Traffic Management with Deployment of Li-Fi Technology

Israa Al_Barazanchi¹, Seba Aziz Sahy², Zahraa A. Jaaz³, haider rasheed abdulshaheed⁴

¹,⁴Baghdad College of Economic Sciences University, Baghdad – Iraq.
²Ministry of Higher Education and scientific Research, Foundation of Technical Education, Institute of Medical Technology Al-Mansur, Iraq – Baghdad
³College of Science - Computer department - AlNahrain University, Iraq - Baghdad

Israa4444@gmail.com
sebaaziz96@yahoo.com
zaj@sc.nahrainuniv.edu.iq
haider252004@yahoo.com

Abstract Light Fidelity or commonly known as Li-fi, is an emerging technology that works on the principle of using light as a medium for transferring signals. It is bidirectional and is fully networked wireless communication that focuses on the use of light from light-emitting diodes (LEDs). The system is affluent and can provide connectivity within a larger area with more security, higher data rates and high-speed as compared to Wi-Fi. Apart from that, it relies on the use of visible light communication or infra-red and near-ultraviolet spectrum majorly working on the idea of switching bulbs on and off within nanoseconds. The paper consists of vivid insights about the use of Li-fi as a solution to the excessive traffic congestion in roadways. The paper is further divided into prominent sections that deal in providing an accurate idea about the working and implication of Li-fi technology in the current scenario. Moreover, the paper also proposes various technical standards and modulation that are and will be followed by Li-fi technologies, thereby focusing on its future implication. Apart from that, the main aim of designing the system is to limit traffic congestion and thus, reduce the increasing number of road accident in the present times.

Keywords. RFID tags, Li-Fi, Traffic management, Congestion, traffic safety.

1. Introduction
Internet is one of the useful tools in the world since its inception in 1998. The internet is a system of interconnected networks that are used to transfer data from one source to another, but the main problem is regarding the speed at which the data is being shared. For this, wireless communication had been in the service for some good time as the data is being transmitted by the radio waves. The speed at which the information is being shared is better than the pre-existing technologies. However, every technology has its advantages and disadvantages, and so, the Wi-Fi possesses the same things [1]. The main consideration of the Wi-Fi is that in the process of data transmission, the radio waves are scarce, there is continuous fluctuation of bandwidth and the interferences that decrease the strength of the signal sent
by the Wi-Fi devices [2]. Another main issue is that the radio frequency signal which would be submitted by the Wi-Fi routers could be blocked by the walls, and this makes the process much more insecure. In order to operate on safer grounds, Dr Harald Hass invented Li-Fi technology in the year 2011 [3]. The advantage of using such technology so that the data is more secure and there is far less interference as compared to its predecessors. As a result, the data is being sent at a faster rate, and due to which, the information could be shared above the 100 Gbps speed. The Li-Fi technology is a much more secure data transfer that uses the LED lamps as the primary data source for sharing information. This technology takes help from LED devices where it uses the light coming out from it in the data transfer activities [4]. Unlike the Wi-Fi technology, Li-Fi does not use the repeaters in it, and so the information is shared at a faster rate. As a result, this technology could be used in the streets, cars and neighboring areas [5]. This had raised a big question of whether or not this technology could be used to monitor the traffic [6]. With a rise in the number of accidents globally, traffic management is must, and the use of Li-Fi technology could provide that. This technology could be incorporated in the cars as well as the streets so that the vehicle and the passenger motions could be tracked easily. This paper on the implementation of Li-Fi technology to manage the traffic flows in the busy areas so that the chances of having traffic to some extent. Along with that, the cars could move from one location to another in a safer manner. In this study, we will make an intelligent traffic controlling system by the use of RFID tags on the cars and using the infrared sensors. We will be using two RFID readers in each direction of the roads separated by some distance. Along with that, a control server would be used. Whenever a vehicle would cross the reader, the information of the cars would be obtained inscribed in the RFID tags [7]. After receiving the data from the reader, the data would be sent to the central servers with the use of Li-Fi technology using the light sensors placed at the top corners near the traffic posts [8]. Then, the information obtained is being analyzed to check which vehicle had crossed the road and this would help in managing the traffic in a proper manner.

