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# Design and Analysis of a Hybrid LiFi-Based IoT System with RF Energy Harvesting for Enhanced Power Management

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ABSTRACT

This research paper describes the detailed design of a hybrid system comprising of Light Fidelity (LiFi) communication and Radio Frequency energy harvesting (RFEH) to serve the Internet of Things (IoT) devices. The system developed is aimed at resolving the essential concerns of the viable transmission of data, energy efficiency, and sustainable functioning of extensive IoT systems. This study tested the main performance indicators, including the Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), energy harvesting (EH) efficiency, and power sharing strategies of several IoT devices, through MATLAB simulations. Solar EH also promotes the ability of the system to satisfy the requirements of the IoT power needs. The comparative analysis to industry standards shows significant performance improvements, which makes the system a sustainable solution in the case of IoT implementation in energy-limited environments. The results validate the design by achieving improved BER performance, enhanced data rate adaptability, and reliable IoT operation under varying energy conditions.

## 1. Introduction

Energy harvesting (EH) is the process of obtaining and converting surrounding environmental energy into usable electrical power [1]. The latest trend in the research is focused on the Internet of Things (IoT technology) merged with numerous interdisciplinary fields [2] . In recent years, the potential for integrating multiple EH techniques into IoT devices has been extensively explored [3].

Radio frequency energy harvesting (RFEH) has demonstrated the capability to power low-power IoT-connected electronic devices by capturing ambient RF signals from conventional communication systems such as Wi-Fi, cellular networks, and broadcasting [4] [5]. Such systems are increasingly promising in remote applications such as agricultural applications where it is hard to supply power to sensors deployed for monitoring and automatic control [6].

The efficiency η of RFEH can be modelled by the rectified power output $P_{harvested}$ (W) as a function of the incident RF signal power $P_{incident}$ (W), and the harvested energy is expressed in (1) as follows [7]:

$$P_{harvested} = \eta \cdot P_{incident} \quad (1)$$

The efficiency of RFEH systems typically ranges from 42% to 70%, depending on the distance from the signal source and environmental conditions [7]. Study exhibited that, despite the inherent power loss in harvesting ambient RF energy, such techniques could meaningfully extend the operational lifetime of IoT-connected devices [8].

The LiFi systems, which use visible light communication for both data transmission and EH, have emerged as a highly efficient solution for IoT networks [9]. The maximum achievable data rate for a LiFi system depends on the modulation technique used, and it can be given by the Shannon-Hartley theorem (2), which states that the data rate R (bps) is a function of the bandwidth B (Hz) and signal-to-noise ratio (SNR) [10]:

$$R = B \cdot log_2(1 + SNR) \quad (2)$$

Scholars have explored the potential use of LiFi technology for IoT applications, representing significantly high data rates of up to 10 Gbps with reasonably high spectral efficiency as compared to traditional communication technologies [11] [12]. Another aspect of research is visible light communication with a data rate of around 100 Mbps

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with a very low error rate [13], which can be used for a range up to 1 km. Moreover, EH with these systems enables concurrent transmission of data and power, in which the energy harvested is proportional to the light intensity. The mathematical relation between harvested energy and light intensity is as follows (3):

$$E_{harvested} = \eta_{LiFi} \cdot I \quad (3)$$

where $\eta_{LiFi}$ represents the efficiency factor that accounts for the transformation of light into useful electrical energy, and I is the intensity of light in candela (cd). This equation estimates the energy generated from incident optical intensity and is used to estimate supplementary energy provision from the LiFi illumination resource. The LiFi systems are especially beneficial in the place where there is a high-density lighting infrastructure since they will be able to supply power to the devices without the need for additional sources of power [7, 14].

Another research aspect that has attracted extensive attention in the powering of IoT devices is solar EH, especially in the outdoor environment or in remote areas [15, 16]. The energy harvested from solar panels is given by (4):

$$P_{\text{solar}} = A \cdot G \cdot \eta_{\text{solar}} \quad (4)$$

where A is the area of the solar panel, G is the solar irradiance, and $\eta_{solar}$ is the efficiency of the solar cells. Solar energy is of significant importance in powering IoT device sensors for environmental monitoring systems in a green/sustainable manner, with solar energy systems capable of providing uninterrupted electricity to the IoT devices during daytime [17].

