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Integrating Wireless Sensor Network with Li-Fi Wireless Communication Technology based on NOMA Technique: A Survey

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Abstract

Li-Fi stands for Light-Fidelity, is a creating department of Optical Wireless Communication (OWC) that gives more noteworthy information transmission using obvious light as a medium rather than conventional radio frequency electromagnetic radiation with the ability to employ surplus users since it uses a wide range of spectrum bandwidth. Recently the implementation of wireless sensors has been increased in the design of high-performance buildings. On the other side, the main challenge in using Wireless Sensor Systems (WSNs) is that the sensor nodes have restricted power in their essential power capacity unit, this power may be rapidly exhausted in case the sensor node remains operational for extended periods of time also data transmission is a significant challenge in WSNs. Non-Orthogonal Multiple Access (NOMA) is a novel encoding technique proposed for next-generation wireless communications. NOMA may send many symbols utilizing the same time, frequency and coding resource but dividing them in the power domain and differentiating them based on the various power levels of distinct symbols, which are subsequently demultiplexed at the receiver using an interference cancellation approach. Since the main requirement of WSNs are high connection, low latency, energy savings, and ultra-high data rates, we give an overview of Li-Fi technology and a study of its performance over WSNs aided by the NOMA technique in this survey article.

Keywords: Visible light communication (VLC), Light Fidelity (Li-Fi), Wireless Fidelity (Wi-Fi), Wireless Sensor Networks (WSNs), Non-Orthogonal Multiple Access (NOMA).

1. INTRODUCTION

Transferring data from one place to another is one of the most important day-to-day activities. When several devices are linked to the present wireless networks that connect us to the internet, they are extremely sluggish. As the number of devices connecting to the internet grows, the available fixed bandwidth makes it increasingly difficult to enjoy high data rates and connect to a secure network. Nowadays, a variety of emerging technologies has been utilized in high-performance applications. One of these technologies is called Light-Fidelity (Li-Fi) that is an unused kind of wireless communication system utilizing light as a medium rather than conventional radio-frequency electromagnetic radiation.

Visible light communication (VLC) is the broader umbrella under which Li-Fi falls. It has emerged as a point-to-point data communication technique that utilizes light-emitting diodes (LEDs) to completely organized wireless systems, which leads to early standardization activities as part of IEEE 802.15.7 this standard is still being revised to include Li-Fi [1]. Furthermore, the visible light spectrum is assumed to be utilized for both uplink and downlink communication in most VLC studies. On the other hand, Li-Fi includes a larger range of networked systems, such as multiuser, bidirectional, multicast, or broadcast communication.

According to the literature, the VLC idea was initially introduced in 2003 at Japan's M. Nakagawa Laboratories; the VLC ID System Development Kit has been accessible there since 2012 [2]. Their primary area of study is currently undersea VLC. Figure 1 illustrates the VLC system model's block diagram.

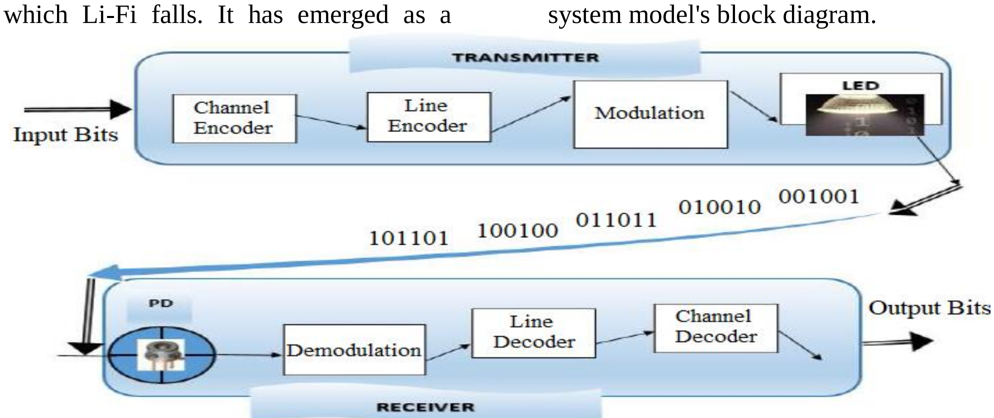

Fig. (1) Block Diagram of the VLC System.

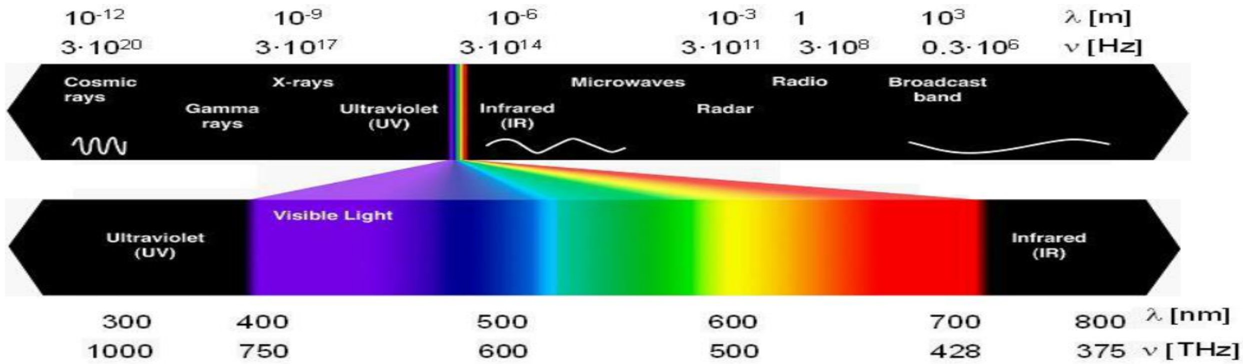

Fig. (2) Electromagnetic Spectrum Wavelength Diagram [3].

Light fidelity is a short-range wireless communication technology that uses visible light of the electromagnetic spectrum between the blue (670 THz) and red to (480 THz) frequencies [3] as shown in figure 2. Li-Fi comprises of wireless organized structure that incorporates bi-directional multiuser communication, too including numerous get to focus shaping the wireless network of a little optical attocell with consistent handover [4]. Li-Fi is implied to supplant, in certain places and circumstances, the well-known stuffed and/or illegal communication by radio waves.

In differentiate to the rare and controlled radio frequency (RF) range, the visible light range is tremendous (approximately 300 THz). Other points of interest that Li-Fi offers over wireless devotion (Wi-Fi) incorporate i) provision of illumination, ii) accessibility in RF-restricted zones, and iii) secure communication since light does not burrow opaque structures [5]. More critically, Li-Fi can give high-speed information transmission to assist satisfy the quickly expanding request for wireless communications. The later investigation appears that with a single light-emitting diode (LED), Li-Fi can accomplish crest data rates over 10 Gbps [6,7].

Li-Fi allows an electronic device to connect to the internet without the use of a cable, hence it is a solution to the shortage of current technology. To establish a communication channel between nodes, a Li-Fi device will require a transceiver to transmit and get information. This transceiver will use a modulation mechanism to enable the LED to transfer information via light. We are all aware that Wi-Fi is presently the foremost well-known innovation for interfacing numerous devices to the web. The use of internet-connected gadgets is increasing with time. Due to radio frequency resource limitations, this increases lowered Wi-Fi bandwidth [8].

Li-Fi and Wi-Fi have contrasts related to congestion, density, security, safety, and speed. The more Wi-Fi empowered gadget exists, the congestion may happen. Within the innovation of Wi-Fi, we can't include more routers in case the user is increased, whereas we will include the light in Li-Fi. The execution of Li-Fi is that superior to the execution of Wi-Fi because the appraised speed of Li-Fi is a thousand times speedier than Wi-Fi [9]. The proficiency and security of the web are the overwhelming issues right presently so for security, based on signal dispersion, Li-Fi is more secure than Wi-Fi. Li-Fi has a light feature that prevents light from passing through the divider. It differs from the Wi-Fi signal, which can reach everywhere. Based on these two advances, the primary conclusion is that Li-Fi provides more secure connection than Wi-Fi.

