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Design and Implementation of a Smart Human Interrupt System Using Long-Range RFID

Imran Khurshid[1,2], Mudassir Khalil*[1], Hassan Moatasam Awan[3], Muzahir Saleem[4]
[1]Department of Computer Engineering (Bahauddin Zakaria University, Multan).
[2]Department of Software Engineering, National University of Modern Languages (NUML)
[3]Department of Informatics and Systems, School of Systems and Technology (UMT Lahore).
[4]Department of Computer Science, School of Systems and Technology (UMT Lahore).
***Correspondence**: mudassir.khalil@bzu.edu.pk

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Communication is a critical component of modern life, supporting essential sectors such as business, healthcare, education, and disaster response. However, in rural and remote environments, traditional GSM and Internet-based communication systems often become unreliable due to power outages, network congestion, and physical infrastructure damage. To address these limitations, this study proposes an independent, infrastructure-free communication system integrating RFID and LoRa technologies. The system utilizes an MFRC522 RFID reader for tag identification and an SX1278 LoRa transceiver for long-range data transmission without reliance on Internet or GSM connectivity. Experimental evaluation was conducted in both indoor and outdoor environments to assess system performance under varying conditions. Indoor results across four floor levels show RSSI values ranging from −99 dBm to −81.4 dBm and SNR values from −6.8 dB to 9.6 dB, indicating varying signal quality depending on floor height and obstruction levels. Outdoor testing demonstrated reliable communication up to 500 meters in open-field conditions, with RSSI values between −65 dBm and −85 dBm and SNR ranging from +5.0 dB to −2.5 dB, achieving a packet delivery success rate of 100% under the tested conditions. In more obstructed environments (tree line), signal degradation was observed (RSSI: −92 dBm, SNR: −5.8 dB), resulting in occasional packet drops. Across multiple trials ($n = 50$), the average RFID read time was measured at 1.2 ± 0.15 seconds, while the average LoRa transmission delay remained below 500 milliseconds (420 ± 60 ms). The total system power consumption was approximately 0.6 ± 0.05 Watts, enabling efficient operation using battery or solar power systems. These results confirm that the proposed RFID–LoRa system is a reliable, energy-efficient, and scalable solution for offline communication in infrastructure-limited and disaster-prone environments, with performance influenced by environmental conditions and physical obstructions.

Keywords: RFID Tag, RFID Reader, LoRa Transceiver, Signal Strength (RSSI), SNR, Low-Power Communication.

Introduction

Communication is the key element of modern society, serving to support the most important spheres of life such as business, healthcare, education, and disaster responses. Facilitating uninterrupted communication technologies have enabled real-time interaction, distant education, and access to online learning materials and has changed the paradigm of pedagogy [1][2][3]. Effective and timely communication systems may enhance telemedicine use and patient monitoring, along with timely coordination among medical first responders, thus representing a major change in the effectiveness of care delivery and improvement of outcomes [1]. Effective situational awareness in disaster response needs quick information flow across control centers, first responders, and the areas of the disaster to allow the authorities to take fast measures [4][5][1].

In rural areas, however, those infrastructures may be destroyed, or there may be a lack of electricity, or network overload, or even a GSM network can be inoperative in such remote locations [6]. In such emergency cases, the use of centralized infrastructure offers liability. One of the ways to mitigate this weakness is through studies of low-power wide area networks (LPWANs), like LoRa, that provide long-range wireless communication with power-efficient and affordable alternatives to support both IoT systems and emergency networks [1][7][8][9].

Under real-life conditions, LoRa allows communication distances of up to about 10 km, and, in ideal conditions, of up to 330 km (Wikipedia, 2025), with minimal power consumption. LoRa mesh implements multi-hop profiles through a peer-to-peer network, and it does not require central gateways, which makes it more resilient, particularly in disconnected settings [10][11][12][13]. The mesh networks can provide extended coverage and improved reliability since nodes can pass messages on behalf of each other, creating decentralized networks well-suited to disaster-prone or infrastructure-poor regions [6][10].