Besides EH methods, IoT devices used in energy-limited conditions require intelligent power management strategies [18]. The models used to allocate necessary power resources are usually deep reinforcement learning algorithms and adaptive power allocation schemes, which generally allocate power resources according to the needs of individual devices and their priorities [19] [20]. The priority-based power allocation scheme is devised as an optimization problem to enhance the number of devices functioning on a limited amount of power resources as in (5).

$$Maximize \sum_{i=1}^{N} P_i \; subject\ to \sum_{i=1}^{N} P_i \leq P_{total} \quad (5)$$

where $P_i$ (W) is the power assigned to device i, and $P_{total}$ is the overall power available. This approach ~~will~~ ensures that high-priority devices get adequate power to handle higher priority tasks, whereas those of low priority are given lower power or scheduled at lower demand periods or during the daylight when the sun is also present. [21]. The other notable aspect of power management by the IoT devices is demand-based scheduling, which changes the functionality of the devices depending on their current power needs. [22]. The scheduling decision can be modelled as:

$$Schedule\ (t) = \begin{cases} 1 & if\ device\ is\ active\ at\ time\ t \\ 0 & if\ device\ is\ inactive\ at\ time\ t \end{cases}$$

The method would therefore ensure that devices that have critical tasks (such as real-time monitoring and data transmission) would be run continuously, whereas those with less priority would be scheduled to be run during the high power availability periods.

In general, the integration of energy collection methods, dynamic allocation of power, and demand-based scheduling solutions makes a formidable solution to effective management of the energy requirements of IoTs [23]. LiFi, RFEH, and solar energy can be correlated to offer continuous, reliable power, and adaptive algorithms can achieve effective operation of devices in energy constrained scenario [20].

### *1.1. System Design*

The designed system includes three main components:

1. LiFi based Communication module facilitating high-speed data broadcast for IoT devices.
2. RFEH module supplies power by harvesting RF signals from nearby transmitters [24].
3. Solar EH module supplements power for devices with unmet energy demands.

The MATLAB software evaluates the performance of the system across various parameters, including data rates, bit error rate (BER), and EH efficiency.

## 2. Materials and Methods

This paper is based on a simulation of a hybrid LiFi communication system, as it will be combined with RFEH methods and IoT devices. The main aim is to evaluate how effective the system is in terms of reliability of communication, energy efficiency, and sustainability. In order to achieve these goals, the system is then modeled in a sequence of steps, which are interconnected.

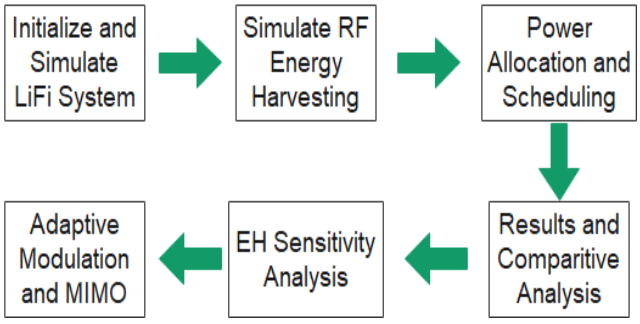


**Fig. 1:** Methodological flow of the LiFi–RF energy harvesting system

Primarily, the parameters for the LiFi communication system, EH methods, and IoT devices are set up to establish the simulation environment. The communication link is analyzed using preset data rate and modulation schemes, and then the RFEH approaches are simulated, including the Resonant Inductive, Magnetically Coupled, and Rectenna.

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The IoT devices are then modelled in the system by indicating their power needs and communication requirements, which makes it possible to assign power to devices according to their preferences in relation to their priority and the particular requirements they may have.

In a further effort to enhance the sustainability of energy, solar energy is incorporated in certain devices to maintain power at an optimal level and to address the deficit in RF energy collected. Further methods of transmission, such as Multiple Input Multiple Output (MIMO) and adaptive modulation, are then given to optimize communication, and generally, the sensitivity of EH efficiency to environmental factors is also modeled. Finally, the performance of different approaches is estimated and compared to the industry standards.

*2.1 LiFi System Design*

Initially, the LiFi communication system, EH models, and IoT equipment parameters are configured so as to create the real-world simulation environment. Simulation of the communication link with definite data rates and modulation schemes is performed, and simulation of RFEH approaches, such as Rectenna, Magnetically Coupled, and Resonant Inductive methods, is presented. The system then models the IoT devices with particular power requirements and communication needs and enables them to allocate power to the devices depending on their priority and needs.

