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DATA TRANSMISSION THROUGH SMART ILLUMINATION VIA "VISIBLE LIGHT COMMUNICATION TECHNOLOGY"

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Abstract— **Light has been around for millions of years. It has created us, has created life and has created all stuffs of life. We can't imagine life without light, light is everywhere, be it at home, at work place, meeting hall, hospitals, aircrafts, street lights, vehicles, traffic lights and so on. In recent years, the rapid development in solid state Light emitting diodes(LED's) material has given rise to next generation 5G data communication called LiFi alias Visible Light Communication or we can say a new WiFi. Thus, just by sitting under the light we can transfer data and access internet. Signals are transmitted from one system to another by using LED as a LiFi transmitter and photodiode as a LiFi receiver. Lifi is fully networked high speed wireless connection, it does not rely on specified frequency spectrum unlike wireless networks which are very much restricted. Lifi is based on Visible Light spectrum is which is,10,000 times faster in transmission of data, more secure and immune to EMI relative to radio waves. This paper presents a how lifi works, how its different, different scenarios in vehicle communication and prototype of how LiFi can be used by vehicles to communicate in highway navigation system, thus understanding the amenability. The Design is accomplished using Microcontroller, along with LiFi transmitter, the LED light is modulated with data signal, converted to binary form in order to support transmission over light source and the signal is received at receiver side by a photo detector, received signal is demodulated to get back the transmitted data conversion is done and data displayed/read out. A Numerical simulation and also experimental results are presented.**

Keywords – light emitting diode, vehicle to vehicle communication, visible light communication, light fidelity, photo detector.

I. INTRODUCTION

Undoubtedly, Wi-Fi is very eminent technology having vast applications encompassing both our personal and professional life. Like water and electricity wireless networks have become basic utility of our day to day life. RF communication has both pros and cons, on one side it provides connectivity among 5 billion cellular phones and 70,000TB of data transfer every year [1] on other hand due to its tremendous usage the RF bands are getting scarce, also RF signals are restricted at hospitals and aircrafts because of its hazardous effects. Several issues related to radio waves are listed below:

1) *Capacity :* We transmit wireless data through radio waves which are limited. Radio waves are scarce and expensive and we only have a certain range of it. With the advent of the generation technology as of like of 2.5G,3G,4G and so on we are running out of spectrum.
2) *Efficiency :* There are 1.4 million cellular radio base station's which consume massive amount of energy.Most of this energy is not use for transmission but for cooling down the base stations.Efficiency of such a base station is only 5% and that raise a very big problem.
3) *Availability :* Availability of radio waves or RF signals causes another concern as we have to switch off our mobiles in aero planes, it is not advisable to use mobiles at places like petrochemical plants, hospitals, defense areas and petrol pumps.
4) *Security :* Radio waves penetrates through walls and they can be intercepted. If someone has a knowledge and bad intentions than he may misuse it.

We have 40 billions of light box already installed and light is part of electromagnetic spectrum. Looking up at this in context of EM spectrum:

Table 1. Electromagnetic spectrum

Radio waves	Infra red	Visible	Ultra violet	X rays	Gamma rays

- Gamma rays are simply very dangerous and thus can't be used for our purpose of communication.
- X-rays are good in hospital and can't be used either.
- Ultra –violet rays are sometimes good for our skin but for long duration it is dangerous.
- Infra red rays are bad for our eyes and are therefore use at low power levels.
- We have already seen shortcoming of radio waves.

So we are left with only visible light spectrum.

