



Beginning LoRa Radio Networks with Arduino



Build Long Range, Low Power
Wireless IoT Networks

Pradeeka Seneviratne

Apress®

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About the Author



Pradeeka Seneviratne is a software engineer with more than ten years of experience in computer programming and systems design. He is an expert in the development of Arduino and Raspberry Pi-based embedded systems and is currently a full-time software engineer working with embedded systems and highly scalable technologies. Previously, Pradeeka worked as a software engineer for several IT infrastructure and technology servicing companies. He is the author of several books, including *Beginning BBC micro:bit* (Apress), *Building Arduino PLCs* (Apress), and *Internet of Things with Arduino Blueprints* (Packt).

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CHAPTER 1

Introduction to LoRa and LoRaWAN

Radios are exciting pieces of hardware that can be used to build wireless communication links. Radios used to listen to voice and audio are known as *receivers*; your home radio, for example, can only tune into and receive radio stations. Radios that can be used to transmit voice and audio are known as *transmitters*; radio stations use transmitters to broadcast programs. Radios that can do both (transmit and receive) are known as *transceivers*; a walkie-talkie is an example of a two-way radio transceiver.

Transceivers use different types of modulations to send and receive data. The network coverage and data capacity are highly dependent on the frequency and type of modulation used. By using LoRa modulation, you can send data to long distances.

By reading this chapter, you will gain a basic understanding of LoRa, LoRaWAN, and LoRaWAN's architecture.

What Is LoRa?

The LoRa spread spectrum is a patented modulation developed by Semtech (<https://www.semtech.com/>) based on the chirp spread spectrum (CSS) modulation. LoRa (short for “long range”) provides long-range and low-power consumption, a low data rate, and secure data

transmission. LoRa can be used with public, private, or hybrid networks to achieve a greater range than cellular networks. LoRa technology can easily integrate with existing networks and enables low-cost, battery-operated Internet of Things (IoT) applications.

Let's try to understand how the LoRa Spread Spectrum Modulation works. A plain radio signal carries no information besides the transmitter being left on. The signal must be modified in some way to convey information. There are several ways in which this can be done. Two of the most popular methods are to modify the amplitude and to modify the frequency.

Amplitude Modulation

In *amplitude modulation* (AM), the signal strength (amplitude) of the carrier wave is varied in proportion to that of the message signal being transmitted. Figure 1-1 shows how the information signal (modulating signal) is transformed into the modulated signal. First, the information signal is mixed with the carrier signal using a mixer (indicated with an X). The carrier signal has a constant frequency and amplitude, generated by an oscillator. During the transformation, the resulting modulated signal varies its amplitude, but the frequency remains constant. This simple modulation technique simplifies the transmitter and receiver design and is cost effective.

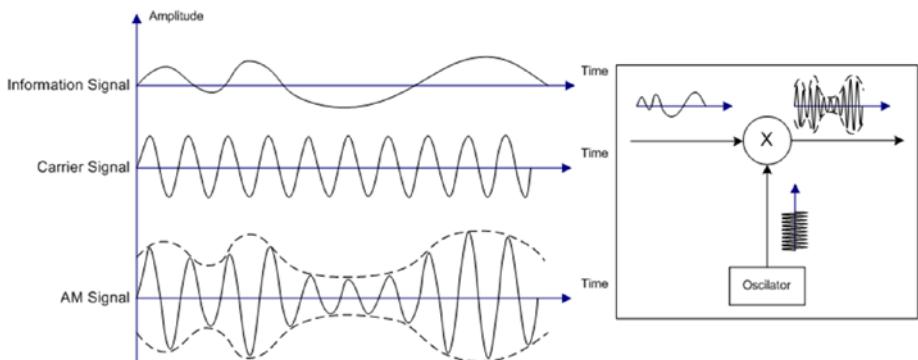


Figure 1-1. Amplitude modulation, including the information signal, carrier signal, and AM signal (source: https://en.wikipedia.org/wiki/Amplitude_modulation#/media/File:Illustration_of_Amplitude_Modulation.png by Ivan Akira, <https://creativecommons.org/licenses/by-sa/3.0>)

Amplitude-modulated signals are less resistant to noise and deliver poor sound quality compared with frequency modulation. However, amplitude modulation signals can be sent over long distances.

Frequency Modulation

Frequency modulation (FM) is widely used for FM radio broadcasting. In frequency modulation, the frequency of the carrier wave is changed in accordance with the intensity of the signal. The amplitude and the phase of the carrier wave remain constant. Only the frequency of the carrier wave changes in accordance with the signal.

Figure 1-2 shows the frequency modulation technique. The information signal is mixed with the carrier signal using a mixer. The carrier signal has a constant frequency and amplitude. When the information signal voltage is 0, the carrier frequency is unchanged. When the information signal approaches its positive peaks, the carrier frequency is increased to a maximum. But during the negative peak of a signal, the carrier frequency is reduced to a minimum. Therefore, the resulting modulated signal has a constant amplitude with varied frequencies.

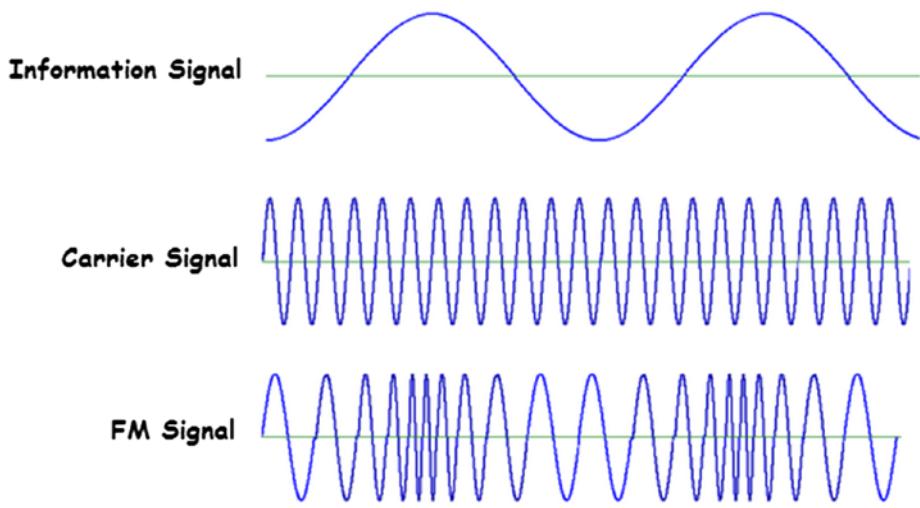


Figure 1-2. Frequency modulation, including the information signal, carrier signal, and FM signal

Frequency-modulated signals are more resistant to noise and deliver better sound quality compared with AM. They can't travel long distances and can be blocked by tall buildings or mountains.

Frequency Shift Keying

Frequency shift keying (FSK) represents a digital signal with two frequencies. One frequency could be used to represent digital 1, and the second frequency could be used to represent digital 0. Figure 1-3 shows how a digital signal is transformed into a modulated analog signal using FSK modulation. A carrier signal and two different frequencies are used to represent digital states, HIGH and LOW. The digital data signal is mixed with the carrier signal and encoded into a modulated analog signal.

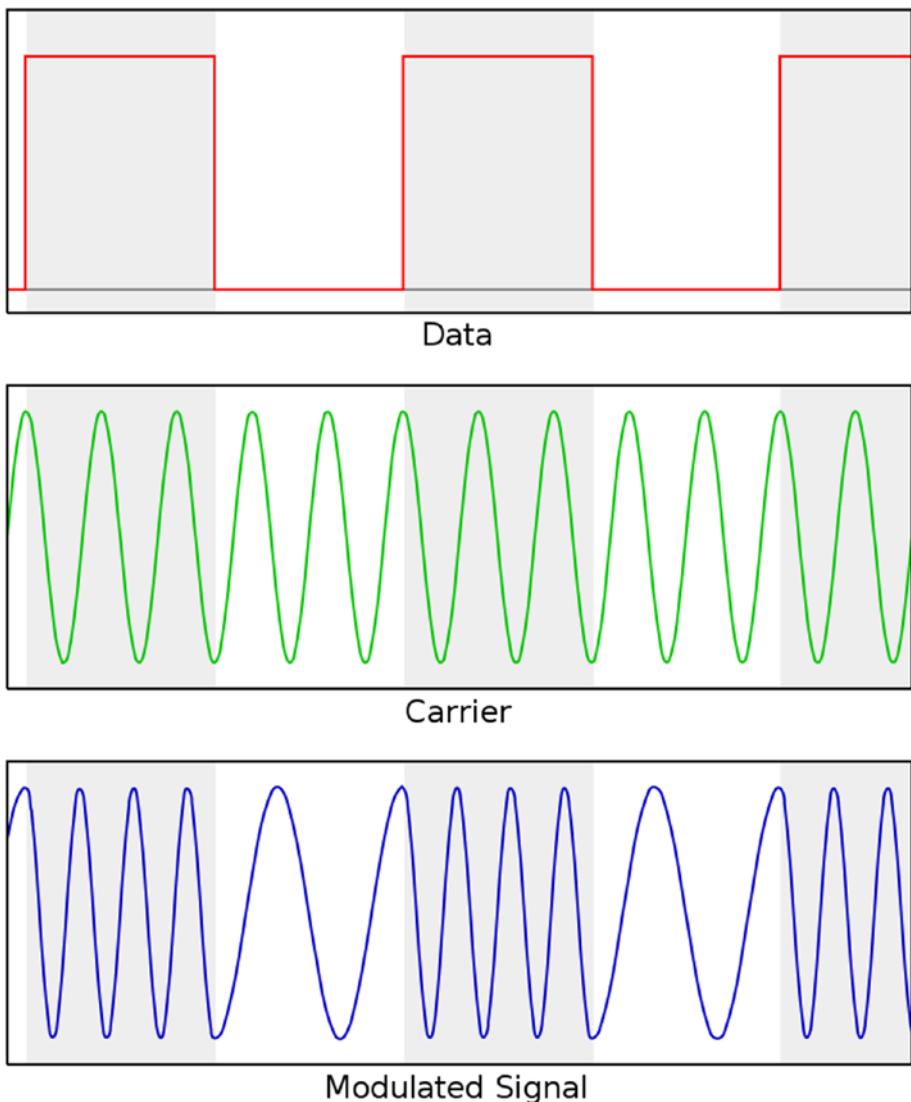


Figure 1-3. FSK modulation transformed digital signal into an analog signal using two frequencies. Each frequency represents a digital state. (Source: https://en.wikipedia.org/wiki/Frequency-shift_keying#/media/File:Fsk.svg; license: <https://creativecommons.org/licenses/by-sa/3.0/>)

Figure 1-4 shows how the signal jumps between its two frequencies (1 and 0); it is known as a *waterfall display*.

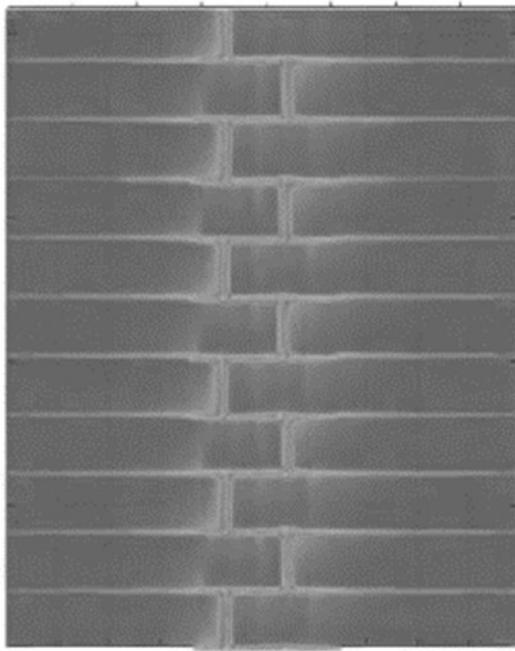


Figure 1-4. Waterfall display for frequency shift keying

Chirp Spread Spectrum

Chirp spread spectrum (CSS) modulation maintains the same low-power characteristics as FSK modulation. It is a spread spectrum technique that uses wideband linear frequency-modulated chirp pulses to encode information.

CSS was developed for radar applications in the 1940s. It has been used in military and space communications for decades because of its long communication distances, low transmission power requirements, and less interference.

LoRa Spread Spectrum Modulation

You already know that LoRa modulation uses the chirp spread spectrum to encode data. Each bit is spread by a chipping factor. The number of chips per bit is called the *spreading factor* (SF). CSS uses spreading factors from 7 to 12. Small spreading factors provide high data rates and require less over-the-air time. Large spreading factors provide low data rates and require more over-the-air time.

LoRa modulation is more complex and resilient to background noise. Rather than just use the two frequencies of SFK, it sweeps between the two frequencies, as shown in Figure 1-5. The bottom part of the image shows the frequency sweeps from up to down. The top part of the image shows the frequency sweeps from down to up.

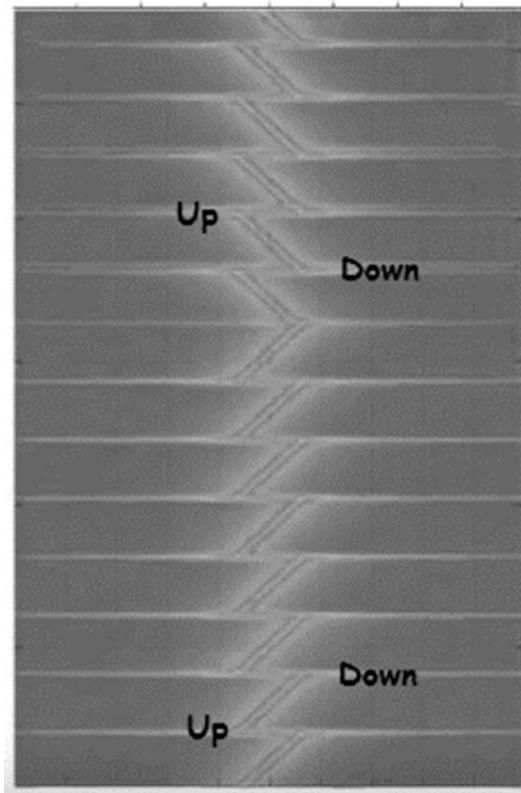


Figure 1-5. Sweeping between the two frequencies (up to down and down to up)

CHAPTER 1 INTRODUCTION TO LORA AND LORAWAN

The LoRa Spread Spectrum Modulation has the following properties:

- Bandwidth scalable
- Constant envelope/low power
- High robustness
- Multipath/fading resistance
- Doppler resistance
- Long-range capability
- Enhanced network capacity
- Ranging/localization

LoRa Applications

LoRa is suitable for building long-range communication channels with low data rates. LoRa wireless sensor networks can be used to build a wide array of applications. Some of them are as follows:

- Agriculture processing
- Air pollution monitoring
- Asset tracking
- Cattle tracking
- Energy management and sustainability
- Fall detection
- Fire detection
- Fleet management
- Fleet tracking

- Home security
- Indoor air quality management
- Industrial temperature management
- Liquid presence detection
- Locating stolen vehicles and cargo
- Medical refrigerator monitoring
- Parking management
- Precision farming
- Predictive maintenance
- Radiation leak detection
- Shipment quality
- Smart home asset tracking
- Smart irrigation
- Smart lighting
- Smart parking
- Tank flow monitoring
- Waste management
- Water flow monitoring
- Water management and protection
- Wireless gas-level monitoring

Network Coverage

A single gateway can cover entire cities or hundreds of square miles/kilometers. The coverage highly depends on obstructions (buildings, trees, hills), the environment (heavy rain), and technical factors (high-level radio interference, antenna type). Figure 1-6 shows a coverage map of LoRa gateways distributed in New Zealand by Spark Digital.

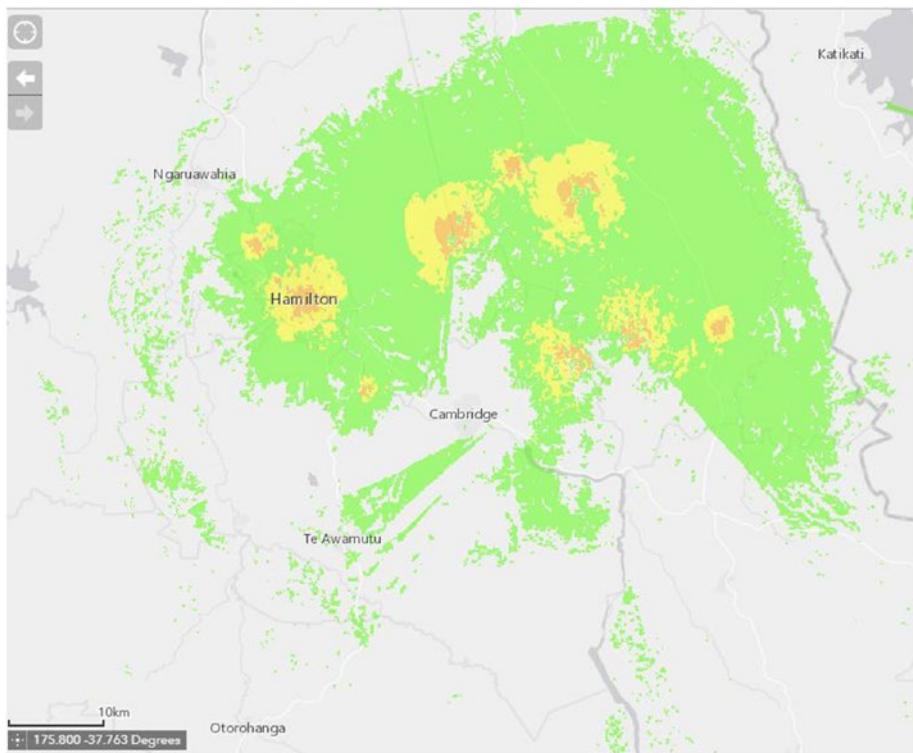


Figure 1-6. Source: <https://www.SparkDigital.co.nz/solutions/mobility/iot/loracoverage/>

The coverage is greater than any other standardized communication technologies such as Bluetooth, ZigBee, Wi-Fi, or cellular. The link budget is the primary factor in determining the range in a given environment for any communication link, typically given in decibels (dB). LoRa modulation can be used to replace some parts of new or existing IoT networks that require small payloads and data rates.

Example

Let's assume we have a vehicle tracking system based on traditional GPS trackers. Each vehicle transmits its current geographical location periodically to a GPS server through a cellular network. Each GPS tracker has a data plan. Let's also assume an organization has 100 vehicles, so they should pay \$100 for the Internet plan.

If we replace each GPS tracker with a LoRa sensor node and a few LoRa gateways, we will only require cellular data plans for the gateways. Let's say we installed ten gateways to cover the entire geographical area. With this implementation, we can highly reduce the cost for cellular data and increase the portion of ownership of the network.

Low-Power Wide Area Networks

LoRa networks are considered low-power wide area networks (LPWANs). The nodes can be battery powered, and the lifetime of the battery is about ten years. The nodes transmit data in small amounts over long distances and a few times per hour (for example, every ten minutes).

What Is LoRaWAN?

Long Range Wide Area Network (LoRaWAN) is the communication protocol and system architecture for the network, while the LoRa physical layer enables the long-range communication link. LoRaWAN has the capacity to have an effect on the following:

- Battery lifetime of the node
- Network capacity
- Quality of service
- Security
- Applications served by the network

LoRaWAN consists of end nodes (end devices), gateways (concentrators), a network server, and application servers (Figure 1-7). In a LoRaWAN network, data transmitted by an end node is typically received by multiple gateways. Once the data is received, each gateway will forward the received packet to the network server through cellular, Ethernet, Wi-Fi, or satellite. The software running on the gateway is responsible for forwarding any incoming data packet to the network server. This software is known as a *packet forwarder*.

The network server sends and receives LoRaWAN messages to and from devices and communicates with upstream application servers. The application server is the destination for device application data sent as the payload in LoRaWAN messages.

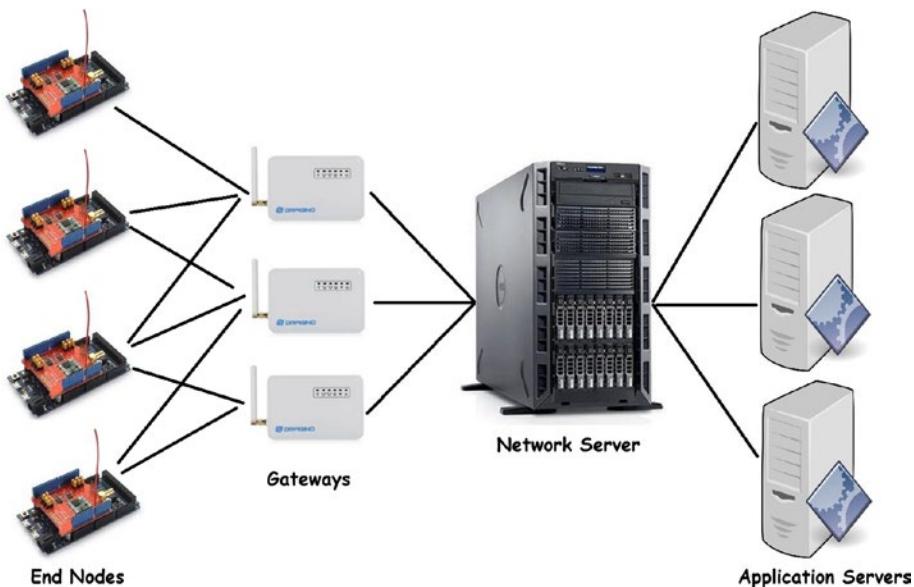


Figure 1-7. Elements of LoRaWAN

Packet Forwarders

A *packet forwarder* is software running on the LoRa gateway. It allows the LoRa concentrator to transmit and receive LoRa packets for both uplinks and downlinks from end nodes to network servers and from network servers to end nodes. Packet forwarders can be categorized into single-channel packet forwarders and multichannel packet forwarders. Only multichannel packet forwarders are LoRaWAN compatible.

Usually a packet forwarder does the following:

- Forwards LoRa packets received by the concentrator (LoRa module) to the network server through the IP/UDP link
- Emits LoRa packets that are sent by the network server

The following are some of the packet forwarders available for different platforms. But they are still developing, and more should be available soon.

- Semtech UDP packet forwarder (https://github.com/Lora-net/packet_forwarder): The Semtech packet forwarder code can be compiled with the Semtech Lora library (https://github.com/Lora-net/lora_gateway). See https://github.com/Lora-net/packet_forwarder/wiki/Use-with-Raspberry-Pi for compile options. It works with the Semtech SX1301 chipset.
- TTN packet forwarder (https://github.com/TheThingsNetwork/packet_forwarder): This works with Multitech Conduit, Kerlink IoT Station, and Raspberry Pi and iC880a setups.
- Dragino single-channel packet forwarder (www.dragino.com/downloads/index.php?dir=motherboards/lg01/sketch/&file=Single_pkt_fwd_v004.ino.hex): This software is written for Dragino LoRa gateways. It works with Semtech SX1272, SX1276, and SX1278 chips.
- Raspberry Pi single-channel packet forwarder (https://github.com/tftelkamp/single_chan_pkt_fwd): This works with the Semtech SX1272 transceiver (HopeRF RFM92W) and SX1276 (HopeRF RFM95W).

Hardware for End Devices

Semtech offers a wide range of chipsets for building end devices to work with different frequency ranges. Table 1-1 shows some of the popular chipsets that can be used to build end devices with the Arduino and Raspberry Pi.

Table 1-1. Chipsets for End Devices /End Nodes

Part Number	Description	Source
SX 1272	Long-range, low-power RF transceiver 860–1000 MHz with LoRa technology	https://www.semtech.com/products/wireless-rf/lora-transceivers/SX1272
SX 1276	137–1020 MHz long-range, low-power transceiver	https://www.semtech.com/products/wireless-rf/lora-transceivers/SX1276
SX 1278	137–525 MHz long-range, low-power transceiver	https://www.semtech.com/products/wireless-rf/lora-transceivers/SX1278

Some transceiver modules are available for building end devices without heavy soldering and additional electronic components. Figure 1-8 shows a LoRa transceiver breakout based on the SX1276/SX1278 chipset. It can be easily used with the Arduino or Raspberry Pi to build end nodes and single-channel gateways.

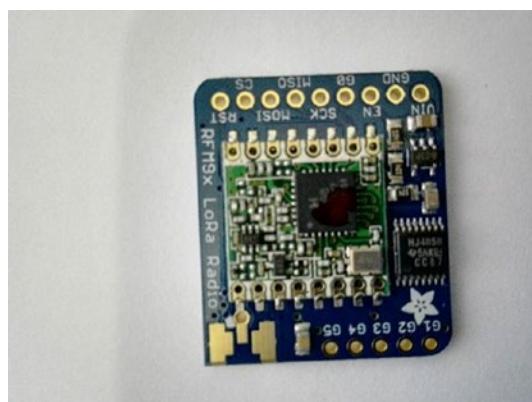


Figure 1-8. Adafruit RFM96W LoRa radio transceiver breakout, 433 MHz

Hardware for Gateways

LoRa gateways can handle data coming from many end devices simultaneously. These gateways can be built from scratch with Semtech chipsets.

Semtech offers the chipsets in Table 1-2 for designing and building multichannel LoRa gateways.

Table 1-2. *Chipsets for Multichannel Gateways*

Part Number	Description	Source
SX 1301	Digital baseband chip for outdoor LoRaWAN macro gateways	https://www.semtech.com/products/wireless-rf/lora-gateways/SX1301
SX 1308	Digital baseband chip for indoor LoRaWAN pico gateways	https://www.semtech.com/products/wireless-rf/lora-gateways/SX1308

However, single-channel LoRa gateways can be built with the same chipsets designed for the end devices (Table 1-3).

Table 1-3. *Chipsets for Single-Channel Gateways*

Part Number	Description	Source
SX 1272	Long-range, low-power RF transceiver 860–1000 MHz with LoRa technology	https://www.semtech.com/products/wireless-rf/lora-transceivers/SX1272
SX 1276	137–1020 MHz long-range, low-power transceiver	https://www.semtech.com/products/wireless-rf/lora-transceivers/SX1276
SX 1278	137–525 MHz long-range, low-power transceiver	https://www.semtech.com/products/wireless-rf/lora-transceivers/SX1278

Also, there are hundreds of ready-to-use LoRa gateways available on the market. Some of them are as follows:

- Dragino LG01-P IoT gateway (www.dragino.com/products/lora/item/117-lg01-p.html): This is a single-channel, indoor gateway (Figure 1-9) and is available in different frequencies such as 868, 915, and 433 MHz.



Figure 1-9. Dragino LG01-P IoT gateway (courtesy of Dragino, www.dragino.com)

- Dragino LG02 Dual Channels LoRa IoT gateway (www.dragino.com/products/lora/item/135-lg02.html): This gateway can simultaneously receive two channels. It also can transmit data on a single channel (Figure 1-10). It is available in different frequencies such as 868, 915, and 433 MHz.



Figure 1-10. Dragino LG02 Dual Channels LoRa IoT gateway (courtesy of Dragino, www.dragino.com)

- Waspmove gateway SX1272 LoRa module SMA 4.5 dBi, 868 MHz (<https://www.cooking-hacks.com/waspmove-gateway-sx1272-lora-sma-4-5-dbi-868-mhz>): See Figure 1-11.



Figure 1-11. Wasp mote gateway SX1272 (courtesy of <https://www.cooking-hacks.com>)

- Wasp mote gateway SX1272 (courtesy of <https://www.libelium.com/products/wasp-mote-sense/>): See Figure 1-12.



Figure 1-12. Wasp mote Plug & Sense (courtesy of www.libelium.com)

CHAPTER 1 INTRODUCTION TO LORA AND LORAWAN

- The Things gateway (<https://www.element14.com/community/docs/DOC-83605/l/things-gateway-use-a-long-range-and-low-power-radio-frequency-protocol-called-lorawan-and-for-short-range-bluetooth-42>): See Figure 1-13.



Figure 1-13. The Things gateway (courtesy of <https://www.element14.com/>)

- Cisco Wireless Gateway for LoRaWAN (<https://www.cisco.com/c/en/us/products/routers/wireless-gateway-lorawan/index.html>): See Figure 1-14.



Figure 1-14. Cisco Wireless Gateway for LoRaWAN (courtesy of <https://www.cisco.com>)

- Figure 1-15 shows the SX1301 and SX1278 eight-channel LoRaWAN gateway module that can be used to build LoRa gateways with the Raspberry Pi. These modules are expensive, so in this book we will focus on building single-channel LoRa gateways.

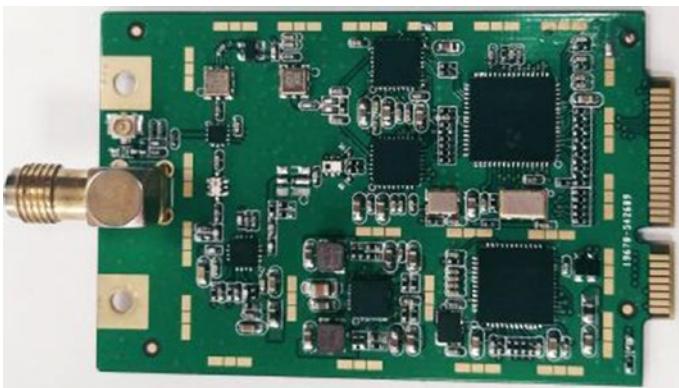


Figure 1-15. SX1301-based eight-channel LoRa gateway module

LoRaWAN Frequencies

LoRa Alliance defines regional frequency profiles to operate LoRaWAN for different regulatory regions worldwide. Table 1-4 lists the frequencies allowed to be used in some countries.

Table 1-4. LoRaWAN Frequencies and Channel Plans

Country	Band/Channels	Channel Plan
United States	902–928 MHz	US902-928, AU915-928
United Kingdom	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other
Canada	902–928 MHz	US902-928, AU915-928
Australia	915–928 MHz	AU915-928, AS923
India	865–867 MHz	IN765-867
France	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Sri Lanka	433.05–434.79 MHz	EU433

The full “LoRaWAN Regional Parameters” document can be downloaded from https://www.lora-alliance.org/sites/default/files/2018-04/lorawantm_regionall_parameters_v1.1rb_-_final.pdf.

Summary

LoRaWAN has significant cost savings in its deployment and required infrastructure compared to existing systems. LoRa and LoRaWAN provide a long range (greater than cellular, deep indoor coverage, star topology), maximum battery life (low power optimized, 10- to 20-year battery life), multiple uses (high capacity, multitenant, public network), and low cost (minimal infrastructure, low-cost end nodes, open software).

CHAPTER 2

Obtaining and Preparing Hardware

In Chapter 1, you learned that the LoRaWAN architecture consists of end nodes (also known as *end devices* or *sensor LoRa nodes*) and gateways. End nodes and gateways can be built with various hardware and software options. This chapter introduces some easy-to-find hardware that you can use to build end nodes and single-channel gateways.

The radio transceivers we will be using for this book don't support building LoRaWAN-compatible multichannel gateways. You should use them for educational and testing purposes only. In fact, using them for industrial purposes may violate the LoRaWAN specification and some of the LoRa regional regulations.

LoRa End Node

A LoRa end node consists of a LoRa radio, sensors, an antenna, and a power supply. Some have actuators too. The LoRa radio can transmit or receive data. It is also known as a *transceiver*. An end node can be built by combining various hardware and software options. Some end nodes are physically fixed and transmit sensor data to a LoRa gateway. Some end nodes transmit data to multiple LoRa gateways. Some end nodes are mobile and transmit data while moving. As an example, a LoRa

CHAPTER 2 OBTAINING AND PREPARING HARDWARE

end node with a GPS module fixed to a vehicle can send geolocation periodically to the LoRa gateway while moving within the network coverage. A LoRa end node can receive data through the downlink from the LoRa gateway.

Figure 2-1 shows a breadboard implementation of a simple LoRa sensor end node. Normally, a LoRa end node consists of a LoRa radio, microcontroller, sensor, power supply unit (PSU), and an antenna.

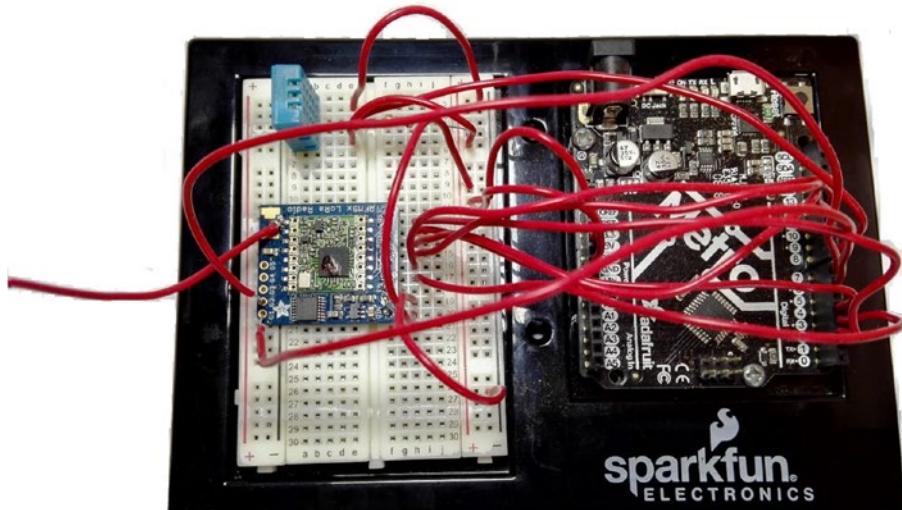


Figure 2-1. Simple LoRa sensor end node built with Arduino

Let's get started filling up our toolbox with commonly available and widely used hardware. At the end of this chapter, you will find a list of hardware with purchase links from leading hardware manufacturers, suppliers, and vendors.

RFM9x LoRa Radio Transceiver Breakouts

Adafruit manufactures and sells LoRa radio transceiver breakouts based on Hope RFM9x LoRa modules (www.hoperf.com/rf_transceiver/lora/). Each LoRa radio transceiver breakout consists of a 74HC4050D logic level translator (which converts Arduino 5V logic to 3.3 V logic that Hope RFM9x can understand) and an AP2112 CMOS process low-dropout linear regulator (which provides the regulated 3.3 V to the LoRa module) that allows you to easily wire it with an Arduino Uno board without requiring any additional components.

These breakouts allow you to build prototypes faster with prewritten software libraries such as RadioHead, Dragino's modified RadioHead library, HopeRFLib, and so forth. You will install some of the libraries on the Arduino in Chapter 3.

Adafruit LoRa radio transceiver breakouts are available in two versions: 868/915 MHz and 433 MHz. Both versions look identical but use different chipsets.

With a simple wire antenna, you can achieve a transmission range of approximately 2 km, but it can be tweaked up to 20 km with various hacks such as avoiding obstructions; changing the frequency (F), bandwidth (BW), spreading factor (SF), code rate (CR), and power output in the software; or using different antenna options.

Let's explore two versions of the radio transceiver breakouts.

868 MHz/915 MHz Version

The 868 MHz/915 MHz LoRa radio transceiver breakout (Figure 2-2) is based on the Hope RFM95W module, which features the Semtech SX1276 chipset.

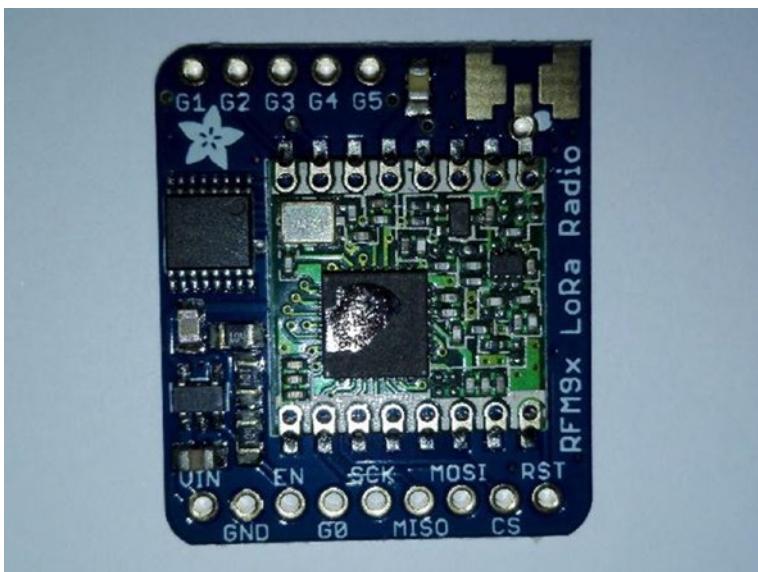


Figure 2-2. Adafruit RFM9x LoRa radio transceiver breakout for 868/915 MHz (<https://www.adafruit.com/product/3072>)

This radio transceiver breakout is suitable for operating over the 868 MHz and 915 MHz license-free Industry Scientific and Medical (ISM) frequency bands in the following regions:

- European ISM at 868 MHz
- American ISM at 915 MHz

The operation frequency can be configured as 868 MHz or 915 MHz with software (e.g., the RadioHead library).

Figure 2-3 shows the Hope RFM96W module that can be found on the 868 /915 MHz version of this radio transceiver breakout.



Figure 2-3. Hope RFM96W module and chipset

433 MHz Version

The 433 MHz version of the radio transceiver breakout (Figure 2-4) is based on the Hope RFM98W module, which features the Semtech SX1278 chipset.



Figure 2-4. Front of the Adafruit RFM9x LoRa radio transceiver breakout, 433 MHz

Figure 2-5 shows the RFM98W module that can be found on the 433 MHz version of the radio transceiver breakout.

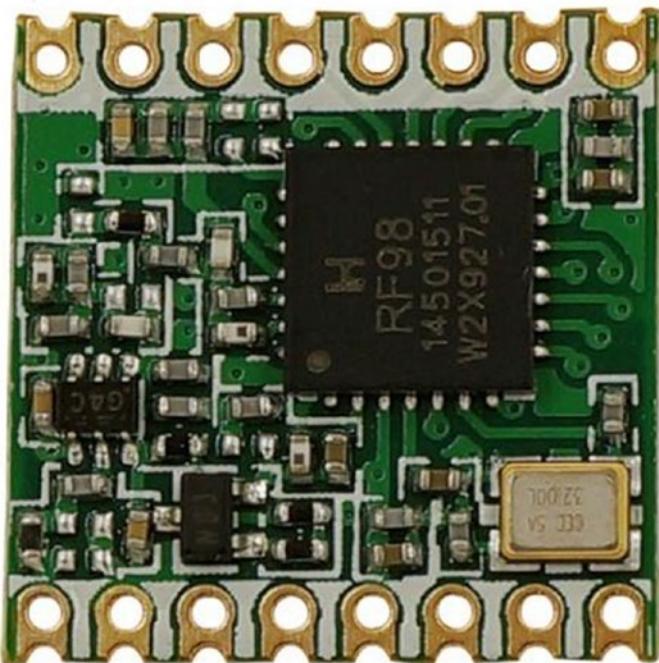


Figure 2-5. Hope RFM98W module and chipset

The 433 MHz version is suitable for operating over amateur or license-free ISM bands in the following regions:

- ITU “Europe” license-free ISM
- ITU “American” amateur with limitations

Finding the Frequency

The frequency of the radio transceiver breakout can be found on the plastic bag (Figure 2-6), or sometimes you may receive it in a different form. As a good practice, write down the correct frequency on the back side of the PCB. A “Freq” field is provided for this (Figure 2-7).

These breakout boards are much smaller than the figures shown in this book, so you will need a tool like a helping third-hand magnifier (<https://www.adafruit.com/product/291>) to tightly hold them while magnifying to clearly see the things on the board.



Figure 2-6. The frequency of the radio transceiver breakout is printed on a sticker affixed to the plastic bag. This one says it is a 433 MHz LoRa radio transceiver breakout. The product page at <https://www.adafruit.com/product/3073> named this product as “Adafruit RFM96W LoRa Radio Transceiver Breakout - 433 MHz - RadioFruit.” The bag also includes a 0.1-inch male header stripe and a sticker with the MAC address printed on it.



Figure 2-7. Back of Adafruit RFM9x LoRa radio transceiver breakout, 433 MHz (<https://www.adafruit.com/product/3073>). Note that two spaces are provided, Node ID and Freq.

To build a peer-to-peer link (or master-slave link), you will need two LoRa radio transceiver breakouts. Before purchasing anything, please check the regulations for operating LoRa radios over license-free ISM frequency bands.

MAC Address

Every radio transceiver breakout has a MAC address printed on a sticker (Figure 2-8) that can be found inside the plastic bag. The MAC address can be used to identify the radio transceiver universally, and it is unique. A LoRaWAN uses these addresses in the MAC payload.

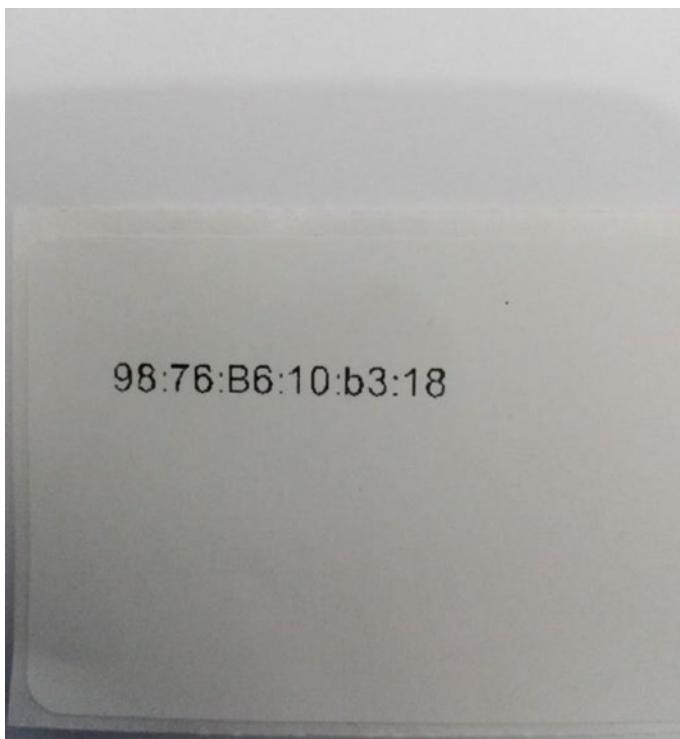


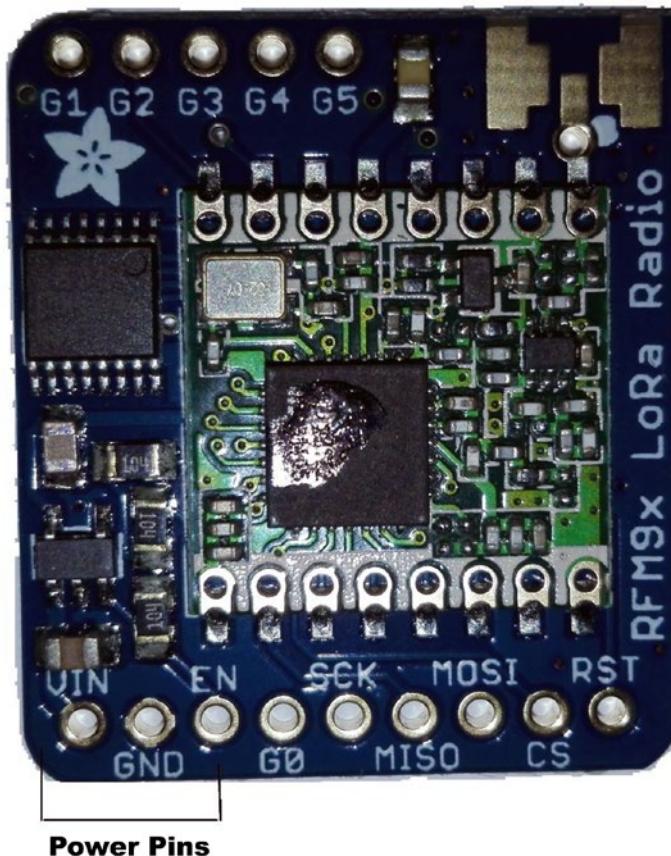
Figure 2-8. MAC address for the radio breakout, which is universally unique

Pins

The LoRa radio transceiver breakout exposes different types of pins such as power, SPI, and GPIO. This is common for both versions.

Power

The pins can be used to power the breakout and shut down the radio (Figure 2-9).



Power Pins

Figure 2-9. Power pins: VIN, GND, and EN

- *VIN*: Through the power in pin, you can supply between 3.3 and 6 VDC. The peak current draw of the radio is about 150 mA, so make sure to supply that much of the current to work it properly. The Arduino Uno can supply 150 mA through the 5 V pin.
- *GND*: The ground is for the logic and power.
- *EN*: This pin is internally connected to the enable pin of the regulator. It is pulled high to VIN by default. You can completely cut power to the radio by connecting it to the GND pin.

Serial Peripheral Interface

These breakouts support the Serial Peripheral Interface (SPI). SPI is the protocol used by microcontrollers for communicating with one or more peripheral devices quickly over short distances. All the communication will be handled through SPI between the radio transceiver and the Arduino or Raspberry Pi. The SPI pins on the radio transceiver support the 3.3 V and 5 V logic levels (Figure 2-10). As pointed out earlier, the level shifter included with the radio transceiver breakout makes the 3.3 V to 5 V logic level conversion. It automatically selects the logic level conversion depending on the VIN pin (power in pin).

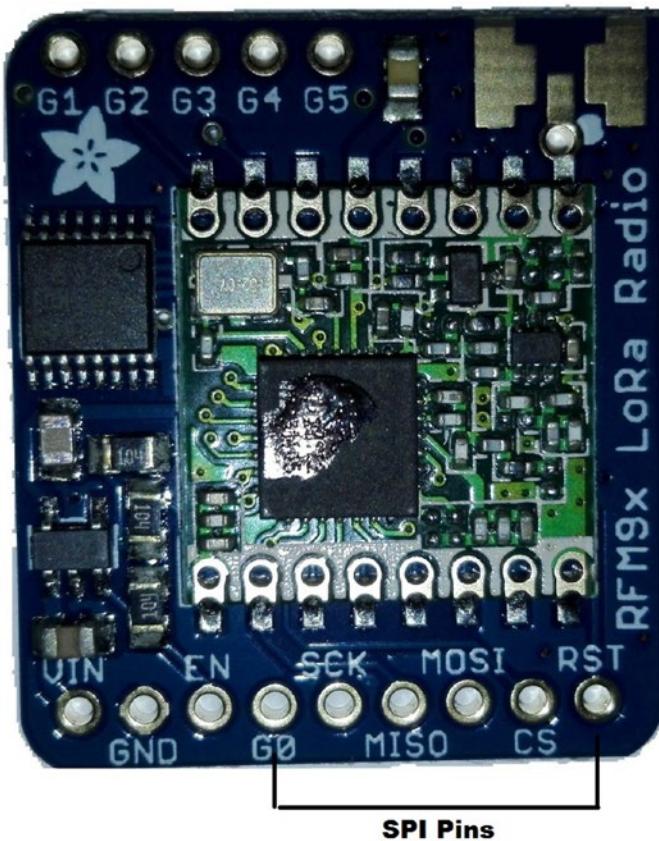


Figure 2-10. SPI pins: G0, SCK, MISO, MOSI, CS, and RST

The following pins on the radio transceiver can be used for SPI communication with the microcontroller (Arduino Uno or Raspberry Pi):

- **MISO:** This is the Master In Slave Out pin; it's for data sent from the radio transceiver to your microcontroller.
- **MOSI:** This is the Master Out Slave In pin; it's for data sent from your microcontroller to the radio transceiver.
- **CS:** This is the Chip Select pin; drop it low to start an SPI transaction. It is an input to the chip.

- *SCK*: This is the SPI Clock pin; it's an input to the chip.
- *RST*: This is the Reset pin for the radio. It's pulled high by default. Pull it down to ground to put it into reset.
- *G0*: This is used for interrupt request notification from the radio to the microcontroller.

Assembling Headers

Each LoRa radio transceiver breakout comes with a male header strip (0.1 inch). You should first solder them onto the breakout to use it with a breadboard. The following steps will show how to assemble male headers:

- Cut part of nine pins from the male header (Figure 2-11).



Figure 2-11. 0.1-inch male header strip

- Insert the long end of the pins into the breadboard (Figure 2-12).

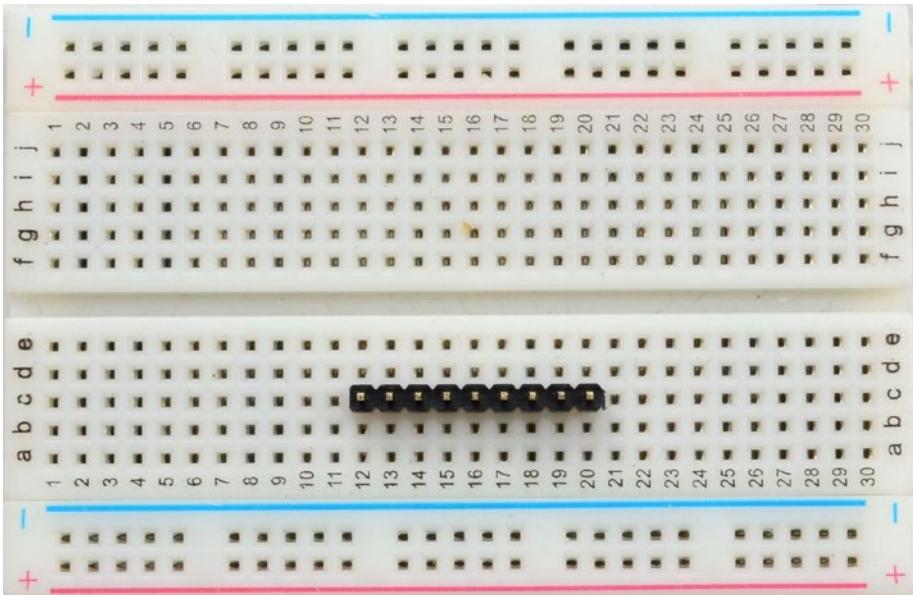


Figure 2-12. Inserting male headers into the breadboard

- Place the breakout board over the header pins (Figure 2-13).

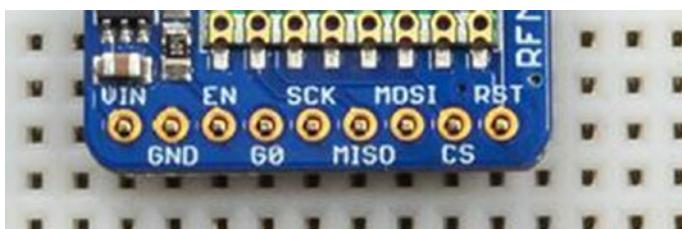


Figure 2-13. Placing breakout over the header pins

- Solder all the breakout pads.

Antenna

LoRa radio transceiver breakouts need an antenna to transmit and receive signals. Antenna provides different antenna connecting options. The options are as follows:

- Whip or wire antenna
- External antenna through U.FL connector
- External antenna through RP-SMA connector

Soldering Wire Antenna

A *wire antenna* (also known as *whip antenna*) is a cost-effective way to achieve up to 2 km line-of-sight communication. It offers low gain, though. A piece of 22 AWG solid-core wire (Figure 2-14) can be used to build a wire antenna.



Figure 2-14. A solid-core wire spool. They come in different colors.

The length of the antenna wire depends on the frequency of the radio transceiver breakout. This is known as *quarter-wave whip antenna* because the length is one-quarter a full wavelength at the transmission frequency. A simple formula can be used to calculate the wavelength, as shown here:

$$\text{wavelength } (\lambda) = \text{wave velocity } (v) / \text{frequency } (f)$$

Here, the wavelength is in meters (m), the wave velocity of the radio signal in a vacuum or air is 299,792,458 m/s, and the frequency is in Hertz.

The following example shows how to calculate the antenna length for the 433 MHz frequency:

$$\begin{aligned} \text{Wavelength} &= 299792458 \text{ ms}^{-1} / 433000000 \text{ Hz} \\ &= 0.69 \text{ m} \\ &= 69 \text{ cm} \end{aligned}$$

$$\begin{aligned} 1/4 \text{ of the wavelength} &= 69 \text{ cm} / 4 \\ &= 17.3 \text{ cm} \end{aligned}$$

Approximately, the previous formula will produce an antenna length of 17.3 cm.

In practical use, you can use the following values for different frequencies:

- 433 MHz: 6.5 inches, or 16.5 cm
- 868 MHz: 3.25 inches, or 8.2 cm
- 915 MHz: 3 inches, or 7.8 cm

In this exercise, you will solder a piece of solid-core wire onto the radio transceiver breakout to build a wire antenna. Follow these steps:

- Take a spool of solid-core wire and cut a piece of wire using a wire cutter that matches with the frequency of your radio transceiver breakout.

CHAPTER 2 OBTAINING AND PREPARING HARDWARE

- Strip a millimeter or two off the end of the wire using a wire stripper. First, tin both the wire and the ANT pad. Then, solder the wire onto the ANT pad of the breakout. Use a mini vise to hold the PCB while soldering.
- Once you have soldered the wire antenna, the breakout should look like Figure 2-15.

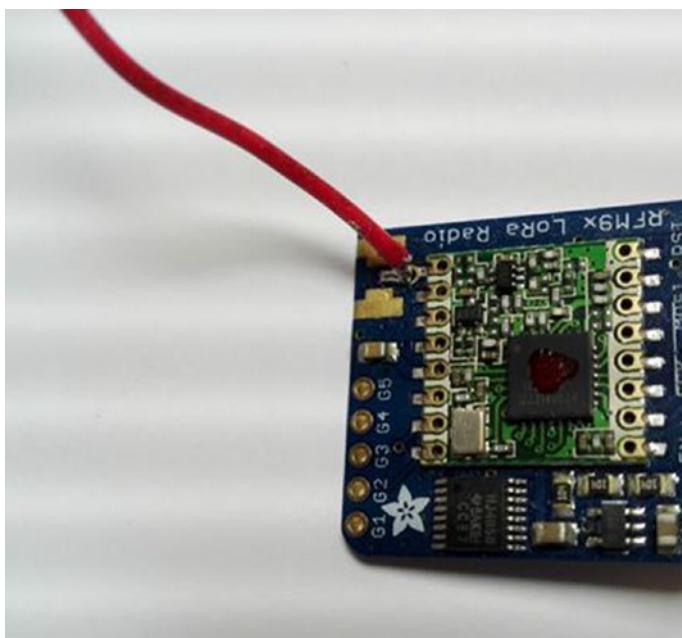


Figure 2-15. *wire antenna*

- Keep the antenna as vertical as possible for the signal to reach the maximum distance.

Arduino

Arduino is an open source prototyping platform. It consists of a processor, RAM, and an I/O line to connect to external peripherals. In this book, you will be using the Arduino Uno board to build LoRa end nodes. It is based on the ATmega328P microcontroller.

Let's take a look at some useful features that can be found on the Arduino Uno board.

- 14 digital input/output pins (6 pins can be used as PWM outputs). These pins have 5 V logic and provide 20 mA each.
- Six analog inputs.
- One SPI interface.
- One I2C interface.
- Built-in hardware serial and software-defined software serial.
- Recommended input voltage: 7 V to 12 V.
- 32 KB of flash memory (ATmega328P) of which 0.5 KB is used by the bootloader

The price of the Arduino Uno REV3 as of this writing is USD \$22 on the Arduino USA store (<https://store.arduino.cc/usa/arduino-uno-rev3>). It is a little bit expensive compared to the Adafruit Metro (Figure 2-16). The Adafruit Metro is only about USD \$17 and is recommended to build the projects in this book. The Adafruit Metro even provides some extra features.

- Optibooth bootloader
- Switch to cut off the power from DC power jack
- Micro-USB port for programming and powering

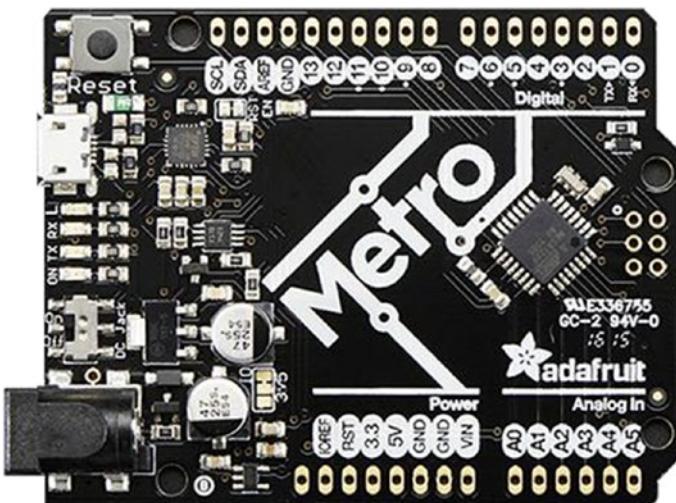


Figure 2-16. Adafruit Metro (image courtesy of Adafruit, <https://www.adafruit.com/>)

The Adafruit Metro doesn't have an ICSP header for a USB interface. A micro-USB cable (Figure 2-17) is needed to upload sketches to the Metro, and the cable can also be used to power up the board through a computer. The Metro will automatically switch between USB and DC. The switch labeled "DC Jack" can be used to cut off the power supply from the 9 V power adapter.



Figure 2-17. Micro-USB cable (image courtesy of Adafruit, <https://www.adafruit.com/>)

Mounting Plate

A plastic mounting plate (Figure 2-18) can be used to attach the Arduino Uno/Metro and the breadboard. Breadboards can be affixed by removing the protective sticker on the bottom. The Arduino can be attached using four machine screws and hex nuts. This will make your hardware setup neater and more organized. You can use solid-core wires to hook up components with the Arduino Uno/Metro.



Figure 2-18. Arduino and breadboard holder (image courtesy of SparkFun, <https://www.sparkfun.com/>)

Arduino SPI

The SPI of the Arduino Uno is accessible with digital pins 10, 11, 12, and 13. The Adafruit Metro also follows this pin layout (Figure 2-19). These pins use the 5 V logic level. Table 2-1 shows the Arduino SPI pin numbers and their functions.

