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Remote Weather Assistant using LoRa Network, an Enhancement of IoT Design

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ABSTRACT

The technologies used for IoT are infested with numerous problems. We are currently experiencing a deluge in the number of connected devices and it will only continue to surge. As such, there is a need to employ a technology that overcomes these shortcomings. LoRaWAN (or Long Range Wide Area Network) which is an LPWAN (Low Power Wide Area Network) technology has been recently gaining a lot of attention as its features are best suited to IoT networks. It leverages a low data rate to optimise battery consumption. Besides this, LoRaWAN uses an unlicensed spectrum, advancing research. In this paper, we will study how LoRaWAN supersedes other technologies using the network deployed for our remote weather assistant. For the purpose of experimentation, we have deployed a LoRaWAN node (which acts as the remote weather station) and a LoRaWAN gateway, which will be used to study the traffic parameters. These parameters will be compared with the rest of the technologies.

Keywords: *LoRa, IoT technologies, Gateway, Node.*

INTRODUCTION

The ubiquitous nature of IoT has led many researchers to believe that the number of "things" will plummet to a staggering 26 billion by 2020. The data being generated from these things is vast. Consequently, the value of such data has proven useful in providing insights into many application areas, which otherwise resorted to traditional methods to provide intelligence. IoT has been around for a long time now and the rapid advancement of IoT technology is unprecedented. Today, a number of technologies are available to transform everyday objects into "things". Each of these has been tailor made to suit different application. There is no technology yet, which caters to all application areas as a single technology cannot overcome all the problems of IoT networks. A major use case of IoT has to deal with deploying applications in remote areas and optimising the network for the same. For this very reason, LPWAN is undergoing a lot of development recently. Sigfox, NB-IoT, Wireless and Symphony are LPWAN technologies, which are competing for market share. LoRaWAN has emerged as the next generation of IoT technology. Its long range, low battery consumption and high coverage area is useful in applications such as Smart Healthcare, Smart Cities, Smart Homes, Smart Industries and so on.

