as it has a short rise and fall time thus faster switching. Due to this, LED lighting is used in all wireless forms of VLC. To function, VLC requires a receiver (photo detector), a transmitter (LED) and a channel of communication. In addition, the circuit features a photodiode, trans-impedance amplifiers, auto gain controllers, high pass filters and in some cases analog-digital converters. From the source of the signal, an enhanced photodiode is fitted so as to convert light into a current. At the source and recipient of the instructions, a digital unit is fitted so as to encode and decode the instructions relayed accordingly. In most of the conventional systems, in order to increase the speed and the gain of the photodiode, a trans-impedance amplifier is used to make the process faster. Additionally, an automatic gain control is featured thus boosting speeds for messages between the sender and the receiver. Once the message is relayed, the photodiode on the other end breaks the current into a voltage that can be interpreted by the computer as a unit of ones and zeros, hence achieving a targeted result. So as to prevent disturbance from surrounding light sources, a high pass filter is used in the model. However, this forms a passive set of both the trans-impedance amplifier and the auto gain controllers are both gainers and hence no more gain was required. With this, the set is completed and thus messages are delivered instantly without any external disturbances.

3. Experimental setup

The Li-Fi mechanism is implemented in every vehicle (four wheelers) and at toll plaza. At the toll plaza, once the vehicles Li-Fi transmitter is paired with the Li-Fi receiver, the system at toll plaza automatically identifies the vehicle details. This paper is based on Li-Fi technology; the Li-Fi system uses Li-Fi which collects information of vehicle passing through the toll plaza and automatically debits the toll amount from prepaid account of vehicle owner, which in return reduces the traffic congestion and human errors. The vehicle owner has to register his vehicle with Li-Fi, creating a rechargeable account. There will be data transmitting LED array connected in the bottom of the vehicles. The data is read from a photoreceptor which is placed on the platform. The data which is a unique id passed to the internet using IoT to a pre-registered database which is used to find the account details, vehicle info and owner details. After deduction, the balance is displayed to the user as sms.

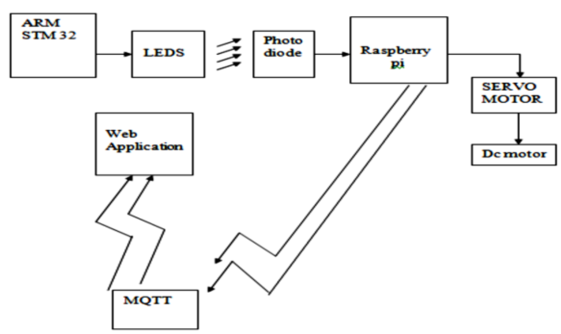

Fig. 1. Proposed project layout

After getting a conformation from the server the gates are opened. The proposed system consists of the following sections:

- Data reading and conversion module (ARM STM32 BOARD)
- Light emitting diode (transmission)
- Photo detector (reception)
- Data connectivity and IoT application (Raspberry Pi)
- User interface module (Web application)

IJRESM
International Journal of Research in Engineering, Science and Management
Volume-2, Issue-6, June-2019
www.ijresm.com | ISSN (Online): 2581-5792

4. Component specification

A. STM32 boards

The STM32 board a.k.a Blue Pill is a Development board for the ARM Cortex M3 Microcontroller. It looks very much similar to the Arduino Nano but it packs in quite a punch. These boards are extremely cheap compared to the official Arduino boards and also the hardware is open source. The microcontroller on top of it is the STM32F103C8T6 from STMicroelectronics. Apart from the Microcontroller, the board also holds two crystal oscillators, one is an 8MHz crystal, and the other is a 32 KHz crystal, which can be used to drive the internal RTC (Real Time Clock). Because of this, the MCU can operate in deep sleep modes making it ideal for battery operated applications. Since the MCU works with 3.3V, the board also houses a 5V to 3.3V voltage regulators IC to power the MCU. Even though the MCU operates at 3.3V most of its GPIO pins are 5V tolerant. The pin of the MCU are neatly pulled out and labeled as header pins. There are also two on-board LEDs, one (red colour) is used for power indication, and the other (green colour) is connected to the GPIO pin PC13. It also has two header pins which can be used to toggle the MCU boot mode between programming mode and operating mode. The complete pin-outs of the STM32 Blue pill board is shown below. That is the G is used to denote the ground pin, 3.3V outputs a regulated 3.3V and the 5V pin can either be used to power the board or obtain the +5V if powered via micro USB. The on-board LED is connected to the PC13 pin of the Microcontroller. Unlike Arduino boards, the STM32 development board has to be manually set to programming mode using the boot 1 and boot 0 jumper wires. The position of Boot 1 is normally not disturbed. But the boot 0 jumper has to be set as 3.3V for programming mode and set to ground for operating mode.

