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Performance Evaluation of Low Cost LoRa Modules in IoT Applications

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Performance Evaluation of Low Cost LoRa Modules in IoT Applications

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Abstract. LoRa is a low power long range wireless communication platform that is designed as an efficient communication platform for small, low powered devices. This makes it very suitable for battery powered devices and IoT implementation. This paper evaluates some low cost LoRa modules available on the market and their suitability, energy efficiency and performance during operation. Two low cost LoRa transceiver from Semtech Industries, the SX1272 and SX1278 were tested for their power consumption and maximum transmission range. This study have evaluated the two LoRa solutions and found that the SX1278 have a better transmission range and uses lower energy compared to the SX1272 thus making it more suitable for embedded implementation as a data gateway.

1. Introduction

An increasing number of radio technologies enabling low-power wireless communication over long distances has emerged in the past years. Ultra-narrowband technologies such as Sigfox (Labège, France) and Weightless-N, as well as spread-spectrum technologies such as LoRa allow for communicating up to few kilometers, and to build up low-power wide area networks (LPWANs) that do not require the construction and maintenance of complex multi-hop topologies [1].

A key characteristic of LPWAN technologies is indeed the ability to trade throughput for range and vice versa, i.e., one has the ability to fine-tune physical layer (PHY) settings to select a more sensitive (but slow) configuration that allows communication over a longer distance. This flexibility makes LPWAN technologies particularly appealing to developers of Internet of Things (IoT) applications requiring long-range communications with relatively low data rates.

LoRa technology is a new wireless protocol designed specifically for long-range, low-power communications. LoRa stands for Long Range Radio and is mainly targeted for Machine-to-Machine (M2M) and IoT networks. LoRa can be operated at the Industrial, Scientific and Medical (ISM) frequency band of 433 MHz, 868 MHz, and 915 MHz. LoRa is primarily intended for portable devices operating up to ten years on battery power alone in regional, national, or global deployment [2, 3]. This makes it very suitable for Internet of Things deployment since it uses very little power and could run for years without maintenance.

This paper tested 2 of the most popular LoRa solutions available on the market on an embedded platform for their effectiveness and efficiency as a data communication gateway.

1.1. LPWAN and LoRa

Low-power wide area networks complement short range wireless technologies such as Wi-Fi, Bluetooth Low Energy, and IEEE 802.15.4, and represent an interesting alternative to cellular technologies for urban-scale IoT applications. The success of LPWANs is due to their ability of providing long-range communication to thousands of devices at minimal cost and limited energy expenditure [4]. Longer communication ranges allow for drastically simplifying duty cycling and networking protocol, as LPWANs can form star topologies where the low-power end devices are able to directly communicate with a more powerful orchestrator [5]. This also allows for designing asymmetric communication schemes and to shift the load to the more powerful central device.

In order to increase the communication range, LPWAN technologies must improve the signal-to-noise ratio (SNR) at the receiver, either by narrowing down the receiver's bandwidth (reducing the receiver's noise-floor) or by spreading the energy of the signal over a wider frequency band (effectively reducing the spectral power density of the signal). NB-IoT and Weightless-P, for example, encode the signal in low bandwidth (<25 kHz) to reduce the noise level and keep the transceiver design as simple and cheap as possible. Sigfox an
d Weightless-N further narrow the signal into ultra-narrow bands as narrow as 100 Hz, further reducing the perceived noise.

1.2. LoRa Technology

LoRa is a proprietary LPWAN technology from Semtech (Camarillo, CA, USA) that recently attracted significant attention due to its ability to trade efficiently communication range against high data-rates, thus enabling IoT applications at an urban scale [6]. LoRa spreads the signal over a wider frequency band, and is more resilient to jamming and interference.

LoRa architecture defines Data Link (DL) layer above the physical layer or wireless modulation used to make long distance communication link [6]. There are many wireless systems that use modulation Frequency Shifting Keying (FSK) at the physical layer because it is a highly efficient modulation to achieve low power. In addition, FSK modulation facilitates demodulation process with the possibility of a small error rate.