The designed LiFi module has a 1 Gbps data rate and 20 MHz bandwidth that can offer high-speed wireless communications. In order to check the performance of the system, the BER is determined in a SNR bit span of 0 dB to 20 dB. This spectrum includes standard operating points of LiFi communication [25], making it possible to fully examine the stability of the system in different environmental conditions and different levels of noise. To model the BER as a function of SNR, the Q-function (7) is used, which relates the error probability to the SNR in a communication system. The Q-function employed to model BER (6) as a function of SNR is as follows:

$$BER = Q\left(\sqrt{(2 \cdot SNR_{linear})}\right) \quad (6)$$

where BER characterizes the probability of bit error during transmission and depends on received signal quality. This equation evaluates communication reliability of IoT devices in the LiFi system. The Q-function definition:

$$Q(x) = \left(1/\sqrt{(2\pi)}\right) \int_x^\infty e^{(-t^2/2)}\, dt \quad (7)$$

The Q-function represents the tail probability of a Gaussian distribution and models noise effects in digital communication channels. The linear SNR (8) from SNR in dB units is as follows:

$$SNR_{linear} = 10^{(SNR_{dB}/10)} \quad (8)$$

This enables calculation using linear SNR values derived from logarithmic dB measurement.

*2.2 RFEH Simulation*

The RFEH module calculates the harvested power $P_{harvested}$ (9) using:

$$P_{\text{harvested}} = \eta \cdot \frac{P_{tx} \cdot G_{tx} \cdot G_{rx}}{\left(\frac{4\pi df}{c}\right)^2} \quad (9)$$

where $\eta$ is the efficiency, $P_{tx}$ (W) is the transmitted power, $G_{rx}$ is the gain of the receiving antenna, $G_{tx}$ is the gain of the transmitting antenna, f (Hz) is the frequency, d (m) is the distance, and c denotes the speed of light [26]. The harvested power is then used to support IoT devices, which have varying power demands ranging from 0.1 to 0.5 W.

*2.3 Battery Backup*

Battery backup can be integrated to power devices with unmet demands after RF harvesting [27]. A 5W mono-facial surface mounted solar panel is used for this purpose to charge the battery [28].

*2.4 IoT Device Simulation*

In this design, 10 IoT devices are modelled and studied, each transmitting random binary data streams to represent typical communication tasks. Such devices are energized, and they use Binary Phase Shift Keying (BPSK) for data communication. The BER of the individual device is measured across different values of SNR, thereby giving information as to the accuracy of data transmission.

The SNR variation is used to mimic various environmental factors, including signal interference and noise. The BER is anticipated to get smaller as SNR gets larger [29], demonstrating improved communication reliability and reduced error rates, hence less processing of energy-intensive error correction algorithms [30]. This analysis helps assess the performance of IoT devices in practical scenarios, highlighting the trade-off between signal strength, data reliability, and error rate.

*2.3 Energy Management Strategy*

The proposed design utilizes a hierarchical energy management strategy to ensure uninterrupted operation of IoT devices under varying energy availability conditions. Initially, harvested RF energy is utilized as the primary power source due to its continuous availability. When RF harvested power becomes insufficient to meet device demand, solar energy harvesting supplements the available power during daytime operation. A battery backup system acts as the final energy reserve and is activated only when harvested energy sources cannot satisfy load requirements.

Power allocation follows a priority-based mechanism, where essential IoT devices receive power first, while low-priority devices are scheduled or temporarily deactivated under energy deficit conditions. This adaptive approach ensures effective

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utilization of harvested energy while sustaining system reliability and continuous operation of high-priority nodes.

## 3. Results and Discussion

The SNR vs BER curve (Figure 1) illustrates a clear-cut reduction in correlation between the two parameters, that is, BER and SNR, which confirms the suitability of the given system in transmitting information under various environmental factors.

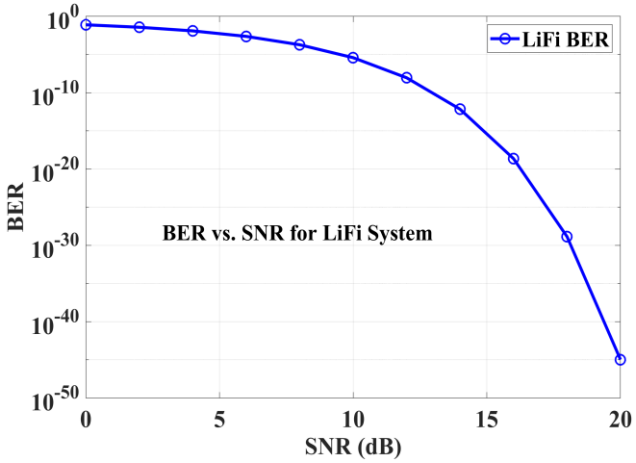


**Fig. 2**. BER vs SNR for LiFi System

According to the relationship, the higher the quality of the received signal (i.e. the higher the SNR), the lower the number of errors in the data exchange. The finding shows that the BER of the LiFi system is increasing with a decrease in SNR at low SNRs, and this indicates that the LiFi system is exceptionally sensitive to noise and interference at low signal strengths.