B. Raspberry pi zero W

The Raspberry Pi is a popular Single Board Computer (SBC) in that it is a full computer packed into a single board. Raspberry Pi Zero W is ideal for making embedded Internet of Things (IoT) projects. The Pi Zero W has been designed to be as flexible and compact as possible with mini connectors and an unpopulated 40-pin GPIO, allowing you to use only what your project requires. At the heart of the Raspberry Pi Zero W is a 1GHz BCM2835 single-core processor, the same as the B+ and A+, with 512MB RAM.

Consists of the following features:

1GHz, Single-core CPU, 512MB RAM, Mini HDMI and USB On-The-Go ports, Micro USB power 40-pin header, Composite video and reset headers, CSI camera connector, 802.11n wireless LAN, Bluetooth 4.0.

- Mini HDMI Unlike the previous models of the Raspberry Pi which use a standard. HDMI connector, the Zero uses a mini HDMI connector to save space. To connect the Zero to a monitor or television, we use a mini HDMI to HDMI adapter or cable.
- USB On-the-Go The Raspberry Pi 3 and other models have traditionally had 2-4 standard size female USB connectors, which allowed for all variety of devices to connect including mice, keyboards, and Wi-Fi dongles. Again to save space, the Zero has opted for a USB On-the-Go (OTG) connection. The Pi Zero uses the same Broadcom IC that powered the original Raspberry Pi A and A+ models. This IC connects directly to the USB port allowing for OTG functionality, unlike the Pi B, B+, 2 and 3 models, which use an on-board USB hub to allow for multiple USB connections. To connect a device with a standard male USB connection, we will need a USB OTG cable. Plug the micro USB end into the Pi Zero, and plug the USB device into the standard female USB end.

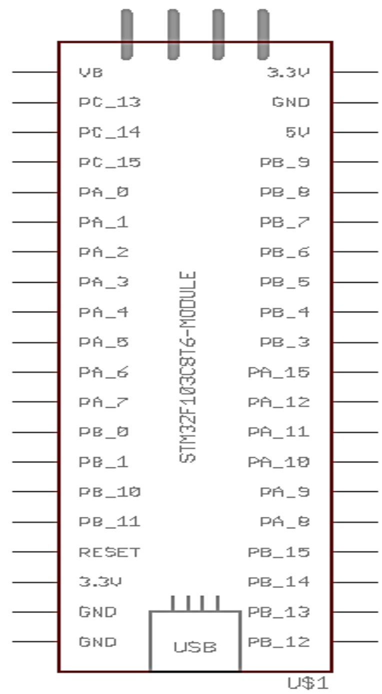

Fig. 2. Schematic of control board

- Power Like other Pis, power is provided through a micro USB connector. Voltage supplied to the power USB should be in the range of 5-5.25V.
- Micro SD Card Slot Another familiar interface is the micro SD card slot where we insert our micro SD card that contains our Raspberry Pi image file.
- Wi-Fi and Bluetooth as with the Raspberry Pi 3, the Zero W offers both 802.11n wireless LAN and Bluetooth 4.0 connectivity. This frees up many of the connections that would have been made over USB, such as a Wi-Fi dongle and a USB keyboard and mouse if substituting a Bluetooth keyboard/mouse.
- The Raspberry Pi Zero V1.3+ and all Zero W's have an on-board camera connector. This can be used to

International Journal of Research in Engineering, Science and Management
Volume-2, Issue-6, June-2019
www.ijresm.com | ISSN (Online): 2581-5792

attach the Raspberry Pi Camera module. However, the connector is a 22pin 0.5mm and different than the standard Pi. We will need a different cable to connect the camera to the Pi Zero W.

