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Lifi-Wifi Integration for Data Transmission

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Abstract: TheWith the increasing demand for high-speed, secure, and interference-free wireless communication, traditional radio-frequency (RF) technologies such as Wi-Fi face limitations like electromagnetic interference, bandwidth congestion, and security vulnerabilities. This paper proposes a hybrid communication system that integrates Light Fidelity (LiFi) and Wi-Fi for efficient real-time environmental monitoring. The system utilizes an Arduino microcontroller connected to temperature, gas, and humidity sensors to collect data. LiFi is employed for high-speed, short-range data transmission using visible light, while Wi-Fi enables cloud-based remote monitoring via the ThingSpeak platform. An LCD display provides on-site data visualization. Experimental results demonstrate the system's effectiveness in achieving low-latency, secure communication, while overcoming the limitations of individual technologies. This hybrid approach is suitable for applications in smart homes, industrial automation, and IoT environments, providing a scalable and reliable solution for next-generation wireless networks.

Keywords: LiFi, WiFi, Hybrid Communication, IoT, Thing Speak, Arduino, Visible Light Communication (VLC), Data Transmission, Environmental Monitoring

I. INTRODUCTION

The rapid growth of wireless communication technologies has led to an increased need for high-speed, secure, and interference-free data transmission methods. Traditional radio-frequency (RF)-based systems like Wi-Fi and Bluetooth are widely used but face significant limitations, including bandwidth congestion, electromagnetic interference, and security vulnerabilities. These issues become critical in environments such as hospitals, airplanes, and industrial settings, where data integrity and signal reliability are essential. [1]. Light Fidelity (LiFi) is an emerging wireless communication technology that utilizes visible light instead of RF waves for data transmission. By modulating the intensity of light-emitting diodes (LEDs), LiFi enables high-speed, short-range communication that is inherently more secure, as light signals cannot penetrate walls. However, LiFi also has constraints, such as a limited range and a requirement for a clear line of sight between the transmitter and receiver. [2]. To overcome these challenges, this paper proposes a hybrid communication system that integrates both LiFi and Wi-Fi technologies. In the proposed system, LiFi is used for high-speed, short-range data transmission, while Wi-Fi is used for long-range communication and cloud integration. This hybrid approach ensures efficient, reliable, and secure wireless communication, combining the strengths of both technologies to mitigate their individual weaknesses.[3]. An LCD display is integrated into the system for on-site visualization of sensor readings. This feature enables users to view real-time environmental data without requiring internet access. The system is designed to be scalable and can be extended by adding more sensors or integrating with advanced IoT platforms. The modular design also allows for easy maintenance and upgrades [4]. This hybrid model has practical applications in areas where secure and high-speed data transmission is essential. In smart homes, it can monitor environmental conditions and trigger alerts. In industrial settings, it can enhance safety by detecting gas leaks or temperature fluctuations. In healthcare environments, the interference-free nature of LiFi makes it a suitable alternative to RF-based systems. [5]. through this research, the paper aims to showcase the effectiveness and feasibility of integrating LiFi and Wi-Fi for real-time data communication. Experimental testing under various environmental conditions demonstrates the reliability of the system and highlights the potential of LiFi as a complementary technology to Wi-Fi. This integration not only enhances performance but also paves the way for future smart communication systems. [6].

II. RELATED WORK

In Several researchers have explored the potential of LiFi technology as an alternative to traditional RF-based communication systems due to its advantages in speed, security, and interference resistance.

The integration of LiFi with existing wireless technologies such as Wi-Fi has also been examined to overcome limitations like line-of-sight dependency and short communication range. In [1], Ashutosh Kumar Pathak et al. proposed a LiFi system that utilizes visible light communication for high-speed data transfer. The study highlights the use of modulation techniques such as On-Off Keying (OOK) and Orthogonal Frequency Division Multiplexing (OFDM) to enhance data transmission efficiency. The authors emphasized LiFi's superior security and minimal electromagnetic interference, making it suitable for use in sensitive environments like hospitals and airplanes. [2]. Velu Aiyyasamy et al. in [2] implemented a LiFi-based voice/audio communication system and presented experimental results comparing its performance with traditional RF-based systems. Their research demonstrated that LiFi can effectively transmit high-speed audio data using visible light while maintaining data integrity and reducing interference. In [3], Rashmi A and colleagues proposed a secure ATM transaction system using LiFi for data transmission. The approach utilized visible light communication to ensure faster transactions and enhanced security by eliminating the use of cards. This study confirmed the suitability of LiFi for secure data environments and introduced novel applications beyond conventional internet-based uses. The work by S.V.S.N. Murthy et al. [4] explored the integration of LiFi in IoT systems for both text and audio transmission. Their research showed that the combination of Arduino microcontrollers and LiFi modules could effectively support smart home and industrial applications by providing fast and interference-free communication. Harsh Sharma et al. in [5] proposed a secure communication system using laser-based LiFi in border areas. The study focused on enhancing national security by using light-based communication that is not easily intercepted. Their system demonstrated good performance in terms of speed and accuracy but highlighted challenges in range and infrastructure requirements. A comparative analysis of these works reveals that while LiFi provides significant benefits in terms of speed and security, its limitations — such as short range, dependency on direct line of sight and vulnerability to external light **restrict** its standalone use. Therefore, many researchers suggest a hybrid communication approach by combining LiFi with Wi-Fi to achieve broader coverage and reliability.

