Advanced Home Automation Using Light Fidelity

Varsha Shrivastava, Kevin Fernandes, Garric Mathias, Shannon Pereira

Abstract: Light Fidelity or Li-Fi is an emerging technology that uses the visible light spectrum for communication. Home automation is one of the very useful ways to control various electronic devices used in a home for our day to day activities. This paper proposes the use of Li-Fi technology, comprising light-emitting diode (LED) bulbs, as means of connectivity. Data is sent through light spectrum on an optical wireless medium as signal propagation. This idea can be implemented as an android application connected to the cloud. All the devices in any home can be monitored and controlled using this app installed in a mobile phone. A user can change the state of any device (ON/OFF) with this app. Changes are made in the cloud, and a message is sent as a binary sequence to the hardware connected to the light source. After translation, the identity of the device that needs to be controlled is obtained along with the message to toggle it between the ON and OFF states. This message is sent across using visible light communication in a secure way as the data remains within the limits of the four walls. Hardware on the receiving end senses the blinking light source, and translates the blinks into a binary sequence thus obtaining the original message. Then the device performs the necessary action and updates the cloud after completion. This is further reflected on the android application of the user's phone. Attackers cannot break into this system easily, as the device identity and the light source is required to manipulate it.

Keywords: Li-Fi; VLC; Light Spectrum; ESP 8266; Home Automation; Internet of Things (IoT); Wireless Data Communication; Cloud Database; Android.

I. INTRODUCTION

Wireless data rates have been growing exponentially in the past decade, while the availability of the radio frequency spectrum remains limited. This gives a lot of scope to use Visible Light Communication (VLC) as a substitute for traditional Wi-Fi. Li-Fi provides a higher frequency bandwidth and immunity to noise and radiation compared to traditional Wi-Fi technology. Also, with advancements in technology, automating all household amenities and appliances has become a reality. A smartphone can control home appliances.

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Thus, by using the concepts of Li-Fi and automation, a smart home can be created.

In recent years, the amount of data to be handled has increased tremendously, along with concerns for security and transmission rate. Wi-Fi has been the traditional medium for wireless data transmission. However, the decrease in the available bandwidth spectrum has limited its use. In contrast, Li-Fi provides a larger bandwidth by utilizing more than 10,000 frequencies, all of which are free and unlicensed. Li-Fi is superior to Wi-Fi as it is immune to interference and does not disrupt other communication media. It is cost-effective as it transmits data while providing lighting simultaneously and requires fewer equipment for operation. Moreover, there are no known safety or health hazards associated with this technology. Li-Fi also offers enhanced security because the light signals used for transmission do not pass through walls and are challenging to intercept [1].

Regarding security, the light signals emitted by LEDs remain confined within the boundaries of four walls. These signals consist of a combined stream of data specifying user intentions with a particular device and device identity, ensuring that only the intended device can execute the specified actions. This technology can be employed for communication in aircraft, where radio wave communication may interfere with onboard communication and navigation devices. Additionally, Li-Fi can be used underwater, where radio waves have limited transmission capabilities due to the medium involved.
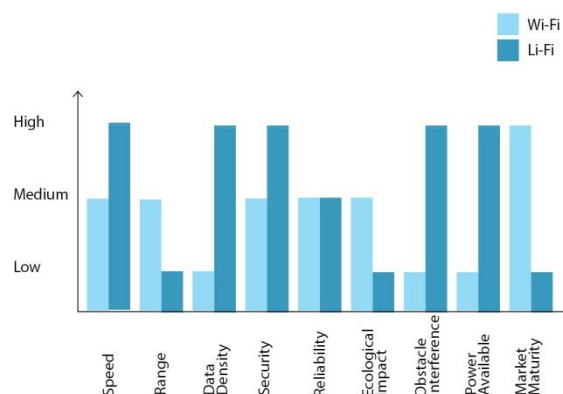

Fig.1 Comparison Between Li-Fi and Wi-Fi

As indicated in Fig. 1, the achievable speed of Li-Fi exceeds that of Wi-Fi, ranging from a minimum of 3Gbps to a maximum of 224Gbps. Li-Fi has a shorter range because light signals do not penetrate walls, unlike the radio waves used by Wi-Fi. Li-Fi can handle higher data density compared to Wi-Fi. Additionally, Li-Fi provides high security since attackers cannot capture the signals transmitted by the light source outside the room walls.

Li-Fi has a low ecological impact as it utilizes existing lighting infrastructure and is nonhazardous to use. In contrast, Wi-Fi experiences low obstacle interference compared to Li-Fi, as Li-Fi signals cannot pass through solid and opaque objects. Due to its status as an emerging technology, Li-Fi has not yet matured in the market as much as traditional Wi-Fi systems.

II. RELATED WORK

Li-Fi has much broader applications than simply as a geo-location tool. Incorporating Li-Fi into the 14 billion existing light bulbs could provide more accessible and secure internet service.

