Proceedings of the 4th International Conference on Computing Innovation and Applied Physics
DOI: 10.54254/2753-8818/107/2025.22636

# *Application of LoRaWAN and Sigfox in Different Agricultural Scenarios*

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***Abstract:*** The deployment of two Low Power Wide Area Network (LPWAN) technologies, Sigfox and LoRaWAN, in several agricultural environments is investigated in this article. Learning how appropriate communication procedures like Sigfox and LoRaWAN are for various kinds of circumstances is absolutely important offered the growing use of Internet of Things (IoT) options in agriculture. The research provides a comparative analysis of these innovations concerning their energy use throughout several release contexts, consisting of improperly inhabited rural regions and intensively populated agricultural areas. One single design is produced to duplicate both scenarios and examine the energy economy and coverage of every technology using MATLAB. The simulation findings reveal that whilst Sigfox is a better fit for sparse situations where power conservation is crucial, LoRaWAN is better for dense websites demanding higher data rates and frequent interaction. The outcomes offer fascinating data for picking the suitable IoT interaction innovation for agriculture, for that reason, promoting more practical and effective resource management. The paper likewise highlights future directions of research study, including the integration of hybrid networks and investigation of performance steps besides power consumption.

***Keywords:*** Agriculture, Power Consumption, Sparse Environments, Dense Areas, MATLAB Simulation.

## 1. Introduction

By allowing data interchange and connection throughout a hitherto unthinkable spectrum of disciplines, the introduction of the Internet of Things (IoT) has actually altered how people interact with the real world in the modern-day age. Amongst a number of IOT communication procedures that have been developing recently due to their benefits in long-range interaction and energy economy, Low Power Wide Area Network (LPWAN) technologies such as LoRaWAN and Sigfox have actually drawn in a lot of interest. These protocols are the best options for several applications and especially assist in enhancing agricultural technology performance. For instance, a LoRaWAN irrigation controlling system helps farmers to specifically tape rains and other weather parameters, trigger flood risk alarms, and other alerts in modifications of water quality or overuse of phytosanitary items [1, 2], thus increasing the yield. However, the LoRaWAN protocol also has many shortcomings and

DOI: 10.54254/2753-8818/107/2025.22636

limitations [3], and it is necessary to compare LoRaWAN and Sigfox to differentiate between their respective situations

This work examines LoRaWAN and Sigfox applications in several contexts, mainly with regard to their coverage range and energy consumption conditions. A condition of smart agriculture has been simulated, and subsequently, the energy-saving and long-range transmitting capabilities of LoRaWAN and Sigfox have been measured. At last, we shall address which technology is more appropriate for any particular situation considering pragmatic factors.

## 2. Technologies overview

### 2.1. LoRaWAN technology

Designed particularly for Internet of Things applications, LoRaWAN is an LPWAN protocol. It enables long-distance wireless communication between devices, making it suitable for situations needing low power usage and extended battery life. The main features of LoRaWAN include:

- Long distance communication: LoRaWAN can achieve a transmitting distance of 2-5 kilometers in urban areas and no less than 15 kilometers in rural areas.
- Low power consumption: Devices of LoRaWAN consume a small amount of power in idle mode so this technology is applicable for battery-powered equipment.
- Massive connectivity: It’s ideal for large-scale deployments of IOT since it supports thousands of devices connect to a single gateway at once.

The LoRa network consists of four basic elements: End devices, gateways, network server and application server. The data is transmitted and processed throughout these components. Figure 1 shows the basic network architecture of LoRaWAN.