The advantage of LoRa is that the ability of long-distance communication, depending on the surrounding environment or barrier at a particular location. The technology uses low power, high security transmission with AES encryption that allows for longer battery lifetime and better mobility [1]. LoRaWAN is a Low Power Wide Area Network (LPWAN) based on LoRa technology that allows LoRa devices communicate to each other and work as a wide area network. This is particularly beneficial for long distances between short range protocols and GSM [7]. LoRa and LoRaWAN™ both have a link budget that is better than the standard of other communications technology.

The core of LoRa technology is its Chirp Spread Spectrum (CSS) modulation: the carrier signal of LoRa consists of chirps, signals whose frequency increases or decreases over time [7]. LoRa's chirps allow the signal to travel long distances and to be demodulated even when its power is up to 20 dB lower than the noise floor. Because of this aspect, carrier sensing in LoRa is quite challenging: LoRa radios allow carrier detection via Channel Activity Detection (CAD) mode, a special reception state consuming half of the energy compared to the normal reception mode. However, the signals produced by different LoRa networks operating on different settings could create interference leading to false detections.

2. Test Setup

In this paper, we have tested two LoRa modules for their suitability to be used in Internet of Things (IoT) implementation. As IoT devices are usually powered using battery supply, we have tested both LoRa modules for their power consumption and maximum transmission range. Two low cost LoRa transceiver modules consisting of SX1272 and SX1278 from Semtech are tested. Using a microcontroller operating as the transmitter and receiver modules, system power consumption during operation are logged and maximum transmission range are tested.

2.1. Arduino Controller and Data Gateway

Arduino is a microcontroller ecosystem that consists of a processor platform and a software IDE. Because of its open-source nature, it is very popular in the embedded world because of its simplicity and ease of use. The platform supports Java and C/C++ programming language together with a multitude of other languages including assembly.

In this paper, Arduino Uno as shown in **Figure 1** is used as the controller platform to handle sensor input and connectivity to the LoRa modules and Internet communication.

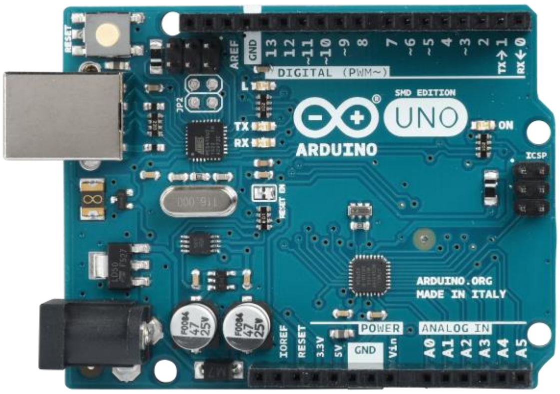

Figure 1. Arduino Uno microcontroller.

Arduino supports both battery and USB power and could be easily be programmed through the USB interface. The specification of the Arduino Nano used in this project is given in **Table 1**.

Table 1. Arduino Nano specifications.

Microcontroller	ATmega328p
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

2.2. LoRa Modules
In this paper, two low cost LoRa modules utilizing LoRa chip from Semtech are used. The SX1272 and SX1278 are both capable of long range wireless transmission with the SX1278 a newer model with some improvement made to it.

2.2.1. SX1272.
The SX1272 (**Figure 2**) can act as transceivers for long range modem. The SX1272 have high interference immunity and provides long range spread spectrum communication.

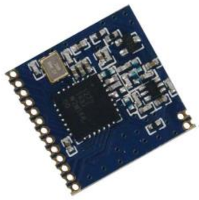

Figure 2. SX1272 LoRa module.

It is a technology that can achieve over -137dBm by using precision crystal. This transceiver support high performance IEEE802.15g. It offers 3 bandwidths with is 125 kHz, 250 kHz and 500 kHz. The frequency set from 433 MHz to 1020 MHz.

2.2.2. SX1278.
The SX1278 (**Figure 3**) also can act as transceivers for long range modem. The SX1278 have high interference immunity and provides very long range spread spectrum communication
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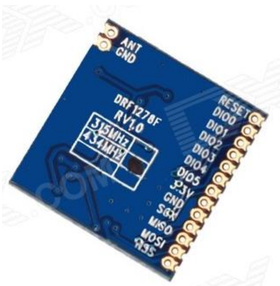

Figure 3. SX1278 LoRa module.

