A LOW POWER AND LONG RANGE IOT KIT DEVELOPMENT WITH LORA TECHNOLOGY FOR SMART USE CASES

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Abstract: LoRa is an advanced technology that is researched and applied widely in the IoT field because of its power-efficiency and distance wireless connection. Therefore, a development kit which support LoRa technology is an important device that can help an engineer to develop an IoT - LoRa-based system faster and more stable. The development kit not only requires a small size to be easily integrated into other systems but also has a low power consumption to adapt to the requirement of IoT devices. In this paper, a development kit for an IoT platform using LoRa technology has been proposed. The results of power consumption and Received Signal Strength Indication (RSSI) of this dev-kit have been measured, which has proved that the dev-kit work well as anticipated.

Keywords: LoRa, LoRaWAN, IoT.

I. INTRODUCTION

Nowadays, Internet of Thing (IoT) is one of the most important elements of the Fourth Industrial Revolution (4thIR). It is widely accepted in many different industries and fields in our lives that are not only in the manufacturing, and industry but also in smart homes, healthcare, etc... IoT is also considered a core of agritech and applied in many areas of agriculture to increase automation, control the vegetative environment, and maintain product quality post-harvest [1] [2].

The definition of IoT was first introduced by Kevin Ashton in the late 90s [3]. The IoT concept is used to describe a network of physical devices that connects and exchanges data with another one or with other systems via the Internet. Since then, a large number of new telecommunication technologies have been developed to support IoT platforms and systems. Therefore, the new transmission protocols become one of the most interesting technology directions today, especially low-power, and long-range wireless communication technologies.

The new communication technologies not only ensure smooth communication in the IoT system, but also increase the connecting distance between IoT devices (nodes, gateways), reduce the system's energy consumption to increase the uptime of each device. There are several wireless communication technologies which have been developed been developed specifically for IoT systems. We can mention several technologies such as Zigbee, Bluetooth [4], WIFI, LoRa [5][6], NB-IoT [7], TI Sub-1Ghz [8][9]… Depending on the requirements of the IoT system to be designed, we can choose one or more suitable communication technologies for our IoT platform.

LoRa is a radio modulation technology for low-power, wide area networks (LPWANs). This modulation method is proposed by Semtech to provide an effective wireless communication for IoT devices [10]. LoRa technology can provide a long-range wireless communication: up to 05 kilometers in urban areas, and up to 15 kilometers or more in rural areas (line of sight). An important characteristic of the LoRa-based solutions is ultra-low-power requirements, which allows the battery-operated devices to have a lifetime up to 10 years. The LoRaWAN is deployed in a star topology, so this network is perfect for applications that require long-range communication among many devices that have low power requirements and collect small amounts of data.

To develop an IoT system, the development kit (dev-kit) is a useful device to support the engineer in the design process. It can reduce the time needed to make the real circuit, which allow users to test the functions of different devices easily. In the market, there are a few dev-kits which support the LoRa technology. Most of them are the shield for the Arduino platform with limited hardware resources. Therefore, a high-performance dev-kit with more hardware resource is very important when an engineer need to design a large IoT system.

This paper focuses on building an IoT dev-kit using STM32 family microcontroller and support LoRaWAN protocol. By using the STM32 microcontroller, the system can operate with high speed, high performance while keeping the low power consumption. The dev-kit is integrated a LoRa module so it can support the wireless connection with a long range up to 1000 meters or more. This development kit will be useful for students or any engineers who are interested in learning, researching, and developing IoT devices and systems operating on the LoRa technology.

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II. THE MODEL OF A LORAWAN-BASED IOT PLATFORM

Basically, the model of an IoT system based on LoRaWAN is given in the **Fig. 1** [10]. In this model, the End Nodes (or End Devices) are the combination between sensors or actuators and a microcontroller. The End Nodes collect the data from the environment and send them to the gateway through the LoRa connection. The gateway communique with many End Nodes in the same area and then push the collected data on the cloud network via an internet connection.

