A Low Power – Long Range IoT Development Board based on LoRa Technology

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Abstract. LoRa is an advanced technology investigated and applied widely to the IoT field because of its power efficiency and wireless connection. Therefore, a development kit supporting LoRa technology is a vital device that helps engineers to develop a faster and more stable IoT – LoRa-based system. 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, we propose a development kit for an IoT platform using LoRa technology. The power consumption and Received Signal Strength Indication (RSSI) of this kit are addressed. The development kit works well, as anticipated.

Keywords: LoRa technology, IoT, power efficiency, distance wireless connection

1   Introduction

Nowadays, the Internet of Things (IoT) has been one of the most essential elements of the Fourth Industrial Revolution (4.0 IR). It is widely accepted in different industries and fields, including the manufacturing industry, smart homes and healthcare. IoT is also considered a core of agritech and is applied to numerous areas of agriculture to increase automation, control the vegetative environment, and maintain post-harvest product quality [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 one or more systems via the Internet. Since then, a large number of new telecommunication technologies have been developed to support IoT platforms and systems. Therefore, 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) and

reduce the system's energy consumption to increase the uptime of each device. Several wireless communication technologies have been developed specifically for IoT systems. We can mention several technologies, such as Zigbee, Bluetooth [4], Wifi, LoRa [5, 6], NB-IoT [7], and 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 and wide-area networks (LPWANs). This modulation method is proposed by Semtech to provide effective wireless communication for IoT devices [10]. LoRa technology can provide long-range wireless communication: up to 5 km in urban areas and 15 km 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 of up to 10 years. The LoRaWAN is deployed in a star topology, so this network is perfect for applications requiring long-range communication among many devices that have low-power requirements and collect small amounts of data.

To develop an IoT system, engineers use the development kit (dev-kit) in the design process. It can reduce the time needed to make the real circuit, allowing users to test the functions of different devices easily. In the market, a few dev-kits can 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 resources is crucial for engineers to design a large IoT system.

This paper focuses on building an IoT dev-kit by using an STM32-family microcontroller and supporting LoRaWAN protocol. With the STM32 microcontroller, the system can operate at a high speed, high performance while keeping low power consumption. The dev-kit integrated with a LoRa module can support the wireless connection with an extended range of up to 1000 metres. This development kit is useful for students or engineers interested in learning, researching, and developing IoT devices and systems operating on the LoRa technology.

2   The model of a LoRaWAN-based IoT platform

Basically, the model of an IoT system based on LoRaWAN is presented in 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 communicates with the End Nodes in the same area and then pushes the collected data to the cloud network via an internet connection.

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

In this paper, a development kit is designed to support the students or engineers to quickly 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; therefore, 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 power consumption. At the same time, the Gateway uses high-bandwidth networks like WiFi, Ethernet, or Cellular to connect to the Cloud Network. To send or receive data from the End Nodes, we equipped the gateways with a LoRa concentrator, and they can, in essence, be considered as a router of sorts.
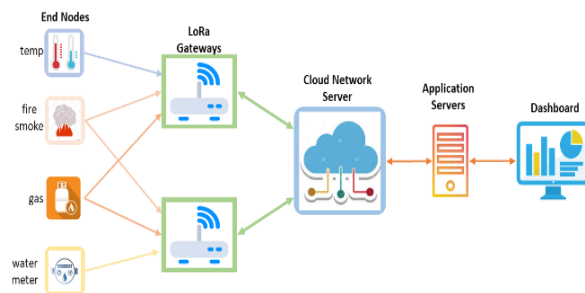

Fig. 1. Model of an IoT platform using LoRa technology

3   Design an IoT – LoRa-based development kit

3.1   Block diagram of the dev-kit

As mentioned in Section 1, the dev-kit is designed based on the STM32-family microcontroller. To be more specific, an STM32F103 microcontroller is used in this design. This is a 32-bit microcontroller, and it incorporates an ARM Cortex-M3 core processor operating at a 72 MHz frequency and high-speed embedded memories. Another advantage of this microcontroller is its compatibility with an Arduino platform. Therefore, the dev-kit can easily reuse a lot of libraries that are developed for the Arduino platform. The block diagram of this dev-kit is shown in.

For the LoRa transceiver, an 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.

Numerous 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 analogue sensors can be connected to the analogue pin of the microcontroller directly.