2. Background of the Study

2.1. Traffic Management

Over past few years, there has been an abrupt rise in the number of vehicles in streets and roadways, thereby resulting in an increased number of traffic accidents and unwanted congestions [9]. However, there are a series of the identified reason that further leads to such discrepancies, namely the ever-increasing population, rapid urbanization and the pertinent increasing car ownership are grave matters of concerns in the Asia-Pacific regions. In order to tackle the chronic issues, Intelligent Traffic Systems (ITS) is implemented that tries to solve traffic issues with the effective use of information communication technologies. However, the recent advancements in the ITS and autonomous vehicles use big data information for the management of traffic [10]. Furthermore, both the standalone and semi-autonomous vehicles system works on on-board sensors of vehicles motion dynamics with the help of their advanced sensor networks. Moreover, in the recent times, Wi-Fi is the commonly used wireless communication means that relies on radio waves, but the main problem with using this technology is the competent lack of radio waves along with the continuous depletion of bandwidth. In order to overcome the existing issues with the use of Wi-Fi in traffic management, Li-Fi technology was invented in 2011 that uses LED lamps as a medium of visible light to control traffic congestion [11].

2.2. Use of RFID Tags in Traffic Management

In order to solve the complex issues of traffic congestion, Intelligent Traffic Control Systems (ITCS) is implemented that relies on using Radio Frequency (RFID) [12]. The proposed idea works on the principle of tracking vehicles with the help of a virtually created radio frequency identification. Moreover, the Central Control System (CCS) present in the road crossings aims explicitly at controlling the RFID readers attached in respective vehicles. As soon as the car passes the reader, the CCS immediately tracks the cars through the RFID tag and retrieves an Electronic Product Code (EPC) [13].
The EPC further comprise of a Vehicular Identification Number (VIN), being an industry standard, it is a mandate for every vehicle to have a respective VIN. Moreover, with the help of a modern take look-up procedure, the VIN can be used to match it with the already fed vehicle record. The data retrieved is forwarded immediately to the CCS by a wireless medium [14]. The CCS comprises a Central Database Processing System (CDPS) for further dispensation of the gathered vehicular data followed by a Decision-Making Section (DMS) in order to control the traffic lights.

The CPDS is further divided into two significant aspects a dynamic and a permanent database. The dynamic database confines to record vehicles that are currently passing the crossing and stores it temporarily [15]. On the other hand, the permanent database stores records of all the cars that have or have been crossing the intersection. Moreover, the dynamic database also arranges the EPC data accumulated from vehicles as per their respective path and direction in the course of travelling. However, if there are any movements between the installed readers, the path is instantly conveyed to the CCS with a time gap between. Meanwhile, the CDPS evaluates and checks data stored in the dynamic database and then computes the present traffic volume for all the roadways that converges at the crossing [16]. The next step then involves forwarding the calculated facts sheet to the DMS of the CCS, which further operates the traffic signals.

2.3. Data Transfer issues in RFID Tags using Wi-Fi Technology
RFID is a useful technique, in minimising the extent of a traffic collision, but is associated with a series of shortcomings and disadvantages. Firstly, the collision problems, the electronic interference can further cause faults of the readers as well as tags, thus, leading to circumstances of the collision [17]. Apart from that, variable transmission between the readers and tags can also cause such scenarios as the tags and channels works on the same frequency channels. The pertinent breaches in the privacy and security of RFID tags have significant effects on individual and organization as a whole [18]. As the tags are not protected, there is an obvious risk of further breaches as they are easy to target to eavesdropping. On the other hand, unauthorized readers can cause privacy breaches by having direct access to multiple tags without having privileged access control [19]. Apart from that, the RFID technology is among a few techniques that can be installed and informed in the operational process of an organization. However, the installation of this technology can further lead to a series of interference problems for multiple RFID components that can bring the RFID operation to an end [20]. The design of RFID tags and readers is also a pertinent challenge faced by this technology; the complexity of the
system also adds up in executing operations [21]. Thus, causing the integration of the RFID technology to the existing infrastructure of the traffic system even more difficult. As the current RFID technology relies on the use of Wi-Fi, it is also a competitive threat to technology as it leads to a series of privacy breaches because the Wi-Fi system is not protected [22]. On the other hand, in order to tackle the issues further ongoing research is undertaken in the direction of Li-fi technology, which is a bidirectional and fully networked wireless communication medium by relying on the light a medium of transferring signals [23].