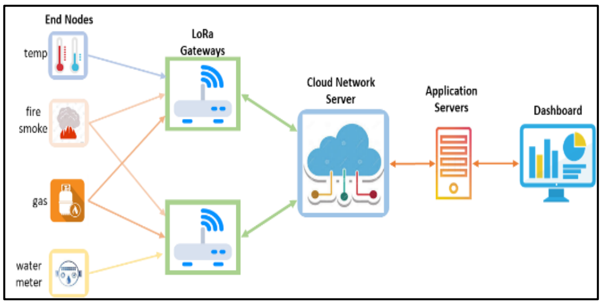


Fig. 1. The model of an IoT platform using LoRa technology.

Meanwhile, the End Nodes can get the control commands that users send via the Dashboard and execute them (such as turn on/off the relays, adjust the motor's speed…).

In this paper, a development kit will be designed to support the students or engineers so that they can easily build up an End Node by attaching several types of sensors and actuators to the dev-kit. With this dev-kit, students can learn about the embedded system as a part of IoT. This dev-kit is designed as an open system, so everyone can develop an embedded system to adapt to the requirements of projects easily.

LoRaWAN Gateways [11] are the bridge between the End Nodes and the Cloud Network. End Nodes connect to the Gateway via LoRa connection to reduce the power consumption, while the Gateway uses high bandwidth networks like WiFi, Ethernet, or Cellular to connect to the Cloud Network. To send or receive the data from the End Nodes, gateways are equipped with a LoRa concentrator and can, in essence, be considered as a router of sorts.

III. DESIGN AN IOT – LORA BASED DEVELOPMENT KIT

A. Block diagram of the Dev-Kit

As mentioned in the section I, the dev-kit is designed based on STM32 family microcontroller. To be more specific, a STM32F103 microcontroller has been used in this design. This is a 32bit microcontroller incorporates an ARM Cortex-M3 core processor operating at a 72 MHz frequency and high-speed embedded memories. Another advantage of this microcontroller is the compatibility of Arduino platform. Therefore, the dev-kit can easily reuse a lot of libraries which are developed for Arduino platform. The block diagram of this dev- kit is shown in the **Fig.** *2*.

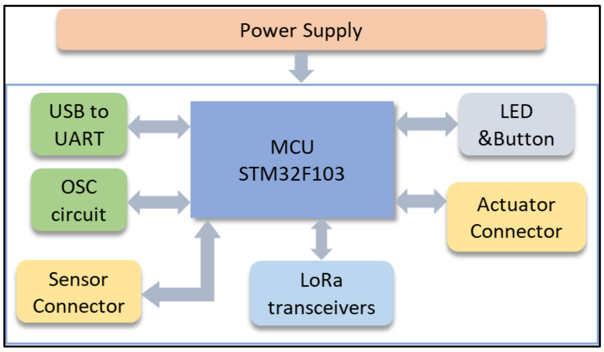


Fig. 2. The block diagram of the development kit.

For the LoRa transceiver, a RFM95W LoRa module is used to provide a long-distance connection while keeping the power consumption low.

The kit also has a USB to UART converter (using CH340) to provide a simple method to program or debug the source code.

Many kinds of sensors can be attached to the dev-kit via the Sensor Connector module. The I2C and SPI connections are implemented in this module. In addition, some kinds of analogs sensors can be connected to the analog pin of the microcontroller directly.

The Power Supply is designed to support many levels of voltage input. The dev-kit can work with a range of voltage from 12V to 3.3V. Then, the power can be provided through a USB connector, header connector, or a coin battery.

The Actuator Connector module is used to send the control signal to the power amplifier. It is needed when we want to control a relay, a motor, or any actuator mechanism. The power amplifier is not integrated into this dev-kit to reduce the power consumption of the system.

B. Development Kit Schematic and PCB Design

Based on the proposed block diagram, the schematic of the dev-kit has been designed as in the figures below. The **Fig. 3** describes the connection between the STM32F103 microcontroller with the RFM95W LoRa transceiver. The LoRa module uses the SPI connection and connects to the microcontroller through two pins: MISO and MOSI. By using the RFM95W module, the dev-kit can work with the LoRa libraries in a similar way as it can in Arduino platform.