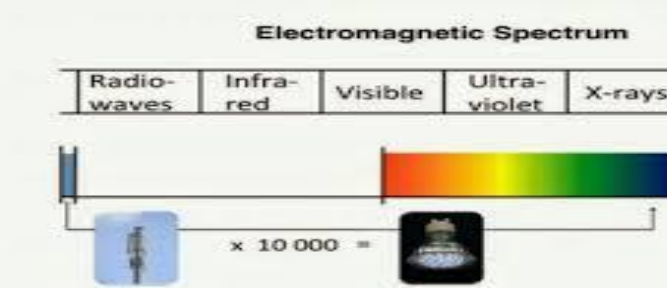

Fig 1 Electromagnetic spectrum

Thus an alternative technology "Visible Light Communication/Light Fidelity(LiFi)" is been developed for short range communication(1000meters) [1].

Comparisons between Li-Fi and Wi-Fi

LI-FI is a term of one used to describe visible light communication technology applied to high speed wireless communication. It acquired this name due to the similarity to WI-FI, only using light instead of radio. Wi-Fi is great for general wireless coverage within buildings, and li-fi is ideal for high density wireless data coverage in confined area and for relieving radio interference issues.

Table 2. Comparison between Lifi and WiFi

COMPARISON BETWEEN LI-FI VS. WI-FI

S. No.	Parameters	Wireless Technologies	
		Light Fidelity	Wireless Fidelity
1.	Speed for data transfer	Faster transfer speed (>1 Gbps)	Data Transfer speed (150 Mbps)
2.	Medium through which data transfers occurs	Used Light as a carrier	Used Radio spectrum
3.	Spectrum Range	Visible light spectrum has 10,000 time broad spectrum in comparison to radio frequency	Radio frequency spectrum range is less than visible light spectrum.
4.	Cost	Cheaper than Wi-Fi because free band doesn't need license and it uses light.	Expensive in comparison to Li-Fi because its uses radio spectrum.
5.	Network topology	Point to point	Point to point
6.	Operating frequency	Hundreds of Tera Hz	2.4 GHz

The current wireless technologies that can be used for transferring data between devices today, i.e. Wi-Fi, Bluetooth and IrDA. Only Wi-Fi currently offers very high data rates. The IEEE 802.11.n in most implementations provides up to 150Mbit/s (in theory the standard can go to 600Mbit/s) although in practice you receive considerably less than this. Note that none out of three of these is an optical technology.

Related work

Advancements in Optical communication technology has opened up doors for many projects and applications, which include use of LiFi in hospitals, aircrafts, aviation, defense, & security, hazardous environments, mobile connectivity, smart lighting, vehicle and transportation and underwater communications. Tremendous amount of research work is going on these fields [3].

Use of VLC in highway navigation has revolutionized the use wireless networks or GPS as Many cars already have LED lamps. Traffic signage, traffic lights, and street lamps are adopting the LED technology so there are massive applications opportunities here. This project demonstrates how VLC can used in vehicular communication.

Vehicular communication systems are networks in which vehicles and roadside units are the communicating nodes, providing each other with information, such as safety warnings and traffic information. They can be effective in avoiding accidents and traffic congestion. Vehicular communications is usually developed as a part of intelligent transportation systems (ITS). Several systems adopted [5] for automobile communication are listed below:

1) 5.9 GHz DSRC Wireless

Dictated short range (1000 meters) communication (DSRC) for Intelligent Transportation Systems (ITS) has opened the door to hundreds of projects and applications of vehicle to vehicle communication around the world. In 1999 the US federal communication commission reserved licensed bandwidth of 75 MHz spectrum around 5.9 GHz that allows information to be exchanged among vehicles regardless of their brand [4]. This spectrum will provide very high data rates with low latency and high security [1] in matter of supporting this wireless communication between vehicles, set of standards were needed to ensure that vehicles understand each other, for example, IEEE 802.11p-2010 standard of wireless link for V2V communications and IEEE P1609.x/D5.8 protocols for information exchange across the wireless link [3].

2) Wireless Ad Hoc Networks

Vehicular Ad-hoc network (VANET) technology was introduced in 2000 as a specified application of mobile ad hoc networks (MANETs). This network uses vehicles in the road as a router or node in order to communicate at a distance of 100-300 m using several protocols. The networks basically rely on Wi-Fi, WI-Max and DSRC technologies in addition to 3G networks [2]-[3].

