Intelligent Traffic lights using Li-Fi Technology

[1]Omkar N Chorge, [2]Aniket A Chauhan, [3]Riddhi Chaudhari [4]Dr. K.T. Patil

[1,2,3]Students, [4]Professor

[1-4]Department of Computer Engineering,

[1]Smt. Indira Gandhi College of Engineering, Navi Mumbai, India.

Abstract: Increase in number of vehicles on the road leads to Traffic congestion across the world to critical limits, especially in the urban areas. Therefore, an intelligent traffic light system is a very important requirement. So, the contemporary traffic system needs to be simulated and optimized to better accommodate this increasing demand. For this purpose, we came up with the idea of controlling the traffic light system by analyzing the traffic using the two types of data, one of which will be received via wireless optical network technology i.e., LI-FI (Vehicle to Infrastructure (V2I) communication) and other data is processed by Computer Vision. The V2I communication is established between vehicle equipped with LI-FI modules and the infrastructure (streetlight) that eventually help us with data acquisition. Both data are used by the algorithm to analyze and provide a precise Signal to traffic light system. This Project uses the artificial Intelligence (AI) Approaches and is based on the data. The designed algorithm processes them and gives an accurate signal to the traffic light system and the algorithm is improvised to ensure a smooth flow of traffic and minimize the delay at intersection.

IndexTerms **– Traffic flow, Intelligent Traffic lights, Reinforcement Learning, Computer Vision, Li-Fi, Emergency Vehicle, SUMO.**

I. INTRODUCTION

Traffic congestion in many cities around the world in recent years has highlighted the need for intelligent control of traffic lights. Traffic congestion is a major problem in transportation, characterized by longer travel times, slower speeds, and a longer queue of vehicles. Increased traffic congestion not only affect the flow of traffic, but most importantly the routes of emergency vehicles, which leads to a delay in the arrival time of patients at the hospital and for firefighter at the scene of the emergency site for evacuation, which in both cases puts people's lives at risk. According to the traffic index, two of India's major metropolitan regions, Mumbai, and Delhi, are in the top 10 worldwide for the past 4 years. [1]. Since traffic congestion increases every year around the world and causes great problems, this paper proposes the approach for an intelligent traffic system using Li-Fi technology. Improving transport conditions could make the city more efficient, improve the economy and make people's daily lives easier.

The intelligent automation of traffic light systems primarily requires the vehicle data, based on which the appropriate algorithms can be applied to achieve the correct results. In our proposed system, our approach to collect vehicle data is based on LI-FI technology. Where the Li-Fi-based communication modules are placed in the vehicle and the corresponding module is integrated into the streetlights. V2I communication (Vehicle to Infrastructure) takes place between vehicles and streetlights, and valuable information required by the algorithm is shared, e.g., Vehicle speed, vehicle waiting time and vehicle type and their emergency state. In addition to the data collected from streetlights at the same time, data is also collected from CCTV cameras at the pedestrian zone to approximately record the number of pedestrians and their waiting time using image processing techniques. Both generated data are analyzed and processed using appropriate artificial intelligence (AI) techniques in order to determine the suitable time cycle for the traffic light phases, taking into account a priority for emergency vehicles.

II. RELATED WORK

2.1 Fuzzy Logic

According to authors **Vipul Vilas Sawake et al.** [2] They have proposed a research work on a fuzzy logic controller for multiple intersection model. The fuzzy logic traffic controller system presented in the paper optimally manages the traffic flow rate at multiple intersections. They have described their system as it can give a better solution on traffic congestion as it considers different length for the green light duration depending on the current traffic density of the junction instead of fixed time duration which gradually optimize green light time duration than other regular systems can. They used a MATLAB simulation to check the effectiveness of FLC to control the traffic rate at multiple junctions. Comparing the proposed control with the conventional fixed-time control, they investigated that the fuzzy logic control shows better performance than the conventional fixed-time control when it comes to increasing the traffic flow rate in terms of the average number of vehicles and the average delay.

According to authors **khiang et al.** [3] They have presented a paper on designing and implementing an intelligent traffic light control system using fuzzy logic technology that can mimic human intelligence to control traffic lights. They have developed a software based on visual basic to simulate a single traffic intersection. The software uses windows system and is graphical in nature. It enables the simulation of different traffic conditions at the intersection and a comparison can be made between the fuzzy logic control and a conventional fixed-time control. The simulation results show that the fuzzy logic controller has better performance and is cheaper.

