Implementation of the Lora System for Temperature and Humidity Monitoring in POLBAN Classrooms

[1]Muhammad Arman*), [1]Muhammad Anda Falahuddin & [1]Susilawati

[1]Jurusan Teknik Refrigerasi dan Tata Udara, Politeknik Negeri Bandung

*) *akangarman@polban.ac.id*

Abstract

The need for temperature and humidity monitoring in classrooms, is very important for the purpose of comfortable teaching and learning processes, especially after the Covid-19 pandemic conditions. At Politeknik Negeri Bandung (POLBAN), there are more than a hundred classrooms. The rooms are spread over several buildings; therefore, the process of monitoring temperature and humidity will be difficult if it is done using a cable (wireline). In this study, a temperature and humidity monitoring system for classrooms at POLBAN will be made using LoRa wireless architecture. In several classrooms, temperature and humidity sensors will be installed combined with a LoRa sending system. There are conditioned room and unconditioned room. On the monitoring center, a LoRa receiver system is also installed. Data from each classroom, will wirelessly be sent to the monitoring center, for further processing. In the implementation stage, one gateway, 4 endnotes with DHT11 sensor are used. Testing process is carried out by verifying and monitoring performance in 4 classrooms and in open spaces. Results of verifying show a difference of 2℃ and 1% of the RH value with a reference measuring instrument. There is no difference in temperature and RH values at the endnode and gateway.

Keywords: *LoRa, temperature, humidity, classroom*.

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Introduction

The important thing in implementing radio systems in data communication starts from the design stage. Similar to LoRa, this system also requires several considerations. In particular, it is important to take into account what data is communicated. Moreover, the location to be monitored is an essential matter that is specifically discussed in this paper, in addition to things that generally must be considered in using the LoRA system. A LoRaWAN network consists of multiple end nodes that communicate with one or more gateways [1]. Two important parts of LoRa systems are the physical layer and MAC layer protocol and network system architecture, called LoRaWAN. Physical Layer is proprietary of Semtech while the Network system architecture is developed by LoRa Alliance [2]. It is important to monitor the temperature and humidity of classrooms at Politeknik Negeri Bandung as the offline classes had begun in early May 2022, after the pandemic period. ASHRAE has issued guidelines and instructions regarding the protection of educational facilities, including by paying attention to the following aspects: ventilation, filtration, air cleaning, and energy saving. Classroom air comfort factor follows ASHRAE 55-1992 standard [3],[4],[5]. This research explores the implementation of LoRa in monitoring temperature and humidity in classrooms at POLBAN. The main parameters discussed in this paper are the quality of the resulting monitoring data.

Literature Review

LoRa (Long Range) which was developed by Semtech, is a proprietary spread modulation technique [6]. LoRa, with its low-power operation, long and wide range, relatively low cost, and endurance to external interference, can be utilized to support a wide range of Internet of Things (IoT) applications. Examples of such applications are the environmental monitoring of remote areas, localization, and industrial applications [7], room and building conditions. LoRa Systems is described in figure 1.

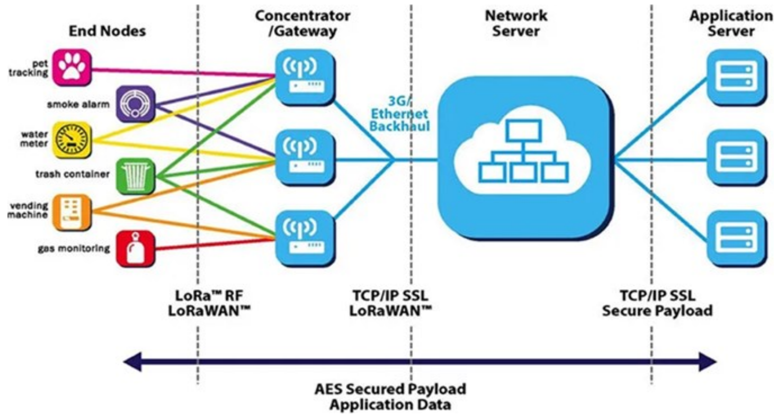


Figure 1. LoRa system (www.semtech.com)

LoRA system starts from end-nodes where sensors, as well as the data or status of equipment such as vending machine, smoke alarms, and water meters, is intended to be monitored. This section is commonly referred to as end-nodes. Basically, there is almost no limit to the number of end-nodes in this system, but functional requirements and the amount of data to be sent should be taken into account. Data from the end-nodes is then sent to the gateway or commonly referred to as the concentrator. The concentrator can handle several end-nodes, depending on the distance, and the position of the end-nodes. Unobstructed open space provides the opportunity for longer data transmission distances between end-nodes and gateways. To maintain data reliability, several gateways can be installed that handle several end-nodes. With 3G or ethernet backhaul support, data from gateways can then be sent to the network server. For more applicable purposes, data can also be forwarded to the application server. This is the reason why LoRa is called the backbone of IoT [8].