3) Without Wi-Fi or GPS

Husain Fidvi et. al [4] have proposed vehicle to vehicle communication system that does not require a tracking global positioning System or even a Wi-Fi or 3G wireless connectivity. It was proposed to use Programmable Interface Controller (PIC) sonar which sends 40 KHz short pulse of sound that is undetectable by human ear. The echo of the signal will be detected by microcontroller. The distance is calculated by the time required for echo signal to be transmitted and received [4].This technology is demonstrated in the figure below.

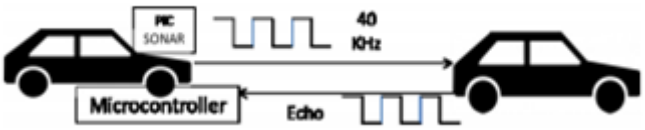

Fig. 2 Communication between Vehicles Using Sonar Pulse

Several research works have been attempted in literature for vehicle to vehicle communication using an advantage of light. As light frequency spectrum is huge, it is beneficial to be adopted in a short-range wireless communication. In this project a system is developed in order to build a cost effective yet inexpensive mechanism for vehicle to vehicle communication through the use of an optical wireless communication medium, which is light. In fact, the usage of LED eliminates the need of complex wireless networks and protocols. [6]

The synopsis is organized as follows. Section II explains the details of the proposed system design. In section III, the system

diagram is explained. Section IV provides details about advantages and applications. Finally, a brief conclusion.

II. PROPOSED SYSTEM

The proposed system demonstrates a prototype of how visible light can be used for communication.

Basic Idea

Remote control has as IR-led and creates a single data stream operating at High speed data rates of 10000 b/s to 20000b/s the basic idea is to replace remote control with light box. With this technology we transmits 1000's of data stream in parallel at high speeds.

Flickering lights are annoying but they may have an upside. Visible light communication(VLC) uses rapid pulses of light to transmit information wirelessly. All we need to do is to replace inefficient fluorescents lights with this new dignitaries of LED lights. It is a semi conductive e-device. The LED bulb will hold a microchip/controller that will do the job of processing the data. Light intensity can be modulated at very high speeds to send data with tiny changes in amplitude.

The system is implemented using LED lamps at the downlink transmitter. These devices are normally used for illumination only by applying a constant current. However, by fast and subtle variations of the current, the optical output can be made to vary at extremely high speeds. This very property of optical current is used in Li-Fi setup. The operational procedure is very simple-, if the LED is on, you transmit a digital 1, if it's off you transmit a 0. The LEDs can be switched on and off very quickly, which gives nice opportunities for transmitting data. Hence all that is required is some LEDs and a controller that code data into those LEDs. All one has to do is to vary the rate at which the LED's flicker depending upon the data we want to encode.

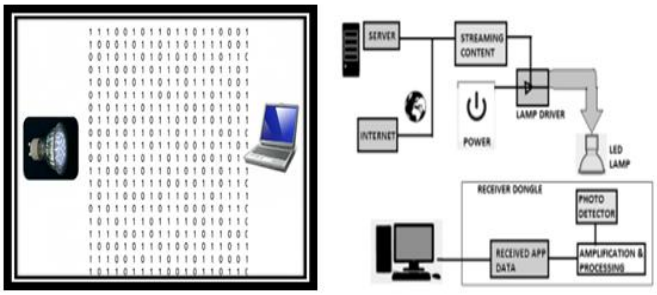

Fig3. Working Principle of Li-Fi

The proposed system uses visible light to communicate and requires a VLC transmitter & receiver at the rare and front ends of the vehicles. Vehicles "talk" to each other exchanging information such as vehicle size, position, speed, heading, lateral/longitudinal acceleration, yaw rate, throttle position, brake status, steering angle, wiper status, turn signal status, enabling safety and mobility applications. In order to avoid traffic jam, accidents and other automobile related issues vehicles communication among themselves. For time being let us consider 2 scenarios

A. First Scenario

As shown in figure 4, when vehicle 1 is braking, the speed meter in the vehicle will be sensing that the current speed is lower than the previous speed. Thus, a message will be sent through the transmitter which is placed in the rear lights to vehicle 2. The message will be received by vehicle 2 using the photodiode which is placed at the front of vehicle 2. A notice of (Slow DOWN) will be displayed in vehicle 2 using an LCD.