With the known shortcomings of the Internet and GSM systems under environmentally challenging conditions, computer science research must be geared toward standalone, energy-efficient, long-range communication systems. Utilization of LPWAN technologies and, in particular, LoRa mesh networks can facilitate strong, scalable, and infrastructure-independent communications platforms that support needed communications. These platforms are especially important in facilitating next-generation human interrupt systems, where prompt identification and action of human-initiated events require connectivity as well as intelligence, where conventional networks are not available.

Internet and GSM networks are the cornerstone of the current communication and data-sharing systems worldwide, serving billions of people globally daily (Garc 0021). These technologies facilitate voice, data services, and multimedia services that facilitate personal use applications and industries. Nonetheless, they are very sensitive to situations that involve cases where they lose connectivity, or the connection is dismally impaired, whether in cases of natural calamities, deployment in rural areas, or deployment of the military forces, particularly when they are faced with disaster services [6]. Moreover, when direly needed, Internet and GSM-based functionalities can be made unusable by infrastructure failures, e.g., lack of electricity, broken cellular tower, and the backbone network infrastructure [1].

A workable solution thus must have the ability to work independently of conventional networks because it will be able to maintain communication in the presence of adverse conditions. Isolated wireless communication systems, especially founded on Low-Power Wide-Area Networks (LPWANs), which include LoRa, have proved to be potential alternatives. LoRa networks also enable long-range communications with low energy requirements and thus are particularly well suited to emergency and off-grid exercises [10]. Contrary to GSM and Internet-based systems, LoRa and other technologies can be used where infrastructure budget may be scarce and maintain connectivity under resource-limited conditions. Moreover, due to the mesh structure, LoRa networks bring resilience because, regardless of node failure or gateway unavailability, devices still can pass data via neighbor nodes, resulting in the phenomenon of peer-to-peer communication (by submitting information to one another) with minimum allocations (such as memory, bandwidth, etc.). Such distributed ownership guarantees increased fault matching with centralized GSM systems that are vulnerable to a single point of paralysis. In case of emergency response and human safety, it gives robustness and scalability in this case.

Literature Review:

The increasing demand for reliable and energy-efficient communication systems in remote and infrastructure-limited regions has accelerated research in long-range, low-power wireless technologies. Among these, LoRa (Long Range) has emerged as a prominent solution due to its ability to support low-power communication over several kilometers while operating in unlicensed spectrum bands. Recent studies have demonstrated its effectiveness in applications such as rural monitoring, disaster response, and smart agriculture, where conventional GSM and Internet-based systems often fail; [14][15][16]. Despite these advantages, LoRa-based systems are primarily designed for data transmission and lack inherent mechanisms for secure identification and authentication.

Radio Frequency Identification (RFID), on the other hand, is widely used for identification and tracking in logistics, healthcare, and security applications. Both passive and active RFID systems provide unique identifiers that enable efficient asset tracking and authentication [17]. However, RFID technology is inherently limited by short communication range and dependence on nearby readers, which restricts its applicability in large-scale and decentralized environments.

To overcome these limitations, recent research has explored the integration of LoRa and RFID technologies. This hybrid approach combines the identification capability of RFID with the long-range communication features of LoRa, enabling both authentication and data transmission without reliance on GSM or Internet infrastructure [18][14]. Such systems are particularly suitable for deployment in disaster-prone or remote areas, where infrastructure is either unavailable or unreliable.

From this comparison, it is evident that while individual technologies provide partial solutions, none fully address the combined requirements of long-range communication, secure identification, low power consumption, and infrastructure independence. Moreover, many existing studies lack comprehensive experimental validation under real-world environmental conditions, particularly in multi-floor indoor and obstructed outdoor scenarios.

Performance evaluation in recent work typically focuses on metrics such as communication range, packet delivery ratio, latency, and energy consumption [14]. For instance, LoRa has been shown to achieve multi-kilometer coverage with minimal packet loss in open environments. Conversely, RFID systems are evaluated based on tag detection accuracy, response time, and performance in high-density environments [17]. However, limited research integrates these metrics within a unified hybrid system and evaluates their performance under diverse environmental conditions.

