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Li-Fi, AI, and IoT Technologies in Creating Sustainable Business

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***Abstract*— Li-Fi technology represents a revolutionary approach to wireless communications, enabling high data transmission speeds, low latency, and enhanced security compared to traditional Wi-Fi and RF networks. Its integration with the Internet of Things (IoT) and Artificial Intelligence (AI) opens up new possibilities across various industries, including smart cities, industrial automation, and healthcare. Research has shown that Li-Fi can improve the efficiency of IoT applications through better resource management, faster data transmission, and increased communication security. In industrial environments, the use of Li-Fi in manufacturing has resulted in a 1.52% increase in efficiency and a reduction in errors, confirming its potential in real-world scenarios. Additionally, AI algorithms combined with Li-Fi technology enable automated decision-making, real-time data analysis, and process optimization. The development of advanced handover algorithms contributes to communication stability in multi-user environments, ensuring greater system reliability.**

Li-Fi technology has the potential to become the standard for future wireless communications, providing solutions to challenges in the IoT ecosystem. Its implementation will facilitate the development of smart and energy-efficient networks, accelerating the digital transformation of various sectors.

Keywords – *Li-Fi (Light Fidelity); Artificial Intelligence (AI); Internet Things (IoT); Business intelligence (BI); Big Data*

I. INTRODUCTION

The development of wireless communications is one of the key factors in the digital transformation of modern society. With the exponential growth of IoT-connected devices, traditional wireless networks such as Wi-Fi and 5G face significant limitations in terms of bandwidth, security, and energy efficiency. In this context, Li-Fi technology offers an innovative solution that uses visible light for data transmission, enabling higher speeds, improved security, and reduced latency compared to conventional radio frequency communication systems [1].

Li-Fi technology, as a subset of optical wireless communication (OWC), utilizes LED bulbs for high-speed bidirectional communication. Its ability to function in high-density device environments and provide more secure communication in enclosed spaces represents significant advantages. When combined with IoT, Li-Fi becomes a key technology for applications in smart cities, healthcare, industrial automation, and other sectors.

One of the biggest challenges in wireless networks is the limited radio spectrum, which is becoming increasingly congested as the number of IoT devices grows. In this context, Li-Fi offers broader spectral resources by utilizing the infrared and visible spectrum, which is approximately 2,600 times larger than the radio frequency spectrum. This feature allows for faster data transmission without interference, which is common in Wi-Fi and mobile networks.

Additionally, security is one of the most critical factors in modern communication systems. Wi-Fi networks are exposed to numerous security threats, including data interception, man-in-the-middle (MITM) attacks, and unauthorized access. Li-Fi, on the other hand, transmits data exclusively within the physical space illuminated by the light source, significantly reducing the risk of data interception outside that space.

The integration of Li-Fi and IoT technologies opens new possibilities for automated and smart systems. In an industrial environment, this synergy contributes to improved efficiency in production processes, cost reduction, and enhanced product quality. Studies have shown that the use of Li-Fi technology in smart manufacturing leads to increased efficiency and reduced error rates.

The objective of this paper is to explore the potential of Li-Fi technology in the context of future wireless communications, its integration with IoT and AI systems, as well as the benefits and challenges it presents. Attention is also given to security, energy efficiency, and application possibilities across different industrial sectors. The following sections analyze existing literature, the latest studies on Li-Fi technology applications, and the possibilities for its implementation in future IoT networks. Through a systematic review, this paper provides insights into how Li-Fi can become a leading technology in the era of 6G communications and smart networks.

II. REVIEW OF RELATED LITERATURE

Future wireless communications are becoming increasingly complex due to various technologies for radio network access and their infrastructure [1]. As a solution to the growing demands of future IoT applications such as "flexible manufacturing, augmented reality, and autonomous vehicles"[2], the ELIoT (Enhancing Li-Fi for Next-Generation Internet of Things) concept has been introduced. Li-Fi offers a vast amount of spectrum, high security[3], and low-latency transmission without interference [4], [5]. Therefore, ELIoT

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focuses on features that enable the next generation of IoT applications for various "indoor and outdoor" [5] use cases in industry and other sectors [6]. A promising result of 5 cm accuracy has been achieved, which the most advanced radio-based systems cannot match.

Wang et al. (2023) [7] proposed a universal scheme for assessing wireless terminal movement and handover in the uplink VLC channel within a bidirectional Li-Fi attocell experimental system. This approach surpasses traditional methods by utilizing an optical uplink channel. The demonstrated method outperformed IHO, DHO, and SHO by 73%, 60%, and 45% [7], respectively, and can be applied in hybrid Li-Fi+5G/6G (i.e., RF) and other OWC scenarios.