OVERVIEW OF METHOD AND RESULTS

Overview:

The proposed system introduces a hybrid communication model that integrates Light Fidelity (LiFi) and Wi-Fi technologies to enable secure, high-speed, and real-time data transmission for environmental monitoring applications. The system addresses the shortcomings of conventional RF-based communication such as interference, security issues, and bandwidth limitations by combining the short-range, interference-free benefits of LiFi with the long-range, cloud-connectivity features of Wi-Fi. [1].The architecture is centered on an Arduino microcontroller that interfaces with a set of environmental sensors, including temperature, gas, and humidity sensors. These sensors continuously collect real-time data from the environment. The LiFi transmitter modulates this sensor data into light signals using an LED, which is then received and decoded by a photodiode at the receiver end. This setup enables short-range, high-speed data transfer without RF interference.

METHOD:

The proposed hybrid communication system integrates LiFi and Wi-Fi technologies to collect, transmit, and monitor environmental data in real-time..

1. Data Acquisition

Environmental monitoring begins with data collection using three key sensors:

- Temperature sensor (e.g., DHT11)
- Humidity sensor (DHT11)
- Gas sensor (e.g., MQ-2 or MQ-135)

2. LiFi-Based Data Transmission

The processed sensor data is transmitted using a LiFi transmitter comprising an LED that modulates light pulses to represent binary data. These light pulses are received by a photodiode, which demodulates the signals and converts them back into digital data on the receiver end. LiFi enables short-range, high-speed, and interference-free communication in a secure line-of-sight environment. The modulation techniques employed may include On-Off Keying (OOK), allowing for efficient encoding of binary signals.

3. Wi-Fi-Based Cloud Communication

Once To overcome the range limitations of LiFi and enable remote monitoring, the system includes an ESP8266 or Node MCU module that transmits sensor data to the Thing Speak cloud platform. The module is programmed to upload data at regular intervals using HTTP requests, allowing users to view historical and real-time data from any internet-connected device.

RESULTS

To evaluate the performance of the proposed hybrid LiFi-WiFi communication system, a series of experiments were conducted under different environmental conditions. The results assess the system's data transmission speed, accuracy, reliability, and overall effectiveness in real-time environmental monitoring..

PERFORMANCE METRICS

The performance of the proposed LiFi-WiFi hybrid communication system was evaluated based on several key metrics. These metrics helped in quantifying the effectiveness, reliability, and suitability of the system for real-time environmental monitoring applications. In terms of transmission speed, the LiFi module demonstrated excellent performance with latency less than 10 milliseconds for short-range communication up to one meter.

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The Wi-Fi module, responsible for uploading data to the Thing Speak cloud platform, maintained an average delay of approximately 1.2 seconds per upload cycle, which is acceptable for most IoT-based applications.

Work flow of model:

The workflow of the proposed hybrid LiFi-WiFi communication model follows a structured, multi-stage process designed to ensure efficient data acquisition, transmission, and monitoring. The system begins with the activation of environmental sensors—temperature, humidity, and gas sensors—that are connected to an Arduino microcontroller. These sensors continuously collect real-time environmental data, which is processed by the Arduino to prepare it for communication.

1. The workflow of the proposed LiFi-WiFi hybrid communication system involves a systematic sequence of operations starting from environmental data collection to cloud-based monitoring. The process begins with the activation of environment sensors, which continuously collect real-time data such as temperature, humidity, and gas levels. This data is sent to a microcontroller that reads and processes the sensor values.
2. In parallel, the system performs two tasks. First, it transmits the sensor data to a LiFi transmitter (usually an LED), which encodes the data into light pulses. These pulses are transmitted over a short distance to a LiFi receiver (a photodiode), which decodes the signals back into digital data. This step enables secure and high-speed short-range communication.
3. Simultaneously, the processed sensor values are displayed on an LCD screen for local real-time visualization, allowing users to monitor environmental parameters instantly without internet connectivity
4. After the LiFi receiver captures the transmitted data, it forwards it to the ESP8266 (WiFi module). The WiFi module is programmed to send the data to the ThingSpeak cloud platform, which serves as a remote storage and visualization tool. Once the data is uploaded, users can access it in real-time from any internet-enabled device