The potential applications of LoRa–RFID systems are extensive, including disaster response, remote healthcare monitoring, smart agriculture, and supply chain management. In disaster scenarios where communication infrastructure is severely damaged, such systems can provide essential communication links for rescue operations [11]. Similarly, in agriculture, RFID-based tagging combined with LoRa communication enables real-time monitoring of livestock and crops over large geographical areas [19][15]. Despite these promising applications, challenges such as scalability, interference in dense deployments, and security vulnerabilities in wireless communication remain open research issues [14][16].

Therefore, there is a clear need for a robust, experimentally validated hybrid communication system that addresses these limitations. The proposed RFID–LoRa system aims to fill this gap by providing a standalone, energy-efficient, and scalable solution, with comprehensive performance evaluation in both indoor and outdoor environments. This work contributes to the existing body of knowledge by not only integrating these technologies but also validating their effectiveness under realistic deployment conditions.

In conclusion, while recent research demonstrates the potential of LoRa and RFID individually and in hybrid configurations, further investigation is required to optimize system performance, ensure scalability, and enhance reliability in real-world scenarios. The proposed system is motivated by these gaps and seeks to advance the development of infrastructure-independent communication solutions.

Methodology:

The research methodology is based on experimental design and testing of a standalone data transfer system integrating RFID and LoRa technologies. The system is particularly designed to operate in environments where GSM and Internet connectivity are not reliable or not available, like rural areas and disaster-prone areas.

The proposed RFID–LoRa communication system is implemented in the experimental framework to ensure clarity, reliability, and repeatability. To enhance the validity of the study, detailed information on the hardware setup, environment, and testing process was included. The prototype was built with an ESP32 microcontroller, MFRC522 RFID reader, and SX1278 433 MHz LoRa transceiver. The experiments were carried out in different settings, such as multi-level indoor and open field - tree-line outdoor scenarios. Each communication test was repeated 50 times with similar operating conditions in order to increase reproducibility and statistical consistency. Some of the important performance metrics, like RSSI, SNR, RFID reading time, packet delivery success rate, transmission delay, and power consumption, were measured and analyzed during the experimentation. These details enable the proposed methodology to be replicated and validated in future studies in similar deployment conditions.

System Development Prototype Design:

The LoRa SX1278 transceiver module, which has robust long-range communication performance, and the MFRC522 RFID reader, which has efficient short-range identification performance, were selected and used as the prototype. The architecture of the system consists of three layers, which is typical of the patterns of IoT design [10][1].

Front-End Service (Edge Node):

The given system includes an RFID reader (MFRC522), an ESP32 microcontroller, an LED display, a relay module, and a LoRa shield that will collaborate to provide the opportunity to identify and transmit data wirelessly in offline mode and safely. Once a user taps an RFID tag or card on the reader, the ESP32 authenticates the tag with a predefined key, which is locally stored in the system. When the tag is valid, the LCD will show the corresponding user details and, at the same time, send them to a remote node via the LoRa communication and, when necessary, actuate the relay. When an unauthorized tag is detected, an error message is posted to show that there is unauthorized access. As well, a desktop application is used to write, update, and manage RFID user data with a cloud database whenever the connection to the network is available, so as to ensure synchronization and easy management of the system.

Gateway Service (Relay Node):

The system uses an ESP32 microcontroller with a LoRa module, which acts as an intermediary between the front-end RFID reader units and cloud infrastructure on the back-end. This node obtains the data packets that are sent to it via the LoRa network by various RFID devices and sends the information that is detected to the cloud via the MQTT protocol. MQTT is a lightweight and reliable messaging protocol; it is small and fits in many applications that have low power and constrained bandwidth in the IoT, thus assuring efficient and reliable data delivery between the edge devices and the cloud [18].

Back-End Service (Cloud Infrastructure):

The implementation of the backend environment is done using a Firebase-based web application and database that is used as the key data management and visualization hub of the system. It is in charge of ensuring the proper storage of all transaction-related records, keeping comprehensive individual activity records, and handling registered users and the connected devices. The gathered information is also displayed in the form of a real-time web dashboard, using which the system administrators can view the performance of the system, its user activity, and make reports effectively, both as an operational and analytical tool.

When an RFID tag gets within the range of the reader, the identifier (UID) of the tag is read, the microcontroller processes this information, and sends it wirelessly using the LoRa module to a remote receiver.