Moreover, as the SNR value is increased, the system is able to achieve perfect data transmission, which demonstrates the robustness and effectiveness of the system in the condition which signal strength is increased to an optimal value in real time. This transmission aspect is important for the assurance of reliable communication even in difficult environments where signal degradation may occur, for example. The results demonstrate the potential of LiFi technology as a suitable solution for high-speed, low-noise communication in real-world applications, particularly in indoor environments where lighting conditions can be controlled.

$$\mathrm{BER}(SNR) = \frac{1}{2} \cdot \mathrm{erfc}\left(\sqrt{\frac{SNR}{2}}\right) \qquad (10)$$

BER(SNR) represents the BER as a function of the SNR as in (10). It is a measure of the likelihood of bit errors existing in a communication system caused by noise. The term erfc is used to describe the complementary error function, the tail of the Gaussian distribution, which is essential to the computation of the probability of error in digital communication systems. SNR is the power of the signal in relation to the noise that plays a role in the transmission. As SNR increases, BER reduces, and the reliability of the system in data transmission is improved.

### *3.1 RF Energy Harvesting*

The harvested power increased to 0.05 W due to improved RF transmission power, improved antenna gains, and reduced transmitter-receiver distance. Despite these improvements, the harvested power is still not high enough to supply the power needs of all IoT devices. While the increase in power is a step in the right direction, it is still not enough to ensure stable operation and performance of the IoT network. Further optimizations, e.g., enhanced EH techniques, or the use of supplemental power sources, may be required to fully support the devices in a sustainable way.

### *3.2 Backup Energy Integration*

The battery can successfully power additional high-priority devices in case the harvested power is insufficient. This allows the total number of operational IoT devices to increase from 8 to 10.

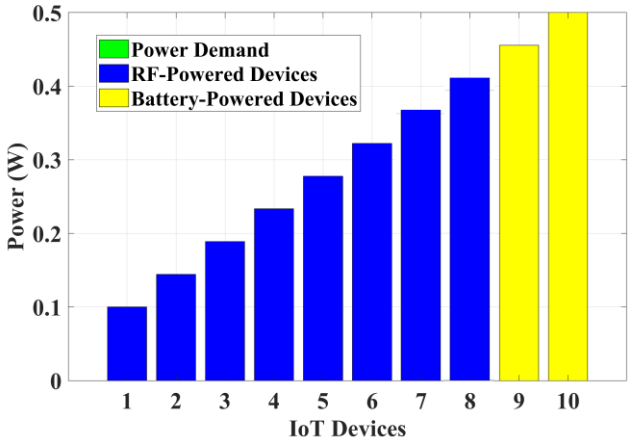


**Fig. 3.** IoT Devices Power Demands vs Harvested Power at 1.5 GHz

As the frequency of communication is enhanced, the power consumption of devices is also enhanced. When the power harvested is smaller than the power needed, the device will either shut off or continue using battery power in case of high priority. In the event of the unavailability of battery power, demand-based scheduling is suggested.

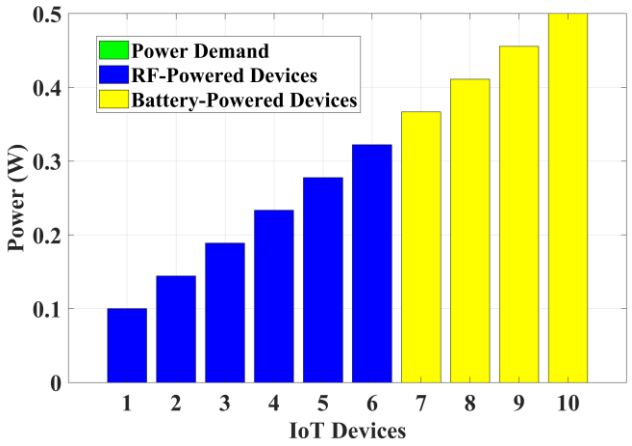


**Fig. 4.** IoT Devices Power Demands vs Harvested Power at 2.4 GHz

It confirms that using a combination of EH techniques is effective in maintaining constant operation. Also, it is possible to use solar modules to recharge the battery,

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which will also supply energy to the critical loads and contribute to increasing the system's reliability.

