

**AI-BASED ENERGY EFFICIENT COMMUNICATION IN IOT SYSTEM***Shital Chavan**UG Student, Department of Electronics and Telecommunication Engineering
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madhav.naiknavare@sknscoe.ac.in***Abstract:**

The rapid growth of the Internet of Things (IoT) has led to a massive increase in the number of connected devices across various domains such as smart homes, healthcare, agriculture, and industrial automation. As these devices are often battery-powered and deployed in remote or large-scale environments, energy efficiency has become a critical concern in IoT communication systems. Traditional IoT networks typically operate using fixed transmission power levels, which do not adapt to changing environmental or network conditions, resulting in unnecessary energy consumption and reduced battery life. To address these limitations, there is a growing need for intelligent and adaptive communication mechanisms that can dynamically optimize power usage without compromising reliability. In this context, Artificial Intelligence (AI)-based adaptive transmission power control has emerged as a promising solution. This review paper presents an analysis of AI-driven techniques that enable IoT devices to adjust their transmission power based on real-time conditions and network requirements. The study explores approaches such as machine learning-based prediction models, which utilize parameters like Received Signal Strength Indicator (RSSI), distance, interference levels, and packet loss rates to determine optimal transmission power. Additionally, the role of edge computing is examined, enabling faster decision-making with reduced latency. The integration of Low Power Wide Area Network (LPWAN) technologies is also discussed for supporting long-range and energy-efficient communication. Furthermore, the paper highlights how adaptive power control improves network performance by reducing energy wastage, minimizing interference, and extending device lifetime.



These benefits are especially useful in applications like smart cities, precision agriculture, and industrial automation. Despite these advantages, challenges such as implementation complexity, resource constraints, and data privacy concerns remain. The paper also outlines future research directions, including the development of lightweight AI models and improved integration with emerging technologies. In conclusion, AI-based adaptive transmission power control significantly enhances energy efficiency and communication reliability, making it essential for the sustainable development of next-generation IoT systems. It also supports scalable and cost-effective deployment of IoT networks in diverse real-world environments.

Keywords: IoT, Artificial Intelligence, Energy Efficiency, Transmission Power Control, Machine Learning,.

LPWAN

Introduction:

With the rapid expansion of IoT networks, energy efficiency has become a critical challenge in modern

communication systems and plays a key role in ensuring sustainable and reliable network operation. IoT devices are typically battery-powered and deployed in large numbers across wide and often remote areas.

Efficient energy utilization is therefore essential for long-term operation, reduced maintenance, and cost-effectiveness. Traditional communication systems use fixed transmission power, which does not adapt to changing network conditions and often results in unnecessary energy consumption.

This issue becomes more significant when devices are located close to each other or when lower transmission power levels are sufficient for communication. As a result, energy resources are wasted, and the overall lifetime of IoT devices is reduced.

To overcome this limitation, intelligent systems based on Artificial Intelligence (AI) and Machine Learning (ML) are being developed to enable smarter, more adaptive, and efficient communication. These systems dynamically adjust transmission power according to real-time network conditions.

Parameters such as signal strength, distance between devices, interference levels, and packet loss are continuously analyzed to make accurate decisions. This helps in optimizing power usage, reducing energy wastage, and maintaining reliable and stable communication.

AI-based adaptive communication systems represent a significant advancement in IoT technology. They improve energy efficiency, enhance system reliability and scalability, and support applications such as smart agriculture, environmental monitoring, industrial IoT, smart cities, and wireless sensor networks.



In addition, these systems contribute to better network management by reducing congestion and improving data transmission efficiency. They ensure that communication remains stable even in dynamic and changing environments.

Furthermore, the integration of AI and ML enables IoT systems to learn from past data and continuously improve their performance. This makes the communication process more intelligent, adaptive, and responsive to real-world conditions.

Overall, AI-based adaptive transmission power control provides a practical and effective solution for modern IoT challenges. It supports sustainable development by optimizing energy usage and enhancing the performance of next-generation IoT networks.