Data Acquisition Performance:

The 13.56 MHz (ISO/IEC 14443 Type A/B) RFID reader operated reliably within a range of 3–5 cm in picking up the tags. The RFID read time was averaged by recording the difference between the time when the tag was presented and the time when it was available and had its UID at the microcontroller.

The mean RFID acquisition time, T_{RFID}, is expressed as:

$$T_{RFID} = 1/N \sum_{i=1}^{N} (t_{read,i} - t_{present,i})$$

where (N) is the number of trials. Experimental results yielded:

Average RFID read time: ~1.2 s

The acquisition process of RFID data and latency is shown in Figure 4.1. The fact that it has a low delay in acquiring it ascertains its appropriateness in near real-time uses like access control, attendance monitoring, and inventory tracking.

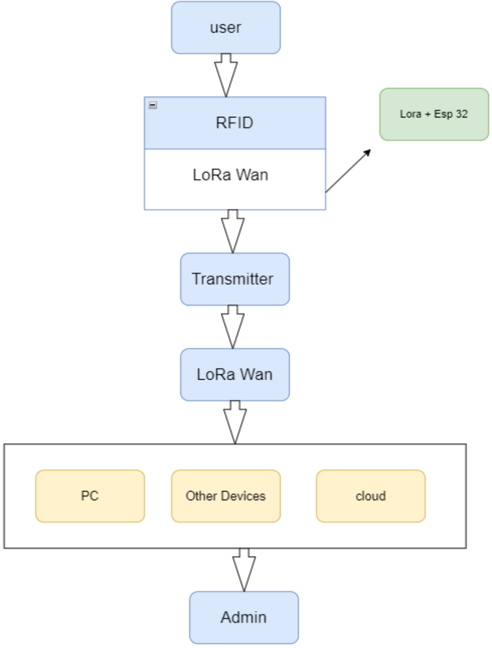

Figure 1. System Flow Chart

The suggested system will offer an infrastructure-independent communication system by combining RFID and LoRa technology. The general working process starts with the user and follows a systematic process of data acquisition to the final monitoring, where the administrator is involved.

The user communicates with the system at the first level by means of an RFID tag. Every user has a unique RFID tag, which contains the identification information. Upon approaching the RFID reader with the tag, the MFRC522 module reads the tag ID. This process requires an average of 1.2 seconds, hence fast and precise recognition.

After the capture of the RFID data, the data is processed by the microcontroller (ESP32 with LoRa). The system at this level is preparing the data to be sent. The ESP32 is used to manage the RFID reader as well as the LoRa communication module, such that the system is compact and energy-efficient.

The processed data is then sent to the LoRa transmitter (SX1278). LoRaWAN communication is used to transmit information over long distances using the transmitter. The primary benefit of such a step is that it does not require any Internet or GSM network, thus making it highly applicable in remote or disaster-stricken regions. Transmission delay is kept at a minimum of 500 milliseconds, which ensures close to real-time communication.

The LoRa network layer acts as the communication gateway between the sender and receiver. The long-range property of LoRa enables the system to operate over several hundred meters to kilometers based on environmental factors. As observed in the experimental results, the signal strength and quality can differ depending on the obstruction; this can be a building or a tree.

On the receiving side, the data is sent to a variety of endpoints, such as PCs or other devices, or even cloud platforms. These endpoints are used to store and present the received information. When there is no connection, the system can be linked with the local devices, and when there is a connection, the system can be integrated with the cloud networks, where data logging and access can be carried out.

Lastly, the processed information is retrieved by the admin (administrator). The admin is observing the system, checking the incoming data, and is able to make decisions based on the information obtained. It is especially handy in disaster management and similar applications where disaster tracking and communication are key.

LoRa Transmission Performance and Transmission Success Rate:

The RFID scan each led to the transfer of a UID packet through LoRa. The Success rate of transmission, η, was determined as:

$$Efficiency\ (\eta) = \left(\frac{Number\ of\ Items\ Received}{Number\ of\ Items\ Sent}\right) x\ 100$$

Nsent is the number of packets that were transmitted, and N_{received} is the number of packets received successfully. During testing, all transmitted packets were successfully received, resulting in a transmission success rate of 100%:

Transmission Success Rate: This confirms the robustness of LoRa communication in offline scenarios.

