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An Integrated Vehicle to Vehicle Communication Control System Using Li-Fi Technology

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***Abstract*—In recent years, vehicle-to-vehicle communication has become a significant aspect of detecting anomalous environmental activities through many wireless devices. Transferring data from one place to another is one of the important daily activities. Though using many wireless devices like Wi-Fi-Bluetooth readers helps us connect, there are also many limitations like providing signal only in the shortest range with fewer security features, speed, and range between the communication. These challenges will give rise to the solution using recent technology developed by Light Fidelity (Li-Fi), which will concise the vehicle-to-vehicle communication to optical networking technology. The proposed system with Li-Fi technology includes an ultrasonic sensor, gas sensor, vibration sensor, temperature sensor, LCD display, normal robot setup, Li-Fi transmitter, and receiver. If any abnormal circumstances are in front of the vehicle, the vehicle will be stopped, and a notification will be sent to the beside vehicle. Li-Fi transmitter and receiver are connected to the microcontroller's UART (Universal Asynchronous Receiver/Transmitter) function. In the proposed system, the object is detected using a Machine Learning (ML) algorithm called the Haar Cascade classification algorithm, where a cascade classification process is trained from the collection of positive and negative images. The proposed system increases the performance metrics like data transfer speed and decreases the time for transferring the communication data. Finally, the system saves many lives of persons from road accidents.**

***Keywords*— Vehicle-to-vehicle communication; Wi-Fi, Li-Fi; Haar Cascade classification; accident prevention.**

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I. INTRODUCTION

Communication has become an incredibly significant aspect of many wireless devices in recent years. Transfer of data [1] from one place to another is one of the important daily activities. Many wireless devices like Wi-Fi [2] and Bluetooth help us connect two or more entities around our environment. At the same time, there are many limitations like providing signals only in the shortest ranges with fewer security features, speed, and range between the communications. These challenges will give rise to solutions using recent technology developed in light fidelity.

Our new proposed system uses light-emitting diodes to transmit data, the most important part of the wireless network. The Li-Fi costs are more efficient than the network. We detect the vehicle environment and driver's activities via different sensors; to predict anomaly data of the front vehicle. In the wireless system, communication will be fast and cheap. Li-Fi often communicates with the LED [3] lights, and some accidents are prevented. This technology will make our lives more safely shortly.

A. Machine Learning

Machine learning is a tool for converting information into knowledge about a hidden pattern within complex data, and data power is brought out for the first time. Later, the machine is fed with a large amount of data. A computer program such as data is accessed, and tasks such as prediction and detection are performed automatically. The process is started when the data is trained into a selected algorithm.

To develop the machine learning algorithm, it needs trained data that can be known or unknown. The algorithm, after testing, predicts whether it works correctly, and the new input data is fed into a machine learning algorithm. Increasing

accuracy will produce the most optimal answer, enabling the algorithm to be continuously learned.

For real-time processing, developed data will be efficient and fast so that it produces an accurate result. The rapid rise in use cases enables analysis with big data chunks, and it will be important for machine learning in modern life. Several machine learning algorithms are distinguished in form or function by their learning style or similarity. While grouped by their style or purpose, all combinations of machine learning algorithms consist of the following parameters: the basic concept of the domain to be understood.

In this new era, machine learning is an interesting branch of Artificial Intelligence [27], [28]. It brings out the power of data differently, like Facebook and Instagram recommending the stories in the list and designed to enable computer systems to continuously learn and enhance their knowledge through the development of computer programs that can access and automatically perform data through prediction and detection.

B. Internet of Things (IoT)

The IoT refers to the many numbers of devices connected around the world by using the Internet to share and collect data. It makes the world smarter and more responsive and is also used for merging the physical and digital universe. During the 1980s and 1990s, the idea of adding intelligence and sensors to objects was discussed. This system means transmitting the data without the need for interactions such as human to human or a computer by interconnecting the various computing devices. These devices are classified into many types, such as mechanical and digital infrastructure with specific identifications.

The technology has grown with the integration of various innovations such as embedded systems, commodity sensors, and machine learning. It has helped many things possible on the Internet through many conventional sectors. On the consumer market, this technology is more similar to 'smart home' products supported by one or more specific ecosystems and can also be regulated by echoscope devices, for example, home protection systems and home appliances. One of the main applications of a smart home is used a care for disabled and older people. The home systems use support devices to deal with the different handicaps of the owner. Voice control will help users with restrictions of accessibility and vision. Sensors that track emergencies like falls or seizures can be part of these features [23], [24]. Intelligent home technology is used to provide consumers with greater flexibility.

C. Environmental Monitoring Using Sensors

Sensors are devices that detect changes or events that send information to other electronics around the environment. Sensors such as touch-sensitive elevator buttons and lamps are used in everyday objects. Diverse sensors such as temperature, ultrasonic, vibration, gas, proximity, IR, pressure, and light sensors are used.