Wireless Sensor Networks (WSNs) are commonly regarded as one of the most important technologies of the twenty-first century. WSNs differ from typical wireless communication networks in several ways, including denser node deployment and greater sensor node reliability, but severe energy, compute, and storage restrictions create numerous new challenges in the development and application of WSNs.

WSNs have gotten a lot of interest from academia and business all around the world in the last decade. A great number of research activities have been conducted to investigate and address different design and application challenges, and significant advances have been made in the development and deployment of WSNs. These are expected to be widely employed in many civilian and military areas soon, revolutionizing the way individuals live, work, and are associated with the physical environment.

In WSNs, sensor nodes integrate the functions of data sensing and communication, these networks consist of sensors that are distributed in an ad hoc manner that is composed of individual devices communicating with each other directly. Due to the increasing demand for uses wireless data which communicates between nodes in WSNs, the available radio spectrum is insufficient also once the battery is exhausted, the sensor nodes will fail to work, which reduces the lifetime of the system. As a result, new designs must be developed, and new technology must be introduced to overcome the challenges in WSNs.

Non-orthogonal multiple access (NOMA) is considered a promising multiple access method for 5th Generation (5G) cellular networks [10,11]. In NOMA, multiple user transmitted signals are multiplexed in the power domain utilizing the same time, frequency, or coding resource, and demultiplexed at the receiver using an interference cancellation algorithm [12].

NOMA shows qualities that we consider as profoundly significant to tending to the sending challenges of remote sensor systems, large-scale systems of remote sensors thickly sent for omnipresent observing of physical situations. Particularly, for a given spectrum bandwidth, NOMA can empower more synchronous associations than existing approaches without the overheads of coding and separation to facilitate the division of the user's signals at the receiver [13].

NOMA has the advantage of allowing each user to access the whole frequency bandwidth while multiplexing the users within the power domain. Typically accomplished by superposition coding for the transmitter and successive interference cancellation (SIC) for the receiver to eliminate incoming interference and then decode the data signals [14]. Based on this, NOMA has been displayed as an exceedingly proficient procedure in cellular systems and wireless sensor systems.

This paper discusses the problem in WSNs, which includes future research based on throughput, energy efficiency, and security challenges. It also explains the newly created technology, Li-Fi, which is given through architecture, modulation, and performance compared with Wi-Fi. This paper is organized as follows:

- Section 2 discusses the VLC-based Li-Fi technology.
- Section 3 discusses Wireless Sensor Networks systems (WSNs).
- Section 4 discusses the NOMA technique's fundamentals.
- Section 5 discusses the integrating WSNs with Li-Fi using NOMA.

This article may be used as a reference and source of knowledge for designing LiFi-WSNs systems.

2. LIGHT-FIDELITY (LI-FI) TECHNOLOGY

The term Li-Fi is an acronym for "Light Fidelity". It is a method of transmitting data through illumination and sending data through an LED light bulb whose intensity varies faster than the human eye can perceive. The term Li-Fi has been adopted by some to represent the fast and low-cost wireless communication technology that is the optical counterpart of Wi-Fi [15]. In fact, light is a very part of our lives for millions and millions of years. So, Li-Fi may be available to use wherever there is the availability of light. We can dispense the need for hotspots by using light to communicate data. This is an opportunity to take advantage of a previously unused portion of the electromagnetic spectrum.

2.1 Historical Perspective

In 1880, Alexander Graham Bell exhibited the photophone, which used sunlight to transmit sound across more than 200 meters. A vibrating mirror, which was linked to a microphone reflected sunlight. A parabolic mirror with a selenium cell in the centre caught the intensity fluctuations of the reflected light and turned them into an electrical signal that was sent into a loudspeaker at the receiver. He was able to send analogue speech signals wirelessly using sunlight because the intensity changes were proportional to the fluctuating current created by the microphone.

Around a long time afterward, the age of light-emitting diodes (LEDs) began [16] and 100 years later, analysts created the first wireless data transmission systems based on artificial light utilizing LEDs, primarily at Bell Labs [17] and IBM Research labs. In the 1980s, IBM analysts made the primary organized infrared-light-based wireless systems as intercontinental between dispersed Pcs [18].

Bell's thought of utilizing light for wireless communications but presently manufactured white light for computerized wireless communication with greatly high transmission speeds have progressed much closer to reality. Around the year 2000, Nakagawa and colleagues at the Visible Light Communication Consortium (VLCC) started utilizing white high-brightness LEDs for information transmission.

In [19,20], they named it visible light communication (VLC) and concentrated their study on application thinks. Other investigate in this area, however, has centred on the advancement of modern methods to progress the data rates of bandlimited phosphor-coated white LEDs in [21], as well as the primary exploratory comes about on the utilize of the high crest factor of orthogonal frequency division multiplexing (OFDM) for intensity modulation/direct location (IM/DD) in [22].

Optical camera communication (OCC) is a type of free-space light communication that employs embedded camera sensors as receivers [23-25]. OCC is usually one-way (basic) communication, with indoor location and navigation as the primary use cases [26-29].

Li-Fi is a subset of VLC that defines a complete wireless network that enables user mobility, handover, and multiuser access and is a component of current heterogeneous wireless networks [1], as shown in figure 3. This type of Li-Fi network is also known as an optical attocell network [30]. An optical attocell network attempts to overcome the coming spectrum problem in radio frequency (RF) communications [31], where data density is more essential than the linked data rate.

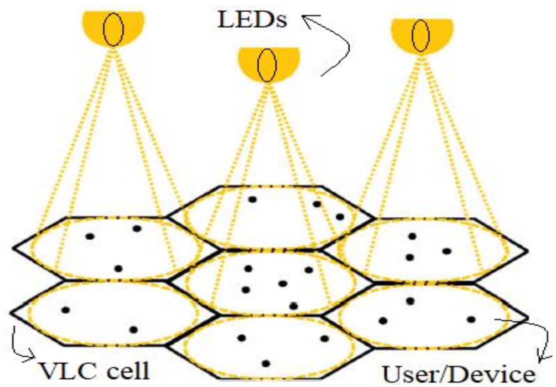

Fig. (3) Schematic of Li-Fi Systems [33].

This is measured in bits per second per unit area. A Li-Fi network has been demonstrated to enhance data density by three orders of magnitude while entirely avoiding interference with current RF-based networks [32]. This implies that the Li-Fi network merely augments the current RF networks in terms of capacity. Most significantly, it will be able to make use of the current lighting infrastructure.

From a lighting industry perception, this advancement has been welcomed because the (20-30) year lifetime of a LED light bulb suggests that trade models must unavoidably move from deals of lighting equipment to services, and light-as-a-service (LaaS) has ended up an overwhelming commerce point within the lighting division. The Li-Fi systems exploit the utilize of the lighting framework and change it into a wireless communication network, possibly empowering hundreds of services [33].

The commercialization of Li-Fi technology has made considerable progress. Discussions on sixth generation (6G) technologies have begun, and it is believed that a new spectrum is necessary, putting VLC and Li-Fi on the map for 6G [34].

2.2 Working Principle

In Li-Fi systems, the information signals flow by switching light-emitting diode (LED) bulbs on and off in nanoseconds so is too speedy. Then, it delicately adjusts the current supply to the LED lights at high rates, and so the modulation conveys the data onto the visible light. Furthermore, the LED lights are not turned on and off in a distracting manner, so users will not get a headache if they are exposed to the lights. Figure 4 shows the basic block diagram of Li-Fi systems.