LoRa uses license-free sub-gigahertz radio frequency bands. Depending on the region, the central frequency may be the 433MHz (Europe and Asia), the 868MHz (Europe), or the 915 MHz (Australia and North America) [1],[9],[2],[7]. Indonesia uses the 920-923MHz frequency.

With LoRa's capabilities, it is possible to vary the physical quantities that can be measured, such as temperature, humidity, pressure, and discharge. Other physical quantities can be transmitted if there are appropriate sensors and signal conditioners that can communicate with the LoRa module. Machine state is also a condition that can be sent via LoRa.

One of LoRa's limitations includes network coverage [10]. Unlike conventional time-division protocols, in LoRaWAN, the gateway cannot always acknowledge all transmissions due to the extremely low radio duty cycle [7]. This results in reliability issues. Issues related to application data should be taken into consideration since data for applications must always be displayed while the data sent has a certain cycle. In this case, the important issue is data synchronization. In this connection, the network capacity must be considered by looking at inputs taken from the packet Time on Air (ToA) or transmission time for the various data rate and the data rate distribution[9]. On the other hand, the fading-channel environment is also a serious consideration of LoRa [11]. Other things that should be taken into account in implementing LoRa are the time shifts on the device, data travel time from end-nodes to gateway(which is different for each location), battery life (which depends on the time and data transmission scenario), and the number of available gateways (including communication and scenarios between gateways). For confidential data, security issues are also a concern.

LoRa modules fall under the category of a physical layer, but they are easy to configure with higher layers. This allows LoRa to be integrated and to become interoperable with the existing network architectures. This technology can minimize interference so that network efficiency increases, as can be seen in figure 2.

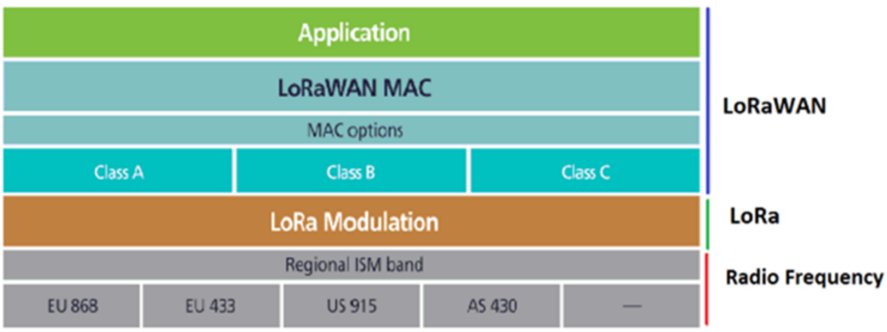


Figure 2. LoRa Protocol Stack [12]

Preamble	PHDR	PHDR_CRC	PHY_Payload	CRC

Uplink PHY Structure

Preamble	PHDR	PHDR_CRC	PHY_Payload

Downlink PHY Structure

MHDR	MAC Payload	MIC

PHY Payload Structure

FHDR	Fport	FRM_Payload

MAC Payload Structure

DevAddr	FCtrl	FCnt	FOpts

Frame Header Structure

Figure 3. Package Structure of LoRaWAN

Incorporated with LoRa Module as a physical layer, the MAC (Medium Access Control) layer, supports device registration, bi-directional communication, end-to-end security, synchronization, and localization services. An end-device in LoRaWAN can belong to one of the following three classes, which is class A, B and C respectively. These classes are different in terms of their communication scenarios, and functionalities. The package structure of LoRaWan can be seen in figure 3 [13].

Practically the communication process starts from the end-nodes to the gateway through the indoor line [14]. It is followed by communication outside the room and then back into the room. The end-nodes where the sensors are installed are in the space where the walls in the room can be an attenuator for the transmission signal. In outdoor communication, outdoor conditions can also be affected by temperature, humidity, regional contours, and barriers between them. When receiving at the gateways, the position of the gateways is usually in the central monitoring room, which may be blocked by thick walls.