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

The actuator connector module sends the control signal to the power amplifier. It is needed 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.
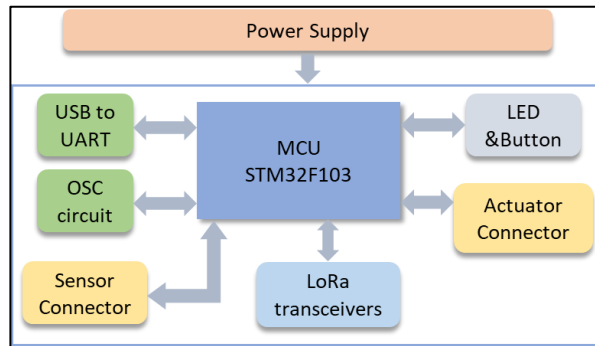

Fig. 2. Bblock diagram of development kit

3.2   Development kit schematic and PCB design

Based on the proposed block diagram, we designed the schematic of the dev-kit, as shown in the following figures. Fig. 3**Error! Reference source not found.** 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 the Arduino platform.

The power supply module is also described in this figure. The power IC-LC1117DT12 is used to provide a stable output voltage for other components in this dev-kit. A couple of 100 uF capacitors are used in this circuit to reduce the noise of the power supply.
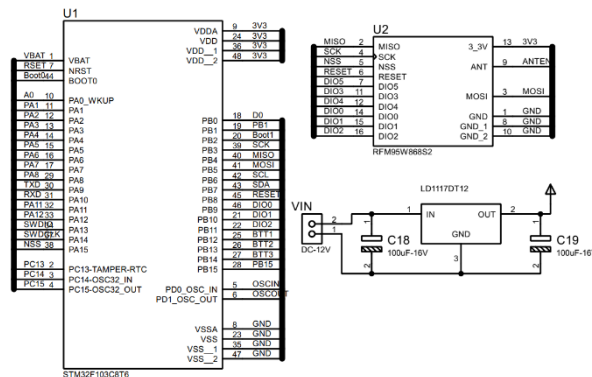
Fig. 3. Connection between STM32F103 with LoRa module

The dev-kit needs various kinds of oscillators for different components. Therefore, three main oscillator sources are designed as in 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.
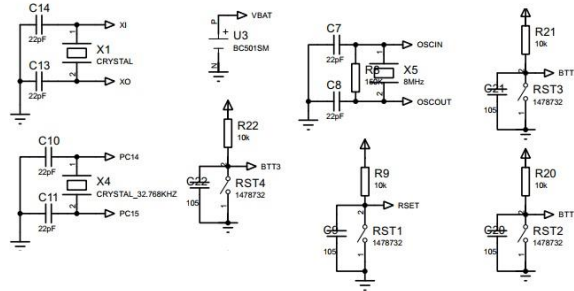

Fig. 4. Oscillator sources circuit

After finishing the schematic design, we designed the printed circuit board (PCB) for board manufacturing. A good PCB design reduces the size of the dev-kit board but still solves the heatsink problem and prevents the crosstalk noise. The PCB design of the dev-kit and the 3D model of this dev-kit are shown in Fig. 5.
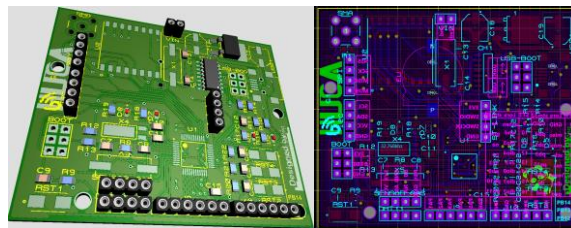

Fig. 5. PCB of the dev-kit and 3D simulation model

The total size of this board is just 65 × 55 mm, making it easy to integrate this dev-kit into larger systems via an expand connector if needed. The complete PCB is displayed in Fig. 6.
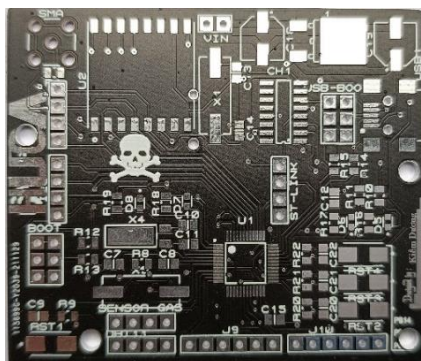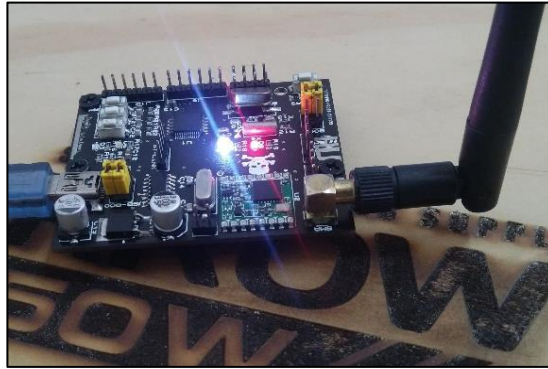
Fig. 6. Manufactured PCB

After soldering the electronic components, the dev-kit is completed, as presented in. A 5-dBi omnidirectional antenna is used in this dev-kit to increase the system sensitivity.