| Frequency | Bandwidth RFID Usage | WLAN and WPAN Use |
|-----------|----------------------|--------------------|
| 58 - 1 KHz | Electromagnetic tags |                     |
| 125 - 135 KHz | LF Passive tags |                     |
| 7.4 KHz – 8.8 MHz | EAS Swept-rf tags |                     |
| 13.56 MHz | HF Passive tags | IEEE802.15 WPAN/Zigbee @ 868 & 915 MHz |
| 868 MHz – 928 MHz | UHF Passive tags | IEEE802.11b & g WLAN IEEE802.15 WPAN (Bluetooth and Zigbee) |
| 902 MHz / 111.5 KHz | EAS Re-radiating tags | IEEE802.11a WLAN |
| 2.4 GHz / 111.5 KHz | Some Wi-Fi based active tags | IEEE802.11ad Wi-Fi |
| 2.4 Hz | | |
| 5 GHz | | |
| 60 Hz | | |

**Table 1.** Showing the risks associated with the use of RFID tags [26]

**Working Principle of Li-fi**

The Light Fidelity or Li-fi technology works on a simple principle of transmitting data by the process of illumination using LED light bulb as a medium [24]. The main highlight of the process is the generation of high brightness LED that can be switched on and off multiple times within a minute. If the LED confines to a binary data where it is on one are transmitted and off, then 0 is transmitted [25]. A constant source of light or a LED bulb is used as a transmitter from one end. However, on the receiver end, a light sensor or a photodetector is used to retrieve transmitted data. As soon as the LED bulb flashes are acts as a trigger which is then received by the photodetector on the other end. Moreover, to construct a message the LED bulb is flashed a million times or an array of LED’s with different colours are used that further helps in attaining different data rates in a specific range of megabits per second. The transmission largely depends on what the LED bulb sense, then the photodetector will provide the output in a binary format, i.e., 0 or 1 [26].

**Figure 2.** Components of the Li-fi technology [27]
The components of the Li-fi transmission includes a data access point, Li-fi enabled light source, and Li-fi allows transceivers to transfer data [27]. The data access point helps in establishing a connection between Li-fi enabled data transmission system with the internet via a switch or high-speed router. On the other hand, as light is the medium of transmission, LED bulbs are used as semiconductors. Moreover, the same light is used for the transfer of signals [28].

2.4. Impact of Li-fi on Traffic and Data Management
As Li-fi depends on the use of LED lamps as the significant source of visible light that used on streets and roadways, therefore, Li-fi eradicates the necessity for repeaters and base stations. Apart from that, Li-fi is the immediate solution to solve the recurrent issues of security breaches and hacking of networks frameworks that leads to the tapping of data [29]. On top of the Li-fi is a competent technology that provides a comfortable, cheap and faster and more secure medium for transfer of data. Moreover, it works on trans-receivers that are installed in with the LED lamps that have the efficacy of both lightings the room as well as transmitting and receiving information from various media [30]. Apart from that, it also implies and uses the visible portion of the electromagnetic spectrum, which is still underutilised. However, apart from the additional benefits of adopting new technology, the emergent and actual need for the use of this technology can be ascertained with the help of Cisco's Visual Network Index, that further submits that the overall user demanded in spectral efficiency is rapidly increasing with respect to its gains. It also states that by 2015, traffic from wireless devices will exceed from that of the wired devices [31]. Therefore, such substantive increases in network traffic need a competent ideology that can change individualistic views on wireless communication and Li-fi is a useful technology that can successfully tackle the prevalent adequacies.

Moreover, within a local Li-fi cloud, there are a series of data-based services that are further supported with the help of a heterogeneous communication system. However, at initial stages, the Li-fi Consortium comprised of a set of technologies that also aided in providing secure, high-speed and reliable wireless communication interfaces. The techniques in the Li-fi Consortium mainly included gig-speed technologies, mobility technologies and navigation, gesture recognition technologies, precession location systems [32].