**Table 1**

IoT Device Power and Communication Data at Various Frequencies

| Device ID | Power Demand (W) | Power Source at f = 1.5 GHz | Power Source at f = 2.4 GHz |
|---|---|---|---|
| 1 | 0.10 | Harvested RF | Harvested RF |
| 2 | 0.14 | Harvested RF | Harvested RF |
| 3 | 0.18 | Harvested RF | Harvested RF |
| 4 | 0.23 | Harvested RF | Harvested RF |
| 5 | 0.27 | Harvested RF | Harvested RF |
| 6 | 0.32 | Harvested RF | Harvested RF |
| 7 | 0.36 | Harvested RF | Battery |
| 8 | 0.41 | Harvested RF | Battery |
| 9 | 0.45 | Battery | Battery |
| 10 | 0.5 | Battery | Battery |

### *3.3 Dynamic Power Allocation*

Prioritizing power distribution is an approach that gives priority to important IoT devices to be powered at the earliest opportunity, so as to optimize the number of devices that operate in case of limited resources. Demand-based scheduling is also more energy efficient as it automatically switches on and off devices according to the real-time requirements of the power and priorities of the tasks. The devices that are of high priority, i.e., those whose tasks are urgent, e.g., real-time data transmission, critical monitoring, etc., are given more frequent or priority access to power and network bandwidth. On the contrary, low-priority devices will be allocated to run when demand is low or when energy sources are available.

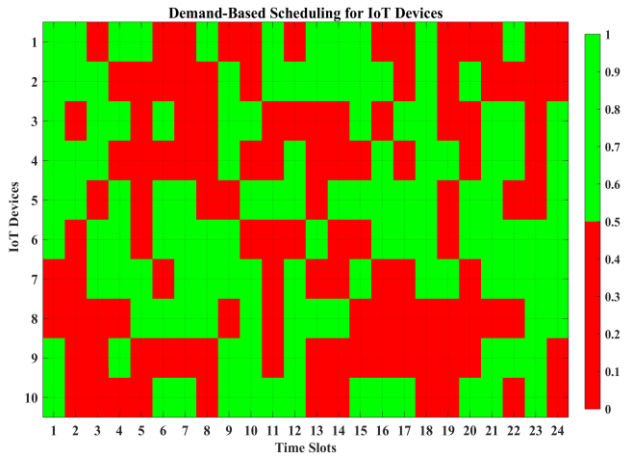


**Fig 5.** Demand-Based Scheduling for IoT Devices

It can maximize energy usage, minimize waste, and keep key devices online in energy-restricted settings, enhancing the efficiency and lifespan of the entire IoT system, especially in domains such as smart towns, industry, automation, and real-time environmental monitoring.

### *3.4 Modulation Schemes Comparison*

Comparative analysis of QPSK, BPSK, 16-QAM, and 64-QAM schemes of modulation shows that there are high trade-offs between BER and data rates.

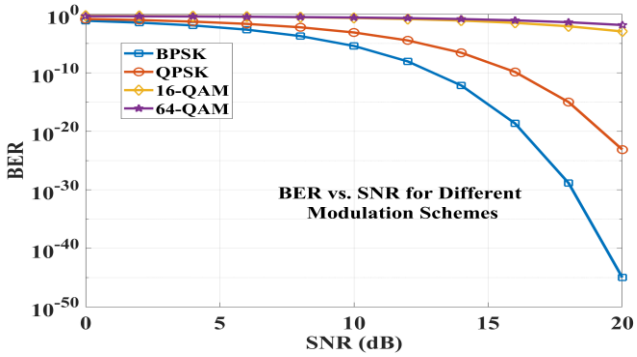


**Fig 6.** BER vs SNR for different modulation schemes

Figure 6 explains the BER performance of BPSK, QPSK, 16-QAM, and 64-QAM modulation schemes as a function of SNR, establishing the fundamental trade-off between reliability and spectral efficiency. Although the higher-order modulation schemes, including 64-QAM, have higher data rates, they are more likely to have larger BERs at low SNR values because the signal constellation is more complicated. However, the higher the SNR, the lower the BER of 64-QAM, which proves that under favorable conditions, it can be more efficient.

Comparatively, QPSK, 16-QAM, and BPSK are characterized by a more gradual decline in the value of BER with the improvement of SNR, with the minimal decrease in BPSK. Based on these results, 64-QAM is suggested in situations where data rate is important, and the SNR is high enough to reduce the increased start-up BER. This ensures that it is highly applicable in applications that need efficient transmission of data in low-interference conditions.

Lower order modulation schemes achieves the lowest BER at low SNR levels due to higher noise immunity, while higher-order schemes (16-QAM and 64-QAM) require significantly high value of SNR to accomplish comparable error performance but offer increased data rates. The gradual performance shift among the curves highlights that no single modulation scheme is optimal under all channel conditions.

#### *3.4.1 Adaptive Modulation Scheme*

The adaptive modulation technique enables the system to maximize its communication performance by dynamically choosing the most suitable modulation scheme according to the signal quality at the moment.