D. Li-Fi Technology

The major factor of technology includes digital communication and the Internet, which are considered the most important nowadays. Complexity in the network [4] traffic and bandwidth storage in the network leads to an exponentially increase in the number of devices accessed by the network. Due to the complex risk, Wi-Fi has a high-frequency bandwidth and storage capacity risk. Wireless communication has introduced a new concept known as light fidelity, which is a high-speed communication network.

The Principle of Visible Light Communication (VLC) applies to Li-Fi technology [5], [29]. It uses various types of spectrums, such as ultraviolet and infrared radiation. This technology has a simple technique when the LED is on, there will be data transmission, and when there is no data transmission, the LED will be OFF.

For encoding the light intensity used in transmission, the sensitive detector photographs are received to signal detection. The light signal, which is decoded, is converted into electronic form. This technology is used in many fields such as aircraft and the navy and is also used by underwater divers. Shortly, this technology is getting very popular and useful; for example, Microsoft, NASA, ESA, and apple have started working with many big organizations.

E. Related Works

Previous studies used the strategies such as the Internet of Things (IoT) and Local Area Radar Sensor [6], [7]. These technologies are used to support which follows up in horizontal and vertical directions of an automated vehicle. First, a linear feedforward and feedback controller is designed to keep track of the previous vehicle speed and ensure a safe inter-vehicle span. Then an estimation method is proposed to determine the vehicle based on historical data transmitted by V2V. The merits of this system are that cost will be effective, and robustness will be efficient in the case of data transmission.

A new approach to wireless data transmission Wi-Fi using visible [8] light developed a design for an efficient and reliable data transfer medium. The end users are exponentially increasing, and the spectrum of radio waves is decreasing rapidly. The optical method is used as an alternate method to overcome the constraints of wireless fidelity and solve crises. This paper suggests that Li-Fi Technology, a cost-effective and working application, has solved the constraints of current data transmission technologies. Moreover, it also offers a platform for existing infrastructure focused on alternate data transmission.

Indoor [9] wireless visual sensor network on light fidelity communication has proposed a concept that is a collective node network equipped with cameras and operated by batteries. Such nodes will store, process, and transmit many images and video data to each other and to the sink. In both functions, such as transmission and processing, the energy is reduced; thus, such a network's life span is increased to transmit and receive data using Light Fidelity Technology. This system ensures high-speed, high-level security, low energy consumption, and good visual quality in multimedia.

Navigation [10] system using light fidelity proposed that the range of the Internet has been rising rapidly with the usage of radio waves. Transmission of data used in the long-distance will make use of this spectrum. As the number of users increases with high-speed connectivity, it has become very tedious to keep up with the demand. The speed of data communication is limited, and it leads to a shortage of radio wave bandwidth. Visible light communication (VLC) [30] will be an alternate and advantageous replacement. While

navigating at night, drivers face such issues due to network connectivity issues and the low battery of mobile phones. This system has a bandwidth of large frequency.

Survey [11] on Light Fidelity, the paper proposed that the most important activity is transferring data from one device to another through wireless communication. According to the spectrum, such as radio, the wave is very harmful and is used only as an audio wave for communication. The adjustment of frequencies is to be done properly, and there are only fewer and restricted radio channels available as opposed to the Internet. The RF waves operate with Wireless Fidelity and are generally used in all common areas such as restaurants and businesses.

As data transmission rises, Wi-Fi faces power, quality, productivity, and security issues. The electric fields also influence the atmosphere and health. A presentation on visible light communication was held at the University of Edinburgh to overcome such issues. Li-Fi is also a hetero-directional high-speed network that transfers the data by light rather than by RF wave. For Li-Fi we use transmitting LED bulbs instead of Wi-Fi routers. LED emits the data while LED flickers are completely undetectable to the human eye by producing a binary code 1s and 0s. Electronic machines with laser diodes are used for processing the data at the receiver end.

Understanding Li-Fi effect on LED light Quality [12] has proposed a concept that the emitted light quality of an LED is presented in the Li-Fi modulation technique. The process developed tends to be long, costly, and consumes more time. Then it is an available tool for designing [13] Li-Fi systems compliant with lighting and data communication requirements. The illumination of LED takes a link between the quality of light and the well-being of the user. This has been very helpful for the LED manufacturers in a given environment or an application for designing LEDs. Therefore, when the Li-Fi uses this LED illumination, expected light quality will be prevented.

What is Li-Fi? [16], [25], [26] proposed to clarify the difference between Visible Light Communication and Light Fidelity. The need for data transmission service has led to a lack of radio spectrum under 10 GHZ have become inadequate. In order to increase the possibility of viewing line (LoS), systems should be built, usually with directional antennas and the use of femto cells. From the device ability perspective, the need for small cells is not a concern. The key factor in enhancing network efficiency in the new cellular contact was the reduction of cell sizes. This makes use of higher frequencies for Earthly contact a realistic choice, contrary to the general understanding.