2.2 Reinforcement Learning: -

According to the authors, they experimented and presented case studies that show that the model they created produced positive results. The model was built using reinforcement learning techniques where the state of the model includes vehicle queue length, number of vehicles, and waiting time for vehicles. [4] The model has been trained for only two light phases and are denoted as binary number 0 and 1. Important parameters that are taken into account in calculating the model's rewards are the sum of queue lengths over the approaching lanes, delayed sum which depends upon the average vehicle speed in that lane upon the speed limit for that lane, total waiting time for all vehicles in a lane where waiting time is calculated as the last timestamp if the vehicle speed is higher than 0.1m/s. The reward is also calculated for changing the traffic light phase, the number of vehicles that have driven during the traffic light phase before the next action, and the driving time of the vehicles that have passed the intersection during a time interval. The model will periodically calculate the state and the reward for the training model and take actions accordingly A comparison is also made for different techniques for controlling the traffic light system based on a real data set as a case study, and several results were obtained using different parameters.

2.3 Computer Vision: -

According to the authors of the presented work. [5,6] The idea is based on a novel image segmentation method for recording the density of vehicles in different lanes at an intersection. Post-processing of the data and determination of the traffic phases with different software technologies. The recognition process requires pre-processing the image in order to collect cleaner data. The image processing methods required for pre-processing include the detection of areas in which confounding factors are excluded in order to improve vehicle detection. The grayscale process is performed to contour the images using the values (0.11,0.59,0.3) [5], thereby enhancing the information that is useful in lane detection and vehicle detection. The authors faced a challenge because matching the vehicle contour did not benefit vehicle identification due to different vehicle shapes and sizes. [5] As an alternative method, the horizontal correction ratio is used in which the windshield of the vehicle is used as an identification measure. However, the results obtained from the experiments [5] and as surveyed by the authors conclude that the accuracy of the vehicle identification process depends on the climatic and light conditions of the area. [7] The survey showed that fog, rain, and snow have a direct impact on the detection process. · Because this method is weather dependent and has other disadvantages, it cannot be used widely.

2.4 RFID technology: -

For the automated traffic light control, the authors suggested a model with RFID technology. [8,9] Where the traffic light phases are based on the density of vehicles in a particular lane. They have also proposed to solve additional problem such as the detection of lost vehicles, priority to emergency vehicles in state of emergency, traffic rules violation detection and vehicle breakdown detection.[8] These additional functions are also covered by our proposed system, which we will discuss in the later section. As we are aware that we can only detect an emergency vehicle but will not be able to classify it as in a state of emergency or not for which we will need another means of communication to classify it. The previously mentioned RFID tag is an ultra-high frequency band (UHF) operating in a bandwidth of 433 MHz at a moderate data rate and has some serious health problems that thermally damage brain tissue. [7] The data collected by these high frequency RFID scanners is processed using a server where logic is applied to the data and the traffic light phases are determined accordingly. The method is not completely reliable as it only depends on the density of the vehicle as there are many factors that affect the density of the vehicle in a given lane.