Transmission Delay: The LoRa transmission delay, TLoRa, was calculated as:

$$T_{\text{LoRa}} = t_{\text{receive}} - t_{\text{transmit}}$$

Delays were also consistently less than 500 ms, thus allowing close real-time system response.

Power Consumption Analysis: The power consumption of the system was measured at the total power under active operation. Power (P) is defined as:

$$P = V * I$$

(V) is the supply voltage and (I) the operating current. The prototype operated with low power consumption.

Power consumption: ~0.6 W. This low power requirement allows the system to operate on batteries or solar energy, making it ideal for energy-constrained environments.

Performance Evaluation: The system was field-tested under both controlled laboratory conditions (indoor) and open-field conditions (outdoor).

Indoor tests focused on short-range RFID validation and LoRa transmission through obstacles (walls, furniture).

Outdoor tests evaluated LoRa's maximum range, scalability, and packet reliability over distances up to 1 km, consistent with prior studies on LPWAN deployments [20].

Performance Metrics:

To evaluate the system's scalability, reliability, and efficiency, the following metrics were measured:

Received Signal Strength Indicator (RSSI): In dBm, uncoded signals of high power (because of the struggle against noise) are usually between -30 dBm and -60 dBm, and decodable weak signals are as low as -120 dBm.

Signal-to-Noise Ratio (SNR): Measured in dB. The positive SNR values (above 0 dB) are a sign of high-quality communication with high reliability, whereas the spread-spectrum modulation of LoRa permits communication even with negative SNR values (between -5 and -10 dB), which is impossible with the traditional RF systems [14].

Packet Delivery Ratio (PDR): Proportion of received packets that were successful compared to the sent packets. PDR was evaluated at different distances and in different environments to determine the reliability.

Latency: Time between RFID tag read and final data storage in the back-end database.

Energy Efficiency: RFID reader and LoRa module power consumption were examined to confirm the ability to implement them in low-power long-term deployments [10].

Results and Discussion:

Overview of Experimental Results:

The paper discusses the experimental findings achieved in the creation and testing of a standalone RFID–LoRa data transmission system. This system was designed to work without using traditional communication tools like GSM networks or the Internet, which made it applicable in rural, remote, and disaster-prone places. Experimental testing aimed at real-time data acquisition, reliability of wireless transmission, power efficiency, and the test performance in indoor and outdoor environments.

System Architecture and Experimental Setup:

Figure 2 shows the entire prototype system that consists of an RFID reader, microcontroller (ESP32/Arduino Nano), and the LoRa transceiver (SX1278). A regulated USB supply was used to power the system, and the system was assembled on a non-conductive surface to reduce electromagnetic interference.

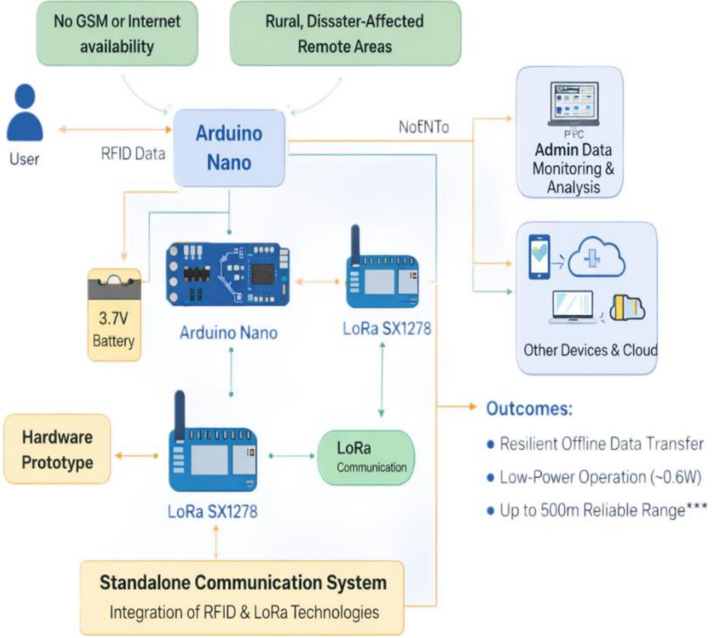

Figure 2. System Architecture

Quantitative Results Summary: These results confirm efficient data acquisition and reliable long-range communication

Table 1. Quantitative Performance Metrics

Parameter	Measured Value
Average RFID read time	~1.2 s
LoRa transmission delay	< 500 ms
LoRa transmission range (LOS)	~1 km
Power consumption	~0.6 W

Indoor Performance Evaluation: In a reinforced concrete multi-storey building, indoor experiments were carried out. The walls and the floors were also structural elements that played an important role in signal propagation.