2.2.1 Transceiver

According to Figure 5, a transceiver is a block that can function as both a transmitter and a receiver this is made up of an LED that transmits light and a photodiode that receives light. An amplifier is included to increase the power of the light received from the photodiode. The modem modulates and demodulates the signal. The photodiode signal is analogy, and it is converted to digital in the modem. The digital signal is converted into an analogy signal in the modem and delivered via LED while the signal is ready to broadcast. The driver prior to the LED operates to drive the current of the LED, resulting in flashing. The flickering is used to activate the LED for data transmission; if the LED is turned on, it communicates a digital '1' if it is turned out, it transmits a digital '0' [35].

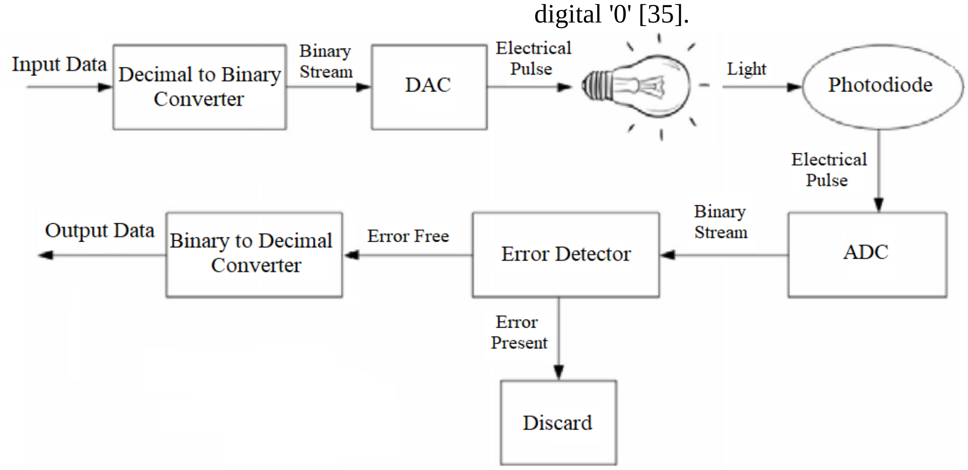

Fig. (4) Block Diagram of Li-Fi Systems.

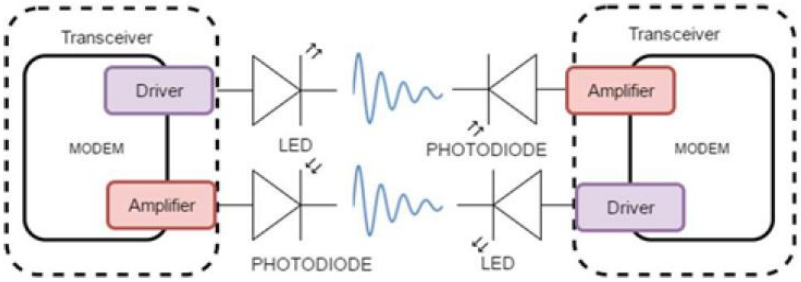

Fig. (5) Block Diagram of Transceiver for Li-Fi Systems [8].

2.2.2 Modulation

Modulation signals are used to switch LEDs at certain frequencies that carry data to be conveyed according to [36], there are many modulation methods used in Li-Fi. Modulation methods are necessary to ensure that communication continues even when light is not required. As a result, a modulation approach may be able to offer dimmable lighting. The change in light intensity corresponds to the information in the message signal. In Li-Fi, there are three forms of modulation: single carrier modulation (SCM), multiple carrier modulation (MCM), and colour modulation. Table 1 summarises the difference between SCM and MCM.

TABLE 1. Modulation Technique for Li-Fi Systems.

Type	Modulation	Definition & Characteristic
SCM	OOK	On-off keying (OOK) is a single carrier pulsed modulation that has been simply utilized in VLC systems with low complexity and cost. It is a simple and well-known modulation technique to provide good adjustment between implementation complexity and system performance.
	PPM	Pulse Position Modulation (PPM) is a modulation technique that allows for variations in the position of pulses based on the amplitude of the modulating signal sampled. It gives effective in variable beat position modulation.
	PAM	Pulse amplitude modulation (PAM) is the basic form of pulse modulation. The signal is sampled at regular intervals in this modulation, and each sample is proportional to the amplitude of the modulating signal. Also, it is delicate to signal distortion [37] combination with other modulation strategies to urge way better execution.
MCM	OFDM	Orthogonal Frequency Division Multiplexing (OFDM) is a way of encoding digital data on multiple carrier frequencies and a kind of digital transmission. It is ideal for instances when numerous transmitters are utilized concurrently to prevent shadowing effects. Interference can be reduced by shifting the system bandwidth to a higher frequency [22].
	DCO-OFDM	It is DC-biased optical OFDM (DCO-OFDM) [38]. In this modulation, the substantial energy dissipation is due to the biasing [39].
	ACO-OFDM	Unevenly Clipped Optical Orthogonal Frequency Division Multiplexing (ACO-OFDM) modulation is one of the strategies that can change over the transmitted signals to be bipolar and genuine without any loss of the transmission data [40]. It is proficient in terms of optical power for lower SNR values for the IM/DD channel [41].
	PAM-DMT	Pulse Amplitude Modulated Discrete Multi-Tone modulation (PAM DMT) is a pulse amplitude modulation of the subcarriers used that the resultant PAM-DMT time signal can be trimmed asymmetrically to generate a unipolar signal for transmission [42]. It has a higher optical power efficiency than DCO-OFDM. [43].
	AHO-OFDM	Asymmetrical Hybrid Optical OFDM is proposed for visible light communication systems, which fully uses the subcarriers and dynamic range of LEDs to accommodate multiple dimming objectives and improve system performance [43-44].
	Flip-OFDM	It is a technique that can be used to compensate for multipath distortion effects in optical wireless channels. It's equivalent to the ACO-OFDM in terms of spectral efficiency and error performance [45-46].
	U-OFDM	Unipolar OFDM (U-OFDM) stands out with its better error rate performance, where each time sample is encoded into a pair of new time samples [47]. In terms of spectrum efficiency and error performance, it is equivalent to ACO-OFDM [46].

2.2.3 Propagation Channel

The propagation channel in Li-Fi is not different from VLC. According to [48], an interior environment distinguished by six distinct link configurations denotes IR connections. In the propagation channel, the transmitter and receiver must interact using one of two criteria: direct or indirect line-of-sight (LOS). These two parameters are subordinate on the degree of directionality of the transmitter and recipient (LOS), while the others are based on light reflection (non-LOS). The joins between the transmitter and recipient are pointed or coordinated at each other in LOS. In the absence of LOS, light is distributed by the reflection of the ceiling or a diffusely reflecting surface. Table 2 summarises the characteristics of each criterion.

The accessibility of line-of-sight (LOS) optical connections is a critical element for achieving high data speeds. A non-directed LOS transmission is equivalent to restricting the data speeds that may be achieved. While the lighting conditions may differ, it is critical to use a dynamic rate to establish a strong VLC connection. According to [49], LOS may no longer be required K-D. Langer's rate-adaptive visible light communication at 500 Mbps is now ready for use. Bidirectional high-speed VLC systems are being developed in real-time.

2.3 Advantages of Li-Fi Systems

Li-Fi is suitable for providing high-density wireless data coverage in confined spaces and avoiding radio interference. Among its characteristics are the following advantages:

- Capacity and high data rate.
- Energy efficiency.
- Security and safety for wireless systems.

2.4 Some Application of Li-Fi Systems

Due to its benefits, Li-Fi has a wide range of Life applications. As a follow some examples of its most important uses.