III.PROPOSED METHOD

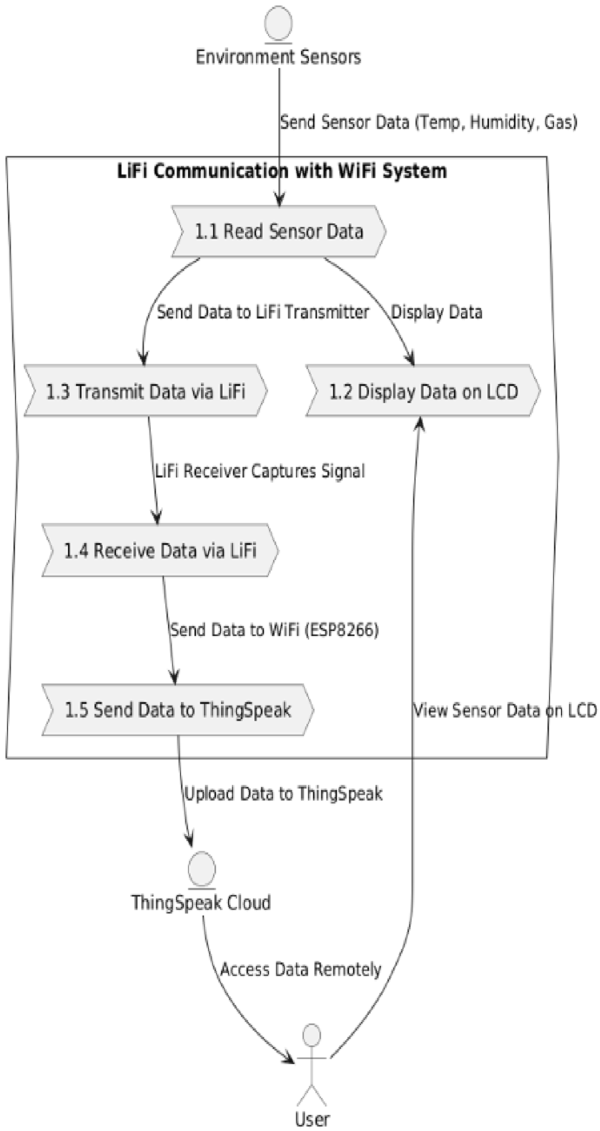

Fig1. Experiment work flow of model.

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The proposed method introduces a hybrid communication system that combines Light Fidelity (LiFi) and WiFi technologies to enable efficient, secure, and real-time data transmission for environmental monitoring. The primary objective is to address the limitations of traditional RF-based communication systems—such as interference, limited bandwidth, and security vulnerabilities by leveraging LiFi for short-range high-speed communication and WiFi for long-range cloud connectivity.

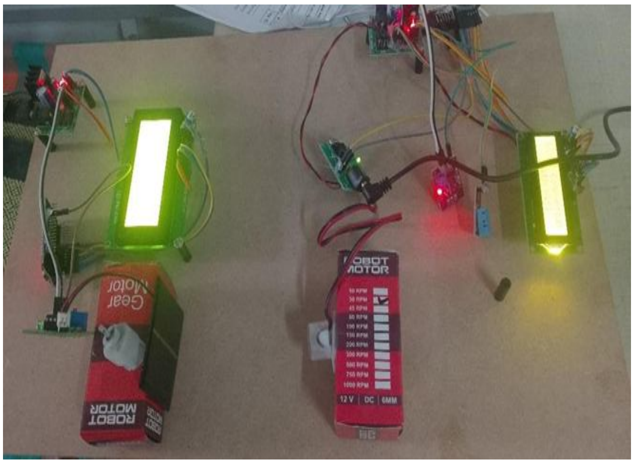
USER INPUT COLLECTION AND PRE-PROCESSING

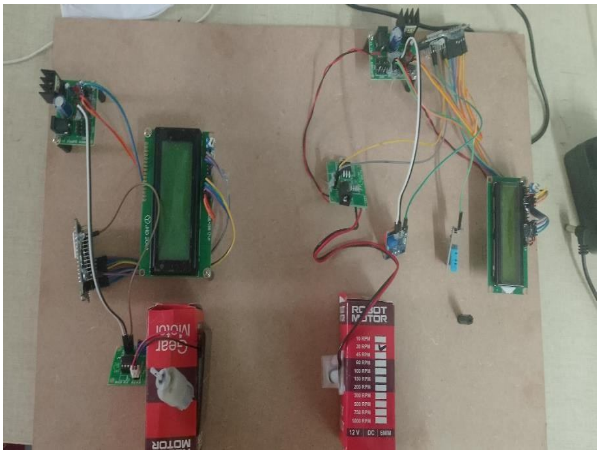
In the proposed hybrid LiFi-WiFi system, user input is primarily collected in the form of environmental data from integrated sensors. These sensors include a temperature sensor (e.g., DHT11), gas sensor (e.g., MQ2 or MQ135), and a humidity sensor, which are all connected to an Arduino microcontroller. These sensors serve as the system's input interface by continuously monitoring surrounding environmental conditions. Once the sensors collect raw data, the Arduino reads these values and performs initial pre-processing. This includes formatting sensor readings into structured digital values, filtering out noise, and validating the data to ensure it falls within acceptable ranges. For example, values that exceed sensor specifications or fall outside of logical environmental limits are discarded or flagged as invalid. This pre-processing step ensures that only accurate and meaningful data is passed forward for transmission. These sensors serve as the system's input interface by continuously monitoring surrounding environmental conditions.