Literature Survey:

Q. Pan et al. [1] proposed an AI-based communication framework integrated with Intelligent Reflecting Surface (IRS) for energy-efficient communication in 6G IoT systems. The system improves signal quality and reduces energy consumption by intelligently controlling wireless communication conditions. This approach enhances communication efficiency but involves high implementation complexity.

S. Thakur et al. [2] developed an AI-driven energy-efficient routing mechanism for IoT-based wireless sensor networks. The system selects optimal communication paths to reduce energy consumption and extend network lifetime. This approach improves routing efficiency but requires complex algorithms and proper training data.

A. A. Mirani et al. [3] presented an industrial IoT-based energy monitoring system using edge data processing. The system processes data near the source, reducing latency and enabling faster decisionmaking. This approach improves real-time performance but is limited by the processing capabilities of edge devices.

M. Chen et al. [4] proposed a cognitive LPWAN-based communication system for energy-efficient IoT networks. The system supports long-range communication with low power consumption, making it suitable for large-scale IoT applications. However, the system increases design complexity.

N. Ansari [5] introduced a machine learning-based resource allocation method for IoT networks. The system dynamically optimizes resource usage to reduce energy consumption and improve network efficiency. This approach enhances performance but requires large datasets for training.

The LoRaWAN energy optimization study [6] focused on the use of AI and machine learning techniques to improve energy efficiency in low-power wide-area networks. The system enhances communication performance and reduces energy consumption, but its flexibility is limited in dynamic environments



The machine learning-based IoT system [7] proposed real-time energy optimization using adaptive algorithms. The system adjusts operational parameters dynamically to reduce energy usage while maintaining performance. However, system accuracy depends on the quality of the trained model.

The clustering-based routing protocol [8] introduced an energy-efficient clustering mechanism for IoT networks. The system balances energy consumption among nodes, improving network lifetime. However, the clustering process increases computational complexity.

The cross-layer framework [9] proposed a secure and energy-efficient IoT system by integrating multiple network layers. The system improves both security and energy performance but introduces additional computational overhead.

The on-device machine learning approach [10] focused on performing data processing directly on IoT devices. This reduces latency and communication overhead while improving energy efficiency. However, hardware limitations restrict its performance.

The federated learning-based system [11] proposed decentralized model training for IoT networks, reducing data transmission and improving privacy. This approach enhances energy efficiency but involves communication overhead during model updates.

The AI-based optimization study [12] introduced intelligent techniques for improving overall energy efficiency in IoT systems. The system dynamically optimizes performance but requires continuous training and data updates.

The ensemble learning approach [13] proposed combining multiple machine learning models to improve prediction accuracy and system performance. This approach enhances decision-making but increases system complexity.

The federated learning-based energy-constrained IoT system [14] focused on optimizing energy usage in low-power devices using decentralized learning techniques. The system improves efficiency but faces resource and hardware constraints.

Table 1 AI-Based Energy Efficient Communication in IoT System

Sr. No .	Authors	Year	Title	Journal / Conference	Technology used
1	Federated Learning Study	2026	Federated Learning for Sustainable IoT: Energy-Efficient Applications	Research Paper	Federated Learning
2	A. A. Mirani, A. Awasthi	2025	Edge-Based Energy Monitoring in IoT Systems	Journal of IoT Systems	Edge Computing + IoT
3	M. Chen, Y. Miao	2025	Cognitive LPWAN for Energy Efficient IoT Communication	IEEE IoT Journal	LPWAN + AI
4	Clustering Routing Study	2025	Energy-Efficient and Balanced Clustering Routing Protocol for IoT	Research Paper	ML + Clustering