Table 2-1. Arduino SPI pins and their functions

Pin Number	Function
10	SS (slave)
11	MOSI
12	MISO
13	SCK

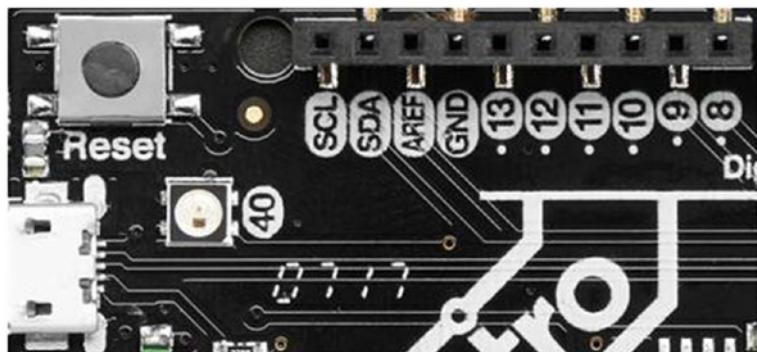


Figure 2-19. Arduino Uno/Adafruit Metro SPI pins 10, 11, 12, and 13

The Arduino Uno has a 2×3 pin header marked “ICSP.” ICSP stands for “in-circuit serial programming.” It breaks out the SPI pins of the microcontroller, power, ground, and reset. Also, there is another 2×3 pin header you can find on the Uno, and it breaks out the SPI pins of the USB interface chip. Figure 2-20 shows that the pinout of the ICSP header belongs to the ATmega328P microcontroller.

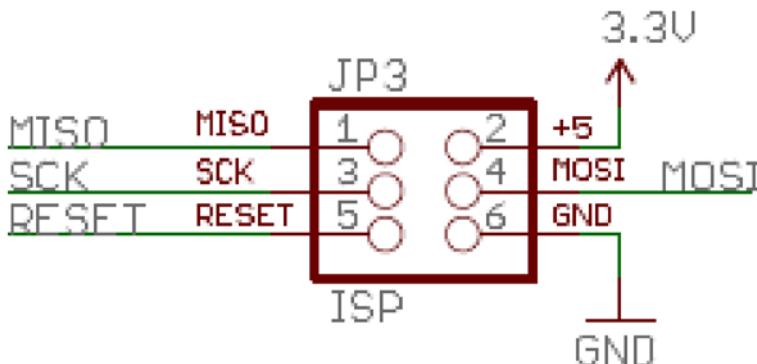


Figure 2-20. Pinout of the Arduino ICSP header. It breaks out the SPI pins of the Arduino MCU.

- *MOSI*: ICSP-4
- *MISO*: ICSP-1
- *SCK*: ICSP-3

You will be using the Arduino SPI interface to perform bidirectional communication with LoRa radio transceivers.

Hardware Serial and Software Serial

The hardware serial pins (Figure 2-21) of the Uno will be used to communicate with the GPS module and to get NMEA strings for further processing. The following are the hardware serial pins. The Uno has one hardware serial interface.

- 0: RX
- 1: TX

You can bypass the limitations of the hardware serial interfaces by using software serial interfaces. With the Arduino SoftwareSerial library, you can define any pair of digital pins as a serial interface.

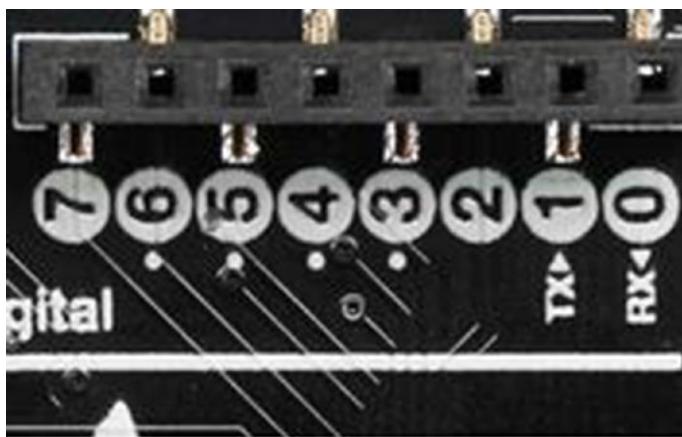


Figure 2-21. Arduino Uno/Adafruit Metro hardware serial pins marked with “TX” and “RX”

Power Supply Unit

A power supply is needed to power up the node. You can use any power source that can provide 5 V and enough current to run the microcontroller and the radio transceiver. The radio transceiver normally takes power from the microcontroller, so you don't need a separate power supply for that. An uninterruptable power supply (UPS) unit is a best solution to continuously supply power to the node during the mains power outage.

Here is the list of powering options for the Arduino Uno and Adafruit Metro:

- 9 VDC 1000 mA regulated switching power adapter (<https://www.adafruit.com/product/63>) [Arduino Uno/Adafruit Metro]
- 9 V alkaline battery (<https://www.adafruit.com/product/1321>) plus 9 V battery clip with 5.5 mm/2.1 mm plug (<https://www.adafruit.com/product/80>) [Arduino Uno/Adafruit Metro]
- 9 V alkaline battery (<https://www.adafruit.com/product/1321>) plus 9 V battery holder with switch and 5.5 mm/2.1 mm plug (<https://www.adafruit.com/product/67>) [Arduino Uno/Adafruit Metro]
- 5 V 2.4 A switching power supply with 20 AWG micro-USB cable (<https://www.adafruit.com/product/1995>) [Adafruit Metro only]

Sensors

Sensors measure changes in their environment or detect events and send them to a computer for further processing. To understand how the sensor data can be transmitted with LoRa wireless, we will be using two cheap

hardware devices. Specifically, we will be using the following sensors with LoRa end devices:

- *DHT11 sensor*: Measures temperature and humidity in the environment
- *GPS module*: Tracks the current geolocation and sends NEMA strings

Let's take a look at some important features of them.

DHT11 Basic Temperature-Humidity Sensor

The DHT11 (Figure 2-22) will be used to gather temperature and humidity data and upload it to a cloud service such as the Things Network, ThingsSpeak, or Adafruit IO. You can plug the DHT11 into any breadboard. The DHT11 sensor comes with a 4.7 k or 10 k pullup resistor as an extra.

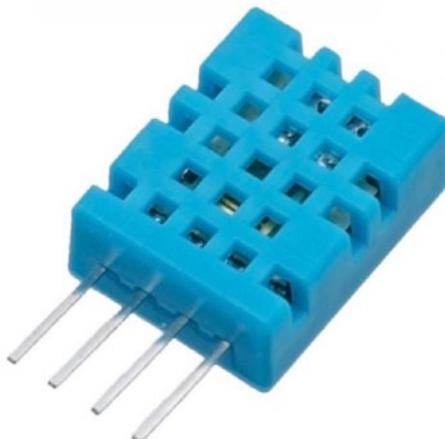


Figure 2-22. DHT11 sensor

Figure 2-23 shows how to connect the DHT11 sensor to the Arduino Uno or Adafruit Metro. The figure also shows the pinout of the sensor, marked from left to right if you hold the sensor face up.

- 1 is VCC (connect to Arduino 5 V power).
- 2 is data out. This is the data line.
- 3 is not connected.
- 4 is ground.

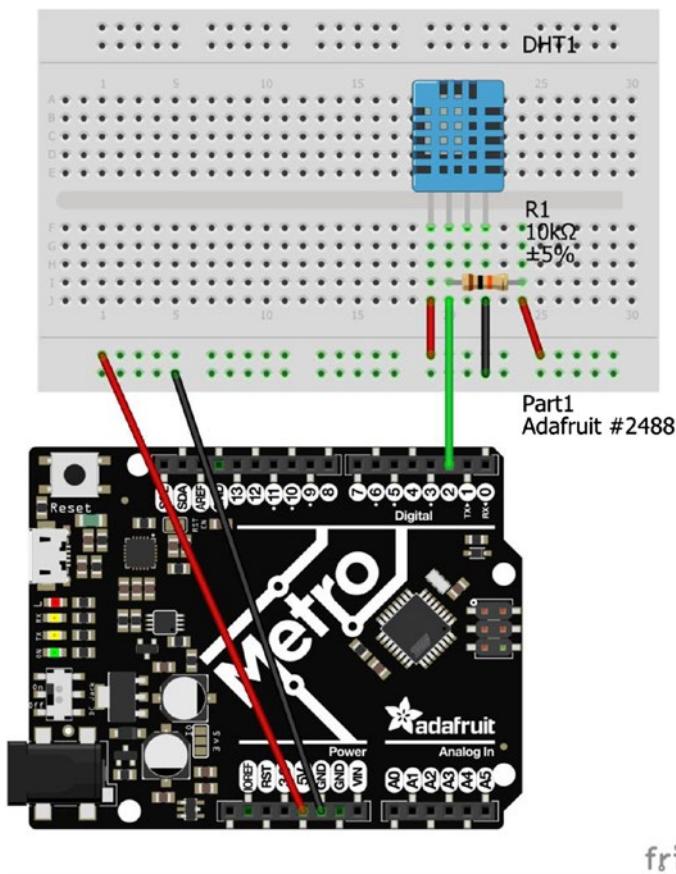


Figure 2-23. Using a pull-up resistor between the data pin and VCC, which is 5 V

GPS Breakout

The Adafruit Ultimate GPS breakout (Figure 2-24) is based on the MTK3339 chipset. It can track up to 22 satellites on 66 channels. The breakout can be powered with an Arduino 3.3 V pin. It uses hardware serial or software serial to communicate with the host microcontroller. The module has two antenna options: a built-in standard ceramic patch antenna and an external antenna. The breakout has a U.LF connector, so you can connect a GPS antenna using a U.LF to SMA adapter.

The module outputs NMEA sentences and can extract useful data such as latitude, longitude, and speed with software libraries.

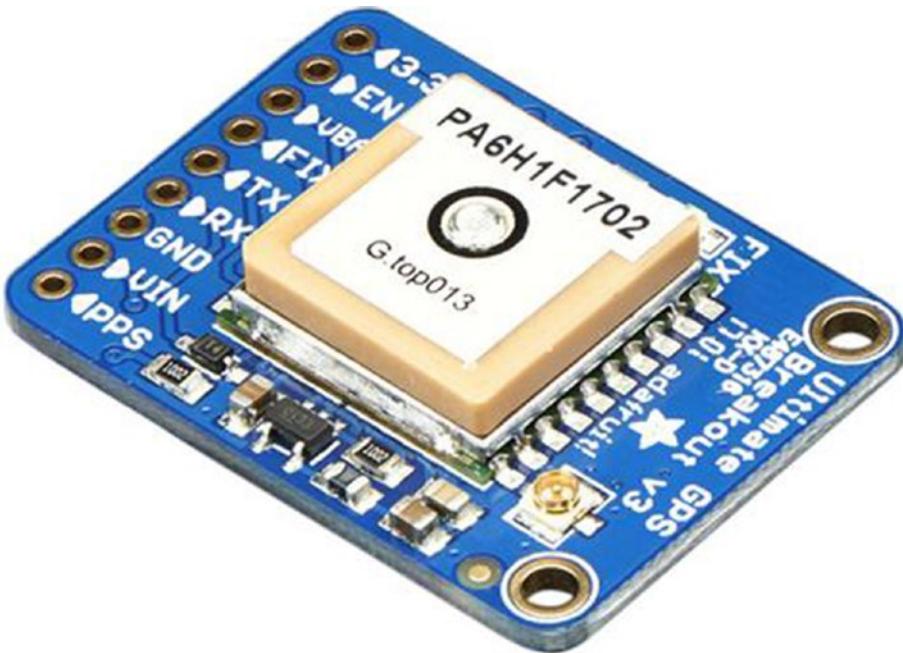


Figure 2-24. Adafruit Ultimate GPS breakout, 66 channels with 10 Hz updates, version 3 (image courtesy of Adafruit, <https://www.adafruit.com/>)

LoRa Gateway

LoRa gateways should have more processing power than the end nodes. A single-channel LoRa gateway can be built with the Raspberry Pi, the Arduino Yun Shield, or a similar hardware platform. These single-channel gateways are not LoRaWAN compliant. However, they can be used to start exploring LoRa radio networks. They can receive LoRa packets on a single frequency and hence offer poor coverage. Assume you have a LoRa end node sending data to a single-channel LoRa gateway using eight different frequencies at different times. But the single-channel LoRa gateway can receive data with only one frequency, and all other frequencies with data are ignored.

A multichannel concentrator consists of a digital baseband chip (SX1301) and one or more RF front ends to digital I and Q modulator/demodulator Multi-PHY mode transceivers (SX1257). The baseband chip is capable of receiving data on multiple frequencies at the same time.

Figure 2-25 shows a breadboard implementation of the Raspberry Pi-based single-channel LoRa gateway.

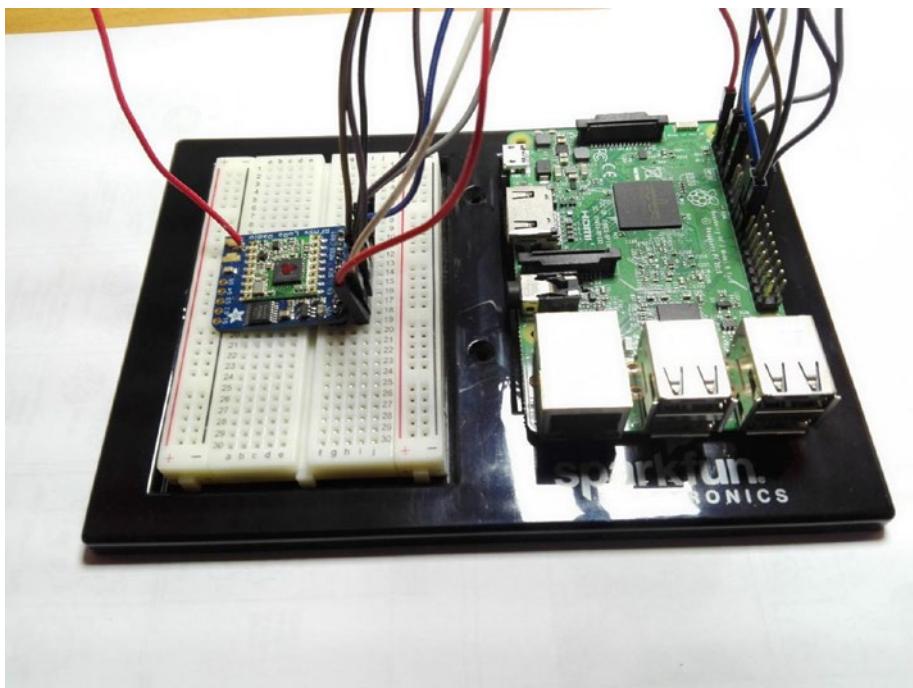


Figure 2-25. Raspberry Pi-based single-channel LoRa gateway

A single-channel LoRa gateway consists of a radio transceiver, microprocessor, power supply, and antenna. For multichannel LoRa gateways, the radio transceiver is known as *a concentrator*.

Chapter 5 shows how to build single-channel LoRa gateways with the Raspberry Pi. Building multichannel gateways is beyond the scope of this book.

Raspberry Pi

The Raspberry Pi 3 (Figure 2-26) is cheaper than other similar hardware (the Arduino Yun Shield) and ideal for building LoRa gateways. Older Raspberry Pi versions also should work with compatible gateway software packages and packet forwarders. They can be easily installed on Raspbian.

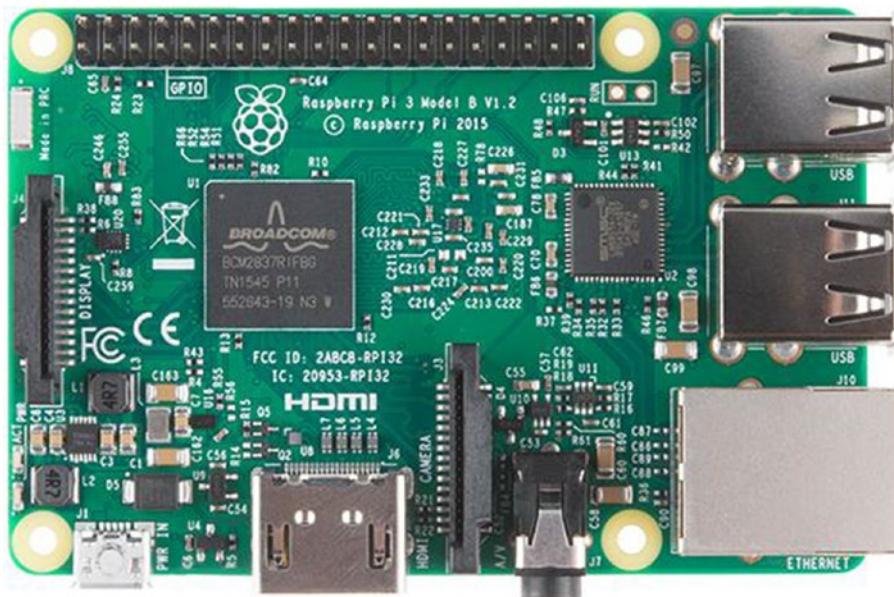


Figure 2-26. Raspberry Pi 3, model B, ARMv8 with 1 GB RAM

Raspberry Pi boards can be powered with a 5.1 V 2.5 A switching power supply (Figure 2-27) that has a micro-USB plug. A Pi board should connect to the micro-USB port on the Raspberry Pi board. Don't use 5 V/2 A-regulated power supplies with the Raspberry Pi 3; they consume more power (current) than previous versions of the Pi, though.



Figure 2-27. Connecting a 5 V-regulated power supply to the micro-USB port of the Raspberry Pi

The Pi 3 comes with a built-in Wi-Fi chip, so you don't want an external Wi-Fi dongle unless you really need more gain.

Raspberry Pi Pin Header

The Raspberry Pi 3 has a 2×20 pin header and can be started to count from the top-left pin, which is pin 1. Figure 2-28 shows the pin numbering and the functions of each pin.

Pi 3												
BCM	wPi	Name	Mode	V	Physical	V	Mode	Name	wPi	BCM		
		3.3v			1	2		5v				
2	8	SDA.1	ALT0	1	3	4		5v				
3	9	SCL.1	ALT0	1	5	6		0v				
4	7	GPIO. 7	IN	1	7	8	1	ALT5	TxD	15	14	
		0v			9	10	1	ALT5	RxD	16	15	
17	0	GPIO. 0	IN	0	11	12	0	IN	GPIO. 1	1	18	
27	2	GPIO. 2	IN	0	13	14		0v				
22	3	GPIO. 3	IN	0	15	16	0	IN	GPIO. 4	4	23	
		3.3v			17	18	0	IN	GPIO. 5	5	24	
10	12	MOSI	ALT0	0	19	20		0v				
9	13	MISO	ALT0	0	21	22	0	IN	GPIO. 6	6	25	
11	14	SCLK	ALT0	0	23	24	1	OUT	CE0	10	8	
		0v			25	26	1	OUT	CE1	11	7	
0	30	SDA.0	IN	1	27	28	1	IN	SCL.0	31	1	
5	21	GPIO.21	IN	1	29	30		0v				
6	22	GPIO.22	IN	1	31	32	0	IN	GPIO.26	26	12	
13	23	GPIO.23	IN	0	33	34		0v				
19	24	GPIO.24	IN	0	35	36	0	IN	GPIO.27	27	16	
26	25	GPIO.25	IN	0	37	38	0	IN	GPIO.28	28	20	
		0v			39	40	0	IN	GPIO.29	29	21	

BCM	wPi	Name	Mode	V	Physical	V	Mode	Name	wPi	BCM
Pi 3										

Figure 2-28. Pin organization of the Raspberry Pi 2x20 header. Each pin is marked with the pin number, name, and function.

Raspberry Pi SPI

Like the Arduino, the SPI pins of the Raspberry Pi can be used to communicate with the concentrator (the LoRa radio transceiver module). Figure 2-29 shows the SPI pins that can be found in the middle part of the 2x20 pin header.

Pin 19	MOSI
Pin 21	MISO
Pin 23	SCLK
Pin 24	CEO
Pin 26	CE1

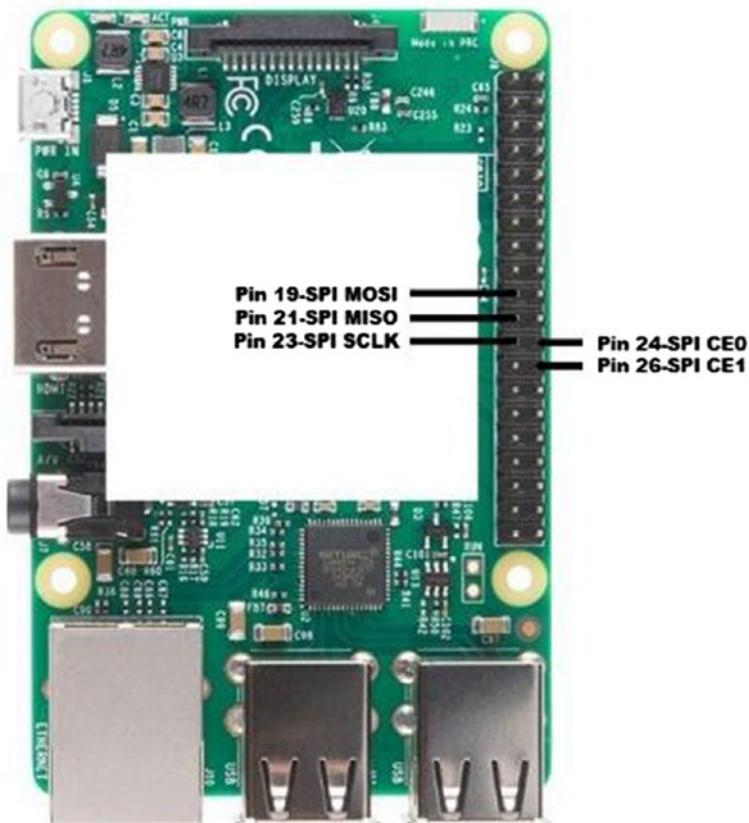


Figure 2-29. SPI pins

You can use female-to-male hookup wires to make a connection with the Raspberry Pi pins. The female end should connect with the pin header. It could start getting messy if you connect more wires to the header. To avoid this, you can use the Adafruit Pi T-Cobbler Plus breakout or SparkFun Pi Wedge.

Pi T-Cobbler Plus

The Pi T-Cobbler Plus breaks out all the power, SPI, I2C, and GPIO pins to any standard breadboard and labels them clearly. It also comes with a

40-pin ribbon cable. You can plug the 40-pin GPIO cable between the Pi computer and the Pi T-Cobbler breakout. The T-Cobbler can plug into any solderless breadboard.

Let's take a look at where you can find the SPI pins on the Pi T-Cobbler. Figure 2-30 highlights the SPI pins.

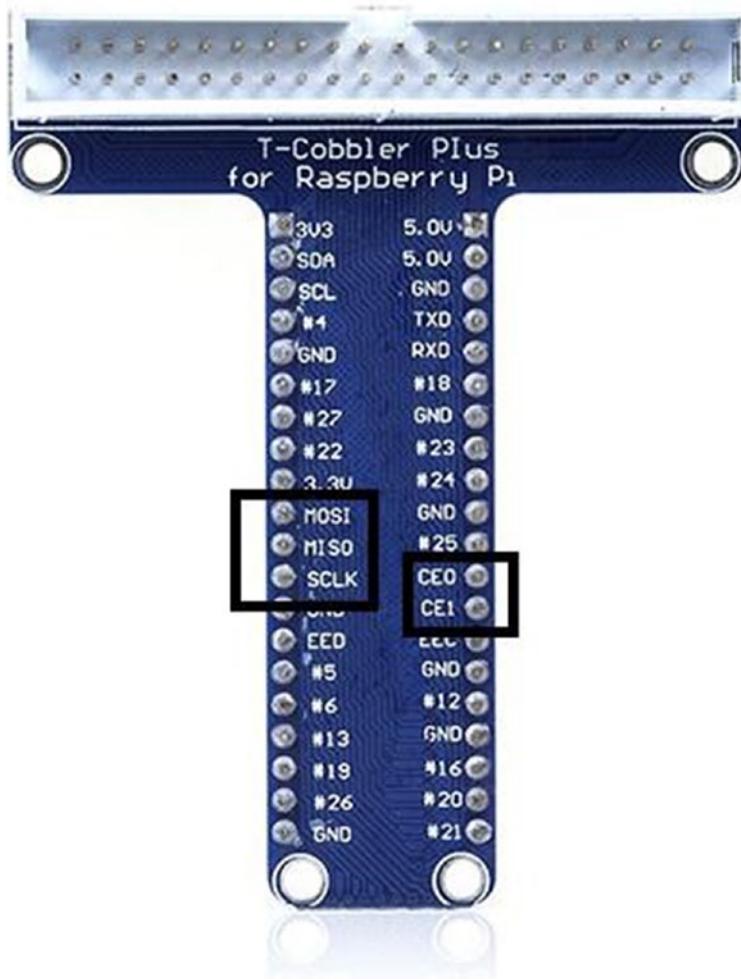


Figure 2-30. Pi T-Cobbler

Plug the Pi T-Cobbler to the breadboard and connect the ribbon cable between the T-Cobbler and the Raspberry Pi.

SparkFun Electronics offers another type of Raspberry Pi pin header breakout called the Pi Wedge (Figure 2-31). It organizes the GPIO, SPI, I2C, UART, and power pins so you can easily find them.

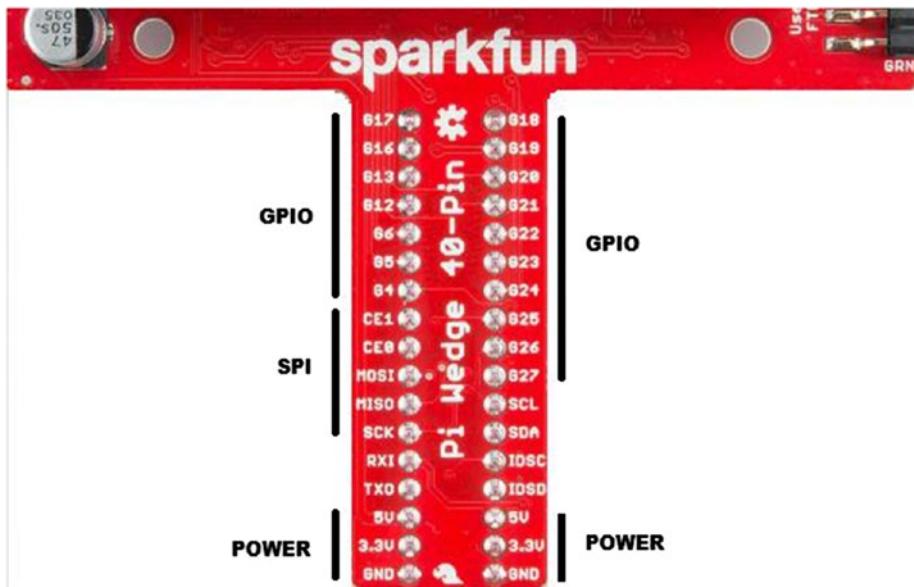


Figure 2-31. SparkFun Pi Wedge, functional grouping of pins

Dragino LG01 IoT Gateway

The LG01 (Figure 2-32) is an open source single-channel LoRa gateway. It lets you bridge a LoRa wireless network to an IP network via Wi-Fi, Ethernet, 3G cellular, or 4G cellular. The LoRa wireless allows users to send data and reach extremely long ranges at low data rates. It provides ultra-long-range spread spectrum communication and high-interference immunity.

The LG01-S has a Wi-Fi interface, Ethernet port, and USB host port. These interfaces provide flexible methods for users to connect their sensor networks to the Internet.

The LG01-S runs the open source OpenWrt system, and users are free to modify the source file or compile the system to support their customized applications.



Figure 2-32. Dragino LG01 IoT gateway (image courtesy of Dragino, www.dragino.com)

The LG01 has a built-in web server. You can manage it using the web UI or SSH through Ethernet or Wi-Fi.

Summary

Now you know that LoRa end nodes/devices and gateways can be built with Adafruit RFM9x LoRa radio transceiver breakouts. The term *transceiver* is used if you use them with end nodes, and the term *concentrator* (not the

CHAPTER 2 OBTAINING AND PREPARING HARDWARE

correct term for single-channel gateways) is used if you used them with gateways. A microcontroller like the Arduino can be used as the processing unit for the end nodes. For gateways, you will need a microcontroller with more processing power (Raspberry Pi, Dragino Yun Shield for Arduino), known as a *microcomputer*.

Sensors can also be connected to the end nodes so they can periodically send sensor data to the gateway through LoRa wireless. End nodes can be physically fixed (a node with a temperature sensor) or portable (a node with a GPS receiver fixed to a vehicle).

Antenna options such as wire whip, U.FL, SMA, and RP-SMA are available to transmit and receive data. A simple wire antenna is suitable for indoor projects.

Various power options such as wall wart adapters and batteries can be used to power up both end nodes and gateways.

Here is the complete shopping list you will need to prepare your LoRa radio network:

LoRa End Nodes and Gateway

- Choose a pair of radios from either frequency (before purchasing, check the frequency regulations in your area).
 - Two Adafruit RFM95W LoRa radio transceiver breakouts, 868 or 915 MHz, RadioFruit (<https://www.adafruit.com/product/3072>)
 - Two Adafruit RFM96W LoRa radio transceiver breakouts, 433 MHz, RadioFruit (<https://www.adafruit.com/product/3073>)

LoRa End Nodes

- Two Adafruit Metro 328 with headers, ATmega328 (<https://www.adafruit.com/product/2488>)

- One DHT11 basic temperature-humidity sensor plus extras (<https://www.adafruit.com/product/386>)
- One Adafruit Ultimate GPS breakout, 66 channels with 10 Hz updates, version 3 (<https://www.adafruit.com/product/746>)
- Two USB cables, A/Micro B, 3 ft (<https://www.adafruit.com/product/592>)

Power Supply Options

- Two 9 VDC 1000 mA-regulated switching power adapter, UL listed (<https://www.adafruit.com/product/63>)
- One of the following, with 9 V alkaline battery
 - Two 9 V battery holders with switch and 5.5 mm/2.1 mm plug (<https://www.adafruit.com/product/67>)
 - Two 9 V battery clips with 5.5 mm/2.1 mm plug (<https://www.adafruit.com/product/80>)
- Two alkaline 9 V batteries (<https://www.adafruit.com/product/1321>)
- Two half-size breadboards (<https://www.sparkfun.com/products/12002>)
- Two Arduino and breadboard holders (<https://www.sparkfun.com/products/11235>)
- One hook-up wire spool set, 22 AWG solid core, 10 by 25 ft (<https://www.adafruit.com/product/3174>)

LoRa Gateway

- One Raspberry Pi 3, model B, ARMv8 with 1 B RAM (<https://www.sparkfun.com/products/13825>)
- One wall adapter power supply, 5.1 V DC 2.5 A (USB Micro-B) (<https://www.sparkfun.com/products/13831>)

Ready-to-Use LoRa Gateway

- LG01 LoRa OpenWrt IoT gateway (https://www.tindie.com/products/edwin/lg01-lora-openwrt-iot-gateway/?pt=ac_prod_search) (before purchasing, check frequency regulations in your area)

Soldering

- Soldering iron, 30W/60W
- Helping third-hand magnifier W/magnifying glass tool, MZ101 (<https://www.adafruit.com/product/291>)
- Solder wire, RoHS lead free, 0.5mm/.02-inch diameter, 50 g (<https://www.adafruit.com/product/2473>)

Cutting and Stripping

- Multi-size wire stripper and cutter, 5023 (<https://www.adafruit.com/product/147>)

The next chapter introduces the essential software components that you will need to build LoRa radio networks.

CHAPTER 3

Setting Up the Software Development Environment

This chapter covers how to set up the software development environment to build single-channel LoRa wireless radio networks. First, you will learn how to install and configure the Arduino IDE on the Windows operating system to work with Arduino boards, RFM9x radio transceivers, GPS modules, temperature sensors, and so forth, for building LoRa end nodes (sensor nodes). In the latter part of this chapter, you will learn how to install PuTTY on Windows as a prerequisite to building a single-channel LoRa gateway with the Raspberry Pi.

Arduino Integrated Development Environment

The Arduino integrated development environment (IDE) allows you to write and upload code to the Arduino board. It also provides facilities for compiling and debugging code. The Arduino IDE is available for Windows (XP and up), Windows Mobile (8.1 or 10), Mac OS X (10.7 Lion and up), and Linux (32-bit, 64-bit, and ARM). It can be downloaded from

CHAPTER 3 SETTING UP THE SOFTWARE DEVELOPMENT ENVIRONMENT

<http://arduino.cc/en/Main/Software>. There is an online Arduino editor for coding known as Arduino Create, available at <https://create.arduino.cc/editor> (Figure 3-1).

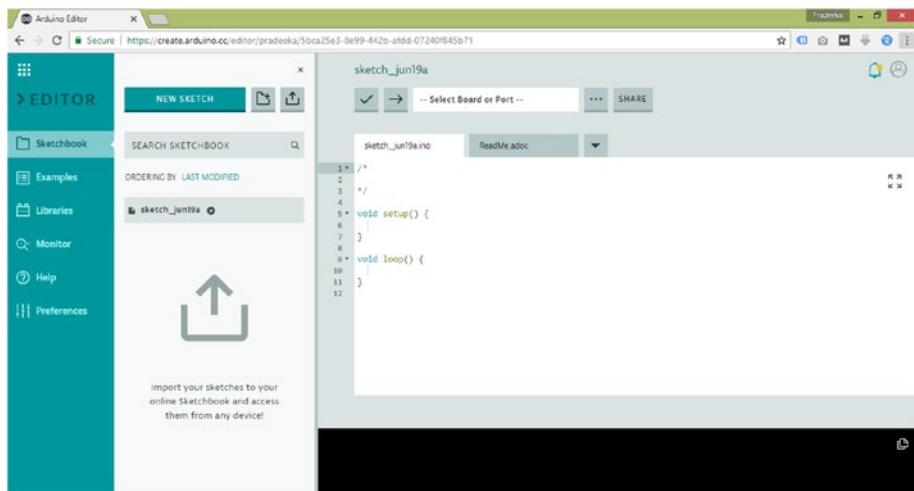


Figure 3-1. Arduino Create online editor

Arduino for Windows

The Arduino software is available as a ZIP file for nonadmin installation and comes with an installer for Windows XP and up. An app is also available for Windows 8.1 and 10. You can use either the admin or nonadmin installation method to set up the IDE on your computer.

Admin Install

Follow these steps:

1. Download the installer by clicking “Windows Installer, for Windows XP and up.”

2. Once the installer has been downloaded, double-click the EXE file to start the installation process.
3. Follow the instructions shown in the wizard to install the Arduino software correctly on your computer.

Nonadmin Install

Follow these steps:

1. Download the ZIP file by clicking “Windows ZIP file for non-admin install.”
2. Once downloaded, extract the ZIP file to any convenient directory in your computer.
3. You will get a folder named arduino<version>. Inside that folder, you can find an application file named arduino along with other files and folders. Simply, double-click it to start the Arduino software. It will take some time for the Arduino software to load.

Figure 3-2 shows the main areas of the Arduino IDE labeled with numbers.

CHAPTER 3 SETTING UP THE SOFTWARE DEVELOPMENT ENVIRONMENT

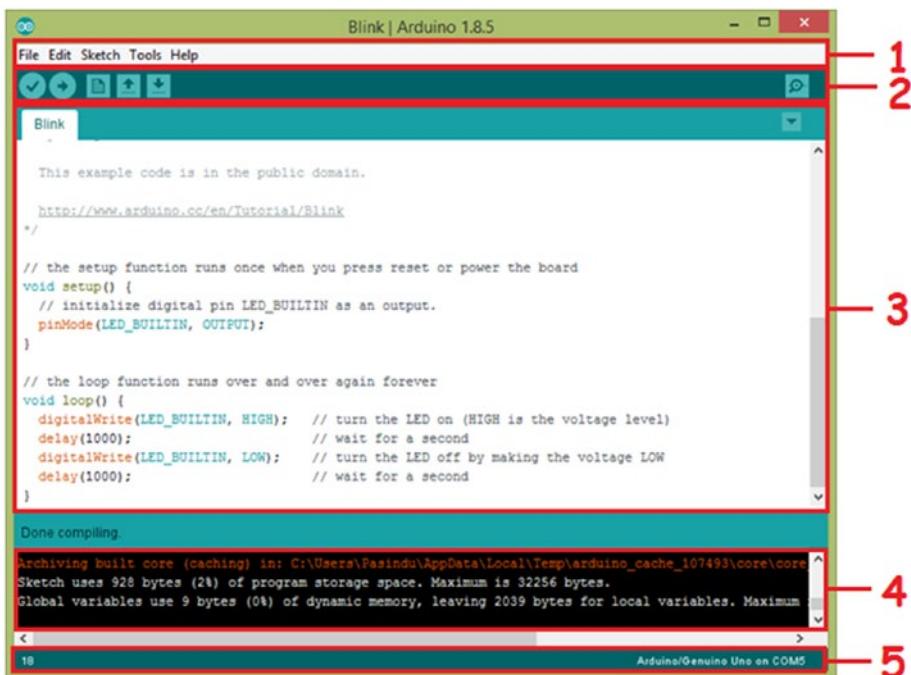


Figure 3-2. Main areas of the Arduino IDE

Here's what each element shown in Figure 3-2 is:

1. *Menu bar*: Provides useful commands
2. *Toolbar*: Provides the most important commands
3. *Sketch editor*: The area you can use to type your code
4. *Text console*: Shows status and error messages
5. *Status bar*: Displays the currently configured microcontroller board with the COM port

Table 3-1 summarizes the function of each button in the toolbar. You can view the name of a toolbar button by placing the mouse pointer over it. A tooltip will show the name of the button.

Table 3-1. Function of Each Toolbar Button in the Arduino IDE

Icon	Name	Function
	New	Creates a new sketch
	Open	Opens a sketch
	Save	Saves the sketch
	Verify	Compiles your code and shows whether it has any errors
	Upload	Compiles and uploads the code to the microcontroller board
	Serial Monitor	Opens the serial monitor window

Installing Drivers for the Arduino

Drivers allow operating systems to properly recognize the Arduino board. The following sections will describe how to install drivers for the Arduino Uno and Arduino Metro on the Windows operating system.

Installing Drivers for Uno

If you have installed the Arduino IDE on your Windows computer using the ZIP file, you will need to install the drivers manually. The following steps show how to install the drivers on Windows 8:

1. Connect the Arduino Uno with your Windows computer using a USB type A to B cable (Figure 3-3). Use the type B end to connect with the Arduino (Figure 3-4) and the type A end to connect with the computer.

CHAPTER 3 SETTING UP THE SOFTWARE DEVELOPMENT ENVIRONMENT



Figure 3-3. *USB type A to B cable (courtesy of SparkFun Electronics)*

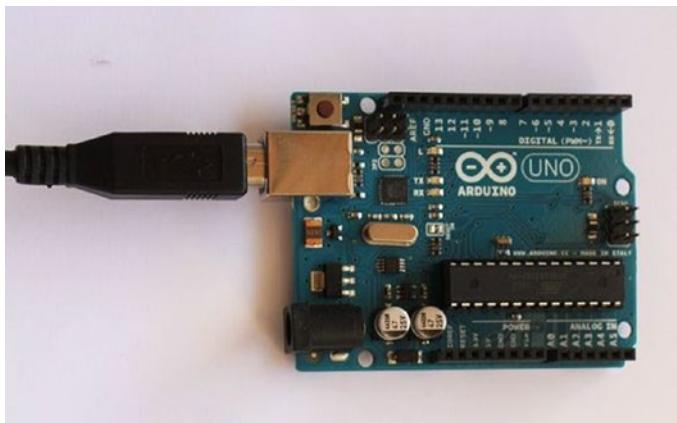


Figure 3-4. *Connecting a USB cable to the Arduino Uno. Use the type B end of the cable to connect with Arduino's USB port B.*

2. Open the Device Manager with Windows 8 by typing **Device Manager** in the Search box (Figure 3-5).

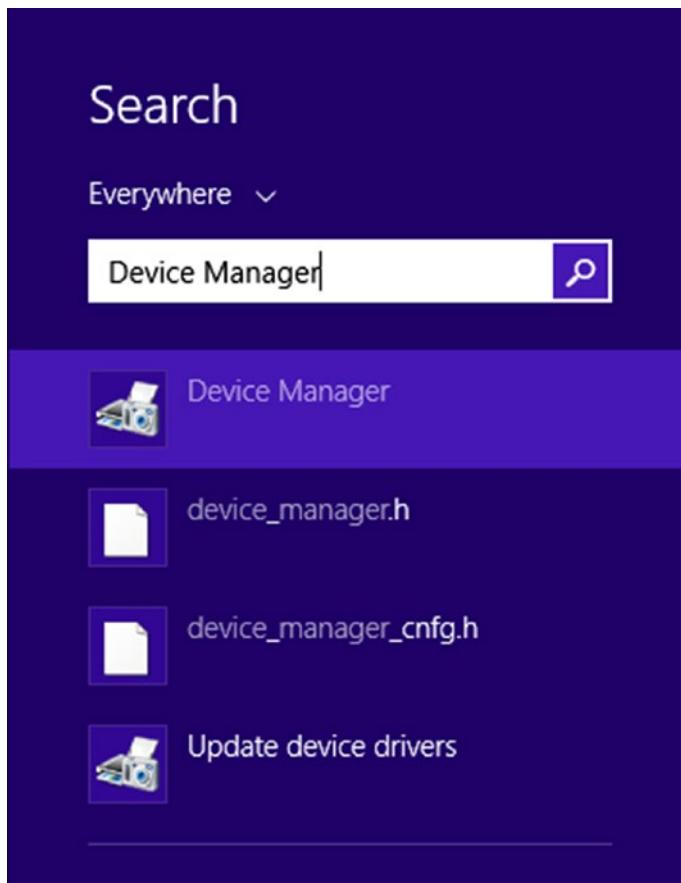


Figure 3-5. Opening an application with Windows Search

CHAPTER 3 SETTING UP THE SOFTWARE DEVELOPMENT ENVIRONMENT

3. In the Device Manager, under “Other devices,” you should see a node named Arduino Uno (with a yellow triangle with a black exclamation mark), as shown in Figure 3-6.

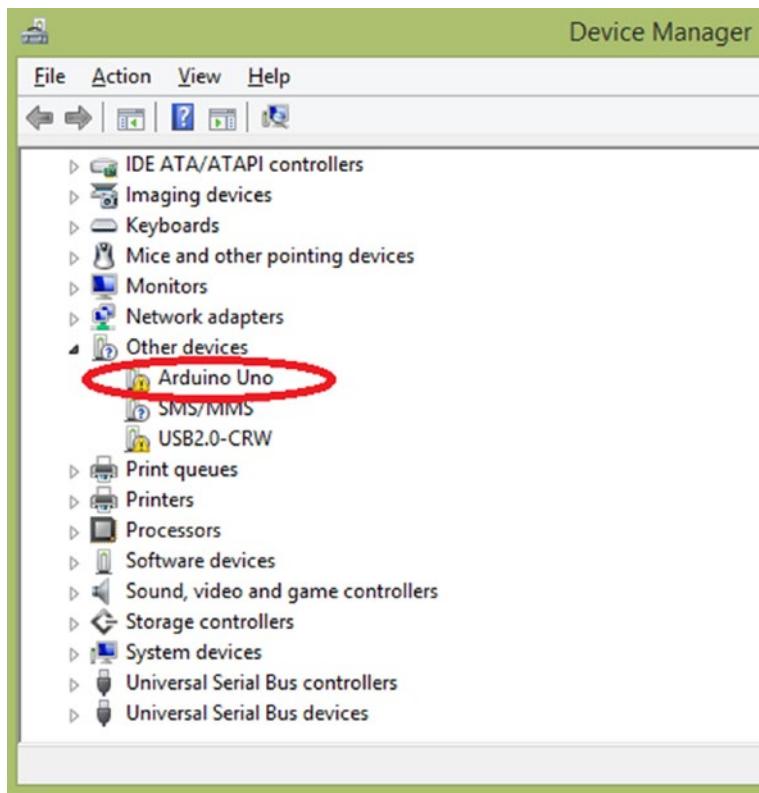


Figure 3-6. Device Manager showing Arduino Uno with a warning

4. Right-click the node Arduino Uno, and from the shortcut menu, choose Update Driver Software (Figure 3-7).

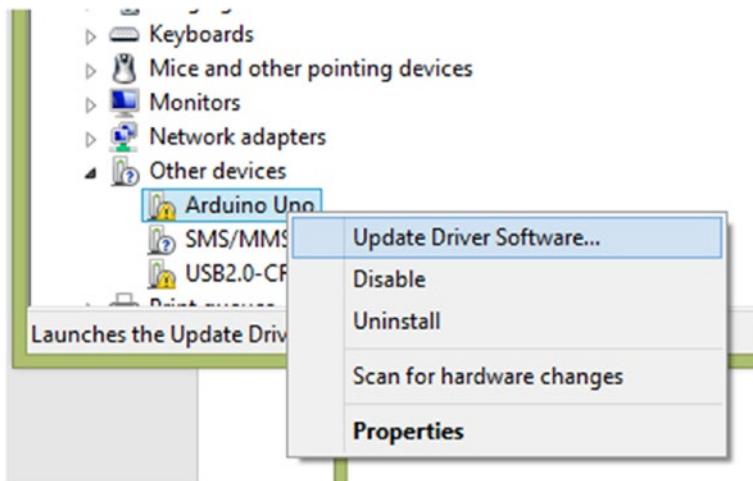


Figure 3-7. Updating the driver software

CHAPTER 3 SETTING UP THE SOFTWARE DEVELOPMENT ENVIRONMENT

5. Click the “Browse my computer for driver software” option to locate and install the driver software manually (Figure 3-8).

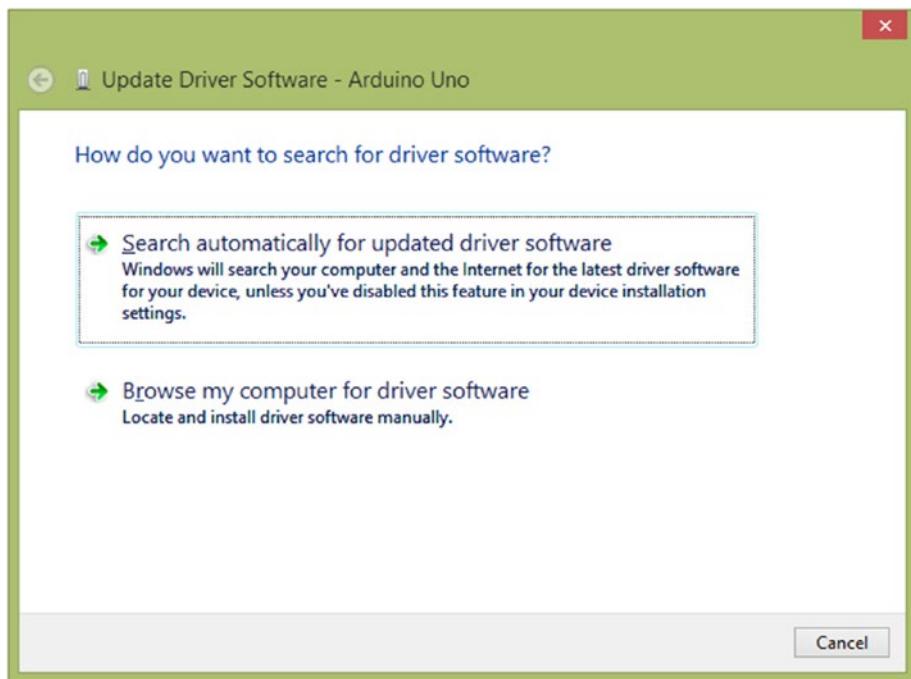


Figure 3-8. Choosing the option for locating and installing the driver software manually

CHAPTER 3 SETTING UP THE SOFTWARE DEVELOPMENT ENVIRONMENT

6. Click the Browse button (Figure 3-9).

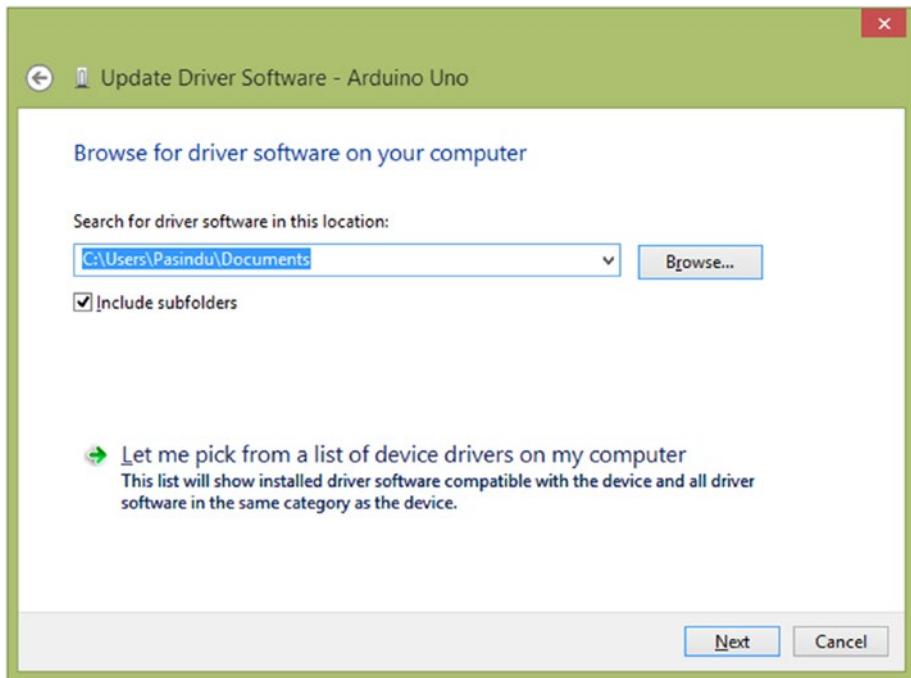


Figure 3-9. Searching for the driver software

7. Browse and select the folder named drivers from the Arduino software download. Then click the OK button (Figure 3-10).

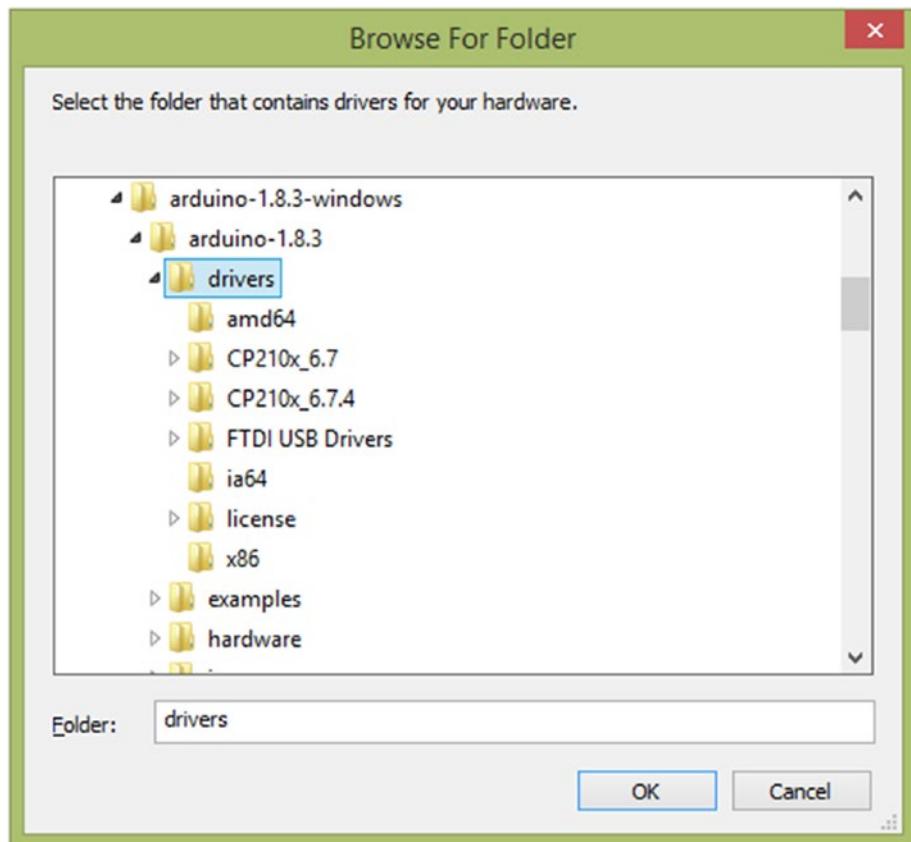


Figure 3-10. The drivers for Arduino Uno can be found in the drivers folder

8. Click the Next button. Windows will start to install the drivers for the Arduino Uno.
9. Click the Close button to exit the wizard (Figure 3-11).

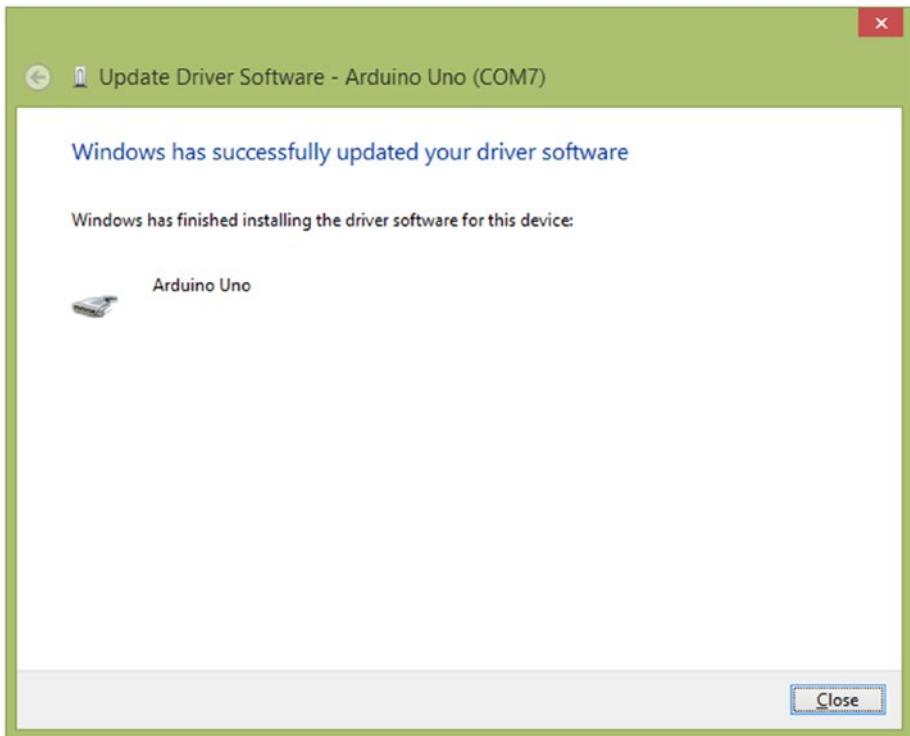


Figure 3-11. This step will confirm that Windows has successfully updated your driver software

CHAPTER 3 SETTING UP THE SOFTWARE DEVELOPMENT ENVIRONMENT

10. Now you can see your Arduino Uno under Ports (COM & LPT), as shown in Figure 3-12.

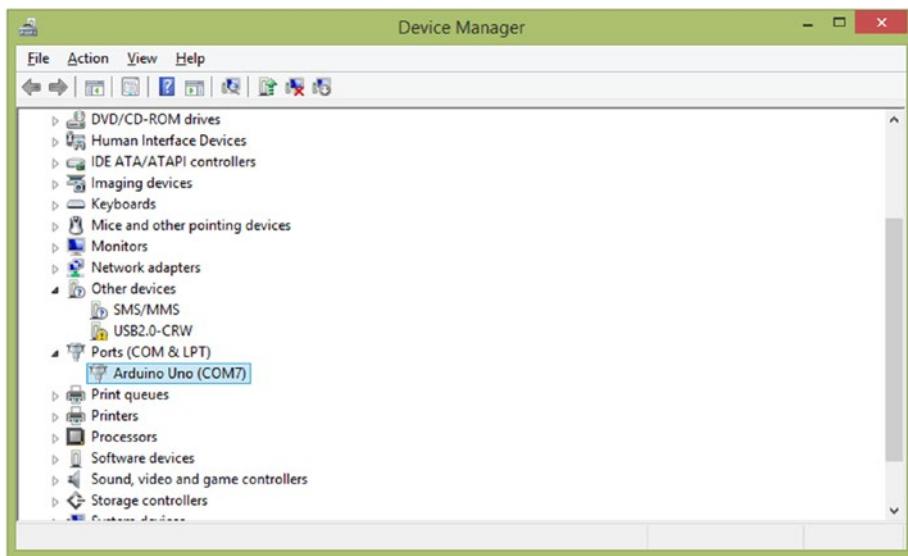


Figure 3-12. In the Device Manager, Arduino Uno is listed under Ports (COM & LPT)

Installing Drivers for Metro

You should install drivers on Windows and Mac OS X to facilitate host communication with the USB/serial chip used for the Adafruit Metro. The USB/serial chip is marked as “CP2014” and can be found near the micro-USB port of the Metro board (Figure 3-13).



Figure 3-13. CP2014 USB/serial chip

1. The drivers can be downloaded from Silicon Labs (<https://www.silabs.com/products/development-tools/software/usb-to-uart-bridge-vcp-drivers>), as shown in Figure 3-14. Click the link labeled as the default (e.g., Download VPC (5.3 MB) (Default)).

Platform	Software
Windows 7/8.1/10	Download VCP (5.3 MB) (Default)
Windows 7/8.1/10	Download VCP with Serial Enumeration (5.3 MB) Learn More »

Figure 3-14. CP2014 USB/serial chip drivers for Windows 7 and up. Download the software marked as the default.

2. After downloading the drivers, extract the ZIP file and find the relevant installer for your Windows version. (For 32-bit Windows, run CP210xVCPIinstaller_x86, and for 64-bit Windows, run CP210xVCPIinstaller_x64.) Follow the instruction in the setup wizard to install them.
3. Once installed, connect the Adafruit Metro with your computer using the micro-USB cable. Now you can find your Adafruit Metro under Ports (COM & LPT), as shown in Figure 3-15.

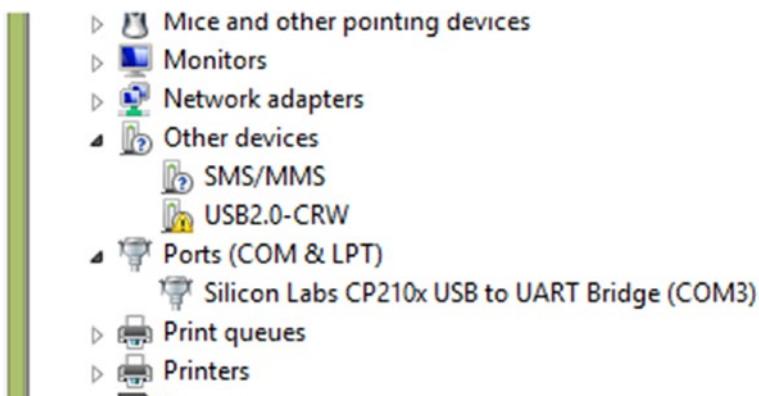


Figure 3-15. The Adafruit Metro is listed as Silicon Labs CP210x USB to UART Bridge under Ports (COM & LPT)

4. The drivers for Mac OSX can also be downloaded from the same page under the section, **Download for Macintosh OSX (vX)** by clicking on the link, **Download VCP**. After downloading the driver, follow the instructions mentioned in the page at <https://learn.adafruit.com/experimenters-guide-for-metro/mac-setup> to setting it up on your Mac OSX.