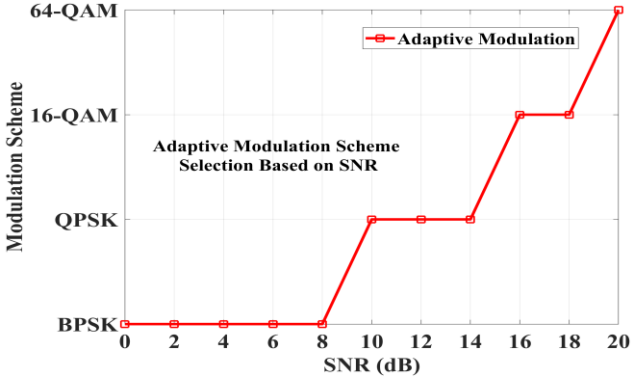


**Fig 7.** Adaptive Modulation Scheme Selection Based on SNR

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The figure shows how the adaptive modulation scheme is chosen depending on the SNR of a communication system. Binary Phase Shift Keying (BPSK) is used when SNR values are low (0-8 dB) because it is more resistant to noise and, thus, it performs better in poor signal conditions. With further SNR ratios (8-14 dB), Quadrature Phase Shift Keying (QPSK) is selected, providing a compromise between the data rate and reliability. At intermediate levels of SNR (16-18 dB), 16-QAM (Quadrature Amplitude Modulation) is used, which can accommodate a higher data rate with a tolerable error rate. Lastly, SNR can be used to revert to the use of 64-QAM when the SNR is greater than 16 dB, and 64-QAM is used, with a higher data rate (more bits encoded per symbol) at the expense of increased sensitivity to noise.

*3.5 Effect of MIMO for Communication*

The data rate of the MIMO and the adaptive data rate vs. SNR graphs show the correlation between the performance of the communication system and the quality of the signal available. In the case of MIMO as in (11), the data rate is proportional to the SNR, as it is beneficial to utilize a combination of multiple antennas to transmit and receive signals at the same time, and thus the system is more able to carry out the transmission of the data at a higher rate.

$$R_{\text{MIMO}} = \log_2\left(1 + \frac{P_{\text{SNR}}}{N_{\text{noise}}}\right) \qquad (11)$$

The adaptive data rate curve indicates that the system dynamically changes the data rate according to the SNR and uses alternative modulation schemes (including BPSK, QPSK, 16-QAM, and 64-QAM) to achieve optimal communication efficiency.

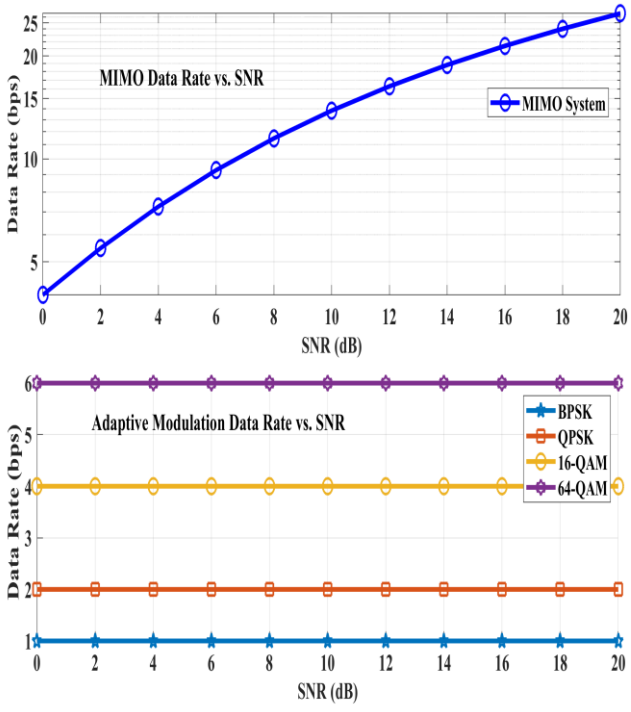


**Fig 8.** (a) MIMO data rate vs SNR. (b) Adaptive Modulation Data Rate vs SNR

Stronger modulation schemes, such as BPSK, are employed at lower SNR levels, and the consequence is a reduced data rate but better reliability. The increase in SNR will cause the use of higher-order modulation schemes such as QPSK, 16-QAM, and 64-QAM, which will result in an increase in data rate, but which will also be more susceptible to noise. The graphs are useful in picturing the trade-off between data rate and reliability in a communication system in different SNR conditions.

