LoRaWAN: Solution for Monitoring Differential Pressure Room in Pharmaceutical Industry

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Abstract: The air conditioning system is a process continuous air control of air temperature, air humidity, air cleanliness, air quality, speed indoor air, air distribution evenly throughout the room as well control the noise that can caused by the air conditioning equipment itself according to the needs and conditions wanted especially in drug factories. In This research we use IoT Technologi to provide system to monitoring Differential Pressure room in Pharmaceutical room based on LoRaWAN. LoRaWAN is one of the LPWAN technologies which also provides a wide range of coverage, low power, and low cost in the implementation. The result of this study are very satisfactory, it can be seen that the results of the LoRaWAN implementation are very good with an indication of the worst RSSI value of -91 dbm and an error value on the Differential Pressure sensor device of 0.65 Pascal.

Keywords: LoRaWAN, pharmaceutical industry, monitoring, internet of things, IoT, Differential Pressure.

1. INTRODUCTION

The drug production process certainly requires supervision to maintain the quality of the drugs produced. The production must be carried out by following established procedures and complying with the regulation of the Good Manufacturing Practices (GMP) standard[1]. Moreover, the air in the room is kept clean and not contaminated by particles or microorganisms from outside To maintain air in the pharmaceutical industry room, an air conditioning system is needed.

The air conditioning system is a process continuous air control of air temperature, air humidity, air cleanliness, air quality, speed indoor air, air distribution evenly throughout the room as well control the noise that can caused by the air conditioning equipment itself according to the needs and conditions wanted. Air management ensures the drug production process quality to produce best quality drugs, good environmental protection of materials and safe exhaust air as well as convenience for the officers[2].

To prevent contamination and cross-contamination, the industry requires a measuring device called differential pressure[3]. According to WHO Guidelines on Heating, Ventilation and Air Conditioning System to prevent room Pressure, 10-15 pascal of differential pressure is maintained between manufacturing and surrounding areas. the aseptic area should always be highly pressured than the non aseptic area and air flow should be always from the aseptic to non aseptic area. this pressure differential is maintained by HVAC[4].

The pressure different of the room in the production room must be well-managed. When the pressure of the production room do not match the predetermined set point, the production must be stopped and reported to the technician and then waiting for a repair response from the technician. This makes the production process stop and reduces the effectiveness and efficiency of the drug manufacturing process. To overcome this problem, an Internet of Things (IoT)-based monitoring system is needed to monitor the differential pressure value in the drug production room so that the condition of the room complies with the predetermined set point. The IoT system will include certain connectivity technologies to send data from the sensor to the internet cloud. The decent connectivity type to be used in IoT is from the low power and wide area (LPWAN) technology[5].

One of the popular LPWAN types in IoT is LoRa/LoRaWAN. The advantages of this technology are low battery consumption, a small data rate so it does not require large bandwidth, and a wide coverage area of about 5 km in urban areas and about 15 km in rural areas. LoRaWAN also uses the ISM Band for (Industrial, Scientific, and Medical) frequency spectrum, which is an unlicensed frequency, making this technology cost-effective for the implementation process[6][7].

This research aims to study the implementation of the Differential Pressure monitoring system in a pharmaceutical factory using LoRaWAN. This paper consists of the introduction in Section I, literature review in Section II, research method in Section III, result and discuss covered in Section IV, and finally, the conclusion in Section V.

2. LITERATURE REVIEW

A. LoRaWAN Overview

LoRa/LoRaWAN is one of the LPWAN technologies that has been popularly adopted in massive IoT use cases these days. Like other LPWAN technologies, it offers low energy use, wide area coverage, and low operational cost[8]. Meanwhile, LoRa has unique benefits: it uses an unlicensed frequency spectrum (while Sigfox does) and it is designed for the open standard network (while Sigfox is a proprietary network). The characteristics of some LPWAN technologies are described in Fig. 1 below[9].

From the architectural view, LoRa works as a common IoT system. An end-to-end LoRa system comprises device, network, platform, and application. The device can be sensors that are utilized to measure phenomenons. LoRa gateway will send the data through internet access (network) to reach the network server (platform). Then the data/information can be visualized in an application. Fig. 2 displayed the LoRaWAN basic architecture[10].