Your First Arduino Sketch

The Arduino Uno and other Arduino-compatible boards have a built-in LED connected to digital pin 13. This LED can be controlled with a sample sketch bundled with the Arduino IDE.

Usually, the Adafruit Metro comes with the preflashed Blink sketch. When you apply power to the board, the red LED (internally connected to digital pin 13, marked with an *L*) will start to blink. If not, upload the sample sketch provided with the Arduino IDE to make sure that the board is working properly. The following steps will show you how to upload a sketch into the Metro board:

1. Open the sample sketch from the menu bar by choosing File ▶ Examples ▶ 01. Basics ▶ Blink.
Listing 3-1 shows the Arduino sketch that can be used to blink an LED connected to digital pin 13.

Listing 3-1. Blinks the Built-in LED Connected to Digital Pin 13

```
// the setup function runs once when you press reset or power  
// the board  
void setup() {  
    // initialize digital pin LED_BUILTIN as an output.  
    pinMode(LED_BUILTIN, OUTPUT);  
}  
  
// the loop function runs over and over again forever  
void loop() {  
    digitalWrite(LED_BUILTIN, HIGH);      // turn the LED on (HIGH  
                                         // is the voltage level)  
    delay(1000);                      // wait for a second  
    digitalWrite(LED_BUILTIN, LOW);       // turn the LED off by  
                                         // making the voltage LOW  
    delay(1000);                      // wait for a second  
}
```

CHAPTER 3 SETTING UP THE SOFTWARE DEVELOPMENT ENVIRONMENT

2. Choose the board you're going to use by selecting Tools > Board > Arduino/Genuino Uno under Arduino AVR Boards (Figure 3-16).

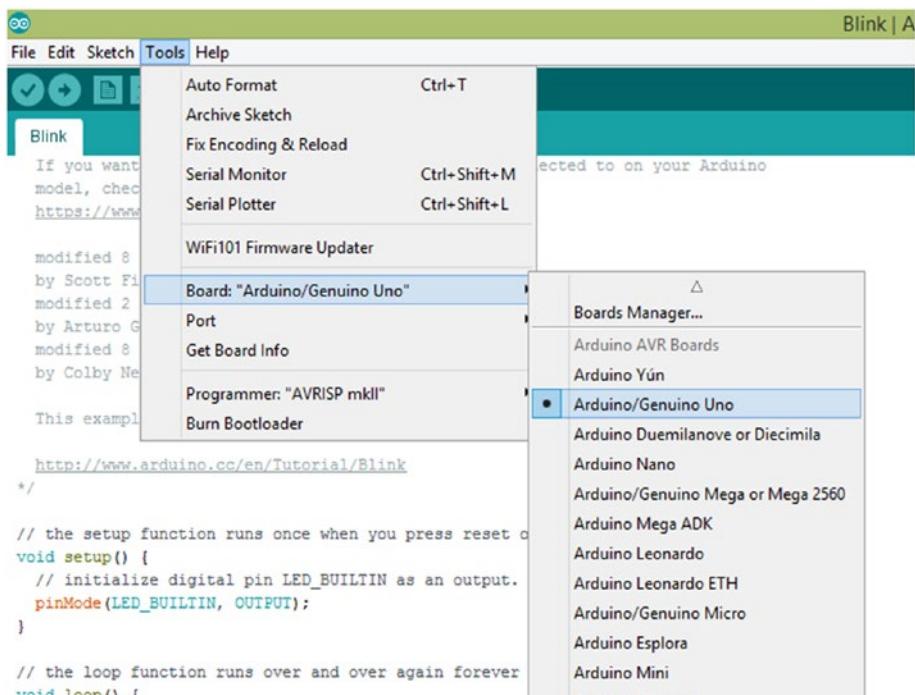


Figure 3-16. Choosing the type of microcontroller board

3. Choose the port associated with the Arduino Uno/Metro board by selecting Tools ► Serial Port ► PORT (Figure 3-17).

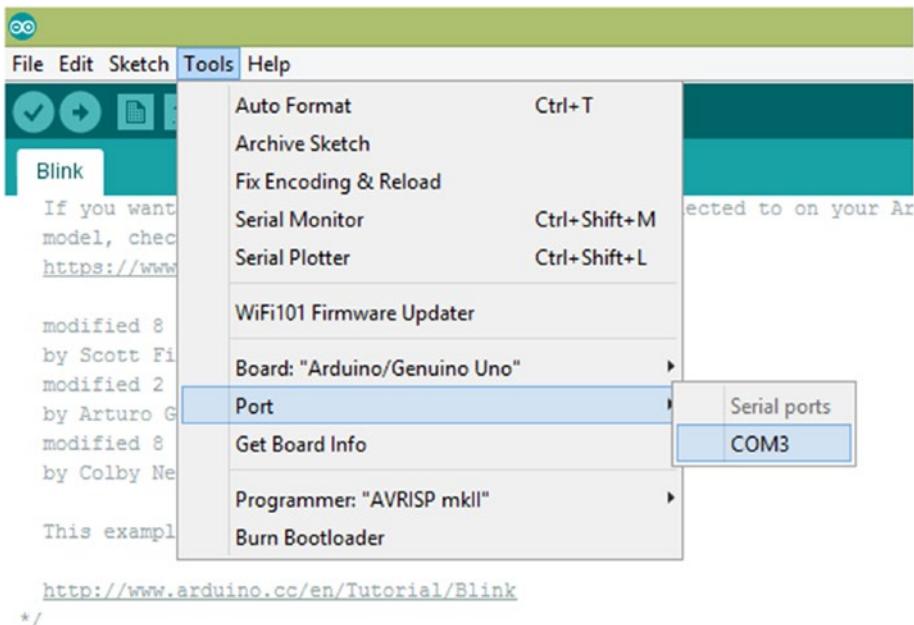


Figure 3-17. Choosing the port

CHAPTER 3 SETTING UP THE SOFTWARE DEVELOPMENT ENVIRONMENT

4. Choose the programmer as AVRISP mkII by selecting Tools ► Programmer ► AVRISP mkII (Figure 3-18).

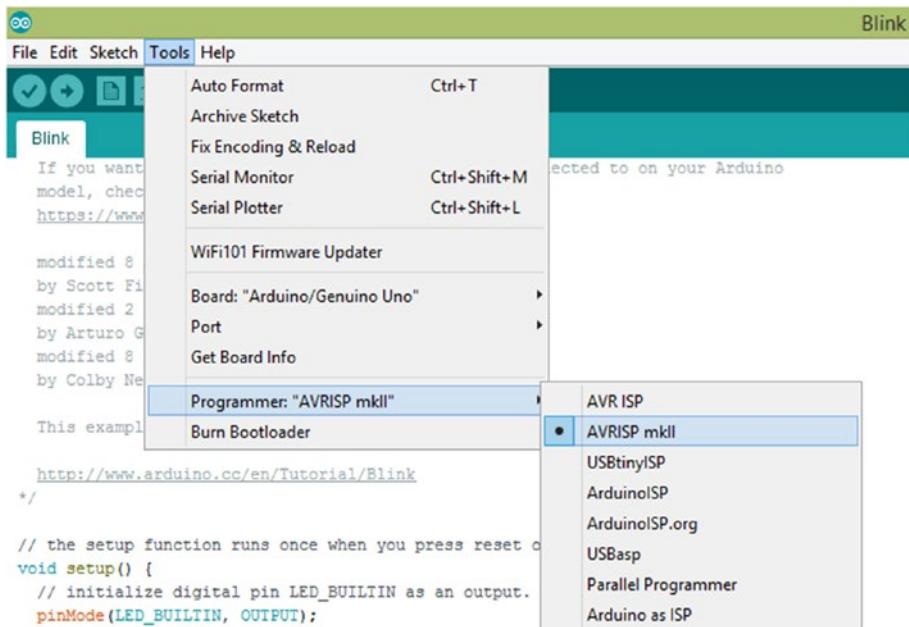


Figure 3-18. Choosing a programmer

5. Verify and compile the sketch by choosing Sketch ► Verify/Compile or pressing Ctrl+R. When the compiler is compiling your sketch, it will report problems that it finds in your sketch. Find and correct them all. This is known as *debugging*. Then compile the sketch again and see whether there are more errors still in the code.
6. Upload the sketch by choosing Sketch ► Upload or pressing Ctrl+U. You can also use the Upload button (the button has a right arrow icon) on the toolbar.
7. After the upload finishes, you should see the LED on the Arduino Uno/Metro start to blink.

Installing the Arduino Libraries

Arduino libraries should be copied to the libraries folder in the Arduino sketch book. There are two ways to install Arduino libraries.

- Manually copy the library master folder to the libraries folder.
- Use the Boards Manager to search, install, and update libraries (some libraries don't support the Boards Manager).

Follow these steps to install an Arduino library:

1. Find your Arduino sketchbook location by selecting File ► Preferences in the Arduino IDE (Figure 3-19).

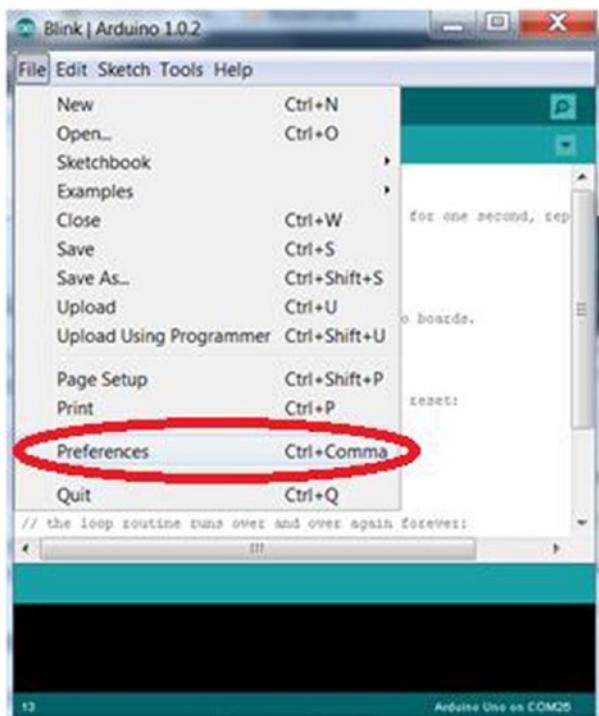


Figure 3-19. Finding the Sketchbook location

CHAPTER 3 SETTING UP THE SOFTWARE DEVELOPMENT ENVIRONMENT

- Usually, the sketchbook location is a folder named Arduino in the Documents folder (Figure 3-20).

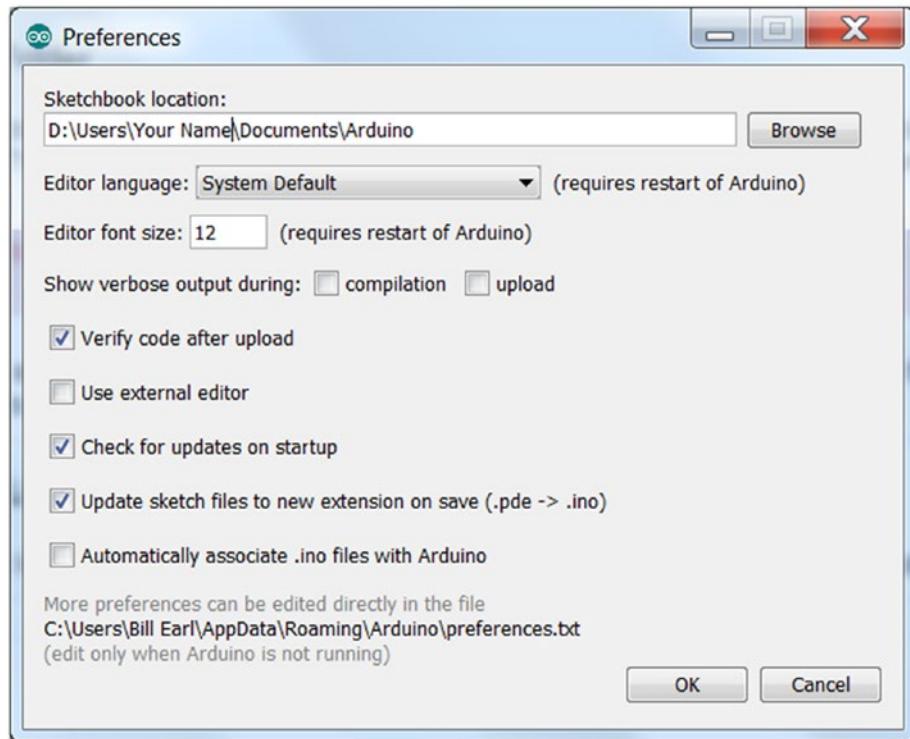


Figure 3-20. Arduino Preferences dialog

- Navigate to the sketchbook location in File Explorer. If there is no folder named libraries, create a new one (Figure 3-21).

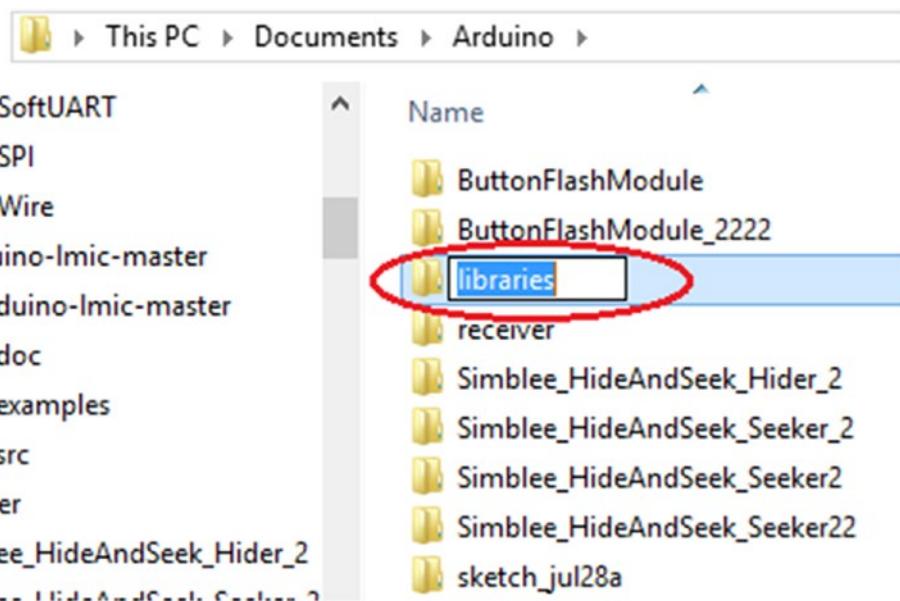


Figure 3-21. Creating a folder named *libraries*

4. Now close all instances of the Arduino IDE.
5. When you download a library from GitHub, Arduino Playground, or any other location on the Internet, usually you will get a ZIP file.
6. Open the ZIP file and navigate until you find the library master folder. This is the folder that has the name of your library.
7. Copy the library master folder and paste it in the *libraries* folder.
8. Restart the Arduino IDE and verify that the library appears in the Sketch ➤ Include Library menu.

The IDE will not recognize folders with hyphens in the name. If your library master folder name contains hyphens, replace them with underscores.

Installing the RadioHead Library

The RadioHead library allows you to work with RFM95/96 modules. It can be downloaded from www.airspayce.com/mikem/arduino/RadioHead/RadioHead-1.84.zip. After downloading the ZIP file, open it and copy the library master folder named RadioHead into the Arduino libraries folder (Figure 3-22).

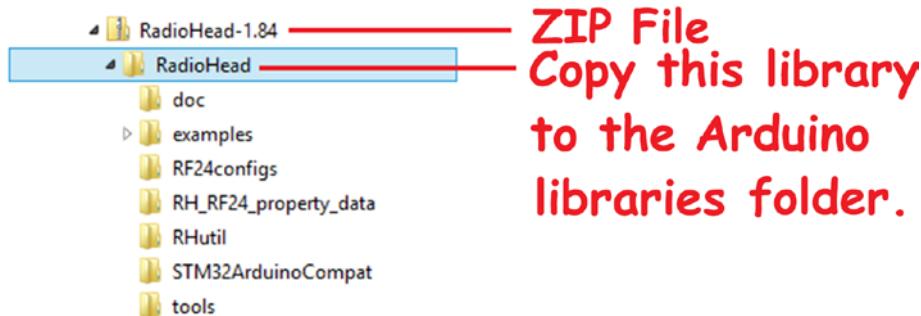


Figure 3-22. RadioHead library

The RadioHead library provides drivers for a wide range of chipsets and modules. For this book, you will need the RH_RF95 class. It allows the driver to send and receive unaddressed, unreliable datagrams via a Lora-capable radio transceiver. The RH_RF95 class supports both 868/915 and 433MHz Adafruit radio transceiver breakouts.

However, Dragino provides an improved version of the RadioHead library known as Dragino's Modified RadioHead library. It provides additional functions to configure the following things:

- Spreading factor
- Signal bandwidth
- Coding rate

The library can be downloaded from <https://github.com/dragino/RadioHead>. After downloading the ZIP file, open it and copy the library master folder named RadioHead-master into the Arduino libraries folder (Figure 3-23).

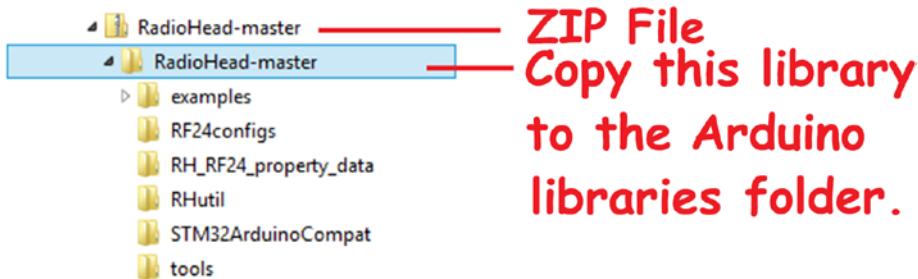


Figure 3-23. Dragino RadioHead library

Once that's copied, rename the folder to RadioHead_master.

Installing the Adafruit DHT11 Library

Adafruit provides an easy-to-use library for the DHT11 and DHT 22 temperature and humidity sensors. You can download it from <https://github.com/adafruit/DHT-sensor-library>. After downloading the ZIP file, open it and copy the library master folder named DHT-sensor-library-master into the Arduino libraries folder (Figure 3-24).

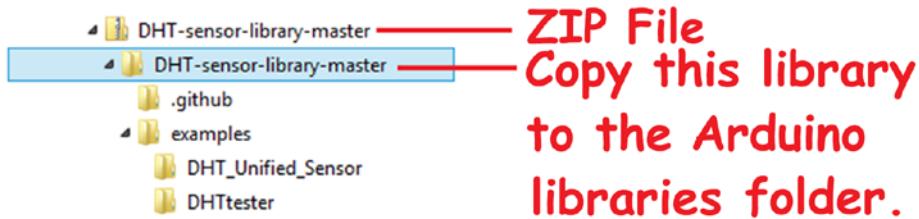


Figure 3-24. Adafruit DHT11 library

Once copied, rename the folder to `DHT_sensor_library_master`.

Installing the TinyGPS Library

TinyGPS allows you to read and parse NMEA sentences to extract actual data from them. It uses background interrupt to read, store, and parse the data. You can download it from <https://github.com/mikalhart/TinyGPS/releases/tag/v13>. On the download page, click “Source code (zip),” as shown in Figure 3-25.

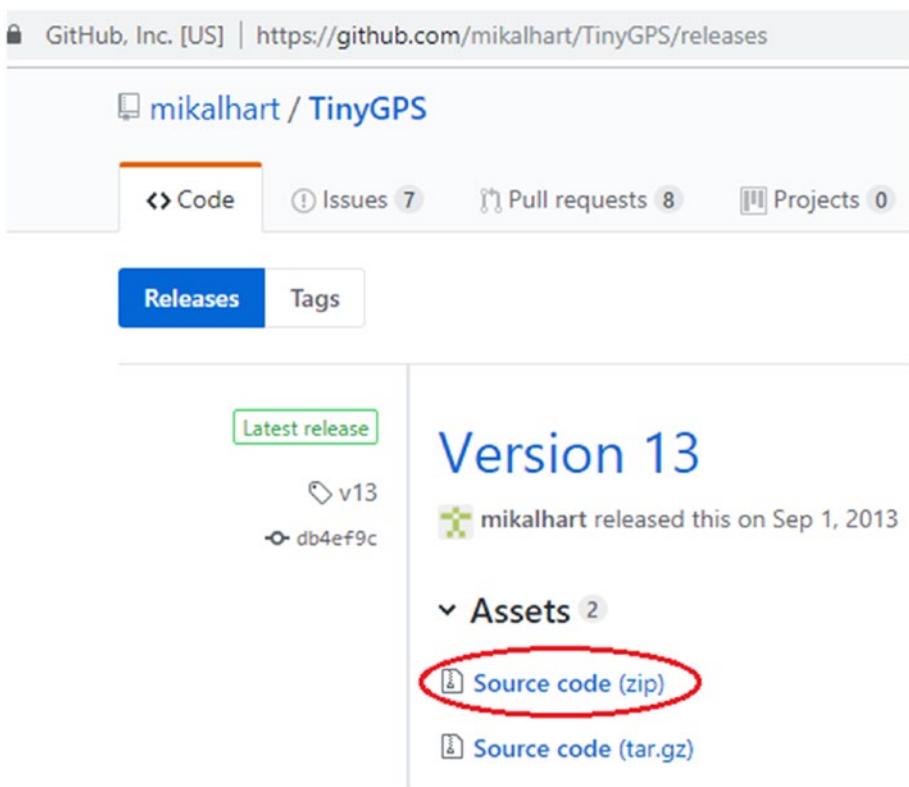


Figure 3-25. Source code for TinyGPS library

After downloading the ZIP file, open it and copy the library master folder named TinyGPS-13 into the Arduino libraries folder (Figure 3-26).

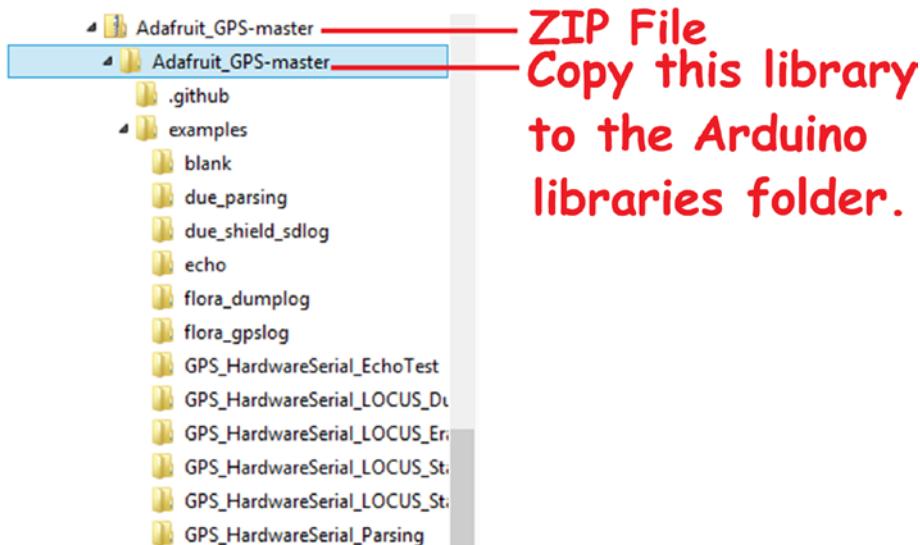


Figure 3-26. *TinyGPS library*

Once copied, rename the folder to TinyGPS_13.

Installing the Arduino LMIC Library

The Arduino-LMIC library allows you to use the SX1272 and SX1276 transceivers and compatible modules (such as some HopeRF RFM9x modules) with the Arduino environment. It is a slightly modified version of the IBM LMIC (LoraMAC-in-C) library.

You can download it from <https://github.com/matthijskooijman/arduino-lmic>. On the GitHub page, first click the “Clone or download” button and then click the Download ZIP link (Figure 3-27).

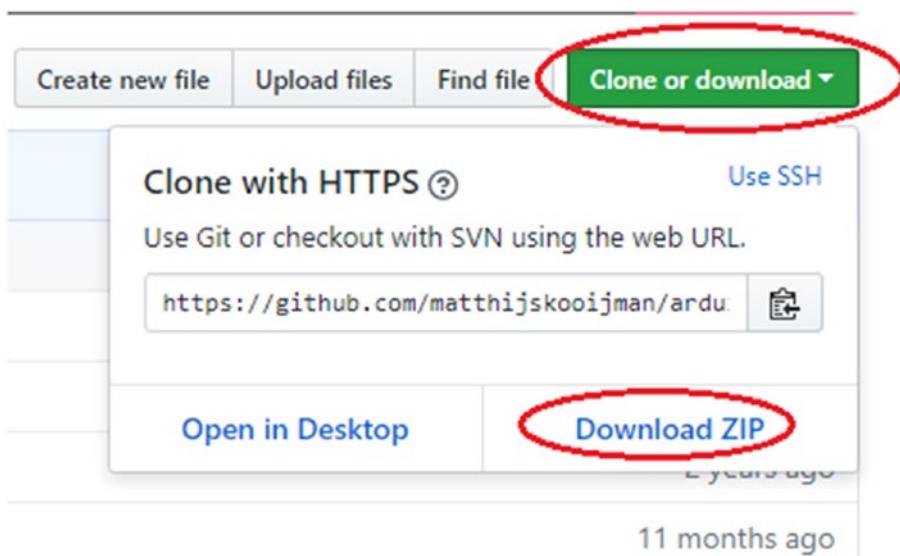


Figure 3-27. Downloading the Arduino LMIC library from GitHub

After downloading the ZIP file, open it and copy the library master folder named arduino-lmic-master into the Arduino libraries folder (Figure 3-28).

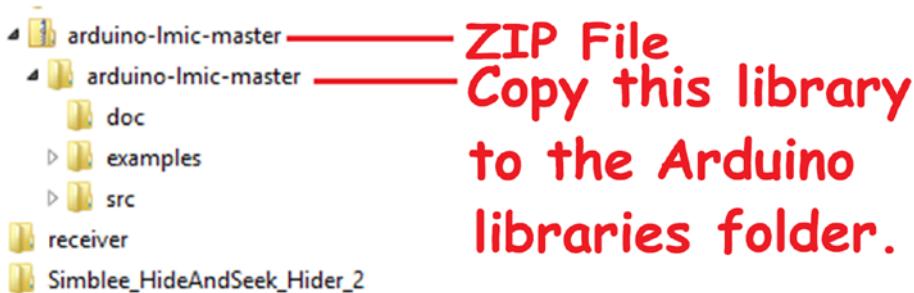


Figure 3-28. Arduino LMIC library

Once copied, rename the folder to arduino_lmic_master.

Now you have installed all the required Arduino libraries for the Arduino IDE.

Installing PUTTY

PuTTY enables any users to remotely access computers (including the Raspberry Pi) over Ethernet or the Internet. It supports SCP, SSH, Telnet, rlogin, and raw socket connection protocols. You can use the SSH protocol to connect with the Raspberry Pi via Ethernet or a Wi-Fi network. You can also enable port forwarding with your router to connect with your Raspberry Pi through the Internet.

Follow these steps to download and install PuTTY on a computer running the Windows operating system:

1. The package files, binary files, documentation, and source code is available at <https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html>.
2. At the top of the page, under the Package files (Figure 3-1), click `putty-0.70-installer.msi` (for 32-bit Windows) or `putty-64bit-0.70-installer.msi` (for 64-bit Windows), as shown in Figure 3-29.

Package files

You probably want one of these. They include all the PuTTY utilities.

(Not sure whether you want the 32-bit or the 64-bit version? Read the [FAQ entry](#).)

MSI (“Windows Installer”)

32-bit:	putty-0.70-installer.msi	(or by FTP)	(signature)
64-bit:	putty-64bit-0.70-installer.msi	(or by FTP)	(signature)

Unix source archive

.tar.gz:	putty-0.70.tar.gz	(or by FTP)	(signature)
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Figure 3-29. Installers for 32-bit and 64-bit Windows

- Once downloaded, run the installer by double-clicking it. The setup wizard will open. Click the Next button to continue (Figure 3-30).

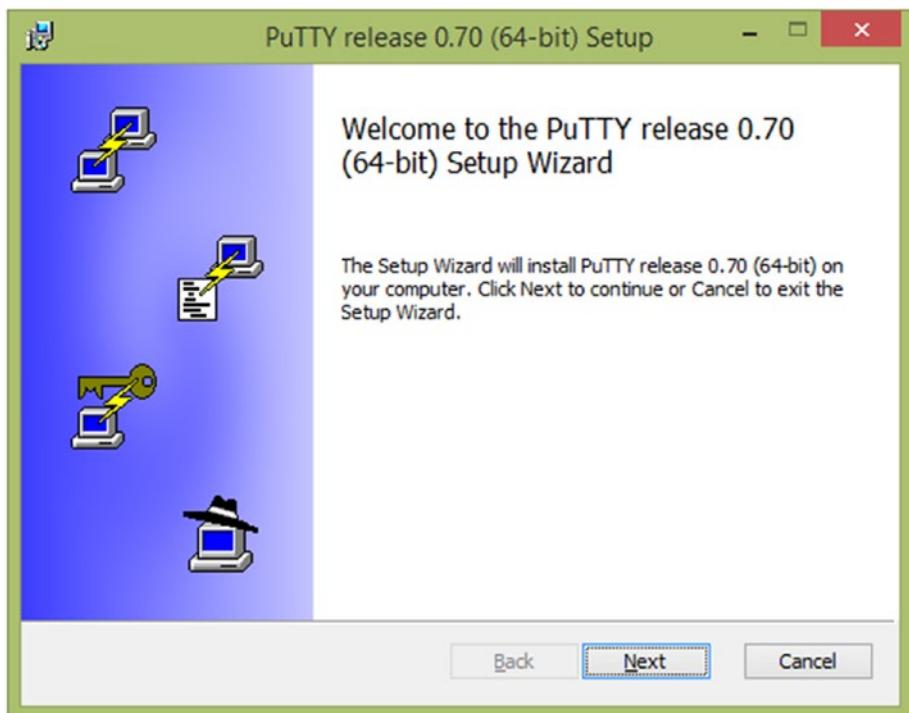


Figure 3-30. PuTTY installation wizard welcome page for 64-bit Windows OS

4. For the default destination folder, PuTTY will install into C:\Program Files\PuTTY\. If you want to install PuTTY in a different directory, first click the Change button. Then browse to a new destination folder. Finally, click the Next button to continue (Figure 3-31).

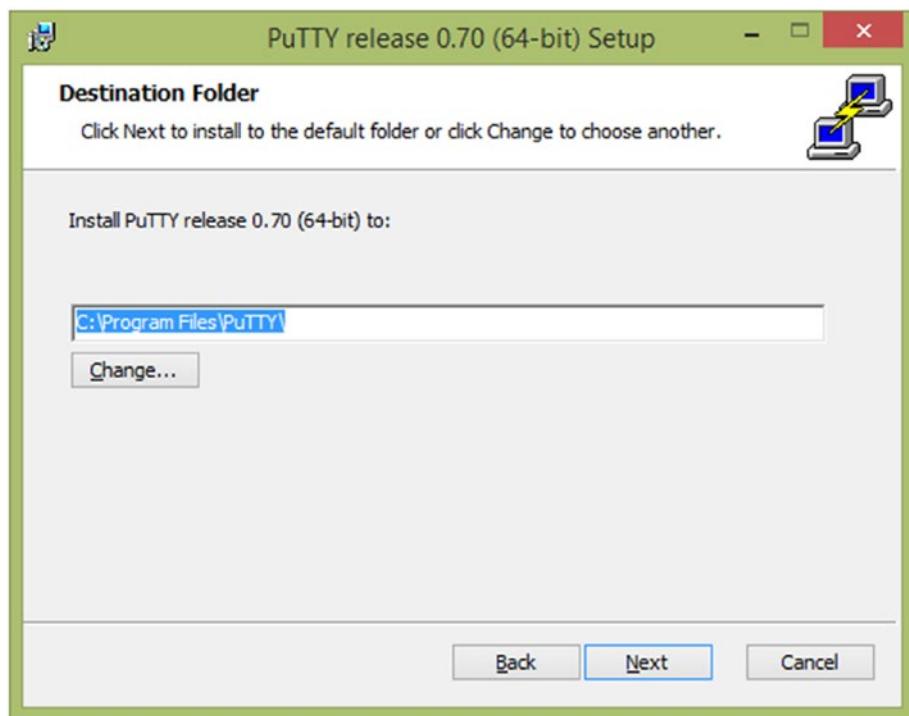


Figure 3-31. Choosing a destination folder for installation

- To add a desktop shortcut for PuTTY, click “Add shortcut to PuTTY on the desktop” (click the button marked with an X), and from the drop-down menu, choose the “Will be installed on the local hard drive” option. Then click the Install button to continue (Figure 3-32).

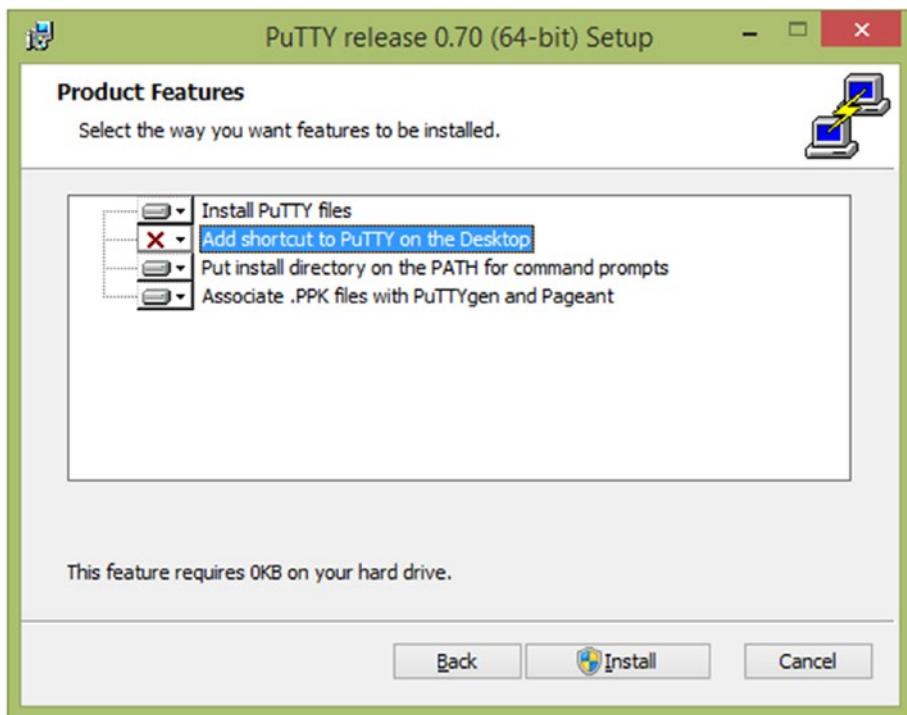


Figure 3-32. Customizing the product features

- In the User Access Control dialog box, click the Yes button to continue.
- PuTTY will start to install on your computer. Wait until it completes.

8. Click the Finish button to exit from the setup wizard (Figure 3-33).

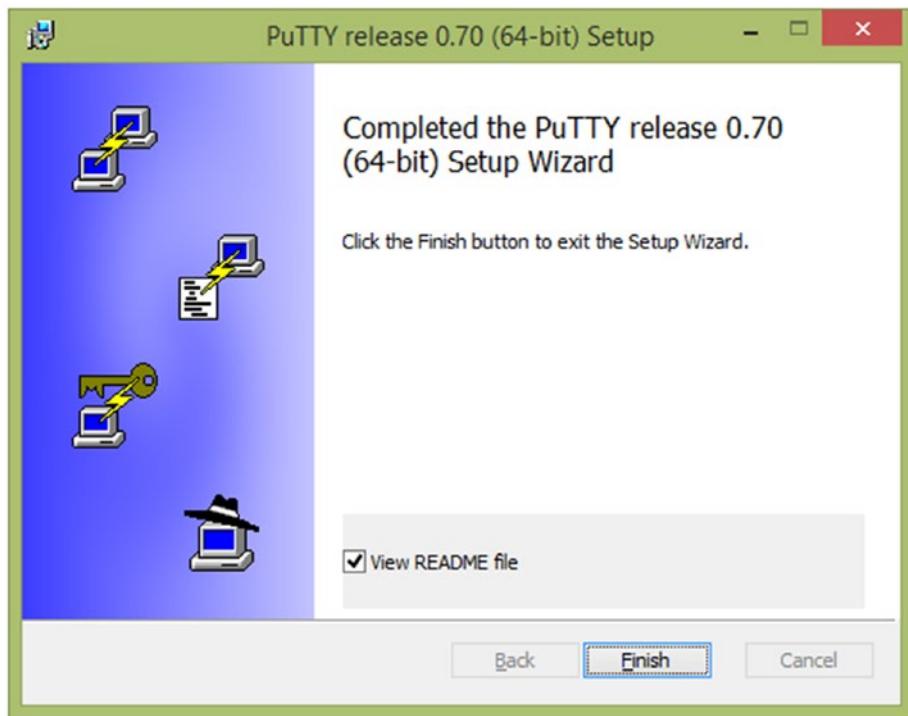


Figure 3-33. PuTTY installation. Final step of the setup wizard.

To verify the installation, double-click the PuTTY shortcut icon on the Windows desktop. If it was successfully installed, the PuTTY Configuration window will open (Figure 3-34).

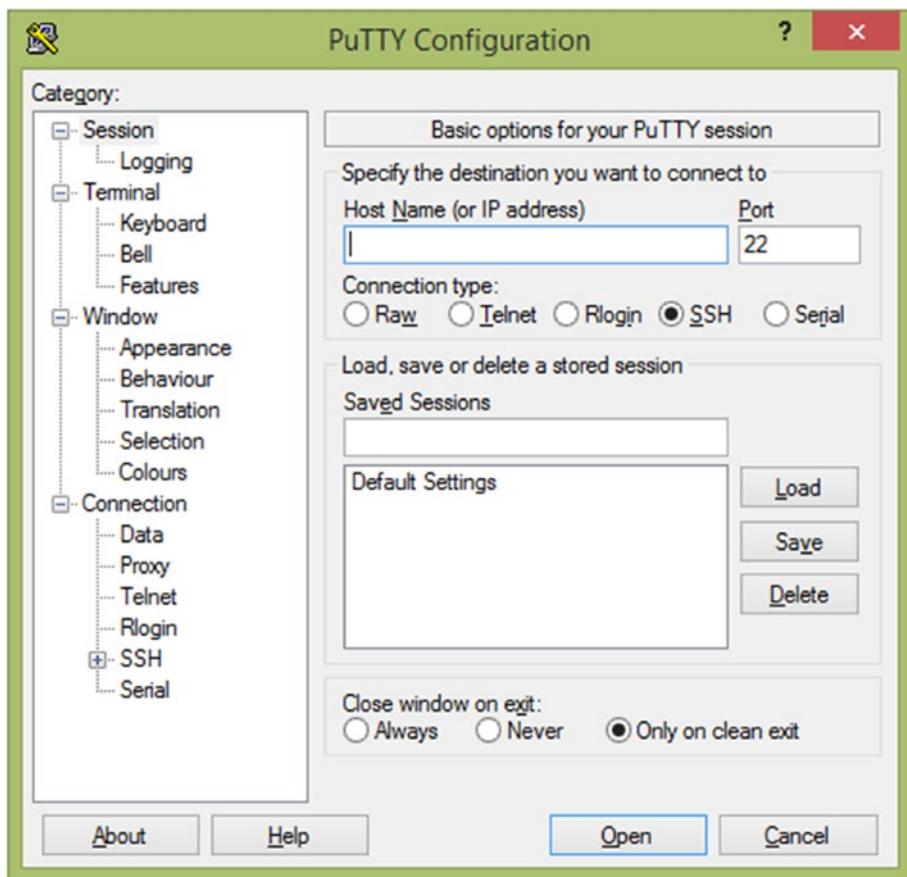


Figure 3-34. PuTTY configuration window

Summary

You installed the Arduino IDE on your computer and configured it by installing drivers. Then you installed some software libraries on the Arduino IDE to work with different hardware components. The RadioHead library is the most important software component. The Adafruit DHT11 library allows you to read sensor values from the DHT11 temperature and humidity sensor. The TinyGPS library allows you to read and parse NMEA sentences received by the GPS module. Finally, you installed PuTTY on Windows to access the Raspberry Pi through SSH.

In next chapter, you will build a peer-to-peer LoRa radio network with Arduino, RFM9x radio transceivers, and the DHT11 temperature and humidity sensor.

CHAPTER 4

Building a Peer-to-Peer Channel

In this chapter, you will learn how to build a peer-to-peer communication channel using two LoRa radio transceiver modules. Building a peer-to-peer communication channel is not LoRaWAN compatible, but it provides a way to better understand how messages can be exchanged between two LoRa radio transceivers.

Things You Need

You will need to use the following hardware from your toolbox:

- Two Adafruit Metro or Arduino Uno boards
- Two RFM9x radio transceiver modules
- One DHT11 temperature sensor
- Two mini breadboards
- Two breadboard holders
- A few hook-up wires

In addition, you will need the RadioHead library to work with the LoRa radio transceivers, and you will need the DHT11 library to work with the DHT11 temperature sensor. In the previous chapter, you learned about how to install these libraries on Arduino IDE.

Hardware Setup

Let's get started building hardware for the two LoRa nodes. You will build one node as a sensor node and the other node as a receiving node. The sensor node can be configured to periodically transmit (broadcast) the temperature data in Celsius. The receiving node can listen to the incoming data. Once the data is received, the receiving node can process the data and display it on the Arduino serial monitor. The receiving node can also send an acknowledgment message to the sensor node. Once that message is received, it will display on the sensor node's serial monitor.

Figure 4-1 shows a peer-to-peer communication channel. The LoRa sensor node is also known as the *client*, and the receiving node is also known as the *server*.

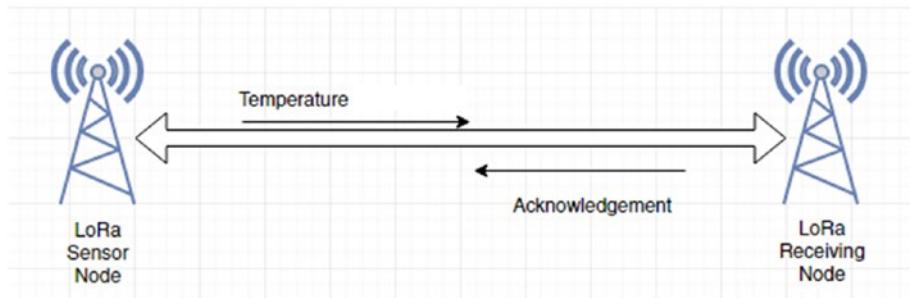


Figure 4-1. Peer-to-peer communication channel

Building the Sensor Node

Now you'll build a LoRa sensor node with a temperature sensor. It periodically collects temperature data from the environment and sends (broadcasts) to the receiving node. Follow these steps to build the hardware setup:

1. First, get the following:
 - Breadboard holder
 - Mini breadboard
 - Adafruit Metro or Arduino Uno board
2. Stick the breadboard to the breadboard holder.
3. Usually the breadboard prototyping holder comes with two screws for mounting the Arduino Uno. Place the Arduino Uno on the prototyping plate and apply screws.
4. Insert the LoRa Radio transceiver, the DHT11 temperature sensor, and the current limiting resistor.
5. Using hook-up wires, connect all the data and power lines between the breadboard and the Adafruit Metro/Arduino Uno. Use the Fritzing diagram shown in Figure 4-2 to make the wire connections between components.

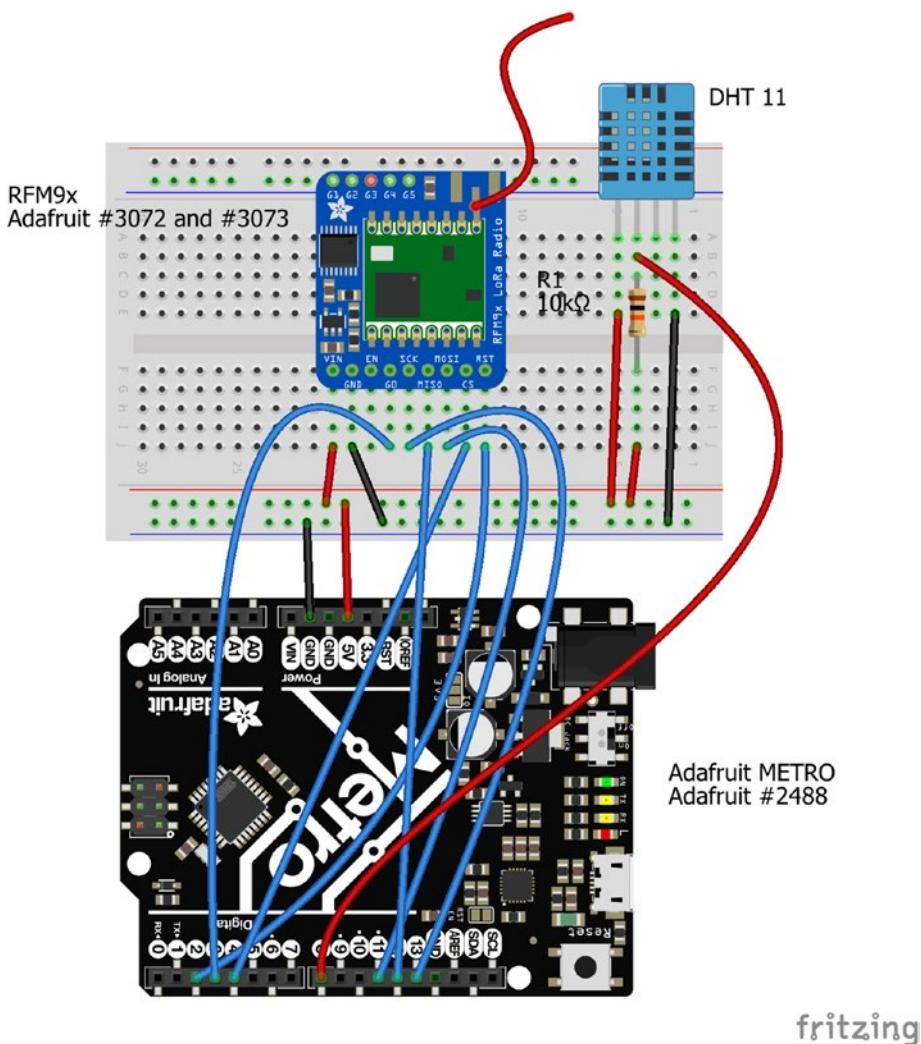


Figure 4-2. Wiring diagram for the LoRa sensor node

Table 4-1 shows the connections between the Arduino/Metro, radio transceiver, and DHT11 sensor.

Table 4-1. Wiring Connections for Sensor Node

Arduino/Metro	Radio Transceiver	DHT11
VIN	VIN	VIN
GND	GND	GND
2	RST	
3	GO	
4	CS	
8		DATA
11	MOSI	
12	MISO	
13	SCK	

Make sure to keep the antenna wire perpendicular to the LoRa radio transceiver module.

Building the Receiving Node

The receiving node receives the temperature data from the sensor node periodically. The following steps explain how to build the receiving node:

1. Take the other prototyping plate, mini breadboard, and the Adafruit Metro/Arduino Uno.
2. Stick the breadboard to the prototyping plate and then connect the Arduino to the prototyping plate using two screws.
3. Place the RFM9x radio transceiver module on the breadboard, as shown in Figure 4-3, and use hook-up wires to make all the data and power connections.

CHAPTER 4 BUILDING A PEER-TO-PEER CHANNEL

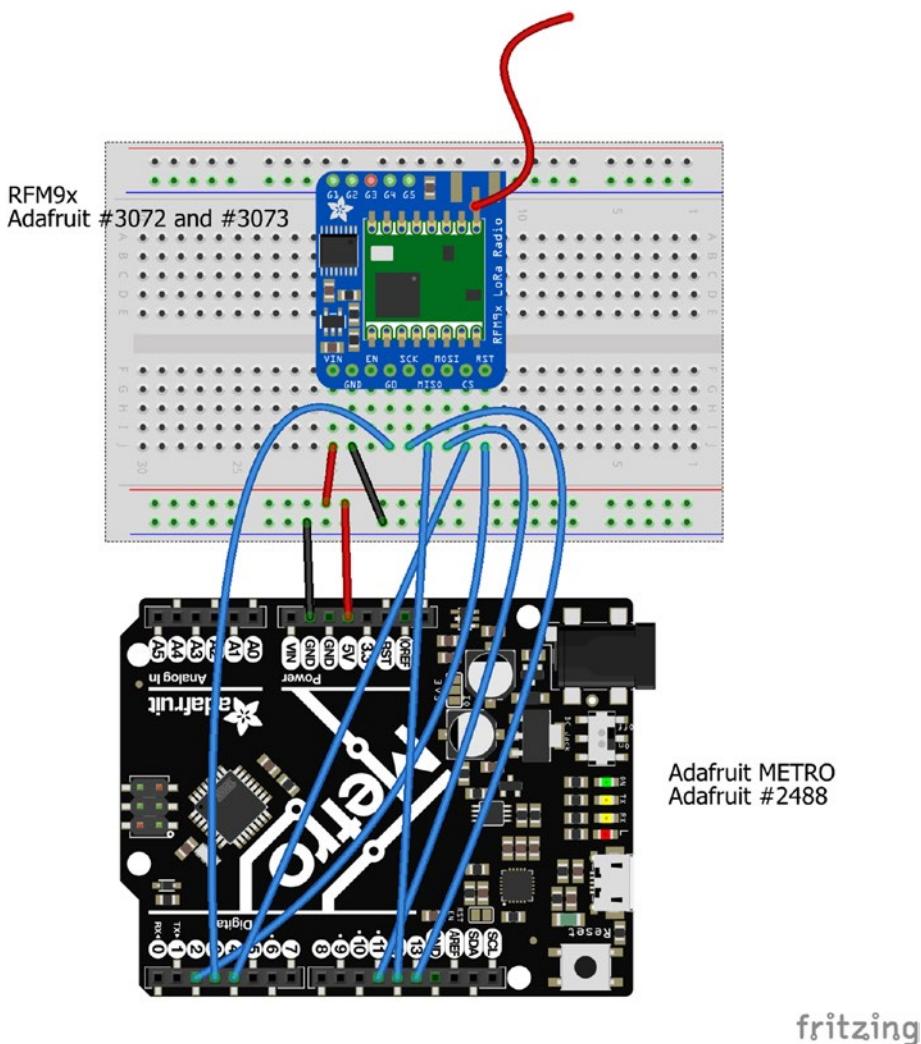


Figure 4-3. Wiring diagram for the LoRa receiving node

Table 4-2 shows the connections between Arduino/Metro, radio transceiver, and DHT11 sensor.

Table 4-2. *Wiring Connections for Receiver*

Arduino/Metro	Radio Transceiver
VIN	VIN
GND	GND
2	RST
3	GO
4	CS
8	
11	MOSI
12	MISO
13	SCK

4. Make sure to keep the antenna wire perpendicular to the LoRa radio transceiver module.

Writing Sketches

Once you have assembled the hardware, you will need to load the Arduino sketches for the project. You can download them from following locations:

- *Sensor node:* Chapter 4/sensor.ino
- *Receiving node:* Chapter 4/receiver.ino

You will be using the RadioHead library to write sketches for both the sensor node and the receiving node. In addition, the sensor node will be using the DHT11 library.

Sensor Node

Listing 4-1 lists the Arduino sketch for the sensor node. The sensor node really works as a client.

Listing 4-1. sensor.ino

```
#include <SPI.h> // Serial Peripheral Interface library
#include <RH_RF95.h> //RadioHead RFM9x library
#include "DHT.h" //DHT temperature and humidity sensor library

//Radio pinout setup
#define RFM95_CS 4 //CS pin is connected to Arduino digital pin 4
#define RFM95_RST 2 //RST pin is connected to Arduino digital pin 2
#define RFM95_INT 3 //Go pin is connected to Arduino digital pin 3
//DHT11 sensor pinout setup
#define DHTPIN 8      // Data out pin is connected to Arduino
digital pin 8

#define RF95_FREQ 433.0

#define DHTTYPE DHT11 // DHT 11 sensor

RH_RF95 rf95(RFM95_CS, RFM95_INT);

DHT dht(DHTPIN, DHTTYPE);

void setup()
{
    pinMode(RFM95_RST, OUTPUT);
    digitalWrite(RFM95_RST, HIGH);

    while (!Serial);
    Serial.begin(9600);
    delay(100);
```

```
digitalWrite(RFM95_RST, LOW);
delay(10);
digitalWrite(RFM95_RST, HIGH);
delay(10);

while (!rf95.init()) {
    Serial.println("initializing...");
    while (1);
}
Serial.println("initialisation succeeded");

if (!rf95.setFrequency(RF95_FREQ)) {
    Serial.println("setFrequency failed");
    while (1);
}
Serial.print("Set Freq to: "); Serial.println(RF95_FREQ);

rf95.setTxPower(23, false);

dht.begin();
}

void loop()
{
    float t = dht.readTemperature();

    if (isnan(t)) {
        Serial.println("Failed to read from DHT sensor!");
        return;
    }

    Serial.println("Sending to receiver");

    char radiopacket[20]= "";
    dtostrf(t,5,2,radiopacket);
```

CHAPTER 4 BUILDING A PEER-TO-PEER CHANNEL

```
Serial.print("Sending "); Serial.println(radiopacket);
Serial.println("Sending..."); delay(10);
rf95.send((uint8_t *) radiopacket, 20);

Serial.println("Waiting for packet to complete..."); delay(10);
rf95.waitPacketSent();

// Waiting for the reply
uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
uint8_t len = sizeof(buf);

Serial.println("Waiting for reply..."); delay(10);
if (rf95.waitForAvailableTimeOut(1000))
{
    // Should be a reply message for us now
    if (rf95.recv(buf, &len))
    {
        Serial.print("Got reply: ");
        Serial.println((char*)buf);
        Serial.print("RSSI: ");
        Serial.println(rf95.lastRssi(), DEC);
    }
    else
    {
        Serial.println("Receive failed");
    }
}
else
{
    Serial.println("No reply, is the receiver running?");
}
delay(1000);
```

Let's take a look at some of the important sections and functions used in the sketch.

1. First you include all the required libraries at the top of the sketch.

```
#include <SPI.h> // Serial Peripheral Interface library  
#include <RH_RF95.h> //RadioHead RFM9x library  
#include "DHT.h" //DHT temperature and humidity sensor library
```

2. Then you define the radio and DHT11 sensor pinout setups. INT is the interrupt pin labeled as "G0."

```
//Radio pinout setup  
#define RFM95_CS 4 //CS pin is connected to Arduino  
digital pin 4  
#define RFM95_RST 2 //RST pin is connected to Arduino  
digital pin 2  
#define RFM95_INT 3 //G0 pin is connected to Arduino  
digital pin 3  
//DHT11 sensor pinout setup  
#define DHTPIN 8      // Data out pin is connected to  
Arduino digital pin 8
```

3. Define the frequency in megahertz. The frequency can be 433 or 915 MHz. Change the frequency to match your LoRa radio transceiver module.

```
#define RF95_FREQ 433.0
```

4. Define the DHT sensor type. For the DHT11 sensor, it should be as follows:

```
#define DHTTYPE DHT11 // DHT 11 sensor
```

5. Instantiate the radio object with the CS and INT pin numbers. RH_RF95() is the constructor. You can have multiple instances, but each instance must

have its own slave select and interrupt pin. After constructing, you must call `init()` to initialize the interface and the radio module. In your hardware setup, the slave select pin is the CS pin connected to the Arduino's digital pin 4. The interrupt pin is the G0 pin connected to the Arduino's digital pin 3.

```
RH_RF95 rf95(RFM95_CS, RFM95_INT);
```

6. Instantiate the DHT object with the data out pin and the DHT sensor type.

```
DHT dht(DHTPIN, DHTTYPE);
```

7. In the `setup()` function, type the following code:

```
void setup()
{
    pinMode(RFM95_RST, OUTPUT);
    digitalWrite(RFM95_RST, HIGH);

    while (!Serial);
    Serial.begin(9600);
    delay(100);

    digitalWrite(RFM95_RST, LOW);
    delay(10);
    digitalWrite(RFM95_RST, HIGH);
    delay(10);

    while (!rf95.init()) {
        Serial.println("initializing...");
        while (1);
    }
    Serial.println("initialisation succeeded");
```

```

if (!rf95.setFrequency(RF95_FREQ)) {
    Serial.println("setFrequency failed");
    while (1);
}
Serial.print("Set Freq to: "); Serial.println(RF95_FREQ);

rf95.setTxPower(23, false);

dht.begin();
}

```

The `init()` function is used to initialize the radio module. It will return true if the initialization succeeded.

```

while (!rf95.init()) {
    Serial.println("initializing...");
    while (1);
}
Serial.println("initialisation succeeded");

```

The `setFrequency()` function is used to set the transmitter and receiver center frequency. The center frequency can be a range from 137.0 MHz to 1020.0 MHz. It will return true if the selected center frequency is within the range. Use the following frequencies for the Adafruit RFM9x LoRa radio transceiver breakouts:

- *Adafruit RFM95W*: 868 or 915 MHz
- *Adafruit RFM96W*: 433 MHz

Setting a frequency outside the range of your radio will probably not work.

```

if (!rf95.setFrequency(RF95_FREQ)) {
    Serial.println("setFrequency failed");
    while (1);
}
Serial.print("Set Freq to: "); Serial.println(RF95_FREQ);

```

The `setTxPower()` function is used to set the transmitter power output level. You can set the transmission power between +5 to +23 in dBm. Set the second parameter to false to enable PA_BOOST for high-power output.

```
rf95.setTxPower(23, false);
```

Inside the `loop()` function, type in the following code.

```
void loop()
{
    float t = dht.readTemperature();

    if (isnan(t)) {
        Serial.println("Failed to read from DHT sensor!");
        return;
    }

    Serial.println("Sending to receiver");
    char radiopacket[20]= "";
    dtostrf(t,5,2,radiopacket);
    Serial.print("Sending "); Serial.println(radiopacket);

    Serial.println("Sending..."); delay(10);
    rf95.send((uint8_t *) radiopacket, 20);

    Serial.println("Waiting for packet to complete..."); delay(10);
    rf95.waitPacketSent();

    // Waiting for the reply
    uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
    uint8_t len = sizeof(buf);

    Serial.println("Waiting for reply..."); delay(10);
    if (rf95.waitAvailableTimeout(1000))
    {
```

```
// Should be a reply message for us now
if (rf95.recv(buf, &len))
{
    Serial.print("Got reply: ");
    Serial.println((char*)buf);
    Serial.print("RSSI: ");
    Serial.println(rf95.lastRssi(), DEC);
}
else
{
    Serial.println("Receive failed");
}
}
else
{
    Serial.println("No reply, is the receiver running?");
}
delay(1000);
}
```

The `dtostrf()` function will convert a float to a char array so it can then be printed easily.

