LG01v2 -- LoRa Gateway User Manual

last modified by Kilight Cao

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1. Introduction

1.1 What is LG01v2

The LG01v2 is an **open-source single channel LoRa Gateway**. It lets you bridge LoRa wireless network to an IP network via **WiFi , Ethernet or Cellular Network** (via Optional 4G module). The LoRa wireless allows users to send data and reach extremely long ranges at low data rates.

LG01v2 is specially design for **peer to peer LoRa** protocol instead of LoRaWAN protocol. The LG01v2 use single channel LoRa module to minimize the deployment cost for a private p2p LoRa wireless network.

LG01v2 uses Open Source Linux system. User can modify the Linux part and develop customize software base on it. It has **1.2Ghz Quad-Core CPU** , **4GB eMMC storage** and **512MB RAM** for most application.

LG01v2 supports **remote management**. System Integrator can easy to remote monitor the gateway and maintain it.

1.2 Specifications

Hardware System:

- CPU: Quad-core Cortex-A7 1.2Ghz
- RAM: 512MB
- eMMC: 4GB

Interface:

- 10M/100M RJ45 Ports x 1
- WiFi 802.11 b/g/n

Operating Condition:

- Work Temperature: -20 ~ 65°C
- Storage Temperature: -20 ~ 65°C
- Power Input: 5V, 2A, DC

1.3 Features

- Open Source Debian system
- Managed by Web GUI, SSH via WAN or WiFi
- Remote Management
- Auto-provisioning for batch deployment and management
- LoRa Gateway
- Built-in ***Node-Red*** local Application server

1.4 Block Diagram

1.5 LED Indicators

LG01-V2 has totally four LEDs, They are:

 # Power LED: This RED LED will be solid if the device is properly powered

 # ETH LED: This RGB LED will blink GREEN when the ETH port is connecting

 # SYS LED: This RGB LED will show different colors in different states:

#SOLID GREEN: The device is alive with a LoRaWAN server connection.

#BLINKING GREEN: a) Device has internet connection but no LoRaWAN Connection. or b) Device is in booting stage, in this stage, it will BLINKING GREEN for several seconds and then with BLINKING GREEN together

#SOLID RED: Device doesn't have an Internet connection.

 # WIFI LED: This LED shows the WIFI interface connection status.

1.6 Button Intruction

LG01-V2 has a black toggle button, which is:

 # Long press 4-5s **:** the gateway will reload the Network and Initialize wifi configuration

LED status: ETH LED will BLINKIND BULE Until the reload is finished.

 # Long press more than 10s: the gateway will restore the factory settings.

LED status: ETH LED will SOLID BULE Until the restore is finished.

2. Quick Start

The LG01-V2 supports network access via Ethernet or Wi-Fi connection and runs without a network.

In most cases, the first thing you need to do is make the LG01-v2 accessible to the network.

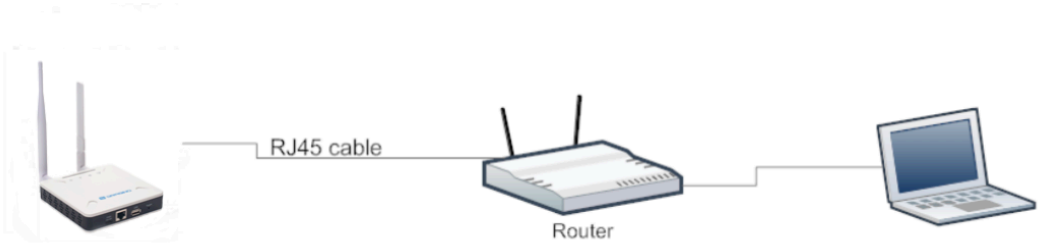
2.1 Access and Configure LG01-v2

2.1.1 Find IP address of LG01-v2

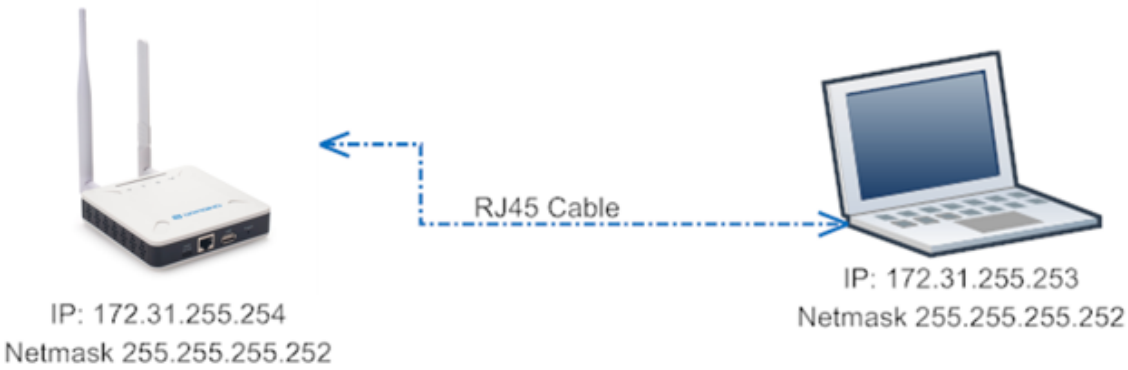
Method 1: Connect via Ethernet with DHCP IP from the router

Connect the LG01-V2 Ethernet port to your router and LG01-V2 can obtain an IP address from your router. In the router's management portal, you should be able to find what IP address the router has assigned to the LG01-V2.

You can also use this IP to connect.



Method 2: Connect via LG01v2 Fallback IP



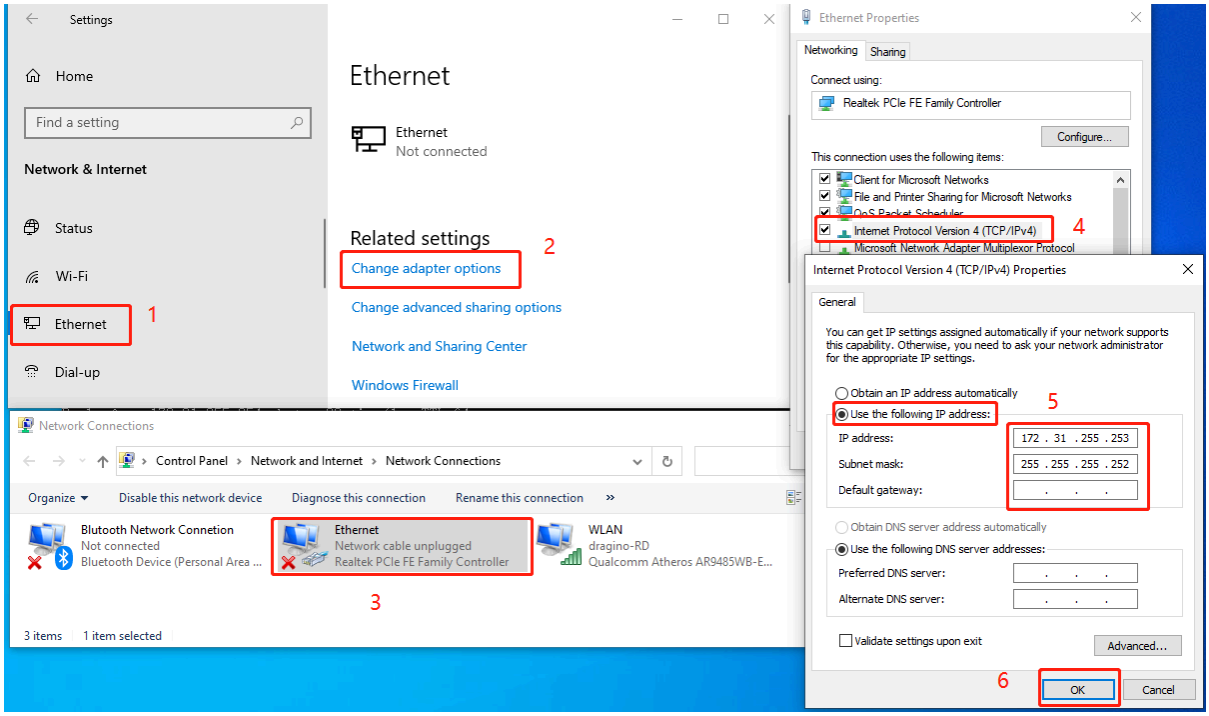
Steps to connect via fallback IP:

1. Connect the PC's Ethernet port to LG01v2's WAN port

2. Configure PC's Ethernet port has IP: 172.31.255.253 and Netmask: 255.255.255.252

Settings --> Network & Internet --> Ethernet --> Change advanced sharing options --> Double-click"Ethernet" --> Internet Protocol Version 4 (TCP/IPv4)

As in the below photo:



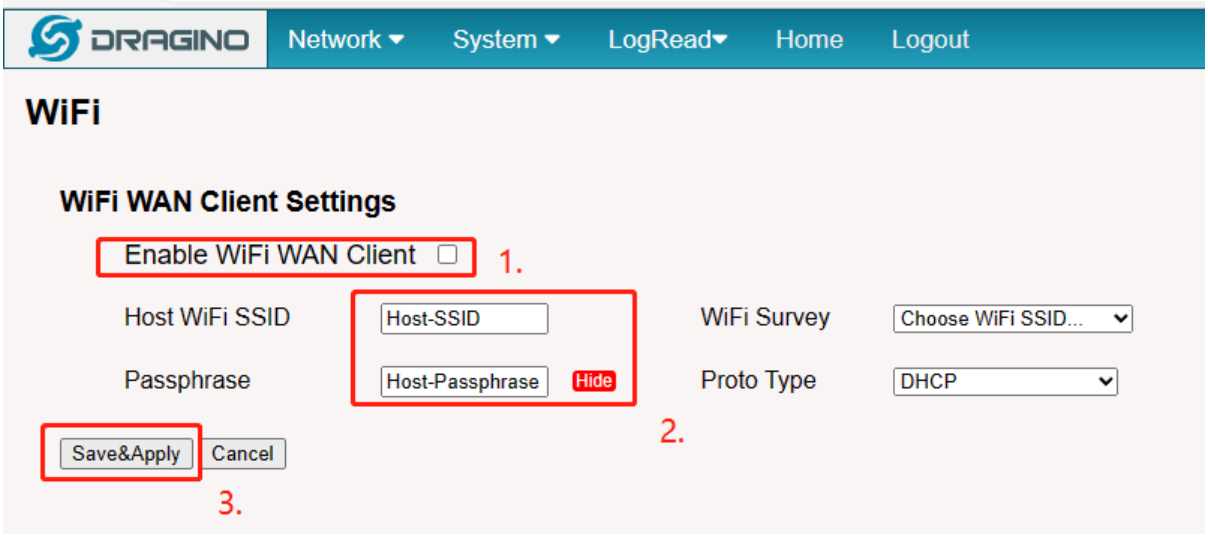
Configure computer Ethernet port steps video: **fallback ip.mp4**

If you still can't access the LG01v2 fallback ip, follow this connection to debug : **Trouble Shooting**

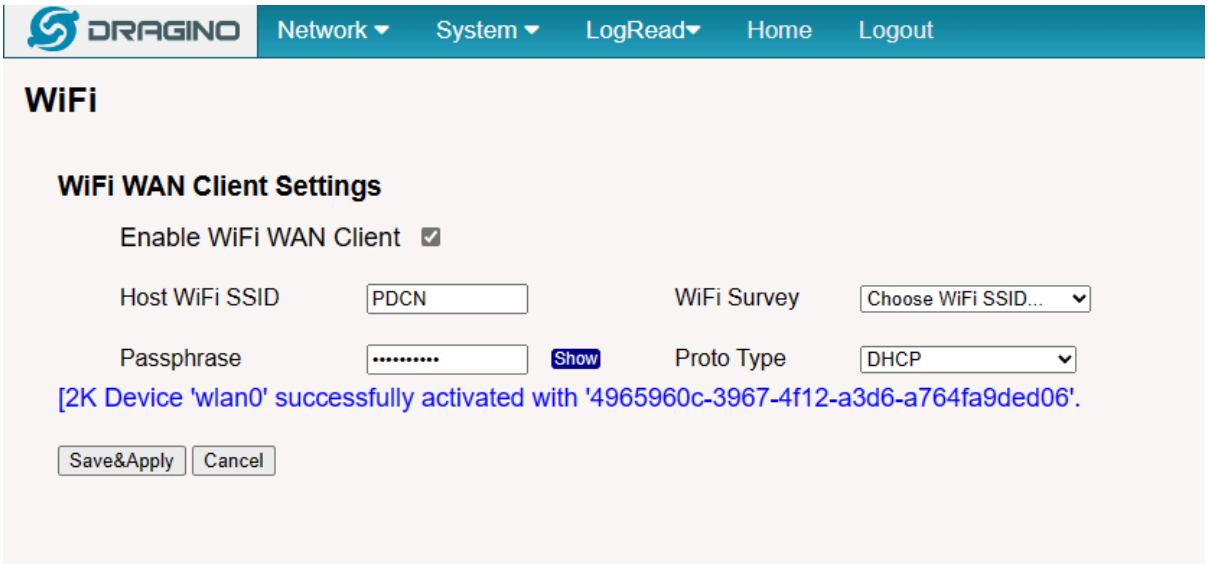
3. In the PC, use IP address 172.31.255.254 to access the LG01v2 via Web or Console.

Method 3: Connect via WiFi with DHCP IP from the router

Fill in the WiFi information by checking the box and clicking **Save&Apply**



Wi-Fi configuration successful



2.1.2 Access Configure Web UI

Web Interface

Open a browser on the PC and type the LG01v2 ip address (depends on your connect method)

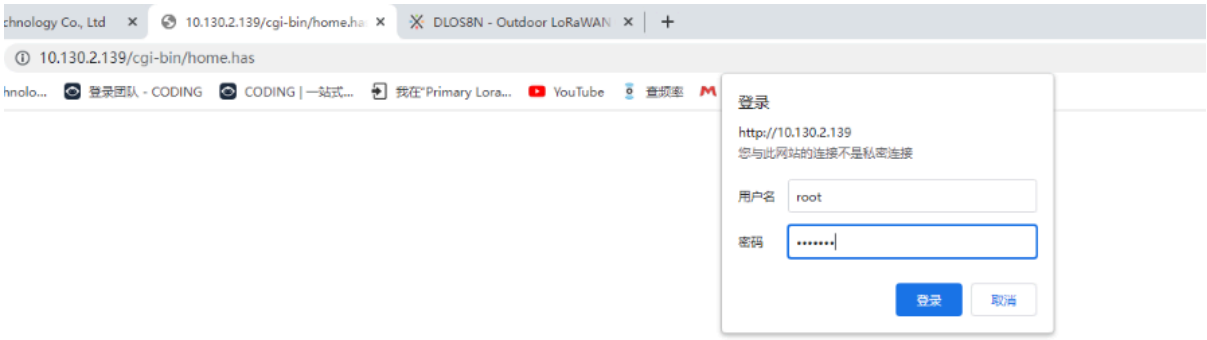
http://IP_ADDRESS or ***http://172.31.255.254***(Fallback IP)

You will see the login interface of LG01v2 as shown below.