- Buildings (e.g., Smart Home, Offices and Companies).
- Underwater Communications.
- Traffic Management.
- Medical Applications.
- Airways.
- Indoor Navigation System.
- In Sensitive Areas or in Hazardous Environments.

2.5 Performance of Li-Fi Systems

The internet's efficiency and security are currently the most pressing problems. The purpose of the design Li-Fi systems is to overcome the disadvantage of Wi-Fi that insufficient to support many users. Table 3 shows the different speeds between Li-Fi and Wi-Fi.

Li-Fi allows the system to employ completely networked wireless communication and has the potential to create a connection that is 100 times quicker than Wi-Fi. The rated speed of Li-Fi is determined by modulation. Using DMT modulation, it can achieve rates of up to 3 Gbps [54]. While the technology is still in development, the rated speed of Li-Fi might be more than 3 Gbps. By several characteristics are utilized to make comparisons, Table 4 illustrates the distinction between Li-Fi and Wi-Fi.

TABLE 2. LOS and non-LOS Characteristics.

	Directed	Hybrid	Nondirected
LOS	- Increases power efficiency. - Reduce route loss and ambient light noise reception.	- The combination between a transmitter and a receiver with varying degrees of directionality.	- Wide-angle transmitters and receivers and helpful to utilize for portable terminals.
Non-LOS	- A surface that reflects light. - Rely on light reflection from the ceiling or another diffused source. - Allowing the link to function even when there are barriers.		

TABLE 3. Different Speeds between Li-Fi and Wi-Fi.

Standards and Speed of Wi-Fi [8]			Speed of Li-Fi Systems		
Standard	Date	Data Rate	Reference	Modulation	Data Rate
802.11b	1999	11 Mbps	[50]	PAM	20 Mbps
802.11a	1999	54 Mbps	[48]	PPM	30 Mbps
802.11g	2002	54 Mbps	[51]	OOK	803 Mbps
802.11n	2007	72-600 Mbps	[52]	CAP	1.1 Gbps
802.11ac	2013	433 Mbps-1.3 Gbps	[53]	OFDM	2.1 Gbps
801.11ax	2018	Under Research	[54]	DMT	3.4 Gbps

TABLE 4. Comparison Between Li-Fi and Wi-Fi [56].

Parameter	Li-Fi	Wi-Fi
Transmitter	LED	Antenna
Receiver	LED	Antenna
Inbuilt Device	Under research and development	Wi-Fi Card/Chip
Average Operation Speed	Greater than 10Gbps (under research)	150-600 Mbps
Frequency band	1000 times of THz	2.4 GHz
Standard	IEEE 802.15.xx	IEEE 802.11.xx
Number of users	All over under the lamp	Depend on access point
Data Transmission	Bits	Radio waves
Coverage Area	10 meters	20-100 meters varies based on type of transmission power and antenna
Interference	No interference issues with RF waves	Interference with neighbour AP routers
Network Topology	Point to Point	Point to Multipoint
Communication	Based on Visible Light Communication	Based on Radio Frequency Communication
Efficiency	More, LEDs consume less energy and highly efficient	Less, Radio Base Stations consume high amount of energy
Availability	Anywhere	Limited
Secure	More secure because light waves cannot penetrate through walls and cannot be intercept by anyone outside the illumination of LED	Less secure because of high penetrating power of radio waves, anyone can intercept
Suitability	Suitable for high data rates and secure communication	Suitable for Aps with high coverage regions
Signal-to-Noise Ratio	High	Maybe more
Power consumption	Less	More
Architecture	Atto Cell	Femto Cell [55]
Environment Impact	Low	Medium

3. WIRELESS SENSOR NETWORKS (WSNs)

Wireless Sensor Networks (WSNs) are commonly regarded as one of the most important technologies used in our time daily life. Recent advancements in microelectromechanical systems (MEMS) and integrated circuits (IC) have enabled the development of small-scale sensors as well as the integration of their actuators and electronics onto a single low-cost high-performance chip. These sensors have evolved over the last decade into smart sensors, which now feature an integrated CPU, memory, and transceiver, all housed in a small-scale factory and powered by a battery supply. These smart sensors are nodes in Wireless Sensor Networks (WSNs), which provide new opportunities for a wide range of civilian and military applications.

WSNs systems include components at various levels, such as sensor devices, sensor processing, and network interfacing, energy-efficient and dependable protocols that support quality of service (QoS) requirements, middleware plan that proficiently collects, archives, and makes information accessible for encouraging preparation and visualization, and applications that utilize the information to form choices relating to a horde of solutions and applications.

WSNs have gotten a lot of interest from academia and business all around the world in the last decade. A great number of research activities have been performed to investigate and solve various design and application challenges, and substantial breakthroughs in the development and deployment of WSNs have been realized. WSNs are expected to be widely employed in different sectors soon, revolutionizing the way we live, work, and interact with the physical environment [57].

3.1 Historical Aspect

The first wireless network was the Sound Surveillance System (SOSUS), which was created by the United States Military in 1950 to detect Soviet submarines during the Cold War. The SOSUS network is intended to include submerged sensors and hydrophones distributed over the Atlantic and Pacific Oceans. Other, more complex acoustic networks for underwater monitoring have been established throughout the years. The National Oceanographic and

Atmospheric Administration (NOAA) currently uses SOSUS to monitor ocean phenomena such as seismic and animal activity [58].

Sensor network research began with the Defence Advanced Research Projects Agency's Distributed Sensor Networks (DSN) program (DARPA). The Arpanet (trailblazer of the Web) had been running for a few a long time at this point, with around another 200 has at colleges and investigate organizations. R. Kahn, the co-inventor of the TCP/IP conventions and an essential figure within the improvement of the Web, was the head of DARPA's Information Processing Techniques Office (IPTO) [59]. He was curious whether the Arpanet communication technique might be used for sensor networks. The network was anticipated to feature many spatially distributed low-cost sensing nodes that collaborate yet function independently with information sent to the node that can best use it.

In 1978, a Distributed Sensor Nets workshop recognized the following technical components for a DSN: Sensors (acoustic), communication (high-level conventions that connect forms running on a shared application in a resource-sharing organize [60], preparing strategies and calculations (including sensor self-location calculations), and dispersed program were all addressed (powerfully modifiable dispersed frameworks and dialect design).

Carnegie Mellon University (CMU) researchers centred on developing a network operating system that enables flexible, transparent access to dispersed resources required for a fault tolerant DSN. Accent [61] is a communication-oriented operating system with primitives that allow transparent networking, system reconfiguration, and rebinding. Accent developed into the Mach operating system [62], which achieved widespread commercial acceptance.

MIT researchers focused on knowledge-based signal processing approaches [63] for monitoring helicopters utilizing a distributed array of acoustic sensors employing signal abstractions and matching algorithms. Signal abstractions consider signals to be multi-levelled, with greater degrees of abstraction (peaks) produced by suppressing specific information in lower levels (spectrum). They give a conceptual foundation for thinking about signal processing systems that are like what individuals utilize while processing and interpreting real-world data interactively. Also, MIT has created the Signal Processing Language and Interactive Computing Environment (SPLICE) to aid DSN data processing and algorithm development.

Sensors, processors, and communication devices are all becoming smaller and less expensive. Commercial firms are developing and implementing small sensor nodes and systems. These companies give a picture of how a network of small, embedded sensor nodes can improve our daily lives. In addition to these businesses offerings, commercial off-the-shelf (COTS) personal digital assistants (PDAs) running Palm or Pocket PC operating systems have substantial computing capacity in a tiny size and may easily be ruggedized to become processing nodes in a sensor network [59].