It is a technology can achieve of over -144 dBm. This transceiver support high performance IEEE802.15g. It offers 3 bandwidths with is 125 kHz, 250 kHz and 500 kHz. The frequency set from 137 MHz to 1020 MHz.

2.3. System Architecture
The system consists of a transmission node acting as the transmitter node and a data gateway as the receiver which provides network communication to the internet. By using this approach, it is possible to have multiple remote nodes connected to single data gateway and at the same time reduce cost and complexity to implement.

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2.3.1. System Block Diagram

System architecture consists of two nodes acting as the transmission node and another one acting as the gateway. The system architecture is outlined in **Figure 4**. The entire system is divided into transmission node (sensor node) which will gather all sensor data and transmit it to the data gateway node.

The transmission node gathers data from input sensor ranging from humidity sensor, temperature sensor and luminance sensor. It is acquired by an ADC inside the Arduino microcontroller, digitized and averaged before being transmitted by the LoRa transceiver. The data gateway also consists of another Arduino microcontroller connected to a LoRa transceiver configured as a receiver. An Ethernet module provides internet access through RJ45 connection to the network.

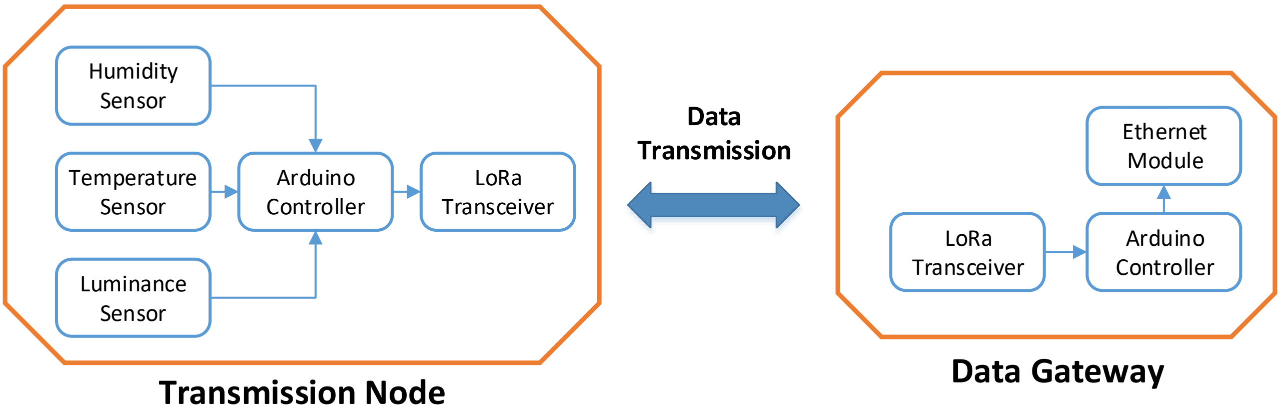

Figure 4. System architecture.

2.3.2. Test Sensors

In this system, 3 input parameters have been selected for implementation ranging from luminance sensor (LDR), humidity sensor and temperature sensor. All the sensors are integrated to the Arduino microcontroller for conversion process before being prepped for transmission to the gateway.

LDR Light Sensor

The Light Dependent Resistors (LDR) is a sensor that is used to detect light intensity. The resistance of the sensor varies with light intensity detected by the sensor with higher resistance in low intensity and lower resistance in higher intensity. The LDR specifications are given in **Table 2**.

Table 2. LDR sensor specifications.

Resistance at 1000 lux	400 ohms
Dark resistance	1M ohm
Maximum current	75 mA
Maximum power dissipation	250 mW
Maximum voltage	320 V

DHT11 Humidity Sensor

DHT11 is humidity sensor measures both temperature and humidity of surrounding air and sends the reading in digital format. The sensor is rated for an accuracy of 5% from 20%-90% humidity and is used as an input sensor in this system. The specification for the sensor is given in **Table 3**.