The account details for Web Login are:

User Name: root

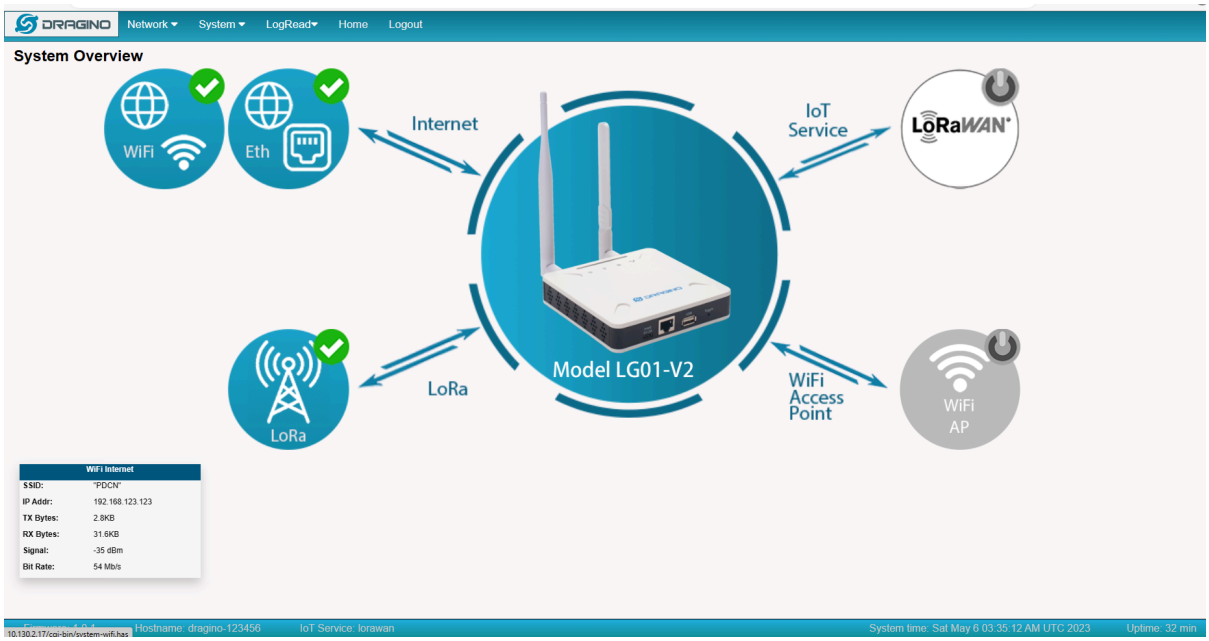
Password: dragino



3. Web Configure Pages

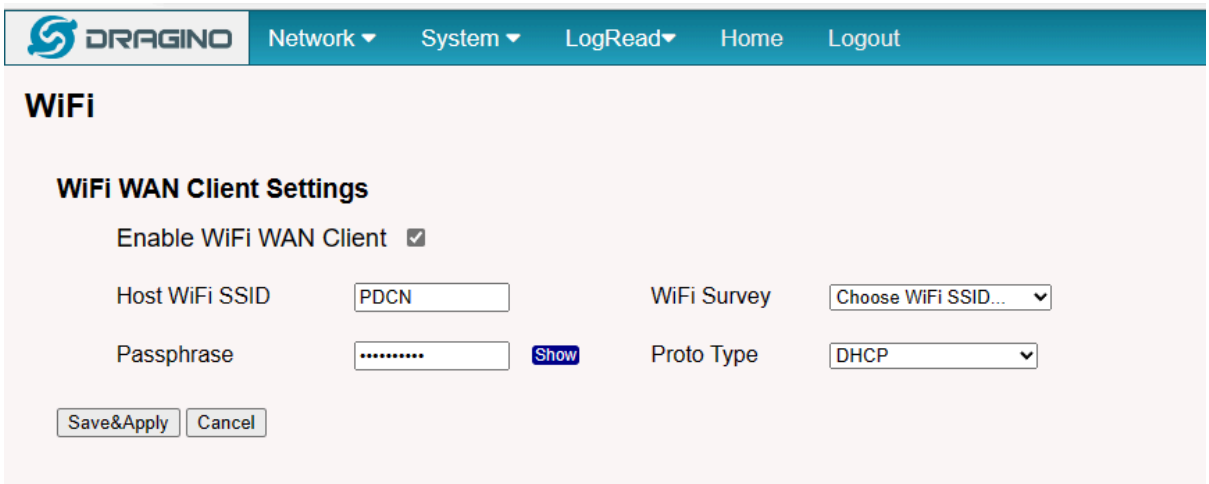
3.1 Home

Shows the system running status:

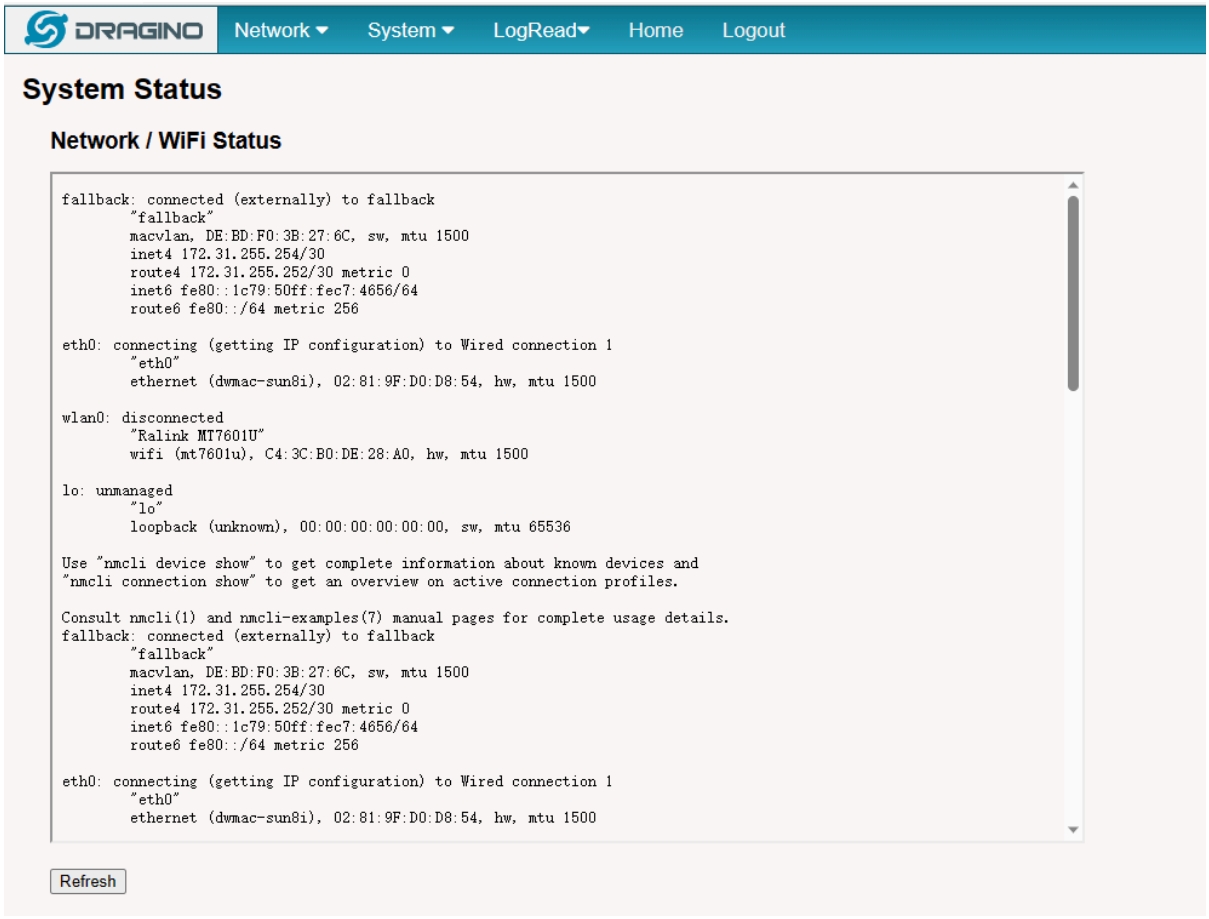


3.2 Network Settings

3.2.1 Network --> WiFi



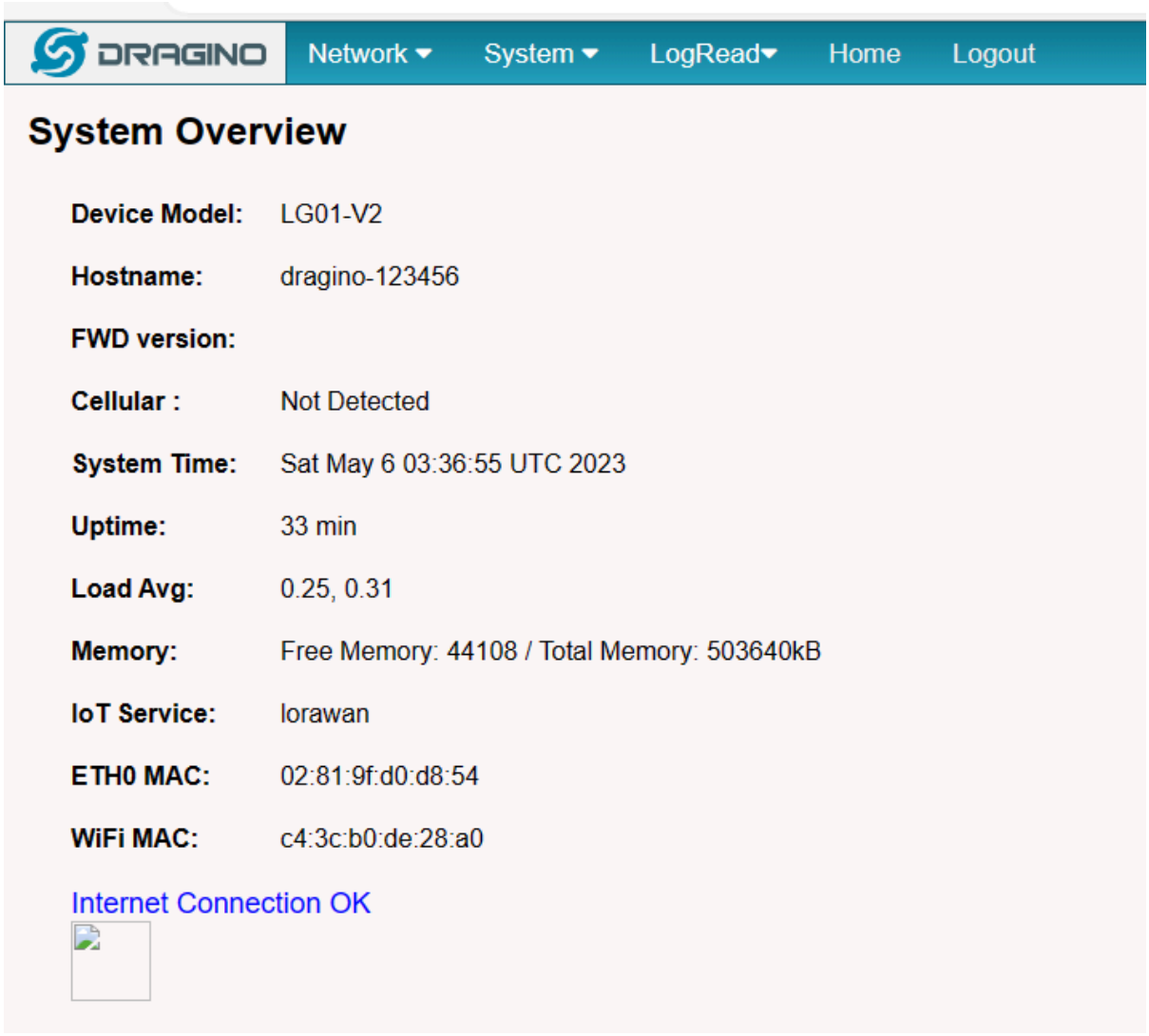
3.4.2 Network --> System Status



3.5 System

3.5.1 System --> System Overview

Shows the system info:

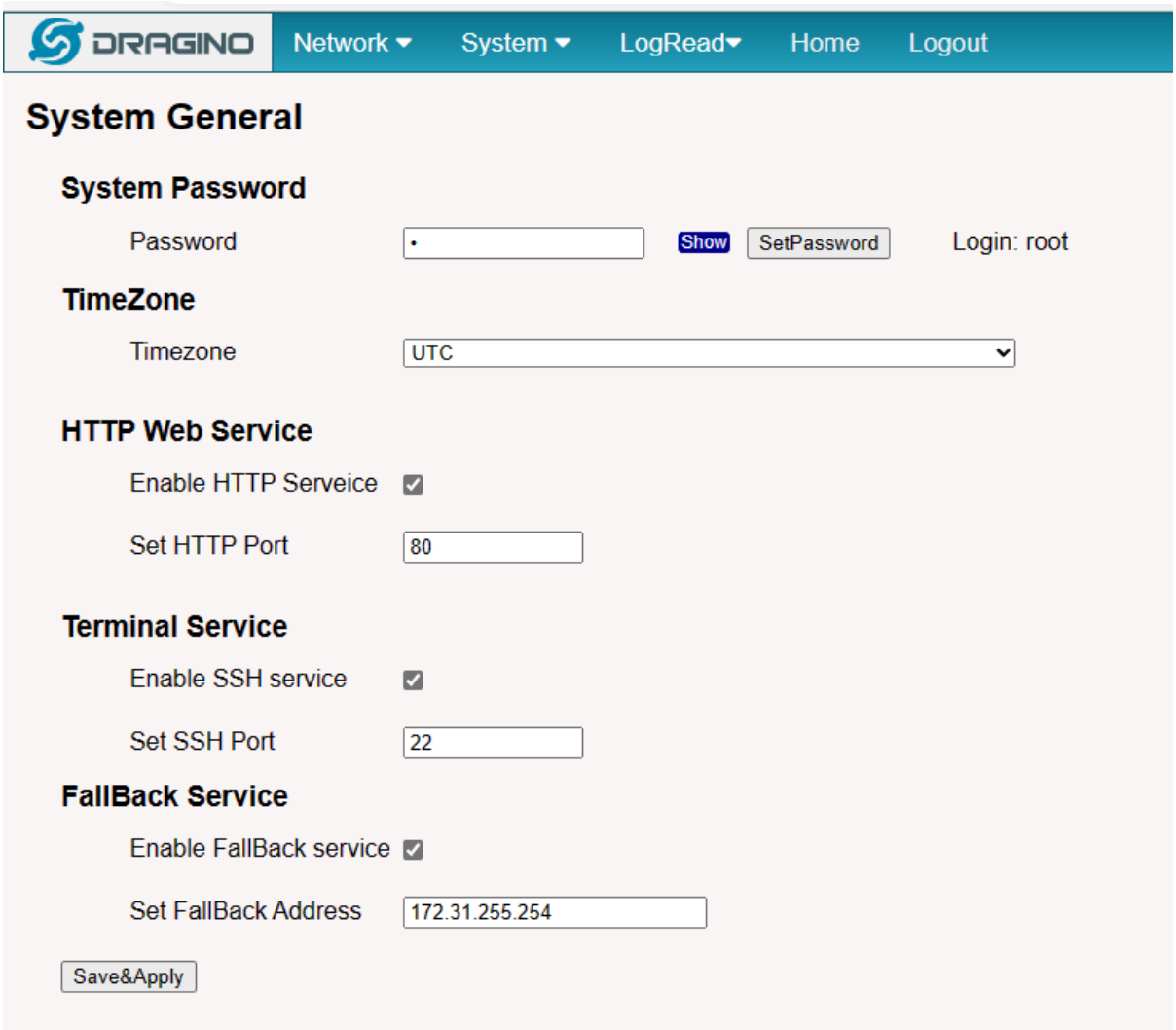


3.5.2 System --> Backup/Restore

3.5.3 System --> System General

In the **System-> System General** interface, Users can customize the configuration System Password and set Timezone.