- Hardware Assembly Depending on the use case, setup for the Pi Zero can be minimal, or it can be cumbersome due to smaller connectors on the Zero and the adapters needed to connect standard devices such as mice, keyboards, and monitors.
- Monitor to attach the Pi Zero to a Monitor or TV that has an HDMI input, attach a mini HDMI to HDMI cable or adapter to the mini HDMI connector on the Pi Zero. Connect the other end to the HDMI port on the monitor or television. Connect the USB OTG cable to the Pi Zero via the micro USB connector. If we have a keyboard/mouse, attach the dongle to the standard female USB end. If we have a separate mouse and keyboard, we will need a USB hub to attach both to the USB OTG cable. Make sure that we have a valid Raspberry Pi image on the micro SD card. Insert the micro SD card into the micro SD slot. Power Pi Zero via the micro USB power input.

The Pi Zero has a 40 pin GPIO connector on the board that matches the pinout of the standard Pi 3. We can solder wires, headers or Pi Hats to this connector to access the GPIO pins or even power. The camera connector will allow we to connect the Raspberry Pi camera although it is worth noting that the connector is a 22pin 0.5mm and different than the standard Pi and will need a different cable to connect the camera to the Pi.

C. Light emitting diode

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. This effect is called electro luminescence. [5] The colour of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor [6]. White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device. The OWC technology uses light from light-emitting diodes(LEDs) as a medium to deliver networked, mobile, high-speed communication. Li-Fi could lead to the Internet of Things with LED lights on the electronics being used as Li-Fi internet access points. LED and photodiode are the major components of Li-Fi circuit. We assume that the noise in an AWGN (additive white Gaussian noise). In optical channels, the quality of transmission is typically dominated by shot noise [15]. The desired signals contain a time-varying shot-noise process which has an average rate of 10^4 to 10^5 photons/bit. In our channel model, however, intense ambient light striking the detector leads to a steady shot noise having a rate of order of 10^7 to 10^8 photons/bit, even if a receiver employs a narrowband optical filter. Therefore, we can neglect the shot noise caused by signals and model the ambient-induced shot noise as a Gaussian process [17]. When little or no ambient light is present, the dominant noise source is receiver pre-amplifier noise, which is also signal-independent and Gaussian (though often non-white).

D. Photodiode

Photodiodes basically perform the opposite effect to LEDs and laser diodes. Instead of using electric current to cause electrons and holes to combine to create photons, photodiodes absorb light energy (photons) to generate electron-hole pairs, so creating an electric current flow.

E. DC motor

DC Motor or Direct Current Motor to give it its full title, is the most commonly used actuator for producing continuous movement and whose speed of rotation can easily be controlled, making them ideal for use in applications were speed control, servo type control, and/or positioning is required. A DC motor consists of two parts, a Stator which is the stationary part and a Rotor which is the rotating part.

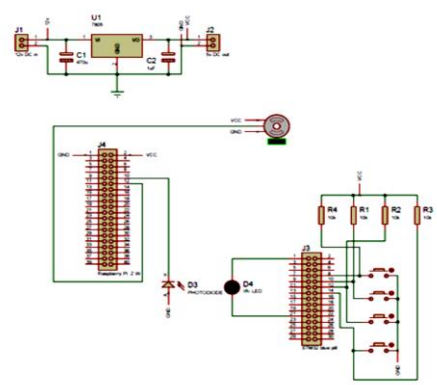

Fig. 3. Circuit diagram

With the circuit complete, various softwares are required for the system to operate. This consists of parts like; data packaging, hardware control, encoding and decoding, error handling and synchronization. With the appliance of Linux network module, VLC technology can be used with any application that runs on a Linux computer. Since the set works with encoding and decoding of data, appropriate software is needed so as to complete it. This will handle packages in the system and ensure that each command is performed appropriately. The transmitter sends a preamble that is synchronized with the receiver and thus data is transmitted followed by a checksum. Once data is submitted, the command is applied or transmitter waits for a message. Once the receiver gets the message relayed, a signal is sent to the transmitter by applying the command. So as to handle any errors that may arise in the process, checksums are sent alongside data. If the sender checksum is identical to the one with a receiver, the message will be relayed thus enabling transmission of the next package. The procedure is carried out repeatedly until packets are successfully relayed and intended purpose is achieved.