Fig. 4 First scenario of vehicle to vehicle communication using Li-Fi

B. Second Scenario

As shown in figure 5, when vehicle 1 is in T- junction, it will keep sending its speed-information to vehicle 2 using the LED at the headlights. The speed-information will be received by the photodiode in vehicle 2 and compared to vehicle 2 speed's. If vehicle 2 is about to cross the junction while vehicle 1 is moving with a high speed, the driver will be alerted to check the other vehicle which is around in the area.

Fig. 5 Second scenario of vehicle to vehicle communication using Li-Fi

III. SYSTEM DAIGRAM

The block diagram of transmission part of the Li-Fi system of proposed system is shown in fig6&7. The data source continuously monitors and checks for parameters like speed, distance and so on, if data from the sensor is peak to peak AC voltage so it will be converted to DC voltage to be readable by the microcontroller. Then the data will be processed by microcontroller (e.g. to compare between the current and previous speed). New processed data will then be transmitted to the LED driver. LED driver will make the current constant to protect LED. Then, data will transmit by the LED light as carrier. the transmitter side will transmit the data. It is connected to the array of LED's through which the data is transferred. Li-Fi will transmit the data through illumination of the LED by taking the fiber out of the fiber optics by sending data through the LED light bulb that varies in intensity faster than the human eye can follow. The LED blubs will hold a micro-chip that will do the job of processing the data. The light intensity can be manipulated to send the data by tiny changes in the amplitude. This technology uses visible spectrum of light, a part of the electromagnetic spectrum that is still not greatly utilized. In fact this technology transfers thousands of

streams of data simultaneously in parallel in higher speed with the help of the special modulation using a unique signal processing technology. The light used to LED is connected to the transmitter and light sensor to the receiver. LED, photo detector registers a binary '1' for ON else its '0' for OFF. The LED'S can be switched ON and OFF very quickly which gives nice opportunities for transmitting data, this is very helpful in transmitting data to many vehicles at a single point of time. LED is light illuminating Device and its intensity can modulate in a way that indictable to the human eye. transmit the data is called D-light by professor Harlad Hass, the inventor of Li-Fi.[6].

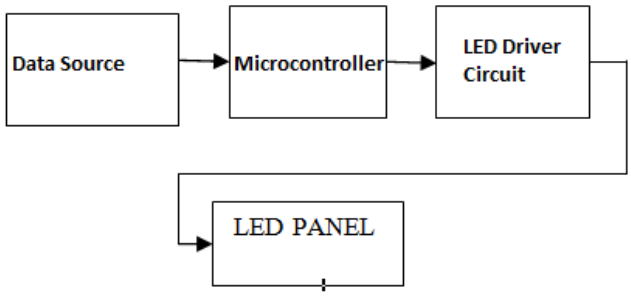

Fig. 6 VLC Transmission Part

The receiver part of the Li-Fi system is shown in Fig. The receiver in vehicles will intercept these incoming data with the help of Photodiode. Photo detector is used primarily as an optical receiver to convert light into either current or voltage. PIC microcontroller can be programmed to carry out a vast range of tasks. The receiver side will receive the data that is transmitted through tand display on The LCD which will provide for assistance to the driver. The transmitted data can be seen by on display unit or a Hyper Terminal software in another laptop.