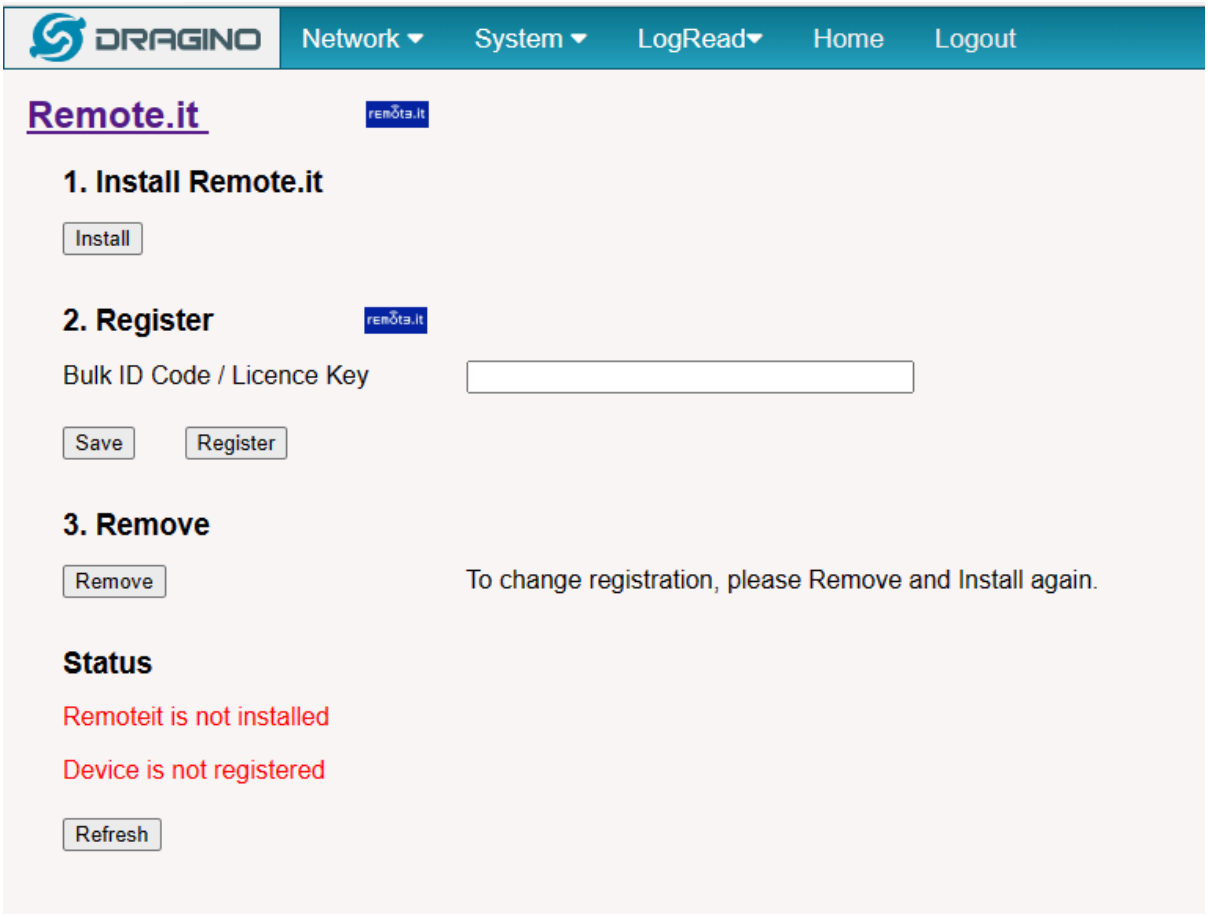
In addition, Users can customize the FallBack IP address.



3.5.4 System --> Remoteit

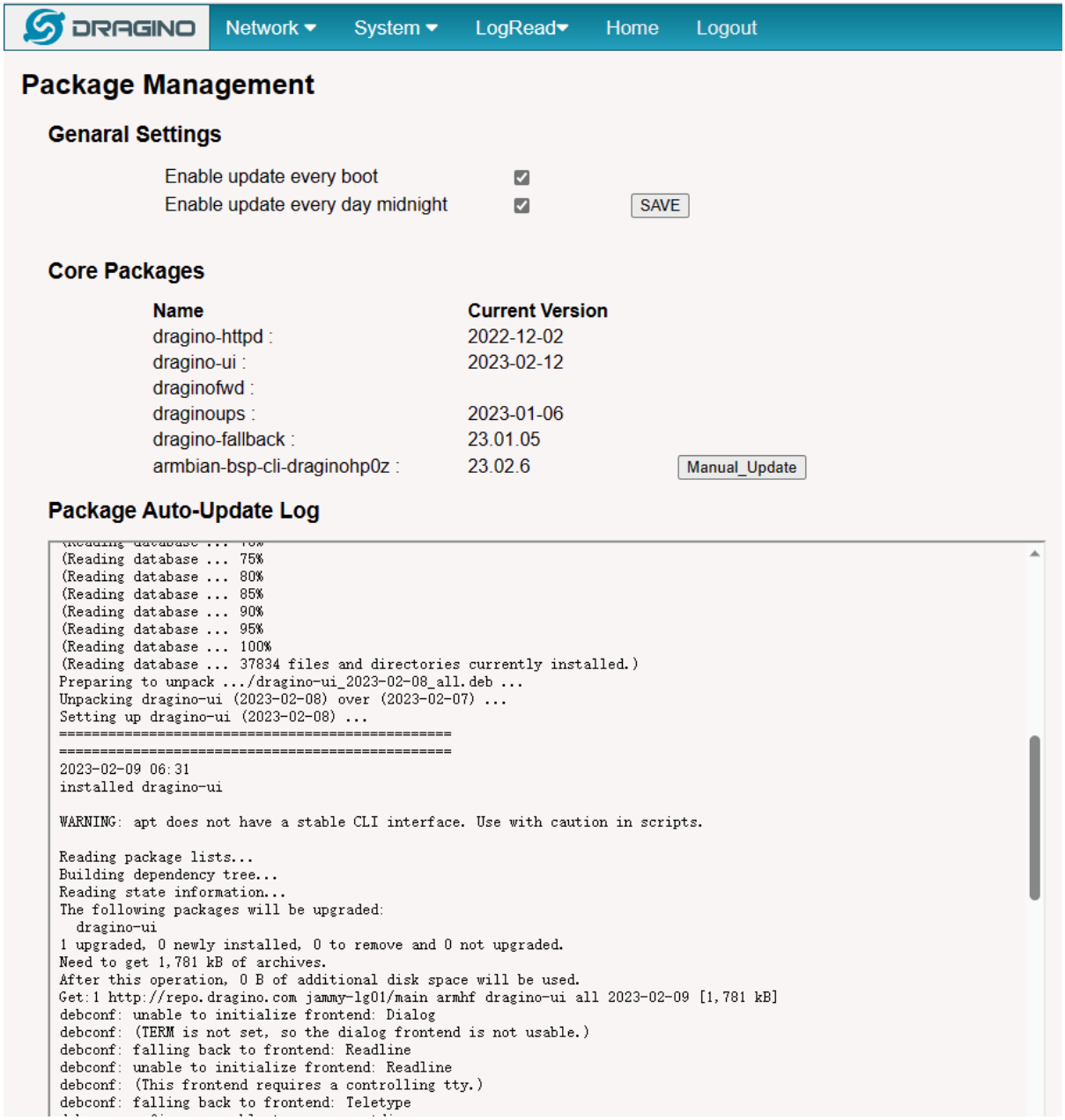
In the **System-> Remoteit** interface, users can configure the gateway to be accessed remotely via Remote.it.

the users can refer to this link to configure them: **Monitor & Remote Access Gateway**



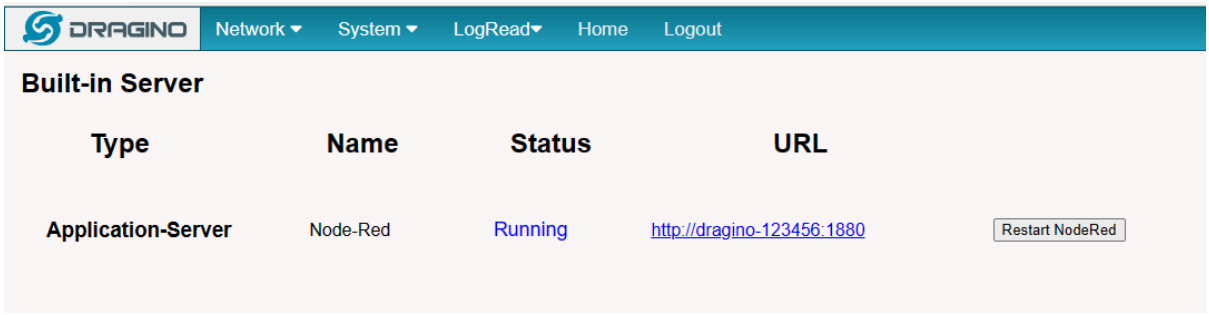
3.5.5 System --> Package Management

In the **System --> Package Management** interface, Users can check the current version of Core Packages.


DRAGINO
Network
System
LogRead
Home
Logout
Package Management
Genaral Settings
Enable update every boot
Enable update every day midnight
SAVE
Core Packages
Name
Current Version
dragino-httpd :
2022-12-02
dragino-ui :
2023-02-12
draginofwd :
draginoups :
2023-01-06
dragino-fallback :
23.01.05
armbian-bsp-cli-draginohp0z :
23.02.6
Manual_Update
Package Auto-Update Log
(Reading database ... 75%
(Reading database ... 80%
(Reading database ... 85%
(Reading database ... 90%
(Reading database ... 95%
(Reading database ... 100%
(Reading database ... 37834 files and directories currently installed.)
Preparing to unpack .../dragino-ui_2023-02-08_all.deb ...
Unpacking dragino-ui (2023-02-08) over (2023-02-07) ...
Setting up dragino-ui (2023-02-08) ...
2023-02-09 06:31
installed dragino-ui
WARNING: apt does not have a stable CLI interface. Use with caution in scripts.
Reading package lists...
Building dependency tree...
Reading state information...
The following packages will be upgraded:
dragino-ui
1 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
Need to get 1,781 kB of archives.
After this operation, 0 B of additional disk space will be used.
Get:1 http://repo.dragino.com jammy-lg01/main armhf dragino-ui all 2023-02-09 [1,781 kB]
debconf: unable to initialize frontend: Dialog
debconf: (TERM is not set, so the dialog frontend is not usable.)
debconf: falling back to frontend: Readline
debconf: unable to initialize frontend: Readline
debconf: (This frontend requires a controlling tty.)
debconf: falling back to frontend: Teletype

4. Build in Server

The default factory version of LG01-V2 is installed with the built-in Applicant server: **Node-Red**



Note:

Path: System --> Built-in Server

Troubleshooting:

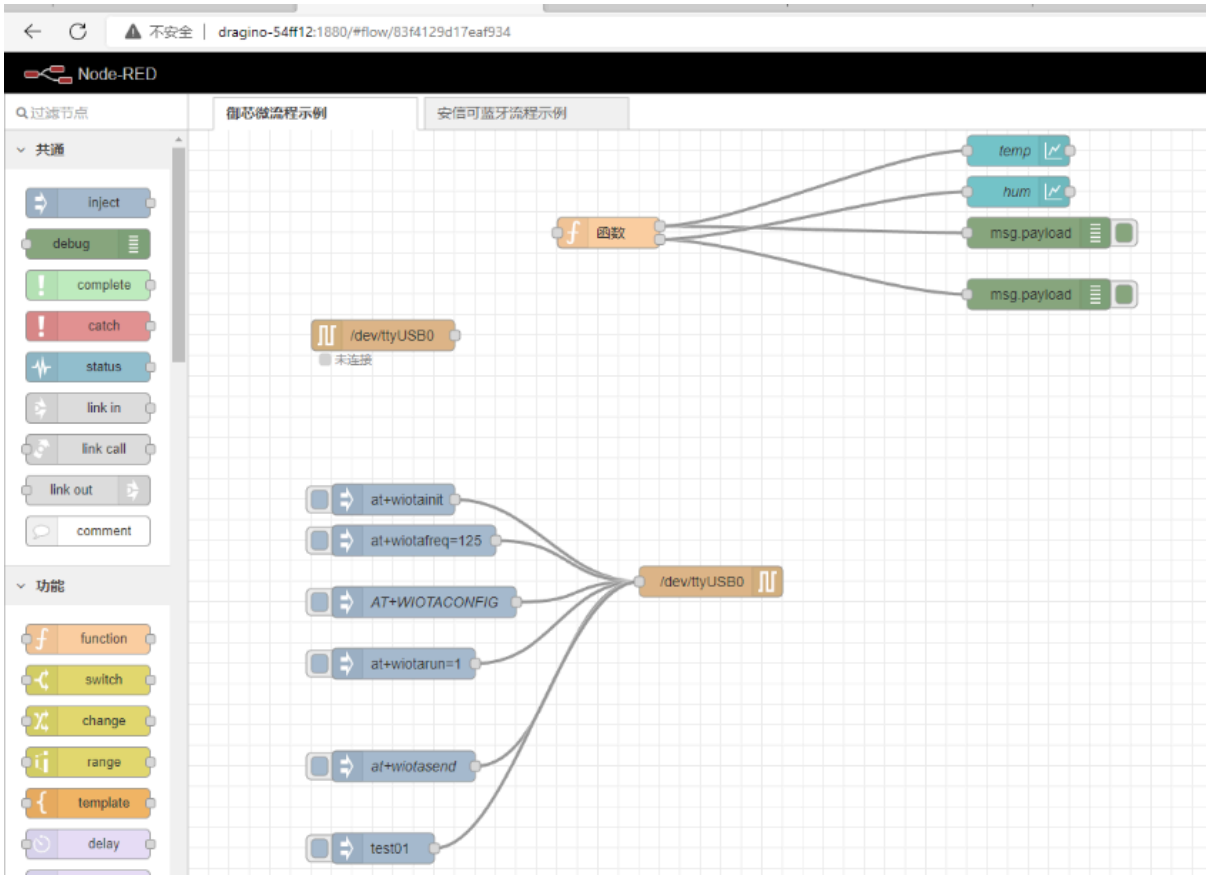
1. URL does not jump properly

For the Node-Red, you can use the local IP address and the port is 1880 to access it.

4.1 Application Server -- Node-Red

You can access the gateway's built-in AS server of **Node-Red** via the URL(***http://<hostname>:1880 or http://<local-IPV4-address>***) in your browser.

Such as ***http://dragino-54ff12:1880 or http://<Local-IPV4-Address>***



5. How to configure the Lora Gateway

5.1 Configure and Debug LoRa wireless of LG01v2

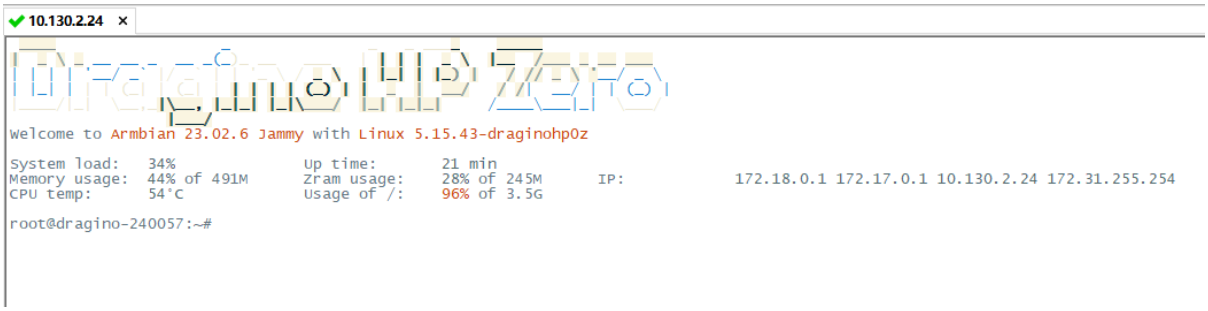
First, the user needs to access the Linux console of LG01v2 via ssh