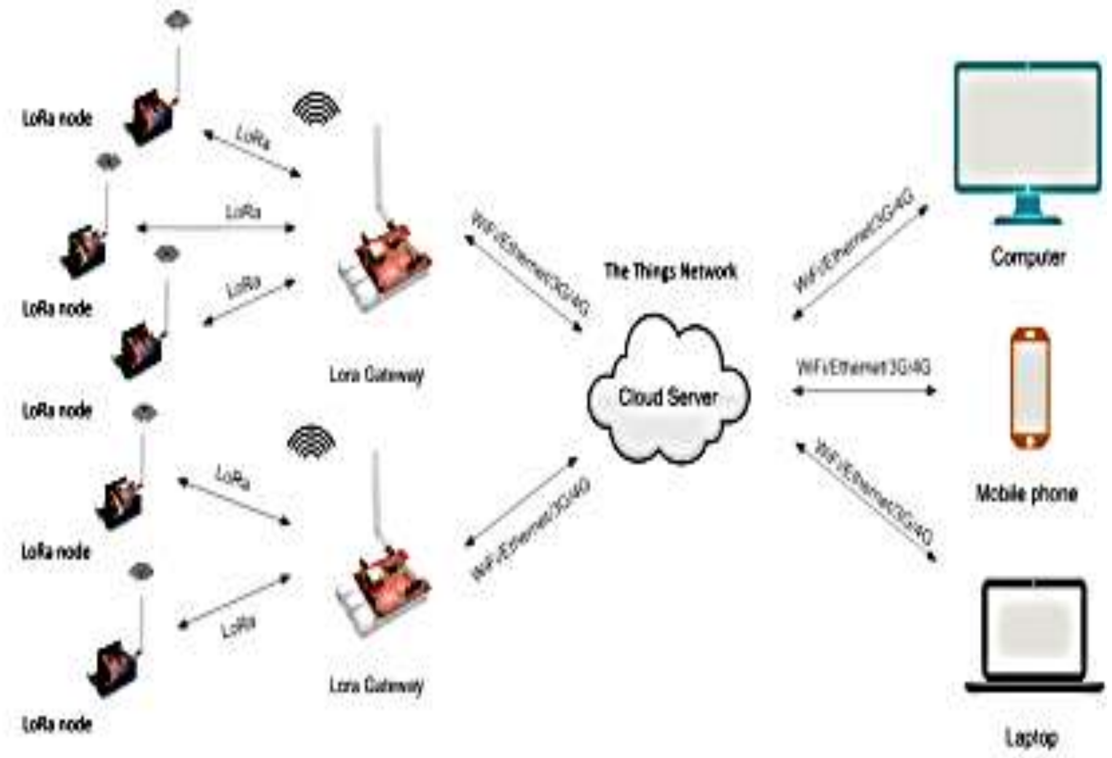

Fig. 1: *LoRa network architecture*

ONGOING RESEARCH

Several studies are being conducted on LoRaWAN and its applications. In [1] LoRa was found to reach distances of 2km in an outdoor setting. The transmit power was found to be 110mA which is lesser when compared to the rest of the technologies. The Dakar Peninsula was used to study the maximum communication range with a spreading factor of 12 for the exchange. It was observed that it can go up to 10km [2]. As there is an increasing need for simulation tools which do not need any actual hardware to be deployed, has led to the inception of several simulation tools. It is used to study network parameters for various deployments. One such tool is FloRa [3] or Framework for LoRa. It uses OMNeT++ and is an open source framework. It has implemented all the layers of the LoRaWAN stack and has the ability to run varying bi-directional simulations. Emphasis has been placed on studying application based LoRa networks such as remote weather monitoring. To study the link capacity for this use case, researchers have tried to study how LoRa performs in rural and urban environments in the Sabah and Sarawak regions [4]. Based on the LoRa setup used in this paper, it was found that it covered a distance of 15 km in rural and 5 km in urban areas. Bit Error Rate of Chirp Spread Spectrum is an important aspect of the communication and is studied in [5]. LoRa makes use of Hamming codes for Forward Error Correction which is a technique for ensuring reliable transmission of data. Hamming code makes use of 4 bits of code information and varying length of code word. LoRa uses 4/5, 4/6, 4/7 and 4/8 as the code rates. Antenna designs have also been optimised to suit the application areas of LoRa. Ongoing research in this field is focused on fitting the antenna on miniaturized boards LoRa devices use, which gives very little space for antenna design [6]. In [7], [8], [9] and [10] an extensive study is done on LoRaWAN networks, in terms of its features, challenges and applications. To study how SF setting relates to distance, experiments were conducted [11] to study their relationship and results were averaged. SF7 was found to display the best throughput value for small distances (1927.3 bit/s). This changed for longer distances as SF8 was the better choice (1204.6 bit/s). SF11 was the most superior of all the settings, as the throughput is closest to theoretical values. SF7 is seen to suffer in shorter distances. [12] Gives a comprehensive overview of LoRa, comparing it to other networks such as ZigBee, WiFi, Bluetooth which are major competitors of market share. A mesh network for LoRa has been proposed in [13] and it is proves to be very promising. The packet data rate has been found to be 88.49%. Current LoRa networks work on star topology which achieves a PDR of about 58.7% in the same conditions. The scalability of both nodes and gateways is studied in [14] in order to give an insight into how LoRa outperforms other technologies. Agriculture today is moving towards more data-driven decisions. However, costly IoT deployments are discouraging and not sustainable. LoRa network is used to build an intelligent architecture platform [15]. Security is an important aspect of LoRa [16].

LoRa PARAMETERS

A. LoRa vs. LoRaWAN - LoRa is a physical layer modulation technique, which enables the long range communication. LoRaWAN on the other hand, is a standardised MAC layer protocol which defines the various specifications of the communication protocol. These two terms are not indistinguishable and the protocol stack shown below is an indication of this fact. LoRa enables peer to peer communication between nodes by using the LoRa modulation developed by Semtech. LoRaWAN implements a much more advanced protocol, developed by LoRa Alliance to ensure interoperability among devices.