The power supply module is also described in this figure. The power IC - LC1117DT12 has been used to provide a stable output voltage for other components in this dev-kit. A couple of 100uF capacitors are used in this circuit to reduce the noise of power supply.

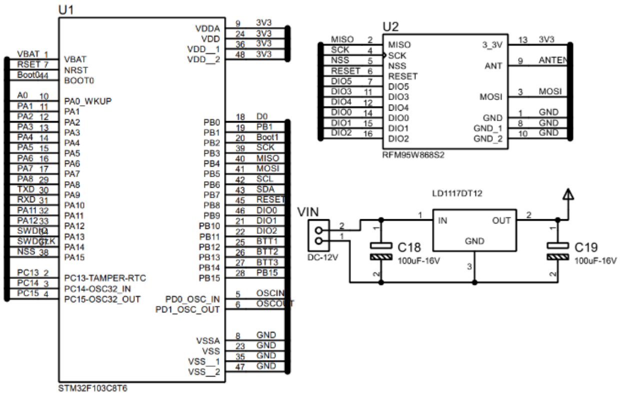


Fig. 3. Connection between STM32F103 with LoRa module.

The dev-kit needs many kinds of oscillators for different components. Therefore, three main oscillator sources have been designed as in the **Fig. 4**. The high-speed oscillator X1 is used for the microcontroller to achieve the highest performance. The X4 source is used for the real-time clock module. The crystal X5 is the oscillator for the LoRa transceiver.

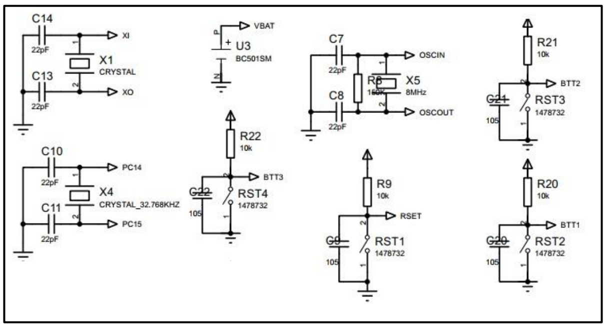


Fig. 4. The oscillator sources circuit.

After finishing the schematic design, the printed circuit board (PCB) design is an important step to have a good layout for board manufacturing. A good PCB design will reduce the size of the dev-kit board but still solve the heatsink problem and prevent the crosstalk noise. The PCB design of the dev-kit and the 3D model of this dev-kit have been shown in the **Fig. 5**.

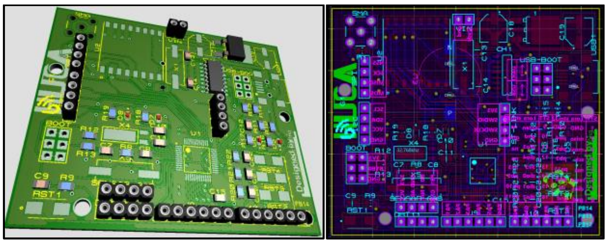


Fig. 5. PCB of the dev-kit and the 3D simulation model.

The total size of this board is just 65x55mm, making it easy to integrate this dev-kit to the larger system via the expand connector if needed. The complete PCB is shown in **Fig. 6**.

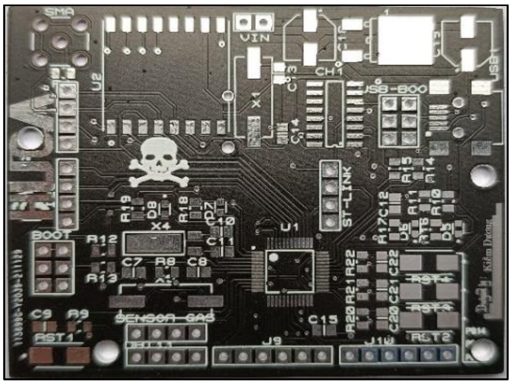


Fig. 6. The manufactured PCB.

After soldering the electronic components, the dev-kit has been completed as in

Fig. 7. A 5dBi omnidirectional antenna is used in this dev-kit to increase the system sensitivity.