III. PROBLEM STATEMENT

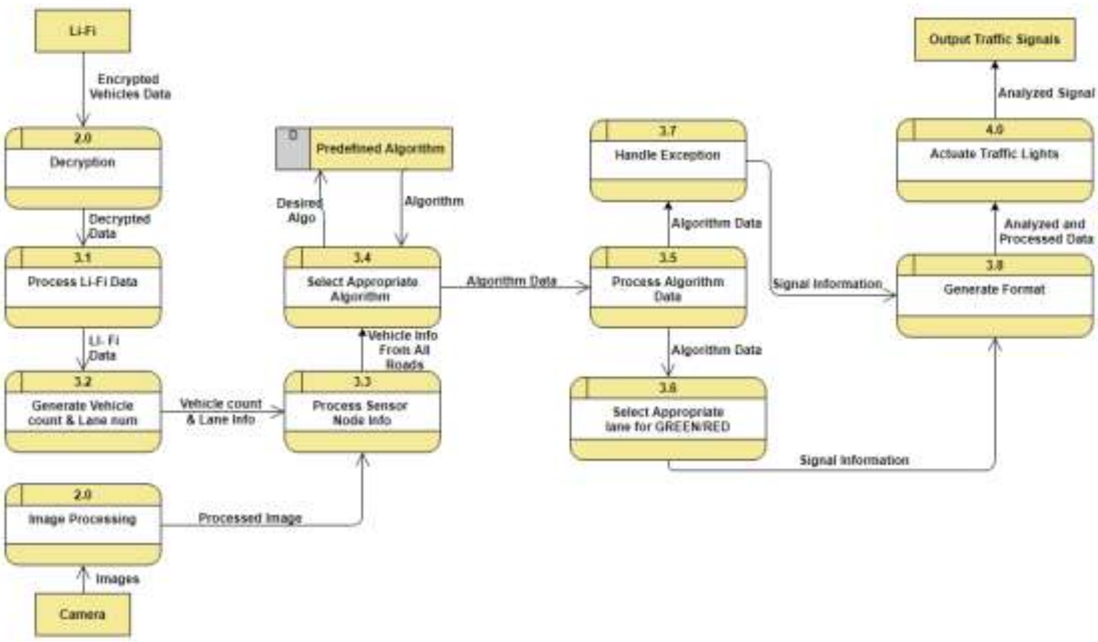
Traffic lights have been used since century for controlling and managing traffic flows, crossing road intersections to increase traffic efficiency and ensure road safety. As increase in number of vehicles on the road is leading to traffic congestion around the world to critical limits, especially in the larger urban areas. Traffic congestion causing critical issues like High fuel consumption, insufficient capacity of the road, environment concerns (CO_2 emission), transportation costs, addition in travel time and increase propensity to break traffic laws. Traffic congestion are not only the root cause for delays and stress to the drivers, but also creates an obstruction for the emergency vehicles to reach their desired destination in time. Today, conventional traffic lights operate on pre-set timer value, every time changing to a different phase after pre-set time interval. however, relying on fixed time cycles may not be an ideal solution in dealing with the increasing level of congestion in cities. Therefore, we need to design a smart traffic light system which is real-time adaptive, to increase the traffic flow rate and overcome cause by traffic congestion.

IV. PROPOSED WORK

4.1 Extraction of Vehicle Data by Li-Fi modules.

Since we have already seen different approaches to automate the traffic light system, our proposed method focuses on the full-duplex communication model for better collection of accurate data. Li-Fi communication plays a vital role in collecting vehicle data as we can collect different types of data, such as vehicle speed, vehicle waiting time, vehicle type and its emergency state. This technology is used for V2I communication between vehicles and infrastructure. In this case, the infrastructure refers to streetlights along the road. This information is very useful as we can separate and prioritize emergency vehicles on their routes when they are in a state of emergency. In addition, data collected from other vehicle types can be used to process and calculate the various traffic phases required for a smooth flow of traffic.

Based on our test performed under normal lighting conditions, we achieved stable communication up to 30 feet using Li-Fi modules. Li-Fi communication allows multiple users to communicate and is more secure and reliable with a higher data rate. [10] Security functions can be added to the system using various cryptographic techniques that are helpful in detecting forged vehicle identities. The model trained to automate the traffic light phases requires data from the vehicle, such as the waiting time of the vehicle, the number of vehicles and the vehicle type with which it calculates the cycle time for a certain phase of the traffic light.



Data Flow Diagram for 3.0 (Level 2)

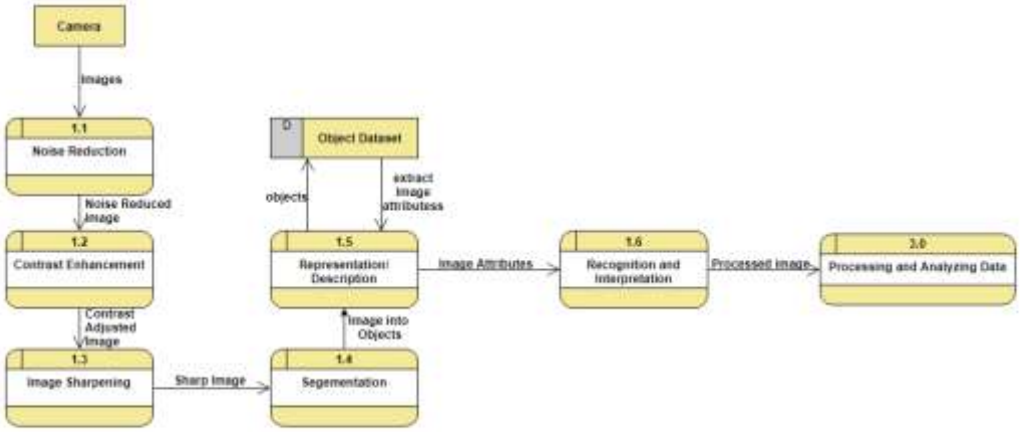
Figure 4.1: Data flow for Li-Fi communication