In regard to utilizing Lora, the Government regulations, which appear on the attachment of Regulation of the Director General of Resources and Equipment of Post and Information Technology Number 3 in 2019 on Technical Requirements for Low Power Wide Area Telecommunications Equipment and/or Devices, should be followed. Based The details are stated in chapter 1, verses 5 and 6 [15]: Narrowband LPWA Non-cellular Telecommunication Equipment and/or Equipment is a single channel Non-cellular LPWA Telecommunication Equipment and/or Equipment with a maximum channel bandwidth of 200 kHz radio frequency and a maximum sub-channel bandwidth of 600 Hz, and Non-cellular wideband LPWA Telecommunication Equipment and/or Equipment are non-cellular LPWA equipment with a radio frequency channel width of 250 kHz at most.

(a) (b)

Figure 4. Test scheme in (a) the lecture hall (8–32 meter distance); (b) open space (25–100 meter distance)

Research Method

This research method is based on literature studies from previous studies, technical specifications from LoRa, and government regulations, which are then combined to obtain a comprehensive picture of design considerations to implement LoRa in Polban's classrooms. During the implementation process, a Lora system was created which consisted of one gateway and four endnodes. Data verification is done by comparing the measurement results to a reference measuring instrument. The performance test is carried out by placing 4 endnodes in several classrooms with different distances. The shortest test distance are 8 meter, while the longest distance are 32 meter. Tests were also carried out in open space starting of 25 meter to 100 meter. The test scheme in the lecture hall is carried out in the U Polban building as shown in figure 4.

Discussion

In general, the technical aspect of concern is the reliability of the data transmitted and received. This aspect becomes very important in the process of monitoring the desired physical quantity. The temperature range in Bandung is 20 – 30 degree Celsius, while the humidity is between 70 – 95 % (https://www.bmkg.go.id/cuaca/prakiraan-cuaca-indonesia.bmkg). These physical quantities force the sensor of temperature and humidity with the medium accuracy of at least 5% error of reading. With this accuracy, the reliability of data can be accounted for. Temperature and humidity variation and speed of change of this parameter imply that the sensor should have good repeatability. During the rainy season, the speed of change rises as the environmental conditions change, caused by the rain.

In the initial implementation of LoRa, the need for data monitoring will be paramount. Furthermore, this monitoring process can be developed by adding parameters such as air quality and air speed, and adding end-nodes due to the number of classrooms, the respective gateways should also be considered in addition to fulfilling data reliability. For further development, the improvement of the air conditioning control function can be integrated with this LoRa. There are some examples of extending the LoRa capability for a smart energy campus [14].

For end-nodes powered by battery, battery lifetime becomes the consideration due to the end- node and gateway working scenario, the number of sending data, repeated sequence, the number of nodes, and the sleep modes [16]. For the gateways as the location is in the central monitoring rooms, battery powered for the power supply, does not generate any issues. For end-nodes located in classrooms, the battery does not generate a major problem.

LoRaWan has several advantages. Wide coverage is one of the paramount strong points for LoRaWan mass deployments [17]. Its advantages also include scalability [1], capacity (with its high number of parameters), a high variety of parameter characteristics to be monitored, and the number of end-nodes. Therefore, LoRa is highly potential to be developed. Moreover, in terms of security, it is not considered a threat in this application as the current data to be monitored is temperature and humidity.

Furthermore, there are also a couple of points for consideration, namely the ecosystem maturity and cost. In regards to the ecosystem maturity, Polban's environment could be considered as a mature environment, as the building and campus development is relatively slow. Related to the cost, it is essential to think about the total investment cost for monitoring, operating, and maintenance costs. It can be deducted in the future based on the buildings' energy savings.

Specific for POLBAN, it can be seen on the map in figure 5.

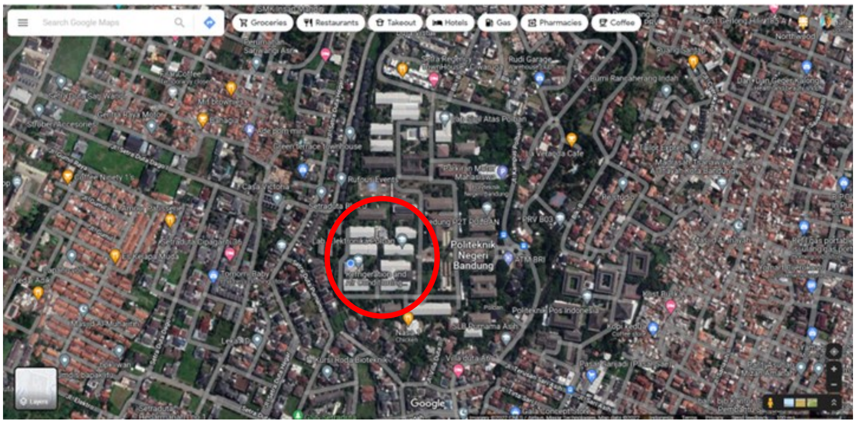


Figure 5. Maps of Polban (satellite view), red circle, relative to their surroundings