The system utilizes devices with visible light communication. The transmitter in this system is made using LEDs that transmit encoded information to receivers. This system can be used for communication in free space that obstructs the optical link. When the receiver receives the signal sent by the transmitter, it decodes and reproduces the original message. Li-Fi can address the issue of decreasing bandwidth in the radio frequency spectrum. It can also enhance security and avoid road obstacles [2].

The system uses Wi-Fi for web server communication and Li-Fi as the network infrastructure inside the home. Home devices can be controlled locally or remotely. Another part is the hardware interface module, which provides the appropriate interface between the sensors and actuators of the home automation system. No additional bandwidth is required, and the transmission speed is fast enough to be imperceptible to the naked eye. The speed of transmission is proportional to the frequency of toggling [3].

A visible light internet access communication system uses visible light as downlink, which can communicate at a distance of 2m. With the application of pre-emphasis technology, a 3-dB transmission bandwidth of 130MHz is achieved. In evaluation experiments, the test computer can access the internet and play online video resources. The maximum downlink data rate is up to 30Mb/s [4].

Wireless internet services are provided to people through Wi-Fi technology in commercial and industrial settings. It operates based on radio waves in the spectrum. These waves are harmful to people with certain medical conditions and sensitive equipment areas. Thus, it cannot be used in environments such as hospitals, scanning centers, and airlines. To overcome these limitations, Li-Fi is developed to operate in such environments. Research shows that Li-Fi provides harmless data transmission at high speeds using light sources [5]. The primary function of LEDs is for illumination. Investigations have been conducted on joint illumination and communication systems that provide lighting and VLC systems. Performance constraints imposed by illumination properties are taken into consideration using various types of luminaries, beam angles, LED lamp arrangements, and reflections off different wall materials. A white-light phosphor-based LED adaptive data rate VLC system is then demonstrated, followed by a discussion of achievable data rates [6].

Wi-Fi provides a speed of 150 Mbps according to standards, but it is insufficient to meet users' network needs. To address this drawback, German physicist Harald Haas developed a new technology called Li-Fi. The paper discusses the numerous advantages and few drawbacks of Li-Fi over Wi-Fi. Li-Fi will not replace Wi-Fi but complement it instead. Both technologies can work together to maximize the utilization of the unlicensed 60 GHz spectrum [7].

Research on visible light communication highlights its various features and advantages over traditional wireless communication using the radio frequency spectrum. It offers high data rates, secure transmission, and more frequencies compared to the radio frequency spectrum. The visible light spectrum is 10,000 times larger than the radio frequency range and can serve as an alternative to existing radio-based wireless communication technologies. It boasts advantages such as no electromagnetic interference, low cost, and high data rates [8][12][13][14][15][16].

A smart vehicular communication system was built using Li-Fi technology, providing protection against vehicular collisions on roads. Li-Fi is an emerging technology that uses the visible light spectrum for communication. This paper focuses on road safety, where headlights equipped with LEDs act as transmitters communicating with photosensors acting as receivers. White LEDs in head and tail lights can efficiently enable short-range communication with photodetectors. The application is cost-effective due to the affordability of LEDs, and simple algorithms are proposed for signal generation and transmission [9].

A home automation system uses a smartphone to enable any novice user to operate all appliances. The system comprises three components: an Arduino microcontroller for device connection, a Bluetooth module for signal transmission, and an Android smartphone running the control application. The system supports voice commands for novice users with command recognition. It interprets the user's voice commands and executes the intended actions. The design is based on a standalone Arduino BT board, and appliances are connected via relays to this board. The smartphone communicates with the Arduino through Bluetooth. The main goal of system development is cost-effectiveness and scalability according to requirements [10].

The initial designs and results of a small-scale prototype for a home automation system and vehicle communication system using Light Fidelity (Li-Fi) technology represent the most effective solution for vehicle communication and accident prevention. LED use eliminates the need for complex wireless networks and protocols. Several case studies exploring vehicle-to-vehicle communication are presented in this work [11].

III. PROPOSED SYSTEM

The existing home automation system uses Wi-Fi for its wireless communication. Wi-Fi utilizes radio waves, which have limited bandwidth. Privacy and security are always concerns because radio waves can easily penetrate through walls, acting as a gateway for attackers. Using Wi-Fi for communication also restricts the potential for creating a multicast environment.
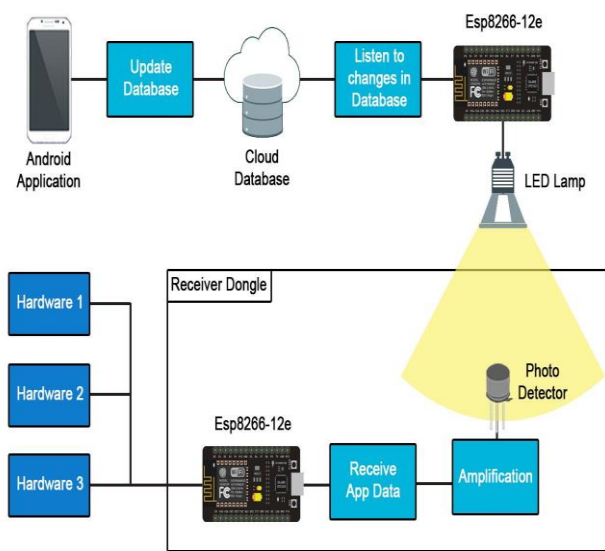
Fig. 2. System Architecture