The function prototype of the `dtostrf()` function is as follows:

```
dtostrf(floatvar, StringLengthIncDecimalPoint,
numVarsAfterDecimal, charbuf);
```

Here is what this means:

floatvar	This is a float variable.
StringLengthIncDecimalPoint	This is the length of the string that will be created.
numVarsAfterDecimal	This is the number of digits after the decimal point to print.
charbuf	This is the array to store the results.

The `send()` function used to send a data packet; it loads a message into the transmitter and starts the transmitter. This function requires the array of data to be sent and the size of data in bytes.

The `waitPacketSent()` function blocks other things until the transmitter is no longer transmitting. Once transmitted, the `recv()` function turns the receiver on and, if there is a valid message available, copies it to the buffer and returns true. Otherwise, it returns false.

The `println()` function is used to print the character buffer.

Receiving Node

Listing 4-2 lists the Arduino sketch for the receiving node. The receiving node works as a server.

Listing 4-2. receiver.ino

```
//This code is based on the original code published by Adafruit
available at https://learn.adafruit.com/adafruit-rfm69hcw-and-rfm96-rfm95-rfm98-lora-packet-radio-breakouts/rfm9x-test

#include <SPI.h>
#include <RH_RF95.h>

#define RFM95_CS 10
```

```
#define RFM95_RST 9
#define RFM95_INT 2

#define RF95_FREQ 433.0

RH_RF95 rf95(RFM95_CS, RFM95_INT);

#define LED 13

void setup()
{
    pinMode(LED, OUTPUT);
    pinMode(RFM95_RST, OUTPUT);
    digitalWrite(RFM95_RST, HIGH);

    while (!Serial);
    Serial.begin(9600);
    delay(100);

    digitalWrite(RFM95_RST, LOW);
    delay(10);
    digitalWrite(RFM95_RST, HIGH);
    delay(10);

    while (!rf95.init()) {
        Serial.println("Initialising failed");
        while (1);
    }
    Serial.println("Initialisation succeeded");

    if (!rf95.setFrequency(RF95_FREQ)) {
        Serial.println("Can't set the specified frequency");
        while (1);
    }
    Serial.print("Set Freq to: "); Serial.println(RF95_FREQ);
```

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```
    rf95.setTxPower(23, false);
}

void loop()
{
    if (rf95.available())
    {
        //Read the availabe message
        uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
        uint8_t len = sizeof(buf);

        if (rf95.recv(buf, &len))
        {
            //Receive the message
            digitalWrite(LED, HIGH);
            RH_RF95::printBuffer("Received: ", buf, len);
            Serial.print("Got: ");
            Serial.println((char*)buf);

            // Send a reply
            uint8_t data[] = "Ack";
            rf95.send(data, sizeof(data));
            rf95.waitPacketSent();
            Serial.println("Sent a reply");
            digitalWrite(LED, LOW);
        }
        else
        {
            //If receive failed
            Serial.println("Receive failed");
        }
    }
}
```

Result

Connect the sensor node and receiving node to your computer using USB cables. Open two instances of the Arduino IDE.

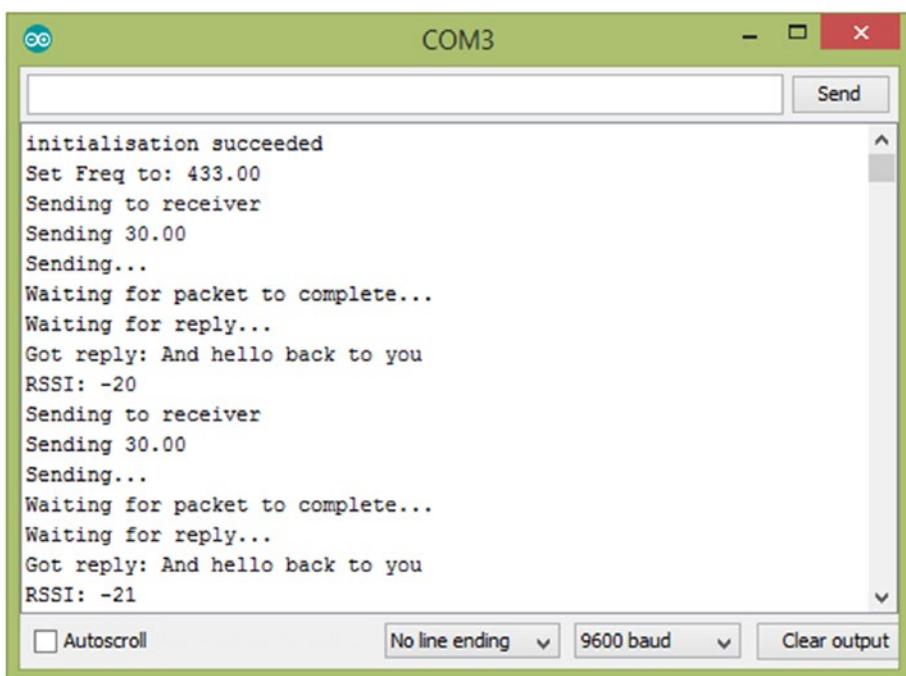
To start a new instance of the Arduino IDE, double-click the Arduino desktop icon (for admin installed) or double-click arduino.exe (for nonadmin installed). The File ➤ New command doesn't create a new instance of the IDE.

Using the first instance of the IDE, upload Listing 4-1 to the sensor node. With the second instance of the IDE, upload Listing 4-2 to the receiving node. Make sure to select the correct COM port before uploading the sketch.

Here's an example:

- *Sensor node:* COM3
- *Receiving node:* COM7

After uploading the sketches, open serial monitors in both IDEs. Figure 4-4 shows the output on the serial monitor for the sensor node. For example, the sensor node sends the current temperature 30.00 Celsius. Then it receives the acknowledgment packet "And hello back to you."



The screenshot shows a Windows-style serial monitor window titled "COM3". The window displays a log of communication between a sensor node and a receiver. The log includes initialization messages, frequency settings, transmission attempts, reception of a reply, and RSSI values. The bottom of the window features standard serial monitor controls: "Autoscroll" (unchecked), "No line ending" (dropdown menu), "9600 baud" (dropdown menu), and "Clear output" (button).

```
initialisation succeeded
Set Freq to: 433.00
Sending to receiver
Sending 30.00
Sending...
Waiting for packet to complete...
Waiting for reply...
Got reply: And hello back to you
RSSI: -20
Sending to receiver
Sending 30.00
Sending...
Waiting for packet to complete...
Waiting for reply...
Got reply: And hello back to you
RSSI: -21
```

Figure 4-4. Serial monitor output for the sensor node

At the receiving end, the receiver receives the data packet containing the temperature, which is 30.00. Then it sends an acknowledgment to the sensor. Figure 4-5 shows the serial monitor output for the receiving node.

The screenshot shows the Arduino Serial Monitor window titled "COM7". The window displays the following text:

```
Arduino LoRa RX Test!
LoRa radio init OK!
Set Freq to: 433.00
Received:
33 30 2E 30 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
Got: 30.00
RSSI: -20
Sent a reply
Received:
33 30 2E 30 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
Got: 30.00
RSSI: -20
Sent a reply
Received:
33 30 2E 30 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

At the bottom of the window, there are three buttons: "Autoscroll" (unchecked), "No line ending" (selected), "9600 baud" (selected), and "Clear output".

Figure 4-5. Serial monitor output for the receiving node

Make sure to use the same frequency for both the sensor and the receiving node.

Summary

Now you know how to use the RadioHead library to send and receive LoRa packets on a specified frequency for both the transmitter and the receiver. In the next chapter, you will build a single-channel LoRa gateway with the Raspberry Pi.

CHAPTER 5

Building a LoRa Gateway

In this chapter, you will learn how to build a low-cost single-channel LoRa gateway based on the Raspberry Pi. The gateway uses a single-channel packet forwarder to forward incoming data packets to the Things Network (<https://www.thethingsnetwork.org/>). Then, you will create an application on the Things Network to decode the payloads to extract sensor data from the data packet.

Things You Need

You will need following things to build this project:

- One Raspberry Pi 3 (<https://www.sparkfun.com/products/13825>)
- One microSD card with adapter, 16 GB, Class 10 (<https://www.sparkfun.com/products/13833>)
- One Arduino Uno or Adafruit Metro (<https://www.sparkfun.com/products/11224> or <https://www.adafruit.com/product/2488>)
- One wall adapter power supply, 5.1 V DC 2.5 A (USB Micro-B) (<https://www.sparkfun.com/products/13831>)

- One 9 VDC 1000 mA--regulated switching power adapter, UL listed (<https://www.adafruit.com/product/63>)
- Two LoRa RFM9x radio transceiver breakouts (<https://www.adafruit.com/product/3072> or <https://www.adafruit.com/product/3073>)
- One DHT11 temperature and humidity sensor (<https://www.adafruit.com/product/386>)
- One 10 K ohm resistor (usually comes with the DHT11 sensor; if not, visit <https://www.adafruit.com/product/2784>)
- Two breadboards (<https://www.sparkfun.com/products/12002>)
- Two breadboard holders (<https://www.sparkfun.com/products/11235>)
- A few hook-up wires (<https://www.sparkfun.com/products/11367>)
- A few male-to-female jumper wires (<https://www.sparkfun.com/products/12794>)

Installing Raspbian on the Raspberry Pi

Your Raspberry Pi doesn't come with a pre-installed operating system. There are plenty of operating systems available for the Raspberry Pi. Among them, Raspbian Stretch LITE is the most suitable lightweight operating system that can be used to build a LoRa single-channel LoRa gateway. It doesn't provide a GUI, but you can access it with the command line. Raspbian Stretch LITE is a minimal image based on Debian Stretch.

1. Go to the official Raspberry Pi download page at <https://www.raspberrypi.org/downloads/raspbian/> and download Raspbian Stretch LITE. You can download it from the torrent by clicking the Download Torrent button, or you can download it as a ZIP file by clicking the Download ZIP button (Figure 5-1).

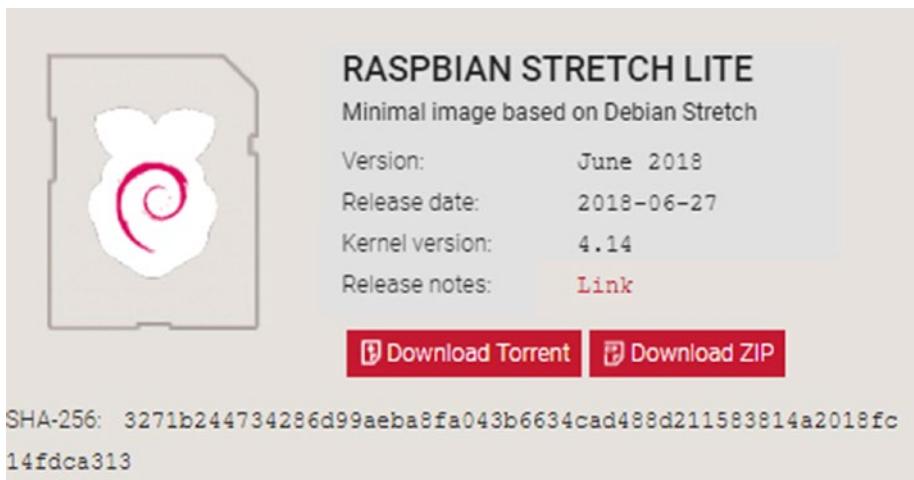


Figure 5-1. Download options for Raspbian Stretch LITE

2. After you download the ZIP file, unzip it using 7Zip (Windows) or the Unarchiver (Macintosh).

Formatting the SD Card

SD Card Formatter is the best software tool for formatting any type of SD card. You can download and install the latest version of SD Card Formatter on your computer by visiting https://www.sdcards.org/downloads/formatter_4/index.html.

1. Insert the microSD card into the slot of the SD card adapter. Then insert the SD card adapter into the SD card port on your computer (laptop). If you have an SD card reader, insert the microSD card into it and connect the SD card reader to the computer with a suitable USB cable.
2. Start SD Card Formatter and under “Select card,” select the SD card from the drop-down list (Figure 5-2).

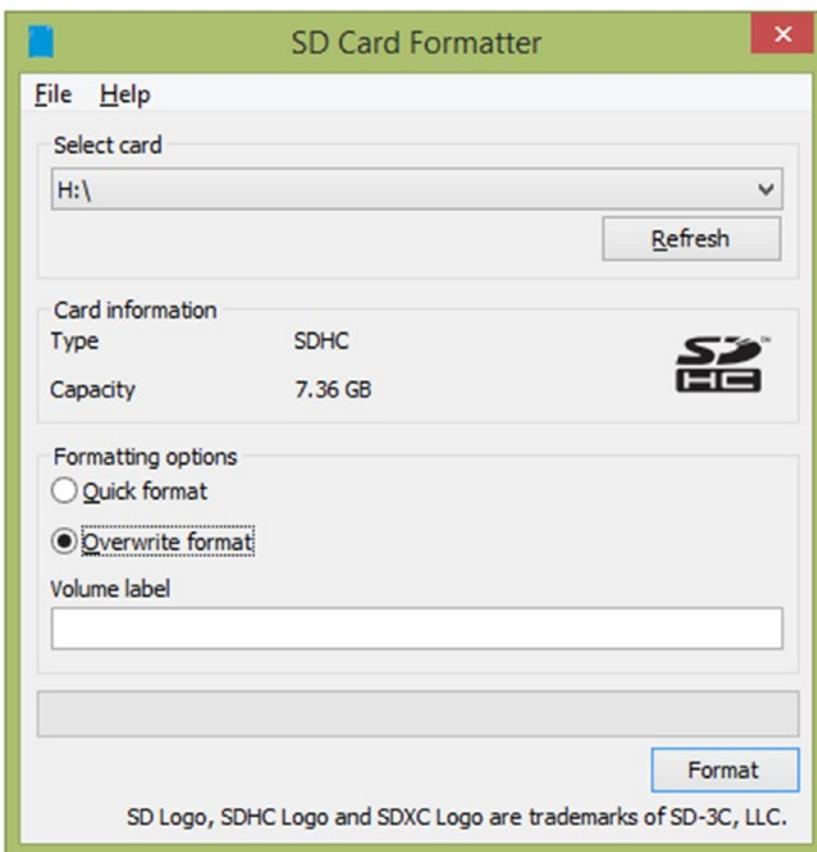


Figure 5-2. Selecting a card and formatting options

3. Under “Formatting options,” select “Overwrite format.”
4. Click the Format button to start formatting. Click the Yes button to confirm.
5. After completing the formatting process, click the OK button.

Writing Raspbian Stretch LITE to the SD Card

You can use Etcher (<https://etcher.io/>) as the image-writing tool to write Raspbian Stretch LITE to the microSD card. It is a graphical tool that works on Mac OS, Linux, and Windows. Etcher also supports writing images directly from the ZIP file, without any unzipping required.

1. On the Etcher download page, choose the correct operating system that you want to use with Etcher from the drop-down list. Depending on your selection, a portable or installer file will download to your computer (Figure 5-3).

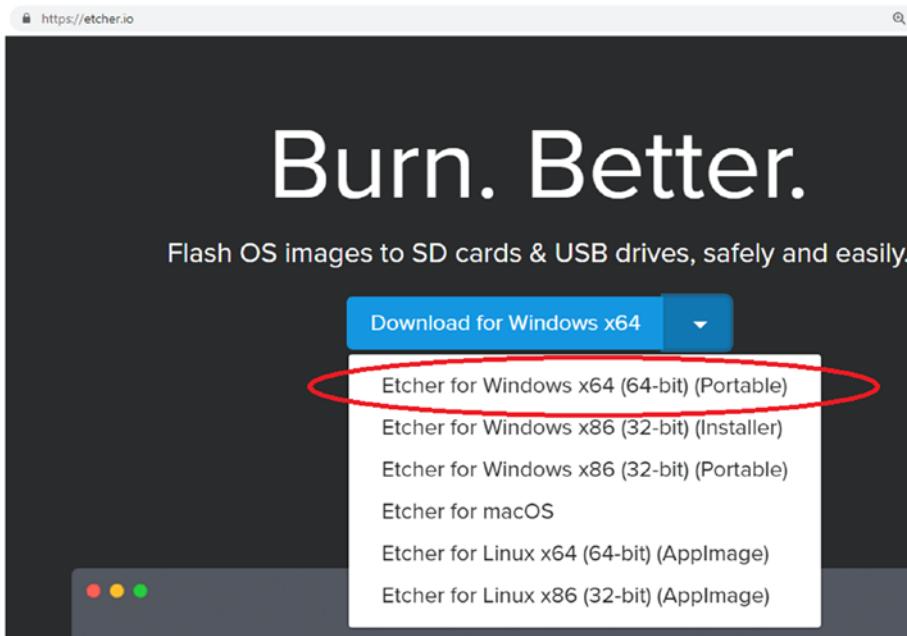


Figure 5-3. Choosing the Etcher portable or installer for your operating system

2. If you have a portable file (such as Etcher-Portable-1.4.5-x64), simply run it to open Etcher. If you have an installer (such as Etcher-Setup-1.4.5-x64), first install it on your computer and then run the program to open the Etcher.
3. In the Etcher window, click the “Select image” button to browse to the downloaded Raspbian Stretch LITE image (IMP or ZIP) from your computer (Figure 5-4).



Figure 5-4. Selecting the downloaded image file

4. Click the “Select drive” button and select the microSD card (Figure 5-5).



Figure 5-5. Selecting the microSD card

5. Review your selections and click the Flash! button to begin writing data to the microSD card (Figure 5-6).

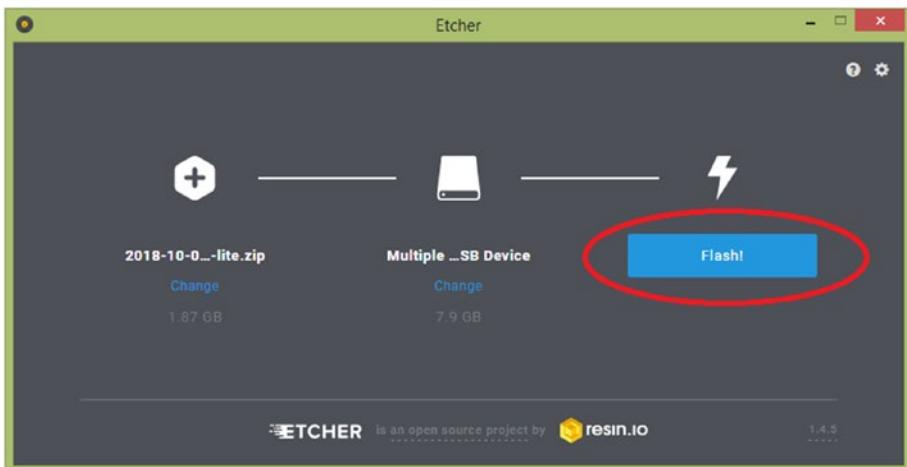


Figure 5-6. Flashing the image

6. After completing the flashing process, close Etcher. Don't remove the microSD card yet.

Adding Wi-Fi Network Details

Raspbian Stretch Lite doesn't provide a graphical user interface to set up Wi-Fi on the Raspberry Pi. As an option, you can create a file to store Wi-Fi configuration settings for your preferred Wi-Fi network.

1. With the SD card connected, in the root of the SD card (boot partition), create a new file named `wpa_supplicant.conf`. To create the file with `.conf` extension, first you can open the Notepad or any text editor and save it as "`wpa_supplicant.conf`", including the quotation marks, in the Save As dialog box.

2. In the file you should add the following configuration script:

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
network={
    ssid="YOUR_SSID"
    psk="YOUR_WIFI_PASSWORD"
    key_mgmt=WPA-PSK
}
```

3. Replace the `ssid` value with the name of your Wi-Fi network, and replace the `psk` value with the password of your Wi-Fi network. As an example, the configuration file will look like this:

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
network={
    ssid="Dialog 4G"
    psk="E76342B148"
    key_mgmt=WPA-PSK
}
```

You can learn about more advanced options for adding network details to the Raspberry Pi by visiting <https://www.raspberrypi.org/documentation/configuration/wireless/wireless-cli.md>.

4. Save the file again to persist the changes and then close the editor.

Enabling SSH

The SSH protocol can be used to connect with your Raspberry Pi from your computer over a network (Ethernet or Wi-Fi). To accept a connection from another computer, you should first enable the SSH protocol on the Raspberry Pi.

1. In the root of the SD card (boot partition), create a file named ssh without any extension. To create the file without any extension, first you can open the Notepad or any text editor and save it as “ssh”, including the quotation marks, in the Save As dialog box.
2. Close the editor.

Inserting the microSD Card into the Raspberry Pi

First safely remove the microSD card from your computer. Then insert the microSD card to the microSD slot that can be found on the rear side of the Raspberry Pi. Firmly push in the SD card, and you will hear a clicking sound once it is locked inside the slot.

Building the Gateway

The hardware setup for the Raspberry Pi-based LoRa gateway can be built in a few minutes with the following items:

- Raspberry Pi 3 with Raspbian Stretch LITE image written
- Wall adapter power supply, 5.1 V DC 2.5 A (USB Micro-B)
- LoRa RFM9x radio transceiver breakout
- Half-size breadboard
- Breadboard holder
- A few hook-up wires
- A few jumper wires (male-to-female)

Figure 5-7 shows the wiring diagram for the LoRa gateway. Table 5-1 shows the wiring connections between each component. You can use male-to-female jumper wires to make connections between the LoRa radio transceiver breakout and the Raspberry Pi. Use hook-up wires to connect the VIN and GND of the LoRa radio transceiver breakout with the power rails of the breadboard.

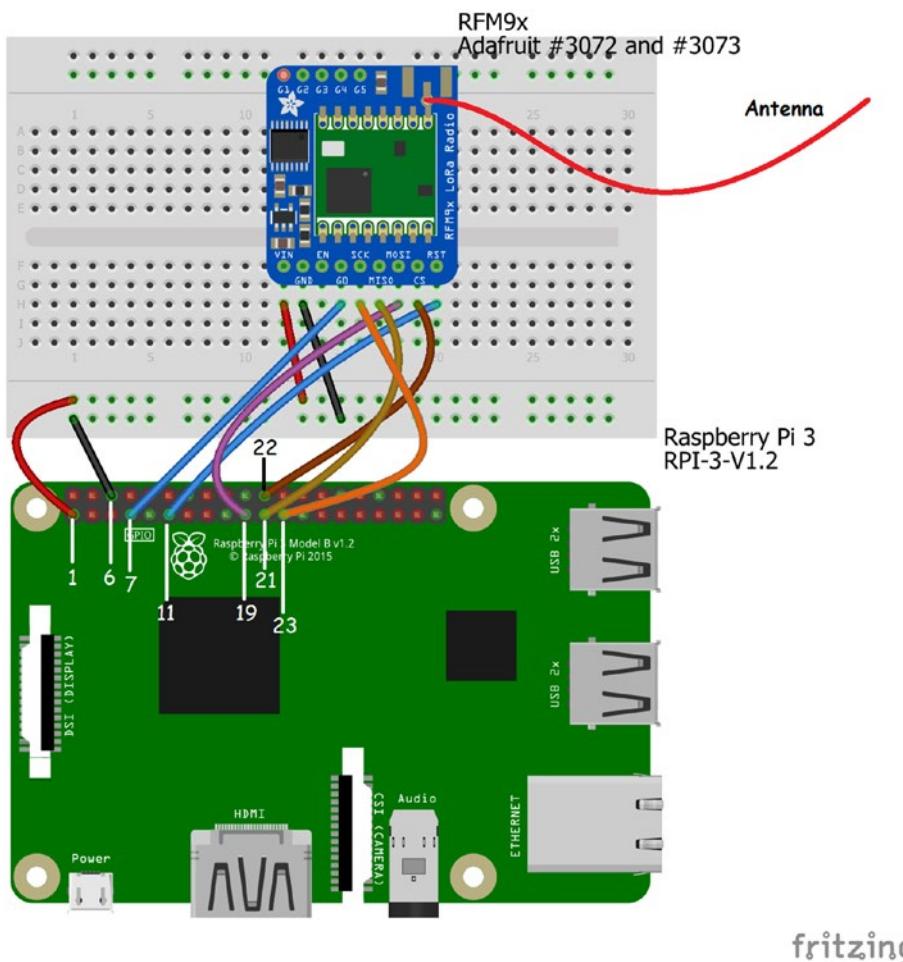


Figure 5-7. Wiring diagram for the LoRa gateway

Table 5-1. *Wiring Connections Between Each Component*

Raspberry Pi	RFM9x
1	VIN
6	GND
7	GO
11	RST
19	MOSI
21	MISO
22	CS
23	SCK

After building the gateway, connect the power supply to the Raspberry Pi and apply the power (Figure 5-8). Wait a few minutes to complete the first-time setup.

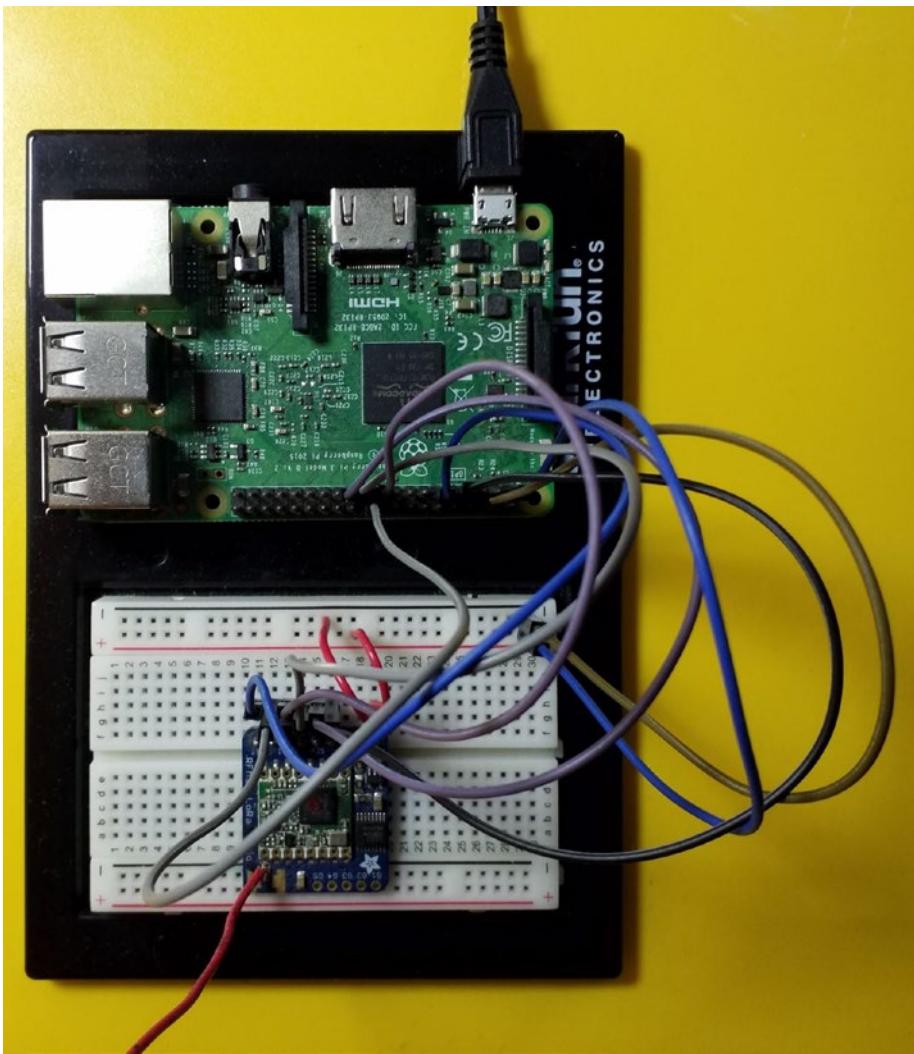


Figure 5-8. Completed hardware setup of the LoRa gateway

SSHing into Your Raspberry Pi

Before SSHing into your Raspberry Pi, first you should know its IP address dynamically allocated by the router. Usually the IP address of any device in your network can be found on your router's configuration

portal. The following steps show you how to find the device list and IP address with the Huawei E5172s-920 router:

1. Launch a web browser, and in the address bar, enter the IP address of your router (or <http://homeroouter.cpe>). Then click the arrow icon or press Enter.
2. In the router's configuration page, in the left navigation bar, click Product Information.
3. Scroll down the page. Under Device List, you can find the dynamically allocated IP address for each device (Figure 5-9).

Device List

Index	Computer Name	MAC Address	IP Address	Lease Time	Status	Type	Operation
1	Pradeeka	9C:2A:70:C3:69:3F	192.168.1.2	0 days 18 hours 20 minutes 8 seconds	Active	Wi-Fi	Kick Out
2	amazon-04fce8ca4	00:71:47:F0:D5:AD	192.168.1.4	0 days 20 hours 59 minutes 17 seconds	Active	Wi-Fi	Kick Out
3	raspberrypi	B8:27:EB:2F:04:80	192.168.1.6	0 days 23 hours 59 minutes 53 seconds	Active	Wi-Fi	Kick Out
4	android-f545dbea0572d0c9	94:FE:22:65:B3:47	192.168.1.3	0 days 0 hours 13 minutes 16 seconds	Inactive	Ethernet	Kick Out
5	amazon-a11873fa6	FC:65:DE:2F:0F:B4	192.168.1.5	0 days 14 hours 23 minutes 53 seconds	Inactive	Ethernet	Kick Out

Figure 5-9. Viewing the list of connected devices

4. Open PuTTY, and in the PuTTY Configuration window, under Host Name (or IP address), type in the IP address of your Raspberry Pi. The default port number for SSH is 22. Then click the Open button (Figure 5-10).

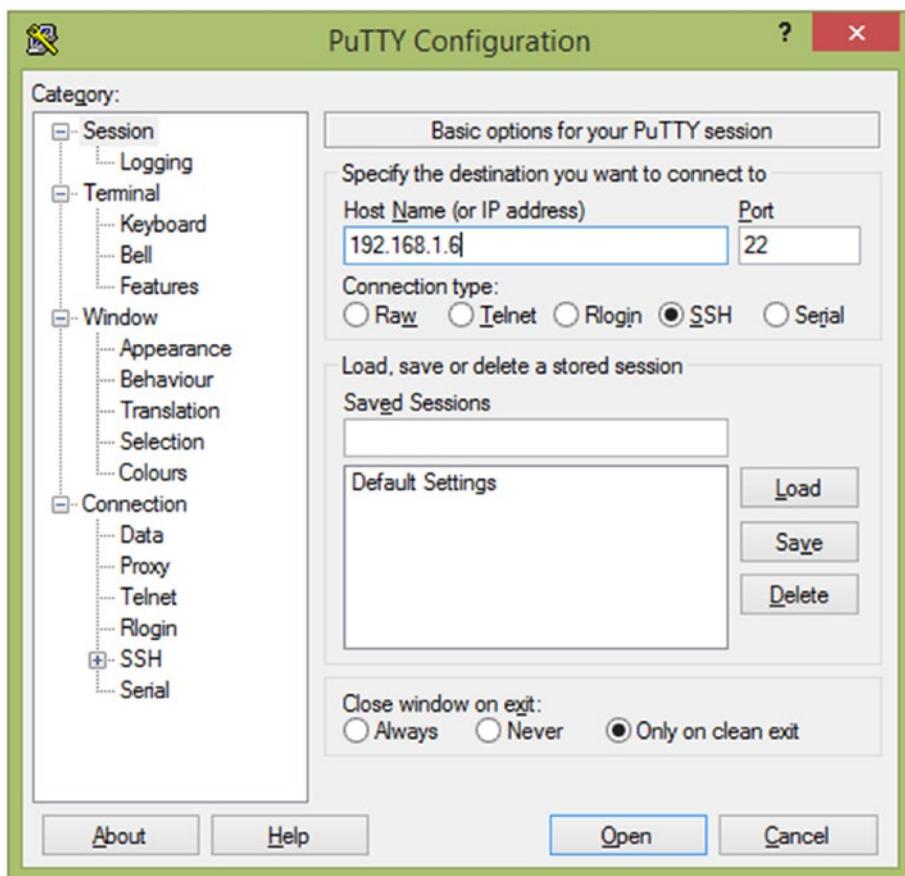
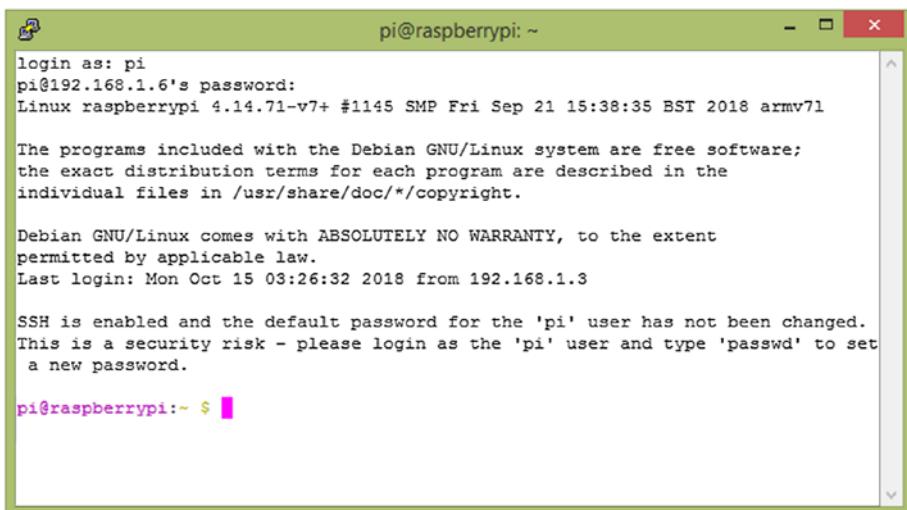


Figure 5-10. PuTTY configuration for the SSH session

5. The default login credentials for your Raspberry Pi are as follows (Figure 5-11):

User - pi
Password -raspberry



```
login as: pi
pi@192.168.1.6's password:
Linux raspberrypi 4.14.71-v7+ #1145 SMP Fri Sep 21 15:38:35 BST 2018 armv7l

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/*copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Mon Oct 15 03:26:32 2018 from 192.168.1.3

SSH is enabled and the default password for the 'pi' user has not been changed.
This is a security risk - please login as the 'pi' user and type 'passwd' to set
a new password.

pi@raspberrypi:~ $
```

Figure 5-11. Logging into the Raspberry Pi using the default credentials through SSH

6. Before installing anything, it is a best practice to make sure the Raspbian operating system is up-to-date. Type the following two commands, one after the other, waiting for them to complete at each step:

```
sudo apt-get update
sudo apt-get upgrade
sudo reboot
```

Enabling SPI Interface

To allow the Raspberry Pi to communicate with the LoRa radio transceiver module, you should enable the SPI interface on the Raspberry Pi.

1. Type the following command to open the Raspberry Pi Software Configuration Tool:

```
sudo raspi-config
```

2. In the Raspberry Pi Software Configuration Tool, select Interfacing Options. Then press the Enter key on your keyboard (Figure 5-12).

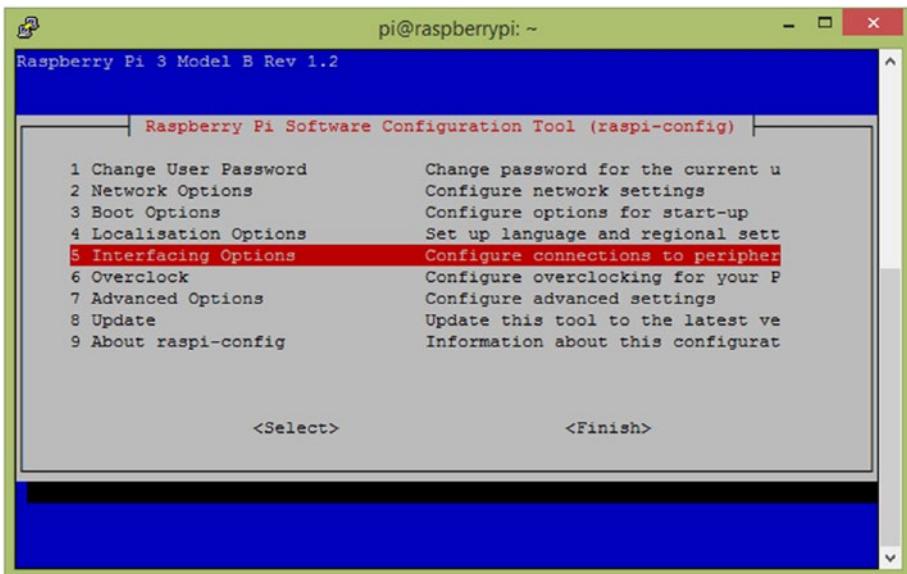


Figure 5-12. Enabling SPI on the Raspberry Pi, selecting Interfacing Options

3. Select SPI and press the Enter key on your keyboard (Figure 5-13).

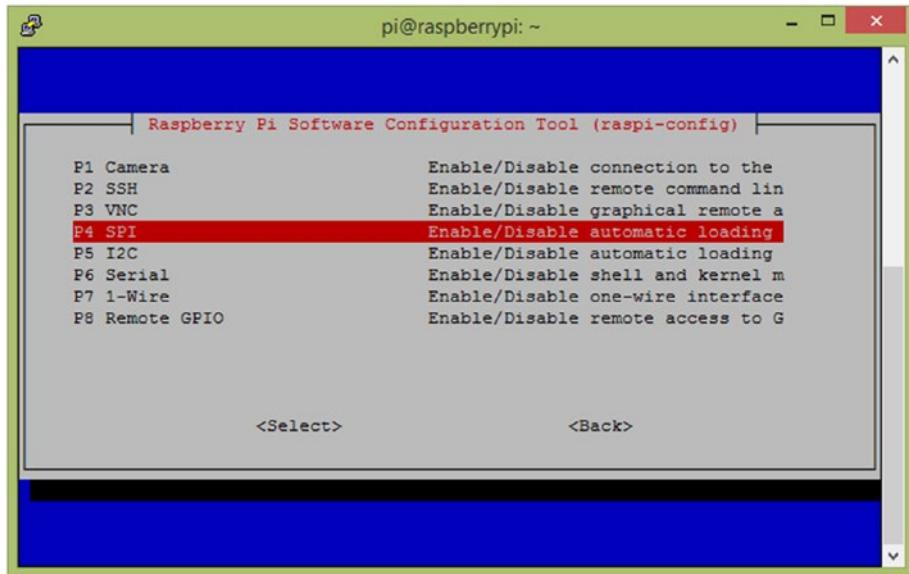


Figure 5-13. Enabling SPI on Raspberry Pi, selecting SPI

4. Select <Yes> and press the Enter key on your keyboard (Figure 5-14).

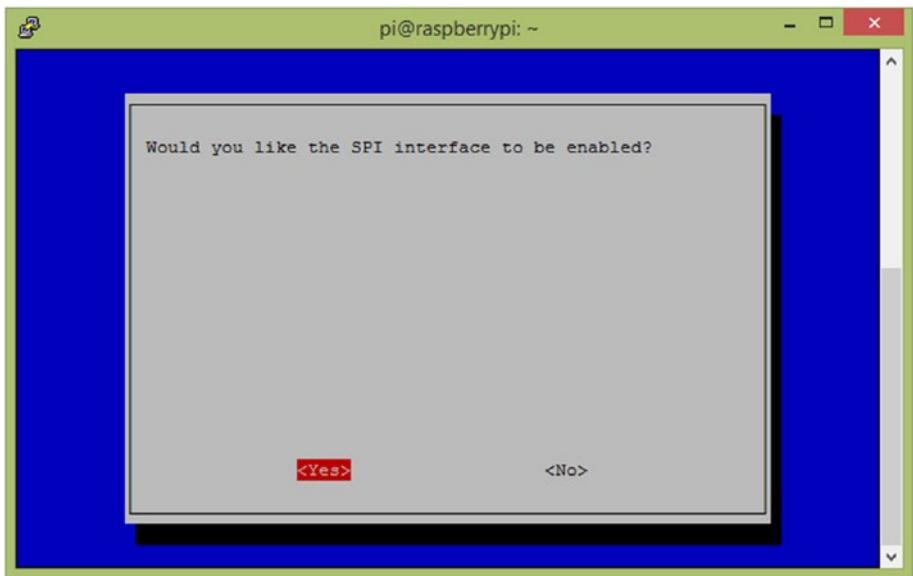


Figure 5-14. Enabling SPI on Raspberry Pi, selecting <Yes>

CHAPTER 5 BUILDING A LORA GATEWAY

5. Press the Enter key on your keyboard to close the message (Figure 5-15).

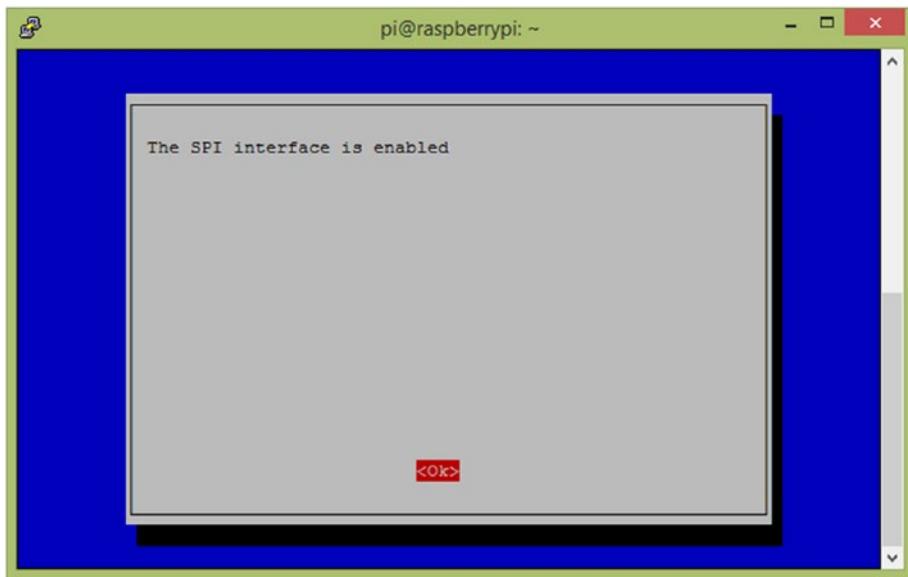


Figure 5-15. Enabling SPI on Raspberry Pi, closing the message

6. Select <Finish> to exit from the Raspberry Pi Software Configuration Tool (Figure 5-16).

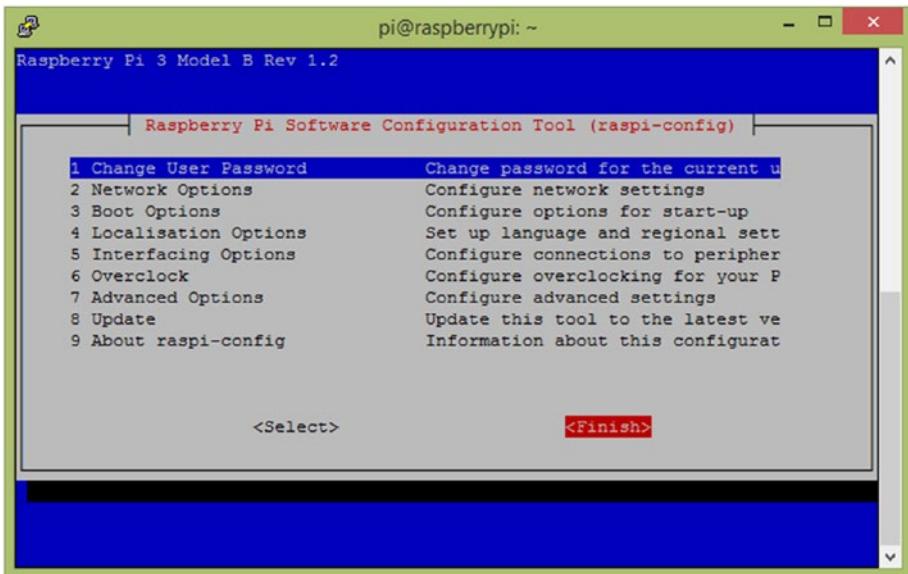


Figure 5-16. Enabling SPI on the Raspberry Pi, exiting

7. Reboot the Raspberry Pi with the following command:

```
sudo reboot
```

Installing Wiring

The WiringPi library allows you to easily interface with the GPIO pins of the Raspberry Pi. It also supports I2C and SPI. You can use the following command to install the WiringPi library on your Raspberry Pi:

```
sudo apt-get install wiringpi
```

Installing and Configuring a Single-Channel Packet Forwarder

Single-channel packet forwarder software can listen on a configurable frequency and has a spreading factor from SF7 to SF12. For this LoRa gateway, you will be installing the single-channel LoRaWAN gateway software maintained at https://github.com/tftelkamp/single_chan_pkt_fwd by Thomas Telkamp. Follow these steps to install single-channel packet forwarder software on the Raspberry Pi:

1. Install Git using the following command:

```
sudo apt-get install git
```

2. Clone the repository found at https://github.com/tftelkamp/single_chan_pkt_fwd using the following command:

```
git clone https://github.com/tftelkamp/
single_chan_pkt_fwd
```

3. After cloning the repository, use the following commands to open the `main.cpp` file in the `single_chan_pkt_fwd` directory:

```
cd single_chan_pkt_fwd
nano main.cpp
```

4. Configure the packet forwarder for the center frequency using the following line of code:

```
uint32_t freq = 868100000; // in Mhz! (868.1)
```

5. Modify the frequency to suit the frequency of the attached LoRa radio transceiver module. As an example, if you have a 433 MHz LoRa radio transceiver module, the center frequency will be as follows:

```
uint32_t freq = 433100000; // in Mhz! (433.1)
```

6. Define the router address to allow the packet forwarder to connect with the Things Network by modifying the following line of code:

```
#define SERVER1 "54.72.145.119" // The Things Network:  
croft.thethings.girovito.nl
```

As an example, to connect with the `router.eu.thethings.network`, use the IP address 52.169.76.203. The modified code should look like this:

```
#define SERVER1 "52.169.76.203" // The Things Network:  
router.eu.thethings.network
```

7. You can find the list of router addresses at <https://www.thethingsnetwork.org/docs/gateways/packet-forwarder/semttech-udp.html#router-addresses>. Simply use the `ping` command to find the IP address for any router address. As an example, to get the IP address for the router address, `router.eu.thethings.network`, use the following command:

```
ping router.eu.thethings.network
```

8. This will output the IP address as follows:

```
PING router.eu.thethings.network (52.169.76.203) 56(84)  
bytes of data.
```

9. Save the file by pressing `Ctrl+X`, followed by `Ctrl+O`.
10. Now you can compile the code using the following command:

```
make
```

11. After compiling the code, run the packet forwarder using the following command:

```
./single_chan_pkt_fwd
```

12. You will get output something similar to Figure 5-17.

This shows the status of the RFM9x LoRa radio transceiver module as “SX1276 detected, starting.” If you get the status message “Unrecognized transceiver,” check again the wiring connections between the RFM9x and Raspberry Pi. Also, you will get the same message for malfunctioning or broken radio transceivers.

13. Note the gateway ID. The gateway ID will be required to configure your gateway with the Things Network. The autogenerated gateway ID for this gateway is b8:27:eb:ff:7a:51:d5.

```
pi@raspberrypi:~/single_chan_pkt_fwd $ sudo /home/pi/single_chan_pkt_fwd/single_
chan_pkt_fwd
SX1276 detected, starting.
Gateway ID: b8:27:eb:ff:7a:51:d5
Listening at SF7 on 433.100000 Mhz.

-----
stat update: {"stat":{"time":"2018-10-19 06:50:56 GMT","lati":0.00000,"long":0.0
000,"alti":0,"rxnb":0,"rxfw":0,"ackr":0.0,"dwnb":0,"txnb":0,"pfrm":"Si
ngle Channel Gateway","mail":"","desc":""})
stat update: {"stat":{"time":"2018-10-19 06:51:26 GMT","lati":0.00000,"long":0.0
000,"alti":0,"rxnb":0,"rxfw":0,"ackr":0.0,"dwnb":0,"txnb":0,"pfrm":"Si
ngle Channel Gateway","mail":"","desc":""})
stat update: {"stat":{"time":"2018-10-19 06:51:56 GMT","lati":0.00000,"long":0.00000,"alti":0,
"b":0,"rxok":0,"rxfw":0,"ackr":0.0,"dwnb":0,"txnb":0,"pfrm":"Single Channel Gateway","mail":"",
"c":""})
```

Figure 5-17. Console output for the single-channel packet forwarder

Registering Your Gateway with the Things Network

The Things Network allows you to register your LoRa gateway in no time with a few simple steps. It also allows you to build applications to decode the payloads and integrate with third-party services to further process your data.

1. Go to the Things Network (<https://www.thethingsnetwork.org/>) and click the Sign Up button in the top-right corner of the page (Figure 5-18).



Figure 5-18. Signing up with the Things Network

2. On the Create an Account page, type in a username, a valid e-mail address, and a password with at least six characters. Then click the “Create account” button (Figure 5-19).



CREATE AN ACCOUNT

Create an account for The Things Network and start exploring the world of Internet of Things with us.

USERNAME

This will be your username — pick a good one because you will not be able to change it.



Type a user name

EMAIL ADDRESS

You will receive a confirmation email, as well as occasional account related emails. If this email address is managed by a third party (such as for corporate email addresses), this third party might block emails coming from The Things Network. This email address is not public.



Type a valid e-mail address

PASSWORD

Use at least 6 characters.



Type a password

Create account

Figure 5-19. Creating a new account

3. Now go to your e-mail account's inbox and open the e-mail (the Things Network account validation). Then click the "Activate account" button.
4. After activating the account, on the welcome page, click Console at the top of the page (Figure 5-20).

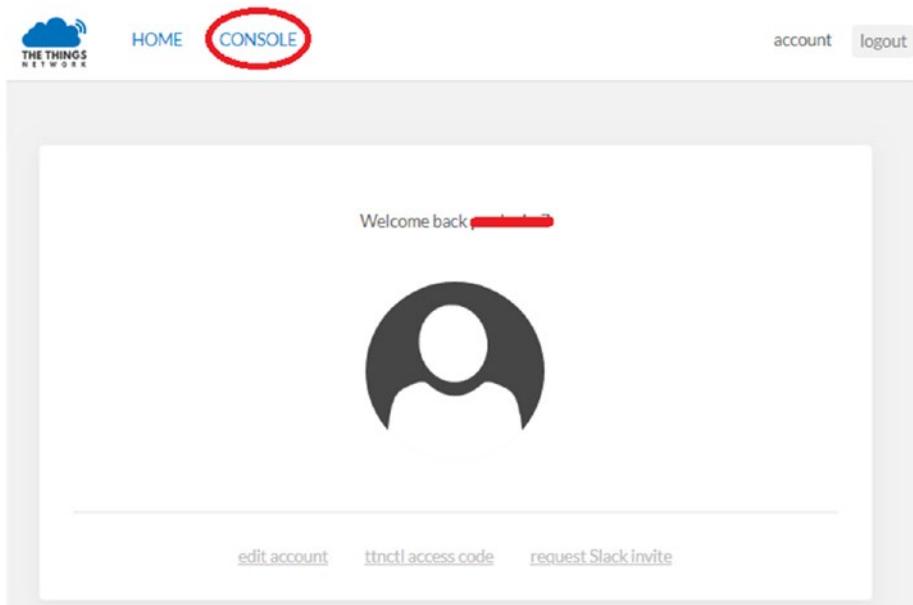


Figure 5-20. Accessing the Things Network console

5. This will bring you to the console at <https://console.thethingsnetwork.org/>. The console allows you to register gateways and devices, build applications, create integrations, and manage collaborators and settings.
6. On the console landing page, click Gateways (Figure 5-21).

CHAPTER 5 BUILDING A LORA GATEWAY

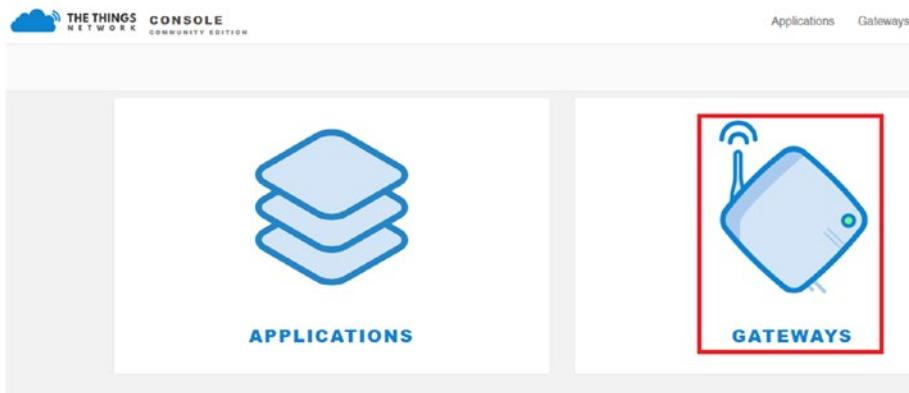


Figure 5-21. Section for registering new gateways and accessing registered gateways

7. Click the “register gateway” link (Figure 5-22).



Figure 5-22. Registering a new gateway

8. On the register page, under the Register Gateway section, fill out the form with the following information (Figure 5-23):
 - *Gateway ID:* This is a unique human-readable identifier for your gateway. Use the gateway ID generated by the single-channel packet forwarder (see “Installing and Configuring a Single-Channel Packet Forwarder”). Type it without colons (for example, **b827ebffff7a51d5**).

- Select the “I’m using the legacy packet forwarder” check box.
- *Description:* Type in a description for your gateway (e.g., **My First Raspberry Pi Gateway**)
- *Frequency Plan:* Choose a frequency plan from the drop-down list to use with your gateway’s LoRa radio transceiver module (e.g., Europe 868 MHz).
- *Router:* Choose a router from the drop-down list to connect your gateway to the Things Network (e.g., ttn-router-eu).
- *Location:* Click the map to mark the location of your gateway.
- *Antenna Placement:* Choose Indoor.

The screenshot shows the 'REGISTER GATEWAY' form on the Things Network website. The form includes fields for Gateway EUI, Description, Frequency Plan, and Router, along with checkboxes for legacy packet forwarder and Semtech packet forwarder.

Gateway EUI
The EUI of the gateway as read from the LoRa module
B8 27 EB FF FF 7A 51 D5 (8 bytes)

I'm using the legacy packet forwarder
Select this if you are using the legacy [Semtech packet forwarder](#).

Description
A human-readable description of the gateway
My First Raspberry Pi Gateway

Frequency Plan
The [frequency plan](#) this gateway will use
Europe 868MHz

Router
The router this gateway will connect to. To reduce latency, pick a router that is in a region which is close to the location of the gateway.
ttn-router-eu

Figure 5-23. Registering a gateway

9. Click the Register Gateway button to complete the registration. You will be navigated to the gateway page.
10. On the gateway page, under the Gateway Overview section, you can view the status of your Raspberry Pi gateway (Figure 5-24). The status should be connected if the packet forwarding software is still running on the Raspberry Pi. If not, run the packet forwarding software and wait for the status to update.

The screenshot shows the 'GATEWAY OVERVIEW' section of the TTN (The Things Network) web interface. Key details displayed include:

- Gateway ID:** eui-b827ebffff7a51d5 (highlighted in yellow)
- Description:** My First Raspberry Pi Gateway
- Owner:** pradeeka7 (with a user icon)
- Status:** connected (indicated by a green dot)
- Frequency Plan:** Europe 868MHz
- Router:** ttu-router-eu
- Gateway Key:** A long string of characters, partially obscured by a redacted area, with an eye icon and a copy/paste button.
- Last Seen:** 5 seconds ago
- Received Messages:** 0 (redacted)
- Transmitted Messages:** 0

Figure 5-24. Overview of the registered gateway

11. If you want to change the settings for your gateway, click the Settings tab. On the Settings page, under Gateway Settings section, modify the fields and click the Update Gateway button.

Creating an Application

The LoRa gateway receives raw data packets. These data packets include payloads and other information related to the transmitter. You should decode the payloads to extract the data from the data packets.

1. In the Things Network console, click Applications.
2. On the Applications page, click the “add application” link.
3. On the Add Application page, in the Add Application section, fill out the form (Figure 5-25).
 - *Application ID:* Enter the unique identifier of your application on the network (e.g., b827ebffff7a51d51).
 - *Description:* This is a human-readable description of your new application (e.g., My sensor network application).
 - *Handler registration:* Select the handler you want to register this application to (e.g., ttu-handler-eu).

CHAPTER 5 BUILDING A LORA GATEWAY

Applications > Add Application

ADD APPLICATION

Application ID
The unique identifier of your application on the network

Description
A human readable description of your new app

Application EUI
An application EUI will be issued for The Things Network block for convenience, you can add your own in the application settings page.

Handler registration
Select the handler you want to register this application to

Figure 5-25. Adding an application

4. Click the “Add application” button to create the application. You will be navigated to the application page. Scroll down the page and locate the Devices section. Then, click the “register device” link (Figure 5-26).

Applications >  b827ebffff7a51d51

DEVICES

[register device](#) [manage devices](#)

 0 registered devices

Figure 5-26. Registering a device

5. On the Devices page, in the Register Device section, fill out the form (Figure 5-27).

- *Device ID*: This is the unique identifier for the device in this application (e.g., 12346789). The device ID will be immutable.
- *Device EUI*: The device EUI is the unique identifier for this device on the network (e.g., 827ebffff7a51d5). The device EUI must consist of exactly 8 bytes.
- *App Key*: The app key will be used to secure the communication between your device and the network. This is an autogenerated key.
- *App EUI*: This is an autogenerated identifier.