However, one downside is that providing support [14] infrastructure for smaller cells is necessary. The movement towards the transition to higher frequencies of the electromagnet spectrum is continuing. Li-Fi uses wireless high-speed light-emitting diodes (LEDs), and the use of optimized DCO-OFDM modulation has been demonstrated at speeds exceeding 3 Gb/s from a single micro-LED.

F. Motivation

In 2018, an incident occurred in Central China due to heavy fog that caused a massive pileup on a national highway. During the incident, 28 trucks crashed into each other, and nine died in this accident. This happened as there was no clear site of the road because of the thick fog. So, if there is communication between the vehicles, then the accident can be avoided. This shows that the communication between the objects from one place to another is one of the important daily activities. Many wireless devices like Wi-Fi and Bluetooth help us connect two or more entities around our environment. At the same time, there are many limitations like providing signal only in shortest ranges with less security features, speed, and range between the communications.

G. Existing System

In the existing system, vehicle-to-vehicle communication uses a radar sensor [15] followed up in horizontal and vertical directions. With the aid of historical data, movement transmitted by vehicle to vehicle is proposed to measure the trajectory of the preceding vehicle route of the estimation process. The front-wheel predictive control method is applied to regulate the steering angle. This system exhibits consistent efficiency that is only accompanied by radar and V2V.

By analyzing longitudinal and lateral vehicle, which gives method of positioning and road marking of high precision. The overall framework is used for the expansion of available vehicle areas. Transmission of data from one place to another place is done with the help of Wi-Fi. Drawbacks in Existing System has a major limitation. Communication is done through (Wi-Fi) which has disadvantages, such as:

- This system has fewer security features, so it leads to the occurrence of denial-of-service attacks.
- Communication using Wi-Fi technology [16] will decrease the data transfer rate and power.
- The consumption of heat and power is also high; thus, it reduces the battery life of mobile devices.
- The signals transmitted by Wi-Fi are only in the shortest range.

II. Materials and Method

The concept of an integrated [17] vehicle to vehicle communication control [18] system with help of Li-FI technology. The proposed system includes ultrasonic, gas, vibration, temperature, LCD Display, normal robot setup, Li-FI transmitter, and Li-Fi receiver. If any abnormal circumstance is in front of the vehicle, the following vehicle will immediately be stopped, notifications will be sent, and the forthcoming accident will be prevented. The ultimate objective and purpose of the project work is described briefly as follows:

- The initial process involves data (Driver's drowsiness, alcoholic level, distance, and LPG leakage) generated using sensors. Then the processed data is generated.
- Four sensors (ultrasonic sensor, vibration sensor, gas sensor, temperature sensor) are used to detect data.
- Ultrasonic sensor is used to find the distance of the front vehicle, and a vibration sensor finds the vehicle vibration.
- The gas sensor measures the alcoholic level of the driver and also the leakage of LPG
- The temperature sensor is used to detect the degree of fog and mist.
- Haar cascade classification algorithm has four stages: 1) selection of Haar features, 2) integral image is created, 3) best features are selected using Adaboost

training, and 4) cascade classifier is used for boosting. This algorithm is used to detect face recognition to identify driver's drowsiness.

- Collect the transmitted data from the Li-Fi transmitter using LI-FI technology, and data passes from one vehicle to another. Communication has occurred with the help of photovoltaic cells.
- After receiving the data, an alarm is raised, then the notification will be displayed behind the vehicle, and thus, the accident will be prevented accordingly.
- Finally, the performance analysis is done by analyzing the accident detection accuracy, data transfer fibrate, and speed of data transfer.

A. System design and operational workflow

Figure 1 shows the architecture diagram of the proposed system, and Figure 2 depicts the proposed block diagram of the vehicle-to-vehicle communication control system with the help of Li-Fi technology. Suppose the front vehicle is disturbed by any means of collision, driver's drowsiness, drunken drive, or any mechanical problem, an accident may occur suddenly.