LPWA	Licensed spectrum		Unlicensed spectrum		
	LTE-M	NB-IoT	LoRa	sigfox	INGENU
Spectrum band	450 MHz – 3.5 GHz Licensed		400/800/900 MHz ISM	900 MHz ISM	2,400 MHz ISM
Coverage radius	1 – 5 km (urban) 15 km (rural)		2 – 5 km (urban) 15 km (rural)	3 – 10 km (urban) 30 – 50 km (rural)	1 – 3 km (urban) 5 – 10 km (rural)
Devices per access point	'X0,000s *10x that of LTE networks*		'X00,000s *100x that of LTE networks*		
Throughput[1]	< 1Mbps	<250 kbps	0.3-50 kbps	100 bps	8 bps – 8 kbps
Battery life	>10 years *vs. day(s) for smart-phones (thanks to improved power consumption of user devices)*				
Module cost[2]	$8 *vs. ~$25 for M2M modules*	$7 *vs. ~$25 for M2M modules*	$7 → $2-3 *vs. ~$25 for M2M modules*		
Use cases	• Applications sending short, sporadic messages, where latency is not crucial • Applications requiring low TOC and long battery life				

Fig. 1. LPWAN characteristics

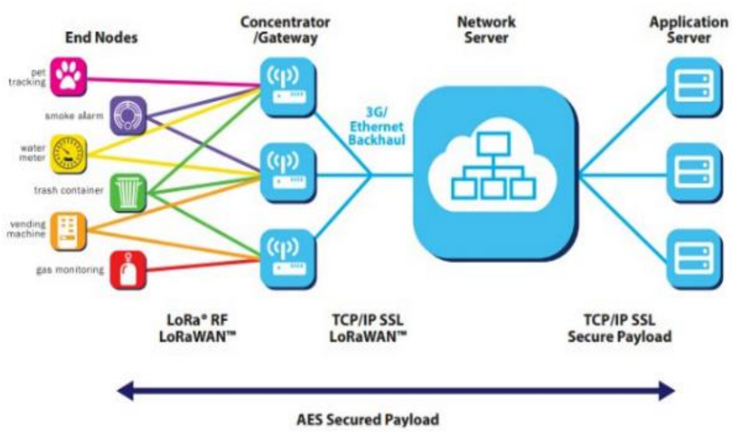

Fig. 2. LoRaWAN architecture

Based on Figure 4, LoRaWAN has 4 important components, namely End Nodes, Gateway, Network Server and Application Server. In LoRaWAN, some important parameters need to be taken care of to implement the system optimally[10]:

1) Bandwidth : Bandwidth is the width of the frequency in the transmission band. Higher bandwidths provide higher data rates (resulting in shorter transmission times), but lower sensitivity (due to additional noise integration). A lower bandwidth has high sensitivity, but a lower data rate.
2) Spreading Factor : The spreading factor can be defined as the number of bits in 1 symbol. A higher spreading factor improves signal to noise ratio (SNR), sensitivity, and range, but also increases packet airtime. Spreading Factor values in LoRa consist of SF7 to SF12, each number in SF represents the modulated chips per symbol. Spreading spectrum uses code division multiple access (CDMA) technique.
3) Duty Cycle : Coding rate refers to the number of bits that contain data or information to be transmitted. The coding rate is formulated to handle packet error rate (PER) due to interference.
4) Receive Signal Strength Indicator : RSSI is a parameter that shows the receiving power of all signals in the channel frequency band used. In LoRaWAN, an RSSI in the range of -90 to -100 is practically acceptable (smaller is better). Table I shows the RSSI level standard.

Table 1 . RSSI level standard [11]

RSSI (dBm)	Information
-30 s/d -60	Very strong. Transmitter and receiver distance is very close
-60 s/d -90.	Very good. Close coverage
-90 s/d -105	Good. There are some data that are not accepted.
-105 s/d -115	Bad. Can accept but often drop-out
-115 s/d -120	Very bad. Weak signal data is often lost

B. LoRaWAN layers

There are two terms that need to distinguish, namely LoRa and LoRaWAN. For the term LoRa, it works at the physical layer (PHY), wireless modulation is used in long-distance communications. While LoRaWAN works on an open network protocol that provides secure two-way communication, mobility, and localization services that are standardized and managed by the LoRa Alliance. Fig. 3 depicts the LoRaWAN layer [12].