5	S. Thakur, N. Sarkar	2024	AI-Driven Energy Efficient Routing in IoT Networks	International Journal	AI + Wireless Sensor Network
6	LoRaWAN Review Study	2024	AI and ML for Energy Efficiency and Performance Optimization in LPWAN	Review Paper	AI + LPWAN
7	Cross-Layer Framework Study	2024	Secure and Energy-Efficient Framework for IoT	Research Paper	Cross-layer Optimization
8	On-Device ML Study	2024	Energy Perspective of On-Device Machine Learning in IoT	Research Paper	Edge AI
9	AI Optimization Study	2024	Energy-Efficient IoT Networks Using AI Driven Approaches	Research Paper	AI Optimization
10	Ensemble ML Study	2024	Energy-Efficient Ensemble Approach for IoT Applications	Research Paper	Ensemble Learning
11	ML IoT Study	2023	Energy-Efficient IoT Systems Using Machine Learning for RealTime Applications	Research Paper	Machine Learning
12	FL IoT Study	2023	Systematic Study on EnergyConstrained IoT Devices	Research Paper	Federated Learning
13	N. Ansari	2021	Machine Learning-Based Energy Efficient Resource Allocation in IoT Networks	IEEE IoT Journal	Machine Learning
14	Q. Pan, J. Wu	2020	Leveraging AI and Intelligent Reflecting Surface for Energy Efficient Communication in 6G IoT	IEEE Access	AI + IRS

Proposed Methodology:

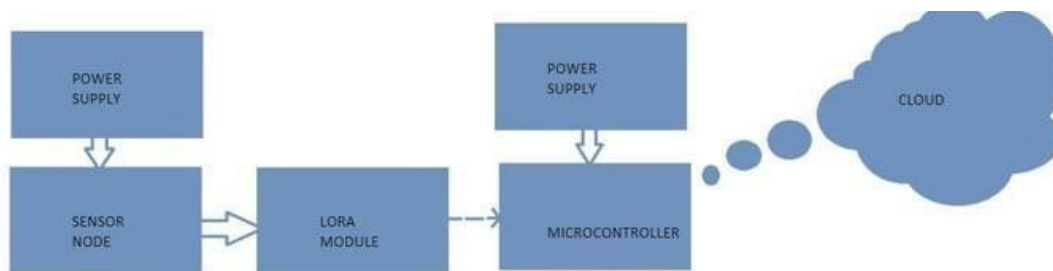


Figure 1 Block Diagram of Proposed System

The diagram represents the architecture of an IoT-based communication system designed for efficient data transmission and monitoring. The system begins with a power supply unit that provides energy to the sensor node, ensuring continuous operation. The sensor node collects real-time data such as communication parameters or environmental conditions and acts as the primary data source. This collected data is then transmitted to the LoRa module, which is responsible for long-range, low-power wireless communication between devices.



The LoRa module forwards the data to the microcontroller, which serves as the central processing unit of the system. The microcontroller receives and processes the incoming data, performs necessary computations, and prepares it for further transmission. It is also powered by a separate power supply to maintain stable and efficient operation. After processing, the data is sent to the cloud platform, where it is stored, analyzed, and visualized.

The cloud enables remote access to the data through mobile or web applications, allowing users to monitor system performance in real time. Overall, the system ensures reliable communication, efficient data handling, and supports applications such as adaptive transmission control and smart IoT monitoring.

In addition, the use of LoRa communication technology allows the system to operate over long distances while consuming very low power, making it suitable for large-scale IoT deployments. This helps in reducing energy consumption and extending the battery life of devices, which is essential for remote and distributed environments.

Furthermore, the integration of cloud technology enhances the scalability and flexibility of the system. It allows data to be accessed, analyzed, and managed from anywhere, supporting better decision-making and system optimization. This architecture can also be extended by integrating AI-based techniques for intelligent control and improved communication efficiency in future IoT applications.