IP address: **IP address of LG01v2**

Port: **22**

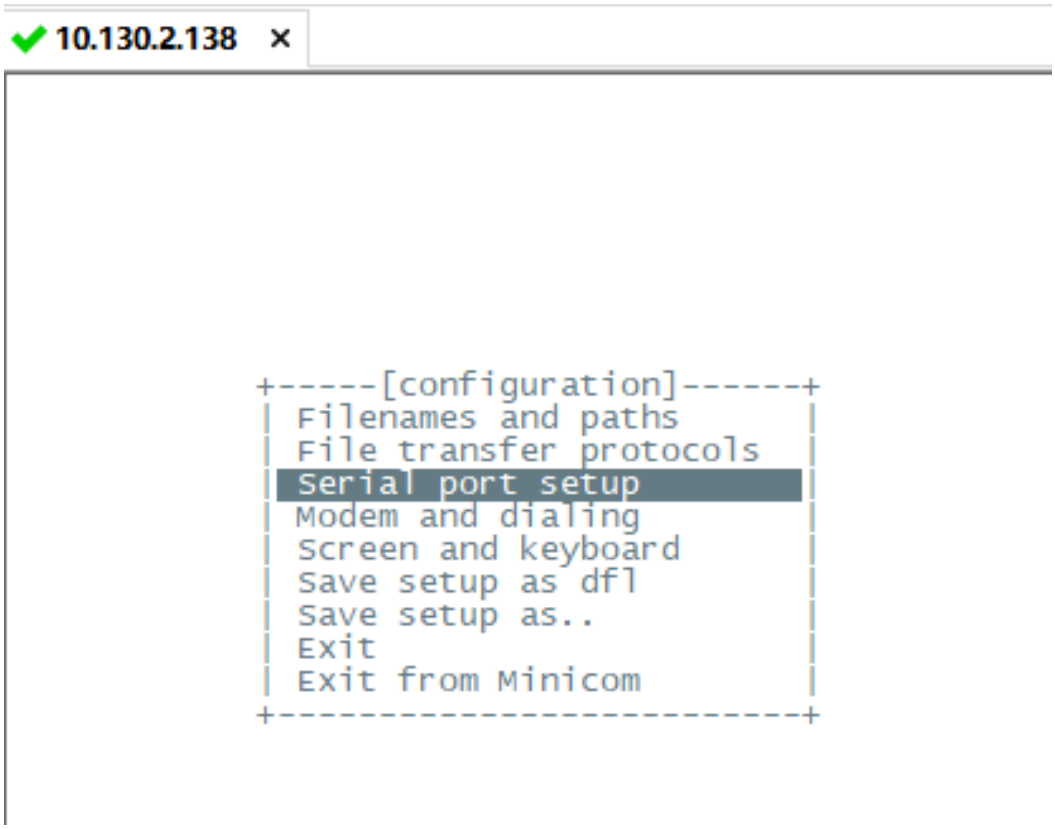
User Name: **root**

Password: **dragino(default)**



Users can access the Lora configuration page by running the following command, then select the option **"serial port setup"**:

root@dragino-2406ef:~# minicom -s

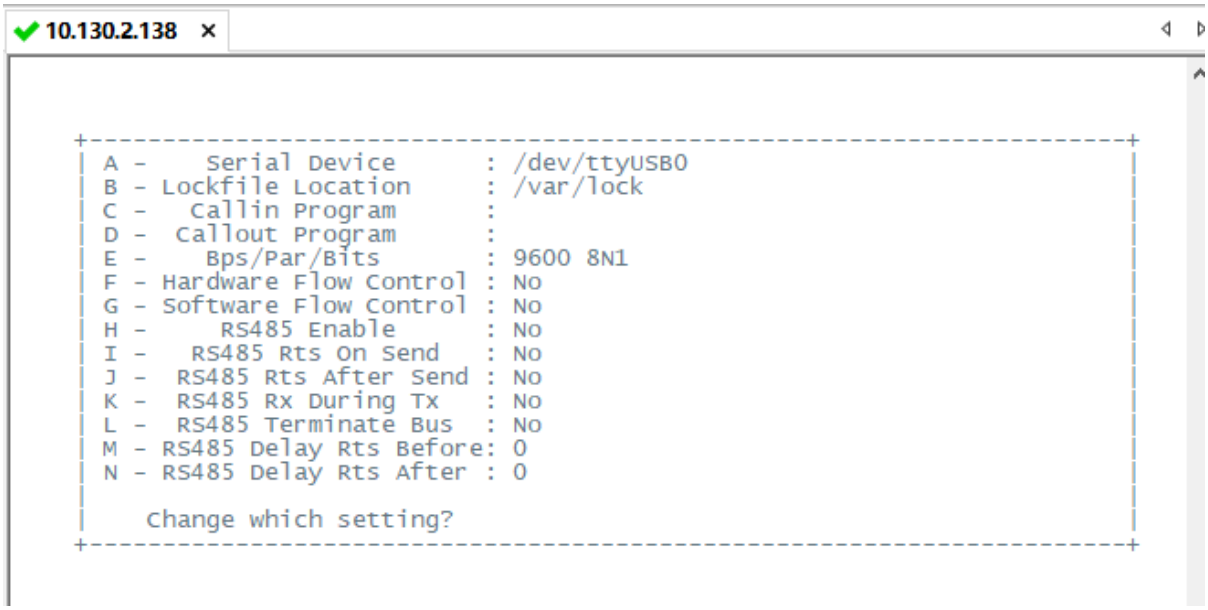


And then, change the setting:

Serial Device : /dev/ttyUSB0

Bps/Par/Bits : 9600 8N1

Note: Enter the corresponding letter to change the configuration, like A,B,C

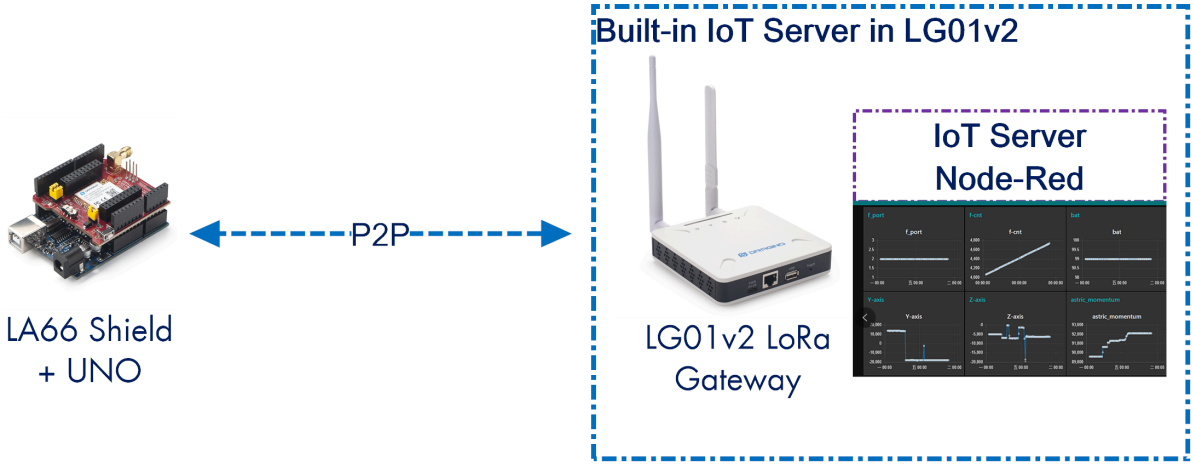


Enter **AT+CFG** in the interface to get the configuration,

AT+FRE=868.100,868.100 **---> TX and RX frequency**
AT+GROUPMOD=0,0 **---> TX and RX group**
AT+BW=0,0 **---> TX and RX Bandwidth**
AT+SF=12,12 **---> TX and RX Spreading Factor**
AT+POWER=14 **---> TX Power Range**
AT+CRC=1,1 **---> TX and RX CRC Type**
AT+HEADER=0,0 **---> TX and RX Header Type**
AT+CR=1,1 **---> TX and RX Coding Rate**
AT+IQ=0,0 **---> TX and RX InvertIQ**
AT+PREAMBLE=8,8 **---> TX and RX Preamble Length**
AT+SYNCWORD=0 **---> Syncword(0: `private, 1:` public)**
AT+RXMOD=65535,0 **---> Rx Timeout and Reply mode**
AT+RXDAFORM=1

5.2 Example: LG01v2

5.2.1 Introduce for the example:



In this example, there are two devices:

- **LA66 Shield + UNO + DHT11**: The UNO will get the temperature and humidity and broadcast the value via LoRa protocol.
- **LG01v2** : LG01v2 is set to listening the LoRa Channel which LA66 is broadcasting. When LG01v2 get the data from LA66, LG01v2 will plot the data in built-in IoT server.

5.2.2 Set Up LA66 Shield + UNO

Set up LA66 Module

LA66 Module is loaded with the firmware **LA66 Peer-to-Peer firmware** and user can use AT Command to set up LA66 with below parameters:

LA66 Shield as Sender:

LA66 Shield configuration:

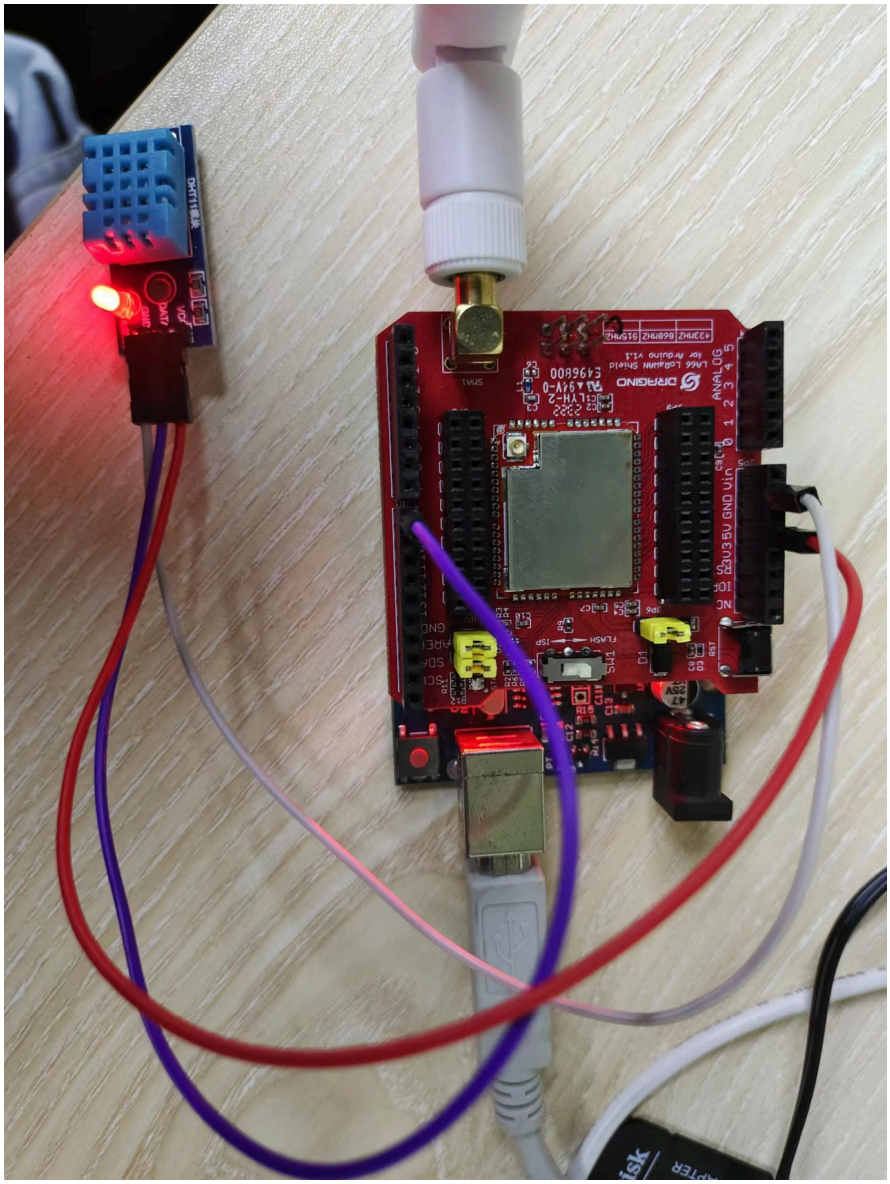
AT+FRE=868.100,868.100 ---> TX and RX frequency set: 868100000
AT+BW=0,0 ---> TX and RX Bandwidth set: 125kHz
AT+SF=12,12 ---> TX and RX Spreading Factor set: SF12
AT+POWER=14 ---> TX Power Range set: 14dBm
AT+CRC=1,1 ---> TX and RX CRC Type
AT+HEADER=0,0 ---> TX and RX Header Type
AT+CR=1,1 ---> TX and RX Coding Rate
AT+IQ=0,0 ---> TX and RX InvertIQ
AT+PREAMBLE=8,8 ---> TX and RX Preamble Length set: 8
AT+SYNCWORD=0 ---> Syncwo**(0: private, 1: public)**
AT+RXMOD=6,0 ---> Rx Timeout and Reply mode

Set up Arduino UNO

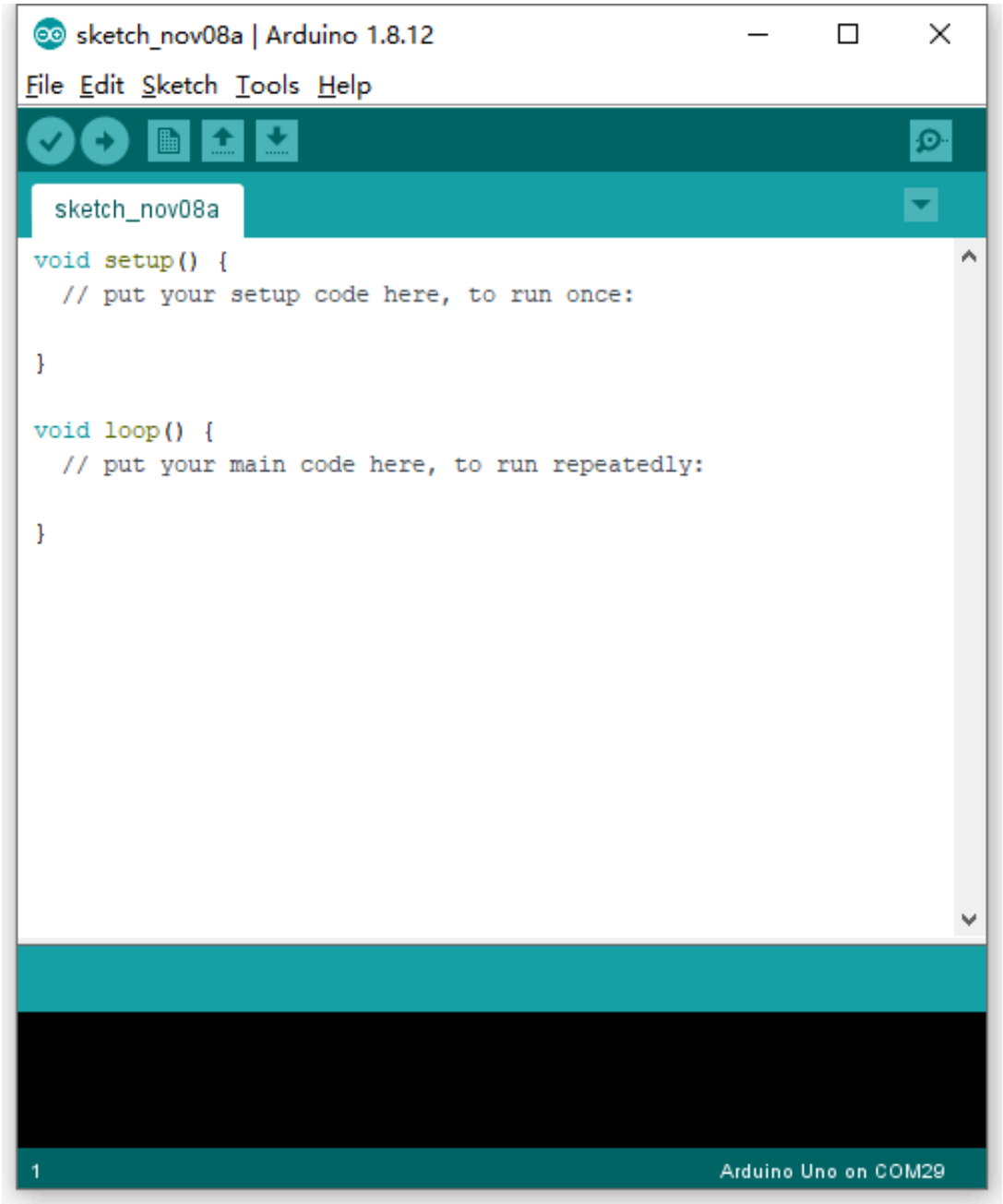
Hardware Connection

The DHT11 sensor connects to the LA66 Shield:

VCC <---> 3.3V (Red line)
DATA <---> PIN8 (Purple line)
GND <---> GND (White line)