Moreover, for Giga-speed technologies the Li-fi Consortium primarily relied on Giga Dock, Giga Shower, Giga MIMO and Giga Spot; these models dealt with tackling different user scenario wireless connection indoors helping them in the easy transfer of data from one point to another. On the other hand, Giga Dock is a wireless charging platform for smartphones tablets or notebooks with a maximum speed of 10 Gbps. Similarly, the Giga Beam model is an on-point data linking platform for kiosk applications or portable-to-portable data exchanges.

2.5. Technical Standards associated with Li-fi and RFID Tags
As per the visible Light Communication interest group, which is certified by the IEEE, with IEEE802.15.7 is the most active standardization used. Apart from that, the standards at VLC (IEEE
802.05.7) encompasses VLC of including mobile-to-mobile (M2M), fixed-to-mobile (F2M) and infrastructure-to-mobile (I2M) communication interfaces [33]. The prime focus of VLC standard is to emphasize on medium-range communication for traffic systems amidst low-speed and short-range M2M and F2M connections with high speeds in order to exchange data. Moreover, the data bases are generally supported up to 1 Gbps with the implementation of modulations schemes. IEEE 802.15.7 confines to Physical Layer (PHY) and Media Access Control (MAC) layers for VLC/Li-fi.

3. Methodology

3.1. Design architecture

The study would use the typical crossing in a narrower street where the Li-Fi technology would be implemented. This process would involve two readers in two sides of the roads in collaboration with the infrared sensors placed at the traffic light postings [34]. The data which would be stored at the central servers would be shared with the help of Li-Fi so that the information could be accessed more safely and securely [35]. The entire design of the use of Li-Fi technology in the traffic system would be shown in the flowchart given in Figure 4. The flowchart given above shows that the information obtained with the help of the readers and light sensors guide in analysing the traffic flow in the busiest areas. The reason for using the readers is that the electronic information about the vehicles could be obtained in an easy manner leading to a proper analysis of the location of the cars [36]. In addition, the light sensors placed at the other end of the roads would help in calculating the position of the pedestrians. While doing so, the analysis of the volume of the people would be done so that the system could know their counting [37]. With the help of Li-Fi technology, the information would be sent to the central servers 1 and 2, from which the analysis would be made properly. Depending on the counting performed by the sensors, the system could know the different volumes of the cars and at the same time, of the pedestrians [38].

![Flowchart](image)

**Figure 4.** Working model of the intelligent traffic management system in linking with the Li-Fi technology.

The big data would be safe as Li-Fi technology is being used and the advantage of this process is that there is less chance of data jamming due to the absence of fewer repeaters.

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Not all the vehicles like to stop when the red light is being shown. The Li-Fi technology could be used to prevent the frequent collisions in the traffic by the use of it where it could send information to the drivers when to stop and start the vehicles thereby making the cars more intelligible than ever before [39]. A decoder would be used so that the drivers could know the electronic interpretation of data in a digital form. If any vehicle tries to break the rules of the traffic, then, he/she would be easily caught by the traffic police as they had access to the data obtained through the RFID tags [40]. The advantage of using RFIFD tags along with the light sensors would help the police to know the information about the drivers and take legal action against them [41]. With the help of the light sensors placed in front and rear sides of the vehicles, the cars could be able to communicate with each other through the echo mechanism where they could know the distance between them respectively.

The distance between the consecutive vehicles could be calculated in this way:

\[
distance = \frac{speed \times time}{2}
\]

In the sideways, the LCD should be in close association with the Arduino microcontroller so that the driver knows the speed of the vehicles and this helps them to reduce the speed [41]. This helps in maintaining a safe environment for pedestrians to cross the road. Another aspect that would be covered through this study would be to reduce the delay of the vehicles getting stuck in traffic which is a healthy sign of better traffic management. With the use of comparative analysis obtained from the data through Li-Fi technology, the traffic system could know the volume of the vehicles and pedestrians [42]. Depending on which volume is higher, the traffic lights would be switched on in that direction. (For further understanding, check the diagram). As a result, the traffic lights would be switched on and off in a smoother manner leading to crossing of streets by the pedestrians in a proper manner. The outcome is that there would be fewer accidents, and the delay of the vehicles would be lowered greatly. This constitutes an intelligent traffic management system under the application of Li-Fi technology.