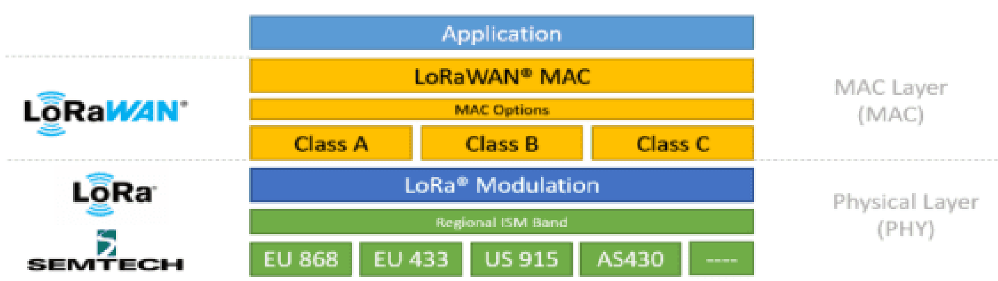

Fig. 3. LoRaWAN Layers

It can be seen in Figure 3, the physical layer is the layer where LoRa works, such as what frequency is used, and what modulation is used. LoRaWAN itself works at the MAC Layer. There are 3 classes, each with its advantages and disadvantages.

C. LoRaWAN Network Class

LoRaWAN has different classes can see in figure 4 of end devices to meet various needs in its application, where the main requirement factor is battery life and communication latency from the network server to the gateway to the device (downlink)[7].

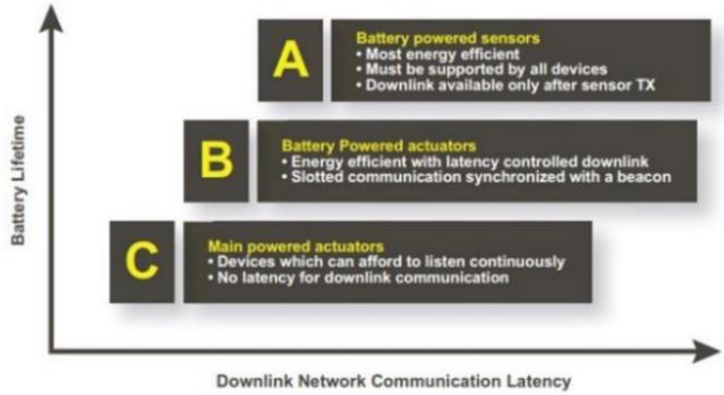

Fig. 4. Class comparison on LoraWAN

Classes in LoRaWAN are divided into 3 classes, namely class A, class B, and class C. Each class has its advantages and disadvantages. It can be seen in Figure 4 that class A has advantages where the power consumption used is low so it can be used for a long period to save battery usage, the drawback in this class can be said that the latency is quite large so that the delivery process takes a longer time. Class B is a class with faster latency and more wasteful battery consumption than class A, for the last class, class C, has a small latency advantage so that data is sent faster than other classes so that data sent in real-time is faster. accurate, but due to the small latency, the power is used more and more often so that it consumes more power and shortens battery life[13].

3. RESEARCH METHODS

The flowchart of this study is described in Fig. 5 below. At first, the sensor must be developed before the next process, location determination is done. The next process is system installation and then data collection and drive test. Then we should match the result with quality standards, so the data transmission is smooth. If complies, we proceed to the system implementation while it does not, we should refer again to the location determination process to obtain the optimum positioning of the gateway and sensors.