Hybrid networks such as Li-Fi/Wi-Fi (WLWnet) combine the high-speed data transmission of Li-Fi with the broad coverage of Wi-Fi [8], mitigating each other is drawbacks. Studies have shown that such networks can achieve better performance than standalone networks [9]. Besjedica et al. [10] examined user behaviour performance, handover models and load balancing, security, and IoT integration [10].With the rapid growth of IoT, new trends and advancements shape its future applications, from smart homes and cities to industrial automation. One of the main trends in IoT is the integration of artificial intelligence and machine learning algorithms, enabling devices to analyse data in real time, make autonomous decisions, and adapt to changing conditions. Although this integration offers many benefits, it also presents challenges regarding privacy, data ownership, and the digital divide [11].

An experiment on smart manufacturing efficiency [12] demonstrated a significant increase in efficiency (1.52%) and a reduction in detected errors, resulting in a higher quality rating (0.76%) [12]. Future IoT applications will depend on advanced real-time processing in cloud-connected mobile IoT devices, and the current radio-based infrastructure cannot provide the necessary bandwidth for 6G networks. Due to its fast data transmission, security, privacy, and numerous access points, Li-Fi, according to Alnajjar, S., et al. (2023) [13], is considered a promising solution for IoT application development.

III. TECHNOLOGIES AND THEIR INDIVIDUAL ADVANTAGES

Li-Fi is a wireless communication technology that uses light to transmit data and determine device position. It enables high-speed, bidirectional communication over a wireless channel using the visible light spectrum in controlled indoor environments such as rooms, vehicles, etc. It supports user mobility and multi-user access, with the infrared and visible light spectrum being approximately 2,600 times larger than the entire radio frequency spectrum. By using visible light as a data transmission medium, a type of VLC system, it requires two components: a photodiode and a light source. The advantages of Li-Fi technology include: a photodiode and a light source.

Advantages of IoT
Faster processing times
Accessibility and mobility
Improved tracking capabilities
Enhanced modern living

Table 1. Characteristics of IoT Technology [25], [26]

The advantages of Li-Fi technology are: 1. Speed – up to ~1Gbps [14], [15], [16], based on experiments with low BER (bit-error rate) [17]; 2. Versatility – easy integration into existing LED systems [18]; 3. Cost-efficiency; 4. Availability; 5. Security – data remains confined within the illuminated space [19], [3].

Parameters	Li-Fi	Wi-Fi
Transmitter	LED	Antenna
Frequency Band	1000 times larger than THz	2.4 GHz – 5 GHz [20]
Standard	IEEE 802.15.xx	IEEE 802.11xx
Number of Users	Dependent on lamps/light coverage	Dependent on access points
Topology	Point-to-Point	Point-to-Multipoint
Communication Type	Visible Light Communication (VLC)	Radio Frequency Communication (RF)
Availability	Available anywhere (airplane, underwater, etc.)	Limited
Power Consumption	Lower	Higher

Table 2. Characteristics of Li-Fi Technology [14], [21]

AI utilizes machine learning and deep learning algorithms to analyse vast amounts of data, recognize patterns, and autonomously improve performance. The integration of AI with IoT is becoming increasingly common due to automated decision-making and process optimization [22].

Impact on the sector	Benefit	
Finance	↓	Risk
	↑	Prediction
	↑	Data Management
	↑	Asset Exchange
Economy	↑	Automation
	↑	Changes in Work Methods
Business	↑	Performance
	↑	Productivity
	↑	Efficiency
	↑	Problem Solving
	↑	Reduction of Unplanned Downtime
	↓	Risk
	↓	Cost

Table 3. Characteristics of AI Technology [23]

Today, IoT encompasses a vast ecosystem of devices, platforms, and applications and is expected to grow significantly in the coming years. AI has the ability to process massive amounts of data generated by IoT devices, uncovering patterns and insights for decision-making. It plays a role in shaping IoT by enabling smarter and more autonomous systems through machine learning and data analytics [24]. This synergy enhances IoT functionality, making systems more efficient, adaptable, and responsive to changing conditions.