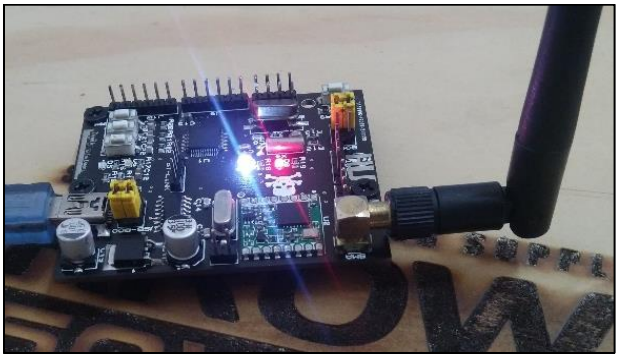


Fig. 7. The completed development kit.

C. Cloud Network Server - Application Server

At Cloud Network Server, we have designed services software running in the background to receive incoming data from the LoRa Gateway (This is data received from sensors at IoT devices/End Nodes) by UDP Datagram packets, analytic and store them into the database system to serve for mining and analysis from the Application Servers (**Fig. 8**).

The service's software uses the UDP (User Datagram Protocol) protocol to receive data as quickly as possible from the LoRa Gateway and store them in the database.

We use NoSQL databases specifically MongoDB for storage, due to the nature of NoSQL that optimizes for large volumes of data, low latency, and especially does not need data consistency.

Application Servers will access the database, process, and analyze functions to provide services related to the information received and return the processed results to the end-user.

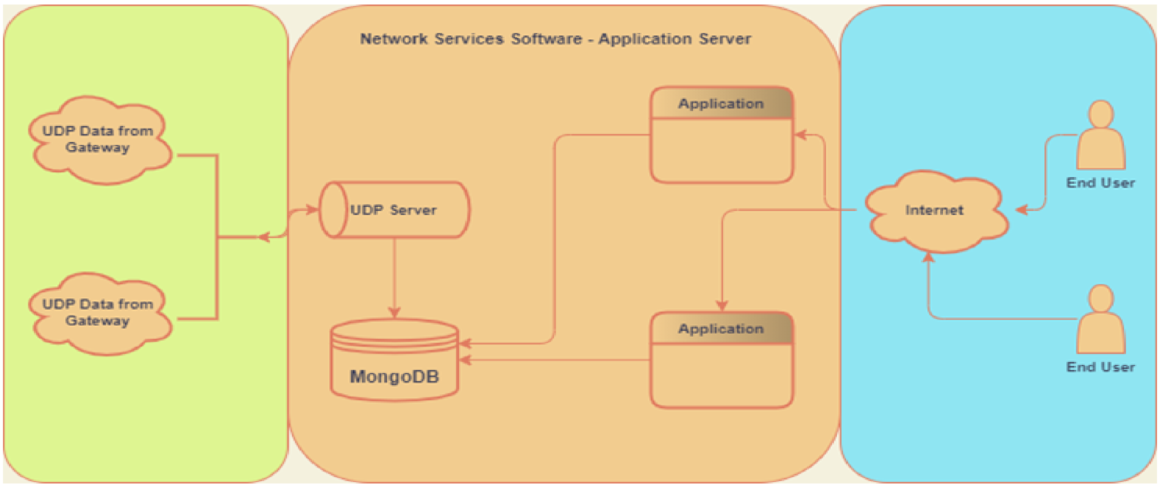


Fig. 8. The service's software and application server.

EXPERIMENT RESULTS

To measure some operation parameters of the dev-kit, a prototype dev-kit has been set up to operate as a Transmitter. Because the transmission always requires more power than the receiving, we can measure the maximum power requirement of the dev-kit when it is in transmission mode.

The dev-kit will be configured to send a data package every 5 seconds. Then, a current-voltage sensor (INA219 sensor) is used to record the load voltage and the current of the dev-kit. From two parameters, we can calculate the power consumption of the dev-kit in transmission mode.

Some measurement results of the Load voltage, Current and Power rendering from the operation of the dev-kit are shown in the **Table 1**.