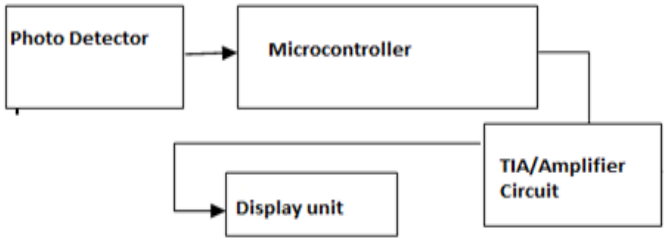

Fig.7 VLC Receiver Part

1.VLC TRANSMITTER

The transmitter is a main component in the process. It has many components

1.1 Light Emitting Diode

LED'S are semiconductor electronic device. Tiny LED is being developed that could do simultaneously many task such as deliver data, display information and provide lightning. It is a next stage to research visible light to transmit essentially

means that we take new generation of energy saving light bulbs which is made of LED and we use same illumination end for data transmission and not only data transmission but very high data transmission. The tiny LED is made from gallium nitrate, a manmade semiconductor material. It's very good characteristics that its intensity can be modulated at a very high speed that means switched ON and OFF at a very high speed which is the basic fundamental property used in LIFI.

1.2 Crystal Oscillator

The crystal oscillator used in this transmitter works at a frequency of 11.05MHz.It provides with a constant and stable frequency so as to maintain a standard clock pulse in the circuit.

1.3 Microcontroller

It is a common and an important component in both transmitter and receiver. It has 256 x 8 bits internal RAM, it has an In system reprogrammable flash memory of 8000 bytes. The microcontroller is programmed with the data of highway routes. In transmitter it interfaces with LED and in receiver it interfaces with photodiode and LCD.

2. VLC RECEIVER

Receiver receives signal through photo detector and signal processing is done in the receiver section. Receiver ignores constant light because receiver is interested only in certain changes or modulated intensity at very high speed. The certain changes in amplitude in light bulb occur at the same time of illumination of light bulb and transmission of data. Other components of the receiver are buzzer, LCD.

2.1 Photo Detector

The Photo Detector is a sensor of light and electromechanical energy. It works in forward bias by absorbing light. The photo detector absorbs light from the light emitting diode. The photo detector picks up the signal which is converted back into a data stream and sent to the client. The client can communicate through its own LED output or over the existing network.

2.2 Buzzer

Buzzer in the receiver alerts whenever it intercepts an incoming signal , in this case when the photo detector comes in contact with the visible light of the LED.

2.3 Liquid Crystal Display

LCD is an electronic visual display which uses light modulating properties of liquid crystals as they do not emit directly. It is capable of displaying fixed and flat images. The LCD used is 2x16 grids in dimension. It displays the data of highway routes from the microcontroller into readable form by parallel communication.

2.4 Voltage Regulator

The voltage regulator is designed to automatically maintain constant level of voltage. It can be a simple feed forward or have a negative feedback loop. Voltage controller has been used in both transmitter and receiver. The controller used here is to step down the voltage supplied in transmitter and receiver respectively

Working

The highway navigation project is based on LI-FI. Two basic components of any project are its transmitter and receiver. The transmitter we have used here is a smart pole. It has many components such as LED which is a high glow white light emitting diode, crystal oscillator which is working at 11.085MHz to provide constant frequency so as to maintain constant clock pulse, voltage regulator, which is giving a

constant voltage of 5V by stepping down the supply voltage from transmitter and receiver. The microcontroller present is a common component in both transmitter and receiver. The microcontroller has the data of highway routes fed in. It is data programmed in it. It also contributes in interfacing. The Receiver in the project is a moving vehicle or any ordinary car which has photo detector, buzzer.