Fig. 7. Completed development kit

4   Experiment results

To measure some operation parameters of the dev-kit, we set up a prototype dev-kit 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 is configured to send a data package every five 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 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

Time	Load voltage (V)	Current (mA)	Power (mW)
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 a USB connector, the average load voltage is about 4.98 V (Fig. 9). The variable amplitude of load voltage is just ±0.01 V. So, it demonstrates that the power supply module works well, as designed.
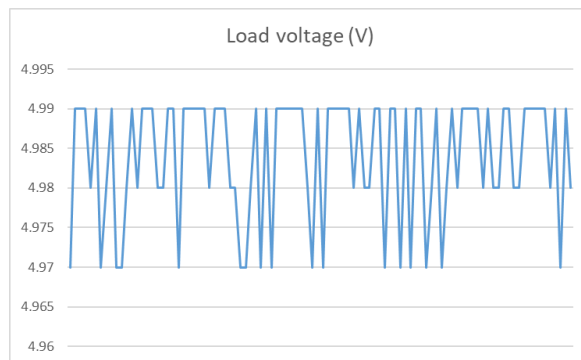
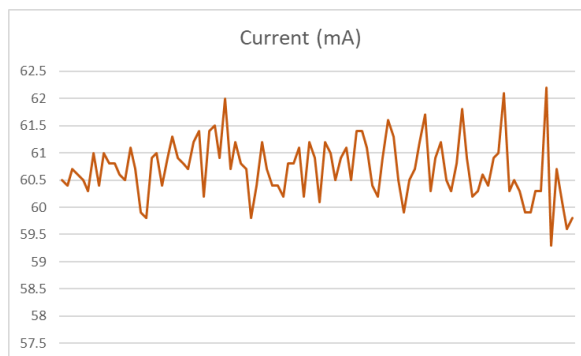**Fig. 8.** Chart of variable load voltage over time

Fig. 9. Chart of variable current over time

The average current in transmission mode is just about 61 mA (Fig. 9**Error! Reference source not found.**). Then, the average power consumption of this dev-kit is about 305 mW (Fig.

10). This consumption is slightly higher than expected. However, this is the power consumption of the kit in the continuous transmission. Even with this result, this dev-kit can continuously work for around 40 hours with only a LiPo 2600 mAh battery.
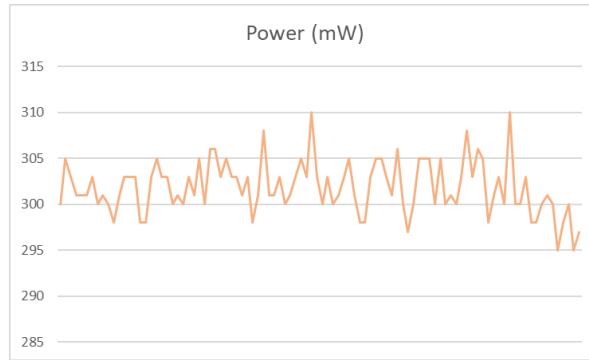

Fig. 10. Power consumption of the dev-kit

Compared with the B-L072Z-LRWAN1 discovery kit from ST Microelectronics [12], the current of this dev-kit is five times lower while it still has an equivalent microprocessor and wireless transceiver module. A short comparison between this dev-kit and the B-L072Z-LRWAN1 development kit is presented 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	3.3–12 V	3.3–12 V
Supply current (5V-USB supply)	61 mA	300 mA

To test the effect of distance on the connection, we set up a dev-kit to send the signal to the RAK7240 gateway at a distance of 800 metres (Fig. 11). The RSSI and signal-to-noise ratio (SNR) parameters are recorded to examine the strength of the signal.

From the chart of RSSI (Fig. 12), we can see that the signal strength is always around –40 dBm. Therefore, the received signal is significantly strong (–30 dBm is the maximum signal strength). The lowest measured RSSI is –47 dBm. It is four 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. 11. RAK2490 Gateway installed at University of Sciences, Hue University

Fig. 12. Chart of Received Signal Strength Indication (RSSI)

5   Conclusions

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

The measurement results prove that the dev-kit works well with low power consumption and long connection while keeping a well-received signal strength.

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