Table 1. Measurement results of Load voltage, current and power consumption in the dev-board.

Time	Load voltage (V)	Current (mA)	Power (mW)
11:32:18 PM	4.97	60.5	300
11:32:10 PM	4.99	60.4	305
11:32:02 PM	4.99	60.7	303
11:31:54 PM	4.99	60.6	301
11:31:46 PM	4.98	60.5	301
11:31:38 PM	4.99	60.3	301
11:31:30 PM	4.97	61.0	303
11:31:22 PM	4.98	60.4	300
11:31:13 PM	4.99	61.0	301
11:31:05 PM	4.97	60.8	300
11:30:57 PM	4.97	60.8	298
11:30:48 PM	4.98	60.6	301
11:30:40 PM	4.99	60.5	303
11:30:32 PM	4.98	61.1	303

With the power supply from USB connector, the average load voltage is about 4.98V (**Fig. 10**). The variable amplitude of load voltage is just +/- 0.01V. So, it demonstrates the Power Supply module works well as in the design.

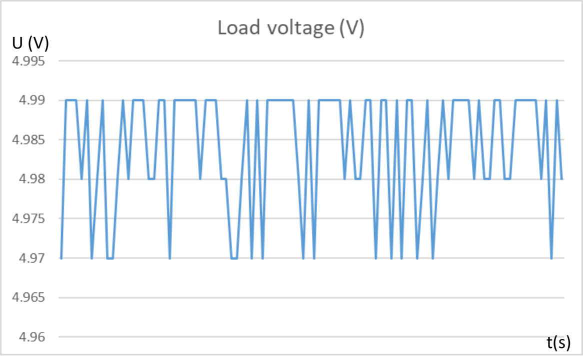


Fig. 9. Chart of variable load voltage over time.

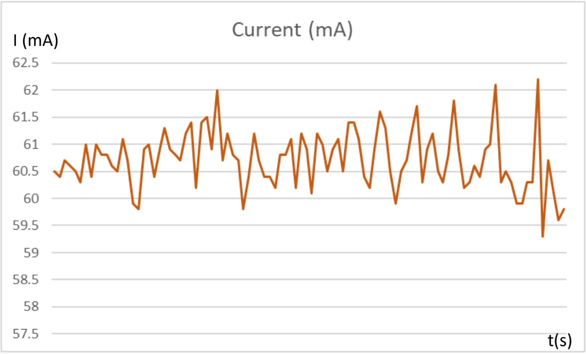


Fig. 10. Chart of variable current over time.

The average current in transmission mode is just about 61mA (**Fig. 10**). Then, the average power consumption of this dev-kit is about 305mW (**Fig. 11**). This result is a slightly higher than expected. However, this is the power consumption of the kit in the continuous transmission. Even with this result, this dev-board can work in around 40 hours continuously with only a Lithium-Ion 3.7V/2600mAh battery.

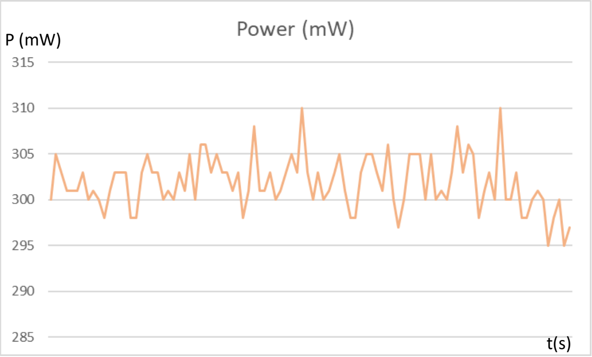


Fig. 11. The power consumption of the dev-kit.

Compared to the B-L072Z-LRWAN1 Discovery kit from ST Microelectronics [12], the current of this dev kit is 5 times lower while it still has the equivalent microprocessor and wireless transceiver module. A short comparison between this dev-kit and the B-L072Z-LRWAN1 development kit is shown as in **Table 2**.

Table 2. A comparison between this dev-kit and the B-L072Z-LRWAN1 kit.