Fig. 2: *LoRa vs. LoRaWAN*

B. Chirp Spread Spectrum, bandwidth and spreading factor - chirp (compressed high intensity radar pulse) spread spectrum (CSS) is a technique for fixed amplitude frequency modulation. A chirp is a sinusoidal signal which has constant amplitude and its frequency increases or decreases over time (often with a polynomial expression for the relationship between time and frequency). For an upchirp, the frequency increases linearly over time. Similarly for a downchirp, the frequency decreases linearly over time. CSS uses its entire allocated bandwidth to broadcast a signal, making it robust to channel noise. Further, because the chirps utilize a broad band of the spectrum, chirp spread spectrum is also resistant to multipath fading even when operating at very low power. CSS is resistant to the Doppler effect, which is typical in mobile radio applications. LoRa uses 3 bandwidths 125 kHz, 250 kHz and 500 kHz (we use 125 kHz since this is the bandwidth suited to Indian region, as per ISM band regulations) whose entire portion is used by the chirp signal. The duration of the chirp is determined by the spreading factor. LoRa uses spreading factors ranging from 7 to 12 (we use SF7 for our network, which usually influences the data rate. In keeping with the bandwidth, the device itself chooses a spreading factor based on regional parameters specified by regulations). As the spreading factor increases, for the same bandwidth, the time on air increases hence the data rate per unit time decreases. For different regions, LoRaWAN uses a different configuration of bandwidth, spreading factor and data rate.

C. Adaptive data rate – It is a mechanism for altering the data rate for the network. Only stationary devices with stable RF conditions are able to use ADR. ADR is usually requested by the end device by setting the ADR flag. Using ADR optimises the range, power and data rate capacities of the network. TTN uses uplink messages from the devices to determine the optimal data rate. It uses Semtech's rate adaptation algorithm for the same.

D. Security – Security is essential to every network to ensure privacy and standards of companies. Security is usually not included in the design of protocols. Instead it is incorporated as a last minute patch. In LoRa, secure communication is ensured at both layers – network and application layer. The security measure at the network layer ensures that the devices that join the network are authentic. At the application layer, the user data is secured from illegal access. For this reason, LoRaWAN is said to use double AES encryption as it makes use of AES keys. The Network Session Key (for communication between the node and the network server), Application Session Key (for communication between the node and the application server, to encrypt/decrypt the payload) and the Application Key are the three keys used. There are two methods for activation – OTAA (over the air activation) and ABP (activation by personalization). In case of OTAA, the session keys are regenerated for every session as indicative of the name. This is generated using the Application Key. Whereas, in case of ABP, the devices are programmed with these keys and remains the same throughout the transfer. We use ABP for our network, to avoid the delay incurred by a join procedure initiated when we use OTAA. For development purposes, ABP serves as a quick prototyping solution for OTAA.

E. Duty Cycle – Since LoRa makes use of an unlicensed spectrum, the government has mandated certain restrictions on the usage of this band to ensure fair usage. It does so by restricting the duty cycle of both nodes and gateways (Duty cycle is the fraction of time for which the device is active). In most regions, it is set to 1% (including the EU region, which applies to our network). TTN also imposes a fair access policy since it is a public community network that limits number of uplink and downlink messages.

EXPERIMENTAL SETUP

The experimental setup proceeded in two phases. The first phase focuses on deploying the gateway and the second on deploying the node and implementing the application. For the purpose of deploying the network, The Things Network has been used as the Network and Application server. As LoRaWAN is a network intensive radio protocol, it demands the node and the gateway to be barebones devices and places most of the burden of transmission logic on the network and application server. The Things Network provides a decentralised approach to all the intelligence that needs to be incorporated into the network. The future sections will highlight how gateways bridge the nodes to the network servers. For devices that support IP stack, the gateway can directly forward the data to the network server. When it comes to devices that implement Non-IP protocols (in this case LoRaWAN) a network server is required that will process the data and then channel it to the application server to be put to use. Both the gateway and the node are registered with the network server.