1. Open Arduino IDE



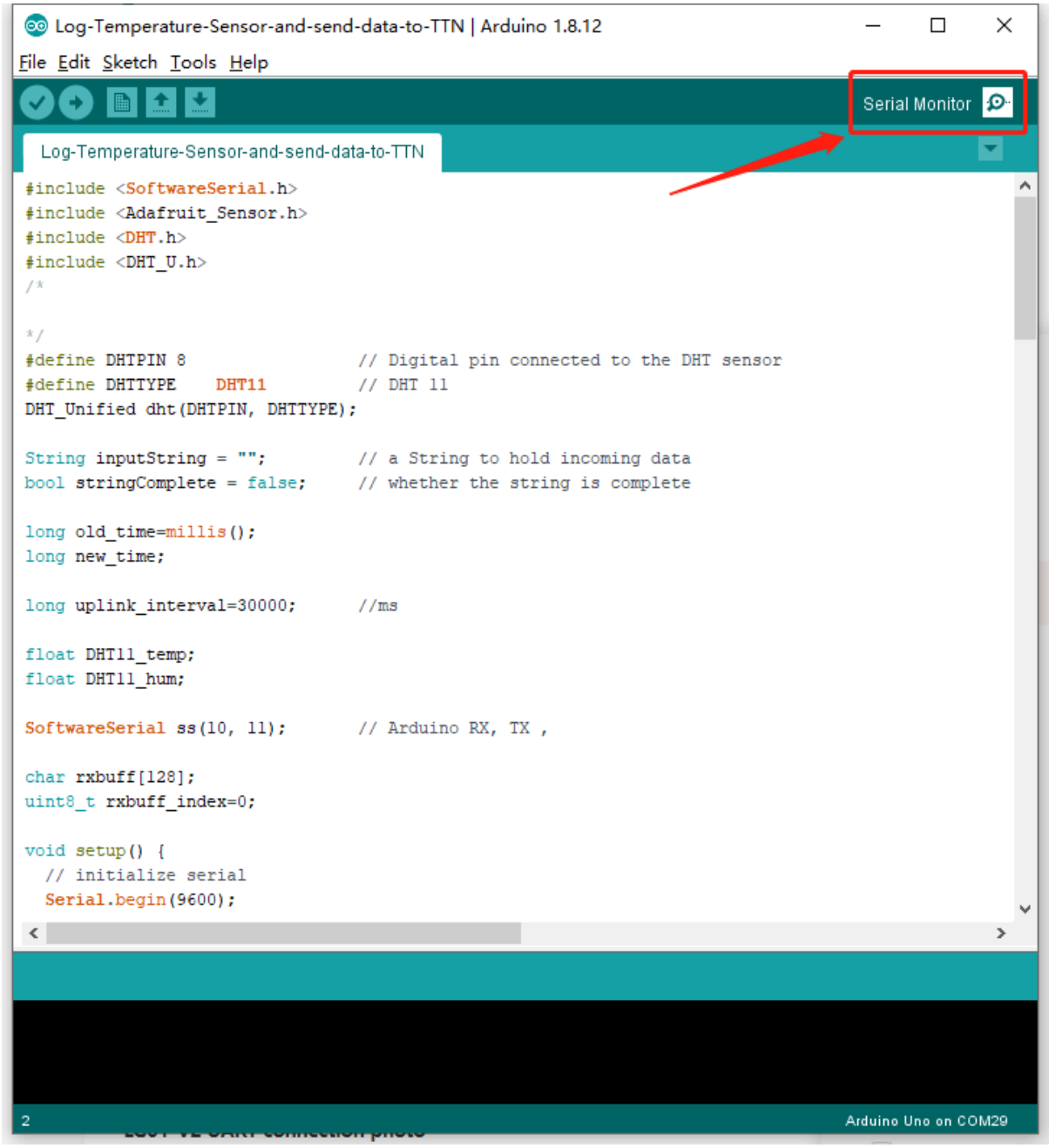
2. Open project

Users can download Arduino files from this link: [Log-Temperature-Sensor-and-send-data-to-Node-red.ino]

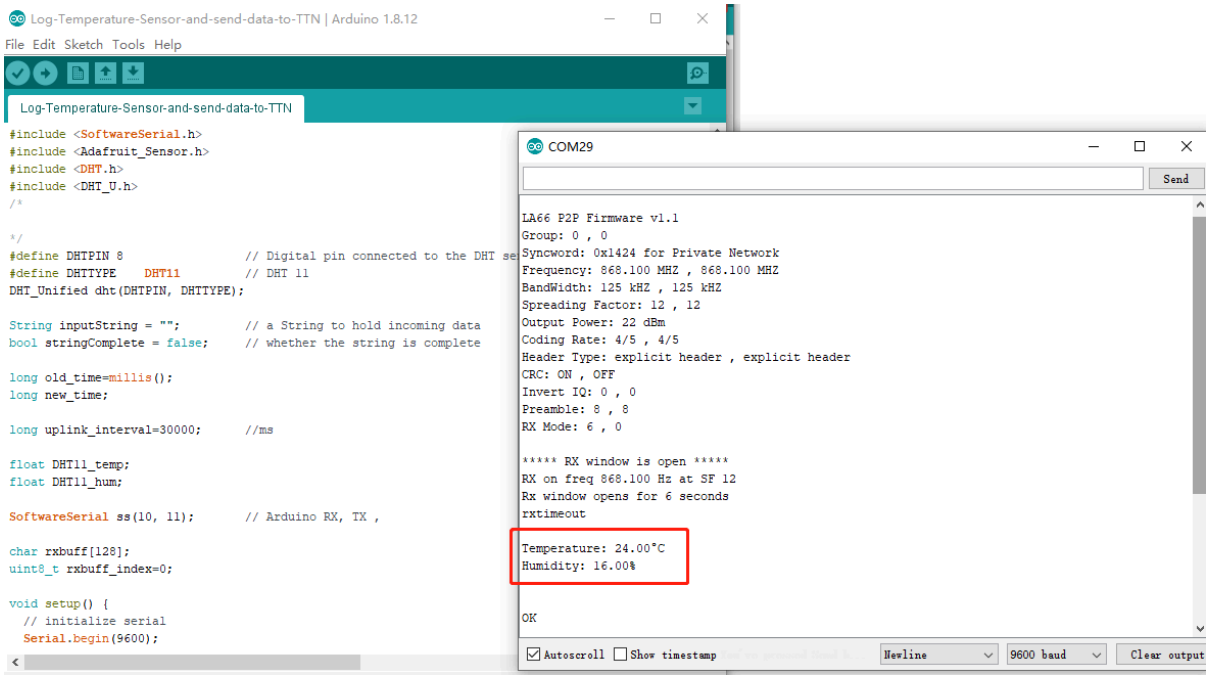
Then click Compile and Upload to LA66 Shield,

3. Open the Serial Monitor to check the LA66 Shield data

The UNO will now reads the temperature and humidity data from the sensor and broadcast it via LoRa wireless,



Sending out data as below.



5.2.3 Set Up LG01v2

Configure LG01v2 LoRa channel parameters so it can get data from LA66 Shield

LG01v2 as Receiver: (configured as AT+RXMOD=65535,2)

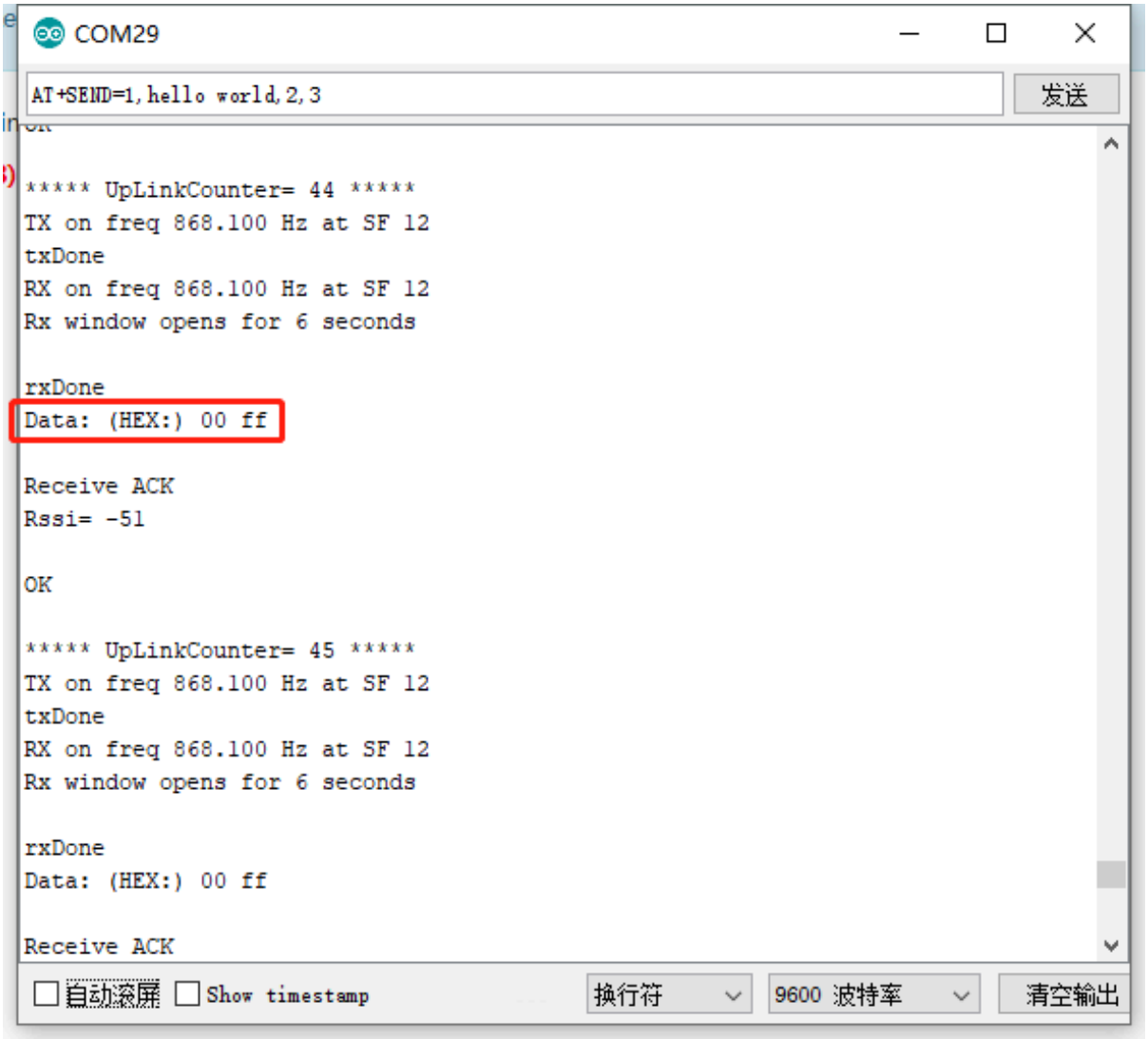
LG01-V2 configuration:

AT+FRE=868.100,868.100 ---> TX and RX frequency set: 868100000
AT+BW=0,0 ---> TX and RX Bandwidth set: 125kHz
AT+SF=12,12 ---> TX and RX Spreading Factor set: SF12
AT+POWER=14 ---> TX Power Range set: 14dBm
AT+CRC=1,1 ---> TX and RX CRC Type
AT+HEADER=0,0 ---> TX and RX Header Type
AT+CR=1,1 ---> TX and RX Coding Rate
AT+IQ=0,0 ---> TX and RX InvertIQ
AT+PREAMBLE=8,8 ---> TX and RX Preamble Length set: 8
AT+SYNCWORD=0 ---> Syncwo**(0:** `private, 1:` **public)**
AT+RXMOD=65535,2 ---> Rx Timeout and Reply mode, RX window always ope**(0:No ACK,**
1:Reply mode, 2:Send an ACK once got a message from another device. ACK Content is 0x00 FF)

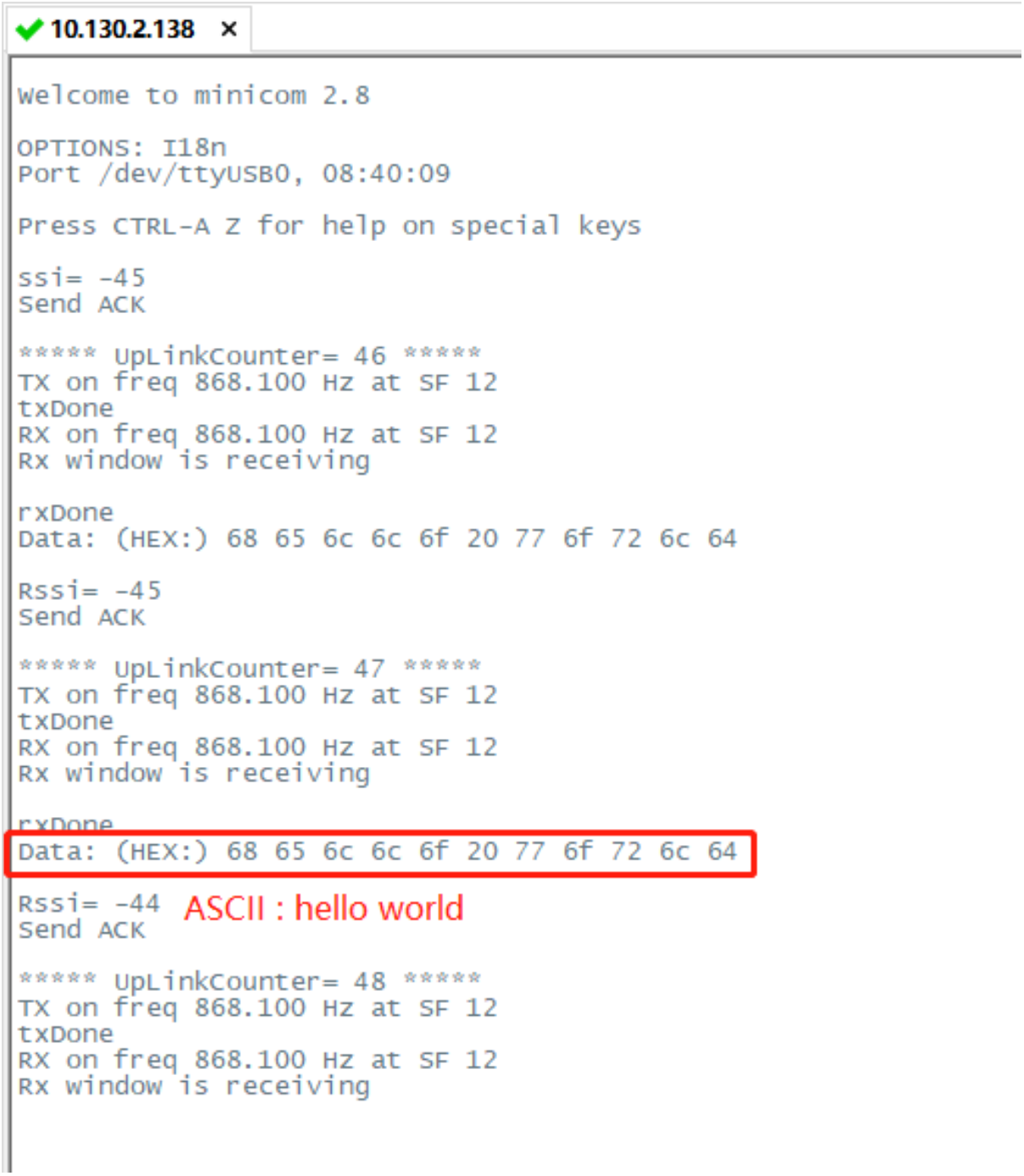
5.2.4 Test result

After the above configuration is complete, users can send test simulation data to check whether the configuration is correct, In LA66 sheild serial console send:**(AT+SEND=1,hello world,2,3).**

When LG01v2 replies with ACK when it receives a packet sent by LA66 sheild.