1. RESULT

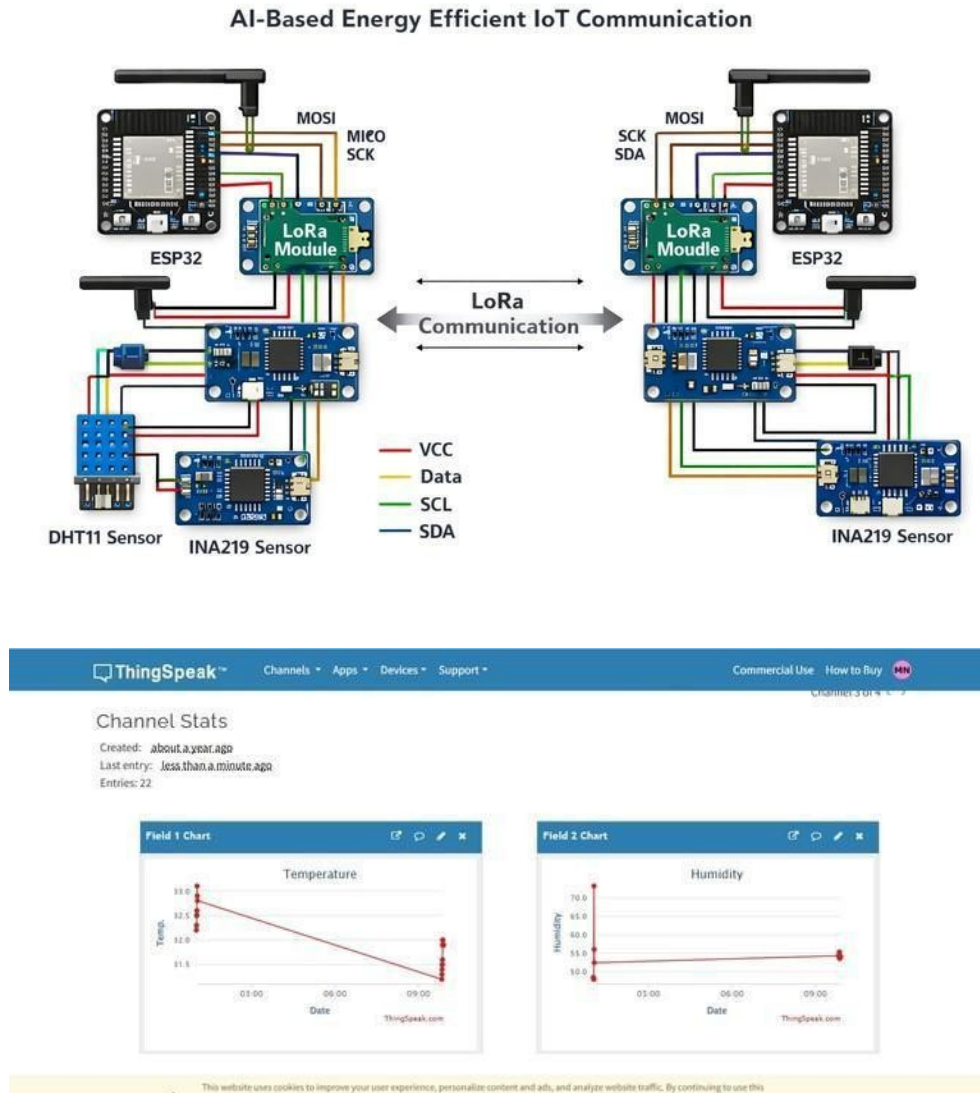


Figure 1 represents the overall system architecture of the proposed AI-Based Energy Efficient IoT Communication system. The system consists of two IoT nodes built using ESP32 microcontrollers and LoRa communication modules for long-range, low-power wireless communication. On the transmitter side, the DHT11 sensor is used to measure environmental parameters such as temperature and humidity, while the INA219 sensor monitors power consumption. The ESP32 processes this data and transmits it through the LoRa module to the receiver node. On the receiver side, another ESP32 receives the data and evaluates communication performance. This architecture enables real-time data transmission, monitoring, and analysis, forming the foundation for adaptive transmission power control and energy efficient communication.

Conclusion:



This review paper highlights the significance of AI-based adaptive transmission power control in improving energy efficiency in IoT systems. By dynamically adjusting transmission power based on real-time network conditions, the system reduces energy consumption while maintaining reliable communication. The study concludes that AI-driven approaches are essential for the future of IoT networks and can significantly enhance performance in various smart applications.

In addition, the paper emphasizes that such adaptive systems help in extending the battery life of IoT devices and reducing overall operational costs. It also highlights the ability of AI models to learn from network patterns and improve decision-making over time. Overall, AI-based energy-efficient communication plays a crucial role in developing sustainable and intelligent IoT ecosystems.

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