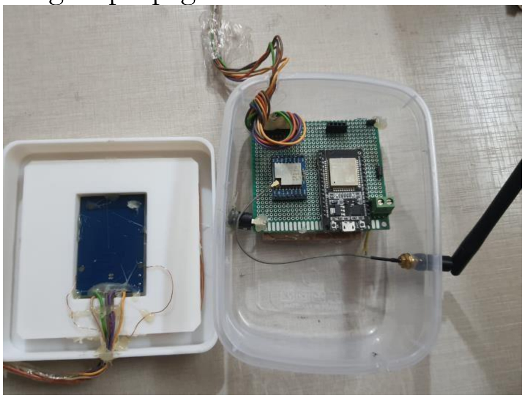

Figure 3. System prototype setup (RFID reader – MCU – LoRa transmitter)

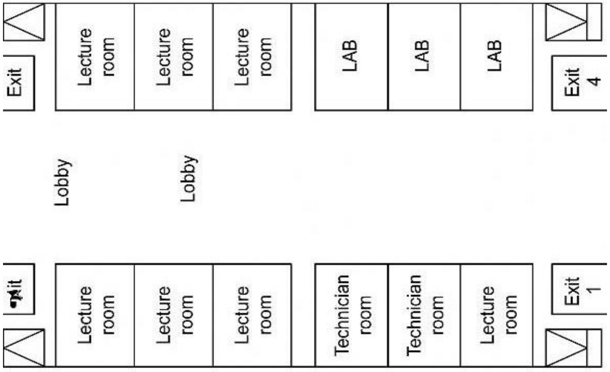

Figure 4 shows the building layout used for testing.

The values of RSSI and SNR were measured in various positions of the transmitters at the floor level. The signal strength was in an expected path-loss behavior in which the RSSI progressively declines with obstruction and distance.

Table 2. Indoor Test Results

Floor Level	RSSI (dBm)	SNR (dB)	Signal Quality
1st Floor	−99	−6.8	Weak
2nd Floor	−87.1	8.2	Moderate
3rd Floor	−81.4	9.6	Good
4th Floor	−88.2	7.2	Fair

Figures 5 and 6 show the RSSI and SNR measurements for the proposed communication system of RFID–LoRa in indoor environments for various floor levels. These measurements were taken to assess the behavior of these signals and the reliability of communication in a multi-floor indoor setting where obstacles like walls, ceiling, furniture, and building materials can impact wireless transmission.