The screenshot shows a web-based device registration interface. At the top, a navigation bar displays 'Applications > b827ebffff7a51d51 > Devices'. Below this, a section titled 'REGISTER DEVICE' contains four fields:

- Device ID**: A text input field containing the value '12346789'. A descriptive note below the field states: 'This is the unique identifier for the device in this app. The device ID will be immutable.'
- Device EUI**: A text input field containing the value 'B8 27 EB FF FF 7A 51 D5'. A note below the field states: 'The device EUI is the unique identifier for this device on the network. You can change the EUI later.' To the left of the input field is a small icon with a cross symbol.
- App Key**: A text input field with a pen icon to its left. A note to the right of the field states: 'this field will be generated'
- App EUI**: A text input field containing the value '70 B3 D5 7E D0 01 38 E6'

Figure 5-27. Device registering form

6. Click the Register button to register the device. You will be navigated to the device page.
7. On the device page, click the Settings tab.
8. On the Settings page, in the Settings section, choose ABP as the activation method. This means activating a device by personalization. Then click the Save button. This will generate the device address, network session key, and app session key (Figure 5-28).

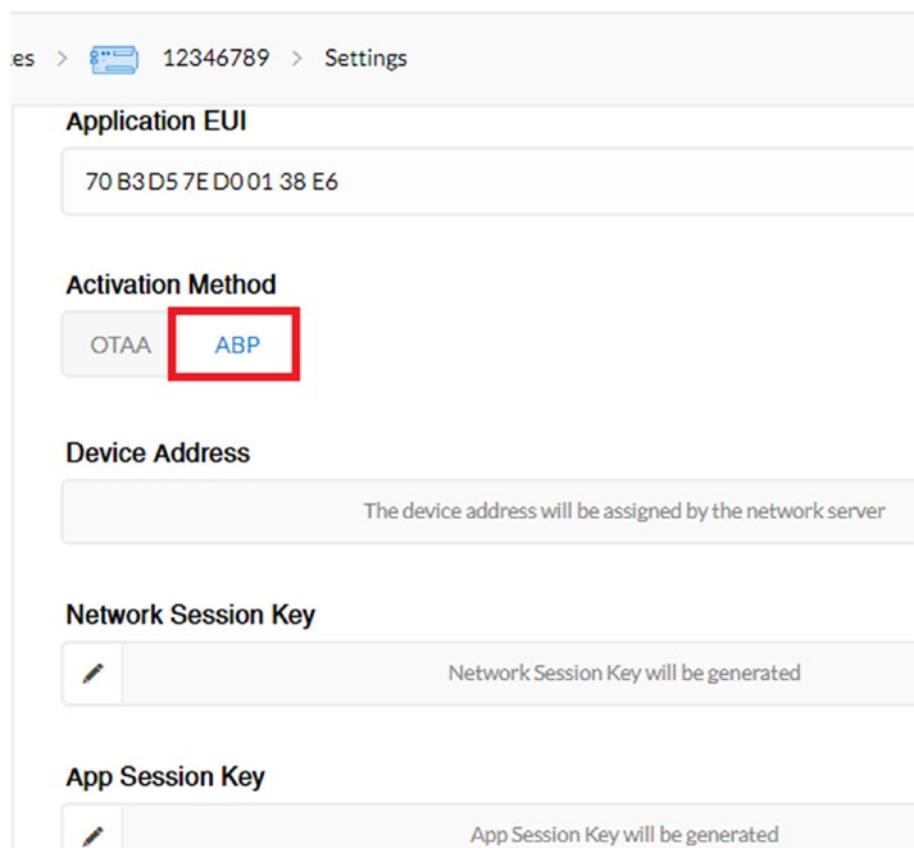


Figure 5-28. Setting the activation method to activation by personalization (ABP)

- Now you can view the autogenerated device address, network session key, and app session key on the device page, in the Device Overview section (Figure 5-29).

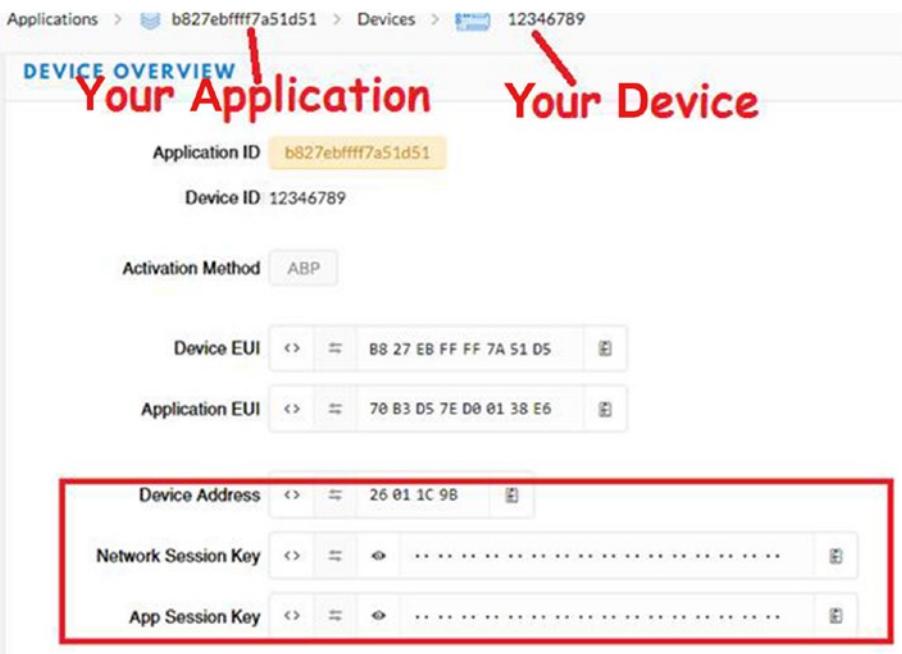


Figure 5-29. Device address, network session key, and app session key

- For the Network Session Key and App Session Key fields, click hex/C-style buttons to view them in C-style. The Copy to Clipboard button can be used to copy them to the clipboard (Figure 5-30).

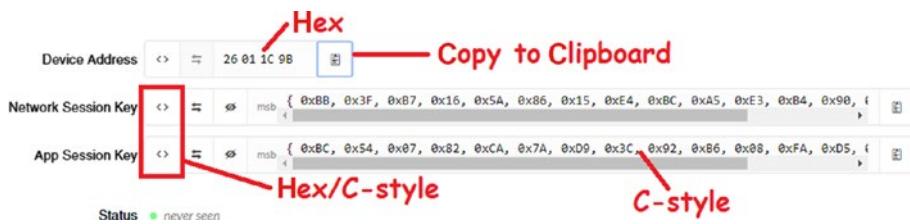


Figure 5-30. Copying keys to the clipboard

11. Now go to the application page and click the Payload Formats tab. On the Payload Formats page, click the Decoder tab. Then replace the existing JavaScript function with the function shown here (Figure 5-31):

```
function Decoder(bytes, port) {
    // Decode an uplink message from a buffer
    return {
        message: String.fromCharCode.apply(null,bytes)
    };
}
```

This function will decode the payload into a human-readable string.

Applications >  b827ebffff7a51d51 > Payload Formats

PAYOUT FORMATS

Payout Format

The payout format sent by your devices

Custom

decoder

converter

validator

encoder

```
1 function Decoder(bytes, port) {
2     // Decode an uplink message from a buffer
3     return {
4         message: String.fromCharCode.apply(null,bytes)
5     };
6 }
```

Figure 5-31. Decoder function

12. Finally, click the “save payload functions” button to save the changes.

Building the Sensor Node

The LoRa sensor node (end device) periodically sends temperature and humidity data to the LoRa gateway. To build the sensor node, you will need the following things:

- Arduino Uno or Adafruit Metro
- 9 VDC 1000 mA-regulated switching power adapter, UL listed
- LoRa RFM9x radio transceiver breakout
- DHT11 temperature and humidity sensor
- 10 K ohm resistor
- Breadboard
- Breadboard holder
- A few hook-up wires

Figure 5-32 shows the wiring diagram for the temperature and humidity sensor node. Use hook-up wires to make connections between each component.

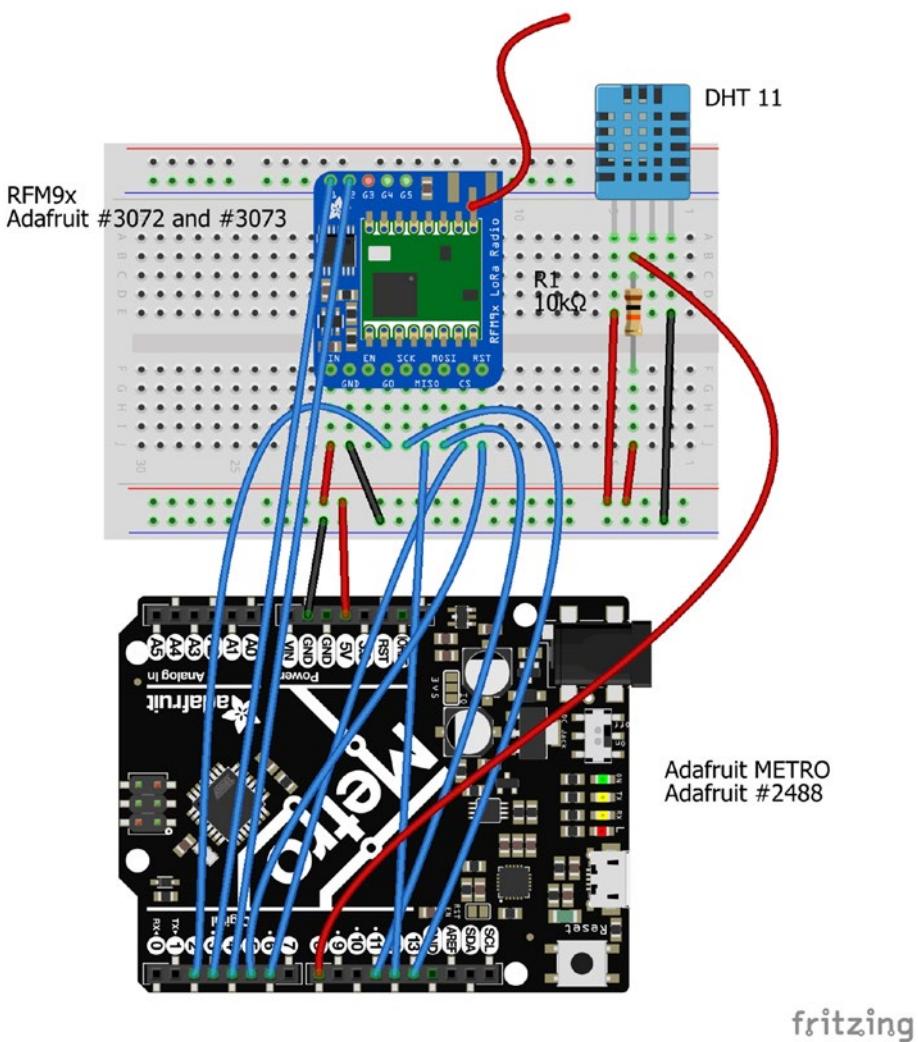


Figure 5-32. Wiring diagram for the temperature and humidity sensor node

Table 5-2 shows the wiring connection between each component of the sensor node.

Table 5-2. *Wiring Connections*

Arduino	RFM9x	DHT11	10 K Ohm
2	G0		
3	G1		
4	G2		
5	RST		
6	CS		
8		DATA	
11	MOSI		
12	MISO		
13	SCK		
5V		VCC	Connects between Arduino (5V) and DHT11 (VCC)
GND		GND	

Figure 5-33 shows the completed hardware setup with all the previously mentioned components.

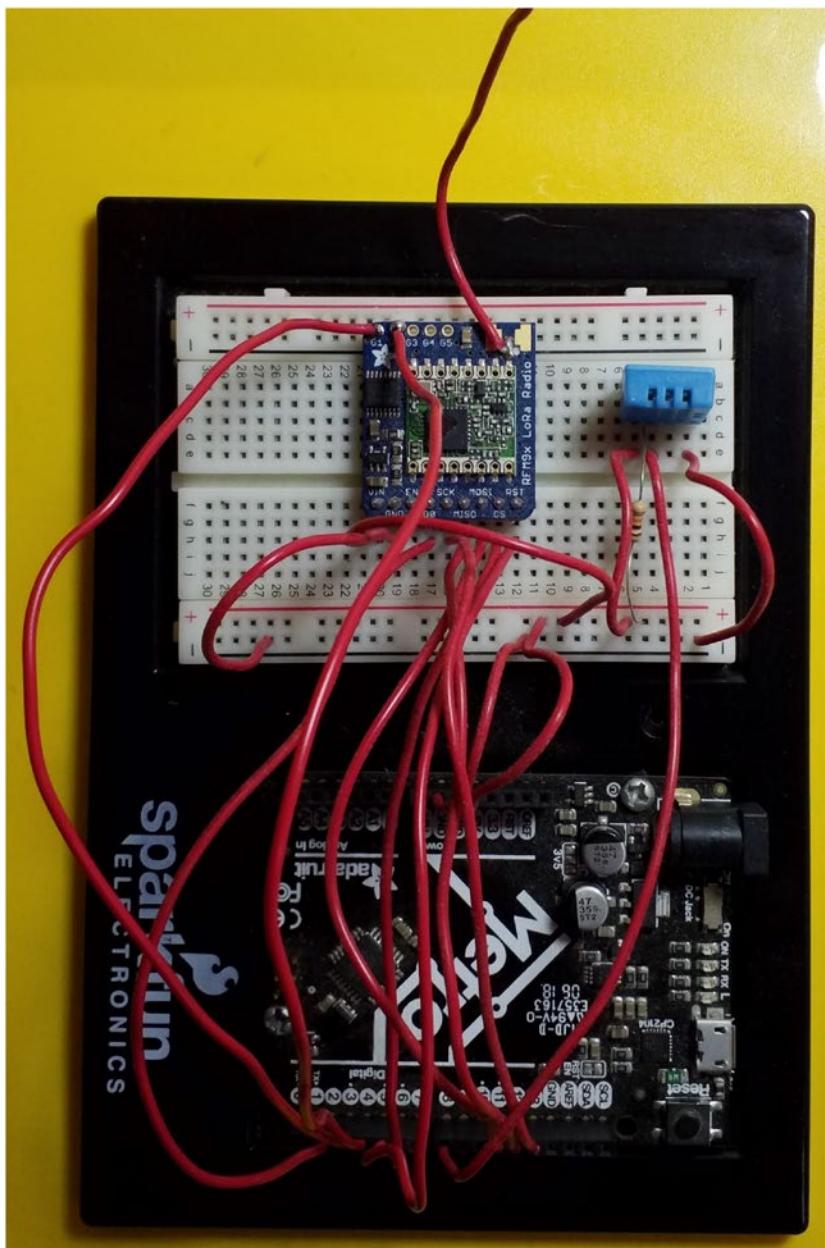


Figure 5-33. Completed hardware setup of the LoRa sensor node

You will be using some sample code hosted at <https://github.com/matthijskooijman/arduino-lmic/blob/master/examples/ttn-abp/ttn-abp.ino> as the template to write the sketch for the sensor node.

The same code can be downloaded from Chapter 5/Original Source/ttn-abp.ino.

1. Open the Arduino IDE and paste the code from
<https://github.com/matthijskooijman/arduino-lmic/blob/master/examples/ttn-abp/ttn-abp.ino>.
2. Save the file to your local drive as ttn-abp.ino.
3. Add following code snippets just below the line `#include <SPI.h>`:

```
#define DHTPIN 8
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);
```

4. Comment the following line of code:

```
static uint8_t mydata[] = "Hello, world!";
```

as follows:

```
//static uint8_t mydata[] = "Hello, world!";
```

5. Replace the network session key, application session key, and end-device address with the Network Session Key, App Session Key, and Device Address values, respectively, that can be found on the Things Network Console's device page.

```
// LoRaWAN NwkSKey, network session key
// This is the default Semtech key, which is used by
// the early prototype TTN network.
```

```

static const PROGMEM u1_t NWKSKEY[16] = { 0xBB, 0x3F,
0xB7, 0x16, 0x5A, 0x86, 0x15, 0xE4, 0xBC, 0xA5, 0xE3,
0xB4, 0x90, 0xC3, 0x26, 0xF0 };

// LoRaWAN AppSKey, application session key
// This is the default Semtech key, which is used by
// the early prototype TTN network.
static const u1_t PROGMEM APPSKEY[16] = { 0xBC, 0x54,
0x07, 0x82, 0xCA, 0x7A, 0xD9, 0x3C, 0x92, 0xB6, 0x08,
0xFA, 0xD5, 0xE6, 0xAC, 0x22 };

// LoRaWAN end-device address (DevAddr)
static const u4_t DEVADDR = 0x26011C9B ;
// <-- Change this address for every node!

```

6. Modify the pin mapping function (Figure 5-34) if your hardware setup has different connections than the wiring diagram shown previously.

```

63 // Pin mapping
64 const lmic_pinmap lmic_pins = {
65     .nss = 6, ━━━━━━ CS
66     .rxtx = LMIC_UNUSED_PIN,
67     .rst = 5, ━━━━━━ RST
68     .dio = {2, 3, 4},
69 };
70
71 void onEvent (ev_t ev) {
72     Serial.print(os_getTime());
73     Serial.print(" + ");

```

Figure 5-34. Pin mapping function for the RFM9x LoRa radio transceiver module

7. Add the following code snippets to the do_send(osjob_t* j) function (Figure 5-35):

```

byte buffer[8];
float t = dht.readTemperature();
float h = dht.readHumidity();
dtostrf(t, 2, 1, buffer);
dtostrf(h, 2, 1, &buffer[4]);
String res = buffer;
res.getBytes(buffer, res.length() + 1);
Serial.println("");
Serial.print("Sending - temperature: ");
Serial.print(t);
Serial.print(", humidity: ");
Serial.print(h);
Serial.println("");

void do_send(osjob_t* j){
    byte buffer[8];
    float t = dht.readTemperature();
    float h = dht.readHumidity();
    dtostrf(t, 2, 1, buffer);
    dtostrf(h, 2, 1, &buffer[4]);
    String res = buffer;
    res.getBytes(buffer, res.length() + 1);
    Serial.println("");
    Serial.print("Sending - temperature: ");
    Serial.print(t);
    Serial.print(", humidity: ");
    Serial.print(h);
    Serial.println("");

    // Check if there is not a current TX/RX job running
    if (LMIC.opmode & OP_TXRXPEND) {
        Serial.println(F("OP_TXRXPEND, not sending"));
    } else {

```

Figure 5-35. Modified do_send() function

8. In the `setup()` function, add the following code just after `Serial.println("Starting");`:

```
dht.begin();
```

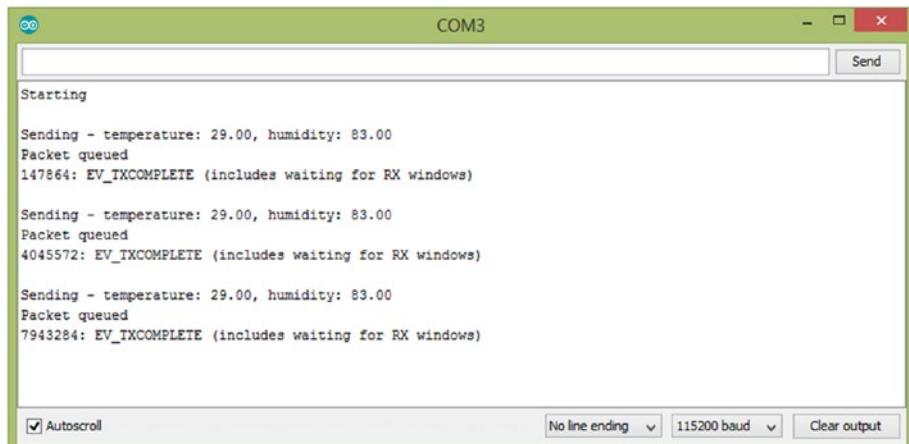
9. In the `setup()` function, define the frequency for the sensor node as follows by commenting all the unnecessary center frequencies (Figure 5-36). Also, the center frequency should be matched with the center frequency you defined in the Things Network Console for the gateway. As an example, the line of code for the center frequency, 433.1 MHz, is as follows:

```
LMIC_setupChannel(0, 433100000, DR_RANGE_MAP(DR_SF12,  
DR_SF7), BAND_CENTI); // g-band
```

```
// WOULD, SO IT IS GOOD FOR DEBUGGING, BUT CAN OVERLAP WITH  
// frequencies, so be sure to configure the full frequency range of  
// your network here (unless your network autoconfigures them).  
// Setting up channels should happen after LMIC_setSession, as that  
// configures the minimal channel set.  
// NA-US channels 0-71 are configured automatically 433.1 MHz  
LMIC_setupChannel(0, 433100000, DR_RANGE_MAP(DR_SF12, DR_SF7), BAND_CENTI); // g-band  
//LMIC_setupChannel(1, 868300000, DR_RANGE_MAP(DR_SF12, DR_SF7B), BAND_CENTI); // g-band  
//LMIC_setupChannel(2, 868500000, DR_RANGE_MAP(DR_SF12, DR_SF7), BAND_CENTI); // g-band  
//LMIC_setupChannel(3, 867100000, DR_RANGE_MAP(DR_SF12, DR_SF7), BAND_CENTI); // g-band  
//LMIC_setupChannel(4, 867300000, DR_RANGE_MAP(DR_SF12, DR_SF7), BAND_CENTI); // g-band  
//LMIC_setupChannel(5, 867500000, DR_RANGE_MAP(DR_SF12, DR_SF7), BAND_CENTI); // g-band  
//LMIC_setupChannel(6, 867700000, DR_RANGE_MAP(DR_SF12, DR_SF7), BAND_CENTI); // g-band  
//LMIC_setupChannel(7, 867900000, DR_RANGE_MAP(DR_SF12, DR_SF7), BAND_CENTI); // g-band  
//LMIC setupChannel(8, 868800000, DR_RANGE_MAP(DR_FSK, DR_FSK), BAND_MILLI); // g2-band  
  
// TTN defines an additional channel at 869.525Mhz using SF9 for class B  
// devices' ping slots. LMIC does not have an easy way to define set this  
// frequency and support for class B is spotty and untested, so this  
// frequency is not configured here.| Comment all unnecessary frequencies  
#elif defined(CFG_us915)  
// NA-US channels 0-71 are configured automatically  
// but only one group of 8 should (a subband) should be active
```

Figure 5-36. Defining the center frequency for the sensor node to match with the gateway's frequency

10. Save the sketch again by clicking File ▶ Save. The modified source code can be found at Chapter 5/ttn-abp.ino.
11. Connect the Arduino board to your computer using a USB cable.
12. Click Tools ▶ Board ▶ Arduino/Genuino Uno.
13. Click Tools ▶ Port and select the correct COM port for your Arduino board.
14. Upload the sketch into the Arduino board by clicking the Upload button.
15. After completing the upload, open the serial monitor by clicking Tools ▶ Serial Monitor (Figure 5-37).



The screenshot shows the Arduino Serial Monitor window titled "COM3". The window displays the following text output:

```
Starting
Sending - temperature: 29.00, humidity: 83.00
Packet queued
147864: EV_TXCOMPLETE (includes waiting for RX windows)

Sending - temperature: 29.00, humidity: 83.00
Packet queued
4045572: EV_TXCOMPLETE (includes waiting for RX windows)

Sending - temperature: 29.00, humidity: 83.00
Packet queued
7943284: EV_TXCOMPLETE (includes waiting for RX windows)
```

At the bottom of the window, there are three buttons: "Autoscroll" (checked), "No line ending", "115200 baud", and "Clear output".

Figure 5-37. Serial monitor output of the sensor node

Viewing Decoded Payload Data

Now you are ready to view the decoded payload on the Things Network Console.

1. On the application page, click the Data tab (Figure 5-38). Then in the Application Data section, click the Uplink tab. You can see all the incoming (uplink) data packets in the list view.

The screenshot shows the Things Network Console interface. At the top, there's a navigation bar with 'Applications' and a specific device ID 'b827ebffff7a51d51'. Below the navigation bar, there are tabs: 'Overview', 'Devices', 'Payload Formats', 'Integrations', 'Data' (which is circled in red), and 'Settings'. Under the 'Data' tab, there's a sub-section titled 'APPLICATION DATA'. This section has a 'Filters' dropdown where 'uplink' is selected (also circled in red). There are also buttons for 'pause' and 'clear'. Below the filters, there's a table with columns: 'time', 'counter', 'port', 'dev id', 'payload', and 'message'. The table contains four rows of data, each representing an uplink packet received at different times (11:55:46, 11:49:31, 11:46:24, 11:43:17) with dev id 12346789 and message "28.085.0".

time	counter	port	dev id	payload	message
▲ 11:55:46	33	1	12346789	32 38 2E 30 38 35 2E 30	"28.085.0"
▲ 11:49:31	27	1	12346789	32 38 2E 30 38 35 2E 30	"28.085.0"
▲ 11:46:24	24	1	12346789	32 38 2E 30 38 35 2E 30	"28.085.0"
▲ 11:43:17	21	1	12346789	32 38 2E 30 38 35 2E 30	"28.085.0"

Figure 5-38. Uplink data captured by the application

2. Click one of the list items to expand (Figure 5-39). In the Fields section, you can view the decoded payload as a readable string containing the temperature and humidity.

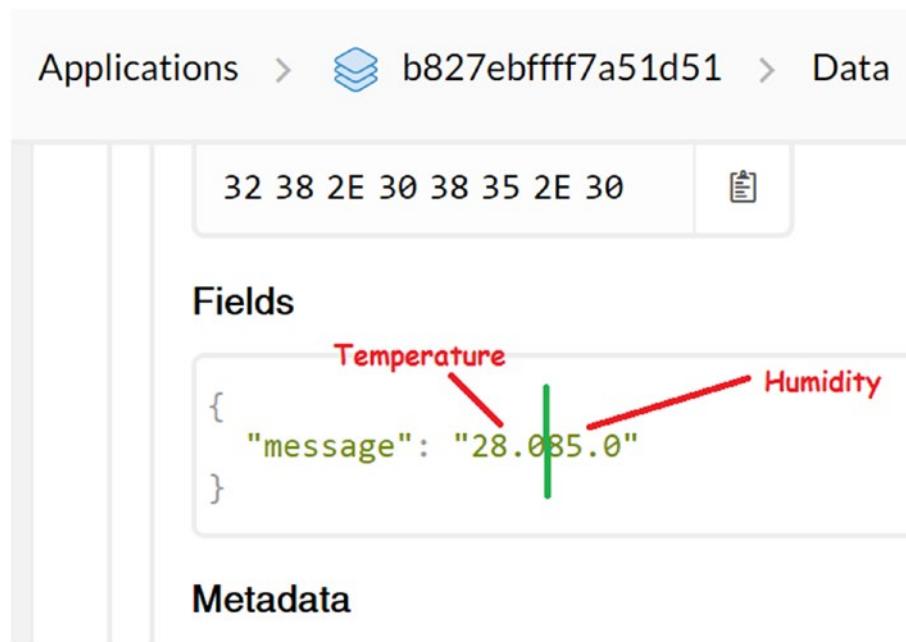


Figure 5-39. Decoding the payload to a single field

3. You can update the decoder function to fetch the temperature and humidity from the previous message. Here is the modified JavaScript function:

```
function Decoder(bytes, port) {
    // Decode an uplink message from a buffer
    return {
        temperature:
            String.fromCharCode.apply(null,bytes).substring(0,4),
        humidity:
            String.fromCharCode.apply(null,bytes).substring(4,8)
    };
}
```

Figure 5-40 shows the result for the updated decoder function. Now you can easily read the temperature and humidity data under Fields.

The screenshot shows a user interface for a LoRa gateway application. At the top, it displays the path: Applications > b827ebffff7a51d51 > Data. Below this, there are three columns: time, counter, and port. Under the counter column, the word "Payload" is highlighted in bold. To the right of "Payload" is a text input field containing the hex string "32 38 2E 30 38 34 2E 30". Next to the input field is a small edit icon. Below this section, under the heading "Fields", is a JSON object: { "humidity": "84.0", "temperature": "28.0" }. Finally, under the heading "Metadata", there is no visible content.

Figure 5-40. Decoding the payload to extract individual data fields

Summary

In this chapter, you built a single-channel LoRa gateway using the Raspberry Pi and connected it to the Things Network. Then you built a simple LoRa sensor node (end device) to send humidity and temperature data to the LoRa gateway. Finally, you developed an application to decode the payload to extract humidity and temperature data from the payload.

In the next chapter, you will learn about how to send data to the ThingSpeak IoT server using the RESTful API.

CHAPTER 6

Connecting with IoT Servers Using a RESTful API

In this chapter, you'll learn how to send data to an IoT server using a RESTful API. A RESTful API is an application program interface (API) that uses HTTP requests to GET, PUT, POST, and DELETE data. The ThingSpeak IoT platform enables clients to update and receive updates from channel feeds through the ThingSpeak RESTful API.

The network you'll build consists of a LoRa end node, LoRa gateway, and the ThingSpeak IoT. The LoRa end node will periodically send temperature and humidity data to the LoRa gateway. Once the data is received, the LoRa gateway forwards the data to ThingSpeak via the HTTP GET method using a RESTful API.

Technical Requirements

To complete the project discussed in this chapter, you will need following hardware and software:

- Arduino Uno or Adafruit Metro
- RFM9x radio transceiver breakout

- DHT11 temperature and humidity sensor
- Dragino LG01 LoRa gateway
- ThingSpeak account

Using ThingSpeak as the IoT Server

The ThingSpeak IoT server allows you to store and display sensor data. You can use a RESTful API to update a channel feed on the ThingSpeak IoT server using the HTTP GET method. First, create a free user account on the ThingSpeak server.

1. Go to ThingSpeak (<https://thingspeak.com/>) and sign up for a new free account. Usually, the Sign Up link can be found in the top-right corner of the page.
2. Fill out the form with all the required information and click the Continue button to create a MathWorks account.

Creating a New Channel

A channel stores all the data that a ThingSpeak application collects. Each channel can have up to eight fields that can hold any type of data, three fields for location data, and one field for status data. Follow these steps to create a new channel on the Thing Speak IoT server:

1. In the top navigation menu, select Channels ➤ My Channels (Figure 6-1).

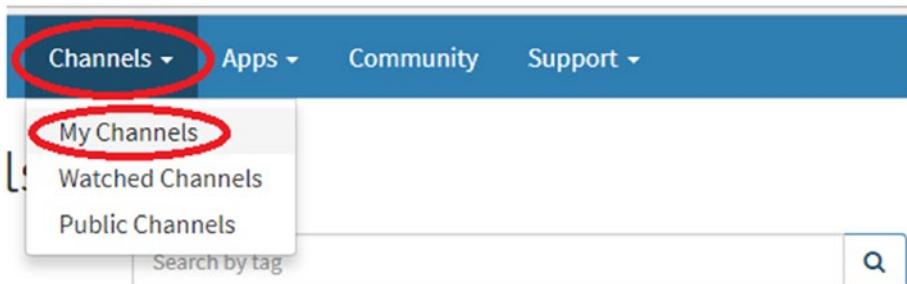


Figure 6-1. Menu command for accessing the My Channels page

2. On the My Channels page, click the New Channel button (Figure 6-2).

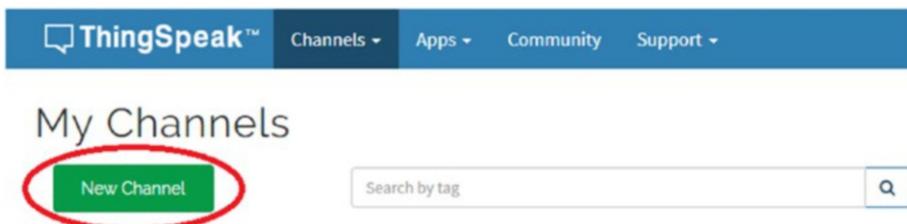


Figure 6-2. Creating a new channel

3. On the New Channel page, fill out the form fields as follows (Figure 6-3):
 - *Channel Name:* Type in a unique name for the ThingSpeak channel (e.g., **My RESTful Channel**).
 - *Description:* Type in a description for the ThingSpeak channel (e.g., **Testing with RESTful API**).
 - *Field #:* Use only two fields to store data. First, enable the Field 1 text box by clicking the check box next to it, and type in **temperature**. Then, enable the Field 2 text box by clicking the check box next to it, and type in **humidity**.
 - Select the Show Status check box.

- Click the Save Channel button.

The screenshot shows the ThingSpeak web interface for creating a new channel. At the top, there's a header bar with a lock icon and the URL <https://thingspeak.com/channels/new>. Below the header are navigation links for Channels, Apps, Community, and Support. The main title is "New Channel". The form fields are as follows:

Name	My RESTful Channel	
Description	Testing with <u>RESTful API</u>	
Field 1	temperature	<input checked="" type="checkbox"/>
Field 2	humidity	<input checked="" type="checkbox"/>
Field 3		<input type="checkbox"/>
Field 4		<input type="checkbox"/>
... . . .		

Figure 6-3. Channel settings

- Once created, you will get the page titled My RESTful Channel. It shows the channel ID, description, author, access level, charts for each data field, channel settings, and API keys (Figure 6-4).

The screenshot shows the ThingSpeak interface for a channel with ID 598903. At the top, there's a navigation bar with links for Channels, Apps, Community, and Support. Below the navigation bar, the main title is "My RESTful Channel". To the left, channel details are listed: Channel ID: 598903, Author: pradeeka, and Access: Private. To the right, it says "Testing with RESTful API". Below the title, there are tabs for Private View (selected), Public View, Channel Settings, Sharing, API Keys, and Data Import / Export. Under these tabs, there are buttons for Add Visualizations, Add Widgets, and Data Export. The "Channel Stats" section shows that the channel was created and updated "about a minute ago" and has 0 entries.

Figure 6-4. My RESTful Channel page

Getting the API Keys

ThingSpeak provides two types of API keys. You need these keys to write to a channel and read data from a private channel. API keys are autogenerated when you create a new channel.

1. In the My RESTful Channel page, click the API Keys tab. It shows the autogenerated Write API key and the Read API key (Figure 6-5).
 - The Write API key allows you to write data to a channel. If you want, you can generate a new Write API key by clicking the Generate New Write API Key button.

- The Read API key allows you to read data from a private channel. If you want, you can generate an additional Read API key for the channel by clicking the Generate New Read API Key button.

The screenshot shows the ThingSpeak web interface for managing API keys. At the top, there's a navigation bar with links for Private View, Public View, Channel Settings, Sharing, API Keys (which is the active tab), and Data. Below the navigation bar, the main content area has two sections: 'Write API Key' and 'Read API Keys'.

Write API Key: This section contains a text input field labeled 'Key' containing the value 'FK7CD7700EM9Q7FY'. Below the input field is a large orange button labeled 'Generate New Write API Key'.

Read API Keys: This section contains a table with one row. The first column is 'Key' with the value 'TD6RM24B83LKX9ZG'. The second column is 'Note' with an empty text input field. Below the table are two buttons: a green 'Save Note' button and a red 'Delete API Key' button. At the bottom of this section is another orange 'Generate New Read API Key' button.

Figure 6-5. Write API key and Read API key

Testing Your Channel with a Web Browser

You can use the HTTP GET method to update a channel feed. Follow these steps to send some sample data to the Thing Speak channel:

1. The URL syntax for the channel update using the HTTP GET method will be as follows:

```
https://api.thingspeak.com/update?api_key=WRITE_  
API_KEY&field1=value1&field2=value2
```

2. Using a web browser, copy and paste the following URLs into the address bar and press the Enter key:

```
https://api.thingspeak.com/update?api_key=FK7CD  
7700EM9Q7FY&field1=15&field2=79
```

```
https://api.thingspeak.com/update?api_key=FK7CD  
7700EM9Q7FY&field1=17&field2=80
```

```
https://api.thingspeak.com/update?api_key=FK7CD  
7700EM9Q7FY&field1=20&field2=78
```

```
https://api.thingspeak.com/update?api_key=FK7CD  
7700EM9Q7FY&field1=18&field2=81
```

```
https://api.thingspeak.com/update?api_key=FK7CD  
7700EM9Q7FY&field1=23&field2=80
```

3. For each successful update for a channel feed, the browser will display an entry ID starting from 1 (Figure 6-6). 0 indicates an unsuccessful update for the channel feed.

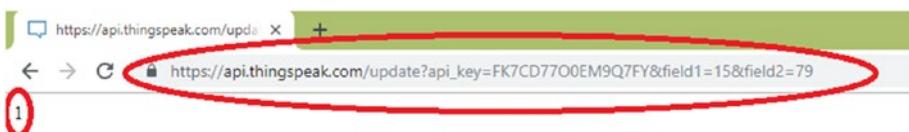


Figure 6-6. Updating a channel feed

- The entry ID is a unique identification number for updating a channel feed. If you want to reset the entry counter, you can do it by clearing all the feed data from the channel. To clear all the data feed from a channel, click the Channel Settings tab and then scroll down the page and click the Clear Channel button. To delete a channel, click the Delete Channel button (Figure 6-7).

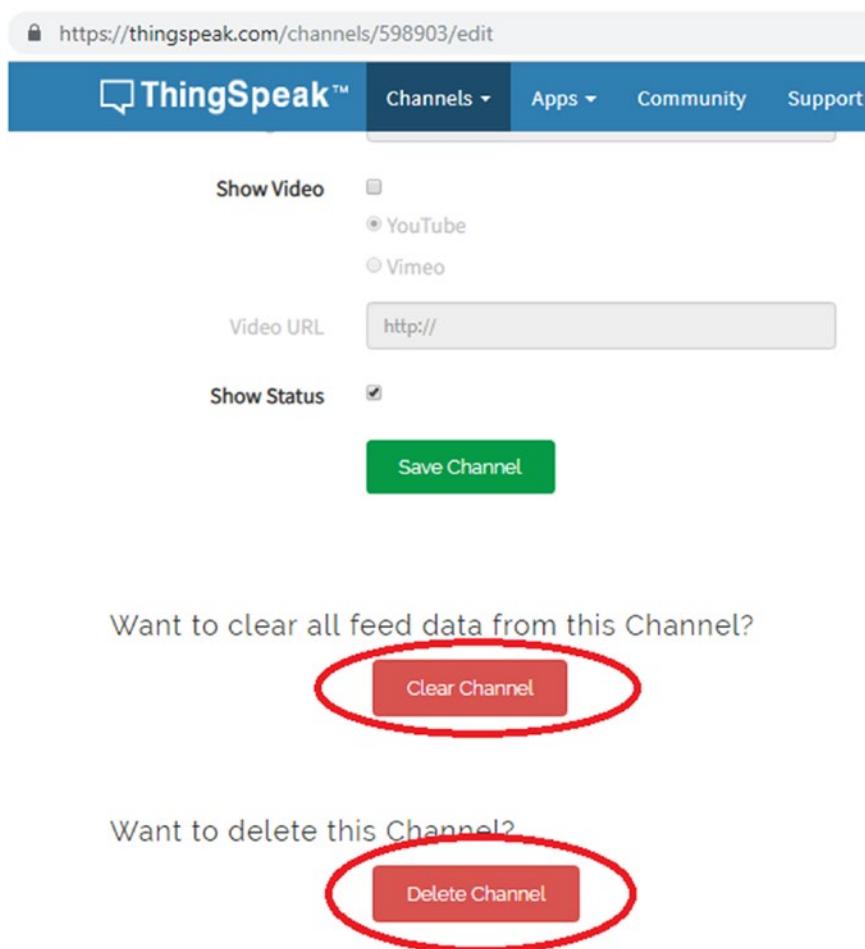


Figure 6-7. Clearing all the feed data from a channel and deleting a channel

- On the Private View tab, you can view the Field 1 Chart and Field 2 Chart graphs with the submitted data through the channel feed (Figure 6-8).

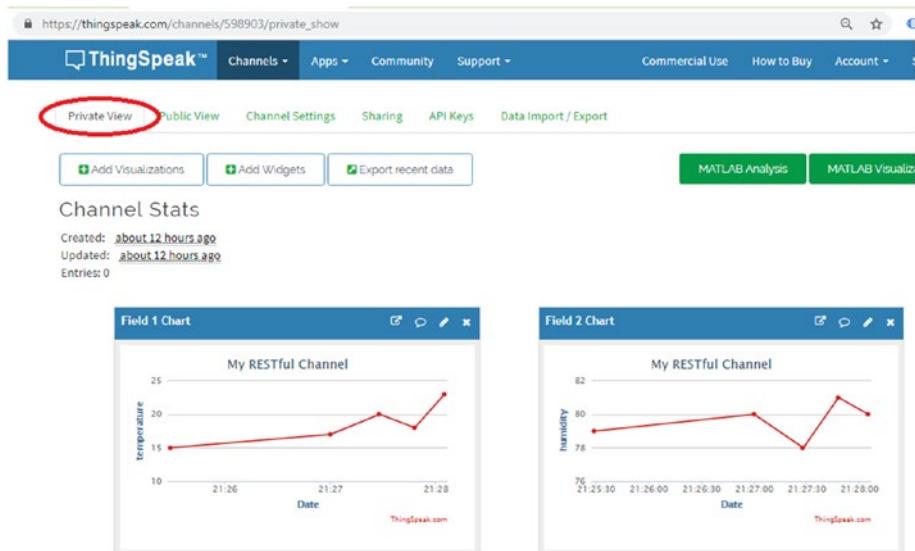


Figure 6-8. Field 1 Chart shows temperature data over time, and Field 2 Chart shows humidity data over time

Testing Your Channel with the LG01 Console

You can send HTTP GET requests to the ThingSpeak server using the LG01 console. It uses a tool known as `curl` to transfer data from or to a server.

- Log in to the LG01 configuration interface by providing the default credentials, which are `root` (the username) and `dragino` (the password).
- In the configuration interface, select Sensor ► IoT Server. On the Select IoT Server page, from the IoT Server drop-down list, choose TCP/IP Protocol (Figure 6-9).

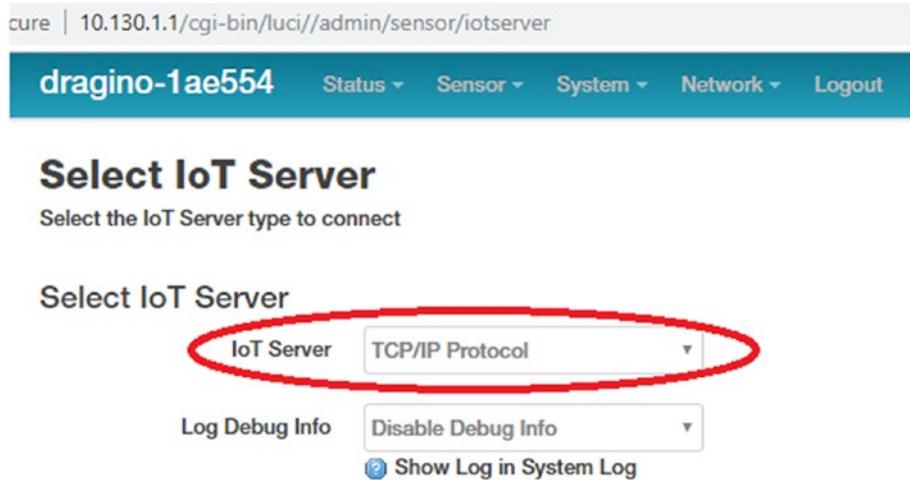


Figure 6-9. Choosing the IoT server for the TCP/IP protocol

3. Click the Save & Apply button.
4. Using PuTTY, connect to the LG01 gateway through the SSH protocol. Use the IP address 10.130.1.1 and port 22 (Figure 6-10).

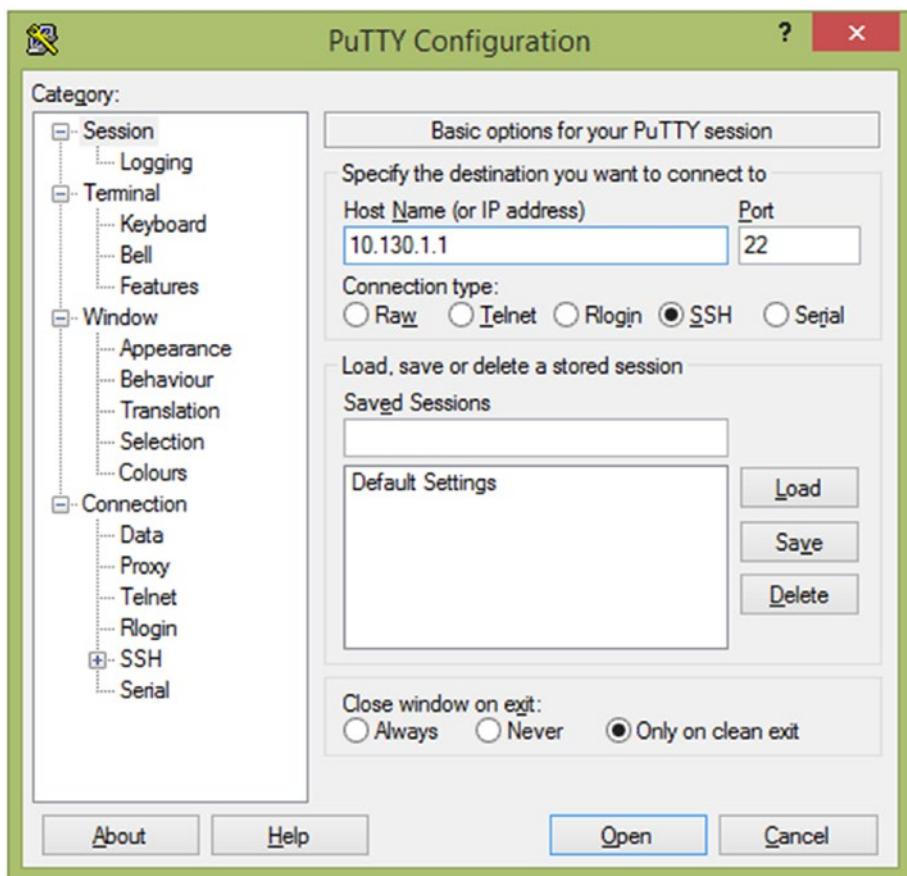


Figure 6-10. PuTTY configuration to specify the destination LG01 console to connect with LG01

5. Log in to the LG01 console using the default user name, *root*, and the password, *dragino*.
6. The syntax for the curl command is as follows:

```
curl -k "https://api.thingspeak.com/update?api_key=WRITE_API_KEY&field1=value1&field2=value2"
```


Channel Stats

Created: [about 23 hours ago](#)
 Updated: [about 23 hours ago](#)
 Last entry: [2 minutes ago](#)
 Entries: 6

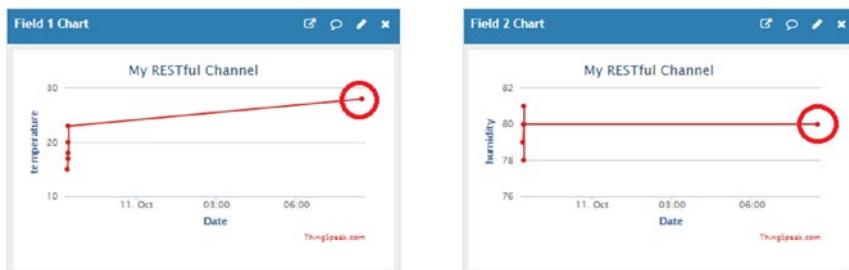


Figure 6-12. New data points for temperature and humidity

Now you should be ready to update the ThingSpeak channel feed with a LoRa wireless network by building a simple sensor node and using the LG01 LoRa gateway.

Building the Sensor Node

The LoRa sensor node (end device) periodically collects temperature and humidity data from the environment. You will need the following things to build the sensor node:

- Arduino Uno or Adafruit Metro
- RFM9x LoRa radio transceiver breakout
- DHT11 temperature and humidity sensor
- 10 kilohm resistor (usually Adafruit provides a free resistor with a DHT11 sensor)
- Solid core hook-up wires
- Half-size breadboard
- Breadboard holder

Figure 6-13 shows the wiring diagram for the sensor node. Using hook-up wires, make connections between all the electronic components.

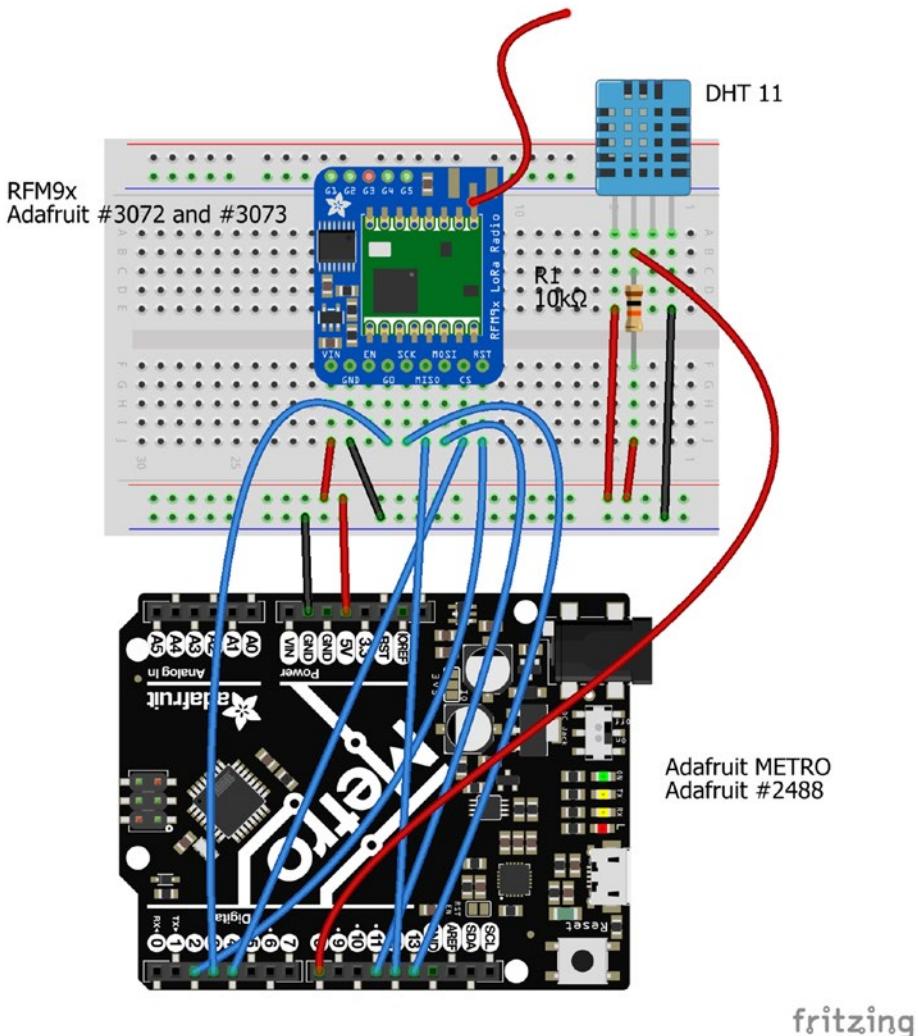


Figure 6-13. Wiring diagram for the LoRa end device (sensor node)

Table 6-1 shows the connections between the Arduino/Metro, radio transceiver, and DHT11 sensor.

Table 6-1. *Wiring Connections for Sensor Node*

Arduino/Metro	Radio Transceiver	DHT11
VIN	VIN	VIN
GND	GND	GND
2	RST	
3	GO	
4	CS	
8		DATA
11	MOSI	
12	MISO	
13	SCK	

Make sure to keep the antenna wire perpendicular to the LoRa radio transceiver module. Figure 6-14 shows the completed sensor node.

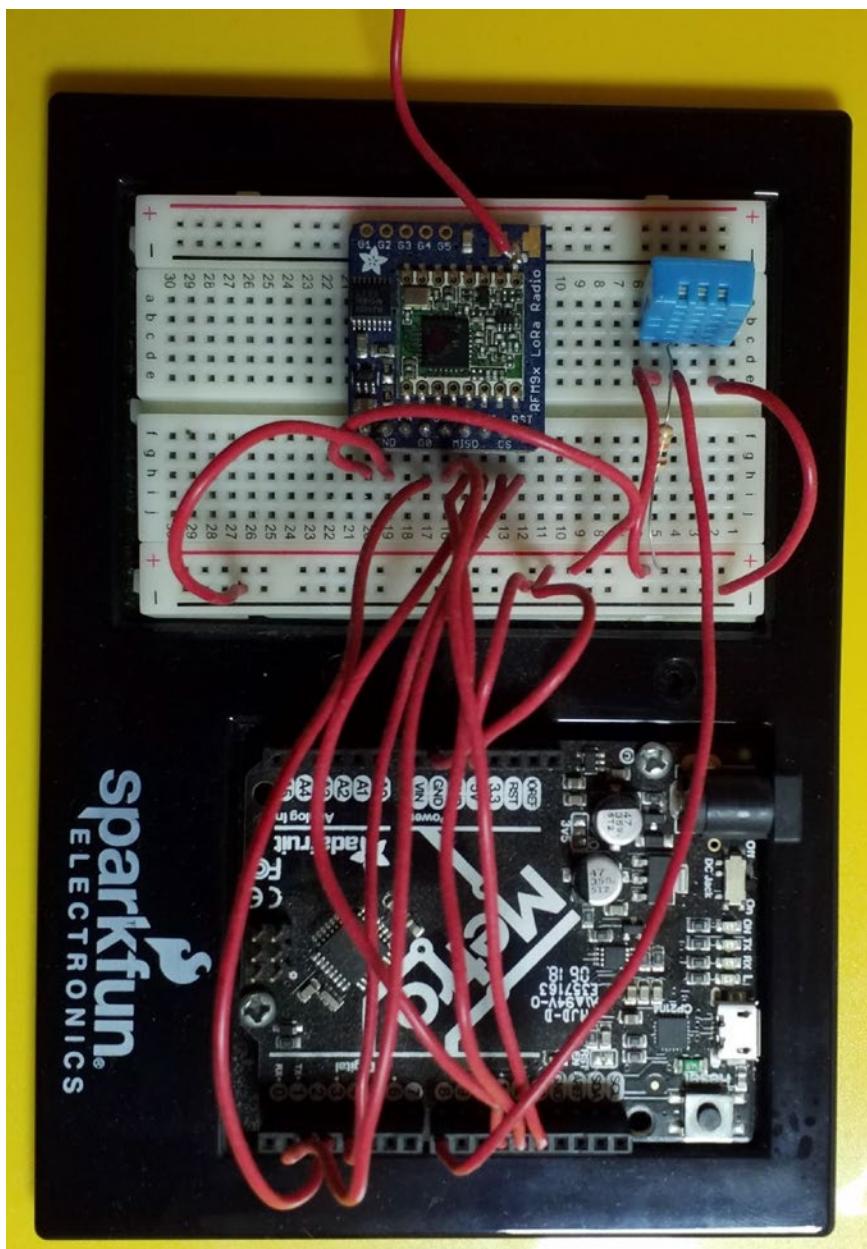


Figure 6-14. Completed LoRa end device (sensor node)

Uploading Sketch to the Sensor Node

Follow these steps to upload the sample sketch to the LoRa sensor node:

1. Go to https://github.com/dragino/Arduino-Profile-Examples/blob/master/libraries/Dragino/examples/IoTServer/ThingSpeak/dht11_client/ and download the sample Arduino sketch, `dht11_client.ino`. The same source code can be found at Chapter 6/Original Source/`dht11_client.ino`.

2. Open `dht11_client.ino` with your Arduino integrated development environment.

3. Find the following line:

```
RH_RF95 rf95;
```

4. Modify it as shown here by passing G0 and CS pins, where G0 is connected to the Arduino digital pin 4 and CS is connected to the Arduino digital pin 3:

```
RH_RF95 rf95(4, 3);
```

5. Then, find the following line:

```
#define dht_dpin A0 // Use A0 pin as Data pin for DHT11.
```

6. The sample code uses Arduino analog pin A0 to connect with the data pin of the DHT11 sensor.

```
#define dht_dpin 8 // Use digital pin 8 as Data pin for DHT11.
```

7. Find the following line:

```
float frequency = 868.0;
```

8. Change it to match with your frequency. For example, if you're using a LoRa radio transceiver with a frequency of 433 MHz, the code can be modified as follows:

```
float frequency = 433.0;
```

9. Save the file by clicking File > Save.
10. Connect the Arduino with your computer using a USB cable.
11. In the Arduino IDE, make sure to choose the correct board type and the COM port. The board type should be Arduino/Genuine Uno. Also, the programmer should be AVRISP mkII (Figure 6-15).