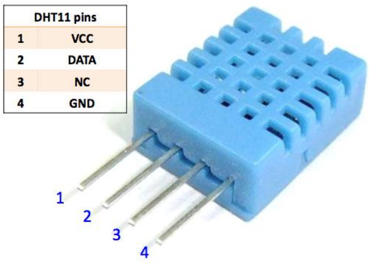

Figure 5. DHT11 sensor.

Table 3. DHT11 humidity sensor specifications.

Parameter	**DHT11**
Relative Humidity Range	20 ~ 90%
Relative Humidity Accuracy:	±5%RH
Temperature Accuracy:	±2°C
Resolution	1%RH,1°C
Repeatability	±1%
Long Term Stability	±1% per year
Operating Temperature Range	0 ~ 50°C
Power Supply:	3,3V ~ 5.5V
Supply Current:	0.5mA ~ 2.5mA
Idle Supply Current:	100uA ~ 150uA
Max sampling period (Max device update rate).	1 second

Sampling for all the sensors are done every 5 second and filtered using a moving window average before being transmitted to the gateway.

2.4. Experimental Test

To test the performance of the transceiver, two testing procedures have been carried out which is power consumption test and maximum distance test. Power consumption test are done by logging the current

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requirement of the nodes during transmission and calculating the power used by multiplying the voltage and current used during the operation.

Maximum transmission range test are carried out by checking the RSSI until the signal is lost. The test are done in a line of sight inside the university compound with the aid of GPS and Google Maps.

2.4.1. System Setup
In this system, the transmission node (sensor node) setup consists of the DHT11 sensor which gathers humidity and temperature reading and an LDR which gathers luminance reading as shown in Fig. 6. Both of the sensor are connected to an Arduino Uno that acquires and processes the sensor data. DHT11 are connected to the digital interface (DIO1) and the LDR is connected to the analog input (AI0) while the LoRa transceiver is connected through the SPI protocol at the ICSP header.

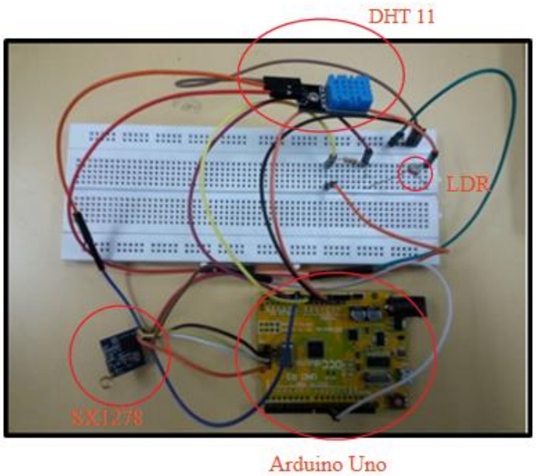

Figure 5. Actual transmit node setup.

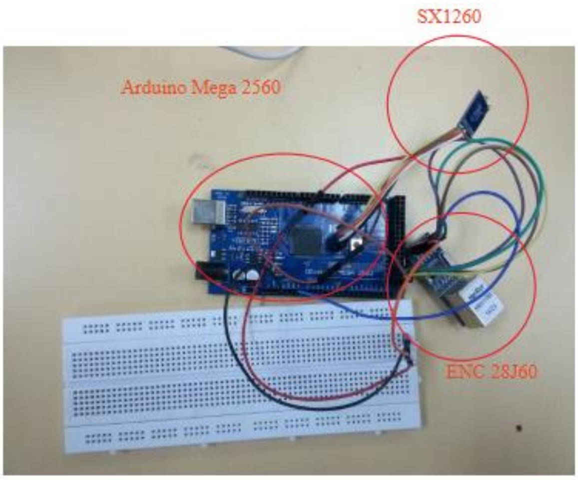

Figure 6. Actual data gateway setup.

The data gateway (**Figure 6**) does not have any sensor attached to it and merely transmits the incoming data from the sensor node and handles communication to the Internet and cloud service. An Arduino Mega2560 is used for as the main controller and an Ethernet module (ENC28J60) is used to provide internet access to the gateway. Data transmitted from the sensor node are processed here before being transmitted to the Internet to be stored in a cloud service.