IV. INTEGRATION OF IOT, AI, BI, AND BIG DATA ANALYTICS FOR ENHANCED BUSINESS SUSTAINABILITYIOT, AI, BI

The convergence of AI with IoT [27] is a key trend in improving business sustainability. IoT devices generate vast amounts of data [28], which AI can analyze to extract valuable insights. In supply chain management, IoT-enabled sensors can track the condition and location of goods in real time, allowing businesses to optimize logistics and reduce waste. This synergy between AI and IoT enhances operational efficiency [27] and contributes to do sustainability goals.

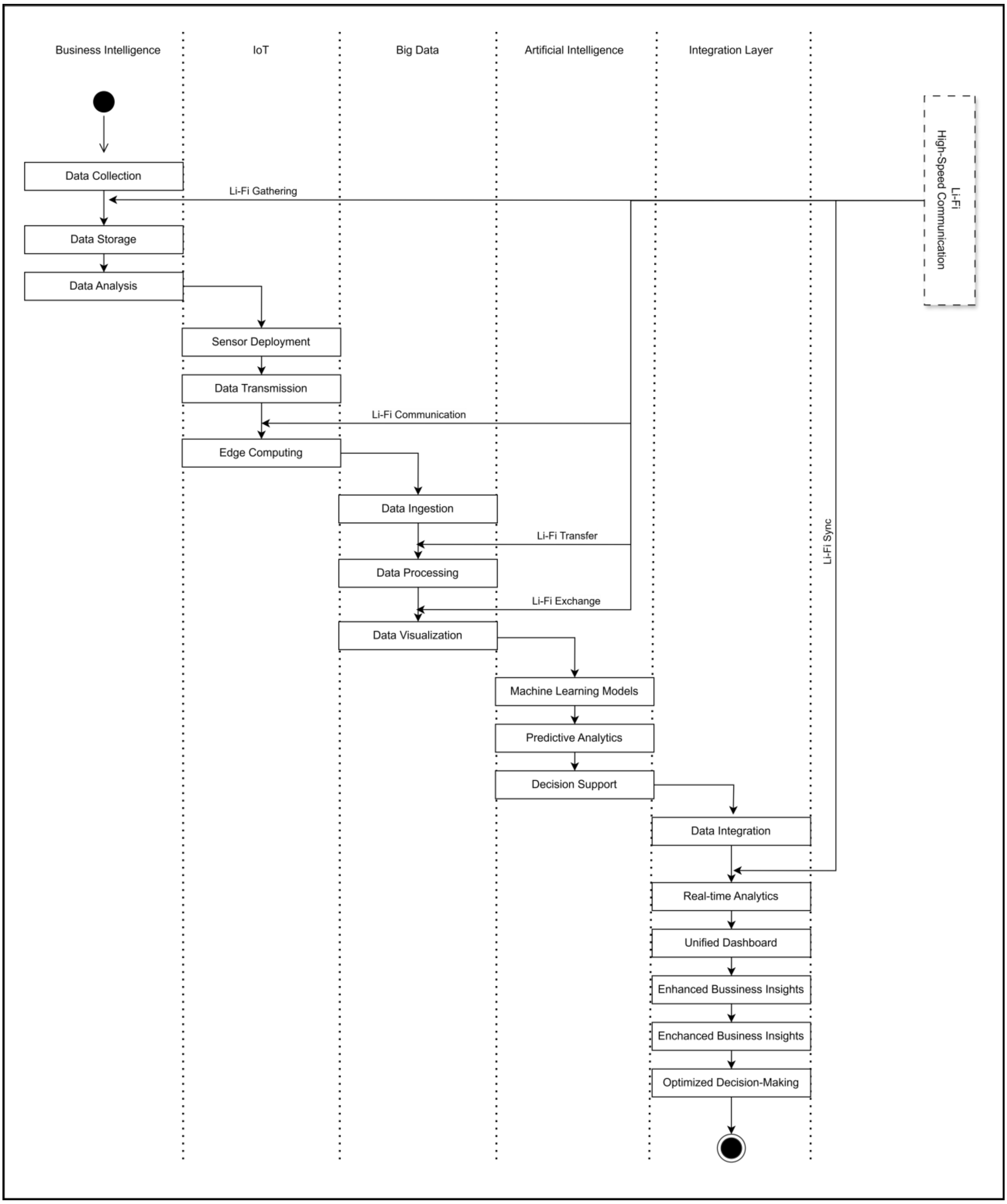

Illustration 1. Integration of IoT, AI, BI and Big Data Analytics[30]

In the agricultural sector, artificial intelligence improves sustainability by ensuring optimal plant growth conditions and optimizing the use of water and minerals, thereby enhancing food security while reducing environmental impact. By utilizing data from satellite imagery, soil sensors, temperature monitoring, etc., AI provides valuable insights for sustainable farming.