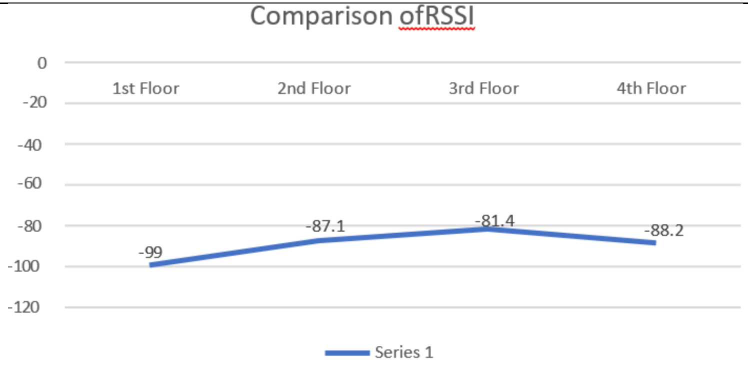

Figure 5. Comparison of RSSI across floors

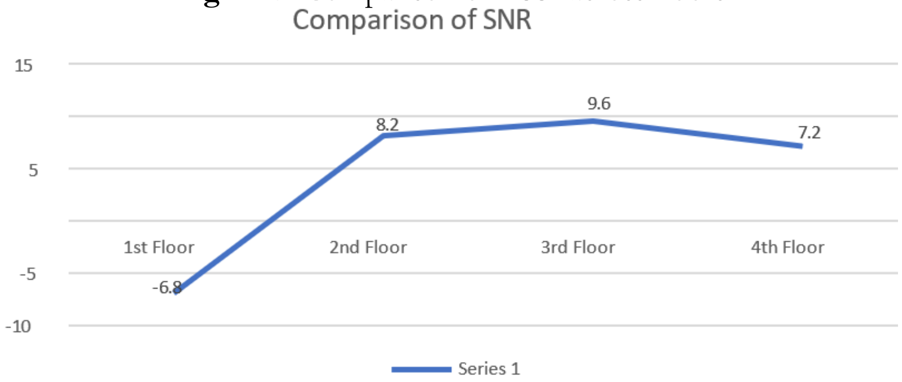

Figure 6. Comparison of SNR across floors

The comparison of RSSI (Received Signal Strength Indicator) values of four floors is shown in Figure 5. The worst signal was observed on the first floor with an RSSI value of −99 dBm, which shows that the signal has been severely weakened by obstructions in the interior and propagation loss. The RSSI was higher at −87.1 dBm on the 2nd floor, and the highest signal was at the 3rd floor level at −81.4 dBm. This improvement indicates that the transmission conditions and the number of obstructions on the third floor were better. The RSSI value, however, dropped a little on the fourth floor to −88.2 dBm, possibly because there were more structural obstructions and a greater vertical distance between the communication nodes. Overall, the RSSI results showed that the signal strength is dependent on floor position and environmental conditions, but the LoRa system could still communicate through all the tested floors.

The comparison of SNR (Signal-to-Noise Ratio) values over the same floors of the building is shown in Figure 6. The SNR on the 1st floor was negative, SNR = −6.8 dB, indicating poor signal quality and increased interference. Although this value is low, but LoRa communication was still possible because it can work under negative SNR conditions. The SNR was significantly improved to 8.2 dB on the 2nd floor, and it was the best at 9.6 dB on the 3rd floor, showing that stable and reliable communication can be achieved with less noise interference. The SNR on the fourth floor was found to be slightly lower at 7.2 dB, but it is still in an acceptable range for effective data transmission.

The joint analysis of RSSI and SNR shows that the proposed RFID-LoRa system demonstrates reliable operation in the multi-floor indoor environment. The quality of the signal was variable because of physical barriers and building construction; however, communication within the system was maintained throughout the experiments. These results show that LoRa is suitable for low-power indoor wireless communication applications in infrastructure-limited environments.

The most optimal indoor performance was recorded in the case of fewer obstructions when the transmitter and receiver are vertically aligned.

Outdoor Performance Evaluation: These tests were carried out in the open field in clear line-of-sight (LOS) conditions. The aim was to examine the degradation of the signal as distance increased and and environmental interference.

Table 3. Outdoor Test Results

Distance	Environment	RSSI (dBm)	SNR (dB)	Packet Status	Quality
100 m	Open field	−65.0	+5.0	Success	Excellent
300 m	Open field	−76.5	+0.5	Success	Good
500 m	Open field	−85.0	−2.5	Success	Fair
500 m	Tree line	−92.0	−5.8	Occasional drops	Weak

Figure 7. Drone view of campus test locations

Outdoor results demonstrate superior performance compared to indoor scenarios due to minimal structural attenuation.

Dashboard and Application Interface: The associated desktop software offers secure authentication, real-time monitoring, and cloud data storage and user management features, making it scalable and user-friendly in large deployments

Figure 8. Web-based dashboard showing RFID activity, RSSI, SNR, and attendance statistics.

Table 4 compares the proposed LoRa-based system with GSM/GPRS-based systems.

Feature	GSM/GPRS Systems	Proposed LoRa System
Internet dependency	Required	Not required
Power consumption	Moderate–High	Low (~0.6 W)
Operational cost	High	Minimal
Coverage	GSM-dependent	~1 km LOS
Infrastructure	SIM, towers	None

Comparative Analysis with Previous Studies: The suggested system has obvious cost, energy efficiency, and infrastructure independence benefits.