Short-range sensor networks are the perfect technology for use in personal area networks (PANs), which, based on IEEE 802.11 standards, may deliver bandwidth comparable to wired networks. Simultaneously, the IEEE's promotion of the development of such short-range technologies and algorithms assures the continuing development of low-cost sensor networks [64]. Furthermore, advances in chip capacity and processor manufacturing capabilities have lowered the energy required per bit for both processing and communication. Sensing, computation, and communications may be done on a single chip, lowering costs, and allowing for larger-scale deployment.

3.2 Network Architecture for WSNs

The inherent highlights of WSNs motes (such as limited processing, memory, and communication capabilities) plan and execution limitations on WSNs routing and communication conventions. Communication conventions are utilized to direct, oversee, and control all components of communication, from the least layer of physical media, get to higher levels capable for end-to-end parcel transmission and information steering to the highest application layer for information and parcel creation. Figure 6 outlines an overview of arranged engineering in WSNs.

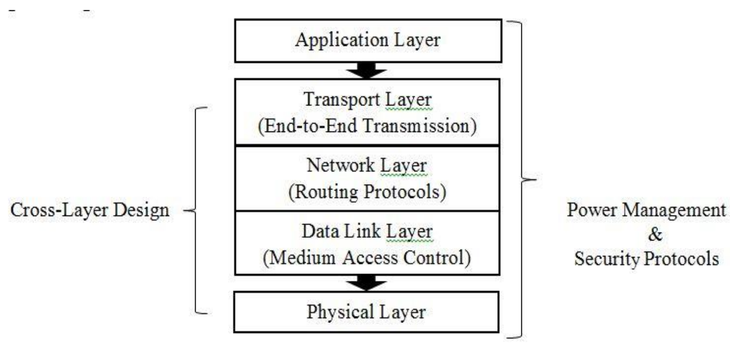

Fig. (6) WSNs Architecture.

Because of the necessity for power management across all levels of the model, this is fundamentally different from normal network models. Furthermore, because of the constrained nature of motes and the application-specific nature of WSNs, there is no obvious separation in network design levels, as there is in traditional network architecture. Fundamental WSNs communication protocols for querying, routing, and data delivery are often incorporated into WSNs data dissemination and aggregation approaches [65]. These constraints necessitate the adoption of a cross-layer approach in the development of network protocols for WSNs.

3.3 Structure of WSNs

A Wireless Sensor Network's structure comprises several topologies for radio communications networks [66-67]. The following is a brief explanation of the networks topologies that apply to wireless sensor networks:

3.3.1 Star Network (single point-to-multipoint)

A star network is a communications architecture in which a single base station may send and/or receive messages from many distant nodes. The distant nodes are not authorized to communicate with one another as shown in figure 6. The benefits of this sort of arrangement for wireless sensor systems are effortlessness and the capacity to keep distant node power consumption to a minimal level. It too empowers low-latency communication between the node and the base station. The drawback of such a network is that the base station must be inside the radio transmission extend of all nodes, and it is less flexible than other systems owing to its dependence on a single hub to run the organization.

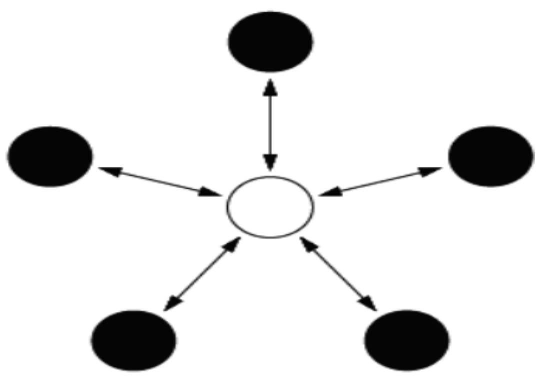

Fig. (7) Star Network Topology.

3.3.2 Mesh Network

A mesh network allows data to be sent from one node in the network to another node in the network that is within radio transmission range. This enables multi-hop communications, which means that if a node wishes to send a message to another node that is out of radio communications range, it may utilize an intermediary node to transfer the message to the target node, as shown in figure 8. This network design provides redundancy and scalability. If a single node fails, a distant node can still connect with any other node within its range, which can then send the message to the target destination. The downside of this form of network is that the nodes that execute multi-hop communications consume a huge amount of energy. Furthermore, as the number of communication jumps to a goal rises, so does the time to transmit the message.

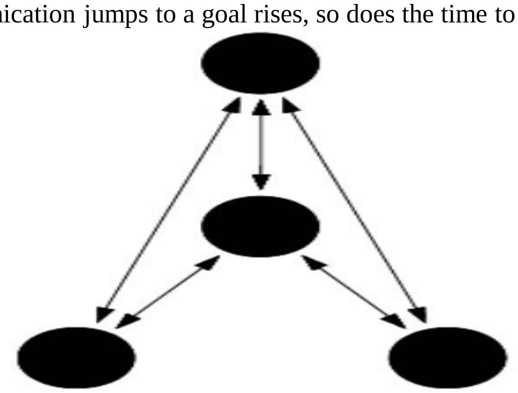

Fig. (8) Mesh Network Topology.

3.3.3 Hybrid Star-Mesh Network Topology

A combination of star and mesh networks provides a powerful and adaptive communications network while keeping wireless sensor node energy consumption. In this network architecture, the sensor nodes with the lowest power are not enabled to forward messages, ensuring that power consumption is maintained to a minimum. Other nodes on the network, on the other hand, have multi-hop capacity, allowing users to send messages from low-power nodes to other nodes on the network, as shown in figure 9.

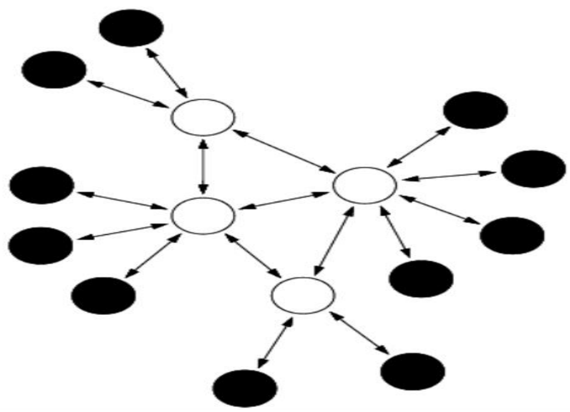

Fig. (9) Hybrid Star-Mesh Network Topology.

3.3.4 Sensor node structure

As illustrated in Figure 10, a sensor node is made up of four fundamental components: a sensing unit, a processing unit, a communication unit, and a power unit which is an important component. It also includes application-specific extras including a location detecting system, a power generator, and a mobilizer. Sensors and analogue to digital converters (ADCs) are the two main components of sensing units [68]. The ADC converts the analogy signals generated by the sensors to digital signals, which are then fed into the processing unit, which is regularly related with a little capacity unit and can oversee the methods that permit the sensor hub to collaborate with the other nodes to perform the relegated required sensing. The node is linked to the network through a transceiver device.

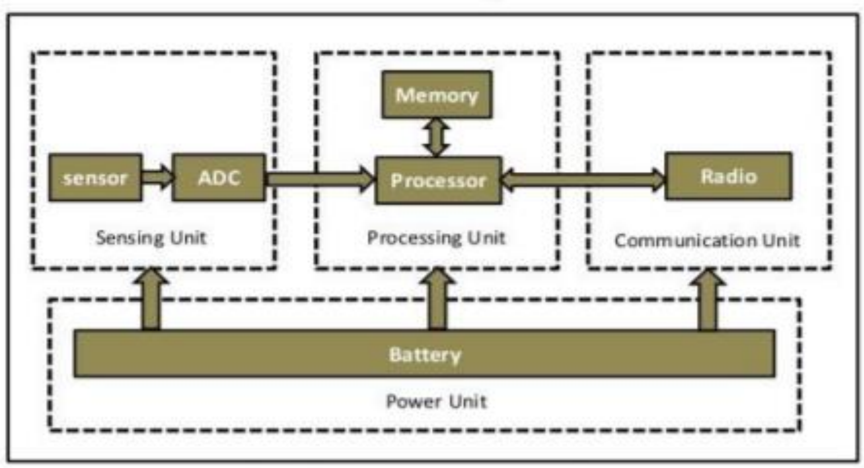

Fig. (10) Sensor Node Components [104].