A. Building the Gateway

Currently, there are two types of gateways that can be built. A commercial gateway or a gateway built from scratch. Gateways bridge the gap between nodes (which uses the specific radio protocol, in this case LoRaWAN) and the network server. The gateway uses WiFi, Ethernet and other conventional technologies to communicate with the network server. Kerlink IoT Station, Multitech Conduit, Cisco LoRaWAN Gateway and many others are available in the market and can be easily purchased. There are few open-source options as well. The approach taken in this paper is building a gateway from scratch. For the purpose of building a gateway, a RaspberryPi and Dragino LoRa Shield (868MHz for the European and Indian region) has been used. The shield has a built in HopeRF RFM95W module and an SX1276 chip. Raspbian is loaded on the Pi and connected to the internet using an Ethernet cable. Once it is booted up after powered using a power cord, an IP scan is run to recognise the dynamic IP address which is assigned by DHCP. Using Remote Desktop Environment, the Pi is accessed. The first step is to install Wiringpi and enable SPI on the Pi. WiringPi is a C library which enables easy access to GPIO pins on a Pi. Enabling SPI allows the Pi to communicate with 2 peripheral devices. Basic parameters of the gateway are configured which includes location (latitude, longitude and altitude), frequency, spreading factor and handler. Once the code for the gateway is up and running, the terminal displays a Gateway ID. This is used for registering the gateway with a network server. The Things Network offers a simple interface to register the gateway. The user needs to specify a gateway ID (since we are using the Semtech technology, the gateway ID will be in a EUI format), a frequency plan (which is 868MHz for the network built) and a router/handler (eu.thethings.network for the network built). The gateway's status (its last seen active status) and various other configuration details can be viewed on the console provided by TTN. The main focus is on the traffic exchange display on the console to view the traffic received from the node.

B. Building the Node and implementing an application

The node was built using a Dragino LoRa shield and an Arduino UNO development board. To make a device LoRaWAN compatible, the radio module needs to be built-in the development board, wired to it or built on a shield. The LoRa shield enables the node to send data across long ranges with low power. This is enabled by the LoRa radio module on the shield, which is same as that discussed for the gateway. The LoRa shield is especially built for Arduino and hence requires no extra connections. It is directly plugged on the Arduino. In a real world scenario, a number of sensors are connected to the node to enable various real-time analyses to be done. For the purpose of this paper, we have integrated a DHT11 sensor to the node to enable the node to sense temperature, humidity and luminosity. This can be used in remote weather stations (wherein, the weather conditions can be controlled and monitored accordingly), in hospitals (where patients require stabilised weather conditions) or even in industries. The data that is received by the gateway can be analysed for RSSI and SNR, so as to compare this network to others. The application and then the device (node) is registered on TTN. When registering the application, an Application ID (to uniquely identify it) needs to be supplied and a handler (as discussed in the gateway section) needs to be chosen. TTN assigns an Application EUI which is used to register a device (node). Next, the device is registered on TTN for which a

Device ID (to uniquely identify it) and a Device EUI (which can be automatically generated) is supplied. TTN assigns an Application key which was discussed earlier. Once the activation method has been set as ABP, additional parameters are assigned by TTN (Device address, Application Session key and network session key). For the purpose of visualising the data, the node is integrated with Cayenne. It offers CayenneLPP which pretty prints the payload so that the user can visualise and access the data on a dashboard (Cayenne further offers IFTT and other tools that can be used to put the data to further use). Once the setup is done, the code is uploaded on Arduino and traffic is observed on the TTN Console.

RESULTS

The sensor data received by the gateway can be measured by using various parameters. In this paper, RSSI (received signal strength indicator which gives an idea of the power of the received signal as well as sensitivity of the receiver) and SNR (signal to noise ratio which gives an idea of the interference in the channel) values of the signal is used in order to compare it with other existing networks. For measurement purpose, the gateway is kept stationary and the node mobile. This enables the study of the relationship between RSSI and distance as well as that between SNR and distance. A number of factors influence these parameters including direct Line of Sight (LoS) available, obstacles, Fresnel distance, etc. RSSI and SNR are measured in both indoor and outdoor environments. As the graph shows, it is observed that in an outdoor setting (having the gateway stationary and mobile node) with not many obstacles in the vicinity, the RSSI steadily decreases with distance in a linear fashion. The decrease is observed due to weakening of signal strength and few obstacles. However, the SNR was observed to be more or less constant, but decreased when there were other routers in the vicinity. For the indoor experiment, the gateway was placed at the middle floor of the college building and the node's location was varied. It was observed that the RSSI reduced drastically from one classroom to another due to obstacles (-22dBm when in close proximity to -47dBm in the next room, to -88dBm in the second room). However, it was observed that the RSSI was stable when horizontal distance was varied. It varied from -78dBm in the floors below to -77dBm in the floors above. SNR values showed similar trends as in an outdoor setting.