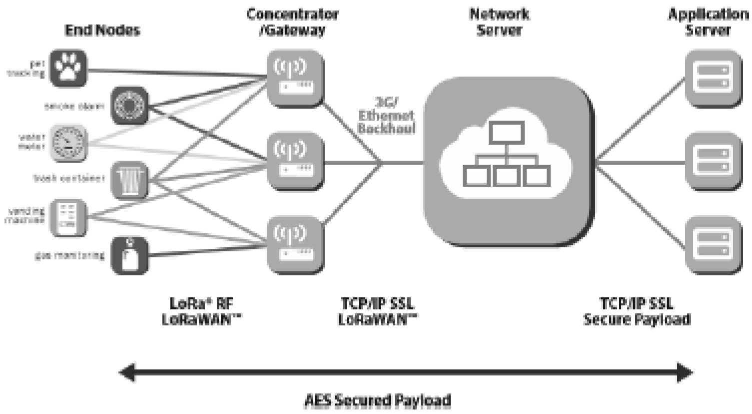


Figure 1: LoRaWAN network architecture [4]

Despite the advantageous mentioned before, LoRaWAN technology still has some limitations to be improved. Some challenges are listed below [4]:

- Only those applications that require low data rate (up to 27 Kbps) can use this.
- Limitations with the Duty Cycles in LoRa networks effectively limits the number of “messages” that can be sent during a specific time frame.
- It is not suited for real time applications that require lower latency.

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### 2.2. Sigfox technology

Sigfox 0G technology is a Low-Power Wide-Area (LPWA) networking protocol owned by UnaBiz. It is designed to connect sensors and devices securely at a low cost while saving the most energy to enable Massive IoT [5].

Sigfox Network Operators (SNOs) set up proprietary base stations that are equipped with cognitive software-defined radios, linking them to backend servers via an IP-based network. End devices communicate with these base stations using Binary Phase Shift Keying (BPSK) modulation within an ultra-narrow (100Hz) Sub-GHz ISM band carrier. Through the employment of Ultra-Narrowband (UNB) technology, Sigfox is able to use bandwidth efficiently and achieve very low noise levels, which leads to enhanced receiver sensitivity, extremely low power consumption, and cost-effective antenna designs [6]. However, this was realized on the price of a limitation of coverage range and a low transfer rate, along with a restricted message size. A Sigfox device may only transmit 36 seconds per hour [7]. The time on air is 6 sec [8] per package, and thus, the maximum is 6 messages per hour with a payload of 4, 8, or 12 bytes [7].

### 2.3. Conclusion

Former literature comparing parameters and features of LoRaWAN and Sigfox reveals several shortcomings on each of them, for instance, a low data rate or a limited coverage. As it's mentioned in section I, IOT technologies are playing a significant part in modern industries like agriculture, therefore a lower power consumption and a wider coverage range seems to be necessary for them for reasons such as to make a higher cost efficiency, to minimize the environmental impact and to realize remote monitoring. Hence there's a demand to explore specific domains where each technology is more suitable, which requires a classification based on their respective merits and drawbacks [9].

## 3. Proposed system and algorithms

### 3.1. Innovation and objectives

The primary innovation of this research is developing a unified model that can simulate both sparse and dense agricultural environments, accounting for varying node densities and communication frequencies. This model allows for a comprehensive comparison of LoRaWAN and Sigfox, focusing on power consumption and network efficiency under different deployment scenarios.

### 3.2. Unified model development

To develop a unified model encompassing both sparse and dense agricultural environments, we define several key parameters:

- *Node Density:* Represented by $N$, the number of nodes in the field.
- *Communication Frequency:* Showed for every node, the total number of communications per unit time.
- *Area Size:* Represented by $A$ (e.g., $A = L \times W$), where $L$ and $W$ are the length and width of the deployment area.
- *LoRaWAN and Sigfox Gateway Positions:* Defined in matrices $G_{\mathrm{LoRaWAN}}$ and $G_{\mathrm{Sigfox}}$, with specific coordinates for each gateway.
- *Transmission Power*: $P_{\mathrm{tx,LoRaWAN}}$ and $P_{\mathrm{tx,Sigfox}}$.
- *Idle Power*: $P_{\mathrm{idle,LoRaWAN}}$ and $P_{\mathrm{idle,Sigfox}}$.
- *Data Packet Size*: $S_{\mathrm{LoRaWAN}}$ and $S_{\mathrm{Sigfox}}$.

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- *Initial Collision Probability:* $\mathrm{CP_{LoRaWAN}}$ and $\mathrm{CP_{Sigfox}}$.