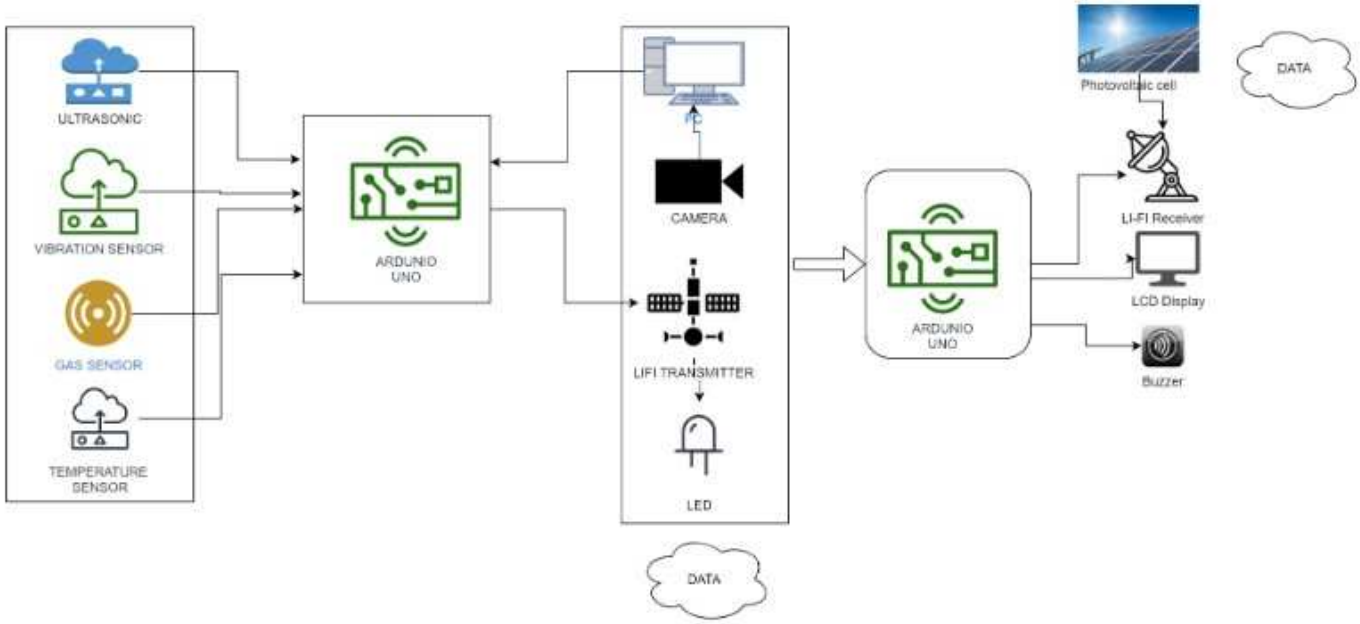


Fig. 1 Architecture diagram

At that time, the vehicle cannot notice or monitor the problem going to occur in front of the vehicle, so such vehicles also go into difficult conditions. In this modern technology, such tragedies cause a huge loss of human life. Using Li-Fi technology, we have to avoid these issues with the help of communication. The communication process involves a collection of the front vehicle information or data that can be transmitted into the following vehicle through Li-Fi transmitter and receiver. For that, the data is generated using sensors. The generated data can be processed with some constraints; finally, the abnormal data values are collected. Sensors continuously read the values from the vehicle.

In the application, we are using four sensors temperature, gas, vibration, and ultrasonic. In this system, we also detect the driver's drowsiness with the help of Haar cascade classifier algorithm. The anomaly data are stored in Arduino UNO and sent to the Li-Fi transmitter, then transmitted to Li-Fi receiver. A receiver receives the data with the help of a photovoltaic cell. Then alarm will be raised, and a notification will be sent to the following vehicle [19]. It is displayed on LCD. In this system, nearing accidents will be avoided. Using this technology, we get higher data transfer speed, data transfer rate, and data reliability than the Wi-Fi and Radar technologies.

Figure 3 depicts an operational workflow diagram; we are collecting the driver's [20] data to establish the communication between vehicles regarding suspicious behavior while driving. The object is known as data collected by sensors with information like distance, temperature, level of LPG, mist, fog, driver's drowsiness, etc. Then the data is fed into a processing system. This data has been referred to as data processing. Eventually, the collected and transmitted data is finished in this method.

In the second process, anomaly data values are measured with the help of sensors. The ultrasonic sensor is used to find the distance of the front vehicle. A vibration sensor is used to find the vehicle vibration. A gas sensor is used to find the alcoholic level of the driver, and the temperature sensor is used to find the degree of fog and mist. Through these various types of sensors, anomaly data is detected.

In the third process, Image recognition is done using Haar cascade classification, which involves four steps as follows. Haar features will be selected, creation of integral image takes place, then the best features are selected using adaboost training and finally cascade classifier is used for boosting. Hence from the algorithm, best features are identified from the live image of the driver.