Figure 11 represents a functional block diagram of a flexible wireless sensor node. The modular design approach provides a dynamic and adaptable platform for addressing the requirements of a wide range of applications. For illustration, depending on the sensors to be positioned, the signal conditioning may be re-programmed or changed, allowing a diverse range of sensors to be employed with the wireless sensing node. Essentially, the radio connection may be changed out as needed to meet the wireless range requirements of a specific application as well as the necessity for bidirectional communications.

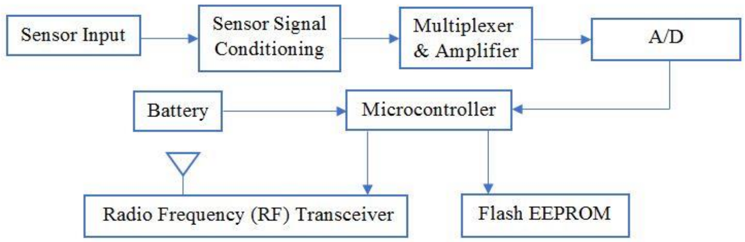

Fig. (11) Block diagram of a Sensor Node.

3.4 Standardization

Several standards in the field of WSNs have been ratified or are in the process of being developed. The Institute of Electrical and Electronics Engineers (IEEE), the Internet Engineering Task Force (IETF), the International Society for Automation (ISA), and the HART Communication Foundation, among others, are prominent standardization groups. These standardization bodies each have a distinct focus, but they all aim to produce worldwide open standards for interoperable, low-power wireless sensor devices. Table 5 compares several WSNs communication protocol standards that are currently available.

TABLE 5. Comparisons of different standards for the communication protocols of WSNs [69].

Type	IEEE 802.11b/g	Bluetooth	UWB-IR	IEEE 802.15.4	Zigbee	Wireless HART	IEEE 802.15.6
Band	ISM 2.4 GHz	ISM 2.4 GHz	3.1GHz - 10.6GHz	ISM 2.4GHz, 915MHz, 868MHz	ISM 2.4GHz	ISM 2.4GHz	400MHz, ISM 2.4GHz, 3.1-10.6 GHz
Spreading	DSSS	FHSS/ TDD	Baseband	DSSS	DSSS	DSSS	DSSS
Modulation	BPSK, QPSK, CCK, OFDM	GFSK	Impulse radio, time domain	O-QPSK	O-QPSK	O-QPSK	Group PPM
Range	100 meters	10 meters	< 5 meters	10 meters	10 meters	< 250 meters	3-10 meters
Rate	< 54 Mbps	1 Mbps	20Kbps, 250Kbp, 10Mbps	250 Kbps	250 Kbps	250 Kbps	< 10 Mbps
Power	High	Low	Ultra-low	Very Low	Very Low	Battery or line power	Ultra-low
Roaming	Yes	No	Yes	Yes	Yes	Yes	Yes
No. of nodes	32 per access point	8 per piconet	10-1000	< 65536	< 65536	5-65536	< 256
Power consumption	Medium	Low	Ultra-low	Very Low	Very Low	Very Low	Ultra-low
Complexity	Complex	Very complex	Simple TX, Complex RX	Simple	Simple	Simple	Simple
Security	WEP, WPA	64 bits or 128 bits	128 bits	NULL, 32 bits, 64 bits or 128 bits	128 bits	128 bits	Scrambled mapping code
Cost	High	Medium	Very low	Low	Low	Low	Low

3.5 Security

Threats to WSNs either breach network secrecy and authentication like packet spoofing, or violation network availability like jamming assaults, or violate some other network functionality [70-71]. Generally, countermeasures in WSNs should fulfil the following requirements:

- Availability, which ensures that the needed network services are always available.
- Authentication, which guarantees that the communication between nodes is legitimate.
- Confidentiality, which ensures that wireless communication channels are private.
- Integrity guarantees that the message or thing under examination is not tampered with.
- Non-reputation, which prohibits malicious nodes from concealing or denying their actions.
- Freshness, which indicates that the data is current and prevents adversaries from replaying old communications.
- Survivability, which guarantees that network services remain acceptable even in the face of node failures and malicious assaults.
- Countermeasures, such as self-security, may incorporate new hardware and software infrastructures into the network which must be safe enough to survive assaults.

3.6 WSNs energy consumption issues

Considering sensor nodes are often powered by a battery, energy consumption is the most crucial aspect in determining the life of a sensor network. Energy optimization might be more difficult in sensor networks since it involves not only reducing energy usage but also extending the network's life as much as feasible. The optimization may be accomplished by incorporating energy awareness into all aspects of design and operation [72]. Network technologies and methods have been researched all around the world to reduce the overall energy consumption of the sensor network. The lifetime of a sensor network may be considerably enhanced if the operating system, application layer, and network protocols are designed to be energy-aware and must be able to exploit specific capabilities of microprocessors and transceivers to decrease the energy consumption of the sensor node.

3.7 Applications of WSNs

As the cost of sensor nodes and communication networks has decreased, a variety of uses, including civilian and military applications, have developed. Listed below are a few instances.

- Environmental Monitoring

It is a good choice for deploying WSNs across large regions for a variety of purposes such as animal monitoring, forest surveillance, flood detection, and weather forecasting.

- Health Monitoring

WSNs may be implanted in a hospital to track and monitor patients as well as all medical supplies. Sensors capable of measuring blood pressure, body temperature, and electrocardiograms (ECGs) can even be woven into clothing to offer remote care for the elderly. When sensors are worn or implanted for medical reasons, they create a sort of sensor network known as a body sensor network (BSN), which transforms the healthcare system by enabling low-cost, continuous, and ambulatory health monitoring with real-time updates of medical records via the Internet.

- Traffic Control

Sensor networks have been used to monitor and manage vehicle traffic. Many intersections include either overhead or hidden sensors to detect cars and operate traffic signals. WSNs will significantly alter the landscape of traffic monitoring and control by embedding low-cost sensor nodes in automobiles, parking lots, highway medians, and along roadsides, etc.

- Industrial Sensing

Many times, equipment failures result in increasing amounts of unexpected downtime. WSNs make it cheaply viable to monitor the health of machines and assure safe operation since sensor nodes may be deeply embedded with equipment. WSNs have also been proposed for use in the food sector to avoid contamination of the food supply chain.

- Infrastructure Security

WSNs have the potential to be utilized for infrastructure security and counter-terrorism applications. Critical structures and infrastructure, such as power plants, airports, and military sites, must be safeguarded from possible attacks. Around these sites, networks of video, acoustic, and other sensors can be installed.

4. NON-ORTHOGONAL MULTIPLE ACCESS (NOMA) TECHNIQUE

Power domain multiple access, also known as non-orthogonal multiple access (NOMA), has recently been presented as a possible 5G wireless network contender [73]. NOMA multiplexes users in the power domain utilizing superposition coding at the transmitter and successive interference cancellation (SIC) at the receivers, allowing each user to access the whole bandwidth for the entire period these make the total rate might be significantly increased. It has been shown that NOMA performs much better in high signal-to-noise ratio (SNR) scenarios also the recent research on NOMA for wireless systems has demonstrated a significant increase in throughput [74].