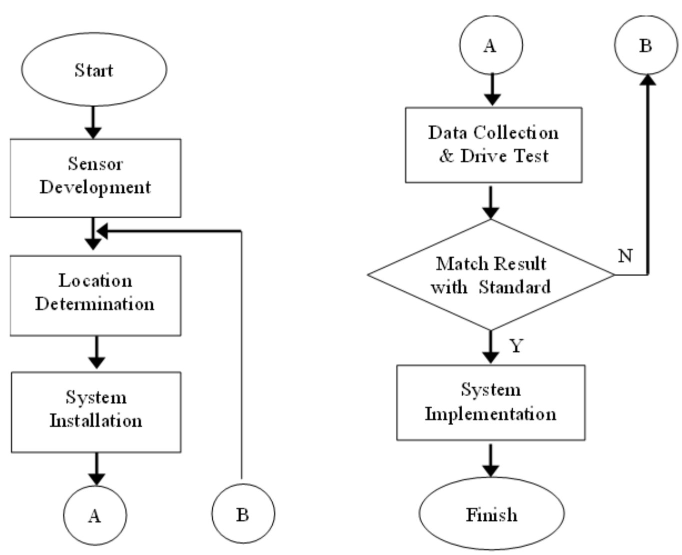

Fig. 5. Research Flowchart

Meanwhile, Fig. 6 depicts the system's architecture. The sensor is configured using LoRaWAN technology to get benefits such as low battery consumption and long-distance range. This device reads the temperature and humidity then the data is sent to the gateway to be forwarded to the network server. On the network server, the data will be processed and then forwarded to the application server so that the data can be viewed and monitored in real-time by the user.

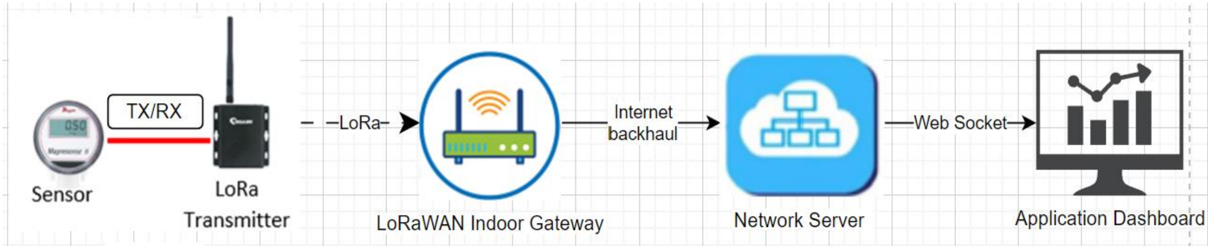

Fig. 6. System Architecture

This system works using Differential Pressure sensors and LoRaWAN Transmitter, where the data will be sent to the platform to be displayed in real-time. The sensor device is connected to the lorawan transmitter using a RS485 communication cable and the transmitter sends data at intervals per second so that sensor data is monitored in real time.

In This Research, system use Differential Pressure using a sensor with the Magnesense type MSX series with the specifications as shown in the Table 2. The sensor Installed with 2 tube connected in main room and reference room to measure the differential Pressure.

Table 2. Magnesense Differential Pressure Sensor Specification[14]

Item	Specification
Accuracy	±1% @ standard conditions
Temperature Limits	0 to 150°F (-18 to 66°C).
Pressure Limits:	1psi (6.89 kPa) maximum, operation; 10 psi (68.9 kPa), burst.
Power Requirements	2-wire, 10 to 35 VDC; 3-wire, 17 to 36 VDC or isolated 21.6 to 33 VAC.
Output Signals	2-wire, 4 to 20 mA; 3-wire, 0 to 10 V or 0 to 5 V.
Communication	Tx/RX Digital

Also he system uses a lora transmitter to transmit data from sensors with the ursalink brand LoRaWAN Transmitter AS923-2 with specifications as in table 3 the system use LoRaWAN transmitter with specification [15]

Table 3. LoRaWAN Transmitter Ursalink Specification[15]

Item	Specification
Accuracy	±1% @ standard conditions
Temperature Operate	-40°C to +70°C (-40°F to +158°F)
Sensitivity	-147 dBm @300bps
Protocol	LoRaWAN class C
Digital Input	Opto-isolated depending on voltage Can accept any DC signals of any type, including: ➢ DC Voltage (3-24 V)
Digital Output	2 x SPDT Relay Contact Rating: 3Amp DC (Max: 30 V) or 3Amp AC (Max: 250 V)