### 3.2. Collection of Data

In order to understand the success rate of the Li-Fi technology in traffic management, a survey had to be conducted, which would help in answering the main challenges in changing the system. The use of Li-Fi technology had some challenges as well as benefits which would be covered with the help of the survey tools. Due to limited time, the entire research focused on using the survey of the traffic management personnel with a motive to undertake the various prospects of controlling the traffic with the help of Li-Fi technology. The data collection has been conducted with the help of online questionnaire developed on Survey Monkey. Concerning the sample size, 200 respondents were taken into consideration. Further, the data analysis has been carried out with the help of the results that were generate on the platform. The respondents have given their views on the success rates of the Li-Fi technology in the traffic management. Through their responses, an evaluation has been made regarding the importance of Li-Fi technology. It is noted that this will help the traffic police in their management if they use Li-Fi technology, which would calculate the significance of decisions taken while managing the traffic congestion.

90 respondents with vehicles devoid of Li-Fi technology were taken into consideration and 70 respondents with vehicles deployed with Li-Fi technology were chosen on a random note. 40 volunteers as pedestrians were chosen and ethnographic research was carried out. The results were practically noted and regression between dependent (Light response) and independent variable (RFID tracking signal) is taken out. The sample size is simulated in a virtual ethnographic research conducted by the use of SPSS.

### 4. Data analysis

| Variables | Explanation |
|-----------|-------------|

---
| **RFID_Tracking**     | The signal in encoded 0/1 value from the tracking device |
|-----------------------|----------------------------------------------------------|
| **Server_1**          | Collecting signals from vehicles                         |
| **Server_2**          | Collecting heat signals from pedestrians                 |
| **Lifi_Vehicle**      | Vehicles with Li-Fi                                      |
| **Non_Lifi_Vehicle**  | Vehicles without Li-Fi                                   |
| **Lifi_Signal**       | Signals when vehicles cross the lane                     |
|                       | (0 = Non-Li-Fi Vehicle, 1 = Li-Fi Vehicle)               |
| **Volume_of_Pedestrians** | Number of passengers in the lane                       |
| **Comparative_Parameter** | Result of both the servers and changing light of signal (0 = Red, 1 = Green) |

Single tail ANOVA test among the variables gave significance for all the variables except for server 2 results since it was unpredictable for the passengers to cross the lane, walk on sideways, crowd the road, etc. Keeping the unpredictableness of the situation as the base line for the ethnographic study, partial positive correlation is observed between the groups of variables taken into consideration.

![Figure 5. Single tail ANOVA test](image-url)
### Table 3.

| ANOVA: RFID Signal | Sum of Squares | df | Mean Square | F     | Sig.  |
|---------------------|----------------|----|-------------|-------|-------|
| Regression          | .042           | 1  | .042        | .166  | .684  |
| Residual            | 39.933         | 158| .253        |       |       |
| Total               | 39.975         | 159|             |       |       |

The linear regression keeping number of passengers as the independent variable for the RFID signal suggests that the signal gives partial perfect correlation when the heat signal is low but when the heat signal is high, the regression values down to \( r = 0.42 \) where \( V_2 > V_1 \).

### Table 4.

| Regression: Li-Fi Signal | R     | R Square | Adjusted R Square | Std. Error of the Estimate |
|--------------------------|-------|----------|-------------------|----------------------------|
|                          | .720  | .519     | .516              | .305                       |

The independent variable is \( \text{Volume of pedestrians} \).

Here, \( r = 0.72 \) showing partial positive correlation between pedestrians and Li-Fi signal. It means that, as the volume of pedestrians increases, the Li-Fi signal helps the vehicle in knowing the congestion on the lane resulting into automatic traffic management by \( V_1 > V_2 \) signaling in the comparative parameter, turning the signal red.

Figure 6. partial positive correlation between pedestrians and Li-Fi signal

The clustered box plots prepared by keeping comparative parameter and Li-Fi vehicle with a cluster of server 1 and the same with Non-Li-Fi vehicle with a cluster of server 2. The results show that, comparative parameter reflects red light, when server 1 gives a signal during increasing volume of pedestrians. The same is shown in Non-Li-Fi comparison with server 1 showcasing that it cannot indicate the red signal due to high volume as the RFID signalling is not present in them. The second set of analysis using volume of pedestrians on Y-axis and comparative parameter on X-axis keeping server 2 as clustered parameter shows that, as \( V_2 > V_1 \), server 2 overtakes the decision-making protocol of comparative variable and signals to give red light for avoiding accidents on a crowded lane.