Recently, the non-orthogonal multiple access (NOMA) scheme, which is a creative multiple access technique, has garnered tremendous interest [74-77].

Although different waveforms like a filter bank multicarrier, might be utilized, the basic signal waveform for NOMA could be based on OFDM or Fourier transform spread OFDM, as well as LTE radio access [78].

Given that VLC systems have high SNRs due to the short distance between the transmitter and the receiver, it is advantageous to use NOMA in VLC systems [79-82]. Furthermore, because NOMA can balance throughput and fairness, it has been recognized as a possible approach for improving spectral efficiency in wireless networks. It has also been used in VLC systems due to its high practicality and performance [83-84].

4.1 Related work

Several review papers on the field of VLC technology have been published in the past [85-94], but none of them addressed how new developing technologies in RF networks might be mapped and implemented in VLC networks, such as the non-orthogonal multiple access (NOMA), energy harvesting (EH), simultaneous wireless information and power transfer (SWIPT), space division multiple access (SDMA), and physical layer security (PLS).

[95] investigates the fairness achieved via downlink NOMA. Based on the availability of idealized normal channel state data, the authors developed ideal power assignment coefficients. When compared to temporal division multiple access (TDMA) and NOMA with fixed power allotment, the outcomes show that NOMA with suggested power allotment keeps up high fairness and communicates advanced outage performance (client rate).

The authors of [74] investigated the performance of downlink NOMA with randomly dispersed users. They assessed performance in two scenarios: QoS and channel condition. The results reveal that a proper rate and power allocation resulted in a superior outage and ergodic sum rate in NOMA than in OMA.

In [96], the authors analysed a multi-cell uplink NOMA cellular network using stochastic geometry. The Poisson cluster process is used to represent the locations of Base Stations (BS) and cellular subscribers. By addressing both intra- and inter-cluster interferences under various SIC situations, closed-form formulas for the Laplace transform of the interference at BS are developed. NOMA is shown to outperform OMA in terms of average rate coverage.

In [97], the authors recommended a client planning procedure from which a closed-form equation for control assignment is created to maximize the vitality productivity of downlink NOMA frameworks with destitute channel state data. The comes about uncover that the proposed framework outflanks current plans and OMA in terms of vitality proficiency. Moreover, in [98], the authors presented energy-efficient client planning and control allotment techniques for NOMA in heterogeneous systems with not as it were fragmented channel state data but moreover shared cross-tier obstructions. They examined the trade-offs between information rate and vitality execution and appeared that NOMA is exceptionally vitality effective in such systems.

Now, NOMA has been examined as it were within the setting of cellular systems. The utilize of NOMA for WSNs has not been proposed within the writing and the detailed execution picks up of NOMA over its counterparts cannot be clearly claimed for WSNs. Typically, since not at all like a cellular network, the sink node in a WSNs has no control over all transmitters inside it extend, counting sensors and sinks of other WSNs beneath other authoritative spaces that utilize the same range, such as Wi-Fi and Bluetooth gadgets. Thus, it is imperative to explore the execution of WSNs utilizing NOMA beneath an interference-limited situation by utilizing Li-Fi technology.

4.2 Basic Concepts of NOMA technique

From a conceptual and implementation standpoint, NOMA solutions may be divided into two major categories: code domain NOMA and power domain NOMA [99]. The key operating idea of code domain NOMA is that several users can share the same resources (time/frequency), which is quite like how conventional CDMA systems operate. However, the coding domain NOMA has remained distinct from CDMA systems because, unlike CDMA, it achieves multiplexing by sparse spreading or non-orthogonal low cross-correlation sequences. Sparse code multiple access (SCMA), low-density spreading CDMA (LDS-CDMA), LDS aided OFDM (LDS-OFDM), multiuser superposition transmission (MUST), and successive interference cancellation aided MA are some prominent code domain NOMA systems (SAMA) [100-102].

The other type of NOMA categorization is based on power domain multiplexing. Numerous users are overlaid in the same resource (time/frequency/code) in contrast to code domain NOMA by allocating various power levels to multiple users. As a result, many users access the channel in a non-orthogonal manner using the superposition coding technique (SC). Advanced multiuser detection (MUD) methods, such as successive interference cancellation (SIC) or dirty paper coding (DPC), are used at the receiver to decode the user's message signals [103]. The categorization of NOMA systems is shown in figure 12.

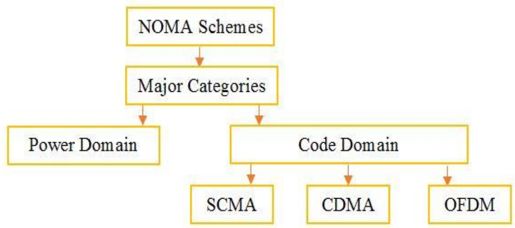

Fig. (12) Classification of Non-Orthogonal Multiple Access (NOMA) schemes.

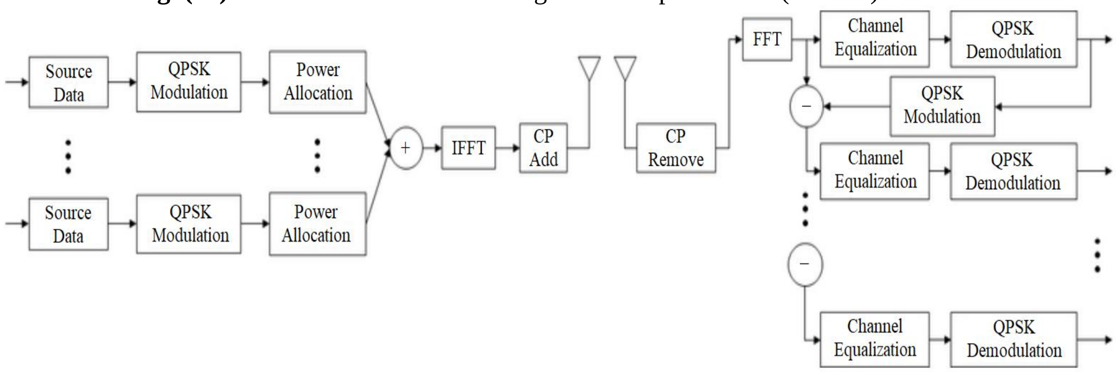

Fig. (13) Block diagram of NOMA technique.

On the other hand, NOMA is an efficient and adaptable multiple access technique that used in VLC systems to increase spectral efficiency for the following major reasons [79]:

- Multiplexing in the power domain is suitable for VLC systems since signal detection is directly connected to received power.
- NOMA is more compelling at multiplexing a little number of clients. This can be steady with VLC frameworks, which depend on transmitting LEDs that work as little cells to handle a constrained number of clients in room.
- SIC requires the use of channel state information (CSI) at both receivers and transmitters to aid in the functions of user demultiplexing, decoding order, and power allocation. This is a significant constraint in RF, but it is not in a VLC system due to the deterministic structure of its channel.
- NOMA outperforms in cases with a high signal-to-noise ratio (SNR). This is true for VLC connections, which have a high SNR by design because of the short LED-PD spacing and the dominating line of sight (LOS) route.
- The execution of a VLC framework may be progressed by altering the transmission points of the LEDs and the field of sees (FOVs) of the PDs. These two degrees of flexibility can move forward channel pick up disparities among clients, which is pivotal for NOMA execution.

Figure 13 demonstrates a basic block diagram of the NOMA technique with a SIC receiver as an example approach for power domain NOMA.

4.3 Application of NOMA technique

The purpose of this part is to demonstrate how NOMA may be used for various types of wireless networks. In the framework of current literature, it must present a fundamental structure and operation of the contemplated NOMA-based wireless network. More specifically, considering recent work, we will show NOMA that is used in communication applications as follow.