  The unified model uses these parameters to represent different scenarios:

- *Sparse Scenario:*

  Lower N and f.
  Lower $\mathrm{CP_{LoRaWAN}}$ and $\mathrm{CP_{Sigfox}}$.

- *Dense Scenario:*

  Higher N and f.
  Higher $\mathrm{CP_{LoRaWAN}}$ and $\mathrm{CP_{Sigfox}}$.
  Model Formulation:
  The model calculates electricity usage with the following formulae:

- Transmission *Power for LoRaWAN*:

$$[\mathrm{P_{transmission,\ LoRaWAN}} = \mathrm{N} \times \mathrm{f} \times \mathrm{S_{LoRaWAN}} \times \mathrm{P_{tx,LoRaWAN}} \times (1 + \mathrm{CP_{LoRaWAN}} \times \mathrm{N})]$$

- Transmission *Power for Sigfox*:

$$[\mathrm{P_{transmission,\ Sigfox}} = \mathrm{N} \times \mathrm{f} \times \mathrm{S_{Sigfox}} \times \mathrm{P_{tx,Sigfox}} \times \left(1 + \mathrm{CP_{Sigfox}} \times \mathrm{N}\right)]$$

- *Idle* Power *Consumption*:

$$[\mathrm{P_{idle,\ LoRaWAN}} = \left(1 - \frac{\mathrm{N} \times \mathrm{f}}{\mathrm{T}}\right) \times \mathrm{P_{idle,LoRaWAN}}]$$

$$[\mathrm{P_{idle,\ Sigfox}} = \left(1 - \frac{\mathrm{N} \times \mathrm{f}}{\mathrm{T}}\right) \times \mathrm{P_{idle,Sigfox}}]$$

  T : the total simulation time.

- *Total* Power *Consumption*:

$$[\mathrm{P_{total,\ LoRaWAN}} = \mathrm{P_{transmission,\ LoRaWAN}} + \mathrm{P_{idle,\ LoRaWAN}}]$$

$$[\mathrm{P_{total,\ Sigfox}} = \mathrm{P_{transmission,\ Sigfox}} + \mathrm{P_{idle,\ Sigfox}}]$$

This standard model lets a thorough comparison of the LoRaWAN and Sigfox technologies by supporting the modeling of small, intense agricultural scenarios in a single framework.

### 3.3. Suitability analysis for LoRaWAN

LoRaWAN is best suited for settings needing flexible data transport and greater data rates[3]. Nodes often broadcast data in packed environments, such greenhouses or clustered fields. Adaptive Data Transfer rate (ADR) and channel hopping features of LoRaWAN help it to manage significant network loads efficiently [9.10]. Furthermore, its encouragement of two-way communication and several classes (class A, B, C) enables more intricate interactions including real-time irrigation system or soil condition monitoring.

### 3.4. Suitability analysis for Sigfox

Sigfox is perfect for sparse, large-area agricultural contexts where nodes are scattered with no need for regular data transfer since it is suitable for ultra-low power consumption and fewer data transmission requirements. Narrowband technology of Sigfox guarantees less interference [9]. While

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establishing and maintaining more sophisticated network setups (like LoRaWAN) there may be difficult in distant places where its basic and low-cost network infrastructure offers benefits.

### 3.5. Solution design and optimization

The simulation focuses on maximizing the use of gateways and the arrangement of communication settings to lower power consumption to the utmost and guarantee consistent data delivery. For LoRaWAN, this involves fine-tuning ADR settings and balancing the number of gateways to adapt coverage and network load. For Sigfox, the focus will be on maximizing the coverage area per gateway and choosing the minimum frequency of data transmissions to conserve power.

## 4. Analysis and simulation results

### 4.1. SExperimental design and simulation parameters

We use MATLAB to build simulations and using it to evaluate the applications of LoRaWAN and Sigfox in different agricultural scenarios. We modeled two typical scenarios: sparsely populated areas (Sparse Area for short) and densely populated areas (Dense Area for short). We use MATLAB simulations to calculate the node coverage and average power consumption for each scenario. Finally, analyzing the power consumption of the two technologies under different node densities and communication frequencies.