5. Results
The virtual ethnographic survey reflected that there are better prospects of the use of Li-Fi technology as it helps in improving the management of the traffic congestion in narrower streets. The analysis of results, reflects the views of the traffic management personnel regarding the use of Li-Fi technology. The results revealed that it is supportive of the use of Li-Fi technology, but there are some negatives as well. Most of the times, the use of Li-Fi technology could maintain traffic flow as the sensors used in this technology could read the time of start and stop of the vehicles. The use of Li-Fi technology helps in reducing the rate at which the accidents are taking place. This is mainly due to the light sensors used in the rear and front of the vehicles where with the help of echo mechanism, the distance between the two cars could be estimated.

As a result, the chances of collision between the vehicles would be reduced to a great extent. This is a major reason that has been pointed out by the respondents in the survey. However, one of the huge problems in making better traffic management is the safety of the pedestrians and to know their volume, infrared sensors are used. This is why equal importance is given to these sensors, along with the light sensors in the Li-Fi technology. The results partially favours the use of Li-Fi technology in making the traffic management system more intelligent and reduce the rate of traffic congestion. However, there are some challenges in implementing the technology as the technique is new and not much amount of the research had been done on it. There are less number of vehicles supporting Li-Fi technology in the present age and hence, virtual research gives limited outcome to the actual employment of the system. The Li-Fi technology could be used to stop the frequent collisions in the traffic by the use of it where it could send information to the drivers when to stop and start the vehicles thereby making the cars more intelligible than ever before. The results from the table are correctly in alignment with the design architecture created in the previous sections. With the accumulation of the RFID tags and the sensors, the traffic could be managed properly as the system would be more intelligent. The reason behind its intelligence would be that the data acquired through the sensors could be appropriately analysed and depending on which, volume is higher whether it is of the pedestrians or the vehicles, red and green lights are switched on and off resulting in the better traffic management system.

6. Conclusion
The research work on the use of Li-Fi technology in managing the traffic is of considerable advantage if it could be implemented properly. The rate at which the accidents are rising is due to the ineffective management of the traffic personnel. This is due to the improper decision taken while maintaining the traffic. It could be improved if the Li-Fi technology could be used to manage the traffic. The Li-Fi technology is a much more secure data transfer as compared to the Wi-Fi because the data is not hacked by anyone and the bandwidth at which the information is being shared does not get weakened with time. The setup of an intelligent system comprising of the RFID tags on the cars and using the infrared sensors helps in giving the necessary information about the surroundings. With the help of this data, the personnel feel that it is easy to control the huge traffic in high times, and this maintains the flow of the cars properly. The design architecture in the research paper give an overview of the intelligent system which could be used to reduce the rate of traffic congestion. Li-Fi technology could be used to stop the frequent collisions in the traffic by the use of it where it could send information to the drivers when to stop and start the vehicles thereby making the cars more intelligible than ever before. As a result, the frequent clashes between the vehicles could be lowered to a huge extent. However, to operate the vehicles without any delay, there should be a proper collaboration between the RFID tags, light and infrared sensors, so that the accurate data could be acquired. This would be fed to the central servers, thereby helping in maintaining the traffic flow properly. The only challenge is that not much amount of study had been done on it, and this presents a huge question of whether the technology could be applied in this scenario. As per the previous studies had been consulted, not much evidence is being founded on it. Therefore, to make it workable, the design architecture of the model should be preferred so that the study helps in designing the entire model practically. The study founded that with the help of the light sensors placed in front and rear sides of the vehicles, the cars could be able to communicate with each other through the echo mechanism where they could know the distance between them respectively. This
reduces the chances of collisions between the successive vehicles leading to better flow and lowering the rate of traffic congestion. The only challenge that might come is the line of sight should be made clear otherwise, the signal might get reflected as it is made up of light. These challenges should be taken into consideration while implementing the model in practical means.

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