4.3.1 NOMA Applied to Cellular Networks

A cellular network may be divided into four types based on conceptual and practical considerations based on the NOMA technique. (1) Single-cell single-tier (SCST), (2) single-cell multi-tier (SCMT), (3) multi-cell single-tier (MCST), and (4) multi-cell multi-tier (MCMT) CNs.

4.3.2 NOMA Applied to Device-to-Device Communications

The use of NOMA to device-to-device (D2D) communication is relatively underexplored in the present literature. Existing research gives minimal attention to examining D2D networks in which D2D nodes communicate using the NOMA transmission technique.

4.3.3 NOMA Applied to Wireless Sensor Networks

Although it was originally proposed for cellular systems, NOMA offers capabilities that we feel are extremely applicable to tackling the deployment issues of ubiquitous wireless sensor networks (WSNs), which are large-scale networks of densely deployed wireless sensors used for pervasive monitoring of physical surroundings. NOMA can permit more simultaneous connections than previous techniques for a given spectrum bandwidth without the overheads of coding and spreading to assist the separation of the user's signals at the receiver. This is especially appealing for facilitating huge connections in WSNs without requiring new spectrum resources.

5. INTEGRATING WSNS WITH LI-FI USING NOMA

In our future work, we can consider a bidirectional LiFi-WSN system, where visible light utilizes in the uplink and downlink for simultaneous illumination and communication that the LiFi AP has a visible light LED transmitter and a photodiode (PD) receiver, whereas each sensor has a PD receiver and a visible light LED transmitter. The selected aim is the ability to transmit data at high speed for bidirectional for WSNs by using the Li-Fi technology.

The visible light LED of the LiFi AP emits white light in the downlink to provide lighting inside its coverage and simultaneously transmit downlink data to all sensors. Using the attached visible light PD, each sensor detects the transmitted data and uses the attached LED to broadcast its send data in the uplink, and the LiFi AP uses PD to collect data from all the sensors using the NOMA technique. As a result, bidirectional communication may be established between the LiFi AP and all sensors in the LiFi-WSN system.

The performance of NOMA is largely dependent on the adopted power allocation strategy. Also, NOMA allows sensors to utilize all the time and frequency resources. The transmitted data of sensors superpose in the power domain and there inevitably exists mutual interference. To ensure their quality-of-service (QoS) requirements, sensors will be allocated with different power values.

In conventional NOMA-based systems, the design of the power allocation strategy aims to maximize the data rate of the system under a total transmit power constraint. Also, when applying NOMA for energy sensitive WSNs, the power allocation strategy should be designed from the energy consumption perspective.

5.1 Relevant Work

There have been a few review articles published in the past on the topic of WSNs combined with Li-Fi technology, but none of them addressed how new evolving technologies may be applied for these networks.

Especially, Kumar et al. reviewed LED-based VLC systems and applications in their early-stage development [85]. Authors in [86] focused on the dual function of LEDs (used in smart lighting and VLC) and investigated their integration possibilities by presenting a new concept: LIGHTNETs (LIGHTing and NETworking) that performs both functions simultaneously.

Although Li-Fi reveals its potential for future WSN networks, the research of Li-Fi enabled WSN is still at an early stage. In [105], a Li-Fi based hierarchical IoT architecture was proposed to analyse the collected data and build smart decisions. In [106] and [107], the energy harvesting issues of LiFi-IoT were investigated. Lately, a LiFi-IoT system vision was reported in [108], where the conceptual architecture with four different types of modes was presented.

To date, NOMA has been investigated only in the context of cellular networks. The use of NOMA for WSN has not been proposed in the literature and the reported performance gains of NOMA over its counterparts cannot be straightforwardly claimed for WSN. This is because, unlike in a cellular network, the sink node in a WSN has no control over all transmitters within its coverage, including sensors and sinks of other WSNs under different administrative domains that share the same spectrum such as Wi-Fi and Bluetooth devices. Hence, it is important to investigate the performance of a WSN employing NOMA under an interference-limited scenario by using Li-Fi technology.

5.2 Motivation and challenges

Sensor nodes in wireless sensor networks (WSNs) have a limited amount of energy in their primary power storage unit, which can quickly deplete if the sensor node is left active for an extended length of time. There are many reasons for the energy consumption of sensor nodes such as data transmission signal processing or hardware operation. On the other hand, the radio spectrum became not enough because the number of connected devices is rapidly increasing over the last 5 years.

Light-fidelity (Li-Fi) is a novel bidirectional, high speed, and fully networked wireless communication technology, that uses visible light as the propagation medium in the uplink and downlink for the purposes of illumination and communication constraint of a room remains unaffected and to avoid interference. Li-Fi offers several important benefits that have made it favorable for future technologies. These include the very large, unregulated bandwidth available in the visible light spectrum, the straightforward deployment that uses off-the-shelf light-emitting diode (LED) and photodiode (PD) devices at the transmitter and receiver ends, respectively, and enhanced security as light, it does not easy to be hacked [109].

Considering that pervasive WSNs are usually required to connect a huge number of sensors per unit area, the Li-Fi access point (AP) of an optical attocell in LiFi-WSN networks should be able to support sensor devices. Therefore, an efficient multiple access technique is of great significance to successfully implement LiFi-WSN in practical scenarios [110]. So far, many multiple access techniques have been introduced for visible light-based downlink Li-Fi communication, i.e., visible light communication (VLC), which can be mainly divided into two categories: one is orthogonal multiple access (OMA), and the other is non-orthogonal multiple access (NOMA). Due to its efficient resource utilization, NOMA has been recognized as a promising multiple access technique for VLC systems.

6. CONCLUSION

The possibilities are extensive and may be further explored because the notion of Li-Fi is now getting a lot of attention because it offers a true and highly efficient alternative to radio-based Wi-Fi. It has a decent possibility of replacing regular Wi-Fi because, as more people use wireless internet, the airways get increasingly crowded, making it increasingly difficult to acquire a dependable, high-speed connection. Data for computers, cellphones, and tablets will be communicated by illumination utilizing Li-Fi in the future. Researchers are working on micron-sized LEDs that can flicker on and off 1000 times faster than bigger LEDs. If this technology is successfully implemented, every light bulb may be utilized as a Wi-Fi hotspot to transfer wireless data, and we will be on our way to a cleaner, greener, safer, and brighter future. This proposal claims to address difficulties such as radio-frequency bandwidth shortages and eliminate Wi-Fi drawbacks. Li-Fi is a developing and expanding technology that serves as a foundation for a variety of other new and previously developed technologies. As a result, future Li-Fi applications may be forecasted and expanded to many platforms and various walks of human life.

Wireless Sensor Networks carry the promise of giving a smart communication paradigm that allows for the establishment of an intelligent network capable of handling applications that grow in response to user requirements. We believe that WSNs research will have a significant influence on our daily lives soon, particularly since improvements in wireless networking and sensor technologies open an exciting potential to govern human activities in smart environments. Future WSNs study will focus about will concentrate on maximizing region throughput in clustered Wireless Sensor Networks, as well as information accumulation methods, simulation, and test confirmation of lifetime-aware steering detecting spatial scope, and the enhancement of craved detecting spatial scope assessment strategies with sensor models.

NOMA shorts for non-orthogonal multiple access, is a new proposal for encoding technology in next-generation wireless communications. It is emerging as a good choice for use as a multiple access method in wireless sensor networks to boost system capacity. It can also transmit multiple symbols using the same time and frequency or code resource but splitting them in the power domain and distinguishing them based on the diverse power levels of different symbols, which are then demultiplexed at the receiver using an interference cancellation technique. Because the primary criteria of WSNs are high connection, low latency, and ultra-high data rates, the combination of NOMA and Li-Fi can be regarded as a viable enabling technology to meet these objectives.

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