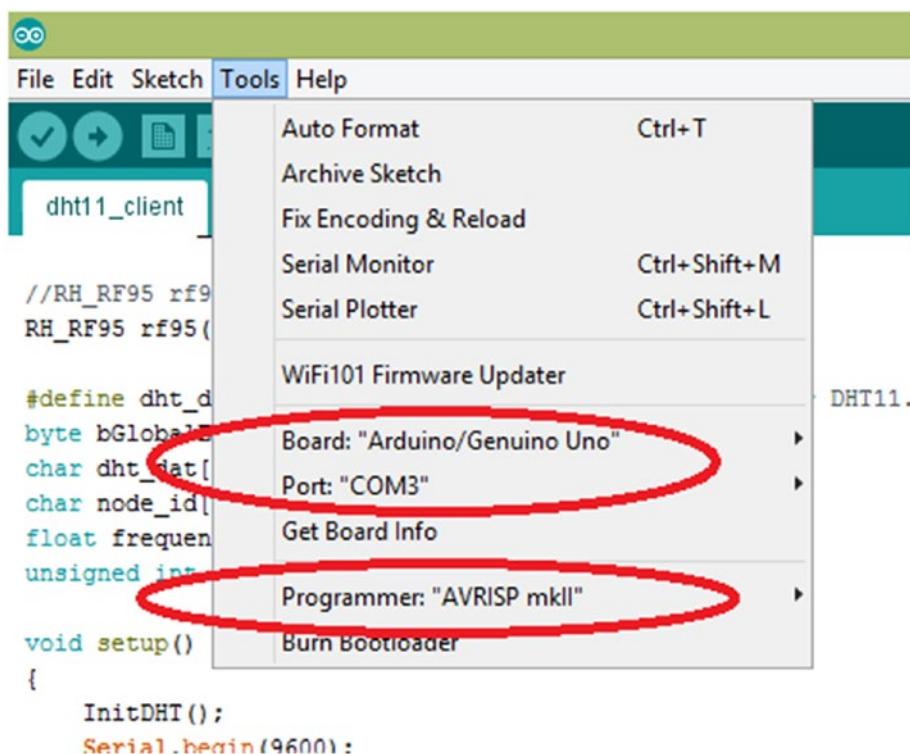


Figure 6-15. Choosing the board type, port, and programmer for the sensor node

12. Verify and upload the code into the Arduino board.

After uploading the sketch, select Tools ► Serial Monitor (Figure 6-16). You can see the node is periodically sending data packets to the LG01 gateway. Note that your sensor node ID is 111 and can be configured with the Arduino sketch.

```
char node_id[3] = {1,1,1}; //LoRa End Node ID
```

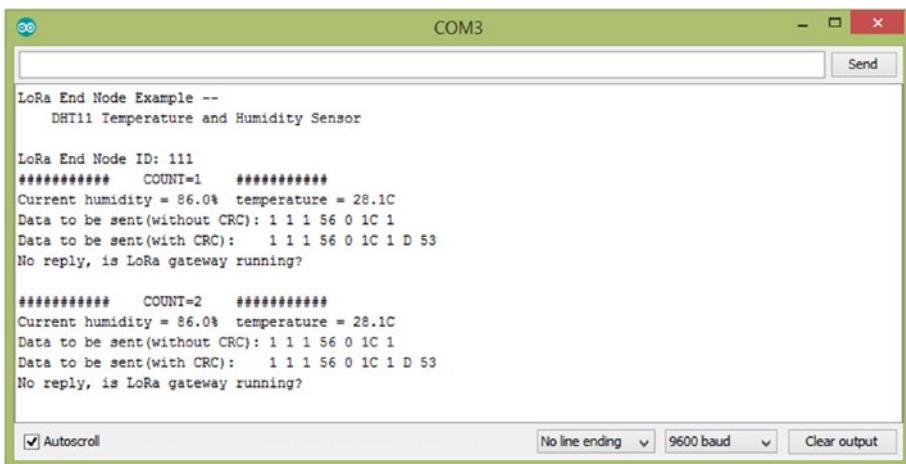


Figure 6-16. Serial monitor output for the LoRa sensor node

Uploading Arduino Sketch to the LG01

Now you should upload the sample Arduino sketch to the LG01 gateway. This allows the LG01 gateway to receive, process, and send data to the ThingSpeak IoT through the HTTP GET protocol.

1. Download the sample Arduino sketch, `LG01_ThingSpeak_RESTful_Single_Data.ino`, from <https://github.com/dragino/Arduino-Profile-Examples/tree/master/libraries/>

[Dragino/examples/IoTServer/ThingSpeak/LG01_ThingSpeak_RESTful_Single_Data/](#). The same source code can be found at Chapter 6/Original Source/LG01_ThingSpeak_RESTful_Single_Data.ino.

2. Open the sketch with a new instance of the Arduino IDE.
3. Find and modify the following lines with your Write API key:

```
String myWriteAPIString = "B9ZOR25QNVEBKIFY";
```

4. Find the following line and modify the frequency to suit your LG01 gateway:

```
float frequency = 868.0;
```

5. Find the following line:

```
while (! Console); // Wait for console port to be available
```

Then, comment it as shown here:

```
//while (! Console); // Wait for console port to be available
```

6. Find the following code in the loop() function:

```
//dataString ="field2=";  
//dataString += h;
```

Uncomment the two lines and add another two lines to append the humidity data to the HTTP GET request.

```
dataString ="field2=";  
dataString += hh;  
dataString += ".";  
dataString += h1;
```

7. Save the file by clicking File ▶ Save.
8. Click Tools ▶ Board and choose Dragino Yun + Uno or LG01/OLG01 (Figure 6-17).
9. Click Tools ▶ Port and choose the correct network port for the LG01 (e.g., dragino-1ae554 at 10.130.1.1 (Arduino Yun)).

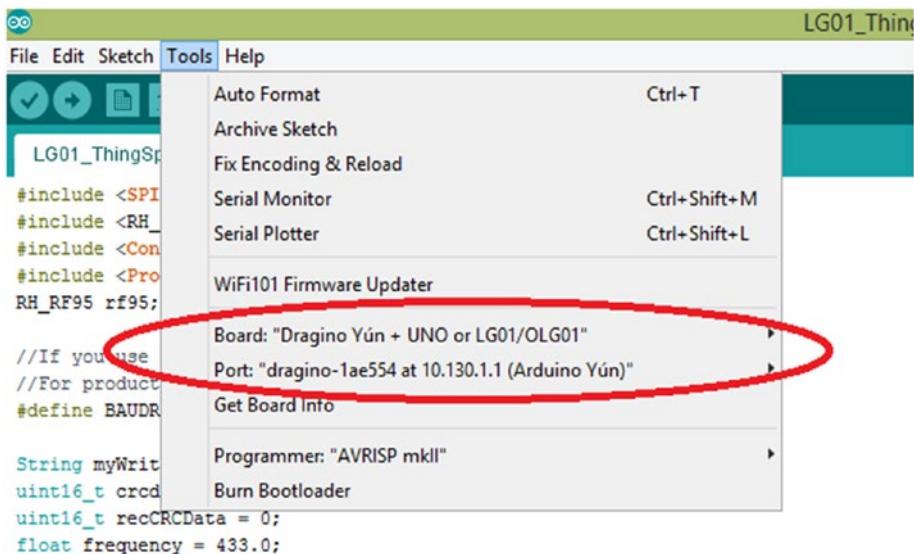
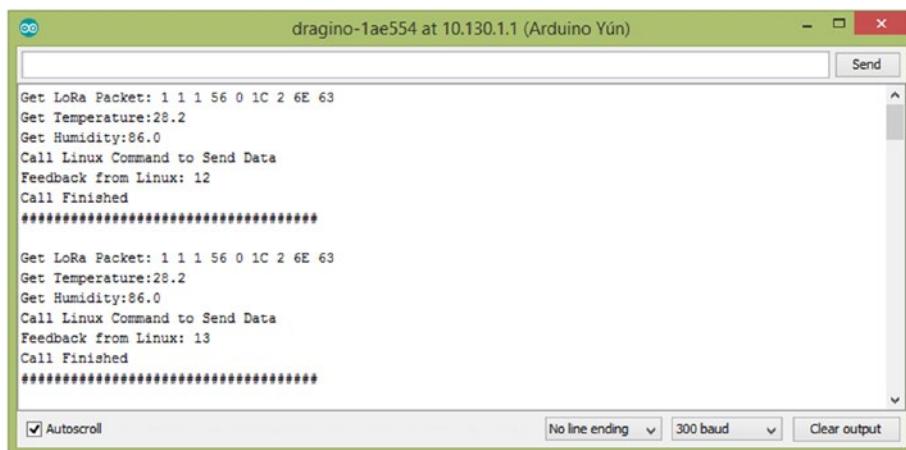


Figure 6-17. Sketch upload settings for the LG01 gateway

10. Verify the sketch by clicking the Verify button.
11. Click the Upload button to upload the sketch into the LG01.
12. If prompted, type **dragino** for the board password. Then click the Upload button.
13. After uploading the sketch, press the Reset (toggle) button. You can use a paper clip to access the reset button resides inside the enclosure.

14. In the Arduino IDE, select Tools ► Serial Monitor.

You can see the details for each data packet received by the gateway and the status of the curl (Linux) command (Figure 6-18).

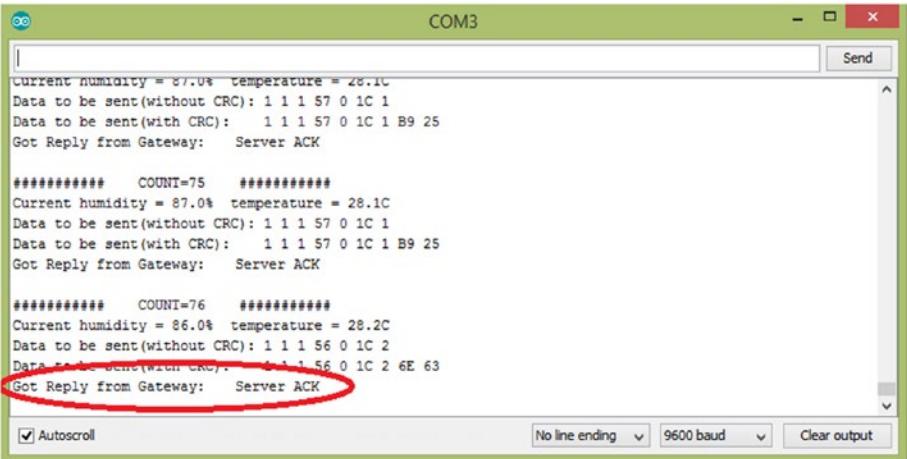


The screenshot shows the Arduino Serial Monitor window titled "dragino-1ae554 at 10.130.1.1 (Arduino Yún)". The window displays two sets of data exchange. The first set shows a LoRa packet received from the node, followed by sensor readings (Temperature: 28.2, Humidity: 86.0), a command to call Linux, and feedback from Linux (Feedback from Linux: 12). The second set shows another LoRa packet received, followed by sensor readings, a command to call Linux, and feedback from Linux (Feedback from Linux: 13). The monitor includes standard controls like "Send", "Autoscroll", and baud rate selection (300 baud).

```
Get LoRa Packet: 1 1 1 56 0 1C 2 6E 63
Get Temperature:28.2
Get Humidity:86.0
Call Linux Command to Send Data
Feedback from Linux: 12
Call Finished
#####
Get LoRa Packet: 1 1 1 56 0 1C 2 6E 63
Get Temperature:28.2
Get Humidity:86.0
Call Linux Command to Send Data
Feedback from Linux: 13
Call Finished
#####
 Autoscroll      No line ending      300 baud      Clear output
```

Figure 6-18. Serial monitor output for the LG01 gateway

15. Again, open the Arduino serial monitor for the LoRa sensor node. Now you can see the sensor node is receiving data from the gateway (Figure 6-19). This means your LoRa network is working properly and performing two-way data transmission.



```

COM3
Current humidity = 87.0% temperature = 28.1C
Data to be sent(without CRC): 1 1 1 57 0 1C 1
Data to be sent(with CRC): 1 1 1 57 0 1C 1 B9 25
Got Reply from Gateway: Server ACK

#####
COUNT=75 #####
Current humidity = 87.0% temperature = 28.1C
Data to be sent(without CRC): 1 1 1 57 0 1C 1
Data to be sent(with CRC): 1 1 1 57 0 1C 1 B9 25
Got Reply from Gateway: Server ACK

#####
COUNT=76 #####
Current humidity = 86.0% temperature = 28.2C
Data to be sent(without CRC): 1 1 1 56 0 1C 2
Data to be sent(with CRC): 1 1 1 56 0 1C 2 6E 63
Got Reply from Gateway: Server ACK

Autoscroll
No line ending 9600 baud Clear output

```

Figure 6-19. Serial monitor output for the sensor node

- Now, go to your ThingSpeak account and open the My RESTful Channel page. Figure 6-20 shows the two charts updated by the LoRa gateway.

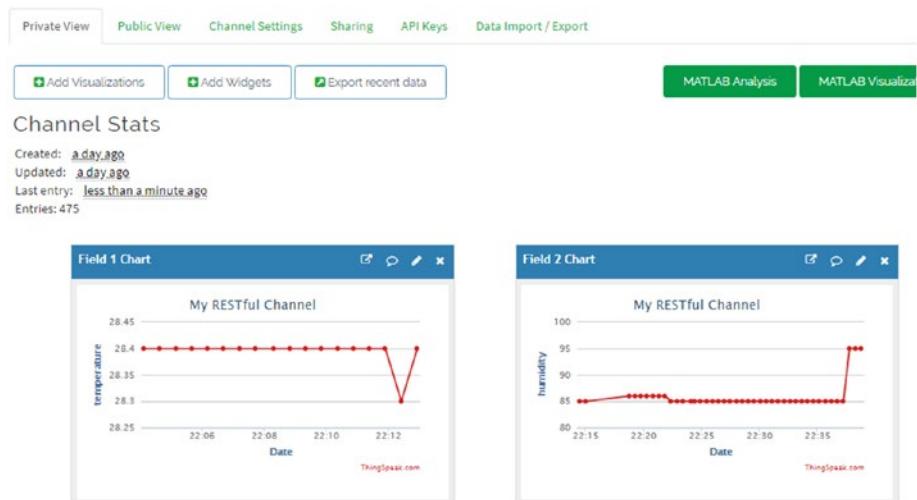


Figure 6-20. Updating charts through the LoRa gateway

You can further improve this project by integrating your ThingSpeak channel with the ThingHTTP app (<https://thingspeak.com/apps/thinghttp>). You specify actions in ThingHTTP, which you trigger using other ThingSpeak apps such as TweetControl, TimeControl, and React.

Summary

In this chapter, you learned how to use the RESTful API to connect and send data to the ThingSpeak IoT server. In the next chapter, you will learn how to connect and send data to the ThingSpeak server using the MQTT protocol.

CHAPTER 7

Connecting with IoT Servers Using MQTT

In this chapter, you will learn how to send data to an IoT server using the MQTT protocol with a LoRa wireless network. The ThingSpeak IoT platform enables clients to update and receive updates from channel feeds through the ThingSpeak MQTT broker. MQTT is a publish/subscribe communication protocol that uses TCP/IP sockets or WebSockets. MQTT over WebSockets can be secured with SSL. A client device connects to the MQTT broker and can publish to a channel or subscribe to updates from that channel.

The network you'll build consists of a LoRa end node (sensor node), a LoRa gateway, and the ThingSpeak IoT server. The LoRa end node will periodically send temperature and humidity data to the LoRa gateway. Once received, the LoRa gateway forwards the data to the ThingSpeak IoT server using the MQTT protocol.

Technical Requirements

In this chapter, you will need the following hardware and software prerequisites to build the LoRa wireless sensor network:

- Arduino Uno or Adafruit Metro (<https://www.sparkfun.com/products/11224> or <https://www.adafruit.com/product/2488>)

- RFM9x radio transceiver breakout
(<https://www.adafruit.com/product/3072> or
<https://www.adafruit.com/product/3073>)
- DHT11 temperature and humidity sensor
(<https://www.adafruit.com/product/386>)
- Dragino LG01 LoRa gateway
(<https://www.tindie.com/products/edwin/lg01-lora-openwrt-iot-gateway/>)
- Breadboard, self-adhesive (white)
(<https://www.sparkfun.com/products/12002>)
- Arduino and breadboard holder
(<https://www.sparkfun.com/products/11235>)
- Hook-up wire, assortment (solid core, 22 AWG)
(<https://www.sparkfun.com/products/11367>)
- MQTT.fx
(<https://mosquitto.org.eclipse.org/mqttfx/jensd.de/index.php/download>)
- ThingSpeak account
(<https://thingspeak.com/>)

Using ThingSpeak as the IoT Server

The ThingSpeak IoT service now supports MQTT subscriptions to receive instant updates when a ThingSpeak channel gets updated. MQTT is a powerful standard for IoT systems. ThingSpeak enables clients to update and receive updates from channel feeds via the ThingSpeak MQTT broker. MQTT is a publish/subscribe communication protocol that uses TCP/IP sockets or WebSockets. MQTT over WebSockets can be secured with SSL. A client device connects to the MQTT broker and can publish to a channel or subscribe to updates from that channel.

Follow these steps to create a new user account on the ThingSpeak IoT server:

1. Go to ThingSpeak (<https://thingspeak.com/>) and sign up for a free new account. Usually, the Sign Up link is at the top-right corner of the page.
2. Fill out the form with all the required information and click the Continue button to create a MathWorks account.
3. You will receive an e-mail to verify your address. In the e-mail body, click the verify button to complete the registration.

Creating a New Channel

Follow these steps:

1. In the top navigation menu, select Channels ► My Channels (Figure 7-1).

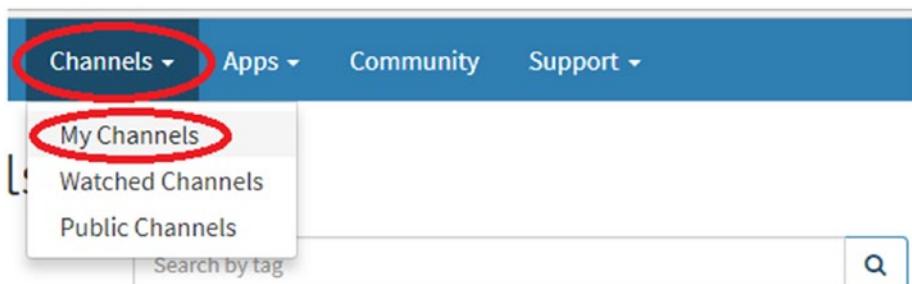


Figure 7-1. Menu command for accessing all the channels associated with your account

2. Under My Channels, click the New Channel button (Figure 7-2).

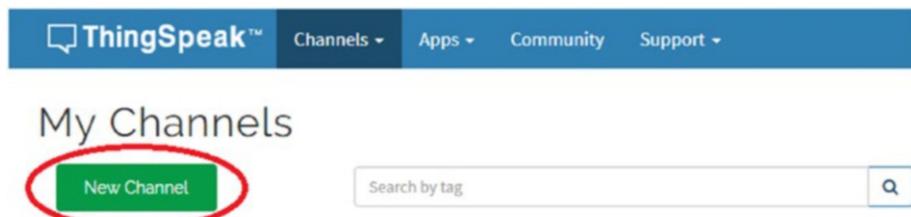


Figure 7-2. Creating a new channel

3. Fill out these form fields to create a new channel (Figure 7-3):

A screenshot of the 'New Channel' configuration page. At the top, the URL is shown as https://thingspeak.com/channels/new. The navigation bar is identical to Figure 7-2. The main title is 'New Channel'. Below the title are four form fields:

- Name:** Weather Channel
- Description:** Weather Channel provides temperature and humidity updates.
- Field 1:** temperature
- Field 2:** humidity
- Field 3:**
- Field 4:**

Figure 7-3. Channel settings for Weather Channel

- *Channel Name:* Type in a unique name for the ThingSpeak channel (e.g., **Weather Channel**).
 - *Description:* Type in a description for the ThingSpeak channel (e.g., **Weather Channel provides temperature and humidity updates.**).
 - *Field #:* Each ThingSpeak channel can have up to eight fields. Click the first check box to enable Field 1 and type in **temperature**. Click the second check box to enable Field 2 and type in **humidity**.
4. Click the Save Channel button.
 5. After creating the channel, you will get a page titled Weather Channel with channel settings, sharing options, API keys, import and export options, and charts for each data field (Figure 7-4).

The screenshot shows the ThingSpeak interface for the 'Weather Channel'. At the top, there's a navigation bar with links for Channels, Apps, Community, Support, Commercial Use, How to Buy, Account, and Sign Out. Below the navigation bar, the channel title 'Weather Channel' is displayed, along with its ID (588163), author (pradeeka), and access level (Private). A description states 'Weather Channel provides temperature and humidity updates.' Below this, there are tabs for Private View (selected), Public View, Channel Settings, Sharing, API Keys, and Data Import / Export. There are also buttons for Add Visualizations, Add Widgets, and Data Export. On the right, there are MATLAB Analysis and MATLAB Visualization buttons. Under 'Channel Stats', it shows creation and update times (4 minutes ago) and zero entries. Two charts are shown: 'Field 1 Chart' and 'Field 2 Chart', both titled 'Weather Channel'.

Figure 7-4. Page for the Weather Channel

Getting the API Keys

ThingSpeak provides two types of API keys. You need these keys to write to a channel and read data from a private channel. API keys are autogenerated when you create a new channel.

1. On the Weather Channel page, click API Keys tab.
It shows the autogenerated Write API key and Read API key (Figure 7-5).
2. The Write API key allows you to write data to a channel. If you want, you can generate a new Write API key by clicking the Generate New Write API Key button.
3. The Read API key allows you to read data from a private channel. If you want, you can generate an additional Read API key from the channel by clicking the Generate New Write API Key button.

The screenshot shows the 'API Keys' section of the ThingSpeak interface. At the top, there are tabs: 'Private View', 'Public View', 'Channel Settings', 'Sharing', 'API Keys' (which is selected), and 'Data Import / Export'. Below the tabs, there are two main sections: 'Write API Key' and 'Read API Keys'.
Write API Key: A text input field labeled 'Key' contains the value 'MI7TBVWCBY0RQ2PV'. Below it is an orange button labeled 'Generate New Write API Key'.
Read API Keys: A text input field labeled 'Key' contains the value 'P3KU862RXDBGJ8YV'. Below it is a text input field labeled 'Note'. At the bottom of this section are two buttons: a green 'Save Note' button and a red 'Delete API Key' button.
On the right side of the page, there is a 'Help' section with a note about API keys being auto-generated, and a 'API Keys S' section with a bulleted list of instructions. There are also links for 'Update a Char' and 'Get a Channel'.

Figure 7-5. Write and Read API keys

Finding Your MQTT API Key

The MQTT API key is required to subscribe to channel topics using the MQTT API. The MQTT API Key can be found on your profile page.

1. Select Account ➤ My Profile.
2. Scroll down the page. Under ThingSpeak Settings, in the MQTT API Key section, click the Generate New MQTT API Key button to generate a new MQTT API key (Figure 7-6).

ThingSpeak settings

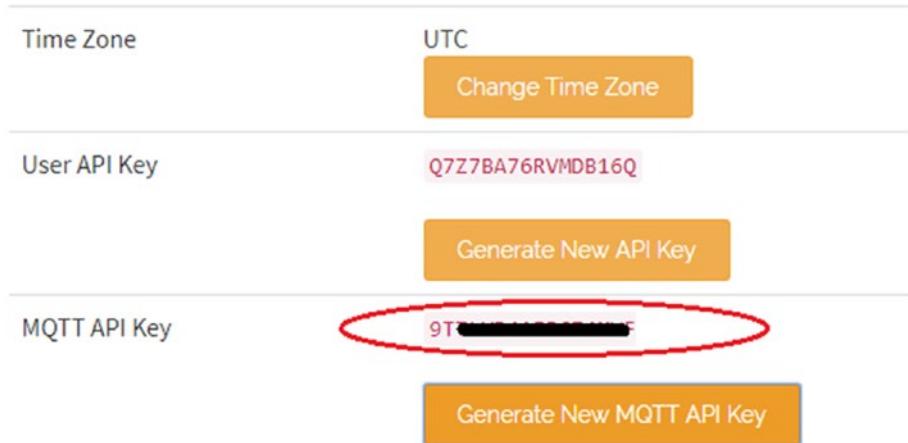


Figure 7-6. MQTT API key

Testing Your Channel

You can use your LG01 gateway console to send direct MQTT messages to the ThingSpeak server using the built-in command `mosquitto_pub`.

1. Using PuTTY, log in to your LG01 gateway through SSH. The default username is *root*, and the password is *dragino*.
2. You can use the following command to update the Weather Channel with temperature and humidity data:

```
mosquitto_pub -h mqtt.thingspeak.com -p 1883 -u user_id  
-P mqtt_api_key -i client_id -t channels/channel_id/  
publish/write_api_key -m "field1=value1&field2=value2&s  
tatus=MQTTPUBLISH"
```

3. By replacing user_id, mqtt_api_key, client_id, channel_id, write_api_key, value1, and value2 with the parameters associated with the ThingSpeak account, the command will look something like this (Figure 7-7):

```
mosquitto_pub -h mqtt.thingspeak.com -p 1883 -u
pradeeka -P 9TTLYB4AERCZ4MWF -i weather_client -t
channels/588163/publish/4ELVID1N7KLD8LG2 -m "field1=23.
5&field2=57.5&status=MQTT PUBLISH"
```

4. client_id is a unique ID and can be anything.

The screenshot shows a PuTTY terminal window with the title '10.130.1.1 - PuTTY'. The session is connected to the IP address 10.130.1.1. The terminal displays the following text:

```
root@10.130.1.1's password:  
BusyBox v1.23.2 (2017-12-21 22:54:56 CST) built-in shell (ash)  
  
W i F i, L i n u x, M C U, E m b e d d e d  
  
OpenWRT Chaos Calmer 15.05  
Version: Dragino-v2 IoT-4.3.4  
Build Mon May 7 14:24:11 CST 2018  
  
www.dragino.com  
-----  
root@dragino-iae554:~# mosquitto_pub -h mqtt.thingspeak.com -p 1883 -u pradeeka  
-P 9TTLYB4AERCZ4MWF -i weather_client -t channels/588163/publish/4ELVID1N7KLD8LG  
2 -m "field1=23.5&field2=57.5&status=MQTT PUBLISH"  
root@dragino-iae554:~#
```

Figure 7-7. Sending data to ThingSpeak using the mosquitto_pub command

CHAPTER 7 CONNECTING WITH IOT SERVERS USING MQTT

1. In the ThingSpeak, click Channels ► My Channels.
2. On the My Channels page, under Name, click Weather Channel (Figure 7-8).

The screenshot shows the 'My Channels' page of ThingSpeak. At the top, there is a navigation bar with links for 'Channels', 'Apps', 'Community', and 'Support'. Below the navigation bar, the page title 'My Channels' is displayed. A green button labeled 'New Channel' is located on the left. To the right is a search bar with a magnifying glass icon. The main content area displays a table of channels. The first channel listed is 'Weather Channel', which is highlighted with a red border. The table has columns for 'Name', 'Created', and 'Updated'. Under 'Name', the channel name is shown with a lock icon. Under 'Created', the date is 2018-09-29. Under 'Updated', the date is 2018-09-29 15:01. Below the table are buttons for 'Private', 'Public', 'Settings', 'Sharing', 'API Keys', and 'Data Import / Export'.

Name	Created	Updated
Weather Channel	2018-09-29	2018-09-29 15:01

Figure 7-8. List of channels

3. Scroll down the page, and you can see two charts for temperature and humidity (Figure 7-9).

Channel Stats

Created: 6 days ago
Updated: 6 days ago
Last entry: 28 minutes ago
Entries: 2

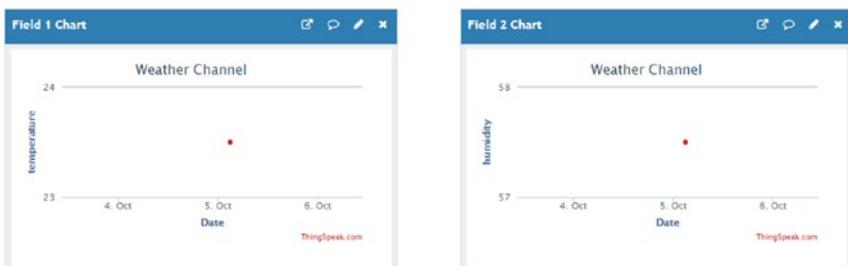


Figure 7-9. Charts for temperature and humidity

Building the Sensor Node

The LoRa sensor node (end device) periodically collects temperature and humidity data from the environment. You will need the following things to build the sensor node:

- Arduino Uno or Adafruit Metro
- RFM9x LoRa radio transceiver breakout
- DHT11 temperature and humidity sensor
- 10 kiloohm resistor (usually Adafruit provides a free resistor with the DHT11 sensor)
- Solid-core hook-up wires
- Half-size breadboard
- Breadboard holder

Figure 7-10 shows the wiring diagram for the sensor node. Using hook-up wires, make connections between all the electronic components.

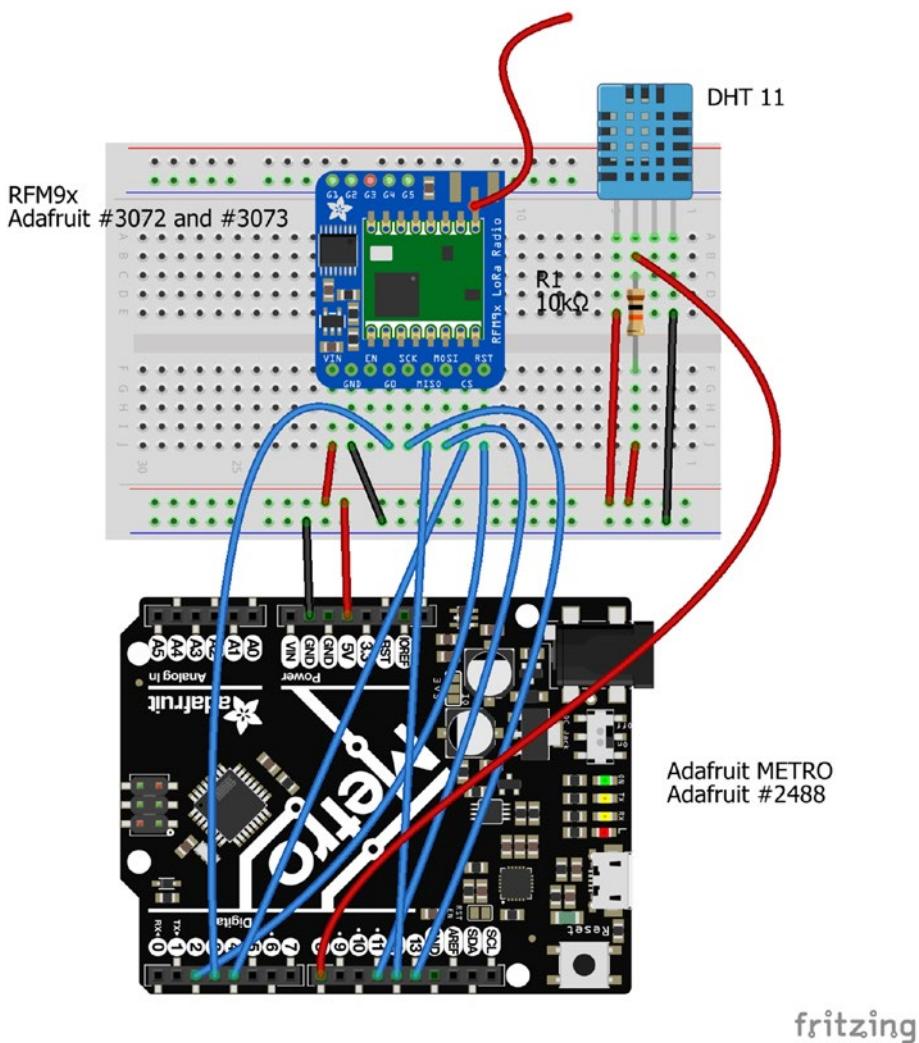


Figure 7-10. Wiring diagram for the LoRa end node

Table 7-1 shows the connections between the Arduino/Metro, radio transceiver, and DHT11 sensor.

Table 7-1. *Wiring Connections for Sensor Node*

Arduino/Metro	Radio Transceiver	DHT11
VIN	VIN	VIN
GND	GND	GND
2	RST	
3	GO	
4	CS	
8		DATA
11	MOSI	
12	MISO	
13	SCK	

Make sure to keep the antenna wire perpendicular to the LoRa radio transceiver module. Figure 7-11 shows the completed sensor node.

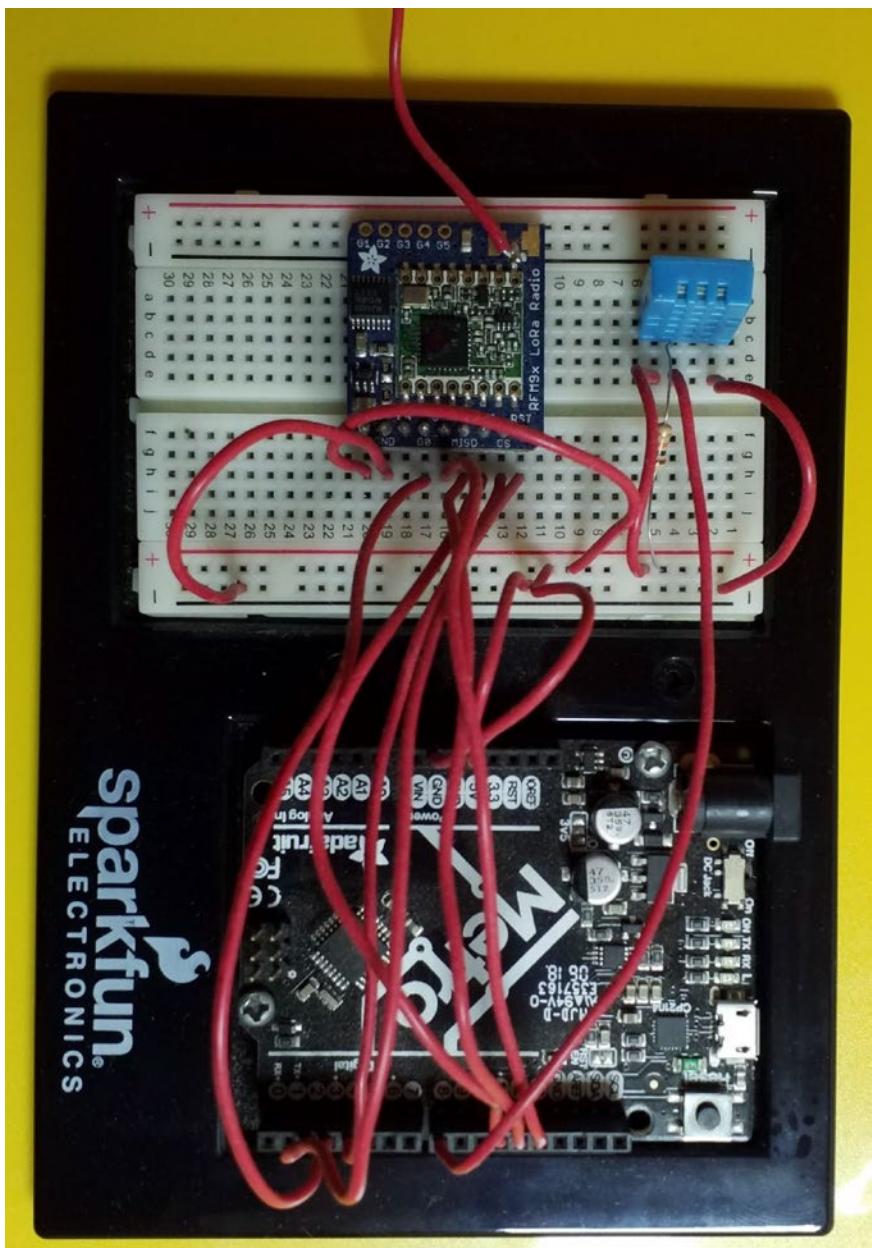


Figure 7-11. Completed LoRa sensor node

Uploading the Sketch to the Sensor Node

The sensor node will periodically send temperature and humidity data as a bundle to the LG01 LoRa gateway using a simple Arduino sketch.

1. Download the sample Arduino sketch, `MQTT_DHT11_Client_updata_to_ThingSpeak_.ino`, from
https://github.com/dragino/Arduino-Profile-Examples/blob/master/libraries/Dragino/examples/IoTServer/ThingSpeak/MQTT_Client/MQTT_DHT11_Client_updata_to_ThingSpeak_/.

The same sketch can be downloaded from Chapter 7/Original Source/`MQTT_DHT11_Client_updata_to_ThingSpeak_.ino`.

2. Open `MQTT_DHT11_Client_updata_to_ThingSpeak_.ino` with your Arduino integrated development environment.
3. Find this line:
`RH_RF95 rf95;`
4. Modify it as shown here by passing the G0 and CS pins where G0 is connected to the Arduino digital pin 4 and CS is connected to the Arduino digital pin 3.
`RH_RF95 rf95(4, 3);`

5. Find the following line:

```
#define DHT11_PIN A0
```

6. The sample code uses Arduino analog pin A0 to connect with the data pin of the DHT11 sensor. Replace it with digital pin 8 as per your hardware setup. The modified line should be as follows:

```
#define DHT11_PIN 8 // Use digital pin 8 as  
Data pin for DHT11.
```

7. Find the following line:

```
float frequency = 868.0; //frequency settings
```

8. Change it to match with your frequency. For example, if you're using a LoRa radio transceiver with frequency 433 MHz, the code can be modified as follows:

```
float frequency = 433.0; //frequency settings
```

9. In the dhtWrite() function, find the following code block:

```
strcat(data,"field1=");  
strcat(data,hum_1);  
strcat(data,"&field2=");  
strcat(data,tem_1);  
strcpy((char *)datasend,data);
```

10. Modify it by swapping the tem_1 and hum_1 variables as shown here:

```
strcat(data,"field1=");  
strcat(data,tem_1);  
strcat(data,"&field2=");  
strcat(data,hum_1);  
strcpy((char *)datasend,data);
```

11. Find the following line to update the node_id value:

```
char *node_id = "<12345>"; //From LG01 via web Local  
Channel settings on MQTT. Please refer <> dataformat in here.
```

12. The node_id value should be match with the local channel in /var/iot/channels/ on the LG01 gateway's MQTT Server Settings page (see "Configuring the LG01 Gateway").
13. If you haven't yet, download and install the modified version of the DHT library from <https://github.com/goodcheney/Lora/blob/patch-1/Lora%20Shield/Examples/DHTlib.zip>.
14. Connect the Arduino with your computer using a USB cable. (For the Adafruit Metro, use USB-A to Micro-B. For the Arduino Uno, use USB A-to-B.)
15. Make sure to choose the correct board type and the COM port. The board type should be Arduino/Genuino Uno. Also, the programmer should be AVRISP mkII (Figure 7-12).

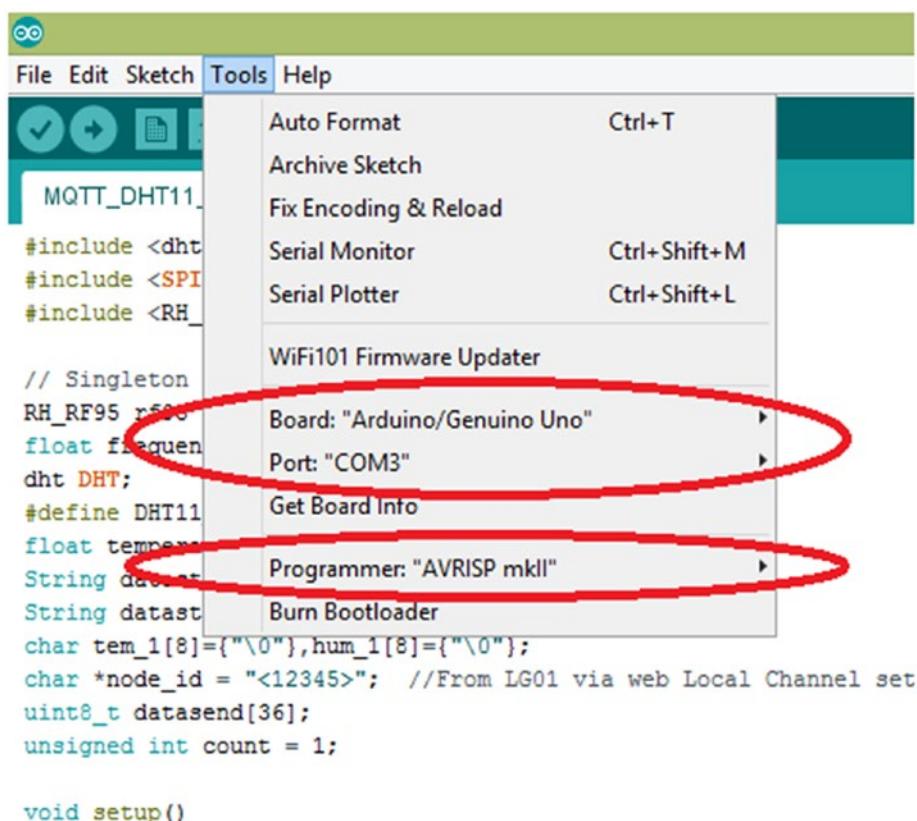
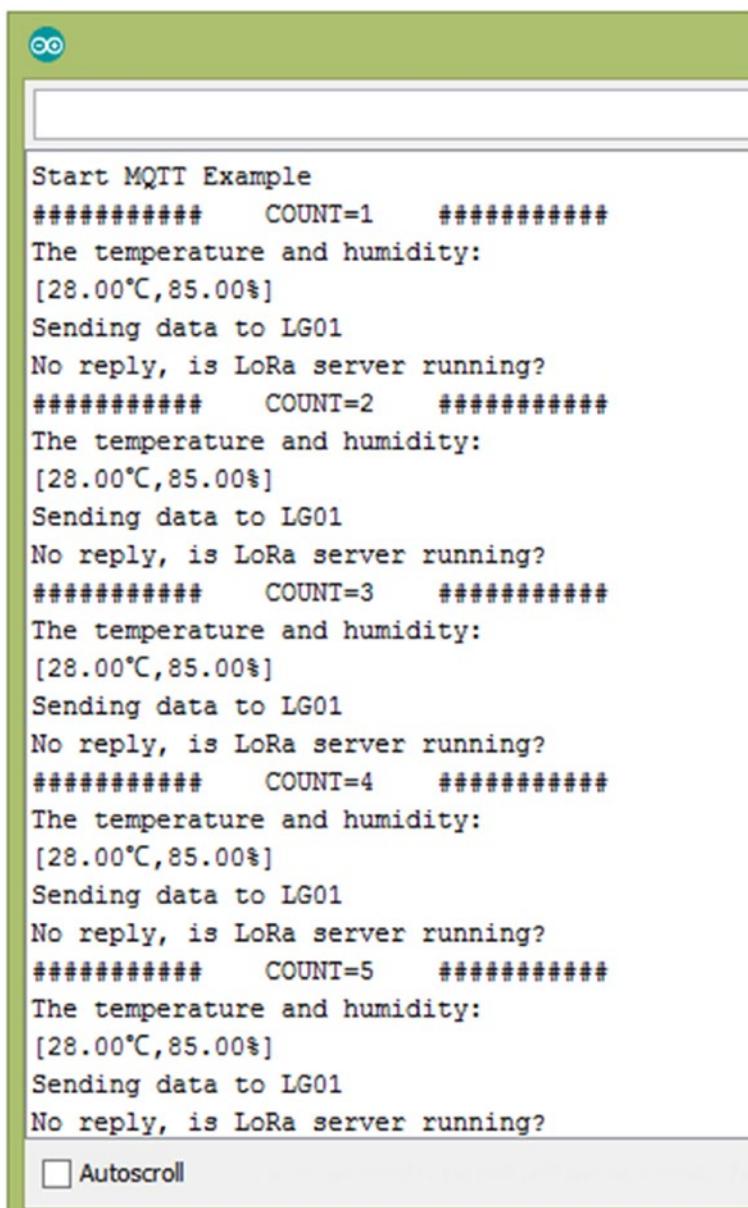


Figure 7-12. Upload settings for Arduino board

16. Verify and upload the code to the Arduino board.
17. After uploading the sketch, in the Arduino IDE, select Tools > Serial Monitor. You should see something like that shown in Figure 7-13.



The screenshot shows a serial monitor window with a green header bar. The main area displays the following text:

```
Start MQTT Example
#####
COUNT=1 #####
The temperature and humidity:
[28.00°C,85.00%]
Sending data to LG01
No reply, is LoRa server running?
#####
COUNT=2 #####
The temperature and humidity:
[28.00°C,85.00%]
Sending data to LG01
No reply, is LoRa server running?
#####
COUNT=3 #####
The temperature and humidity:
[28.00°C,85.00%]
Sending data to LG01
No reply, is LoRa server running?
#####
COUNT=4 #####
The temperature and humidity:
[28.00°C,85.00%]
Sending data to LG01
No reply, is LoRa server running?
#####
COUNT=5 #####
The temperature and humidity:
[28.00°C,85.00%]
Sending data to LG01
No reply, is LoRa server running?
```

At the bottom left of the window, there is a checkbox labeled "Autoscroll".

Figure 7-13. Serial monitor output for the sensor node

18. Close the serial monitor.

Configuring the LG01 Gateway

The LG01 gateway should be configured to receive and forward data to the ThingSpeak IoT server. Follow these steps to configure it for MQTT and radio settings:

1. Using your web browser, log in to the configuration interface of the LG01 gateway. The default username is *root*, and the default password is *dragino*.
2. In the configuration interface, select Sensor ► IoT Server. On the Select IoT Server page, from the IoT Server drop-down list, choose MQTT Server (Figure 7-14).

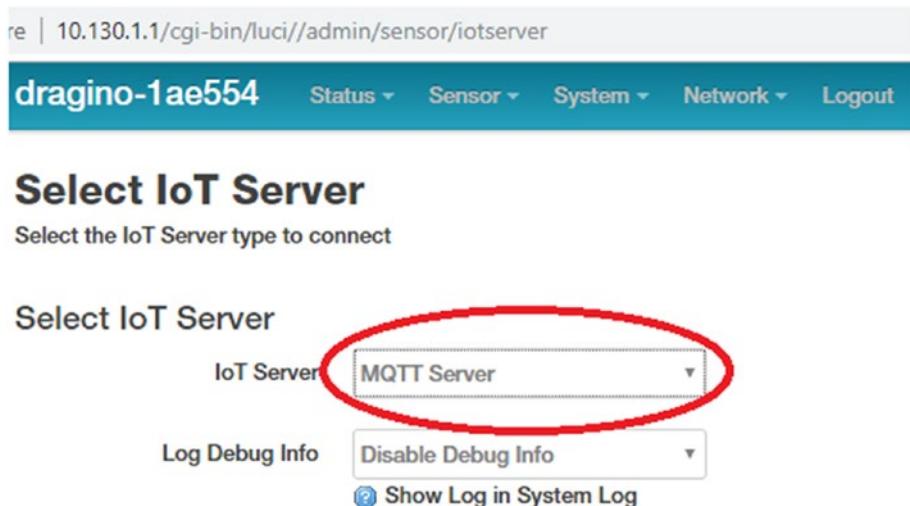


Figure 7-14. Choosing the MQTT server as the IoT server

3. Select Sensor ► MQTT. On the MQTT Server Settings page, fill out the form to configure the LG01 to communicate with the MQTT server (ThingSpeak) (Figure 7-15).

- *Select Server:* Choose ThingSpeak MQTT from the drop-down list.
 - *User Name [-u]:* Enter your ThingSpeak account's username.
 - *Password [-p]:* Enter your MQTT API key.
 - *Client ID [-i]:* Enter your any unique ID (e.g., **weather_client**).
4. Click the Save & Apply button.

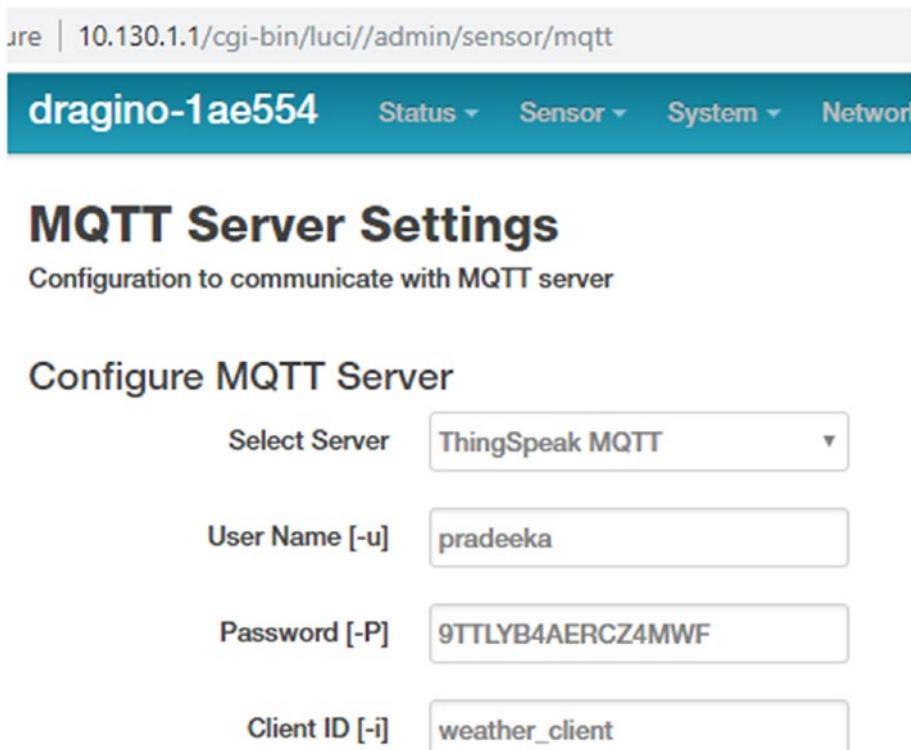


Figure 7-15. MQTT server settings

5. Under MQTT Channel, click the Add button. On the Sensor Channels page, fill out the form (Figure 7-16).
 - *Local Channel ID*: Enter a unique ID with a combination of digits.
 - *Remote Channel ID*: Enter the channel ID in your ThingSpeak account.
 - *Write API Key*: Enter the Write API key in your ThingSpeak account.

The screenshot shows a web interface for managing sensor channels. At the top, there's a URL bar with the address `http://10.130.1.1/cgi-bin/luci/admin/sensor/channel/12345`. Below the URL is a header bar with the device name **dragino-1ae554** and navigation links for Status, Sensor, System, and Network. The main content area has a title **Sensor Channels**. Below it, a section titled **How local channel match remote channel** contains three input fields: Local Channel ID (12345), Remote Channel ID (588163), and Write API Key (4ELVID1N7KLD8LG2).

Local Channel ID	12345
Remote Channel ID	588163
Write API Key	4ELVID1N7KLD8LG2

Figure 7-16. Sensor channels (how the local channel matches the remote channel)

- Click the Save & Apply button. Now your MQTT Server Settings page should look like Figure 7-17.

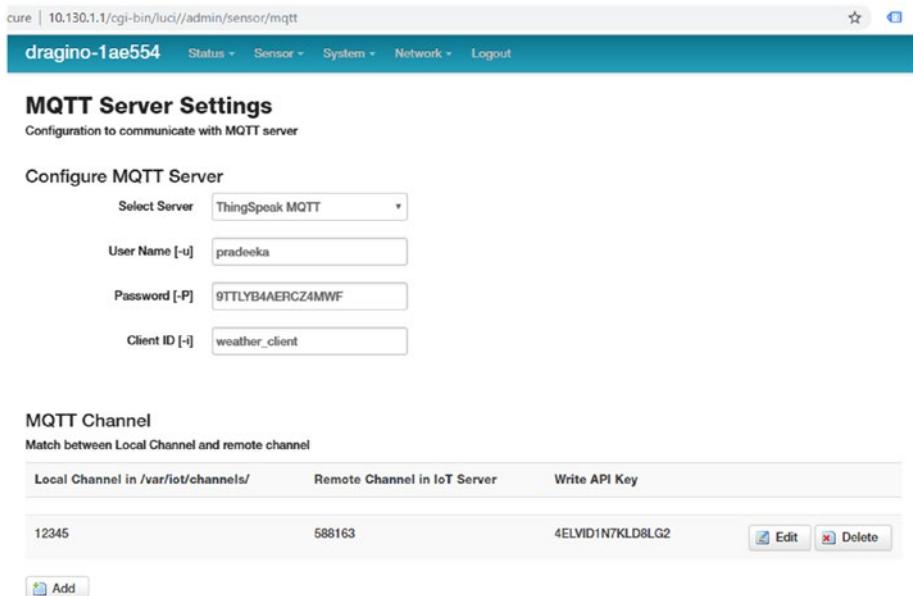


Figure 7-17. Completed MQTT Server Settings page

Uploading the Sketch to the LG01 Gateway

The LG01 gateway uses a simple Arduino sketch to process incoming data packets and extract temperature and humidity values from the payload.

- Download the sample Arduino sketch, `MQTT_Simple_Server.ino`, from https://github.com/dragino/Arduino-Profile-Examples/tree/master/libraries/Dragino/examples/LoRa/MQTT_Simple_Server.

The same sketch can be downloaded from Chapter 7/ Original Source/`MQTT_Simple_Server.ino`.

CHAPTER 7 CONNECTING WITH IOT SERVERS USING MQTT

2. Open `MQTT_Simple_Server.ino` with your Arduino integrated development environment. (Open it with a new instance of the IDE.)

3. Find the following line:

```
while (!Console) ; // Wait for console port to be available
```

4. Comment it as shown here:

```
//while (!Console) ; // Wait for console port to be available
```

5. Save the file by clicking File ➤ Save.

6. Connect the LG01 gateway with your router using an Ethernet cable (connect LG01's WAN port with the router's LAN port).

7. Select Tools ➤ Board and choose Dragino Yun + UNO or LG01/OLG01 (Figure 7-18).

8. Select Tools ➤ Port and choose the correct network port for the LG01 (e.g., `dragino-1ae554 at 10.130.1.1` (Arduino Yun)).

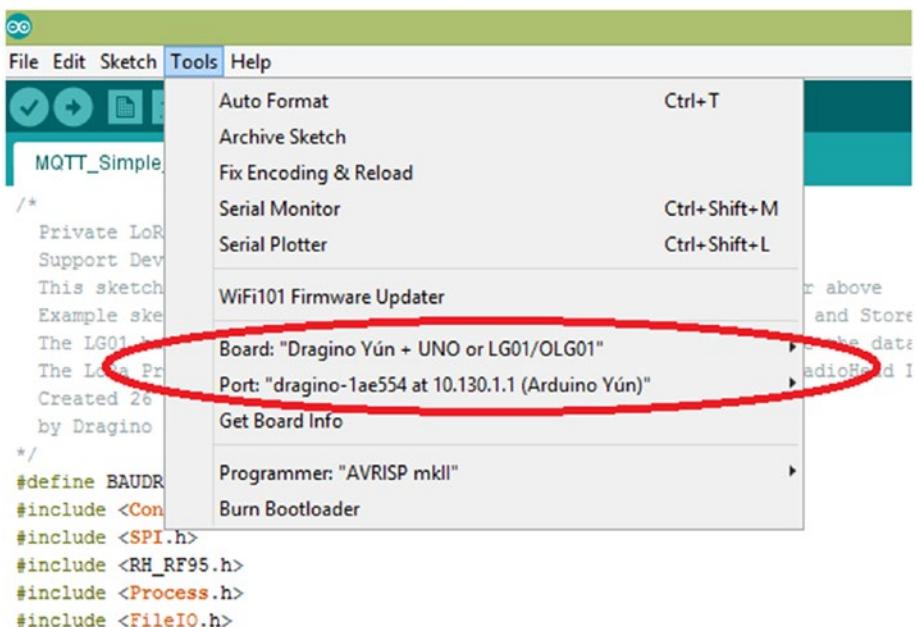


Figure 7-18. Upload options for LG01 gateway

9. Verify the sketch for errors and then click the Upload button to upload the sketch into the LG01. If prompted, type the board password as **dragino** and click the Upload button (Figure 7-19).

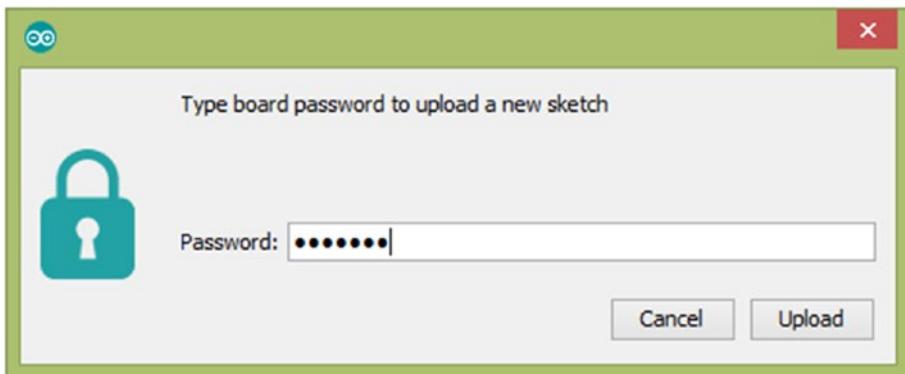


Figure 7-19. Providing the board password

10. After uploading the sketch, press the Reset (toggle) button in the LG01 gateway (Figure 7-20). You can use a small paper clip to access the Reset button placed inside the enclosure by inserting it through the hole.

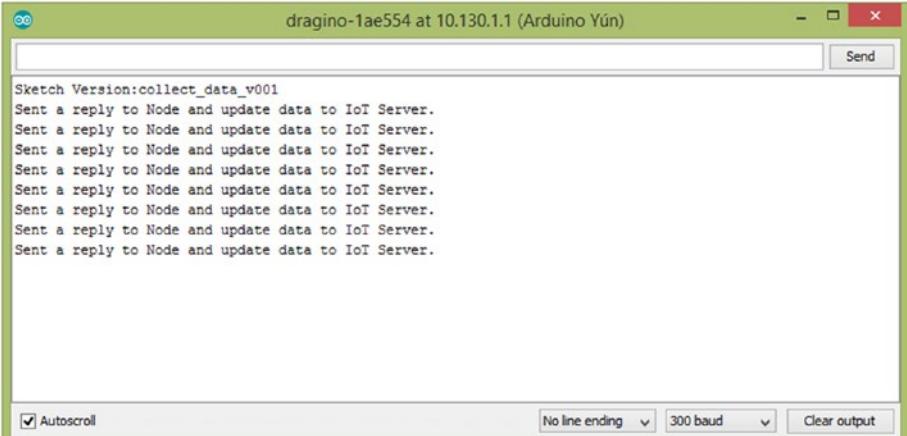


Figure 7-20. Reset/Toggle button

Testing the Sensor Network

Now it's time to test your LoRa sensor network. Follow these steps to test it with your Arduino IDE and the ThingSpeak IoT server:

1. In the Arduino IDE, open the serial monitor by selecting Tools ▶ Serial Monitor. You will get the output shown in Figure 7-21. If prompted for the password to access the serial monitor, use **dragino**.