After the system has been implemented, the next procedure is to test the functionality of the sensor. Here are the steps of this procedure:

1) Make sure the Differential Pressure sensor has been installed in the room according to the equipment ID of each sensor device.
2) Make sure the power supply or battery on the sensor is plugged in and the sensor is on.
3) To Validate The value on the sensor , can be seen in the display on the sensor
4) Ensure that the sensor reading data listed on the dashboard corresponds to what is seen in real-time on the sensor using the mobile phone user interface on the site with a transmission duration every second.
5) Ensure that the sensor reading data on the dashboard is in accordance with the testing equipment. In this study, a device used is TEC Differential Pressure measuring instruments that have been calibrated to industry standards

Fig. 7 describes the architecture of the system's test.

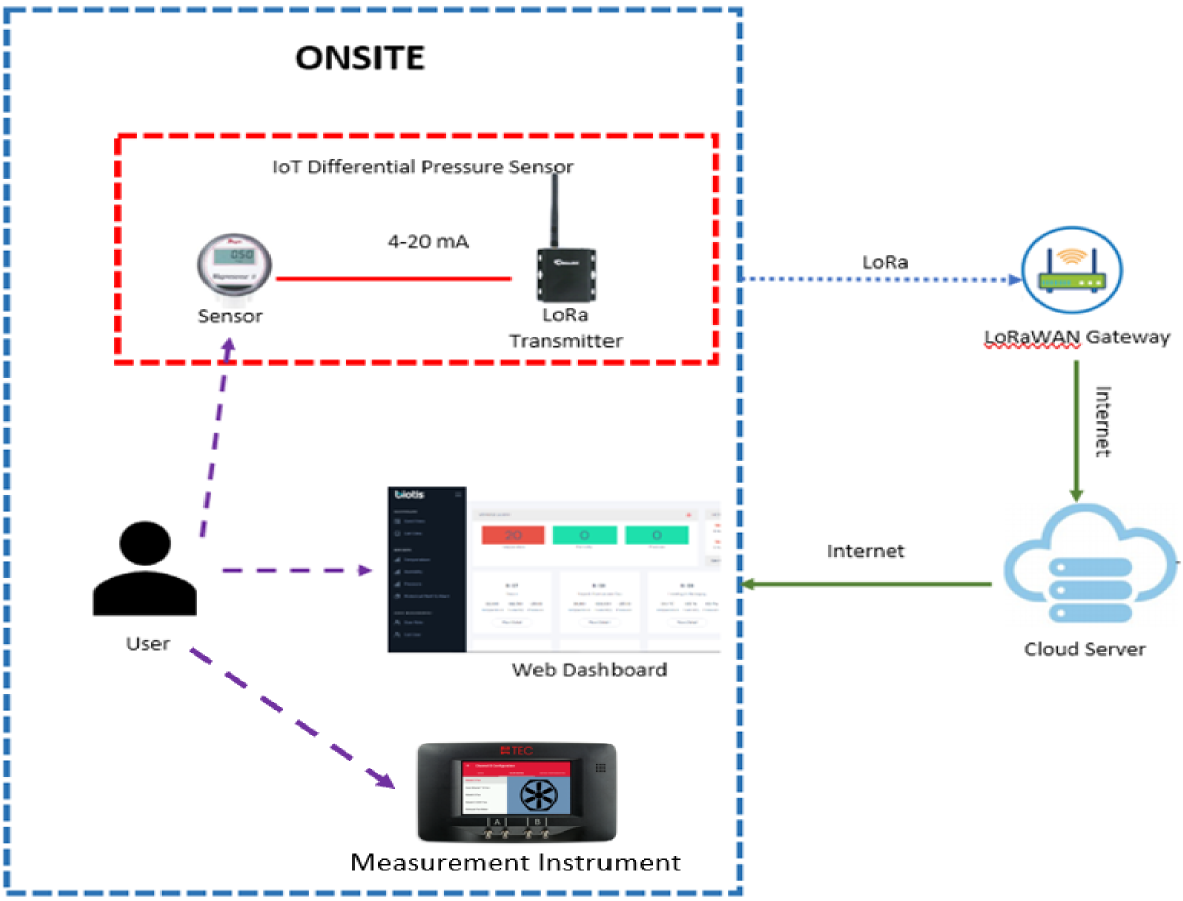

Fig. 7. Differential Pressure sensor test architecture

4. RESULT AND DISCUSION

In this study, the implementation experiment was carried out in a pharmaceutical factory building where in the building there was 21 sensor devices or end devices, each end device installed in a different room. The LoRa gateway is installed in the main area of the building, not more than 100 meters from each sensor.