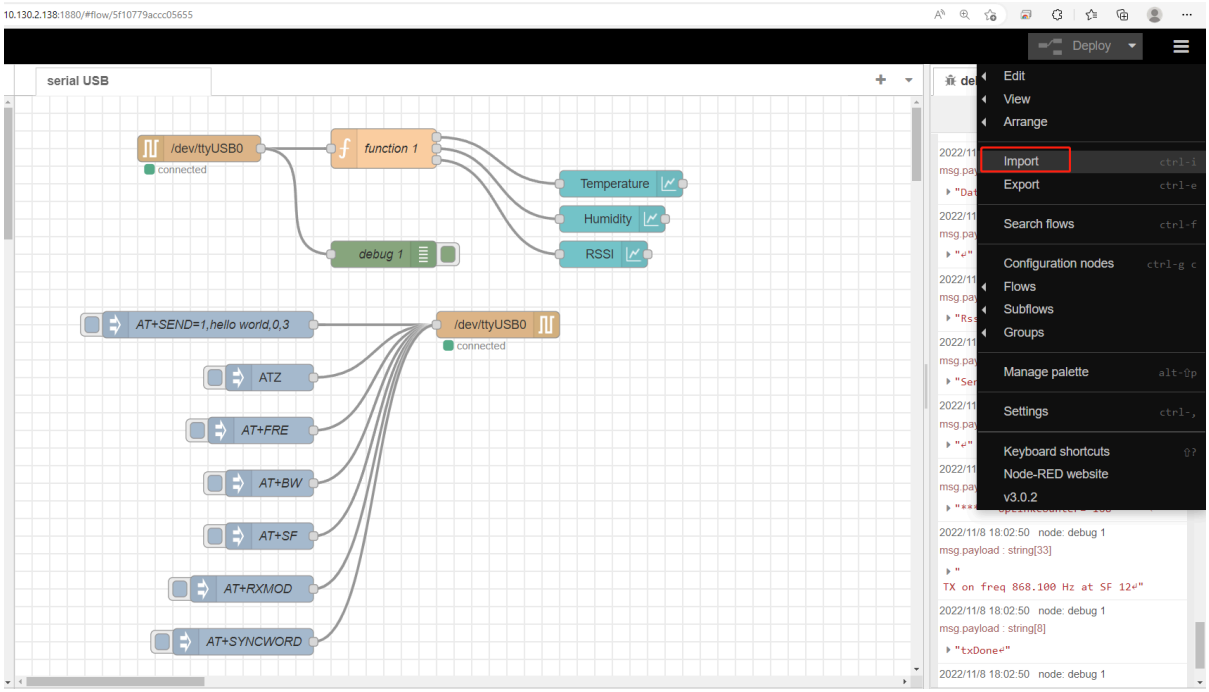
In the real-time log of LG01v2:



5.2.5 Plot data chart in LG01v2

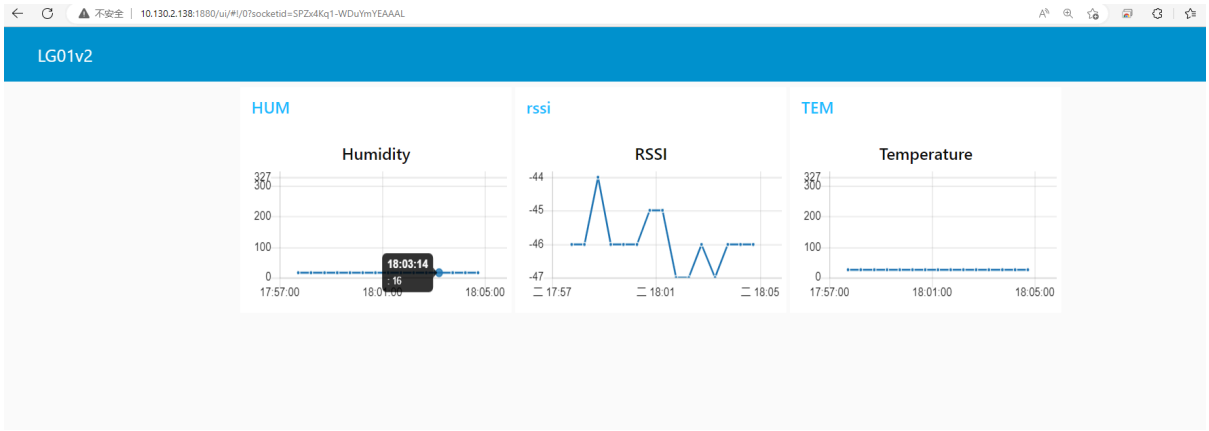
User can plot the temperature and humidity chat via LG01v2 built-in IoT server.

User can import this example in Node-Red: Log-Temperature-Sensor-and-send-data-to-Node-red.json



The temperature and humidity chart is displayed in the built-in node-red UI

Browser input: *http://<local-IPV4-address>*



6. How users can access LG01v2 using serial USB

USB TTL to LG01v2 Connection:

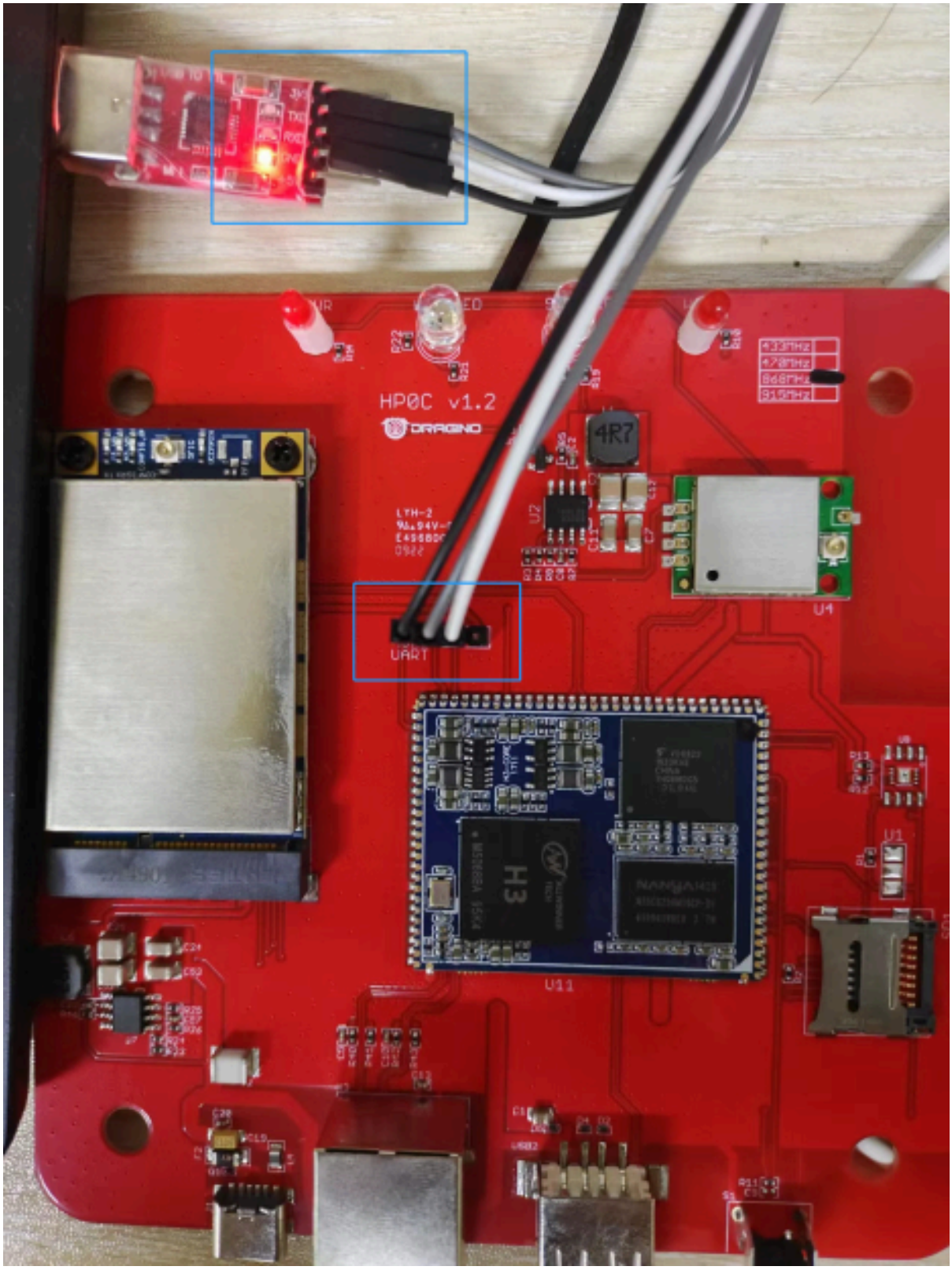
Port 1 of the UART on the LG01v2 is GND

TXD <---> UART RXD (Gray line)

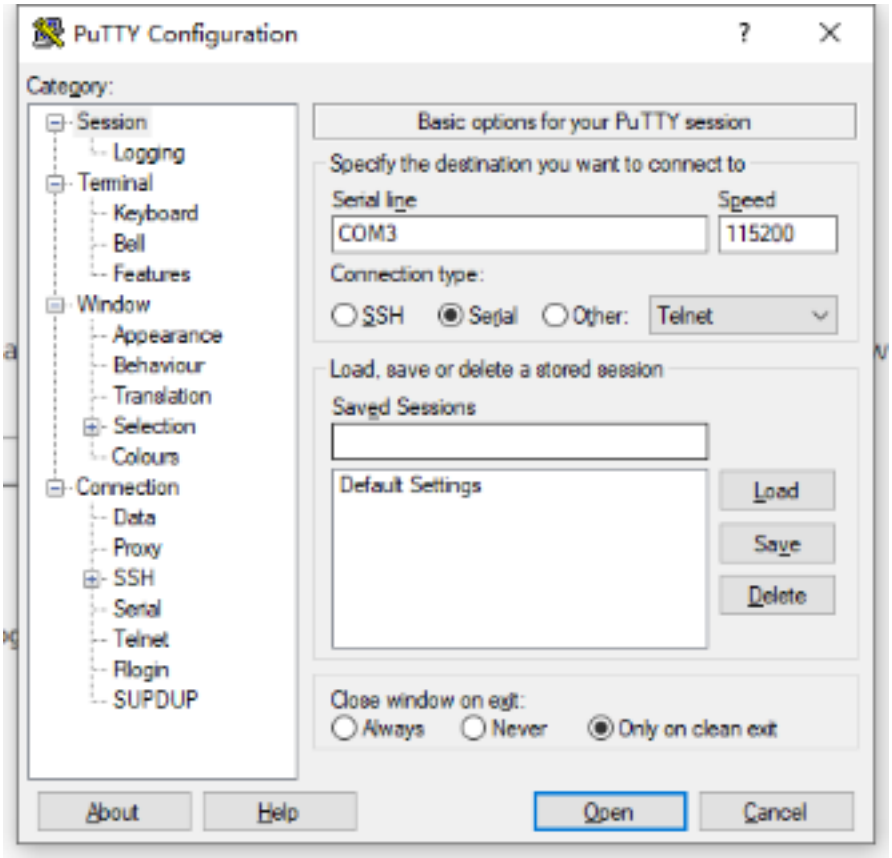
RXD <---> UART TXD (White line)

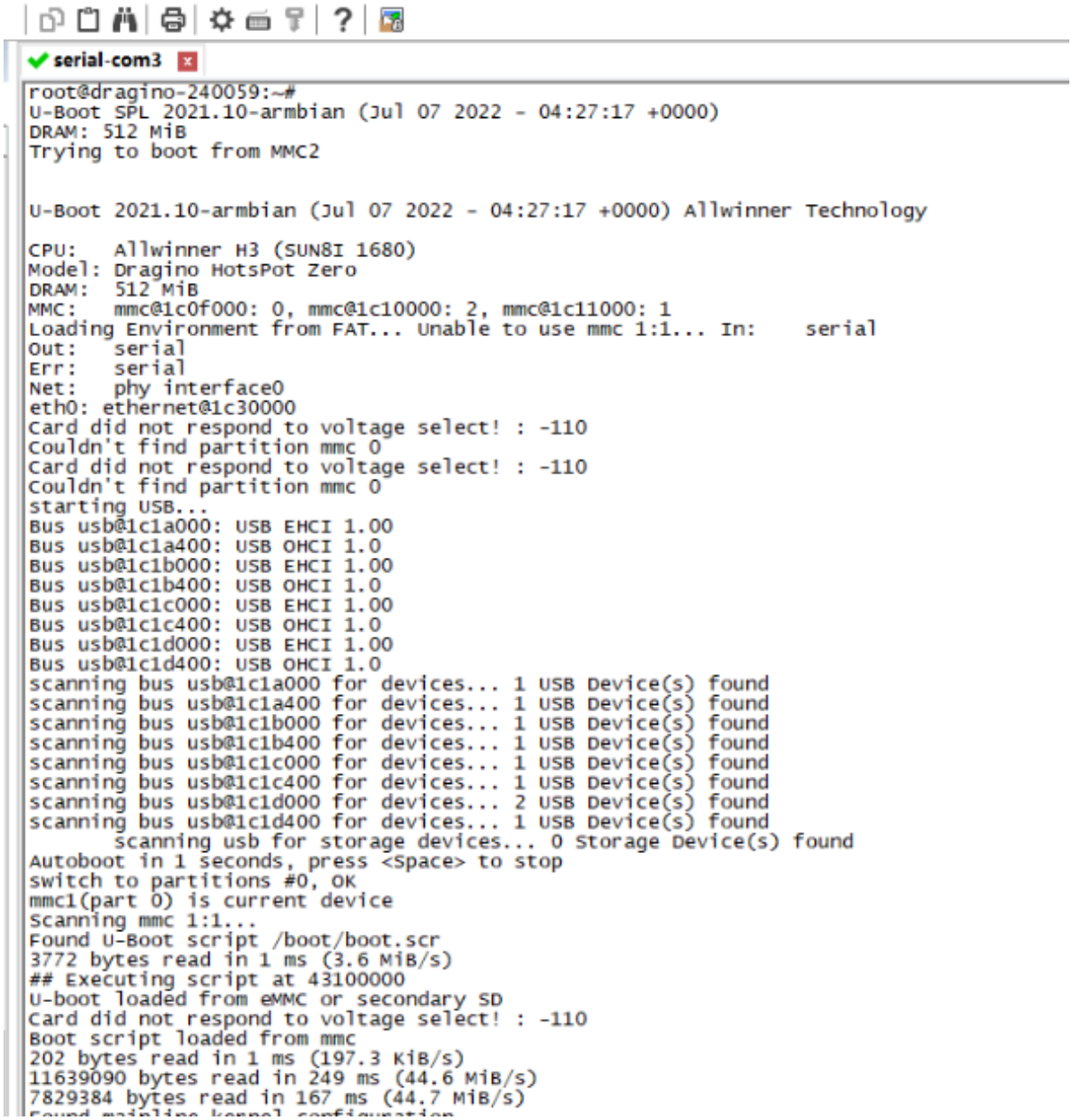
GND <---> GND (Black line)

LG01v2 UART connection photo



In the PC, you can use the serial port tool(such as putty in Windows), you need to set the serial baud rate to **115200** to access the serial console for LG01v2. LG01v2 will output system info once power on as below:


PuTTY Configuration
Category:
Session
Logging
Terminal
Keyboard
Bell
Features
Window
Appearance
Behaviour
Translation
Selection
Colours
Connection
Data
Proxy
SSH
Serial
Telnet
Rlogin
SUPDUP
Basic options for your PuTTY session
Specify the destination you want to connect to
Serial line
Speed
COM3
115200
Connection type:
SSH
Serial
Other:
Telnet
Load, save or delete a stored session
Saved Sessions
Default Settings
Load
Save
Delete
Close window on exit:
Always
Never
Only on clean exit
About
Help
Open
Cancel



7. OTA System Update

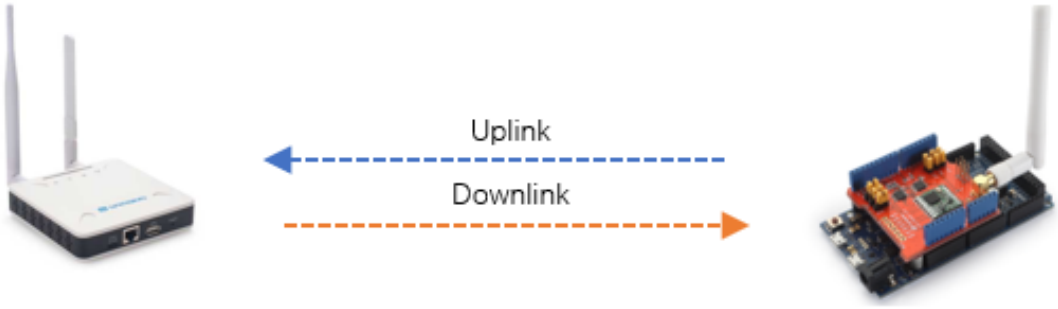
LG01v2 supports system auto update via OTA, please see **this URL** for the detail of this feature.