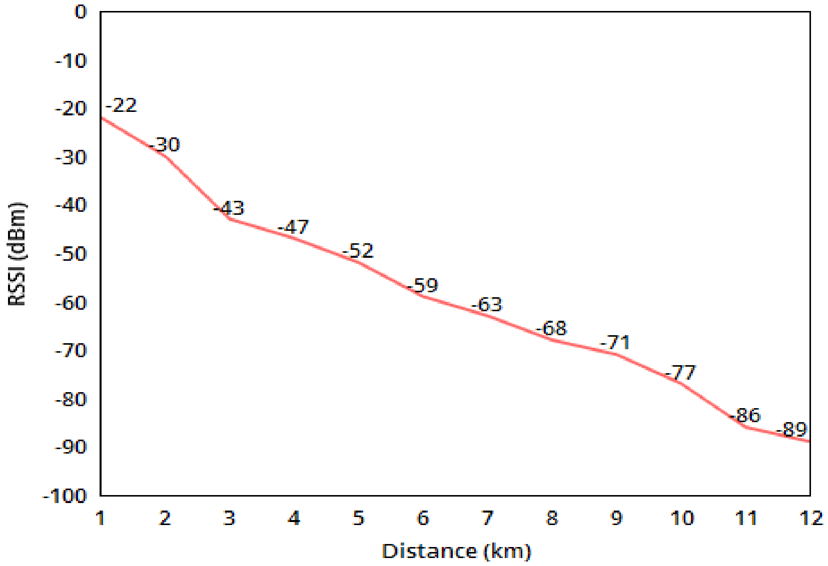

Fig. 3: *RSSI vs. Distance in outdoor environments*

Table 1: *RSSI vs. Distance in outdoor environments*

Serial Number	Distance (km)	RSSI (dBm)
1	1	-22
2	2	-30
3	3	-43
4	4	-47
5	5	-52
6	6	-59
7	7	-63
8	8	-68
9	9	-71
10	10	-77
11	11	-86
12	12	-89

COMPARISON WITH OTHER NETWORKS

Minimum achievable RSSI for this network was found to be -22dBm. Theoretically, closer the RSSI value is to 0 better is the signal. Compared to conventional networks such as WiFi (which has a maximum achievable RSSI of -50dBm), Bluetooth (which has a maximum achievable RSSI of -66dBm) and LTE (which has a maximum achievable RSSI of -65dBm), LoRa performs exceedingly well in both indoor and outdoor settings. SNR was also found to be competitive with other networks. SNR for LTE is about 13dB whereas WiFi needs a minimum of 20dB to define the range boundary. It can be said that LoRa performs better on many counts compared to other networks. Its long range enables a single gateway to be used for a large area, hence supporting a large coverage area simultaneously reducing architecture cost. The protocol is specifically designed to consume less power, hence making it ideal for IoT applications which require efficient battery consumption. As discussed earlier, it is secure due to the embedded AES encryption. It is ideal for running an isolated or private network on a farm or in a city. The costs of investing in creating one's own network will be offset by having your own network which means you can create coverage where it is needed and nothing else exists. However, limitations on the used frequency band can cause high latency on delivered messages. It is therefore not an option for IoT products that require an immediate feedback loop. It also has limited coverage of a private network.

FUTURE WORK AND CONCLUSIONS

The gateway built is only a demonstration of a real world multi-channel gateway and cannot be replaced by our implementation of single channel gateway. However, the results are promising and indicative of the possibilities using LoRa. By scaling up the number of nodes and the gateways in a star network, a low cost, long range and low power network can be deployed which connects even the most remote areas. This model can also be made applicable to several areas of application such as industries, hospitals, etc.

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