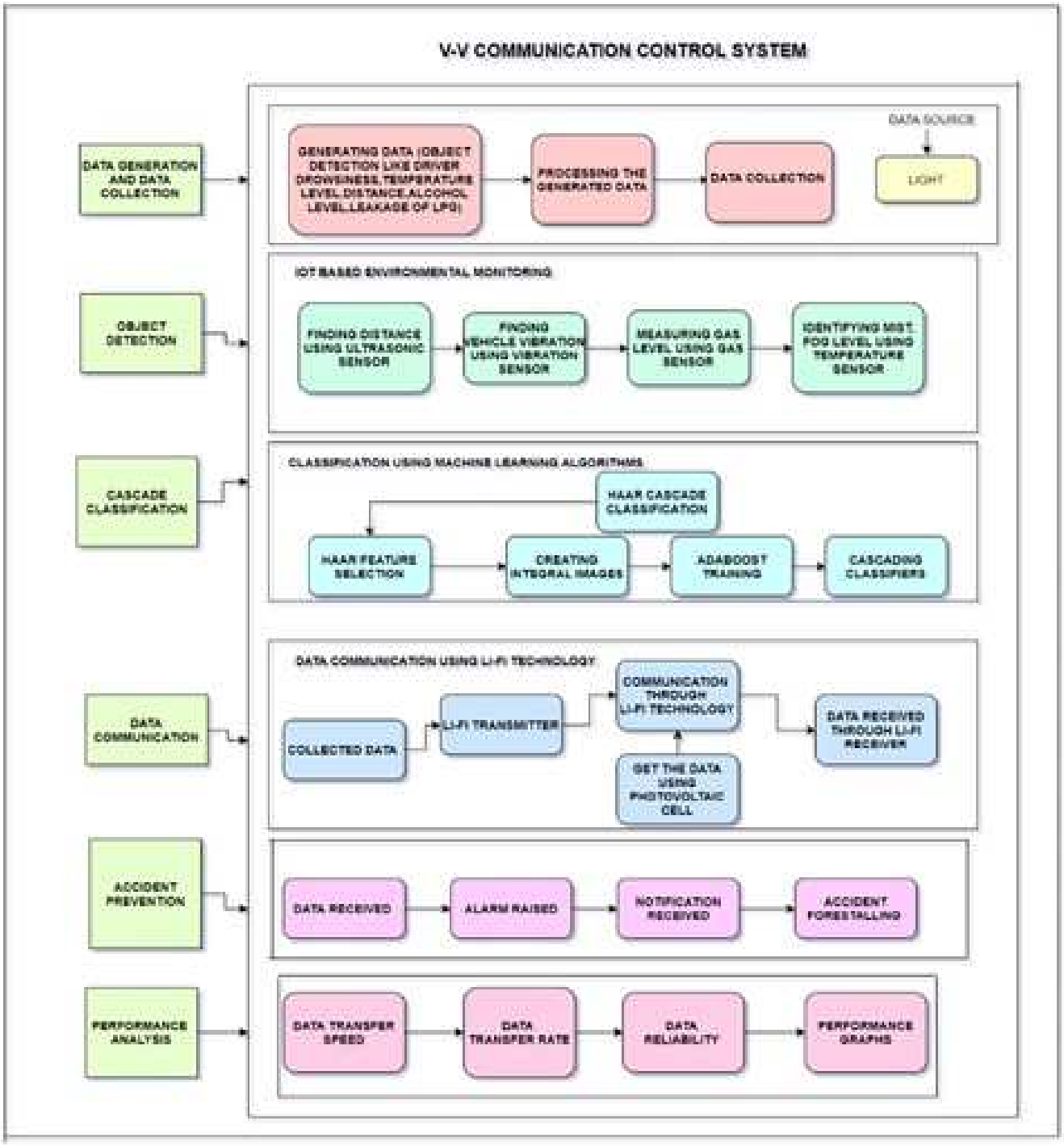


Fig. 2 Block diagram

The fourth process describes the accurate data transmitted for communication by effective modern innovation known as Li-Fi technology. From the Li-Fi Transmitter the process of this technology begins. An encoder encodes the data. The transmitter detects and transmits information about various events through LED's. As the contact is made, the LED starts to blow signaling the transmitter is able to move the data successfully, and then the process continues with receiving data from the Li-Fi receiver using the photovoltaic cell. Then the data is received using a decoder in order to retrieve the original data from the front vehicle.

In the fifth process, the preventability of incidents by using the machine language (0, 1) provided by Li-Fi receiver and then transmitted through a Li-Fi transmitter. The alarm is used in this case to indicate that the recipient receives the data. Then the encoded data are translated into original data by means of a decoder process which displays the data on the LCD display to prevent an accident. The last module explains the performance of different classification modules optimized and evaluated to provide successful results compared with the algorithms in the proposed Li-Fi technology. The identification of transmission rates compared t radar, Li-Fi and Wi-Fi is fast and reliable.

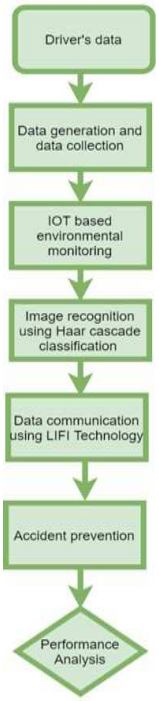


Fig. 3 Operational Workflow Diagram

B. System Modules

The proposed system consists of the following modules:

- Data Generation and Data Collection
- IoT based environment monitoring
- Image Recognition using Haar Cascade Classification
- Data Communication using Li-Fi Technology
- Accident Prevention
- Performance analysis

1) Data generation and collection: Figure 4 illustrates the data generation and collection. We say that the objects are identified through different sensors to prevent drivers from an accident. The object of these modules [21] is a vehicle that environment, through the statistical level of nature cause, is lesser than the manufactured vehicle and driver activity. It is compulsory to identify the scenario of an object (normal state of the driver and drunken driver). Here, the object is known as data collected by sensors with information like distance, temperature, level of LPG, mist, fog, driver drowsiness, etc.). Then, the data are injected into an algorithm for processing. Such data are known as processed data. Finally, the processed data is collected and ready to transmit.