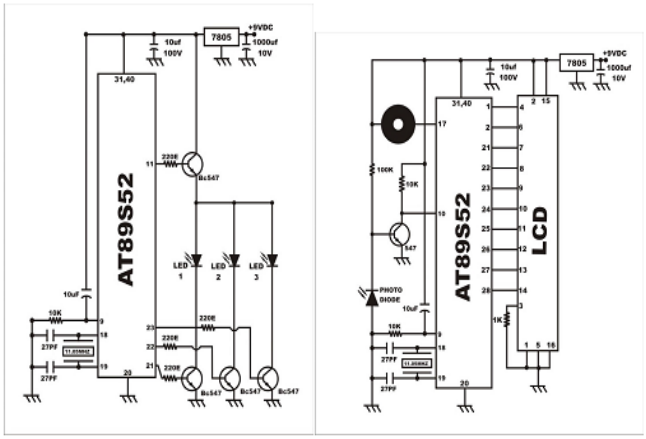

Fig 8 Interfacing diagram of VLC Transmitter and Receiver

The photo detector absorbs the incoming light from the LED's and passes onto the microcontroller which intercepts the light into data to visible on the LCD in the vehicle. The buzzer will beep as soon as the data is received by the photo detector.

To summarize, the project is basically a transmission and reception of information and data in form of light energy which is used for navigation.

IV. ADVANTAGES AND APPLICATIONS

ADVANTAGES

i. It is used to transmit data serially at 38400 baud rate.
ii. Distance of 1 feet to 10 feet can be achieved.
iii. No inference by radio waves.
iv. It works under low power requirement.
v. LIFI is faster than WIFI**.**
vi. There s no effect on human health.
vii. It is highly secure compared to Wi-Fi because data cannot be intercepted without a clear line of sight.
viii. More secure Prevent piggybacking.
ix. Can be used in sensitive areas like airplane hospitals petrochemical industries.

APPLICATIONS OF Li-Fi

i. Smart Lighting

Smart buildings require smart lighting. Smart lighting with VLC provides the infrastructure for illumination, control and communications and will greatly reduce wiring and energy consumption within a building.

ii. Mobile Connectivity

By pointing a visible light at another device you can create a very high speed data link with inherent security. This overcomes the problems of having to pair or connect and provides a much higher data rate than Bluetooth or WiFi.

iii. Hazardous Environments

Communicating in areas where there is risk of explosions can be a problem (e.g. in mines, petro-chemical plants, oil rigs etc.) . VLC is inherently safe and provides both safe illumination and communications.

iv. Vehicle & Transportation

Many cars already LED lamps. Traffic signage, traffic lights, and street lamps are adopting the LED technology so there are massive applications opportunities here.

v. Defence & Security

The ability to send data quickly and in a secure way is the key to many applications. The fact that the visible light cannot be detected on the other side of a wall had great security advantages.

vi. Hospitals & Healthcare

There are advantages for using VLC in hospitals and in healthcare. Mobile phones and WiFi's are undesirable in certain parts of hospitals, especially around MRI scanners and in operating theatres.

vii. Wifi SPECTRUM RELIEF

WiFi's have got faster over but cannot keep up with demand for wireless data. VLC can provide data rates greatly in excess of current WiFi and this can be done at low cost since the RF components and antenna system have been eliminated.

viii. Aviation

VLC coverage inside aircraft. Radio is undesirable in passenger compartments of aircraft. LEDs are already used for illumination and can also be used instead of wires to provide media services to passengers. This reduces the aircraft construction costs and its weight.