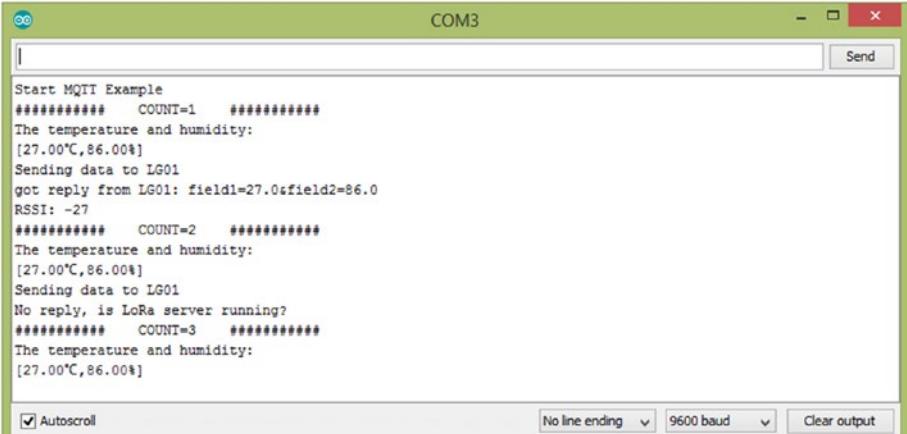
The screenshot shows the Arduino Serial Monitor window titled "dragino-1ae554 at 10.130.1.1 (Arduino Yún)". The text area contains the following output:

```
Sketch Version:collect_data_v001
Sent a reply to Node and update data to IoT Server.
Sent a reply to Node and update data to IoT Server.
Sent a reply to Node and update data to IoT Server.
Sent a reply to Node and update data to IoT Server.
Sent a reply to Node and update data to IoT Server.
Sent a reply to Node and update data to IoT Server.
Sent a reply to Node and update data to IoT Server.
```

At the bottom, there are checkboxes for "Autoscroll", "No line ending", "300 baud", and "Clear output".

Figure 7-21. Output on serial monitor for LG01 gateway

2. In the `MQTT_DHT11_Client_updata_to_ThingSpeak_.ino` sketch, open the serial monitor. This should be a new instance of the Arduino IDE. You will get the output shown in Figure 7-22.



The screenshot shows the Arduino Serial Monitor window titled "COM3". The text area contains the following output:

```
Start MQTT Example
#####
COUNT=1 #####
The temperature and humidity:
[27.00°C,86.00%]
Sending data to LG01
got reply from LG01: field1=27.0&field2=86.0
RSSI: -27
#####
COUNT=2 #####
The temperature and humidity:
[27.00°C,86.00%]
Sending data to LG01
No reply, is LoRa server running?
#####
COUNT=3 #####
The temperature and humidity:
[27.00°C,86.00%]
```

At the bottom, there are checkboxes for "Autoscroll", "No line ending", "9600 baud", and "Clear output".

Figure 7-22. Serial monitor output for the sensor node

3. Now your sensor node is receiving replay messages from the LG01 gateway. This will indicate your LoRa sensor network is up and running. However, you should confirm with the ThingSpeak IoT server.
4. Go to the ThingSpeak and open your channel (Weather Channel). Scroll down the page, and you can see your charts are populated with temperature and humidity data (Figure 7-23).

Channel Stats

Created: 8 days ago
Updated: a day ago
Last entry: about a minute ago
Entries: 326

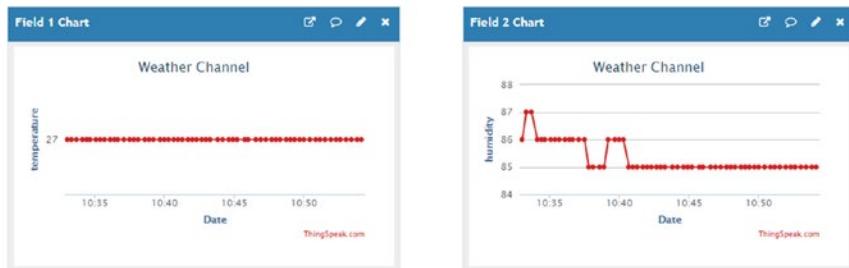


Figure 7-23. Charts for temperature and humidity data

You can modify the LoRa sensor node hardware by replacing the DHT11 temperature and humidity sensor with any type of sensor for remote monitoring. You can also enhance this application by using the ThingHTTP app (<https://thingspeak.com/apps/thinghttp>) to trigger text messages from IFTTT. You can find a good example about how to use the ThingHTTP app to trigger a text message from IFTTT at <https://www.mathworks.com/help/thingspeak/use-ifttt-to-send-text-message-notification.html>.

Summary

In this chapter, you learned how to connect and send data to the ThingSpeak IoT server using the MQTT protocol. The next chapter will explain how to build a GPS tracker to send data through LoRa wireless to a LoRa gateway and display real-time tracking with the Traccar server.

CHAPTER 8

GPS Tracking

The Global Position System (GPS) is a satellite-based navigation system that provides continuous positioning and timing information anywhere in the world under any weather condition.

In this chapter, you will learn how to build a GPS tracker to use real-time location tracking. The LoRa end node will parse GPS data and send it to the LoRa gateway using LoRa wireless. The LoRa gateway will encode the data and send it to GPS tracking software.

GPS satellite signals can be processed with a GPS tracker. Usually, a GPS tracker consists of a GPS module, a processing unit, and a cellular module. The GPS module receives GPS signals and outputs raw GPS NMEA sentences. These NMEA sentences can be further processed using a processing unit to take out information such as the time, date, latitude, longitude, altitude, estimated land speed, and fix type. Finally, these coordinates are sent to GPS tracking software to display the current location of the device. A cellular data connection is needed to send the location data to the GPS tracking software.

With LoRa wireless, you can replace some parts of the cellular network. With the LoRa-based GPS tracking system, only an Internet connection is needed for the gateway. GPS trackers can send data to the gateway using LoRa wireless without the aid of a cellular network.

Prerequisites

You need the following hardware, software, and user accounts to build the LoRa-based GPS tracking network.

Hardware

Here is the hardware needed:

- Arduino Uno or Adafruit Metro
- Adafruit RFM9x LoRa radio transceiver (three frequency options are available)
 - Adafruit RFM95W LoRa Radio transceiver breakout, 868 or 915 MHz, Radio Fruit
 - Adafruit RFM96W LoRa Radio transceiver breakout, 433 MHz, Radio Fruit
- Adafruit Ultimate GPS breakout, 66 channel with 10 Hz updates, version 3, <https://www.adafruit.com/product/746>
- GPS external active antenna, 3 to 5 V 28 dB 5 meter SMA (optional), <https://www.adafruit.com/product/960>
- SMA to full/U.FL/IPX/IPEX RF adapter cable (optional), <https://www.adafruit.com/product/851>
- 9 V alkaline battery (<https://www.sparkfun.com/products/10218>)
- 9 V to barrel jack adapter (<https://www.sparkfun.com/products/9518>)

- Dragino LG01 gateway (three frequency options)
<https://www.tindie.com/products/edwin/lg01-lora-openwrt-iot-gateway/>
 - *LG01-P 868*: LoRa gateway, best tuned at 868 MHz frequency
 - *LG01-P 915*: LoRa gateway, best tuned at 915 MHz frequency
 - *LG01-P 433*: LoRa gateway, best tuned at 433 MHz frequency

Software

You should install the following Arduino libraries in the Arduino IDE to compile and upload sketches to the Arduino Uno:

- RadioHead library modified by Dragino, <https://github.com/dragino/RadioHead/archive/master.zip>
- TinyGPS, <https://github.com/mikalhart/TinyGPS/releases/tag/v13>
- Arduino LMIC library, <https://github.com/matthijskooijman/arduino-lmic>

User Accounts

You'll need these user accounts:

- Create a free account at <https://www.traccar.org/> to visualize the real-time location of the GPS tracker on a map.
- Create a free account on the Things Network (<https://www.thethingsnetwork.org>).
- Create a free account on IFTTT (<https://ifttt.com/>).

Configuring the Gateway

You can use the Dragino LG01 single-channel gateway (Figure 8-1) to forward any incoming data packet from the GPS tracker to the Things Network (<https://www.thethingsnetwork.org/>).



Figure 8-1. Dragino LG01 LoRa single-channel gateway

The same gateway can be built with a Raspberry Pi by installing the single-channel packet forwarder software (refer to Chapter 5 for a detailed explanation).

Follow these steps to configure the LG01 gateway to forward the data packets to the Things Network:

1. Download the hex file for the single-channel packet forwarder from www.dragino.com/downloads/index.php?dir=motherboards/lg01/sketch/. Make sure to download the latest file (Figure 8-2). At the time of this writing, the latest version is v004.

Dragino Download Server . / downloads / motherboards / lg01 / sketch /			
File	Size	Modified	
Parent Directory			
changelog	235.0 B	2018-Aug-07	
single_pkt_fwd_v002.hex	49.3 KB	2017-Aug-19	
single_pkt_fwd_v003.ino.hex	47.5 KB	2018-May-14	
Single_pkt_fwd_v004.ino.hex	49.1 KB	2018-Sep-08	
4 Files - 0 Folders		Total size: 146.2 KB	
Powered by AutoIndex PHP Script			

Figure 8-2. Single-channel packet forwarder software for LG01

2. Connect the LG01 gateway to the Internet (connect LG01's WAN port to your router's LAN port using an Ethernet cable). In the LG01 configuration interface (<http://10.130.1.1>), choose Sensor ➤ Flash MCU (Figure 8-3).

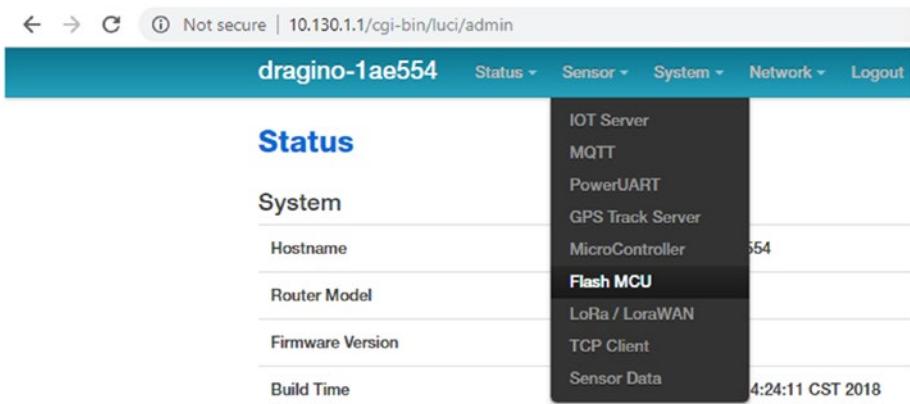


Figure 8-3. Menu command for uploading an MCU image

3. On the Upload Image to MCU page, click the Choose File button to browse and locate the downloaded hex file (Single_pkt_fwd_v004.ino.hex). Then click the Flash Image button to start uploading it to the LG01 gateway (Figure 8-4).

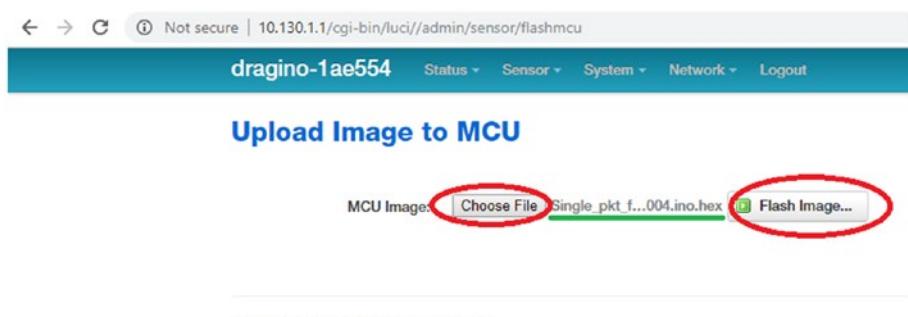


Figure 8-4. Uploading image to MCU

4. Once uploaded, reboot the LG01 gateway.
5. After rebooting the LG01 gateway, in the configuration interface, select Sensor ➤ Microcontroller to verify the flashed hex file (Figure 8-5).

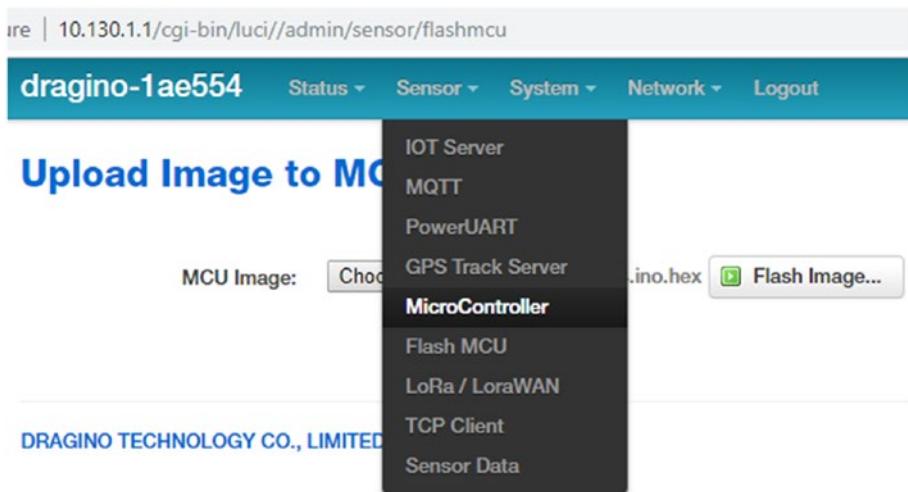


Figure 8-5. Menu command for accessing microcontroller settings

6. On the “Micro-controller settings” page, under MCU Upload Profile, you should see the file name of the uploaded hex file next to the MCU version (Figure 8-6).

The screenshot shows a web interface for a Dragino device. At the top, there's a header bar with the IP address '10.130.1.1/cgi-bin/luci//admin/sensor/mcu', the device name 'dragino-1ae554', and navigation links for Status, Sensor, System, Network, and Logout.

The main content area is titled 'Micro-Controller settings'. A sub-section titled 'MCU Upload Profile' is displayed. It includes fields for 'MCU Part' (set to ATmega328P), 'Profile' (set to Arduino Uno w/ATmega328P), and 'MCU Version' (set to single_pkt_fwd_v004). The 'MCU Version' field is circled in red. Below these, there are checkboxes for 'Add Bootloader' (checked) and 'Add Arduino bootloader while upload' (unchecked). There are also checkboxes for 'MCU Watchdog' (unchecked) and 'Reset MCU while sketch hang up' (unchecked).

Figure 8-6. Finding the MCU version. The MCU version is equivalent to the version of the single-channel packet forwarder software.

7. In the configuration interface, select Sensor ➤ LoRa/LoRaWAN (Figure 8-7).

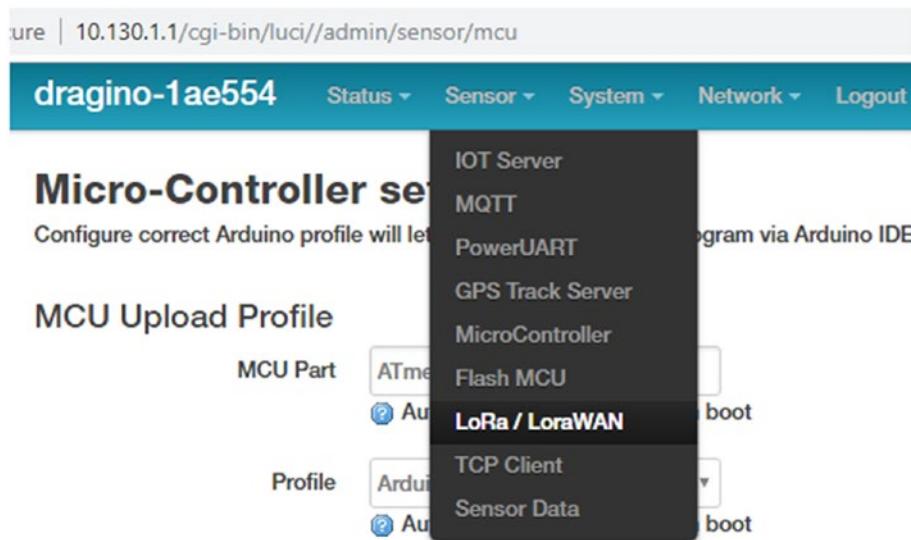
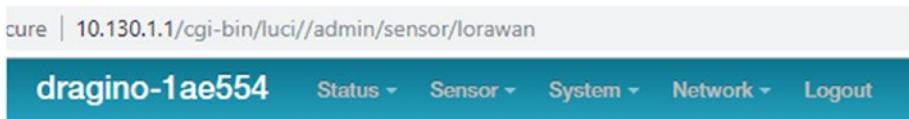


Figure 8-7. Menu command for accessing the LoRa/LoRaWAN settings

8. On the LoRa Gateway Settings page, under LoRaWAN Server Settings, fill in the following fields (Figure 8-8):
 - *Server Address:* Use one of the following server addresses from the Things Network:
 - router.eu.thethings.network (EU 433 and EU 863-870)
 - router.us.thethings.network (US 902-928)
 - router.cn.thethings.network (China 470-510 and 779-787)
 - router.au.thethings.network (Australia 915 to 928 MHz)
 - *Server Port:* Use the port number 1700 for all the servers.

- *Gateway ID:* Use the Media Access Control (MAC) address of your LG01 gateway by appending FFFF to the end. As an example, if you have an LG01 gateway with the MAC address A840411AE554, the resulting gateway ID would be A840411AE554FFFF.
- *Mail Address:* Provide a valid e-mail address.
- *Latitude and Longitude:* Provide the geographical coordinates of your gateway. This assumes you have mounted your gateway in a fixed location.



LoRa Gateway Settings

Configuration to communicate with LoRa devices and LoRaWAN server

LoRaWAN Server Settings

Server Address

Server Port

Gateway ID

Mail Address

Latitude

Longitude

Figure 8-8. LoRaWAN server settings

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9. Scroll down the page and find the Radio Settings section (Figure 8-9). Type the frequency in hertz for TX Frequency and RX Frequency. Use the same frequency for both input boxes. Figure 8-1 shows the radio settings for EU-433 LoRaWAN 433.175 MHz.
10. Don't provide an encryption key.
11. For Spreading Factor, Transmit Spreading Factor, Coding Rate, Signal Bandwidth, and Preamble Length, use the default values.

ure | 10.130.1.1/cgi-bin/luci//admin/sensor/lorawan

dragino-1ae554

Status ▾ Sensor ▾ System ▾ Network

Radio Settings

Radio settings requires MCU side sketch support

TX Frequency	433175000
	ⓘ Gateway's LoRa TX Frequency
RX Frequency	433175000
	ⓘ Gateway's LoRa RX Frequency
Encryption Key	Encryption Key
Spreading Factor	SF7
Transmit Spreading Factor	SF12
Coding Rate	4/5
Signal Bandwidth	125 kHz
Preamble Length	8
	ⓘ Length range: 6 ~ 65536

Figure 8-9. Radio settings

12. Click the Save & Apply button to save the configuration settings.

13. Finally, in the configuration interface, select Sensor ➤ IoT Server (Figure 8-10).

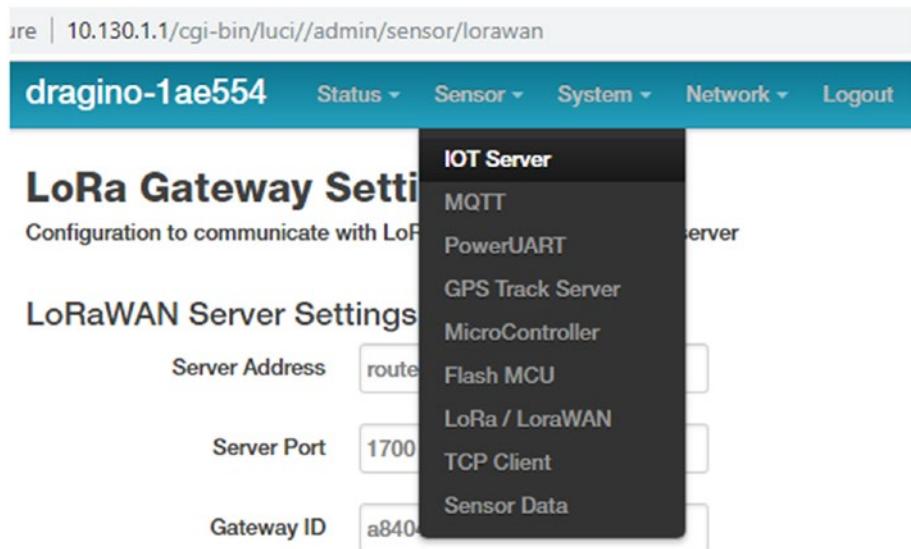


Figure 8-10. Menu command for accessing IoT Server settings

14. On the Select IoT Server page, under Select IoT Server, choose LoRaWAN from the IoT Server dropdown list (Figure 8-11).

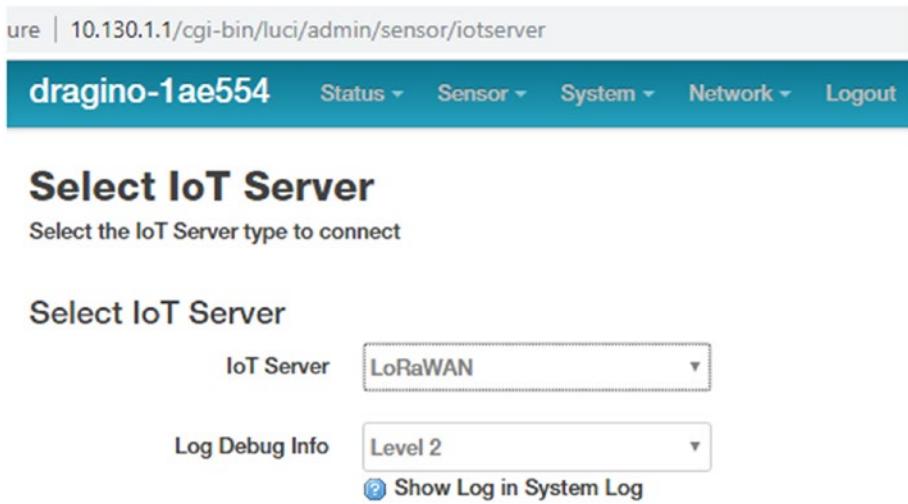


Figure 8-11. Selecting the IoT server

15. Click the Save & Apply button.

Registering Your Gateway with the Things Network

Before forwarding any data packets to the Things Network, you should register your LG01 gateway with the Things Network Console. In Chapter 5, you created an account with the Things Network. You can use the same credentials with the Things Network Console.

1. Log in to the Things Network using your credentials (<https://account.thethingsnetwork.org/users/login/>).
2. After you successfully logged in, click the Console link (Figure 8-12).

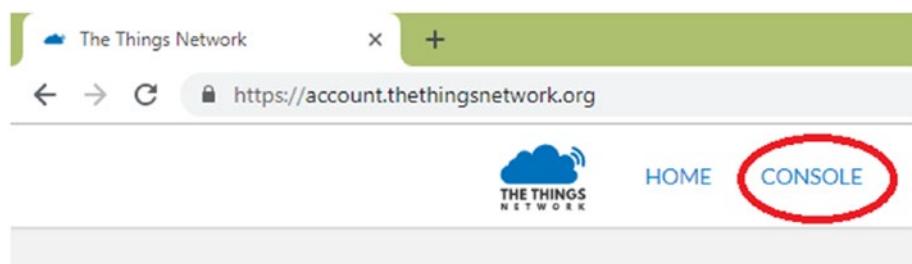


Figure 8-12. Accessing the Things Network Console

3. Click Gateways (Figure 8-13).

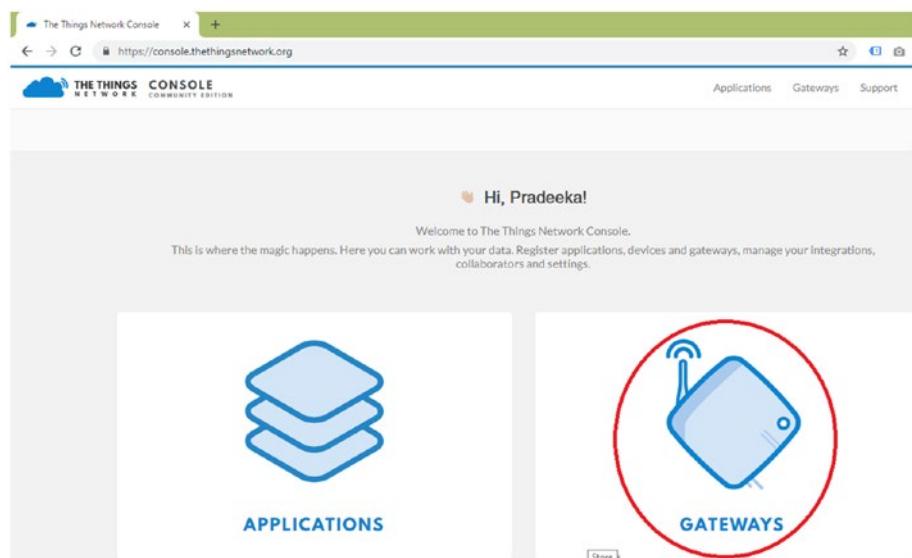


Figure 8-13. Accessing gateways

4. On the Gateways page, click the “register gateway” link.
5. In the Register Gateway page, fill out the form with the following technical details:

- **GATEWAY EUI:** Type in the MAC address of the LG01 gateway (Figure 8-14) by appending FFFF to the end. As an example, if you have an LG01 gateway with the MAC address A840411AE554, the resulting gateway ID would be A8 40 41 1A E5 54 FF FF.



Figure 8-14. MAC address of the LG01 gateway

- Select the “I’m using the legacy packet forwarder” check box.
- **Description:** Type in a human-readable description for the gateway (e.g., **Dragino LoRa Gateway**).
- **Frequency Plan:** Choose a frequency plan from the list (e.g., Europe 868MHz) to match your gateway’s frequency. It doesn’t show a frequency plan for EU433. However, if your gateway supports 433 MHz, you can use any frequency plan from the list. This will not affect the correct operation of your gateway (Figure 8-15).

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Frequency Plan

The frequency plan this gateway will use

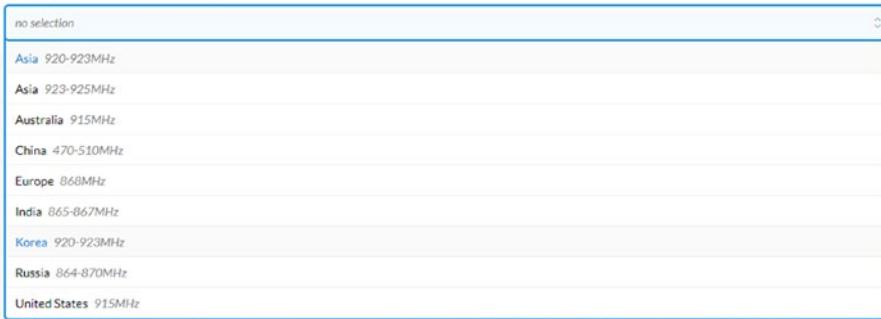


Figure 8-15. Frequency plans for different regions

- *Router:* Choose a router from the list to connect your gateway. To reduce latency, pick a router that is in a region that is close to the location of the gateway (Figure 8-16).

Router

The router this gateway will connect to. To reduce latency, pick a router that is in a region which is close to the location of the gateway.

Router	Status	Address
ttn-router-eu	public	ttn.thingsconnected.net
digitalcataput-uk-router	public	thethings.meshed.com.au
meshed-router	public	ttn.opennetworkinfrastructure.org
switch-router	public	asia-se.thethings.network
ttn-router-asia-se	public	brazil.thethings.network
ttn-router-brazil	public	eu.thethings.network
ttn-router-eu	public	asia-se.thethings.network
ttn-router-jp	public	us-west.thethings.network
ttn-router-us-west	public	

Figure 8-16. TTN routers located in different regions

- *Antenna Placement:* Click the “indoor” button.
- 6. Click the Register Gateway button to register your LG01 with the Things Network.

- After that is successfully registered, you can see the status as “connected” (Figure 8-17). Sometimes it will take few minutes to change the status from “not connected” to “connected.”

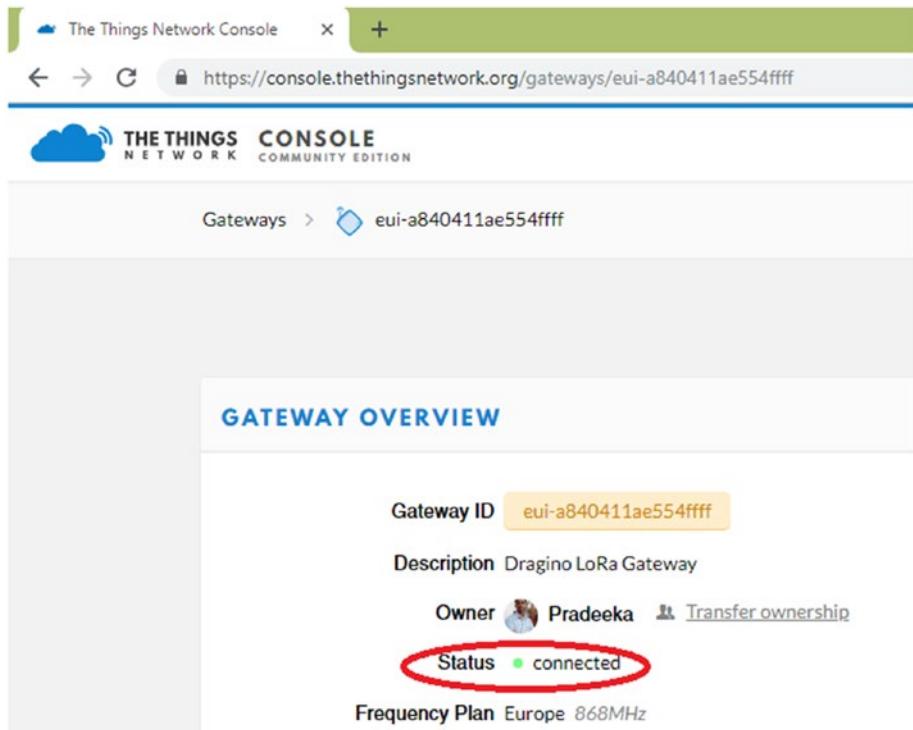


Figure 8-17. Connection status of the gateway with the Things Network

Creating an Application

The application allows you to decode the incoming payload to extract useful data. The following steps will guide you how to create a simple application to decode the payload and extract the ID, longitude, and latitude data. It will also trigger the IFTTT recipe for a webhook to send HTTP GET requests to the Traccar GPS server.

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1. In the Things Network Console, click Application.
2. Under Applications, click the “add application” link.
3. On the Add Application page, fill out the following form fields:
 - *Application ID*: Type a unique identifier for your application (e.g., **a840411ae554ffff**).
 - *Description*: Type a human-readable description for your application (e.g., **GPS Tracker**).
 - *Handler*: From the drop-down list, select the handler you want to register this application with (e.g., **ttn-handler-eu**).
4. Click the “add application” button.
5. Now your application can be found under Applications (Figure 8-18). Click the application name (GPS tracker) for an application overview.



Figure 8-18. The GPS tracker application is listed under Applications

6. Click the Payload Formats tab (Figure 8-19).

The screenshot shows a web browser window for the THE THINGS NETWORK CONSOLE. The URL in the address bar is <https://console.thethingsnetwork.org/applications/a840411ae554ffff>. The page title is "THE THINGS NETWORK CONSOLE COMMUNITY EDITION". On the left, there's a navigation menu with "Applications" and a link to "a840411ae554ffff". On the right, there are links for "Applications" and "Gateways". Below the navigation, there's a breadcrumb trail: "Applications > a840411ae554ffff". A horizontal navigation bar at the top of the main content area has four tabs: "Overview" (blue), "Devices" (gray), "Payload Formats" (red circle), and "Int.". The main content area is titled "APPLICATION OVERVIEW". It displays the following details:

- Application ID:** a840411ae554ffff
- Description:** GPS tracker
- Created:** 13 days ago

Figure 8-19. Accessing the payload formats

7. On the Payload Formats page, for the payload format, choose Custom from the drop-down list. Then click the Decoder tab (Figure 8-20). Replace the existing JavaScript code with the following code:

```
function Decoder(b, port) {
    var lng = (b[0] | b[1]<<8 | b[2]<<16 | (b[2] & 0x80 ? 0xFF<<24 : 0)) / 10000;

    var lat = (b[3] | b[4]<<8 | b[5]<<16 | (b[5] & 0x80 ? 0xFF<<24 : 0)) / 10000;

    return {
        id: 868142, //id
        lon: lng, //lng
        lat: lat //lat
    };
}
```

```

12
13
14
15 function Decoder(b, port) {
16
17
18 var lat = (b[0] | b[1]<<8 | b[2]<<16 | (b[2] & 0x80 ? 0xFF<<24 : 0)) / 10000;
19
20 var lng = (b[3] | b[4]<<8 | b[5]<<16 | (b[5] & 0x80 ? 0xFF<<24 : 0)) / 10000;
21
22 return {
23
24 id: 868142, //id
25

```

Figure 8-20. JavaScript function for decoding the payload and extracting the device ID, latitude, and longitude

8. Click the “Save payload functions” button.

Using IFTTT

You will need an IFTTT account to create a webhook to send HTTP GET requests to the Traccar server.

1. Go to <https://ifttt.com/> and click the “Sign up” button at the top-right corner of the page.
2. If you have a Google or Facebook account, you can use one of them to sign in with IFTTT. If not, click the “sign up” link at the bottom of the page (Figure 8-21).

IFTTT

Get started with IFTTT

G Continue with Google

f Continue with Facebook

Or use your password to [sign up](#) or [sign in](#)

Figure 8-21. Sign-up options with IFTTT

3. Type in a valid e-mail address and a password and click the “Sign up” button.

Now you have successfully created an account on IFTTT.

Integrating with IFTTT Webhooks

IFTTT webhooks allow you to make HTTP requests to a web server. The Traccar server supports HTTP GET requests. Follow these steps to integrate your application with the IFTTT webhooks:

1. In the Things Network Console, in the GPS tracker application section, click Integrations (Figure 8-22).

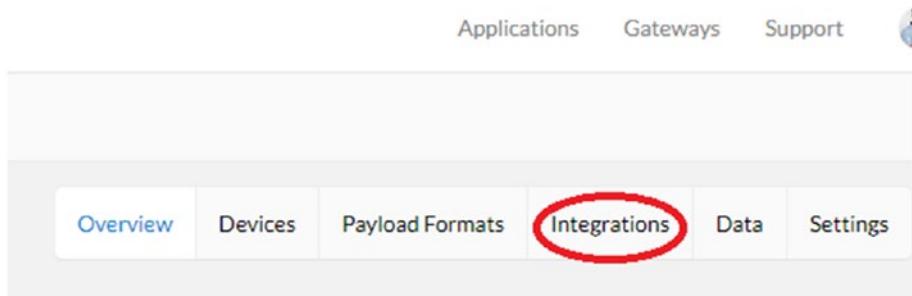


Figure 8-22. Accessing integrations from the top navigation menu

2. Click the “add integration” link.
3. On the Add Integration page, click IFTTT Maker (Figure 8-23).



Figure 8-23. Choosing the integration option as IFTTT Maker channel

4. Click the “documentation” link (Figure 8-24).

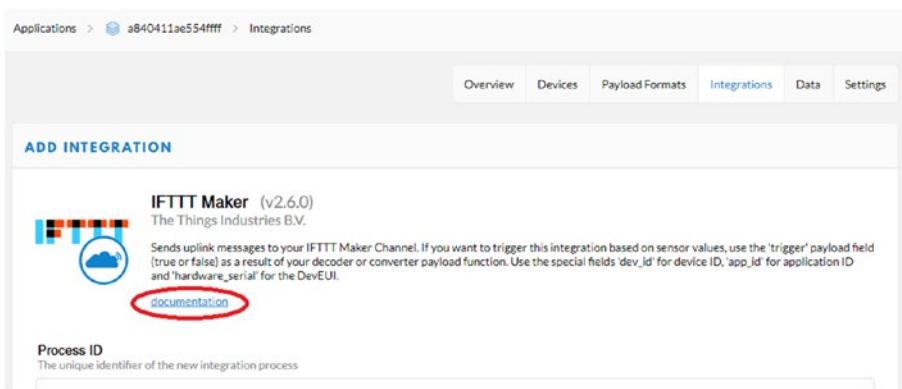


Figure 8-24. The documentation link will open the page at https://ifttt.com/maker_webhooks.

5. This will take you to the IFTTT Webhooks page (https://ifttt.com/maker_webhooks).
6. At the top-left corner of the page, click My Applets (Figure 8-25).

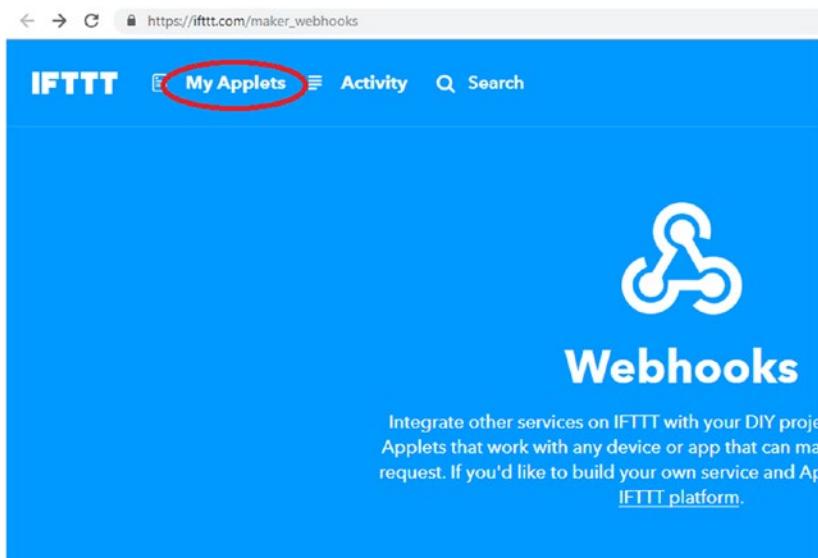


Figure 8-25. Accessing My Applets from the top navigation menu

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- Under Applets, click the New Applet button (Figure 8-26).

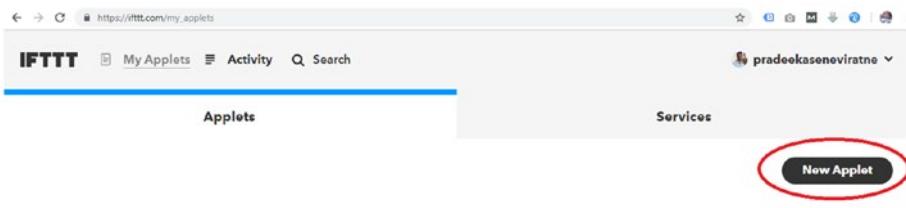


Figure 8-26. Creating a new applet

- On the New Applet page, you can see the IFTTT recipe format for your webhook. Click the “+this” link (Figure 8-27).



Figure 8-27. IFTTT recipe format first condition

- On the “Choose a service” page, in the search services text box, type **Webhooks**. Then click the Webhooks button (Figure 8-28).

Choose a service

Step 1 of 6

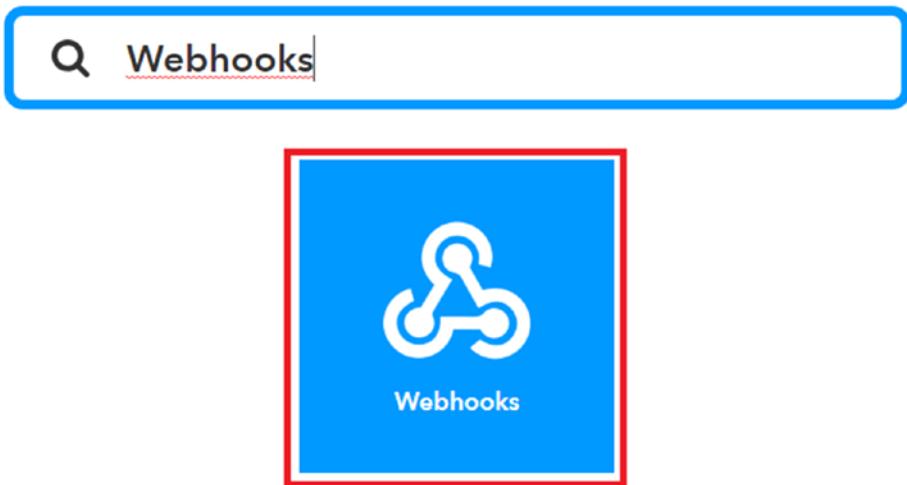


Figure 8-28. Choosing a service

10. On the “Choose trigger” page, click “Receive a web request” (Figure 8-29).

◀ Back



Figure 8-29. Choosing a trigger

11. On the “Complete trigger fields” page, type in a name for the event (e.g., **gps_received**) and click the “Create trigger” button (Figure 8-30).

The screenshot shows a mobile application interface for setting up a trigger. At the top left is a blue icon with three white curved arrows. To its right, the title "Complete trigger fields" is displayed in large, bold, black font. Below the title, the text "Step 2 of 6" is shown in a smaller, gray font. The main content area has a blue background. It features a section titled "Receive a web request" in white font. Below this, a detailed description in white text explains that the trigger fires every time the Maker service receives a web request to notify it of an event. It provides instructions to go to the service settings and tap the listed URL (web) or username (mobile). A form field labeled "Event Name" contains the value "gps_received". Below the field, a descriptive note in white text says "The name of the event, like "button_pressed" or "front_door_opened"". At the bottom of the screen is a large, rounded rectangular button with the text "Create trigger" in white.

Complete trigger fields

Step 2 of 6

Receive a web request

This trigger fires every time the Maker service receives a web request to notify it of an event. For information on triggering events, go to your Maker service settings and then the listed URL (web) or tap your username (mobile)

Event Name

gps_received

The name of the event, like "button_pressed" or "front_door_opened"

Create trigger

Figure 8-30. Completing the trigger fields

12. Click the “+that” link (Figure 8-31).

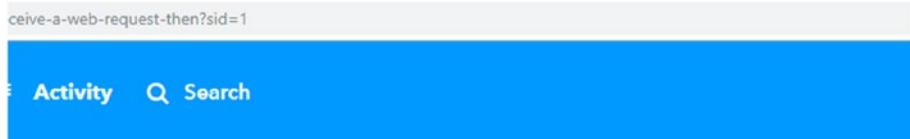


Figure 8-31. IFTTT recipe format second condition

13. On the “Choose action service” page, again search for *Webhooks* (Figure 8-32). Then click the Webhooks button.

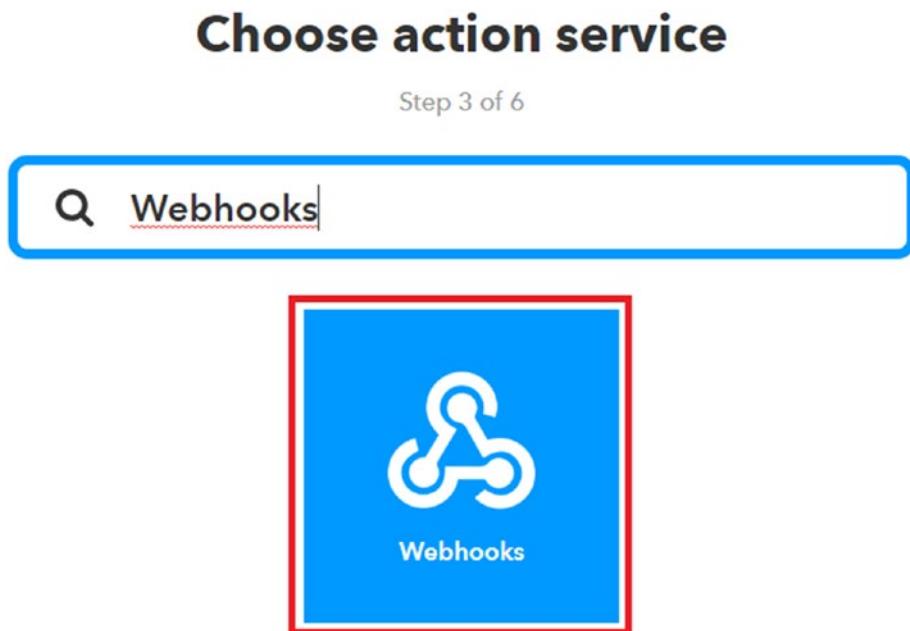


Figure 8-32. Choosing an action service

14. On the “Choose action” page, click the “Make a web request” box (Figure 8-33).

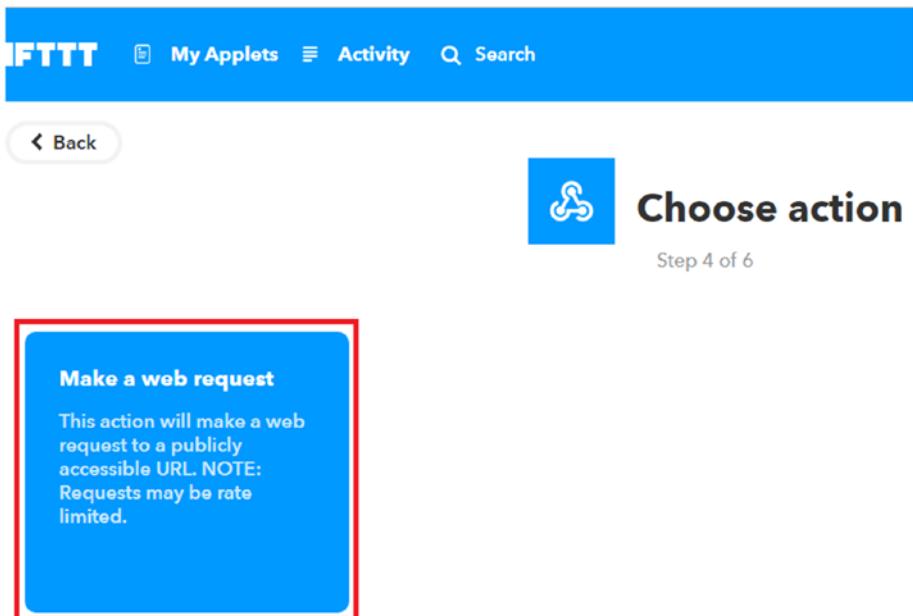


Figure 8-33. Choosing an action

15. On the “Complete action fields” page, fill out the “Make a web request” form as explained here:
 - *URL:* Type the URL for the HTTP GET request (Figure 8-1): `http://demo.traccar.org:5055/?id={{Value1}}&lat={{Value2}}&lon={{Value3}}`
 - The {{Value}} fields can be added by clicking the “Add ingredient” button (Figure 8-34). Then choose the following:
 - *Value 1:* id
 - *Value 2:* Value 2: lat
 - *Value 3:* Value 3: lon

CAUTION After adding the values from the drop-down list, remember to remove all the white spaces in the URL. If you don't do this, the webhook will not work as expected.

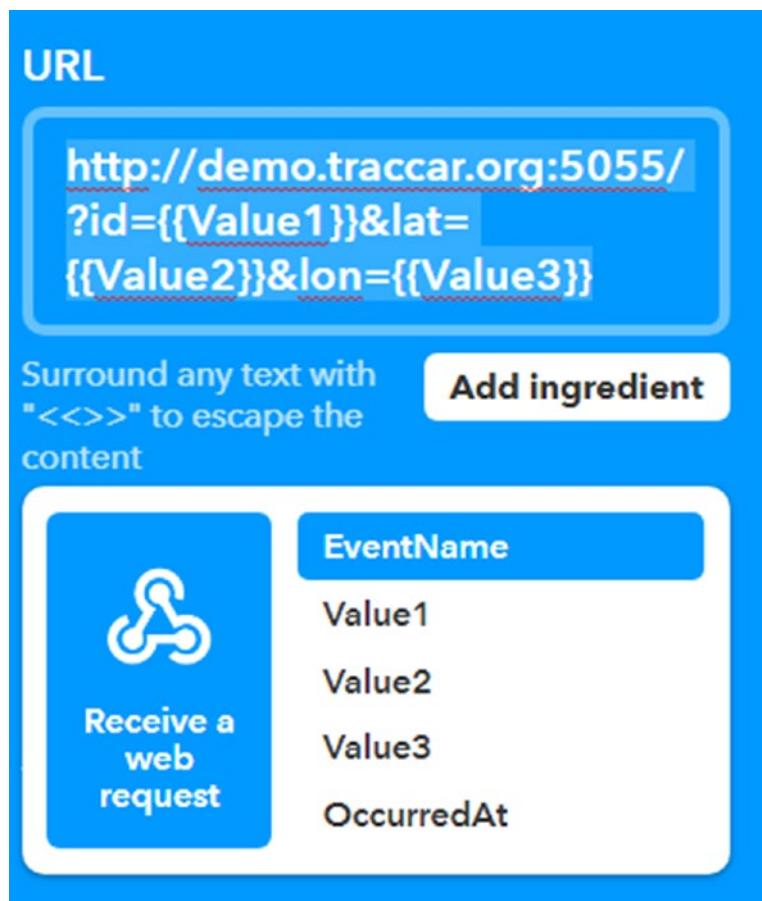


Figure 8-34. Building an HTTP GET request

- *Method:* GET
- *Content Type (optional):* application/json

16. Click the Create Action button to create the action.
17. On the “Review and finish” page, click the Finish button to save the recipe (Figure 8-35).

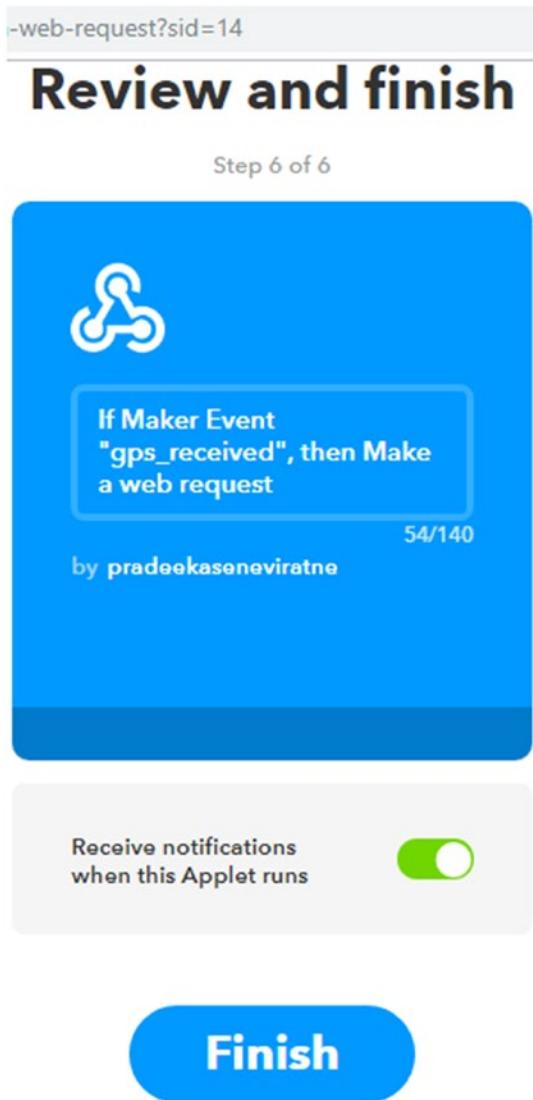


Figure 8-35. Confirming the recipe

18. Now you can see the summary of the webhook recipe. At any time you can turn it off by clicking the On button (Figure 8-36).

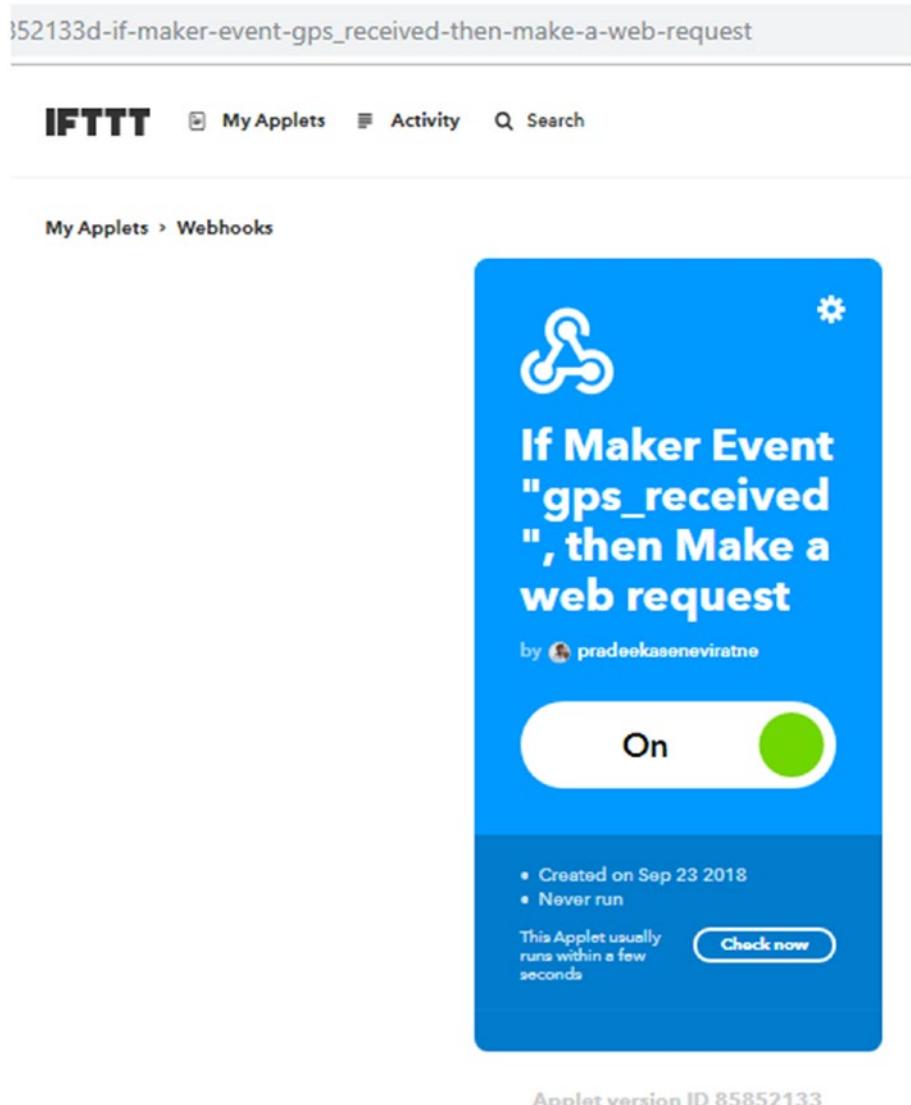


Figure 8-36. Summary of the webhook recipe

19. Now you have successfully created a recipe with IFTTT webhooks to make HTTP GET requests to the Traccar server. Still you will need to find one more thing: the key. On the Webhooks page (https://ifttt.com/maker_webhooks, click the Settings button (Figure 8-37).

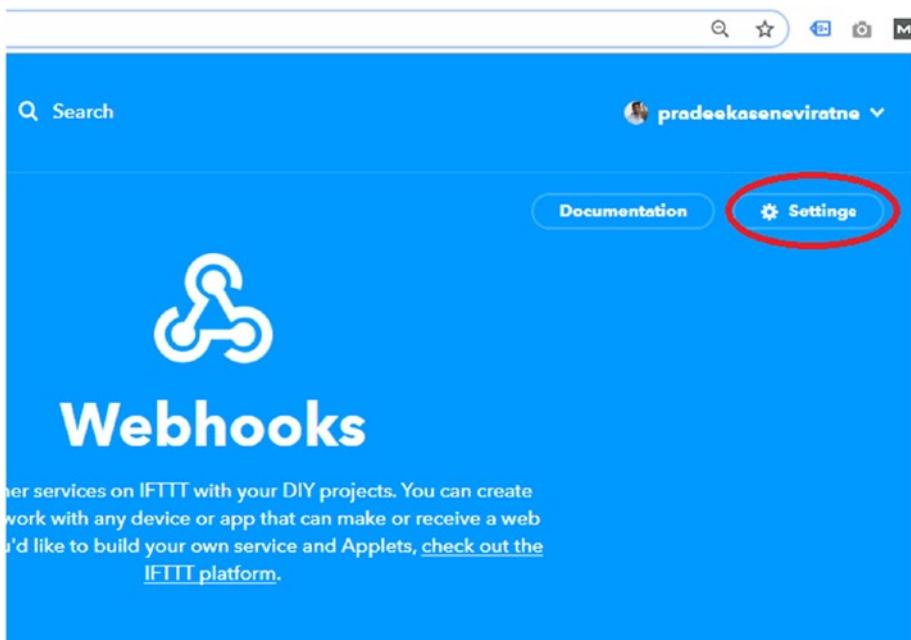


Figure 8-37. Accessing the webhook settings

20. On the Webhooks Settings page, under Account Info, copy the last part of the URL for the key (Figure 8-38).

The screenshot shows the 'Webhooks settings' section of the Things Network Console. At the top is a blue logo consisting of three interconnected circles. Below it is the heading 'Webhooks settings'. Underneath the heading is a link 'View activity log'. A horizontal line separates this from the main content. The main content area is titled 'Account Info'. It displays the following information:

- Connected as: pradeekaseneviratne
- URL: https://maker.ifttt.com/use/mdwNeoX1Jms-P_xDsYXN98tFC4503510pHnWbBT7NN
- Status: active

A red arrow labeled 'Key' points to the URL, specifically to the last part of the string 'P_xDsYXN98tFC4503510pHnWbBT7NN'. Below this information is a button labeled 'Edit connection'.

Figure 8-38. Webhook settings. The key can be taken from the last part of the URL.

21. You will need this key to integrate the IFTTT webhook that is created under your IFTTT account with the Things Network Console.
22. Now go back to the IFTTT integration settings page and fill out the form as shown here (Figure 8-39):
 - *Event Name:* Enter the event name of your IFTTT recipe (e.g., **gps_received**).

- *Key:* Enter your key (e.g., **mdwXeoX1Jms-P_xDsYXN98tXXXXUb3I8pHJfiBbT7XX**).
- *Value 1:* This is the payload field name to send as value 1 (e.g., **id**).
- *Value 2:* This is the payload field name to send as value 2 (e.g., **lat**).
- *Value 3:* This is the payload field name to send as value 3 (e.g., **lon**).