Interpretation of Findings: The experimental results confirm that the RFID–LoRa system.

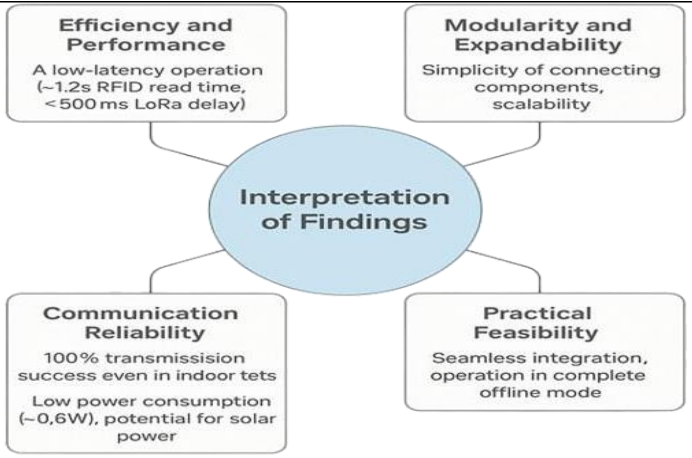

Figure 9. Summary interpretation of system performance

Operates reliably in fully offline environments
Provides low-latency, real-time data transmission
Maintains stable communication indoors and outdoors
Consumes minimal power, enabling long-term autonomous operation

Practical Implications: The modular design can also be easily expanded, can be easily expanded to include GPS, environmental sensors, or data logging modules. The efficient combination of RFID identification and LoRa communication proves that it is demonstrates the practical feasibility of the system for applications such as: attendance system, asset tracking, wildlife monitoring, and disaster-response communication.

Recommendations and Future Work:

The proposed RFID–LoRa communication system exhibited low power consumption, reliable and efficient performance in infrastructure-limited environments. Future work should focus on to further enhance the range and stability of the LoRa communication network in both indoor and outdoor environments with obstacles, by utilizing higher-gain antennas, node positioning, or mesh-based LoRa architectures. The use of Artificial Intelligence (AI) and machine learning techniques could also improve system performance by adapting transmission control, predicting signal quality, and detecting communication failures. Furthermore, the implementation of more robust security features like encryption, secure authentication methods, and intrusion detection systems should be considered to enhance data protection and the reliability of the system.

Scalability of the system could also be investigated in future work by testing with larger LoRa networks with multiple distinct nodes spread out across larger geographical areas. Long-term deployments can benefit from the use of advanced power-management options like solar charging and energy harvesting, as well as sleep-mode operation. Cloud integration can be extended via mobile apps, GPS tracking, and real-time alerting for applications such as disaster management, healthcare, smart agriculture, and more. More testing would be required in various environments, including high interference and dense urban settings, to better understand the practical capabilities and limitations of the proposed communication system and its robustness.

Conclusion:

The paper provides an overall experimental analysis of the suggested standalone RFID-LoRa-based data transmission system, its functionalities, and reliability in offline environments. The results show the system successfully manages to incorporate RFID data acquisition with long-range LoRa communication to facilitate real-time transfer without relying on GSM networks or Internet connectivity. Experiments have shown that the RFID module is accurate in detecting tags within 1.2 seconds, and the LoRa link has a 100% success rate and a response time of less than 500 milliseconds, making the system suitable for time-sensitive applications.

The environmental factors on signal propagation were shown by conducting tests in an indoor and outdoor setting. Indoor tests showed that building materials such as reinforced concrete walls had a great impact on RSSI, SNR values, and the highest performance was found when the transmitter and receiver were vertically aligned without much obstruction. Experiments in the open environment supported the benefits of LoRa in open spaces and at distances of several hundred meters, demonstrating superior signal quality over line-of-sight measurements in the over several hundred meters in open-air conditions.

An analysis of power consumption showed that the overall system consumes about 0.6 W, making it highly energy-efficient in power-constrained systems with battery or solar power sources. This proposed framework offers several advantages as compared to the traditional GSM-based solutions, such as independence of the infrastructure, reduced cost of operation, and convenient installation. Overall, the results indicate the technical feasibility and robustness of this RFID-LoRa self-driven communication system for future scalability and practical applications.

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