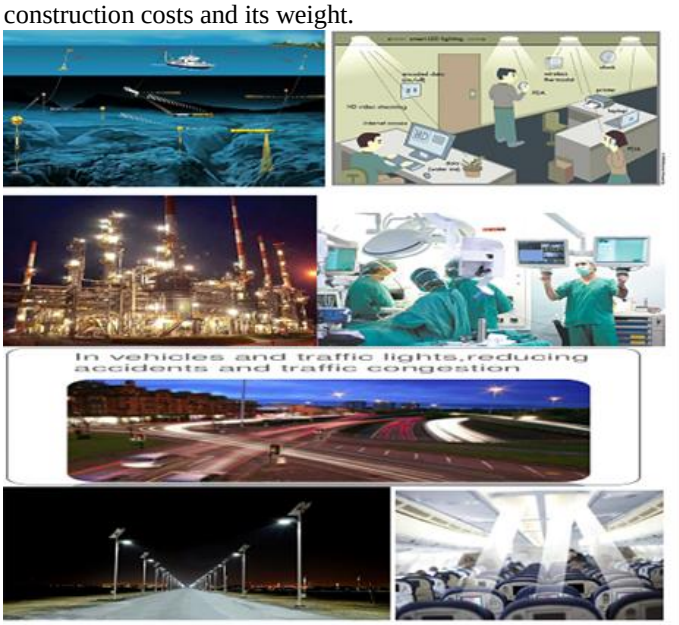

Fig 9 Li-Fi Applicaton scenarios

i. Underwater Communications

RF does not work underwater but visible light can support high speed data transmission over short distances in this environment. This could enable divers and underwater vehicles to talk to each other. Navigation, Submarine and ship to ship communication.

ii. Location Based Services

Each visible light information source can be uniquely identified, so the location of any VLC device can be identified quickly and accurately.

V. CHALLENGES AND FUTURE SCOPE

The main challenge in implementing the proposed system is the interference due to other lighting sources and the distance achieved between the transmitter and receiver with the maximum distance of 65 cm. Presence of light and clear line of sight (LOS) is very necessary. Also, Noise interference due to the influence of the fluorescent light and indirect sunlight in the room during the experimentation, reduces the quality of the received signal.

The transmitter circuitry can be improved by including the amplifier, using lens in the receive circuitry, high efficiency solar panel and noise cancellation circuit, the audio/video data transmission can be achieved up to few meters without the ambient light interference and hence high data rate can be achieved.

Eco friendly VLC can be implemented by using solar panel as a surrogate to photodiode optical sensor hence reducing the requirment of photodiode and other external power supplies to bias the circuit. Hence, leading to low installation cost and less environmental hazards.

In this project focus on downlink transmission, tremendous amount of work is going to provide uplink connectivity, by using an optical transceiver unit at both the transmitter and receiver side which requires serious modifications, along with access to internet server. All one needs to do is to connect the VLC system to the server using different protocols/techniques. [6]. Raspberry an credit card sized minicomputer can be used instead of microcontroller, as it is user friendly and increases the processing speed.

In addition, an internal circuit consisting of speed sensors, brake circuitry, obstacle detections sensors may be included or embedded along with VLC system, to continuously monitor and check for all the parameters like speed limit, distance between two vehicles, obstacle, etc and take necessary actions like automatically apply brake if any obstacle is a few meters ahead, automatically slow down the speed of vehicle, when the driver becomes ignorant about his safety.

This project has very wide scope in near future as it can help navigate better not only on highways but anywhere we want. This VLC based highway navigation can also be modified to navigate on a different level, like navigation for people at

night, blind people, deaf and dumb people etc.

Further enhancements can be made in this method, like using an array of LEDs for parallel data transmission, or using mixtures of red, green and blue LEDs to alter the light's frequency with each frequency encoding a different data channel. Such advancements promise a theoretical speed of 10 Gbps – meaning one can download a full high-definition film in just 30 seconds. Light Flickers 120times/sec[6]

VI. CONCLUSION

The possibilities are numerous and can be explored further. If his technology can be put into practical use, every bulb can be used something like a Wi-Fi hotspot to access and transmit wireless data. The concept can be executed with existing trends and techniques used for automotive communication. This project aims to propose a small scale prototype which provides solution to reduce accidents by sending data through illumination using VLC technology. It is economical as it requires optical visible light for communication and hence it overcomes the limitation of RF spectrum by promising and proceeding towards cleaner, greener, safer and brighter future.

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