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Distressed Positioning System based on Long Range Module (LoRa)

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Abstract

Several new wireless technologies have been proposed to provide internet of things (IoT) sensors with long-range communication. Long Range module (LoRa) has been investigated for long-range performance among these. Although LoRa shows good performance for long-range transmission, its radio signals can be attenuated over distance and the signals may be interfered with by buildings, trees, and other radio signal sources. A natural disaster is a major adverse event that results from the Earth's natural processes. A natural disaster can result in loss of life or damage to property and typically leaves some economic damage in its wake, which depends on the resilience of the affected population (recovery capacity) and the available infrastructure. There are many methods for transmitting data through a widely dispersed internet network, but after the natural disaster, respondents need an efficient way to coordinate recovery efforts when access is lost. This paper creates a network of fast-deployed hotspots that can collect valuable information from vulnerable citizens. In this paper, a concentrator/gateway is designed using a LoRa module, wireless fidelity (Wi-Fi) module, Raspberry Pi, and radio frequency (RF) transceiver to handle large-scale public networks. A basic communication interface is created to achieve this.

Keywords: Beacon, Data collection, IoT, Long-range network, LoRa, LoRa WAN.

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Introduction

After natural disasters, such as, earthquakes, tsunamis, hurricanes, and floods, all basic networking infrastructure is severely damaged due to a long-term loss of connectivity in the affected area. That could cause havoc and discomfort among the disaster-affected public. Most people have smartphones with various connectivity features, like Wi-Fi, bluetooth, and near-field communication (NFC). Those features can be used to send vital rescue center information.

The physical "cluster duck" network consists of hubs resembling rubber ducks that, if needed, can float in flooded areas. Only five are needed to cover a square mile, and they create a mesh network that can use conversational systems to send voice-based communication to a central application.[1] Lora is a long-range, low-power, low-bit rate, wireless telecommunications system marketed as an IoT connectivity solution: end-devices use LoRa to communicate to gateways via a single wireless hop, linked to the internet, and then act as transparent bridges and relay messages between these end-devices and a central network server.[2] This paper focuses mainly on building a gateway to communicate between the clusters of nodes. LoRa node cluster is connected to the Wi-Fi module, which creates a public point of access (i.e., hotspot).[3] LoRa communicates using RF signals; the gateway may catch certain RF signals.

LoRa technology offers major advantages in both blocking and selectivity over conventional modulation techniques, overcoming the tradition between range compromise design, immunity interference, and energy consumption. The LoRa RF platform complements M2M cellular infrastructure and provides a low-cost solution for connecting battery-operated devices to network infrastructure.[4]

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Operational methods:

- Hyper Text Markup Language (HTML) interface—The rescue team can deploy the end nodes in the affected area after the calamitous damage. With the aid of a smartphone, stuck people will connect to the hotspot created by the end-node. The HTML page will appear on the screen; as soon as the link is established, the distress message can be sent.
- Usage of end nodes, such as, beacon-end-nodes can be deployed long before the disaster in disaster-prone regions. The operating methods will be taught to people. Pressing the button on the beacon will send the pre-drafted distress signal to the gateway, and then to the control center. Existing rescue operations after natural

disasters do not cover large geographic areas. Intrinsically, they are slow in establishing formal communication networks. Using a node cluster for quick deployment, over-solution will help establish a helpline. This will cover as quickly as possible, large geographical areas.

Wireless Technologies

Wireless sensor networks can be implemented using several low power wireless technologies that are available. The selection criteria of wireless technology for an application include the study of range, frequency, bandwidth, and power consumption and data rates. LoRa network provides moderate bandwidth for short to long range applications without much deviation as can be observed. The comparison between various technologies with respect to key parameters is given in Table 1 (Figure 1).

LoRa Technology

LoRa wide area network (WAN) defines the network's communication protocol and system architecture. LoRa architecture allows for long-range communication links. These two elements combine to help determine a node's battery life, network capacity, service quality, safety, and other network-serviced applications. One aspect in which LoRa WAN differs from other network specifications (specs) is that it uses a star architecture with a central node linked to all other nodes and gateways acting as a transparent bridge relaying messages between end-users and a central network server in the backend.[5] Gateways are linked via standard IP connections to the network server, while end-devices use wireless single-hop communication to one or more gateways. All end-point communication is bi-directional, allowing multicast, and enabling airborne software upgrades. This helps preserve the battery life and achieve long-range connections, according to LoRa-Alliance, the non-profit organization that created LoRa WAN specifications.[6]

LoRa is also based on modulation of the chirp spread spectrum, in which the alliance claims maintain characteristics of low power and significantly increases communication range. Communication between end-devices and gateways is diffused across various frequency channels and data rates. Data rate selection is a trade-off between the communication range and the duration of the message. Communications with different data levels do not interfere with each other due to the spread spectrum technology and generate a collection of "virtual" channels that increase the gateway's capacity. A single gateway or base station allowed by LoRa may cover entire cities or hundreds of square kilometers. Range, of course, depends on a given location's climate, but LoRa and LoRa WAN claim to have a link budget, the primary factor in deciding contact range, greater than any other standardized communication technology.[6]

System Description

The project mainly focuses on constructing a gateway to communicate between node clusters (beacons). LoRa beacons are connected with the Wi-Fi module that creates a public access point (hotspot). The Wi-Fi module will have an HTML interface as it must communicate with the end client. End clients will send a distress signal which will be captured by gateways. Gateways are connected to and managed by the command center.