- *Sparse Scenario:*

The position represents agricultural environments such as large agricultural land, pastures and remote agricultural land, where nodes (sensors and equipment) are distributed over large areas. The communication frequency of the nodes is usually low due to the infrequent data transmission requirements.

1) Number of Nodes (N): 50 nodes.
2) Communication Frequency (f): 2 communications per hour.
3) Initial Collision Probability ($CP_{LoRaWAN}$): 0.005 for LoRaWAN.
4) Initial Collision Probability ($CP_{Sigfox}$): 0.001 for Sigfox.

- *Dense* Scenario:

The scenario represents small, high-density agricultural areas, such as greenhouses, vertical farms, or dense orchards, where the nodes are tightly packed and require frequent communication. The initial probability of collision in both techniques is high due to the increased probability of packet collision in high-density environments.

1) Number of Nodes (N): 150 nodes.
2) Communication Frequency (f): 10 communications per hour.
3) Initial Collision Probability ($CP_{LoRaWAN}$): 0.01 for LoRaWAN.
4) Initial Collision Probability ($CP_{Sigfox}$): 0.02 for Sigfox.

The model for each scenario will include parameters such as node location, gateway arrangement, communication range, transmission power, idle power, packet size, and probability of network conflict.Key parameters such as transmission power ($P_{tx,LoRaWAN}$= 100 mW, $P_{tx,Sigfox}$= 160 mW), idle power ($P_{idle,LoRaWAN}$ = 0.1 mW, $P_{idle,Sigfox}$ = 0.05 mW), and data packet size ($S_{LoRaWAN}$ = 50 bytes,$S_{Sigfox}$ = 12 bytes) will keep constant during the simulation to ensure the reliability of the experimental results.

### 4.2. Performance metrics evaluation

Performance is evaluated mainly by the average power consumption of each node, which will include transmission power during active communication and idle power when nodes are in standby mode. Furthermore taken under consideration might be packet transmission success rate, average latency, and network throughput to offer a more complete picture of network performance.

### 4.3. Results analysis

Examining the simulation results helps one to ascertain the best performance of every technology under various circumstances:

- *Sparse Areas:*

  *Some nodes are not covered by LoRaWAN. Please adjust the LoRaWAN gateway settings.*
  *Some nodes are not covered by Sigfox. Please adjust the Sigfox gateway settings.*
  *Average energy consumption for LoRaWAN: 1.37 mW*
  *Average energy consumption for Sigfox: 0.76 mW*
  *The average energy consumption for Sigfox is lower than LoRaWAN.*

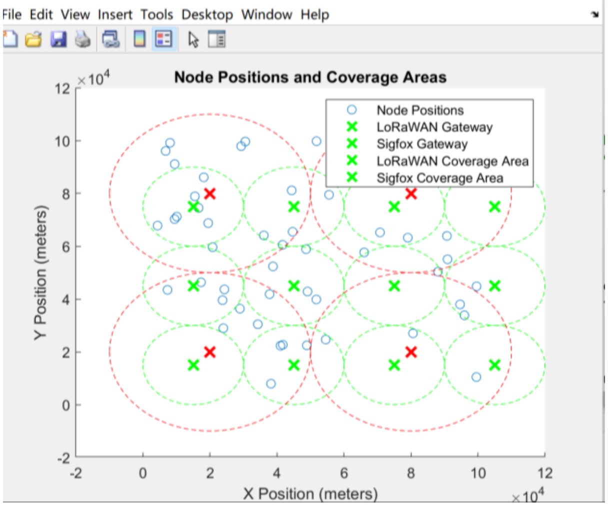


Figure 2: Comparison of coverage areas in sparse areas

Figure 2 presents the coverage area and coverage rate of the two technologies in a sparse area, where the red signs represent Sigfox and green ones represent LoRaWAN technology. Low data transmission frequency and low collision probability, according to the investigation, help Sigfox to consume less power. Sigfox is, for that reason, much better appropriate for sparse agricultural environments where nodes are distributed extensively and require long-lasting operation.