The adaptive data rate $R_{\text{adaptive}}$ (12) is as follows:

$$R_{\text{adaptive}} = M \cdot \log_2(1 + \text{SNR}) \qquad (12)$$

Adaptive data rate, which is abbreviated $R_{\text{adaptive}}$ is calculated based on the modulation scheme used and the SNR. M is the number of symbols per modulation scheme, which is 2 in the case of BPSK, 4 in the case of QPSK, 16 in the case of 16-QAM, and 64 in the case of 64-QAM. $R_{\text{adaptive}}$ can be configured in bits per second (bps). This set of equations gives a mathematical representation of how the system works with different SNR conditions, and they are important in understanding the behaviour that was observed on the simulation graphs, of how the rate of data changes with the quality of the channels available.

*3.6 LED Types Comparison for Energy Efficiency and Data Performance in LiFi*

The comparison of various LED types in the LiFi system indicates significant differences in efficiency, maximum power consumption, and data rate.

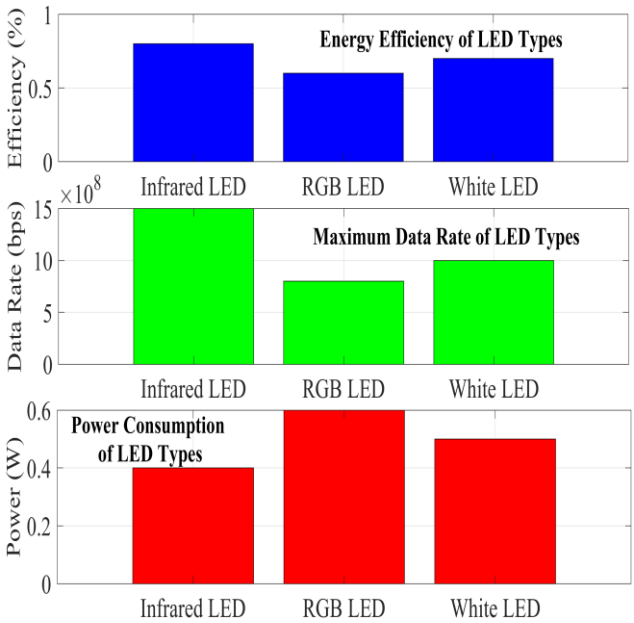


**Figure 9.** Energy efficiency of LED Types and Power Consumption of LED types

Infrared (IR) LEDs have the highest energy efficiency of 0.8, a maximum data rate of 1.5 GHz, and power consumption that is relatively low at 0.4 W. White LEDs have an energy efficiency of 0.7, a maximum data rate of 1 GHz, and relatively lower power consumption of 0.5 W. RGB LEDs have the lowest energy efficiency with 0.6, a maximum data rate of 800 MHz with a relatively lower power consumption of 0.6 W.

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This table highlights the trade-offs in terms of energy efficiency, data transmission capacity, and power usage, which are important when choosing the type of LED used in a LiFi-based system. The IR LED is the most efficient and the most performing, so it is a perfect product to use where energy is a concern. In brief, the results are as follows:

**Table 2**

Energy efficiency, max data rate, and power consumption of various LEDs

| LED Type | Energy Efficiency | Max Data Rate (bps) | Power Consumption (W) |
|---|---|---|---|
| Infrared LED | 0.8 | $1.5 \times 10^9$ | 0.4 |
| White LED | 0.7 | $1.0 \times 10^9$ | 0.5 |
| RGB LED | 0.6 | $0.8 \times 10^9$ | 0.6 |

*3.7 Comparative Analysis of EH Techniques:*

This sub-section is an assessment of EH techniques with emphasis being placed on efficiency, power generation, and their frequency range. This comparison allows establishing the advantages and disadvantages of each method, giving some understanding of the relevance of each one to various applications, including IoT systems and energy solutions for sustainability. This section of the paper seeks to inform the choice of the best EH solution out of the three discussed approaches: Rectenna, Resonant Inductive, and Magnetically Coupled harvesting, to suit the needs of a given system.