	The dev-kit	**B-L072Z-LRWAN1 Kit**
Microprocessor	STM32F103	STM32L072C
Lora Modem	RFM95W	SX1276
Supply Voltage	3.3V – 12V	3.3V – 12V
Supply Current (5V-USB supply)	61 mA	300mA

To test the effect of distance on the connection, the dev-kit has been set up to send the signal to the RAK7240 gateway at a distance of 800 meters. The RSSI and Signal-to-Noise Ratio (SNR) parameters are recorded to examine the strength of the signal.

Fig. 12. The RAK2490 Gateway is installed at Hue University of Sciences.

From the chart of RSSI as in **Fig. 13**, the signal strength is always around -40dBm. So, the received signal is significantly strong (-30dBm is the maximum signal strength). The lowest measured RSSI is -47dBm. It is 4 times higher than the minimum requirement RSSI of the LoRa connection. The measurement results of RSSI prove that we can increase the distance of the connection, but the received signal is still ensured.

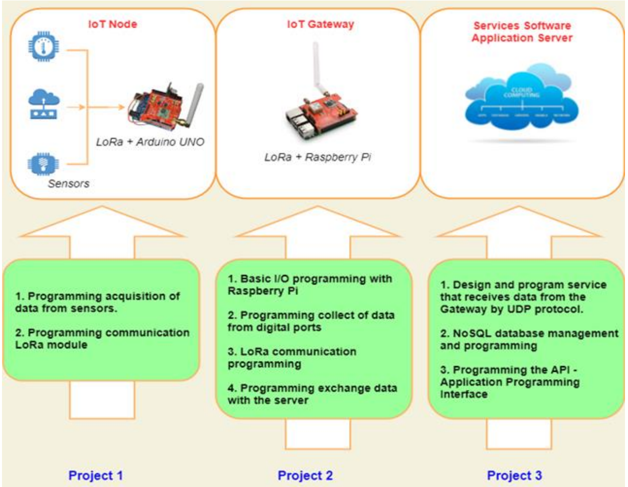
Fig. 13. Chart of Received Signal Strength Indication (RSSI).

IV. PRACTICAL APPLICATIONS

A. IoT Platform Development

The design of lab projects for IoT experiments for IoT platform development. To effectively implement projects

We have designed three development phases as following and depicted in **Fig. 14**:



1. Programming acquisition of data from sensors.
2. Programming communication LoRa module

1. Basic I/O programming with Raspberry Pi
2. Programming collect of data from digital ports
3. LoRa communication programming
4. Programming exchange data with the server

1. Design and program service that receives data from the Gateway by UDP protocol.
2. NoSQL database management and programming
3. Programming the API - Application Programming Interface

Fig. 14. Suggested project phases.

The goal of Phase 1: Collect data from sensors such as humidity sensor, CO2,... and program communication with LoRaWAN network to send the received data to Gateway.

The goal of Phase 2: Basic communication with an embedded computer system - Raspberry Pi, receiving data from the digital signal ports of the RPI device, transmitting and receiving data through LoRaWAN communication, and forwarding data received from IoT Devices/ End Nodes to the cloud network system by UDP protocol.

The goal of Phase 3: Transmit and receive data from the IoT Gateway via UDP communication, store the received