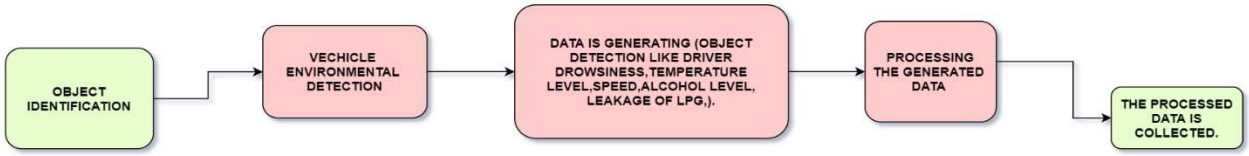


Fig. 4 Data Generation and Data Collection

2) IoT-based environment monitoring: Figure 5 depicts the sensors and environment monitoring conditions. Sensors are used to evaluate the values of anomaly data. In this paper, we have used various efficient sensors for detecting the driving environment. Accidents based on nature like fog and mist can be avoided by using temperature sensors. So, it helps the drivers to quit driving the car.

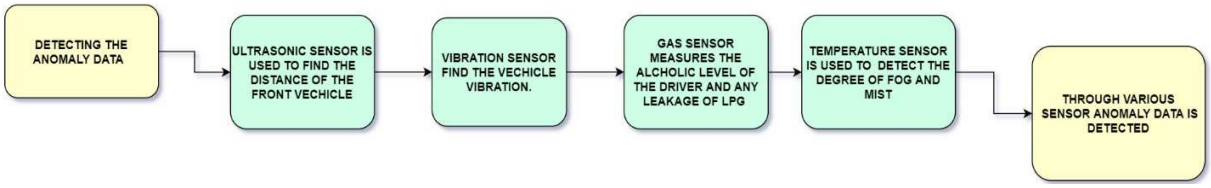


Fig. 5 IoT-based environmental monitoring

In case of vehicle damage caused by leakage of dangerous gases or fuel (alcohol) with heavy odor can affect the drivers to breathe or even it causes an accident. Such events can be identified and prevented through the gas sensor. Sudden occurrence of accident by obstacles to a front vehicle which may not be noticed by the following vehicle. In such a situation, the vehicle may fail to detect parameters like distance, speed, or the front vehicles, leading to frequent accidents.

To prevent such accident, sensors are used to detect the distance of the front vehicles. The internal part of the car example engine can be affected by lack of maintenance or heat caused by vibration. To detect such causes, the vibration sensor is used and prevent accident.

3) Image Recognition using Haar Cascade Classification: Haar cascade algorithm consists of four stages which are described as follows:

Step 1: To select the Haar features.
Step 2: After creating the integral images.
Step 3: The best feature is trained using the Adaboost algorithm.
Step 4: Finally cascade classifier is used for classification.

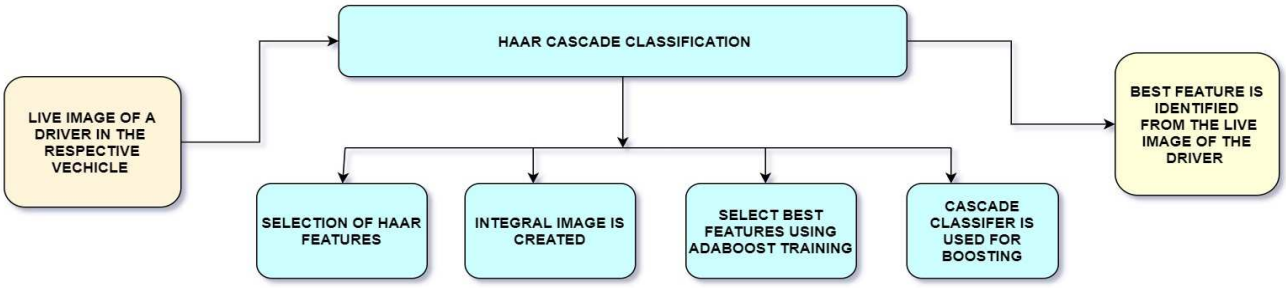


Fig. 6 Image Recognition using Haar Cascade Classification

Figure 6 shows Image Recognition using Haar Cascade Classification.