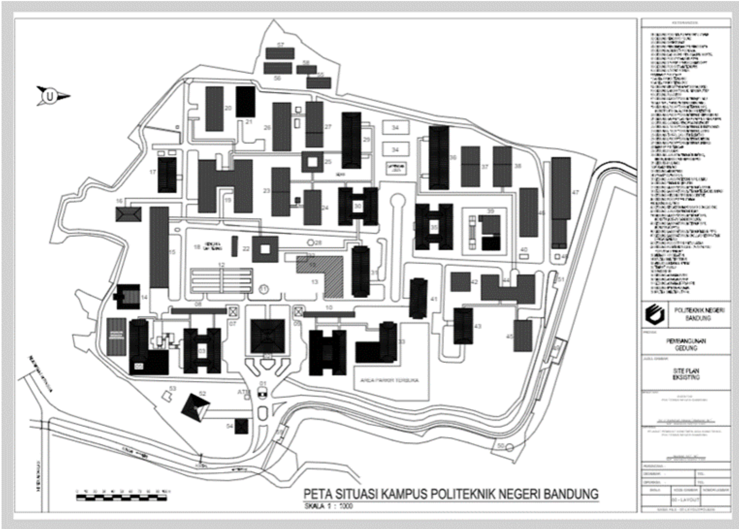


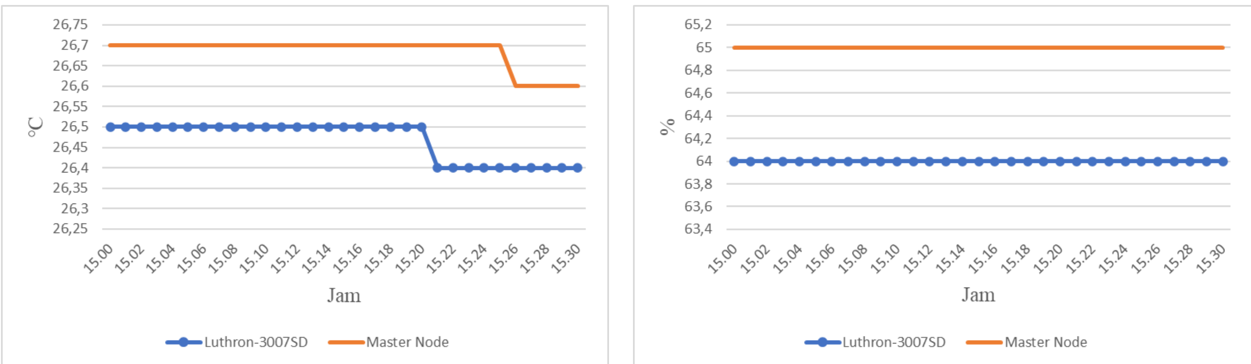
Figure 6. Campus Situation Map of Polban

Polban is located within an urban area. There is only a slight variation in contours. The structure of the buildings is dominated by three-story buildings with thick walls. Meanwhile, the distance between the buildings varies from 50 to 200 meters. In detail, the locations of Polban's buildings can be seen in figure 6.

The complete details of facilities in Polban can be seen in table 1.

Tabel 1. Room Room and facility in Polban

No	Facility Description	Area (m^2)	Number of Room
1	Campus Area	246,269	
2	Library Area	1,639.93	
3	Laboratories Area	11,399.67	119
4	Studio Area	724.92	8
5	Classroom Area	6,787.40	105
6	Lecturer Room Area	2,935.14	74
7	Office and Administration Area	5,568.66	
8	Dormitory Area	3,100	



(a) (b)