- *Dense Areas:*

  *Some nodes are not covered by LoRaWAN. Please adjust the LoRaWAN gateway settings.*
  *Some nodes are not covered by Sigfox. Please adjust the Sigfox gateway settings.*
  *Average energy consumption for LoRaWAN: 68.30 mW*
  *Average energy consumption for Sigfox: 110.78 mW*
  *The average energy consumption for LoRaWAN is lower than Sigfox.*

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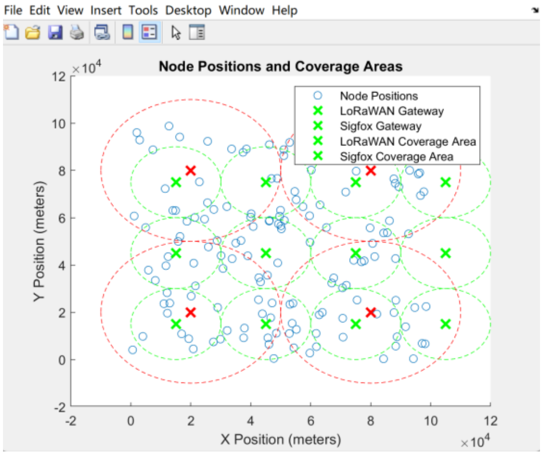

Figure 3: Comparison of coverage areas in dense areas

As it is shown in Figure 3, with strong channel hopping, data adaption speeds, and handling of high data transmission frequencies and collision rates, LoRaWAN is projected to excel in a congested environment. For settings needing frequent data updates and real-time communications, LoRaWAN is thus more practical.

A comparative examination of these findings will confirm that Sigfox is better suited for sparse agricultural situations while LoRaWAN is better suited for dense surroundings.

## 5. Discussion

The several uses of LoRa and Sigfox in agriculture were investigated in this work. While other studies have explored the various differences between LoRa and Sigfox in the physical and MAC layers, they have not analyzed and simulated deployments of LoRa and Sigfox in specific scenarios. In our study, the agricultural applicability of lora and sigfox is determined by calculating the average power consumption and node coverage in sparse and dense regions. The simulation results show that sigfox is more suitable for sparse agriculture areas, while lora is suitable for dense agriculture areas.

## 6. Suggestions for future work

This study explored the selection of lora and sigfox based on energy consumption in different agricultural scenarios. However, long-term studies may be needed to analyze whether the selection of LoRa and Sigfox should be based on other aspects, such as data security and stability.

### 6.1. Data processing

Sigfox and LoRa also differ in terms of data processing [9,11]. Sigfox uses the cloud data processing model, and the device sends the data to the Sigfox cloud platform for processing and analysis. This makes data processing simpler and more efficient, but can also lead to issues with data security and privacy. LoRa supports local data processing and storage, and data processing and analysis can be performed on the device side, improving data security and privacy protection capabilities.

### 6.2. Network coverage

Both Sigfox and LoRa have extensive network coverage that can cover urban, rural and remote areas. However, in practical applications, the coverage of the LoRa network may be affected by many factors, such as antenna height, transmitting power, and obstacles [3]. it is necessary to plan the

DOI: 10.54254/2753-8818/107/2025.22636

network layout and equipment configuration reasonably. In contrast, Sigfox network coverage is more stable and reliable.

We will study these later by simulating several different sets of special scenarios, controlling for other factors

## 7. Conclusion

Through the introduction and comparative analysis of SigFox and LoRa two mainstream LPWA communication technologies, respective characteristics and limitations could be shown. For applications that require large areas of coverage, such as smart cities, agriculture, etc., LoRa may be a better choice because it has a longer communication distance and higher openness.

For some applications that require very strict power consumption, such as smart homes, health monitoring, etc., SigFox may be a better choice because of its lower transmission power consumption.

In actual applications, the selection of LoRa and Sigfox should base on specific application scenarios, requirements, complexity and diversity of them, and take appropriate measures to ensure the security and privacy of data.

As the technology continues to develop and improve, LPWA communication technology will play an even more important role in the future of the Internet of Things.

## Author contributions

Yifei Wang is the first author of this work, while Yijin Zhong and Yuchen Wu contributed equally as co-second authors.

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