IV. DESCRIPTION

With our proposed system, a user will be able to control their home appliances in different rooms with an easy and intuitive user interface on their smartphones. One LED Lamp is required in each room to control all the hardware appliances present in that room. The LED Lamp thus performs the dual functionality of automation and lighting the room simultaneously. Using Li-Fi in the system also makes it more secure, cost-effective, and faster.

The 'Advanced Home Automation using Light Fidelity' system employs an Android application to monitor and control hardware devices remotely. Firebase, a real-time cloud database, stores the current state and unique identity code of all the hardware. The hardware is categorized within the database based on room ID. A high-brightness LED Lamp serves as the transmission source and is connected to an ESP8266 ESP-12E, which acts as a Wi-Fi chip and microcontroller unit.

Whenever the database updates, the ESP-12E generates a binary string representing the unique identity code of the hardware and its state. Each '1' bit signifies an ON state, while each '0' bit signifies an OFF state. The LED Lamp toggles ON and OFF based on this binary string, with toggling happening so rapidly that it is imperceptible to the naked eye. The LED Lamp in each room is identified and toggled based on its room ID.

At the receiving end, a receiver dongle includes a Photo Detector, Amplifier, and another ESP8266 ESP-12E. The Photo Detector detects the transmitted binary string of 1s and 0s from the LED Lamp, amplifies it, and sends it to the ESP-12E for further data processing. The ESP-12E, equipped with multiple I/O pins, connects to multiple hardware devices. The unique identity code facilitates identification of which hardware needs to be turned ON. Whenever hardware is manually switched ON or OFF, the receiving ESP-12E updates the database and notifies the user on their smartphone.
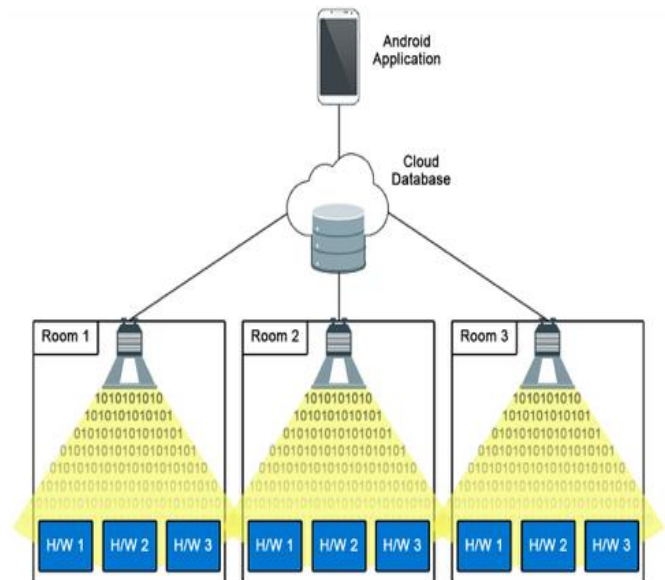

Fig. 3. Multicasting Connectivity

Fig. 3 shows the connection between the Android application, database, LED lamps, and the hardware. This is an example of a house with three rooms, each containing three pieces of hardware. All the hardware in a room can be controlled with the Android application through the LED lamps. Once any application update occurs, the room ID helps identify the LED in the room that needs to be toggled, and the hardware in that room is turned ON or OFF based on the command and the unique identity code.

V. CONCLUSION AND FUTURE WORK

Li-Fi solves many issues, such as the shortage of radio-frequency bandwidth, and aims to create new communication channels using existing equipment. Currently, the Li-Fi concept is attracting considerable interest as it provides an authentic and highly efficient alternative to wireless devices that use radio spectrum. A system composed of LEDs can transmit data at rates superior to traditional Wi-Fi systems while ensuring security and safety. Additionally, its environmental impact is negligible. This system utilizes free space as a communication medium, requiring the receiver to be in line-of-sight (LOS) with the transmitter. Communication can still occur even if they are not in direct sight, as long as the light is received at up to 50% of its original strength, beyond which the data rate may decrease.

Its applications are not limited to homes but can also extend to cars, aircraft, and underwater environments where Wi-Fi may not perform well. The Li-Fi market was valued at USD 630 million in 2015 and is projected to grow at a CAGR of 80.8% from 2016 to 2023.

Research into smarter home appliances that communicate machine-to-machine (M2M) using LED lights as Li-Fi access points is already extensive.

This development will likely require manufacturers to recognize the need for incorporating appropriate chips and firmware in these appliances to enable integration with other controllers on the home network.

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
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AUTHORS PROFILE

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