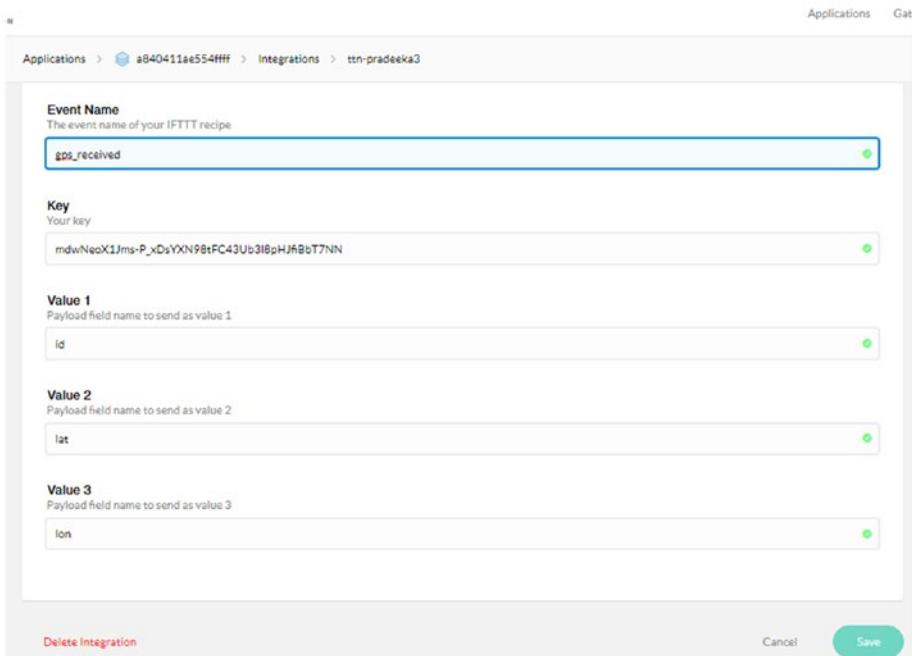


Figure 8-39. IFTTT integration settings

23. Click the Save button to save the integration. Now, under Integration Overview, you can see the status as Running (Figure 8-40).

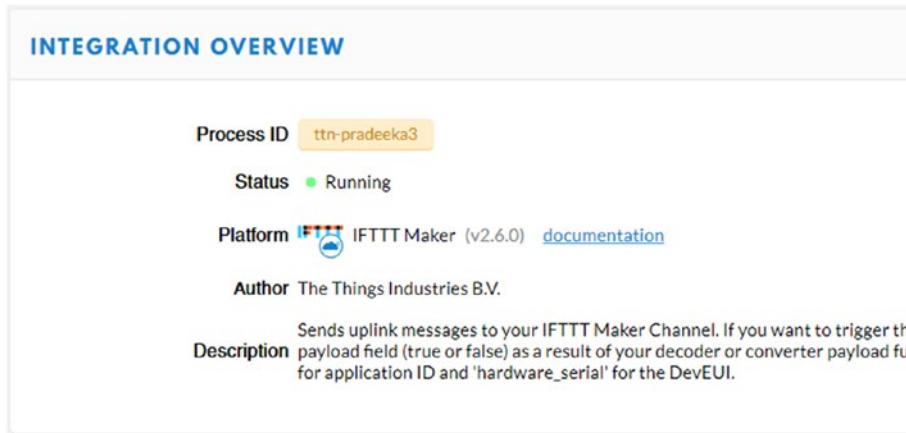


Figure 8-40. IFTTT integartion overview

Building the GPS Tracker

Usually, a GPS tracker periodically sends its geographical coordinates (latitude, longitude, and elevation) to GPS software (hosted on a cloud service) through an existing GPRS/GSM network. It has a cellular module that allows users to insert a SIM card with a cellular data plan.

With LoRa wireless technology, you don't need a SIM module and a cellular data plan for the GPS tracker hardware. The LoRa GPS tracker can send its geographical coordinates to the nearby LoRa gateway mounted on a rooftop of a tall building or a tower. The gateway has an Internet connection through Ethernet, Wi-Fi, or cellular. Gateways continuously hear data packets from the GPS tracking devices. Once the data is received, the LoRa gateway will forward the data packet to the GPS software hosted on a cloud service. The GPS software shows the current position of the device on a map using the geographical coordinates. A single gateway can handle many GPS tracking devices simultaneously. (The Dragino LG01 gateway can handle up to 8 GPS tracking devices.)

Figure 8-41 shows the wiring diagram for the GPS tracker. The processing unit of the GPS tracker is an Arduino Uno (or Adafruit Metro) board. A GPS module and a LoRa radio transceiver module are connected to the Arduino. The GPS module receives data from GPS satellites. Then, the Arduino will process and format the GPS data. Finally, the LoRa transceiver sends data to the LoRa gateway.

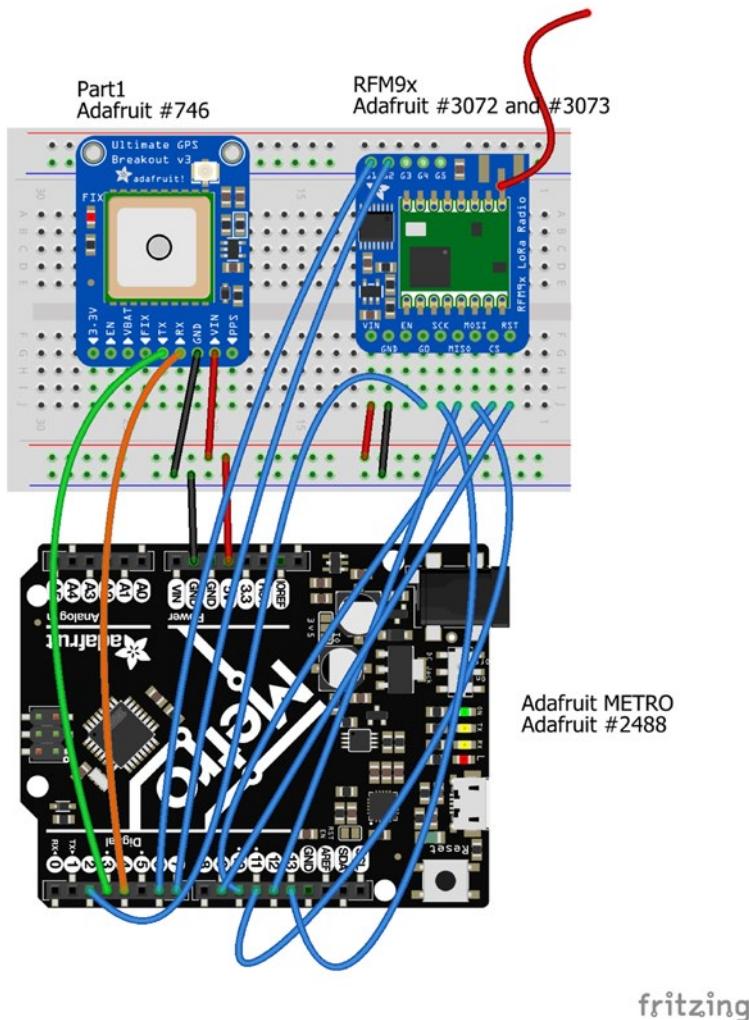


Figure 8-41. Wiring diagram for the GPS tracker

CHAPTER 8 GPS TRACKING

Table 8-1 shows the connections between each component of the GPS tracker.

Table 8-1. *Wiring Connections Between Components*

Arduino	RFM9x	GPS module
5V	VIN	VIN
GND	GND	GND
9	RST	
2	G0	
6	G1	
7	G2	
10	CS	
3		RX
4		TX
11	MOSI	
12	MISO	
13	SCK	

If you want to place the GPS tracker inside an enclosure, you may want to use an external active antenna. Active antennas draw power from the GPS module but provide more gain and sensitivity. Figure 8-42 shows how to connect an external active antenna with a GPS module through an SMA to a full adapter cable.



Figure 8-42. Connecting external antenna to the U.LF connector of the GPS module (image owner: lady ada; license: Attribution-ShareAlike Creative Commons, <https://creativecommons.org/licenses/by-sa/3.0/>)

Once completed, go to https://github.com/goodcheney/Arduino-Profile-Examples/blob/patch-4/libraries/Dragino/examples/LoRa/LoRaWAN/LoRa_GPS_Shield_TTN to get the Arduino sketch for the GPS tracking device. Copy the code and paste it in a new Arduino file. This chapter assumes you installed all the required software libraries on the Arduino IDE in Chapter 3. Before uploading the sketch to the Arduino board, edit the code to suit your hardware setup.

CHAPTER 8 GPS TRACKING

First, find the device overview of your LoRa gateway. The device overview is associated with the application (GPS tracker) that you created in The Things Network Console to decode the payloads coming from the GPS tracker. Follow these steps to view the device overview:

1. In the Things Network Console (<https://console.thethingsnetwork.org>), click Applications (Figure 8-43).

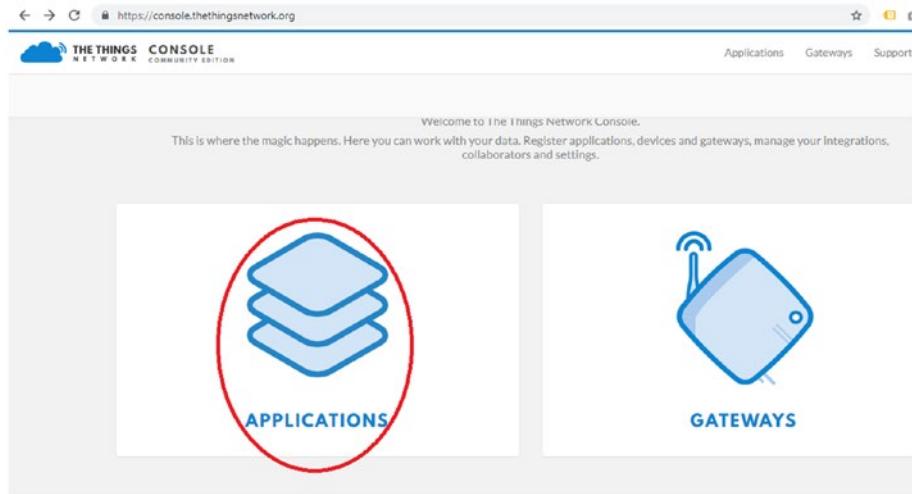


Figure 8-43. Accessing the Applications section

2. Under Applications, click “GPS tracker” (Figure 8-44).



Figure 8-44. GPS tracker application showing under Applications

3. Click Devices (Figure 8-45).

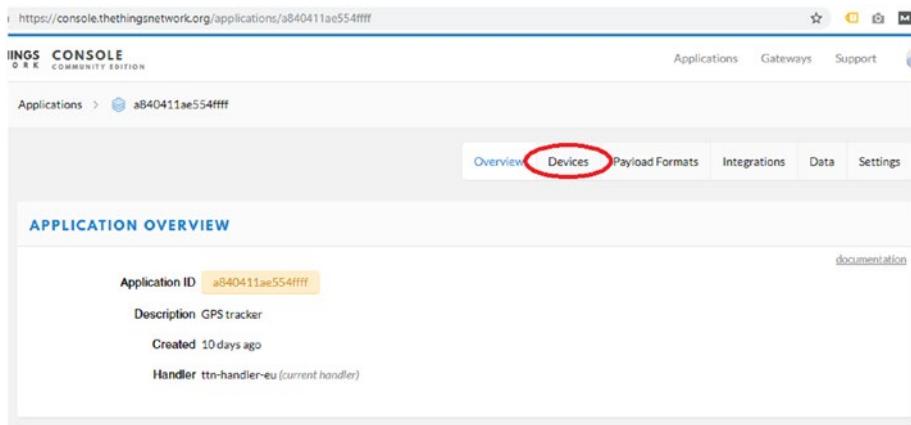


Figure 8-45. Accessing devices

4. Click the Device EUI (Figure 8-46).

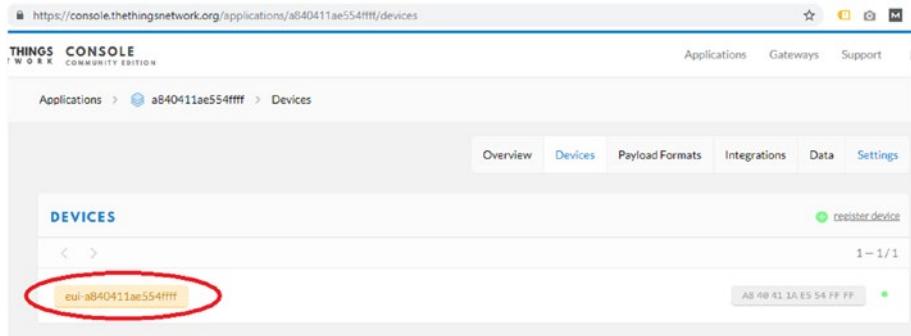


Figure 8-46. Device EUI showing under Devices

5. Now you can see the Device Overview page (Figure 8-47).

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The screenshot shows the 'DEVICE OVERVIEW' section of the Things Network Console. At the top, the URL is https://console.thethingsnetwork.org/applications/a840411ae554ffff/devices/eui-a840411ae554ffff. Below the header, there are links for Applications, Gateways, and Support. The main area displays device configuration parameters:

- Application ID:** a840411ae554ffff (highlighted in yellow)
- Device ID:** eui-a840411ae554ffff
- Activation Method:** ABP
- Device EUI:** A8 40 41 1A E5 54 FF FF
- Application EUI:** 70 B3 D5 7E D0 01 23 D2
- Device Address:** 26 01 11 62
- Network Session Key:** (hex values: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00)
- App Session Key:** (hex values: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00)

Figure 8-47. Device Overview page

Now you can edit the sketch, as described in the following steps.

6. Find the following piece of code in your sketch and replace the NWSKEY value with the network session key of your application:

```
/* LoRaWAN NwkSKey, network session key
   This is the default Semtech key, which is used by
   the prototype TTN
   network initially.
   tttn*/
static const PROGMEM u1_t NWKSKEY[16] = { 0xEE,0x0D,0x3
1,0x15,0x75,0x72,0x0E,0xDD,0x31,0x10,0xD3,0xFE,0x3F,0x1
0,0xFD,0xAF };
```

The network session key can be found on the Device Overview page. Click the hex/C-style button to view the network session key in C-style (Figure 8-48). Then click the Copy to Clipboard button.

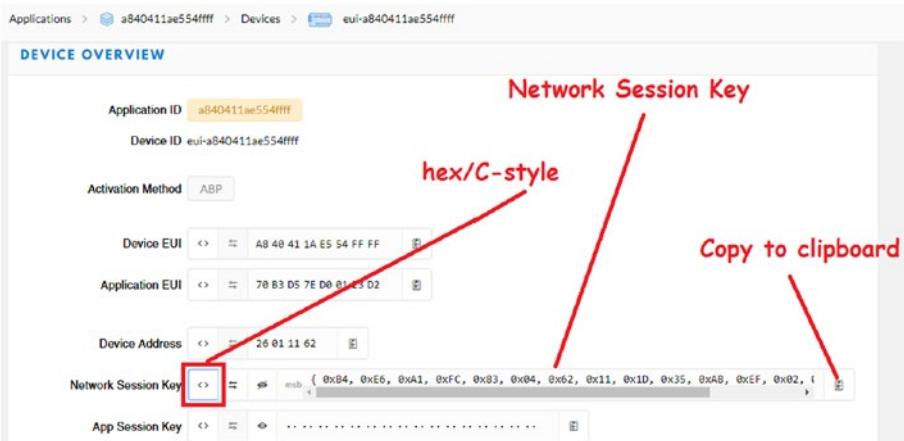


Figure 8-48. Network session key

7. Replace the existing NWSKEY value with the new network session key. Now your Arduino code looks similar to the following:

```
static const PROGMEM u1_t NWKSKEY[16] = { 0xB4, 0xE6,
0xA1, 0xFC, 0x83, 0x04, 0x62, 0x11, 0x1D, 0x35, 0xAB,
0xEF, 0x02, 0x5B, 0x15, 0xB1 };
```

8. Find the following code to modify the APPSKEY value:

```
/* LoRaWAN AppSKey, application session key
This is the default Semtech key, which is used by
the prototype TTN
network initially.
ttn*/
```

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```
static const u1_t PROGMEM APPSKEY[16] = { 0x6A, 0x2A,  
0xE6, 0xA8, 0x5C, 0xD1, 0xF0, 0xC1, 0xB9, 0xA4, 0xBD,  
0xEC, 0xB4, 0x42, 0xC4, 0x97 };
```

9. Replace the APPSKEY value by copying the application session key from the Device Overview page (Figure 8-49).

The screenshot shows the 'DEVICE OVERVIEW' page of the Things Network console. At the top, the URL is https://console.thethingsnetwork.org/applications/a840411ae554ffff/devices/eui-a840411ae554ffff. The navigation bar includes Applications, Gateways, and Support. Below the navigation, the path is Applications > a840411ae554ffff > Devices > eui-a840411ae554ffff. The main section is titled 'DEVICE OVERVIEW'. It displays various device parameters: Application ID (a840411ae554ffff), Device ID (eui-a840411ae554ffff), Activation Method (ABP), and several EUI and Address fields. A red arrow points to the 'Application Session Key' field, which contains a long hex string: B4 E6 A1 FC B3 04 62 11 1D 35 AB EF 02 5B 15 B1. This field is highlighted with a red border.

Figure 8-49. Application session key

10. Once modified, your Arduino code looks similar to the following:

```
/* LoRaWAN AppSKey, application session key  
This is the default Semtech key, which is used by  
the prototype TTN  
network initially.  
ttn*/
```

```
static const u1_t PROGMEM APPSKEY[16] = { 0xF5, 0x30,
0xFD, 0x19, 0xFB, 0x4D, 0xB7, 0x9F, 0x84, 0xFC, 0x56,
0xB8, 0x81, 0x7E, 0x08, 0x9F };
```

11. Find the code for DEVADDR and replace it with the end device address. Use C-style before copying it in to the clipboard (Figure 8-50).

```
/*
LoRaWAN end-device address (DevAddr)
See http://thethingsnetwork.org/wiki/AddressSpace\_ttn*
static const u4_t DEVADDR = 0x26011A81;
```

The screenshot shows the 'DEVICE OVERVIEW' section of the Things Console. The 'Application ID' is highlighted in yellow as 'a840411ae554ffff'. The 'Activation Method' is set to 'ABP'. The 'End Device Address' is labeled in red text above the 'Device EUI' field. The 'Device EUI' field contains the value 'A8 40 41 1A E5 54 FF FF'. The 'Application EUI' field contains the value '70 B3 D5 7E D0 01 22 02'. The 'Device Address' field contains the value '26 01 11 62'. The 'Network Session Key' field contains a long hex string: 'B4 E6 A1 FC 83 04 62 11 1D 35 AB EF 02 5B 15 B1'. The 'App Session Key' field contains a multi-line hex string: 'mub { 0xF5, 0x30, 0xFD, 0x19, 0xFB, 0x4D, 0xB7, 0x9F, 0x84, 0xFC, 0x56, 0xB8, 0x81, 0x7E, 0x08, 0x9F }'.

Figure 8-50. End device address

12. The modified code with the end device address looks similar to the following:

```
/*
LoRaWAN end-device address (DevAddr)
See http://thethingsnetwork.org/wiki/AddressSpace
ttn*/
static const u4_t DEVADDR = 0x26011162;
```

13. You can also change the transmission interval by modifying the value of the TX_INTERVAL variable. The default is 20 seconds.

```
/* Schedule TX every this many seconds (might become
longer due to duty
cycle limitations)*/
const unsigned TX_INTERVAL = 20;
```

14. Find the following line:

```
while (!Console);
```

15. Comment it to allow the GPS tracker to send data packets after powering up without waiting for the serial monitor connection. You can comment the line as follows:

```
// while (!Console);
```

16. Finally, replace the code inside the function GPSWrite() with the following:

```
/*Convert GPS data to format*/
datastring1 +=dtostrf(flat, 0, 4, gps_lat);
datastring2 +=dtostrf(flon, 0, 4, gps_lon);
//datastring3 +=dtostrf(falt, 0, 2, gps_alt);
```

```
if(flon!=1000.000000)
{
    strcat(gps_lon,"");
    strcat(gps_lon,gps_lat);
//strcat(gps_lon,"");
//strcat(gps_lon,gps_alt);
    int i = 0;
for(i = 0; i < 2; i++)
{
    //datasend.toFloat();
    atof(gps_lon);
    //Serial.println((char*)datasend);
    Serial.println("Testing converted data:");
    Serial.println(gps_lon);
    // atof(gps_alt);
    // Serial.print(gps_alt);
}
strcpy(datasend,gps_lon); //the format of datasend is
longitude,latitude,altitude
Serial.print("#####      ");
Serial.print("NO.");
Serial.print(count);
Serial.println("      #####");
Serial.println("The longitude and latitude are:");
Serial.print("[");
Serial.print((char*)datasend);
Serial.print("]");
Serial.print("");
/*
for(int k = 0; k < 20;k++)
{
```

```
Serial.print("[");
Serial.print(datasend[k], HEX) ;
Serial.print("]");
}

Serial.println("");
Serial.println("");*/
count++;
}

int32_t lng = flat * 10000;
int32_t lat = flon * 10000;

datasend[0] = lat;
datasend[1] = lat >> 8;
datasend[2] = lat >> 16;

datasend[3] = lng;
datasend[4] = lng >> 8;
datasend[5] = lng >> 16;
smartdelay(1000);
```

17. After modifying the file, save it as `LoRa_GPS_Tracker_TTN.ino`.

Adding the EU433 Frequency Band

By default, the Arduino LMIC library supports only the EU868 and US915 frequency bands. However, you can modify the EU868 band to use the EU433 band in Activation by Personalization (ABP) mode.

1. In the Arduino LMIC library folder, open the file `lorabase.h` with any text editor. The `lorabase.h` file is located in the Arduino libraries folder (`libraries/.../scr/lmic/lorabase.h`).

2. Find and comment the following code snippet in the file as shown:

```
// Default frequency plan for EU 868MHz ISM band
// Bands:
// g1 : 1% 14dBm
// g2 : 0.1% 14dBm
// g3 : 10% 27dBm
//           freq          band   datarates
/*enum { EU868_F1 = 868100000,    // g1    SF7-12
        EU868_F2 = 868300000,    // g1    SF7-12 FSK
                                SF7/250
        EU868_F3 = 868500000,    // g1    SF7-12
        EU868_F4 = 868850000,    // g2    SF7-12
        EU868_F5 = 869050000,    // g2    SF7-12
        EU868_F6 = 869525000,    // g3    SF7-12
        EU868_J4 = 864100000,    // g2    SF7-12 used
                                during join
        EU868_J5 = 864300000,    // g2    SF7-12
                                ditto
        EU868_J6 = 864500000,    // g2    SF7-12
                                ditto
    };
enum { EU868_FREQ_MIN = 863000000,
        EU868_FREQ_MAX = 870000000 }; */
```

3. Add the following code snippets for EU433 support:

```
/Modify the EU868Mhz band configure for EU433Mhz temporary use.
enum { EU868_F1 = 433175000,      // g1    SF7-12
        EU868_F2 = 433375000,      // g1    SF7-12 FSK SF7/250
        EU868_F3 = 433575000,      // g1    SF7-12
        EU868_F4 = 433775000,      // g2    SF7-12
```

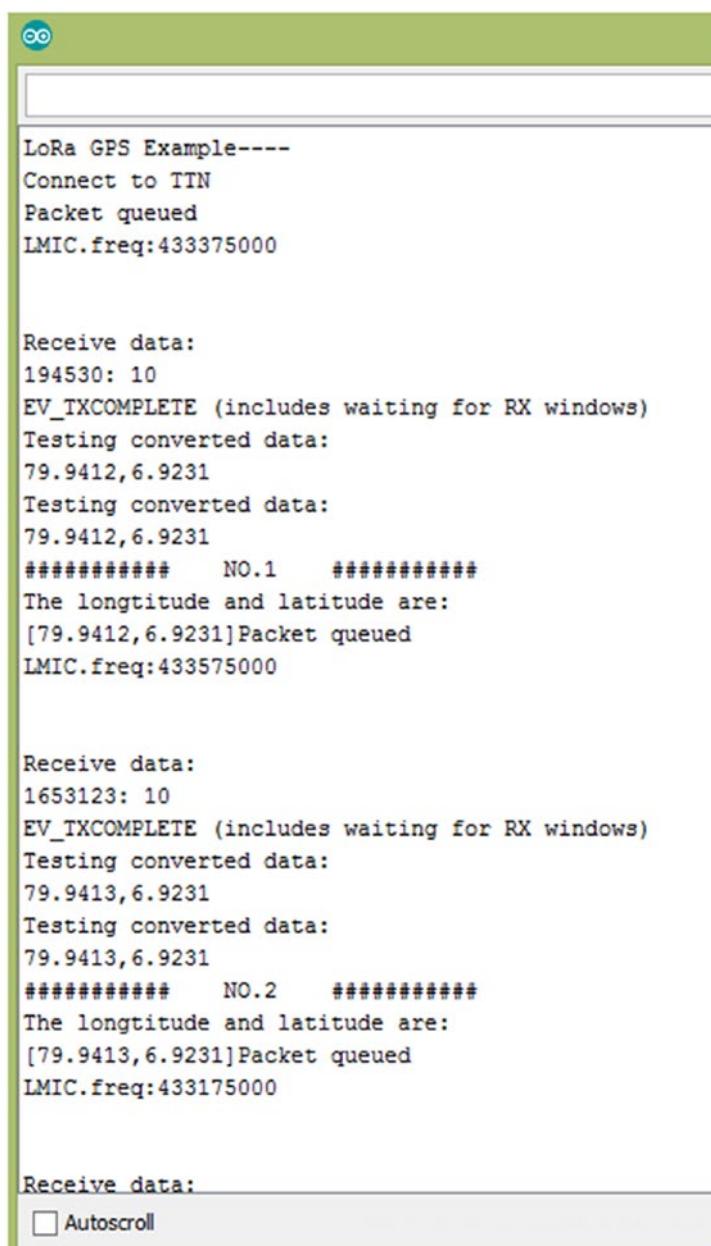
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```
EU868_F5 = 433975000,      // g2  SF7-12
EU868_F6 = 434175000,      // g3  SF7-12
EU868_J4 = 434375000,      // g2  SF7-12 used during join
EU868_J5 = 434575000,      // g2  SF7-12  ditto
EU868_J6 = 434775000,      // g2  SF7-12  ditto

};

enum { EU868_FREQ_MIN = 433050000,
EU868_FREQ_MAX = 434900000 };
```

4. Save the file and close the text editor. Usually this is a read-only file, so first you should grant the permission for this file to modify.
5. Connect the Arduino Uno with your computer using a USB cable. Choose the correct type of USB cable depending on the Arduino and Adafruit Metro boards.
6. In the Arduino IDE, select Tools > Board > Arduino/Genuino UNO. Select Tools > Port and choose the correct port associated with the Arduino board.
7. Verify and upload the Arduino sketch to your Arduino board.
8. If successful, open the serial monitor in the Arduino IDE. You can see that the output looks similar to Figure 8-51. The tracker transmits data packets on different frequencies as configured in the lorabase.h file.



The image shows a screenshot of a serial monitor window. At the top, there is a green header bar with two small circular icons on the left. Below the header, the main area displays text output from a program named "LoRa GPS Example". The output is divided into three distinct sections, each starting with "Receive data:" followed by a timestamp and some status information. The first section shows data for coordinates 79.9412, 6.9231. The second section shows data for coordinates 79.9413, 6.9231. The third section is partially visible at the bottom. At the very bottom of the window, there is a light gray footer bar containing the text "Receive data:" and a checkbox labeled "Autoscroll".

```
LoRa GPS Example----  
Connect to TTN  
Packet queued  
LMIC.freq:433375000  
  
Receive data:  
194530: 10  
EV_TXCOMPLETE (includes waiting for RX windows)  
Testing converted data:  
79.9412,6.9231  
Testing converted data:  
79.9412,6.9231  
##### NO.1 #####  
The longitude and latitude are:  
[79.9412,6.9231]Packet queued  
LMIC.freq:433575000  
  
Receive data:  
1653123: 10  
EV_TXCOMPLETE (includes waiting for RX windows)  
Testing converted data:  
79.9413,6.9231  
Testing converted data:  
79.9413,6.9231  
##### NO.2 #####  
The longitude and latitude are:  
[79.9413,6.9231]Packet queued  
LMIC.freq:433175000  
  
Receive data:  
 Autoscroll
```

Figure 8-51. Serial monitor output for the *LoRa_GPS_Tracker_TTN.ino*

CHAPTER 8 GPS TRACKING

9. Remove the GPS tracker (Arduino) from the computer and power it by using a 9 V alkaline battery. Use a 9 V to barrel jack adapter to connect the battery to the Arduino.
10. In the Things Network Console, click Applications. On the Applications page, click your application named “GPS tracker.” Then click the Data tab. You can see the application data including time, counter, port, dev id, payload, id, lat, and lon (Figure 8-52).

The screenshot shows the Things Network Console interface. At the top, there's a navigation bar with 'Applications' and a device icon followed by 'a840411ae554ffff'. Below this is a sub-navigation bar with tabs: 'Overview', 'Devices', 'Payload Formats', 'Integrations', 'Data' (which is highlighted in blue), and 'Settings'. The main area is titled 'APPLICATION DATA'. It features a table with columns: 'time', 'counter', and 'port'. There are also 'Filters' buttons for 'uplink', 'downlink', 'activation', 'ack', and 'error'. The table contains five rows of data, each representing a message. The first row is expanded to show detailed information: 'time' is 10:11:32, 'counter' is 302, 'port' is 1, 'dev id' is [eu1-a840411ae554ffff](#), 'payload' is B4 32 0C 6E 0E 01 32 2C 36 2E 39 32 33 31 00 00 00 00 00, 'id' is 968142, 'lat' is 6.9423, and 'lon' is 79.9412. The other four rows are collapsed, showing only their summary information.

Figure 8-52. Application data

11. You can view the application data in detail by clicking the particular row (Figure 8-53). Under Fields, you can see the decoded data such as id, lat, and lon in the payload.

Applications >  a840411ae554ffff > Data

uplink downlink activation ack error

Filters time counter port

Fields

```
{  
  "id": 868142,  
  "lat": 6.923,  
  "lon": 79.9412  
}
```

Metadata

```
{  
  "time": "2018-10-02T04:41:32.977646287Z",  
  "frequency": 433175000,  
  "modulation": "LORA",  
  "data_rate": "SF7BW125",  
  "coding_rate": "4/5",  
  "gateways": [  
    {  
      "gtw_id": "eui-a840411ae554ffff",  
      "timestamp": 2302314380,  
      "time": "2018-10-02T04:41:32.774209Z",  
      "channel": 7,  
      "rssi": -48,  
      "snr": 7.8,  
      "latitude": 6.92483,  
      "longitude": 79.94285  
    }  
  ]  
}
```

Figure 8-53. Application data in detail

Displaying the Real-Time Path with Traccar

Traccar (<https://www.traccar.org/>) is a personal, secure, open source, and modern GPS tracking platform that can be integrated with your LoRa GPS tracking system through the IFTTT webhooks.

1. Go to <http://demo.traccar.org/> and click the Register button (Figure 8-54).

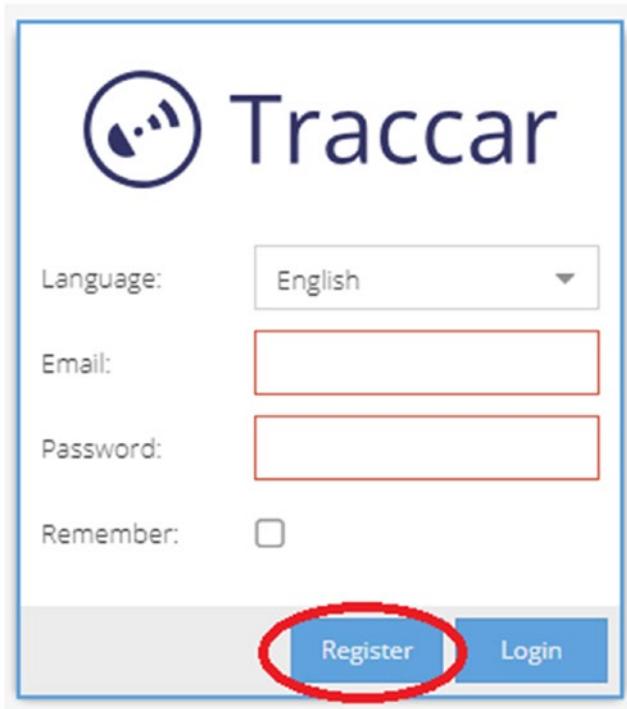


Figure 8-54. Registering with Traccar server, step 1

2. In the Register dialog box, type in a username, a valid e-mail address, and a password. Click the Save button to create the new account (Figure 8-55).

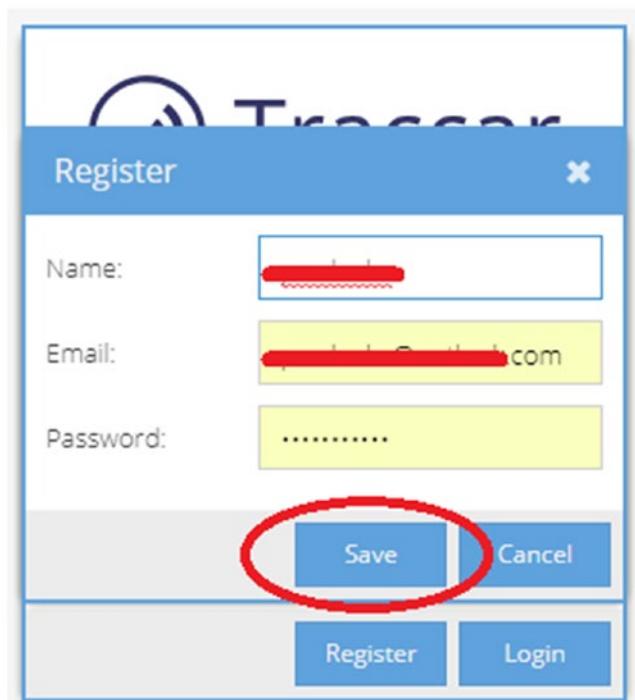


Figure 8-55. Registering with Traccar server, step 2

- Once registered, type in the e-mail and password again. Then click the Login button (Figure 8-56).

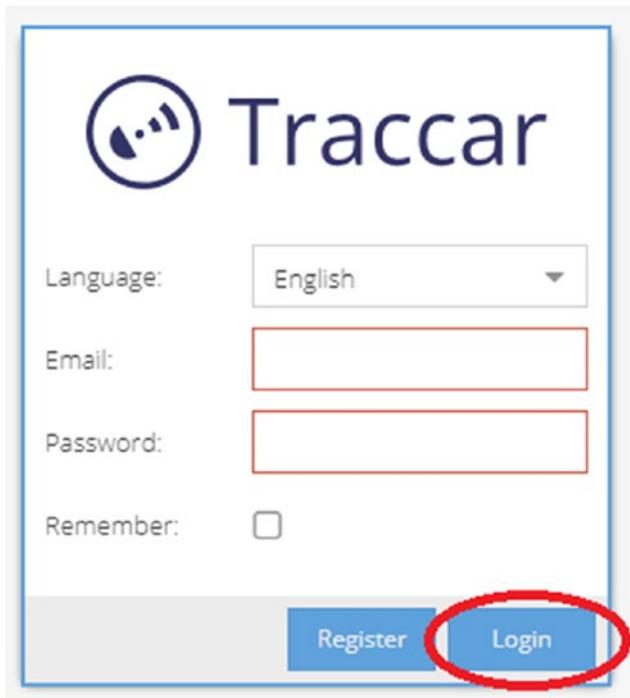


Figure 8-56. Log in to Traccar with credentials

- Once you are logged in to the demo, add a new device by clicking the Add button (Figure 8-57).

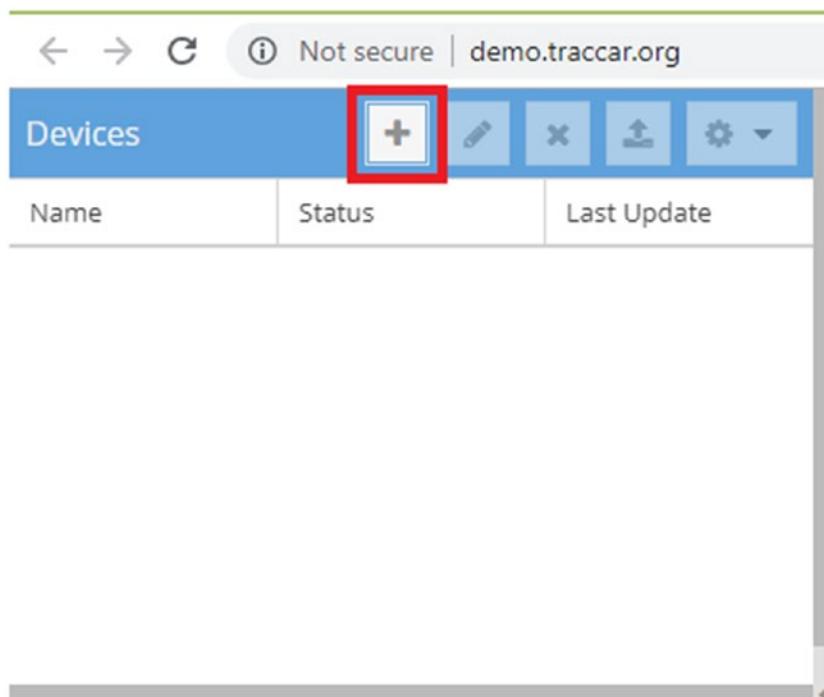


Figure 8-57. Adding a new device, step 1

5. In the Device dialog box, type in a name for your GPS tracker and a unique number for the identifier (Figure 8-58). The identifier is globally unique across all the Traccar accounts. Then click the Save button.

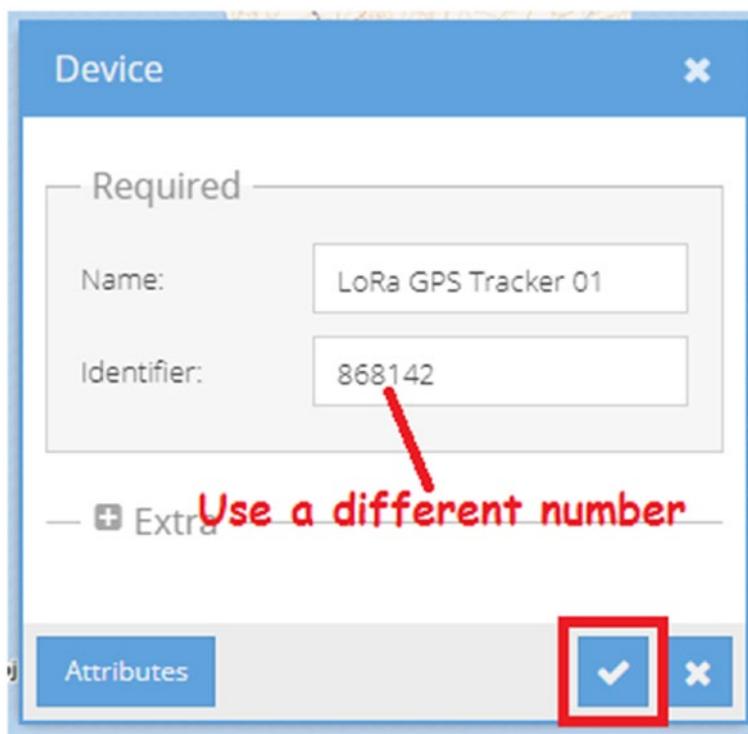


Figure 8-58. Adding a new device, step 2

- Now you can see your new GPS tracker under Devices. The status is Offline because it hasn't received any GPS data yet (Figure 8-59).

The screenshot shows a web browser window with the URL <https://demo.traccar.org>. The page title is "Devices". The header includes navigation icons (back, forward, refresh), a "Not secure" warning, and the URL. Below the header is a toolbar with five buttons: a plus sign (+), a pencil, a delete (X), an upload (up arrow), and a gear (settings). A dropdown menu is open next to the gear icon. The main content area is a table with three columns: "Name", "Status", and "Last Update". A single row is visible, showing "LoRa GPS Tracker 01" in the Name column, "Offline" in the Status column, and no information in the Last Update column. The entire row has a pink background.

Name	Status	Last Update
LoRa GPS Tracker 01	Offline	

Figure 8-59. The device is currently offline

- Traccar supports the OsmAnd protocol (<https://www.traccar.org/osmand/>), and you can use this protocol to report your GPS data to the Traccar server. The OsmAnd live tracking web address format is as follows:

<http://demo.traccar.org:5055/?id=123456&lat={0}&lon={1}×tam...>

8. In the web address, 123456 is the unique identifier of your device, lat is the latitude, and lon is the longitude. You will only need these three parameters to test the device, so you can simplify the web address as follows:

<http://demo.traccar.org:5055/?id=123456&lat={0}&lon={1}>

9. You can simulate the map by sending GPS coordinates to the Traccar server using the web address. As an example, you can simulate the location for GPS coordinates (40.726115, -74.004780) using the web address as follows:

<http://demo.traccar.org:5055/?id=868142&lat=40.726115&lon=-74.004780>

Type the previous address in your web browser's address bar and press the Enter key. Then go to Traccar, and you can see that the status of your device is Online. Simply double-click the name of your device to view it on the map (Figure 8-60).

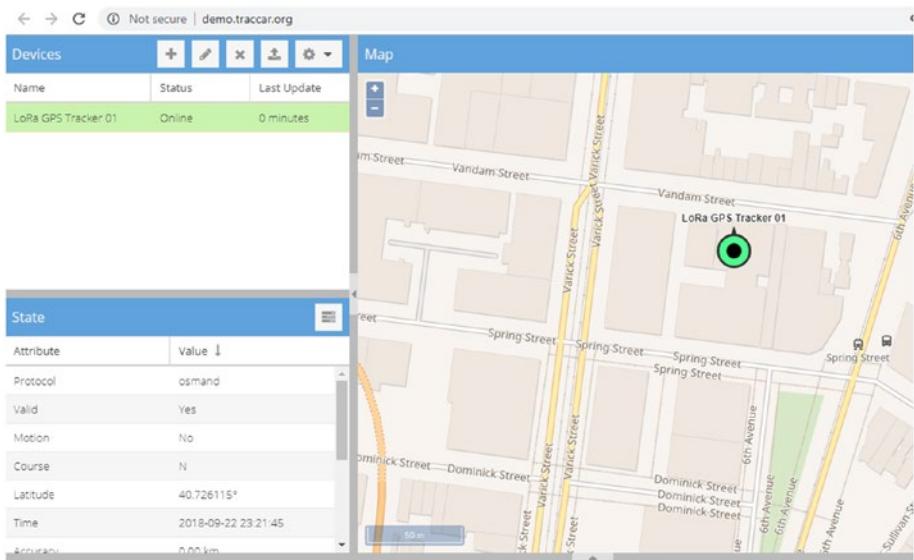


Figure 8-60. Simulated location for GPS coordinates (latitude 40.726115, longitude -74.004780)

Using the GPS Tracker

Figure 8-61 shows the real-time path tracking with the LoRa GPS tracker on the Traccar demo server.

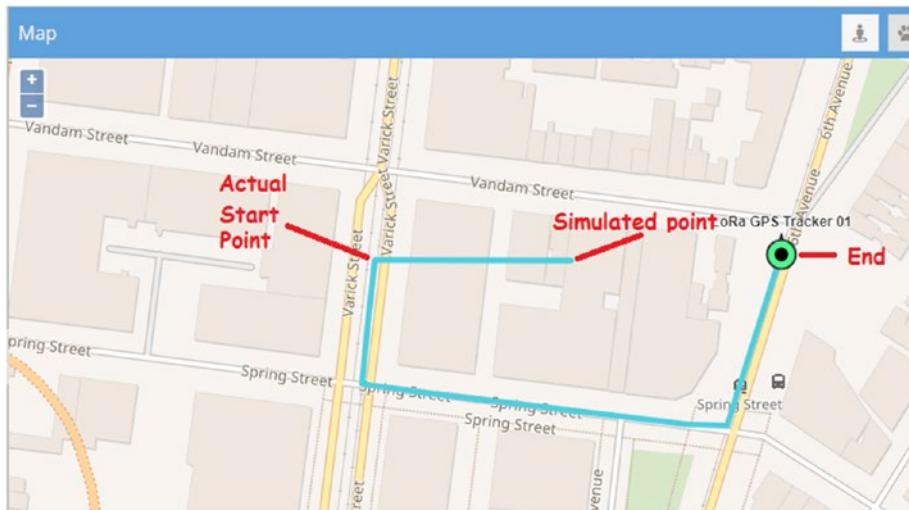


Figure 8-61. Real-time path tracking

You can test the GPS tracker by changing the TX_INTERVAL value in your Arduino sketch to different values. The default value is 20 seconds, which will send five pairs of GPS coordinates per minute to the LoRa gateway.

Figure 8-62 shows the completed hardware for the LoRa GPS tracker with an active antenna. Using an active antenna enables your device to receive GPS signals inside a building, but you will experience approximate location tracking.

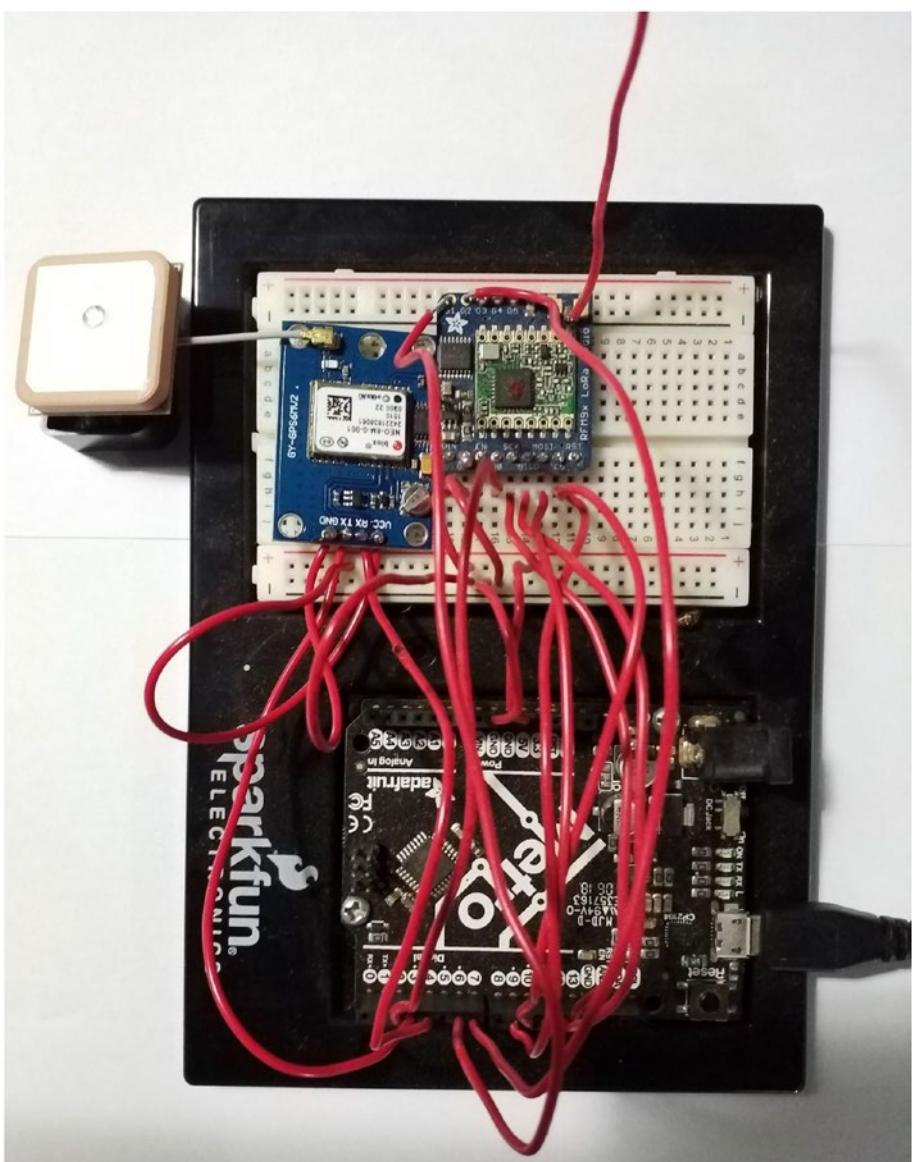


Figure 8-62. Completed hardware setup for the LoRa GPS tracker

APPENDIX A

LoRaWAN Channel Plans

To support the identification of LoRaWAN channel plans for a given country, Table A-1 provides a quick reference of suggested channel plans listed in priority order for each country (source: <https://lora-alliance.org/resource-hub/lorawantm-regional-parameters-v11rb>).

Table A-1. Channel Plan per Country

Country Name	Band/Channels	Channel Plan
Afghanistan		None
Albania	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other
Algeria	433.05–434.79 MHz	EU433
	870–876 MHz	Other
	880–885 MHz	Other
	915–921 MHz	Other
	925–926 MHz	Other

(continued)

Table A-1. (*continued*)

Country Name	Band/Channels	Channel Plan
Andorra	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Armenia	863–870 MHz	EU863-870
	433.05–434.79 MHz	EU433
Argentina	902–928 MHz	AU915-928, US902-928
	(915–928 MHz usable)	
Austria	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Australia	915–928 MHz	AU915-928, AS923
Azerbaijan	433.05–434.79 MHz	EU433
	863–868 MHz	Others
Bahrain	862–870 MHz	EU863-870
Bangladesh	433.05–434.79 MHz	EU433
	818–824 MHz	Other
	863–869 MHz	EU863-870
	925.0–927.0 MHz	Other
Belarus	433.05–434.79 MHz	EU433
	864.4–868.6 MHz	EU863-870
	869–869.2 MHz	EU863-870
Belgium	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870

(continued)

Table A-1. (*continued*)

Country Name	Band/Channels	Channel Plan
Burma (Myanmar)	433–435 MHz	EU433
	866–869 MHz	EU863-870
	919–923 MHz	Other
Bolivia	915–930 MHz	AU915-928, AS923
Bosnia and Herzegovina	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Botswana		None
Brazil	902–907.5 MHz	Other
	915–928 MHz	AU915-928
	433–435 MHz	EU433
Brunei Darussalam	866–870 MHz	EU863-870
	920–925 MHz	AS923
	433–435 MHz	EU433
Bulgaria	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Cambodia	866–869 MHz	EU863-870
	923–925 MHz	AS923
Cameroon		None
Canada	902–928 MHz	US902-928, AU915-928
Chile	902–928 MHz (915–928 MHz usable)	AU915-928, AS923, US902-928

(continued)

APPENDIX A LORAWAN CHANNEL PLANS

Table A-1. (*continued*)

Country Name	Band/Channels	Channel Plan
China	920.5–924.5 MHz	AS923
	779–787 MHz	CN779-787
	470–510 MHz	CN470-510
	433.05–434.79 MHz	EU433
	314–316 MHz	Other
	430–432 MHz	Other
	840–845 MHz	Other
Colombia	902–928 MHz	AU915-928, US902-928
Congo Rep.		None
Costa Rica	920.5–928 MHz	AS923
Croatia	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Cuba	433.05–434.79 MHz	EU433
	915–921 MHz	Other
Cyprus	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Czech Republic	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Denmark	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other

(continued)

Table A-1. (*continued*)

Country Name	Band/Channels	Channel Plan
Dominican Republic	915–928 MHz	AU915-928
Ecuador	902–928 MHz	AU915-928, US902-928, AS923
Egypt	433.05–434.79 MHz 863–876 MHz	EU433 EU863-870
Estonia	433.05–434.79 MHz 863–873 MHz 918–921 MHz	EU433 EU863-870 Other
Finland	433.05–434.79 MHz 863–873 MHz	EU433 EU863-870
France	433.05–434.79 MHz 863–870 MHz	EU433 EU863-870
Georgia		None
Germany	433.05–434.79 MHz 863–870 MHz	EU433 EU863-870
Ghana		None
Greece	433.05–434.79 MHz 868–870 MHz	EU433 EU863-870
Guatemala	902–928 MHz (915–928 MHz usable)	AU915-928, AS923, US902-928
Haiti		None

(continued)

APPENDIX A LORAWAN CHANNEL PLANS

Table A-1. (*continued*)

Country Name	Band/Channels	Channel Plan
Honduras	915–928 MHz	AU915-928
Hong Kong	433.05–434.79 MHz	EU433
	865–868 MHz	Other
	920–925 MHz	AS923
Hungary	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other
Iceland	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
India	865–867 MHz	IN765-867
Indonesia	923–925 MHz	AS923
Iraq		None
Iran	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	915–918 MHz	Other
Ireland	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other
Israel	433.05–434.79 MHz	EU433
	915–917 MHz	Other
Italy	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870

(continued)

Table A-1. (*continued*)

Country Name	Band/Channels	Channel Plan
Ivory Coast		None
Jamaica	902–928 MHz (915–928 MHz usable)	AU915-928, US902-928
Japan	920.6–928.0 MHz (steps of 200kHz) 920.8–927.8 MHz (steps of 600kHz)	AS923 AS923
Jordan	865–868 MHz	Other
Kazakhstan	433.05–434.79 MHz	EU433
Kenya		None
Korea (DPR)		None
Kuwait	433.05–434.79 MHz	EU433
Kyrgyz Republic		None
Laos	433–435 MHz 862–875 MHz 923–925 MHz	EU433 EU863-870 AS923
Latvia	433.05–434.79 MHz 863–870 MHz	EU433 EU863-870
Lebanon	433–435 MHz 862–870 MHz	EU433 EU863-870
Liechtenstein	433.05–434.79 MHz 863–873 MHz	EU433 EU863-870

(continued)

APPENDIX A LORAWAN CHANNEL PLANS

Table A-1. (*continued*)

Country Name	Band/Channels	Channel Plan
Libya		None
Lithuania	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Luxembourg	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other
Macao		None
Macedonia, FYR	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Malaysia	433–435 MHz	EU433
	919–924 MHz	AS923
Maldives		None
Malta	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Mauritius		None
Mexico	902–928 MHz	US902-928, AU915-928
Moldova	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Mongolia		None
Montenegro	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870

(continued)

Table A-1. (continued)

Country Name	Band/Channels	Channel Plan
Morocco	433.05–434.79 MHz	EU433
	867.6–869 MHz	EU863-870
Netherlands	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
New-Zealand	915–928 MHz	AS923, AU915-928
	819–824 MHz	Other
	864–870MHz	EU863-870
	433.05–434.79 MHz	EU433
Nicaragua	902–928 MHz (915–928 MHz usable)	AU915-928, US902-928
Nigeria	863–870 MHz	EU863-870
Norway	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other
Oman	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Pakistan	433.05–434.79 MHz	EU433
	865–869 MHz	EU863-870
	900–925 MHz	AS923
Panama	902–928 MHz	AU915-928, US902-928, AS923
Paraguay	433.05–434.79 MHz	EU433
	915–928 MHz	AU915-928, AS923

(continued)

APPENDIX A LORAWAN CHANNEL PLANS

Table A-1. (*continued*)

Country Name	Band/Channels	Channel Plan
Peru	915–928 MHz	AU915-928, AS923
Papua New Guinea	915–925 MHz	AU915-928
Philippines	915–918 MHz	Other
	868–869.2 MHz	EU863-870
	869.7–870 MHz	EU863-870
	433.05–434.79 MHz	EU433
Poland	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other
Portugal	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Qatar	433.05–434.79 MHz	EU433
	868–868.6 MHz	EU863-870
	868.7–869.2 MHz	EU863-870
	869.4–869.65 MHz	EU863-870
	869.7–870 MHz	EU863-870
Romania	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Russian federation	866–868 MHz (licensed)	RU864-870
	864–865 MHz	RU864-870
	868.7–869.2 MHz	RU864-870
	433.075–434.75 MHz	EU433
	916–921 MHz (licensed)	Other

(continued)

Table A-1. (*continued*)

Country Name	Band/Channels	Channel Plan
Salvador	915–928	AU915-928, AS923
Saudi Arabia	863–870 MHz	EU863-870
	433.05–434.79 MHz	EU433
Senegal		None
Serbia	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
Singapore	920–925 MHz	AS923
	433.05–434.79 MHz	EU433
	866–869 MHz	EU863-870
Slovak Republic	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other
Slovenia	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other
South Africa	433.05–434.79 MHz	EU433
	865–868.6 MHz	EU863-870
	868.7–869.2 MHz	EU863-870
	869.4–869.65 MHz	EU863-870
	869.7–870 MHz	EU863-870
	915–921 MHz	Other
	917–923.5 MHz	KR920-923

(continued)

APPENDIX A LORAWAN CHANNEL PLANS

Table A-1. (*continued*)

Country Name	Band/Channels	Channel Plan
Spain	433.05–434.79 MHz 863–870 MHz	EU433 EU863-870
Sri Lanka	433.05–434.79 MHz	EU433
Sudan		None
Sweden	433.05–434.79 MHz 868–870 MHz	EU433 EU863-870
Switzerland	433.05–434.79 MHz 863–873 MHz	EU433 EU863-870
Syrian Arab Rep.		None
Taiwan	920–925 MHz	AS923
Tajikistan		None
Tanzania		None
Thailand	433.05–434.79 MHz 920–925 MHz	EU433 AS923
Trinidad and Tobago		None
Tunisia	433.05–434.79 MHz 868–868.6 MHz 868.7–869.2 MHz 869.4–869.65 MHz 869.7–870 MHz	EU433 EU863-870 EU863-870 EU863-870 EU863-870
Turkey	433.05–434.79 MHz 863–870 MHz	EU433 EU863-870
Turkmenistan		None

(continued)

Table A-1. (continued)

Country Name	Band/Channels	Channel Plan
Uganda	433.05–434.79 MHz	EU433
	865–867.6 MHz	Other
	869.25–869.7 MHz	Other
	923–925 MHz	AS923
Ukraine	433.05–434.79 MHz	EU433
	863–865 MHz	EU863-870
	868–868.6 MHz	EU863-870
United Arab Emirates	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
	870–875.8 MHz	Other
	915–921 MHz	Other
United Kingdom	433.05–434.79 MHz	EU433
	863–873 MHz	EU863-870
	918–921 MHz	Other
United States	902–928 MHz	US902-928, AU915-928
Uruguay	902–928 MHz (915–928 MHz usable)	AU915-928, AS923, US902-928
Uzbekistan	433.05–434.79 MHz	EU433
Venezuela	922–928 MHz	AS923
Vietnam	433.05–434.79 MHz	EU433
	863–870 MHz	EU863-870
	918–923 MHz	Other
Yemen, Rep.		None
Zimbabwe		None

APPENDIX A LORAWAN CHANNEL PLANS

Table [A-2](#) provides a quick reference of common channel plans listed for each formal plan name.

Table A-2. Regional Parameter Common Names

Channel Plan	Common Name
EU863-870	EU868
US902-928	US915
CN779-787	CN779
EU433	EU433
AU915-928	AU915
CN470-510	CN470
AS923	AS923
KR920-923	KR920
IN865-867	IN865
RU864-870	RU864

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