Algorithm 1 - Image Recognition using Haar Cascade Classification
Input: Original test image
Output: Image with face indicators as rectangles
Process:
Step 1: Collect the Haar features such as driver eyes, cheeks, nose. Haar feature consists of edge, line, and four rectangle features
Step 2: Create the integral image of the driver who has drowsiness. Integral images are used to make a super-fast collection of images about the state of the driver
Step 3: The integral images are collected and trained using the Adaboost training
Step 4: The best feature of the driver's drowsiness is selected using Adaboost training algorithm.
Step 5: Train the classifiers (positive and negative)
Step 6: Features classifications using cascade classifier to classify the images as positive and negative
Step 7: Detection is done by taking the positive images from the classified images
Step 8: Comparison is made between the training images and collected images
Step 9: Image is recognized successfully.

4) Data Communication using Li-Fi Technology: Figure 7 describes how informative data transmitted for communication is executed successfully by the effective modern technology known as Li-Fi technology. This technology starts with Li-Fi transmitter, and data are encoded using an encoder. Through the transmitter, informative data of various events are detected and transmitted using LED. During the time of communication, the LED starts to blow, indicating that the transmitter is successfully transmitting the data. Then the process continues by receiving data through Li-Fi receiver [22] with the help of a photovoltaic cell. The received data is decoded using the decoder to get the original data transmitted from the front vehicle.

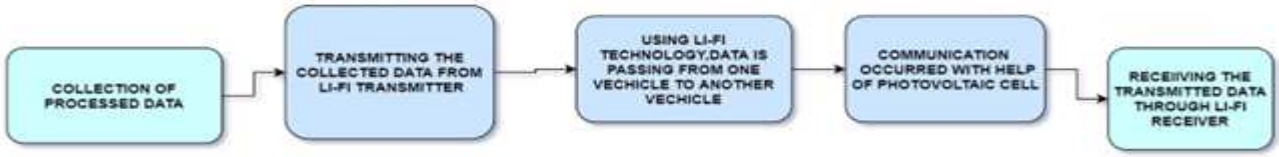


Fig. 7 Data Communication using Li-Fi Technology

5) Accident Prevention: Figure 8 shows the module process for accident prevention. The accidents are prevented by using the binary data or machine language (0,1), which are received by Li-Fi receiver and transmitted by a Li-Fi transmitter. Here alarm is used to indicate that a receiver receives the data. These data are converted from encoded data into original data using the process also known as decoding with the help of a decoder. Then the original data is displayed on the LCD, which helps prevent the accident

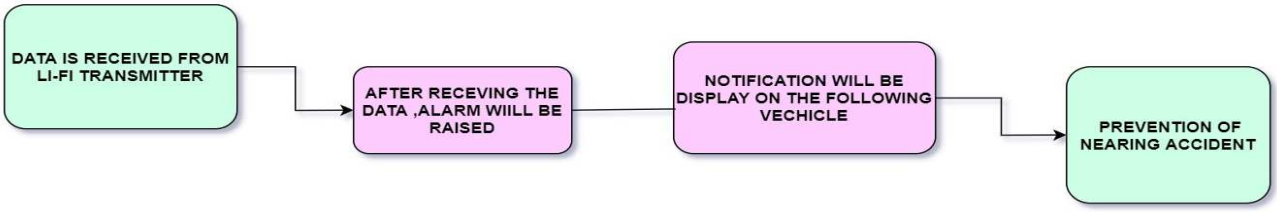


Fig. 8 Accident Prevention

6) Performance analysis: Figure 9 depicts the performance analysis of the proposed system. The performance of various classification modules that are refined and analyzed to provide effective results by comparing with the existing and the proposed algorithms in the Li-Fi Technology are Accident Detection Accuracy, Speed of Data Transfer and Data. Transfer Rate Detection is effectively and efficiently compared with Radar, Li-Fi and Wi-Fi. The performance analysis such as Reliability, scalability, and security are achieved.

Fig. 9 Performance Analysis

III. Results and Discussion

A secure real-time application is developed, which consists of various modules where the data is collected and fed into the processing module in the initial stage. Here data collection takes place where the malicious app training data set, and the benign app's data are collected and kept ready for processing. The collected are processed using the Anaconda Navigator in Jupyter Notebook using the Pandas and NumPy libraries, which perform data cleaning, transformation, and reduction data. The system performance is evaluated with the number of malware apps identified with a number of mobile apps, data accuracy, number of mobile app permission values with data accuracy, and number of mobile apps with time complexity values.

A. System Performance and Discussions

Accident Detection Accuracy: Figure 10 shows Data Transfer Rate Vs Accident Detection Accuracy. It shows as the performance analysis graph with the data transfer rate on its X-axis and accident detection accuracy on its Y-axis. Different spectrums such as Li-Fi, Radar, and Wi-Fi show us how the data are transferred at a particular rate to detect the accident accuracy. When it comes to Li-Fi, there will be high data transfer rate, and in the case of Radar, there will be a continuous increase in the data transfer rate. Moreover, when it comes to Wi-Fi, the data transfer rate will be slow.