4.2 Extraction of Pedestrian Data by CCTV Cameras using Image Processing.

Images of pedestrian zone across the zebra crossing are snapped at regular intervals by CCTV cameras, placed at each road intersections. Further, these real-time images are sent for image processing to the central processing unit for calculating the density of pedestrian waiting at the zebra crossing. The Process of image processing is comprised of Noise Reduction, Image Acquisition, Image Sharpening, Image Segmentation, recognition and interpretation of pedestrian density.

Noise is abrupt change in pixel values in an image. Therefore, when it comes to filtering of images, the first intuition that comes is to replace the value of each pixel with the average value of pixels around it. Noise reduction smoothens the image. For this, we have used a Gaussian blur (also known as Gaussian Smoothing) which typically reduce image noise and reduce detail. The noise reduced real-time images are converted to grayscale image. The reason for differentiating such images from any other sort of color image is that less information needs to be provided for each pixel. In fact, a `gray' color is one in which the red, green, and blue components all have equal intensity in RGB space, and so it is only necessary to specify a single intensity value for each pixel, as opposed to the three intensities needed to specify each pixel in a full color image. After the image acquisition, we partition the image into various parts called segments. It's not a great idea to process the entire image at the same time as there will be regions in the image which do not contain any information. By dividing the image into segments, we can make use of the important segments for processing the image. That, in a nutshell, is how image segmentation works. We have used instance segmentation because it identifies different instances of the same object and are segmented with different color maps.

Then, Histogram of Oriented Gradient (HOG) is used to extract features from segmented image. The HOG is a feature descriptor used in computer vision and image processing for the purpose of object detection. It is method of intensive descriptors that is used for local overlapped images, constitutes features by calculating the local direction of gradient. At present, the approach combining HOG with Support Vector Machine (SVM) has been widely applied to image recognition and achieved a great success especially in human detection. This technique counts occurrences of gradient orientation in localized portions of an image (counts occurrence of the pedestrian at each node). The count of pedestrians at each node is transmitted to central processor at the road intersection.



Data Flow Diagram for 1.0 (Level 2)

Figure 4.2: Data flow for Image processing

4.3 Reinforcement Learning Approach using collected data.

Once the vehicle data is collected using Li-Fi modules, it contains the accumulated vehicle waiting time, number of vehicles, the types of vehicle and their emergency state. Our proposed model is based on reinforcement learning technique where our model is trained based on these factors. The intelligent traffic light agent in this model is responsible for providing an optimal action that increases the flow of traffic. Considering real world traffic into picture, we used SUMO (Simulation of Urban Mobility) to simulate and study different traffic scenarios and worked to optimize and improve the results of our proposed system. We built a network with SUMO that contained a single intersection and carried out number of episodes for vehicle tours through that intersection to train our model. Additionally, we trained this model with a negative reward reinforcement technique to increase response. The method is based on DQN (Deep Q-Network) algorithm, a deep learning model that is used to determine the actions that an agent can take in any state of the reinforcement learning environment. The agent action here is predefined for each lane and gives all vehicles waiting in this lane a green corridor. The set of actions for the model contains the green signal for each of the four directions (North, South, East, West). With this approach, emergency vehicles such as ambulances and fire brigades are prioritized by the training model by increasing the weight parameter for emergency vehicles and calculating a weighted reward. However, in a state of emergency, these methods can be overridden by fully prioritizing the emergency vehicle's lane so that emergency vehicles have a completely green corridor for their routes that can be achieved using hardware protocols. When examining different traffic scenarios with SUMO, we concluded that the same approach can be applied and desired results can be achieved for different networks, regardless of the number of lanes, intersections, and vehicles. Once the model is implemented, it can be improved by feeding in newer data collected from the respective intersections.