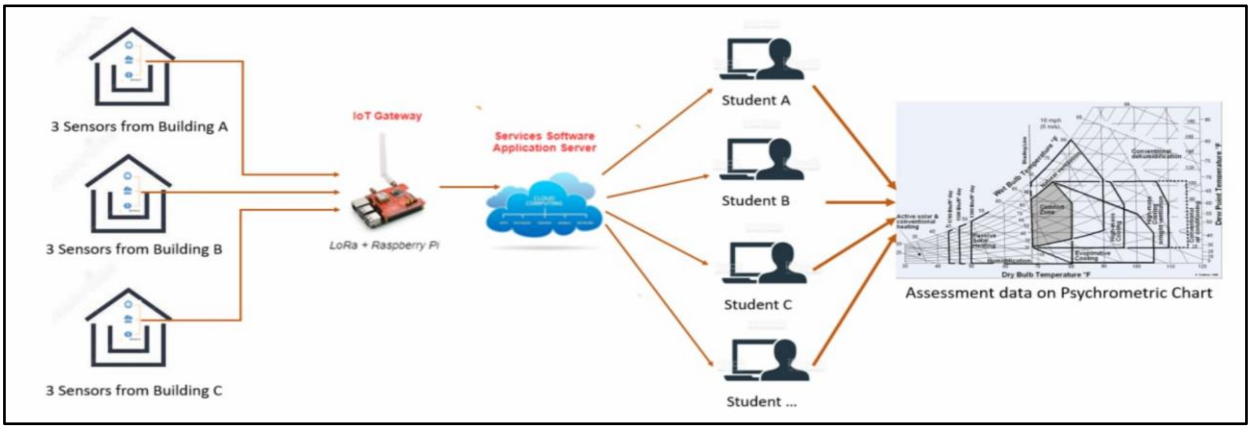


Fig. 15. Suggested application of LoraWan IoT supporting students' practice in Physical Architecture course.

information into the database system, and program supporting APIs for applications that need to process and analyze data for specific goals.

B. Application of LoraWan IoT in Physical Architecture for Smart city

The practice use case using IoT platform for evaluating the current conditions of assessing the current state of thermal comfort conditions for the construction (**Fig. 15**). In which, humidity, temperature and velocity are three factors that affect the human comfort heat. For architecture projects based on hand-held measuring devices and comparing psychrometric charts to experimentally determine a comfortable thermal environment in the design. However, the disadvantage of this traditional method is that it is difficult to visualize data and illustrations over a period of time as well as experimental space, and it is difficult to measure many points to compare the results. different programs.

Using this LoRaWAN IoT system, the practice and monitoring work are extended easily from a distance, the data is streamed, and the results are shared with the team, so that they can quickly evaluate and choose the design plan.

With the above application support, the professional have a variety of options in many practical environments from indoor and outdoor of the construction site and many different works to compare.

A limitation of the test is only 3 out of 5 elements of the psychrometric chart due to sensor conditions support, however with the scope of practice and comparison of different construction characteristics still ensure the quality of the assessment for the practical uses.

V. CONCLUSION

In this paper, a low-power, long-ranger development kit for IoT system has been proposed. The dev-kit is design based on the high-performance microcontroller STM32F103 and the LoRa module RFM95. A prototype of the dev-kit has been manufactured and applied in a real application to test the important parameters such as power consumption and RSSI.

The whole process of building the IoT kits is not only about technology and engineering but also the pedagogic aspect. The SCL and PBL approaches that we applied to this IoT platform design and implementation through learning projects with the proactive participation of students and lecturers are quite effectively and practically proved.

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PHÁT TRIỂN BỘ KIT IOT VÙNG RỘNG VÀ NĂNG LƯỢNG THẤP VỚI CÔNG NGHỆ LORA CHO CÁC ỨNG DỤNG THÔNG MINH

Tóm tắt— LoRa là công nghệ tiên tiến được nghiên cứu và ứng dụng rộng rãi trong lĩnh vực IoT bởi tính năng tiết kiệm năng lượng và khoảng cách kết nối không dây. Do đó, bộ công cụ phát triển hỗ trợ công nghệ LoRa là một thiết bị quan trọng giúp kỹ sư có thể phát triển hệ thống dựa trên IoT - LoRa nhanh hơn và ổn định hơn. Bộ công cụ phát triển không chỉ yêu cầu kích thước nhỏ để dễ dàng tích hợp vào các hệ thống khác mà còn có mức tiêu thụ điện năng thấp để thích ứng với yêu cầu của các thiết bị IoT. Trong bài báo này, một bộ công cụ phát triển cho nền tảng IoT sử dụng công nghệ LoRa đã được đề xuất. Kết quả về mức tiêu thụ điện năng và Chỉ báo cường độ tín hiệu đã nhận (RSSI) của bộ công cụ phát triển này đã được đo lường, điều này chứng tỏ rằng bộ công cụ phát triển hoạt động tốt như mong đợi.

Từ khoá— LoRa, LoRaWAN, IoT.

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