FEATURES EXTRACTION USING CNN

The processed data is then prepared for two modes of communication. For LiFi transmission, the data is encoded into light signals by modulating an LED at high speeds. For WiFi communication, the data is serialized and prepared for HTTP transmission to the Thing Speak cloud platform using an ESP8266 or Node MCU module. Additionally, the system provides feedback to users through an LCD display. This on-site display allows users to verify sensor readings in real time. In some cases, the system may also allow users to define thresholds (e.g., critical gas levels), which can be entered through the Arduino code or an optional user interface. These thresholds are used to trigger alerts if dangerous conditions are detected. The primary features extracted by your system are the real-time readings from the temperature, gas, and humidity sensors connected to the Arduino microcontroller. These sensors generate continuous streams of raw data that are essential for monitoring environmental conditions in smart homes, industrial settings, or healthcare environments. This raw sensor data is first transmitted via the LiFi module, which uses visible light for short-range, high-speed, and interference-free communication. Simultaneously, the same data is uploaded to the Thing Speak cloud platform via WiFi, enabling remote monitoring and historical data. In the proposed hybrid LiFi-WiFi system, user input is primarily collected in the form of environmental data from integrated sensors. These sensors include a temperature sensor (e.g., DHT11), gas sensor (e.g., MQ2 or MQ135), and a humidity sensor, which are all connected to an Arduino microcontroller. These sensors serve as the system's input interface by continuously monitoring surrounding environmental conditions. Beyond environmental data, your system extracts communication performance features such as data transmission speed, accuracy, and reliability for both LiFi and WiFi channels. These features are vital for comparing the effectiveness of LiFi (which offers high security and low interference but is limited by line-of-sight and range) with WiFi (which provides broader coverage but is more susceptible to interference and security risks). By analyzing these features under different environmental conditions and distances, your project can quantitatively evaluate the strengths and weaknesses of each technology. Another set of features relates to security and operational constraints. For example, LiFi's inability to penetrate walls is a feature that enhances security by reducing the risk of unauthorized access. The system also monitors the presence or absence of a direct line-of-sight between the LiFi transmitter and receiver, as well as the impact of environmental factors like ambient light or obstacles, which can affect data integrity. To support real-time, on-site decision-making, your system includes an LCD display that provides immediate visualization of sensor data. The availability and timeliness of this data, both locally and on the cloud, are operational features that ensure users can respond quickly to environmental changes or hazards. These extracted features are fundamental for real-time monitoring, system optimization, and future enhancements such as AI-driven analytics or predictive maintenance. They also provide a robust foundation for validating the effectiveness and reliability of your hybrid LiFi–WiFi system in practical IoT applications. If you need further expansion on how to process these features, how to use them for machine learning, or examples of feature extraction code for Arduino or ThingSpeak, let me know!

SAMPLE OUTPUT:





CONCLUSION

This project successfully demonstrates the design and implementation of a hybrid LiFi–WiFi communication system for real-time environmental monitoring. By integrating LiFi technology with WiFi connectivity, the system leverages the high-speed, secure, and interference-free advantages of visible light communication alongside the broad coverage and remote accessibility provided by WiFi. The use of temperature, gas, and humidity sensors interfaced with an Arduino microcontroller enables accurate and continuous environmental data collection, which is transmitted locally via LiFi and uploaded remotely to the Thing Speak cloud platform via WiFi. The inclusion of an LCD display further enhances local data accessibility, providing immediate visualization of sensor readings. while optimizing the reuse of wardrobe items, thereby promoting sustainable fashion practices [2]. Additionally, the flexibility of the architecture enables future expansion, such as natural language preference inputs or e- commerce integration for suggesting matching accessories or missing wardrobe items. In summary, the proposed solution advances traditional styling methods by offering a smart, user-centric, and efficient way to select outfits. Its foundation in machine learning and personalized data makes it a practical and scalable tool for modern fashion needs.

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