8. FAQ

8.1 How does LG01v2 communicate with Lora shield (LoRa.h)

This example describes how to use LG01v2, LoRa Shield to set up a LoRa network,

LG01-V2 communicate with Lora shield (LoRa.h):



Prerequisites: The configurations of LG01v2 and Lora shield must match

LG01v2 configuration:

AT+FRE=868.100,868.100 ---> TX and RX frequency set: 868100000
AT+BW=0,0 ---> TX and RX Bandwidth set: 125kHz
AT+SF=12,12 ---> TX and RX Spreading Factor set: SF12
AT+POWER=14 ---> TX Power Range
AT+CRC=1,1 ---> TX and RX CRC Type
AT+HEADER=0,0 ---> TX and RX Header Type
AT+CR=1,1 ---> TX and RX Coding Rate
AT+IQ=0,0 ---> TX and RX InvertIQ
AT+PREAMBLE=8,8 ---> TX and RX Preamble Length set: 8
AT+SYNCWORD=0 ---> Syncwo**(0:** `private, 1:` **public),** the corresponding Lora shield syncword is 0x12
AT+RXMOD=65535,0 ---> Rx Timeout and Reply mode,RX window always open
AT+RXDAFORM=1

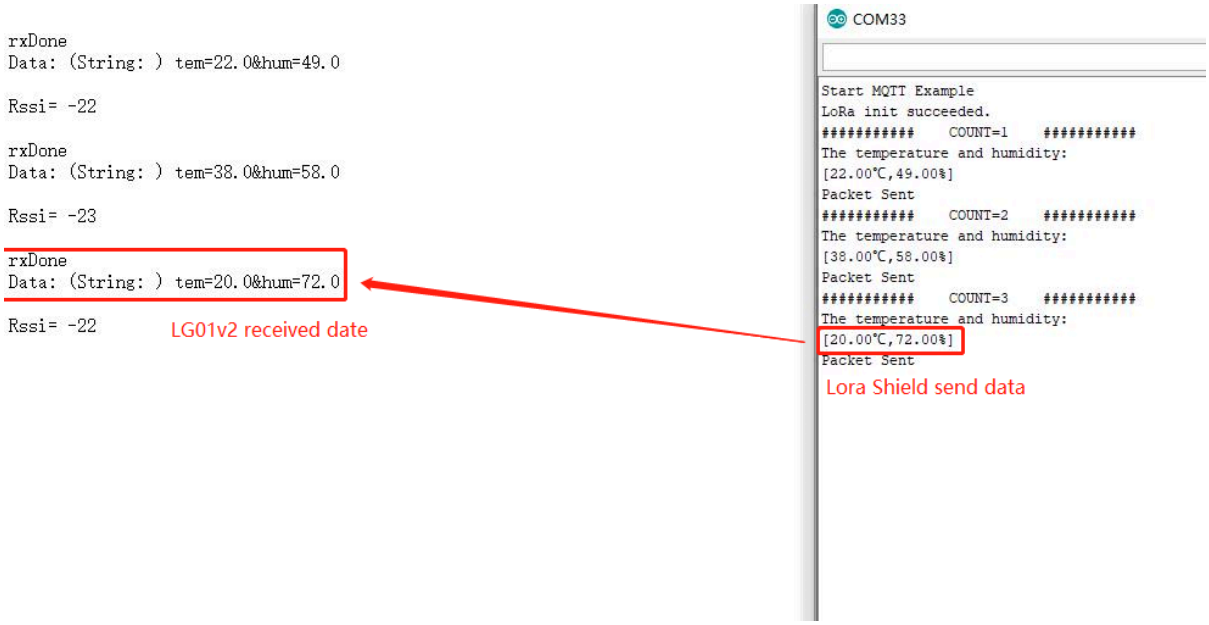
Lora shield configuration:

Lora Shield example: LoRa_Shield_Sketch_For_MQTT.ino , arduino-LoRa-master.zip

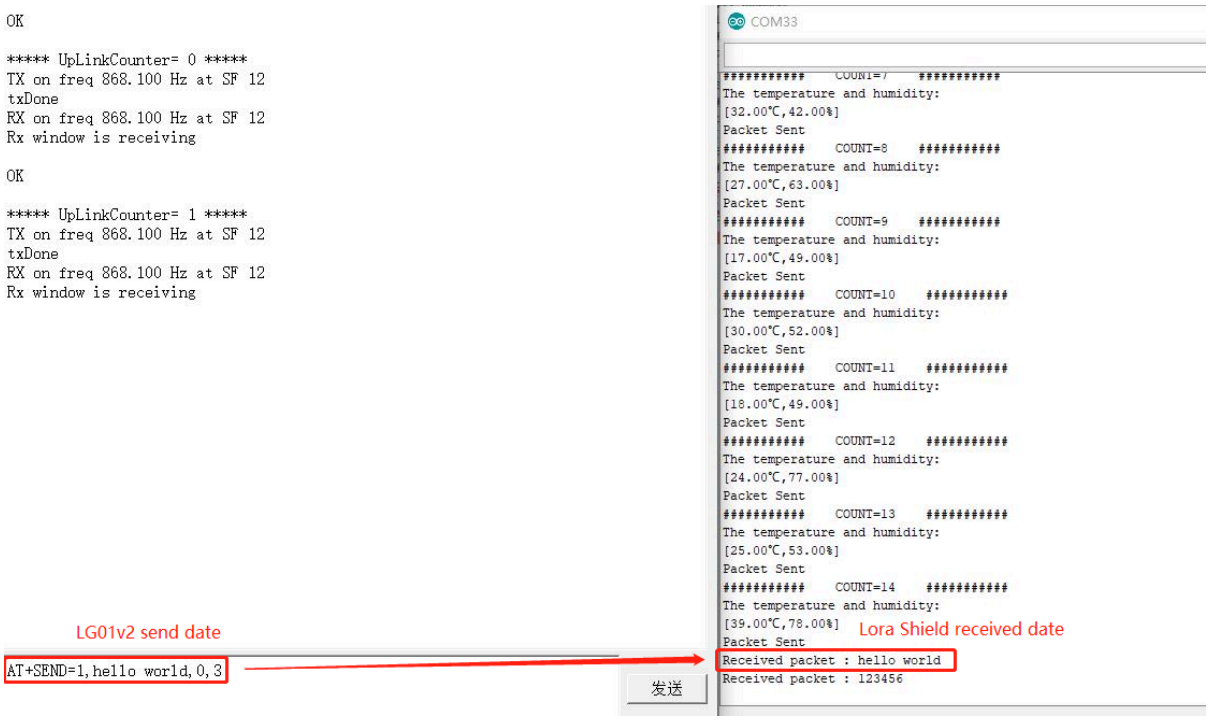
LoRa_Shield_Sketch_For_MQTT

```
unsigned int count = 1;
unsigned long new_time,old_time=0;

void setup()
{
      Serial.begin(9600);
      while (!Serial);
      Serial.println(F("Start MQTT Example"));
      if (!LoRa.begin(868100000))   //868000000 is frequency
      {
          Serial.println("Starting LoRa failed!");
          while (1);
      }
      // Setup Spreading Factor (6 ~ 12)
      LoRa.setSpreadingFactor(12);

      // Setup BandWidth, option: 7800,10400,15600,20800,31250,41700,62500,125000,250000,500000
      //Lower BandWidth for longer distance.
      LoRa.setSignalBandwidth(125000);

      // Setup Coding Rate:5(4/5),6(4/6),7(4/7),8(4/8)
      LoRa.setCodingRate4(5);
      LoRa.setSyncWord(0x12);
      void disableCrc();
      LoRa.disableInvertIQ();
      LoRa.explicitHeaderMode();
      Serial.println("LoRa init succeeded.");
      LoRa.onReceive(onReceive);
      LoRa.receive();
}

void dhtTem()
{
       tem = random(15,40);
```

Test LG01v2 to receive Lora Shield data:



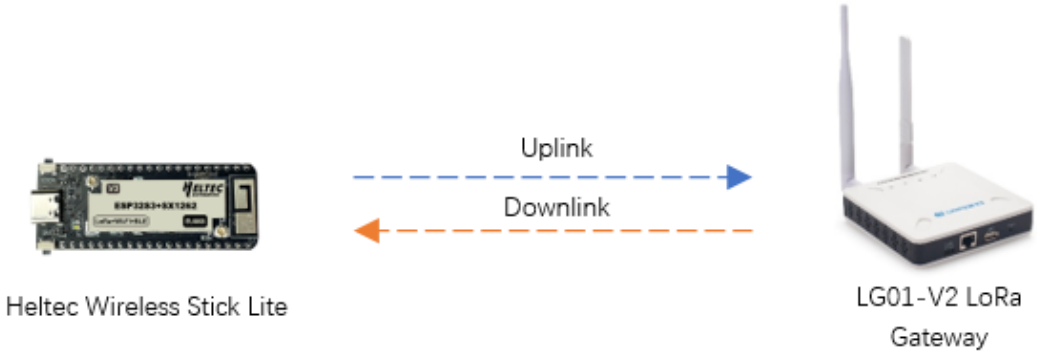
Test the LG01v2 to send data:



8.2 How does LG01v2 communicate with Heltec LoRa Node

This example describes how to use LG01v2 and Heltec LoRa Node to set up a LoRa network,

LG01-V2 communicate with Heletc LoRa Node：



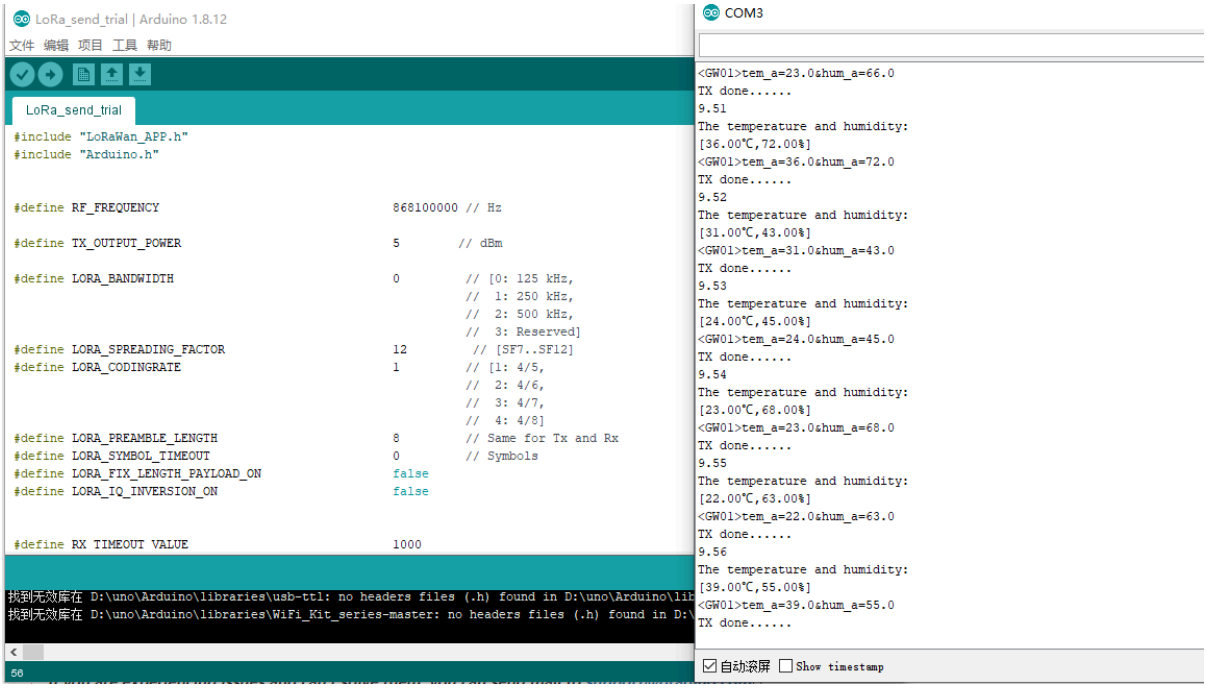
Prerequisites: The configurations of LG01v2 and Lora shield must match

LG01v2 configuration:

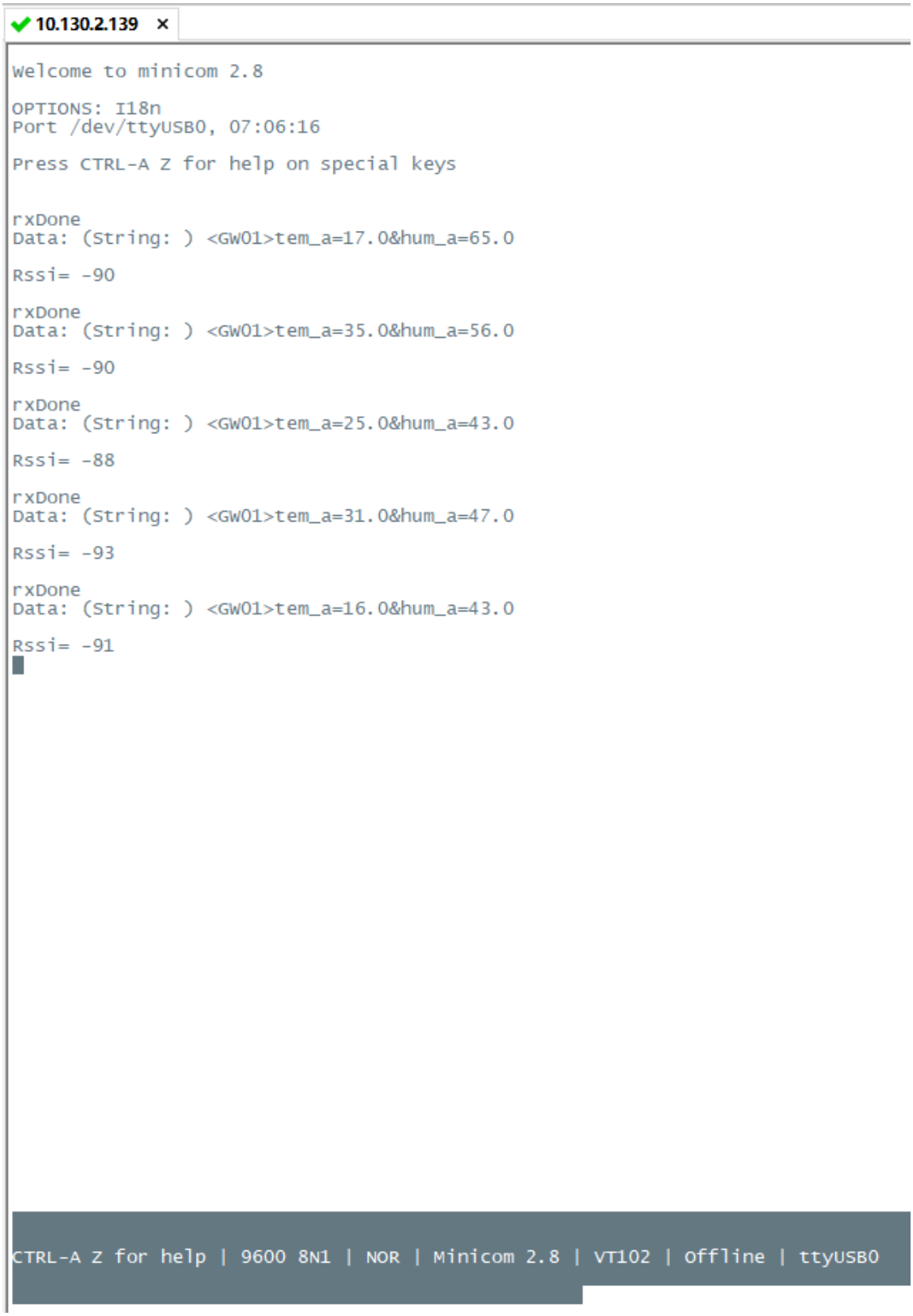
AT+FRE=868.100,868.100 ---> TX and RX frequency set: 868100000
AT+BW=0,0 ---> TX and RX Bandwidth set: 125kHz
AT+SF=12,12 ---> TX and RX Spreading Factor set: SF12
AT+POWER=14 ---> TX Power Range
AT+CRC=1,1 ---> TX and RX CRC Type
AT+HEADER=0,0 ---> TX and RX Header Type
AT+CR=1,1 ---> TX and RX Coding Rate
AT+IQ=0,0 ---> TX and RX InvertIQ
AT+PREAMBLE=8,8 ---> TX and RX Preamble Length set: 8
AT+SYNCWORD=0 ---> Syncwo**(0:** `private, 1:` **public),** the corresponding Lora shield syncword is 0x12
AT+RXMOD=65535,0 ---> Rx Timeout and Reply mode,RX window always open
AT+RXDAFORM=1 ---> RX data format`(0:` **Hex ,1:** `String)`

After we upload the sketch to Heltec LoRa Node, we can see below output from Arduino.

Lora Shield example: LoRa_send_trial.ino



And we can see the logread of gateway as below, means the packet arrive gateway:



8.3 How does LG01v2 communicate with LoRaWAN node

This example describes how to use LG01v2 and LSN50 to set up a network,

In this case, users need to set LSN50 to work in ABP mode and transmit in only one frequency.

Assume we have a LG01v2 working in the frequency 868100000 now, below is the steps.