Pedestrian data collected through image processing techniques can also be used to determine an additional phase for the zebra crossing. Simulation studies show that if we can accurately count the waiting time and count pedestrians without hardware or processing drawbacks, we can keep training the model to work accordingly. Emergency vehicle priority is mainly determined by knowing the state of emergency in order to categorize it and then using the first in, first out (FIFO) method to deduct it according to the order of arrival. In addition, the data collected from the LI-Fi communication model can be very useful in extracting data such as stolen vehicle identification, accident detection, traffic law violation detection, and vehicle breakdown detection.

V. RESULTS AND DISCUSSION

According to the test cases performed in SUMO, we obtained results for various simulation networks that contain simple intersections, two adjacent intersections and a grid network, in which we each got similar results, and we can say that the model is scalable. We also simulate the same network with the same vehicle routes using the traditional method to better understand and compare the two results. Pedestrian data was generated randomly using simulation software (SUMO) and the credibility of the model was tested to accommodate changes to new traffic phases, using the same approach by calculating pedestrian data, which is the number of people waiting in pedestrian zones and their accumulated waiting time.

Method	**Intelligent Approach**			**Traditional Approach**		
Variable	**minimum**	**mean**	**maximum**	**minimum**	**mean**	**maximum**
Waiting time	0	8	33	10	63	98
Average speed	3.597	6.434	11.598	0.432	2.09	8.751
Travel Time	8	59	138	18	186	768
Fuel consumption	13.67	80.46	187.20	14.09	210.16	821.63
CO_2 consumption	31804.27	187195.86	435502.70	32790.36	488889.66	1911302.74

Table 5.1: Comparison table (Intelligent and Traditional)

Table 5.1 is a comparison table between the traditional system and our proposed method. The data is generated with SUMO, with the routes of the vehicles and the network being the same for both test cases. We record each value that represents the minimum maximum and its means, and we have seen more clearly from the table that the waiting time, travel time, fuel consumption and CO_2 emissions are less for our proposed method than the traditional approach, while the average speed for our approach has increased due to shorter travel time.

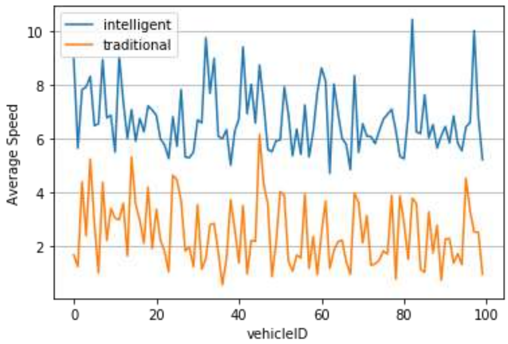


Figure 5.1: Waiting Time comparison

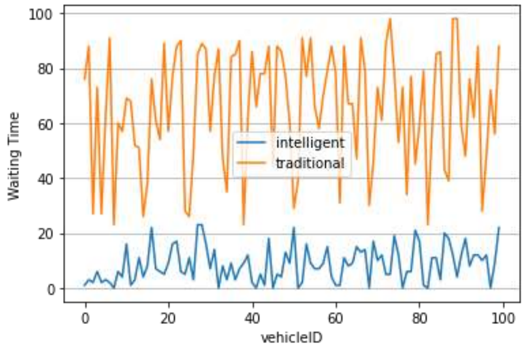


Figure 5.2: Average Speed comparison

Figure 5.1 and Figure 5.2 is the result of 100 vehicles that were randomly sampled from 1600 vehicle routes in order to compare the waiting time and the average speed for individual vehicles respectively. As we can see in the figure, there is a significant gap between the traditional method and the proposed method where we see improvements for all vehicles that have less waiting time and higher average speed, and the proposed system is not predisposed to any vehicle unless it is an emergency vehicle.

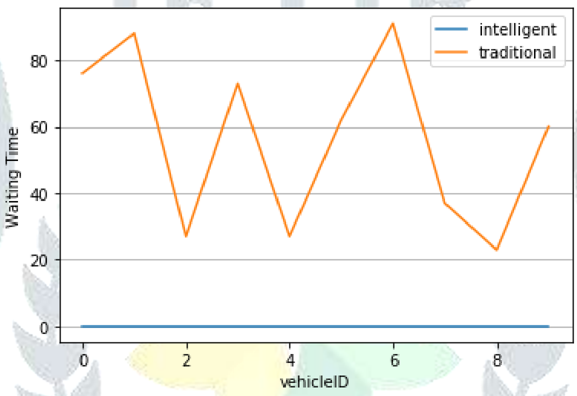


Figure 5.3: Waiting Time comparison for emergency vehicles.