5. Advantages of li-fi based systems

- *Speed and bandwidth:* Li-Fi can deliver multiple Gbps speeds in mobile devices. This next generation technology will drive wireless beyond any current capability, opening up unprecedented bandwidth.
- *Reliability:* Li-Fi provides enhanced reliability enabling interference-free communication and 1000 times the data density, dramatically improving the user experience.
- *Low latency:* Li-Fi currently offers latency by a factor of three times lower than Wi-Fi and can radically enable innovation, automation, and applications such as AR and VR.
- *Security:* Light can be contained, and secured in a physical space. Li-Fi enables additional control as Li-Fi offers precise localization for asset tracking and user authentication.
- *Localisation:* Li-Fi is fully networked, and each Li-Fi enabled light has its unique IP address which means advanced geofencing can be deployed simply in a Li-Fi network.
- Interference Free: RF is vulnerable to interference from a wide range of devices such as cordless phones, microwaves and *Neighboring Wi-Fi networks.* Li-Fi signals can be defined by the area of illumination, which means interference is much simpler to avoid and even stop altogether. This also means Li-Fi can be used in RF hostile zones such as hospitals, power plants and airplanes [9].

Li-Fi is the optical wireless communication for data, audio and video streaming in LEDs, this type of new invention can be encouraged to produce a safe and green technology.

6. Results

The main aim of the proposed model is to reduce or in future, remove the waiting period of the vehicles at the tolls. Successful simulation of the project was possible with minimum delay between the transaction and gate opening. Adequately good baud rates were achieved with no distortion in the received data.

7. Conclusion and future scope

Being the fastest means of relaying messages, VLC has been put to use in a number of fields. However, wired VLC is used in more instances as wireless VLC is limited to open spaces and cannot pass through fields that have obstructions like walls. This limits wireless VLC to indoor applications and few outdoor functions provided that no barrier exists between the sender of the message and the recipient.

- *Smart lighting:* With the infusion of technology with real estate development, smart homes have become a trendy topic. With VLC in housing, one will be able to connect to fast speeds of data transmission in the house and also have a cheaper source of bright light. With appliance of VLC in a building, one will not only cut on the cost of wires but also save the electricity costs.
- *Infrastructure and transportation:* Among the fields that highly apply visible light communication, the transport sector is on top of the list. Ranging from traffic signs, street lamps, and car LEDs VLC proves to be a great addition. Not only because the minimal wiring is required but also because the systems get to operate efficiently with minimal chances of damage. In vehicle indicators, VLC is used to send signals to the LED lights thus achieving communication between vehicles. The messages indicated via this medium include breaking warning, direction indicators, and hazard lighting. This, in turn, prevents road accidents and carnages.
- *Security purposes:* Unlike other media transmission of data, chances of messages being relayed via VLC getting intercepted are equally low. This given that one across the wall cannot access the messages getting delivered on the other side of the wall. This, in turn, reduces the ability of messages leaking as the messages will be accessed by people within a given door space. Additionally, this method is way faster than other methods present and thus few instances of delay of messages.
- *Mobile connectivity:* By directing a visible light to another device, a high-speed medium of data transmission is created. This medium is way faster than Bluetooth and equivalent transmission methods hence ability to transfer large data packets within a small duration of time.
- Healthcare sector: In hospitals, several machines will benefit from VLC as they will get less interference from radio waves from other machines. This will reduce interruption from other devices using radio waves hence easier operation. Li-Fi, unlike Wi-Fi, where a radio frequency is used, Li-Fi solely depends on the light so as to operate. With this, data is relayed faster and costs on wiring are saved.
- *Aviation:* Since radio frequency is warned against by several flights in passenger compartments, VLC would be a great replacement. This provided that LED lighting already exists in aircraft. Usage of VLC will reduce the overall weight of the plane and cut on wiring costs. Additionally, passengers will enjoy fast data connections hence easy communication in flight [4].

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