Step1: Configure the LG01v2

AT+FRE=868.100,868.100 ---> TX and RX frequency set: 868100000
AT+BW=0,0 ---> TX and RX Bandwidth set: 125kHz
AT+SF=12,12 ---> TX and RX Spreading Factor set: SF12
AT+SYNCWORD=1 ---> Syncwo**(0:** `private, 1:` **public),** the corresponding Lora shield syncword is 0x12

Step2: Run AT commands to make the LSN50 work in Single frequency and ABP mode. Below are the AT commands:

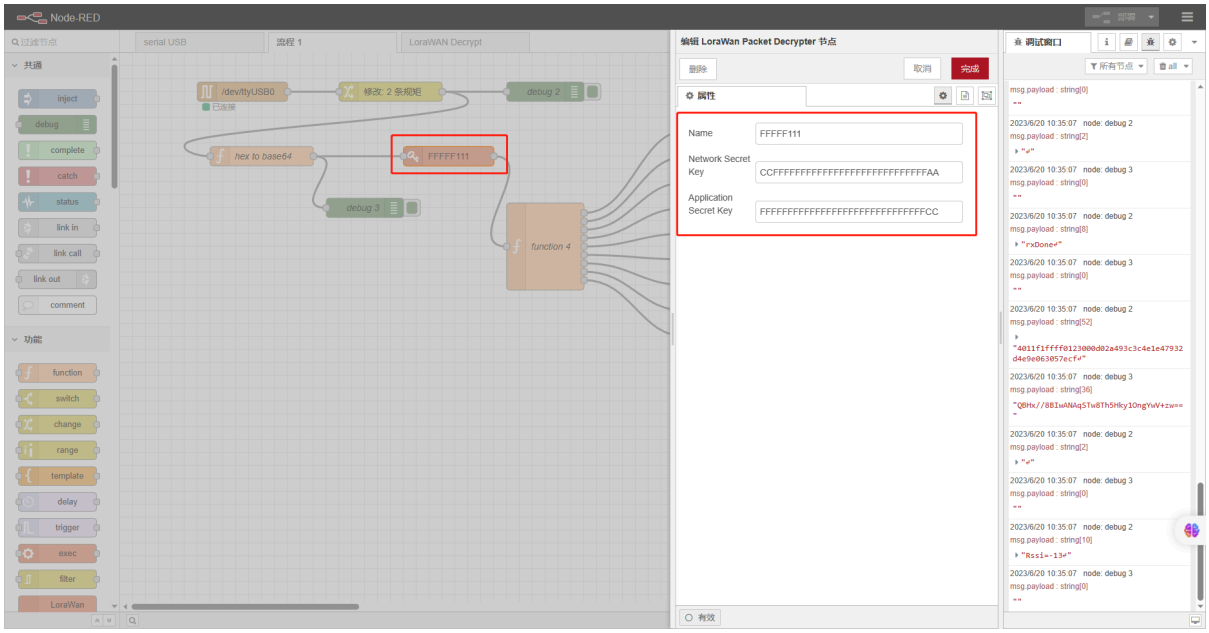
AT+FDR ---> Reset Parameters to Factory Default, Keys Reserve
AT+NJM=0 ---> Set to ABP mode
AT+ADR=0 ---> Set the Adaptive Data Rate Off
AT+DR=0 ---> Set Data Rate (Set AT+DR=3 for 915 band)
AT+TDC=300000 ---> Set transmit interval to 5 minutes
AT+CHS=868100000 ---> Set transmit frequency to 868.1Mhz
AT+DADDR=FFFFF111 ---> Set Device Address to 26 01 1A F1
ATZ ---> Reset MCU

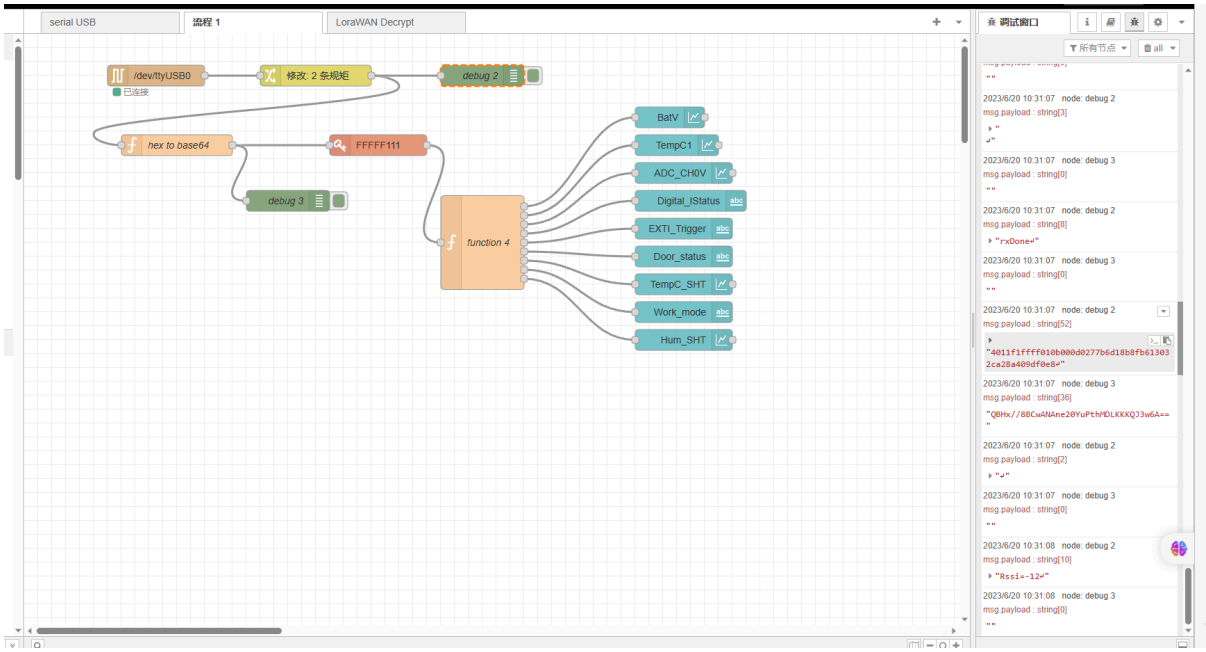
Step3: Check result

User can plot the temperature and humidity chat via LG01v2 built-in IoT server.

User can import this example in Node-Red: LG01v2_LSN50v2_S31.json

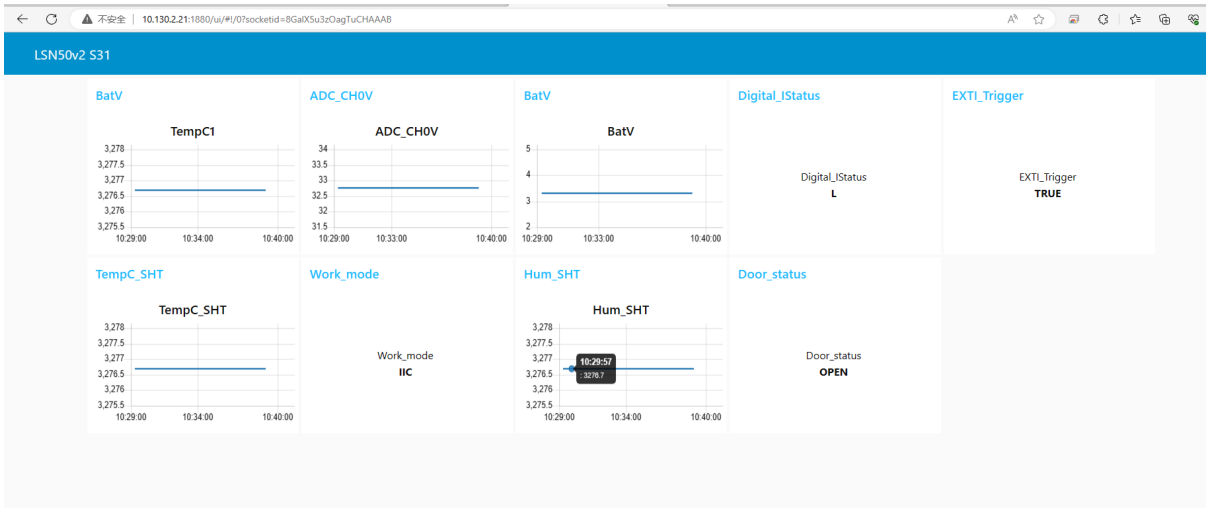
First the user needs to fill in the NwkSkey and AppSkey in the LoraWan Packet Decrypter node.


Node-RED
部署
过滤节点
serial USB
流程 1
LoraWAN Decrypt
共通
inject
debug
complete
catch
status
link in
link call
link out
comment
功能
function
switch
change
range
template
delay
trigger
exec
filter
LoraWan
/dev/ttyUSB0
已连接
修改 2 条规则
debug 2
hex to base64
FFFFF111
debug 3
function 4
编辑 LoraWan Packet Decrypter 节点
删除
取消
完成
属性
Name
FFFFF111
Network Secret Key
CCFFFFFFFFFFFFFFFFFFFFFFFFFFFFAA
Application Secret Key
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFCC
有效
调试窗口
所有节点
all
msg.payload : string[0]
""
2023/6/20 10:35:07 node: debug 2
msg.payload : string[2]
"↵"
2023/6/20 10:35:07 node: debug 3
msg.payload : string[0]
""
2023/6/20 10:35:07 node: debug 2
msg.payload : string[8]
"rxDone↵"
2023/6/20 10:35:07 node: debug 3
msg.payload : string[0]
""
2023/6/20 10:35:07 node: debug 2
msg.payload : string[52]
"4011f1ffff012300d02a493c3c4e1e47932d4e9e063057ecf4"
2023/6/20 10:35:07 node: debug 3
msg.payload : string[36]
"QBHx//8BIwANAq5Tw8Th5Hky1OngYwV+zw==
"
2023/6/20 10:35:07 node: debug 2
msg.payload : string[2]
"↵"
2023/6/20 10:35:07 node: debug 3
msg.payload : string[0]
""
2023/6/20 10:35:07 node: debug 2
msg.payload : string[10]
"Rssi=-13↵"
2023/6/20 10:35:07 node: debug 3
msg.payload : string[0]
""



The data will be displayed in the built-in node-red UI

Browser input: *http://<local-IPV4-address>*



9. Trouble Shooting

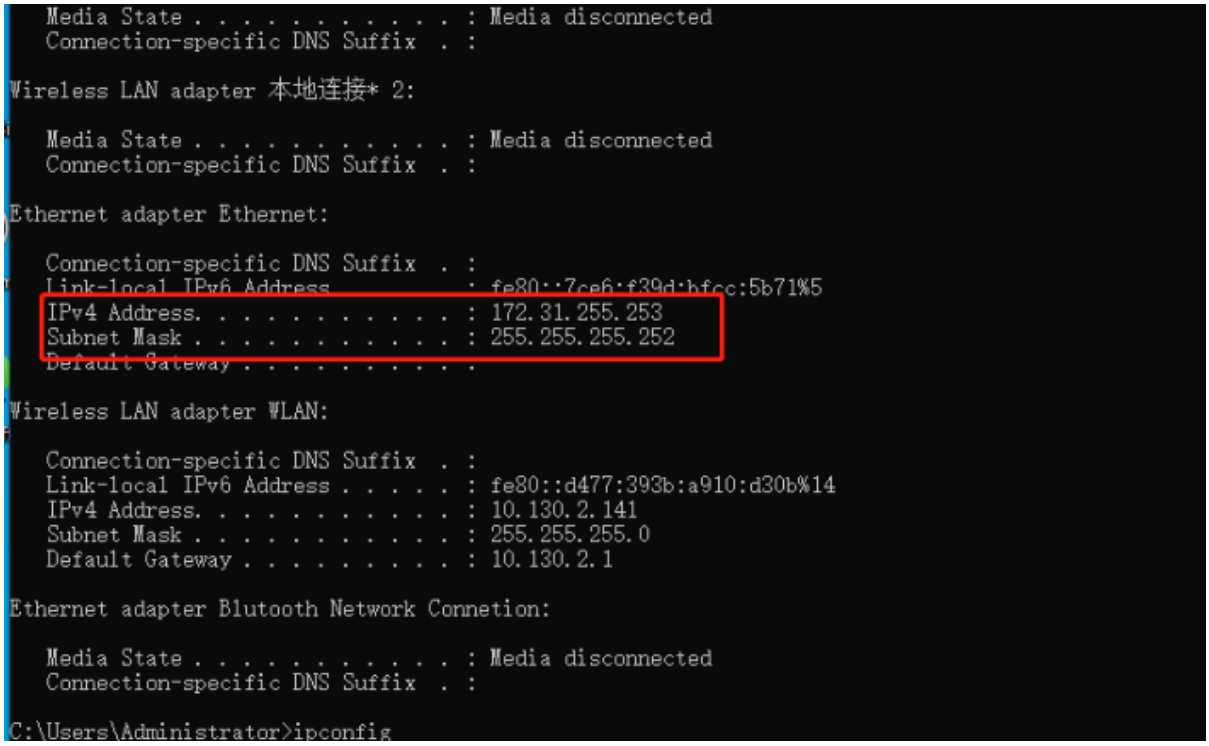
9.1 Fallback IP does not work, how can users check

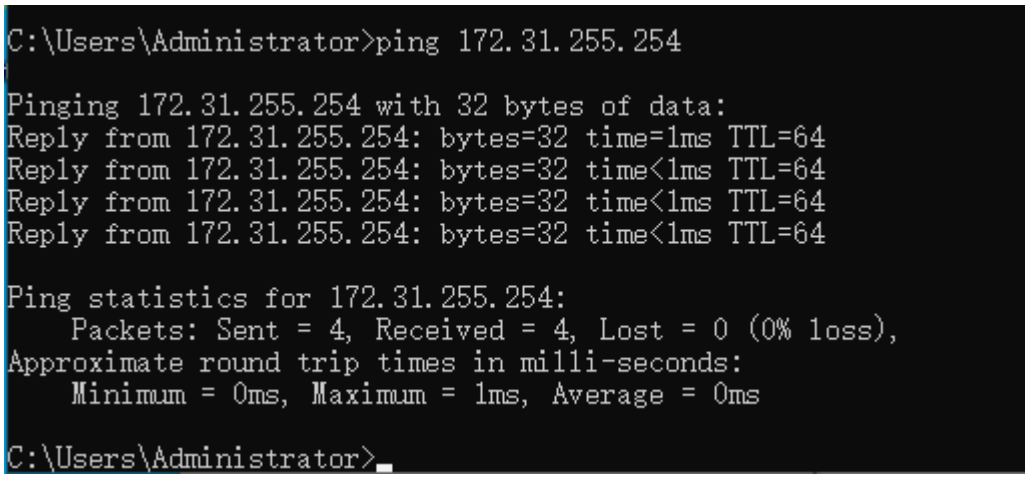
When the computer has completed the above fallback IP configuration,the LG01v2 Web UI is still not accessible via fallback IP.

1.Check whether the configuration is correct

Run the CMD command to ipconfig and ping 172.31.255.254.

If this fails, the user needs to reconfigure.





2. Check whether the firewall is disabled

If the firewall is not down, this will affect access to the gateway.

10. Supports

If you are experiencing issues and can't solve them, you can send mail to support@dragino.com.

With your question as detailed as possible. We will reply and help you in the shortest.

11. Reference

- Install Tago Core: Refer **Install Tago Core in LG01v2** in Instruction.
- Advance OS Reference Guide for LG01v2.

12. Order Info

LG01v2-XXX-YYY

XXX: Frequency Band

- **868**: For frequency : 863 ~ 870Mhz
- **915**: For frequency : 902 ~ 928Mhz

YYY: 4G Cellular Option

- **EC25-E**: EMEA, Korea, Thailand, India
- **EC25-AFX**: America: Verizon, AT&T(FirstNet), U.S.Cellular; Canada: Telus
- **EC25-AUX**: Latin America, New Zeland, Taiwan
- **EC25-J**: Japan, DOCOMO, SoftBank, KDDI

More info about valid bands, please see EC25-E product page.

13. Manufacturer Info

Shenzhen Dragino Technology Development co. LTD

Room 202, Block B, BCT Incubation Bases (BaoChengTai), No.8 CaiYunRoad

LongCheng Street, LongGang District ; Shenzhen 518116,China

14. FCC Warning

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

-- Reorient or relocate the receiving antenna.

-- Increase the separation between the equipment and receiver.

-- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

-- Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.