A. Drive Test Coverage

The drive test is used to determine the RSSI parameters obtained by the end device. The RSSI parameter represents the signal strength received by the device, measured with an RSSI tool device namely Rising HF with 10 times sampling. The results are quite satisfactory, where the minimum RSSI found is -90.1 dBm and the maximum is -66 dBm. It is because an indoor gateway is used, nearby distance with each sensor. The drive test result is written in Table 4 below.

Table 4. LoRaWAN Drive test result

Room Number	Room Name	Avg RSSI (dBm)
B-127	Decon	-73.4
B-128	Unpack Aluminium Cap	-76.5
B-129	Labeling & Packaging	-72.6
B-130	Label Temp. Storage	-84.7
B-131	Material Temp. Storage	-90.1
B-135	Unpacking	-70.7
B-136	Vial temp. Strg	-70
B-701	Buffer	-73.5
B-701A	MAL	-73.3
B-704	Air Lock	-74.5
B-706	Clean Corridor	-72.9
B-707	Blending-1	-73.8
B-708	Blending-2	-72.7
B-709	Filling	-66
B-710	Air Lock	-72.8
B-711	Capping	-79.8
B-712	Decon	-84.3
D-403	Buffer	-85.5
D-404	Sterility Room	-82.7
D-405	Sterility Room	-80.5

B. Differential Pressure Validation

Data validation is needed to determine the accuracy of the sensor in reading the differential pressure in the room. First, the data comparison is done by comparing dashboard output with the measurement instrument. Table 5 shows that the accuracy level of the sensors is excellent, with the worst error value being different 0,65 Pa.

Table 5. Differential Pressure Validation

Room Name	Room target	Room Reference	Dasboard (Pa)	Validator Instrument (Pa)	Error (Pa)
Decon	B-127	B-114	2,1	2,28	0,18
Unpack Aluminium Cap	B-128	B-114	2,1	2	0,1
Labeling & Packaging	B-129	B-114	2,1	2,7	0,6
Label Temp. Storage	B-130	B-129	-0,6	-0,5	0,1
Material Temp. Storage	B-131	B-129	2,3	2,58	0,28
Unpacking	B-135	B-114A	0,1	0	0,1
Vial temp. Strg	B-136	B-135	-0,9	-0,88	0,02
Buffer	B-701	B-205	2,1	2,5	0,4
MAL	B-701A	B-701	-1,5	-1,38	0,12
Air Lock	B-704	B-706	2,7	2,5	0,2

Room Name	Room target	Room Reference	Dasboard (Pa)	Validator Instrument (Pa)	Error (Pa)
Clean Corridor	B-706	B-701A	-1,9	-2,38	0,48
Blending-1	B-707	B-706	-1,8	-1,63	0,17
Blending-2	B-708	B-706	5,9	5,38	0,52
Filling	B-709_1	B-706	4,6	5,25	0,65
Filling	B-709_2	B-706	4,2	4,25	0,05
Air Lock	B-710	B-706	2,7	3	0,3
Capping	B-711	B-710	1,1	1,5	0,4
Decon	B-712	B-706	3,3	3,25	0,05

5. CONCLUSION

The pharmaceutical industry is an industry that is air quality to guarantee the quality of its products. Based on the results of this study, it can be concluded that Lorawan can be implemented well in the pharmaceutical industry area for monitoring differential pressure with good signal conditions with drivetest measurement results getting RSSI -66 to -91 dBm. And the results of the differential pressure sensor validation with a calibrated measuring instrument have the largest error value of 0.65 Pascal.

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