A significant application of AI in business sustainability is predictive analytics, which involves using historical data and machine learning to forecast future trends and behaviors. Regarding sustainability, predictive analytics enables businesses to anticipate product demand, optimize supply chains, and minimize waste [29]. For example, AI can optimize logistics processes by analyzing delivery routes and suggesting the most efficient paths, reducing fuel consumption and greenhouse gas emissions. Additionally, AI can predict plant growth conditions and optimize water and mineral use accordingly. Autonomous systems represent another aspect of AI is role in enhancing business sustainability. Examples include robotic warehouses and autonomous ships, which improve logistics and transport efficiency. Autonomous ships can optimize maritime routes, reduce fuel consumption, and lower emissions. Similarly, robotic warehouses allow for faster and more precise order processing, minimizing waste and operational costs.

Optimization algorithms analyse vast datasets to identify the most efficient ways to allocate resources, manage inventory, and plan production. By optimizing these operational aspects, businesses can achieve greater sustainability and cost savings. By integrating IoT, AI, BI (Business Intelligence), and Big Data analytics, businesses can gain deeper insights into their operations, customer behavior, market trends, and more. This integration enables not only real-time insights but also the ability to predict future trends and make proactive decisions, fostering sustainable growth and long-term success.

Li-Fi is unlocking its potential for future IoT networks due to its low-cost implementation and better energy efficiency compared to other types of wireless communication. The main reason for this is LED bulbs [31], which are already proven to be energy-efficient. An LED is a semiconductor device that emits light when an electric current passes through it. In the case of Li-Fi technology, LEDs function as data transmitters [32]. Any LED bulb can be used for this purpose, provided that it is equipped with a microchip to simultaneously provide illumination and enable wireless data transmission [33]. Efficient multiple access techniques are crucial for the successful implementation of Li-Fi-IoT [34], as IoT typically requires connecting a large number of devices per unit area [31], [35]. Li-Fi is well-suited for this need, as it can support a high number of connected devices [34].

This Li-Fi-based architecture enables the creation of a multi-layered IoT system, facilitating the development of various Li-Fi applications across different sectors. It serves as a starting point for designing a scalable and generic system based on GeoLi-Fi for both indoor and outdoor environments.

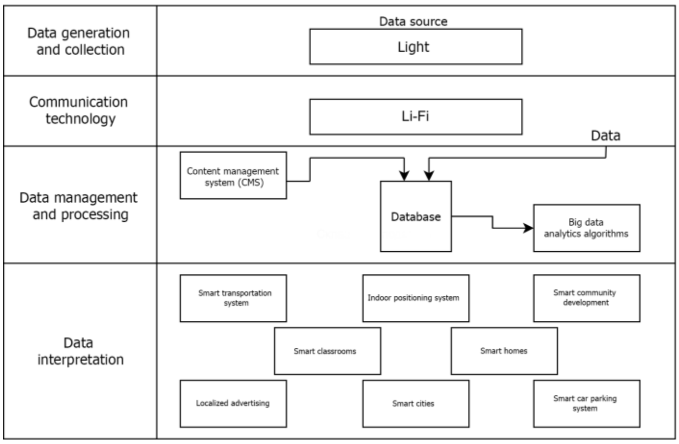

Illustration 2. Proposed IoT Hierarchical Architecture Based on Li-Fi [36]

The system aims to develop a Content Management System (CMS) for Li-Fi-generated content and a mobile application for users. The first three levels of the system are currently in development. However, once the system is fully deployed and functional, data will be collected and analysed across different scenarios. As the significance of Li-Fi technology continues to grow, the demand for such systems will also increase accordingly.

V. CONCLUSION

Li-Fi technology represents a significant advancement in the field of wireless communications, offering solutions to many challenges associated with future IoT applications. Due to its capability for fast and secure communication, Li-Fi has the potential to become a key component in the development of 6G networks and smart systems. With increasing demands for higher bandwidth and lower latency, Li-Fi ensures more reliable and energy-efficient networks compared to traditional Wi-Fi systems.

As the IoT ecosystem expands, Li-Fi technology is becoming a crucial factor in developing advanced and energy-efficient communication systems. Its implementation will contribute to the development of smart networks, enhance data security, and enable faster and more reliable real-time communication.

In the future, further research and development in Li-Fi, AI, and IoT will define new standards for wireless communication and unlock opportunities for innovative applications across various industrial sectors

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