Figure 5.3 focuses on the emergency vehicles sampled out of the same simulation network where we compare the waiting time between the emergency vehicles including both ambulances and fire brigade. We can conclude that the proposed system prioritizes emergency vehicles regardless of other traffic conditions. This approach can be very useful in saving lives by reducing the travel time for emergency vehicles.

VI. CONCLUSION

In this paper, we emphasize the need for intelligent traffic lights to reduce the increasing congestion in urban areas. We discuss our approach using Li-Fi technology to collect vehicle data, which in turn gives us our result by using DQN algorithm to take specified actions in our environment and train our model. In addition, we also prioritize emergency vehicles on their routes. We performed tests to achieve stable Li-Fi communication up to 30 feet under normal lighting conditions. Pedestrian data is also considered, and traffic phases are scheduled accordingly to have a systematic traffic light system. This paper therefore discusses an efficient method for controlling the traffic light system to maintain and increase the flow of traffic and to prioritize emergency vehicles.

VII. FUTUREWORK

The idea of collecting data using the full duplex communication model will provide us with enough data in the future to predict various requirements, which are mapping of the CO_2 footprint, the planning of maintenance and repair work in a planned time taking into account the congestion of the traffic. The need for pedestrian bridges (fob) at different intersections can be predicted based on pedestrian data. The generated traffic dataset can be used for algorithm development for better performance. Vehicles can be charged with fees (toll) in real time. And parking lots can now also keep records and charge vehicles accordingly.

REFERENCES

[1] TomTom International BV, 2021, accessed 22 May 2021, https://www.tomtom.com/en_gb/traffic-index/ranking/

[2] Sawake Vilas Vipul, Borkar Prashant. “Traffic Signal Timings Optimization Using Fuzzy Logic Controller”. International Journal of Advanced Research in Computer Science and Software Engineering. 2017.

[3] Khiang Kok & Khalid Marzuki & Yusof Rubiyah. (1997). Intelligent Traffic Lights Control By Fuzzy Logic. Malaysian Journal of Computer Science. 9. 29-35.

[4] Hua Wei, Guanjie Zheng, Huaxiu Yao, and Zhenhui Li. 2018. IntelliLight: A Reinforcement Learning Approach for Intelligent Traffic Light Control. In Proceedings of the 24th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining (KDD '18). Association for Computing Machinery, New York, NY, USA, 2496–2505. DOI:https://doi.org/10.1145/3219819.3220096

[5] L. Junwei and L. Shaokai, "A novel image segmentation technology in intelligent traffic light control systems," 2013 3rd International Conference on Consumer Electronics, Communications and Networks, 2013, pp. 26-29, doi: 10.1109/CECNet.2013.6703263.

[6] P. Choudekar, S. Banerjee and M. K. Muju, "Implementation of image processing in real time traffic light control," 2011 3rd International Conference on Electronics Computer Technology, 2011, pp. 94-98, doi: 10.1109/ICECTECH.2011.5941662.

[7] Aniket Chauhan, Omkar Chorge, Riddhi Chaudhari and Dr. Kishor T Patil, " A Survey Paper on Intelligent Traffic Lights," 2021 Volume8, Issue05 May-2021.

[8] B. S. Meghana, S. Kumari and T. P. Pushphavathi, "Comprehensive traffic management system: Real-time traffic data analysis using RFID," 2017 International conference of Electronics, Communication and Aerospace Technology (ICECA), 2017, pp. 168-171, doi: 10.1109/ICECA.2017.8212787.

[9] B. J. Saradha, G. Vijayshri and T. Subha, "Intelligent traffic signal control system for ambulance using RFID and cloud," 2017 2nd International Conference on Computing and Communications Technologies (ICCCT), 2017, pp. 90-96, doi: 10.1109/ICCCT2.2017.7972255.

[10] V. Aleksieva, H. Valchanov and D. Dinev, "Comparison Study of Prototypes based on LiFi Technology," 2019 International Conference on Biomedical Innovations and Applications (BIA), 2019, pp. 1-4, doi: 10.1109/BIA48344.2019.8967478.