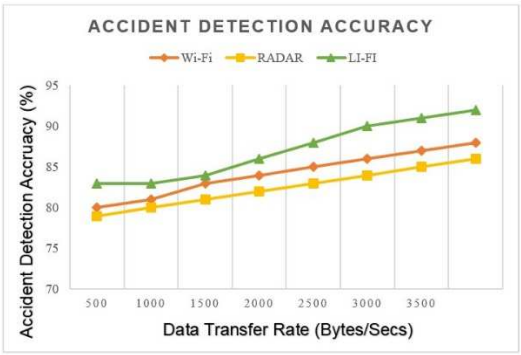


Fig. 10 Data Transfer Rate Vs. Accident Detection Accuracy

1) Data Transfer Rate: Figure 11 depicts the data transfer rate analysis when the time varies in seconds. Here is the time taken to transfer data with the data transfer rate. The X-axis is the time in seconds taken to transfer data, and the y-axis is the rate of data transfer (B/S). The data transfer rate ranges from 0 to 3500, and the time taken for data transfer ranges from 10 seconds to 60 seconds. As we know, Li-Fi has the fastest data transfer rate; for every second, time also increases. When the data transfer rate ranges from 500 to 800, it takes only 10 seconds to transfer the data.

Fig. 11 Time Vs. Data Transfer Rate

2) Speed of data transfer: 12 depicts the data transfer Rate Vs. Speed is compared using the data transfer rate and speed. The x-axis shows us the data transfer rate, and the y-axis shows the speed. The data transfer rate ranges from 500 to 3000(b/s), and the speed ranges from 0 to 250 (m/s). As the data transfer rate increases, the data interpretation speed between the transmitter and receiver also increases.

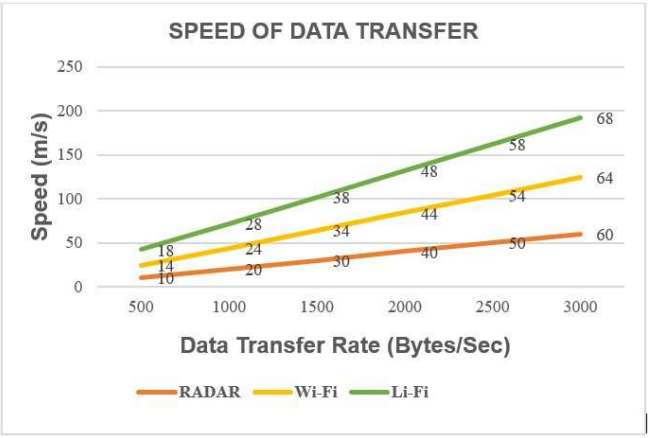


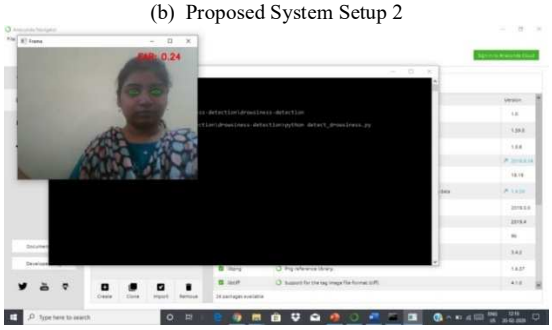
Fig. 12 Data Transfer Rate Vs. Speed

B. Experimental Results

The results of the experiments are presented in the following Figure 13.

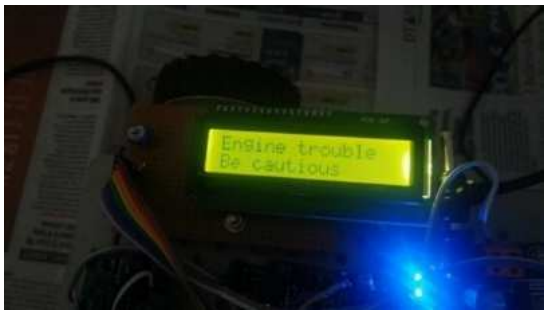
(a) Proposed system setup 1

(b) Proposed System Setup 2



(c) Application Execution

(d) Message Notification of Ultrasonic Sensor



(e) Message Notification of Vibration Sensor

(f) Message Notification of Gas Sensor

(g) Message Notification of Temperature Sensor

Fig. 13 Experimental results

IV. CONCLUSION

An inspiration of Li-Fi transmitter and receiver enabling an integrated vehicle-vehicle communication network. We detect the vehicle atmosphere and driver behaviors with different sensors to predict front car abnormal data. Li-Fi receiver is used with a photovoltaic cell for the reception of data. In this method, we are just warning the behind vehicle to be careful. Li-Fi is right for the coverage of primary density and is assumed to be more than 10Gbps in the technology is used for transmitting data obtained to the following vehicle in this case.

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