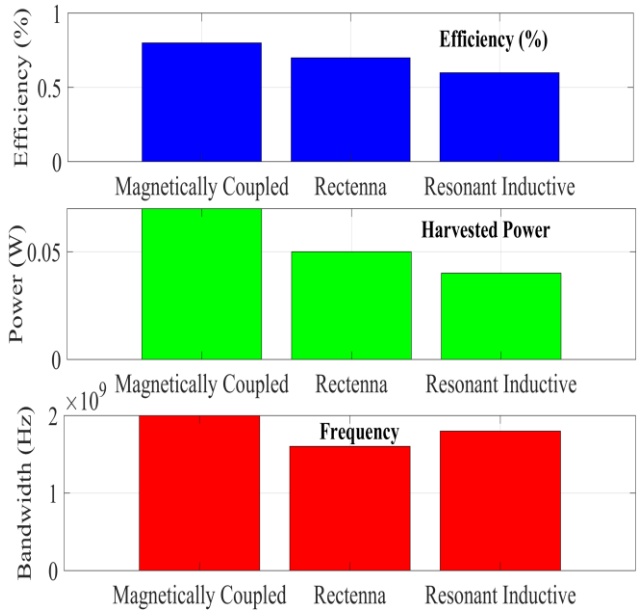


**Fig. 10.** Efficiency of various EH methods, harvested power, and frequency bandwidth of RF methods

The efficiency of 70% was achieved using the Rectenna method, which collects 0.05 W of power and works within the frequency spectrum 800 MHz to 2.4 GHz. A resonant Inductive harvesting that has a lower power of 60% can harvest 0.04 W that falls between the frequencies of 1.0-2.8 GHz. The Magnetically Coupled technique has the greatest efficiency of 80%, making it harvest 0.07 W of energy within the frequency spectrum of 3 to 5 GHz. The summary of the results is as follows:

**Table 3**

Comparison of RFEH Methods: Efficiency, Harvested Power, and Frequency Range

| Harvesting Method | Efficiency | Harvested Power (W) | Frequency Range (Hz) |
|---|---|---|---|
| Rectenna | 70% | 0.05 | 800 MHz - 2.4 GHz |
| Resonant Inductive | 60% | 0.04 | 1 GHz - 2.8 GHz |
| Magnetically Coupled | 75% | 0.07 | 3 GHz - 5 GHz |

This table is a comparison of the different RFEH techniques according to their efficiency, amount of power harvested, and frequency. Each of these approaches provides a variety of trade-offs between efficiency, power harvesting, and frequency range, with each method applicable to a particular application when the energy requirements of that system are considered.

*3.8 Industry Benchmarking*

In order to justify the effectiveness and usability of the suggested hybrid LiFi-based IoT system, a comparative analysis was carried out with the existing standards and benchmarks in the industry. The benchmarking reviews key metrics of core performance, including EH efficiency, data rate, and BER at different environmental conditions.

**Table 4**

Industry Benchmarking and Comparative Performance Analysis

| **Metric** | **Industry Standard / Typical Value** | **This Work** | **Reference** |
|---|---|---|---|
| LiFi Data Rate | 10 Mbps to ~~0~~=9.6 Gbps (IEEE 802.11bb) | 1 Gbps | [31], [32] |
| RFEH Efficiency | 42%–70% | 75% | [7], [33] |
| BER at 10 dB SNR (BPSK) | ~$10^{-4}$ (typical for LiFi systems) | <$10^{-5}$ | [34] |
| IoT Device Power Fulfillment | Priority Based | Fully met at day time, priority based at night | [35] |

The simulated hybrid system proves to be more successful in RFEH; the efficiency of the system attains 75 percent, and this is more successful in comparison to conventional methods by a margin of 5 percent. The performance of the BER under BPSK modulation is also higher than that of typical indoor

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LiFi communication systems, and this guarantees strong transmission at lower SNRs.

Compared to the IEEE 802.11bb LiFi standard [31], the proposed system maintains the same data rates with an in-built EH feature, which is significant in energy-limited systems.

Moreover, the combination of adaptive modulation and MIMO algorithms also boosts the data throughput even more without reducing the reliability. This makes the system a potential and effective solution to smart applications with low-latency and energy-autonomous operations, including smart cities, industrial IoT, and environmental monitoring.

## Conclusion

The current study proposes a hybrid LiFi-based IoT platform with built-in RF and solar EH to offer a sustainable solution for powering of IoT networks. The system is designed to provide credible data transfer and power optimization and EH efficiency, which are the major issues of the traditional IoT networks, including the scarcity of power sources and energy wastage. A variety of energy sources allows the proposed system to continue working uninterruptedly in conditions with fluctuating light conditions or weak RF signals.

The effective implementation of these technologies leads to a general increase in the effectiveness of EH, therefore, providing long-term and autonomous performance of the IoT devices. In the future, the practical implementation of the proposed system will be considered to prove its functionality in given dynamic, real-life conditions.

Also, more research on higher energy management methods, including smart power distribution and automatic scheduling, will be conducted to streamline the system performance and scalability to an extensive IoT implementation. The presented work opens the path to sustainable and energy-efficient solutions for future IoT networks, and the opportunity to be implemented in smart cities, industrial automation, and other energy-sensitive devices is high.

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