Figure 7. Verification result for temperature and humidity

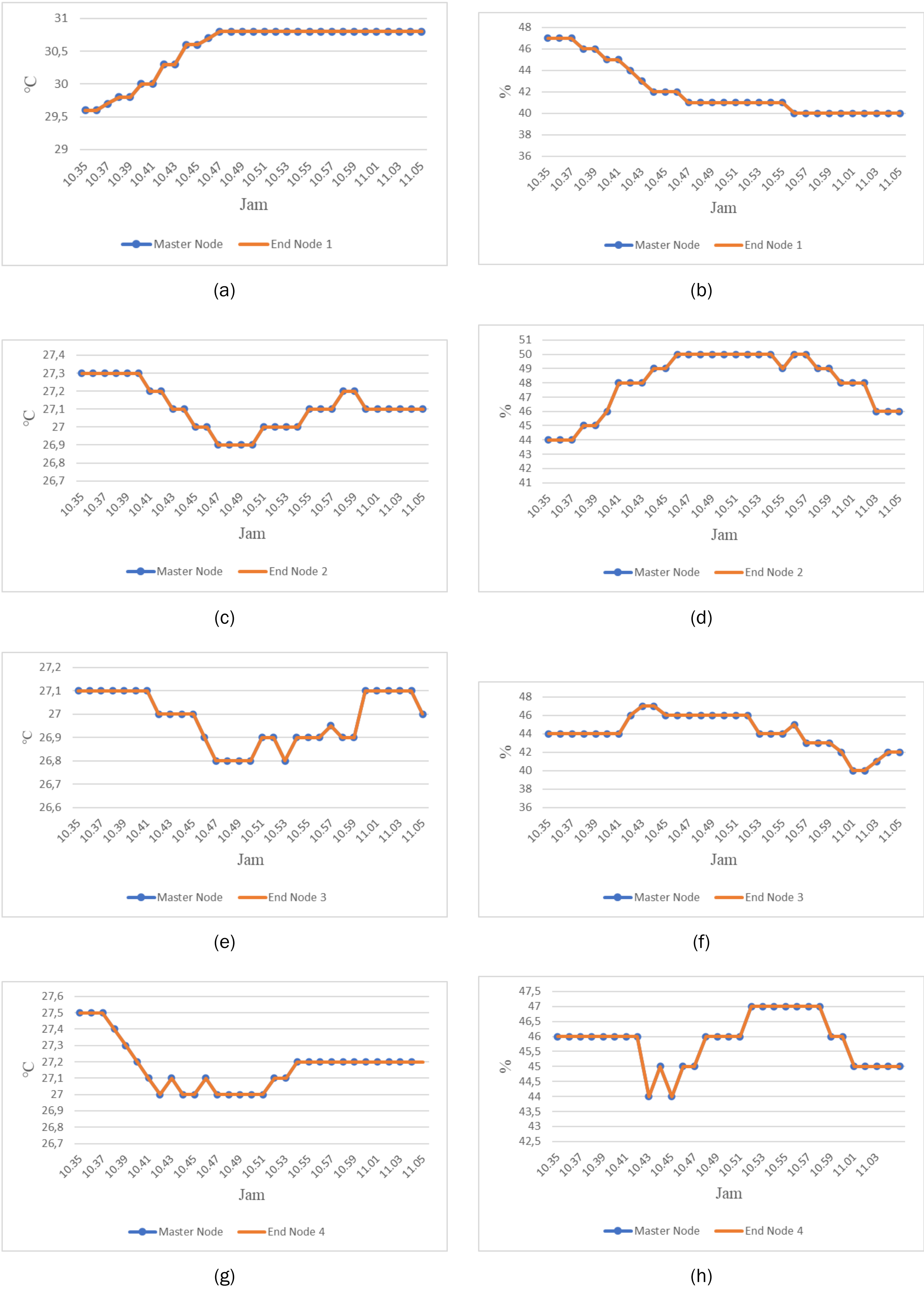


Figure 8. Verification result for temperature and humidity

Key Decision criteria and recommendations in designing for LoRa implementation in Polban,

a. LoRa frequency to be used as it should follow the government regulations.
b. The number of buildings, which should be prioritized during the implementation stage, due to the density of class activities, saving energy potential.
c. The number and size of the rooms to be monitored, as it will contribute to the number of end-node and gateways to be provided.
d. Location of the rooms relatively to central monitoring room, to tide over data transmission problems.
e. Purpose of Monitoring and monitoring scenarios.

Furthermore, the results of the implementation are shown by the verification and performance of the system made. The verification results showed no significant difference to the reference instrument. The required error value must be less than 5% to be met in systems made for temperature and humidity measurements (figure 7).

The results of temperature and humidity monitoring in the four classrooms, showed no difference between the readings in the classrooms (endnodes) when compared to the gateways (masted node), as shown in figure 8.

Conclusion

Designing a temperature and humidity monitoring application in Polban campus lecture hall by using the LoRa architecture, requires several things to consider namely: the LoRa frequency to be used, the monitoring objectives and scenarios to be carried out, the determination of the monitoring center room relative to the class location, available electricity sources, as well as operational and maintenance investment costs.

The results of the implementation of the temperature and humidity monitoring system with LoRa in the classroom reveal opportunities for wider application in other lecture rooms because the reliability of the system that has been created, namely the similarity between the endnode and gateway values, shows relevant results. The error value of 2 degrees Celsius for temperature and 1% for humidity still meets the required requirements.

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