3. Result and Discussion

In this study we have collected power consumption and transmission range data from both of the modules during transmission. Average power requirement of the system during data transmission are averaged across 10 samples. Range test are taken after 10 consecutive timeout that signifies out of range condition.

3.1. Power Consumption

Power consumption of the transmission node and gateway node are monitored using a current meter and voltmeter. Actual power requirement of the system are then calculated by multiplying the values to produce the power rating. An average reading of 10 values are taken and tabled in Table 4, Table 5 and Table 6. The transmission power settings are set inside the code and passed to the transmitter modules as configuration flags.

Table 4. SX1272 average power consumption during operation (average of 10 reading).

Power Setting	***Reading***	***Average Reading***	***Average Power, W***
Max	Voltage, V	5.047	0.2423
	Current, A	0.048	
High	Voltage, V	5.044	0.2219
	Current, A	0.044	
Intermediate	Voltage, V	5.042	0.2168
	Current, A	0.043	
Low	Voltage, V	5.038	0.2015
	Current, A	0.04	

Four transmission power settings are tested for the SX1272 and the average power requirement of the SX1272 shows an increase from the low power transmission to the maximum power. The same pattern is also visible for the SX1278 whereby the power requirement increased according to the transmission power.

Table 5. SX1278 average power consumption during operation (average of 10 reading).

Power Setting	*Reading*	*Average Reading*	*Average Power, W*
Max	Voltage, V	5.145	0.3499
	Current, A	0.068	
High	Voltage, V	5.142	0.2622
	Current, A	0.051	
Intermediate	Voltage, V	5.149	0.2523
	Current, A	0.049	
Low	Voltage, V	5.146	0.247
	Current, A	0.048	

Table 6. SX1272 and SX1278 power consumption difference.

	Average Power Requirement (W)		*Difference (%)*
Transmission Power	**SX1272**	**SX1278**	**%**
Low	0.2015	0.247	18.42
Intermediate	0.2168	0.2523	14.07
High	0.2219	0.2622	15.37
Max	0.2423	0.3499	30.75

Comparison of the SX1272 and SX1278 shows a higher power requirement of the SX1278 compared to the SX1272. An average difference of about 15% is expected except at the maximum transmission power where the power consumption differs by about 30% between the SX1272 and SX1278.

3.2. Transmission Range

Maximum transmission range test are carried out by moving the receiver away from the transmitter until the signal is lost. The transmitter location and test range are given in **Figure 7**.

Figure 7. Maximum range test setup.

The maximum range are tested for a number 10 times and averaged. The SX1272 library supports a total number of 3 transmission mode which varies the transmission sensitivity, bandwidth and speed. The SX1278 library supports all 10 different transmission modes and the results are logged in Table 7 below. The difference between transmission modes can be referred inside respective modules datasheets.

Table 7. SX1272 and SX1278 maximum transmission range.

	SX1272	***SX1278***
Mode	Range	Range
1	350 m	1km
2	250 m	1km
3	N/A	1km
4	220 m	900m
5	N/A	800m
6	N/A	700m
7	N/A	650m
8	N/A	600m
9	N/A	600m
10	N/A	500m

From the results gathered, it is found that for the SX1272, lower transmission mode which is optimized for low speed, maximum range does give the longest transmission range which is 350 meters. But for the SX1278, lowering the transmission speed and increasing the sensitivity using lower mode configuration does not improve the range after mode 3. The maximum range achievable could probably be improved with better antenna.

While both modules could transmit to relatively long range, the SX1278 have a much further transmission range compared to the SX1272 albeit at a higher power requirement.

4. Conclusion

The test carried out have shown that the SX1278 has a much further transmission range compared to the SX1272 albeit using more power during transmission operation. While the power requirement at the maximum transmission power varies by as much 30%, at lower settings the difference is much smaller ranging from 14-18%. This is still within acceptable values considering our test have shown that the SX1278 has a much further transmission range reaching a distance of 1km.

Acknowledgement

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