Block Diagram

The basic design of the LoRa wireless mesh network module is shown in Figure 2. It is based on the ESP32 Wi-Fi module, an ARM M0 microprocessor, and a Semtech SX1278 LoRa RF 868 MHz transceiver with a 1.9-dBi gain helical antenna. The current design focuses on the efficiency of wireless communication rather than, for example, low-power requirements; hence, all nodes are a battery and gateways (GW's) are well powered by 5V USB adapters.

Stage I

ESP32 module: It is an on-chip microcontroller with low power and cost, built-in Wi-Fi, and dual-mode Bluetooth.[7] This makes the chip, an all-rounded up for IoT projects and networking. In this paper, the module helps to establish a temporary network/hotspot. ESP32 implements TCP/IP, full 802.11 b/g/n/e/I WLAN MAC protocol and specification for

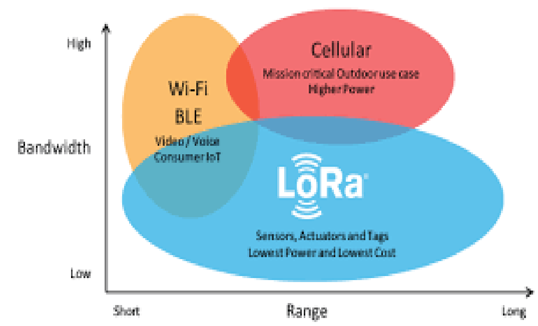

Figure 1: LoRa technology overview[6]

Table 1: Comparison of wireless technologies

Parameter	*Bluetooth*	*Wi-Fi*	*LoRa*	*Zigbee*
Frequency	2.4 GHz	2.4 GHz/5.8 GHz	430 MHz/433 MHz/868 MHz/ 915 MHz	2.4 GHz/784 MHz/868 MHz/ 915 MHz
Bandwidth	720 kbps	54 Mbps/1.3 Gbps	0.3 to 50 Kbps	250 Kbps
Range	10 m	100 m	15–30 km	300 m
Power consumption	Low	High	Low	Low

Wi-Fi Directs. This means that when used in station (client) mode, ESP32 can speak with most of the Wi-Fi routers out there. It is also able to build a complete 802.11 b/g/n/e/I Access Point. ESP32 supports Direct Wi-Fi as well.[5] Wi-Fi-Direct is a good peer-to-peer connection option without needing an access point.

Wi-Fi-Direct is easier to set up and the speed of data transmission is much higher than bluetooth. This could be used to configure projects based on ESP32 from a phone/ tablet that supports direct Wi-Fi.[7]

Semtech SX1278: The Semtech SX1278 is a low power long-range RF transceiver operating between 137 and 525 MHz. The system has an Rx sensitivity greater than -148 dBm and can transmit power up to +20 dBm.[8] It incorporates a LoRa long range modem that offers connectivity of the ultra-long-range spread spectrum and high sensitivity to interference while reducing current consumption. The transceiver is suitable for use in applications, such as, automatic meter reading, long-range irrigation network, building automation, wireless alarms, and protection systems. The radio also supports system high performance (G) FSK modes, like WMBus, IEEE802.15.4 g.

Whip antenna: The antenna used to transmit and receive the signal at the end nodes is TX868-JZ-5. It is a vertical, high antenna with an operating frequency of 868 MHz and a gain of 2 dBi. It has an interface of high quality and anti-oxidation coating.

Stage II

Arduino Nano: Based on ATmega328p (Arduino Nano V3.x)/ Atmega168 (Arduino Nano V3.x), Arduino Nano is a lightweight, compatible, scalable, and breadboard-friendly microcontroller board built by Arduino.cc in Italy.[9] It comes with the same features as with Arduino UNO, but very small in scale. It comes with a 5V operating voltage, but the input voltage may vary from 7–12 V.

Numerous functions are allocated to each of the digital and analog pins, but their key function is to be configured as input or output. When interfacing with sensors, they serve as input pins, but if you move a certain load then use them as output.

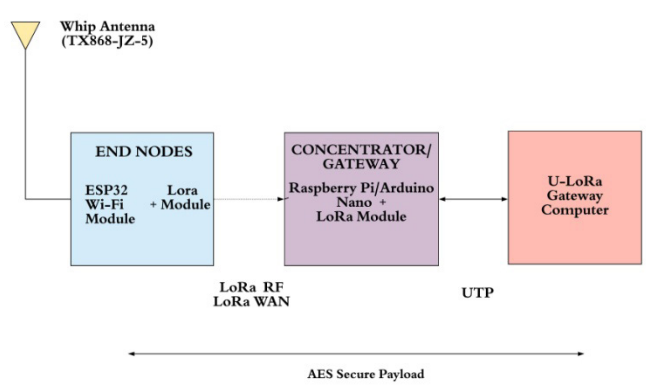

Figure 2: LoRa communication network

Raspberry Pi: The Raspberry Pi is a full-fledged mini machine, capable of doing something with a machine that you may be doing.[10] It comes with 4x USB, HDMI, LAN, built-in Bluetooth/ Wi-Fi support, 1 GB RAM, 1.2 GHz quad-core ARM CPU, 40 General Purpose Input Output (GPIO), and more.

Arduinos are perfect for basic tasks; however, Raspberry Pi processors will push the project automation to a different stage. Raspberry Pi's are low-cost microcomputers that have a high degree of processing power. The website of Raspberry Pi provides information about the different products available and guides users by setting up their computer. Also, the website offers a comprehensive list of projects that users can try with their app, which includes coding tutorials in different languages, such as, Python with Scratch. The website also offers a forum for users with specific queries, as well as, detailed product documentation and associated code. Raspberry Pi is for researchers a versatile and inexpensive computing device, and worth checking out. Step -by-step execution takes place as shown in Figure 3.

Implementation

End Nodes

In Figure 4, device A is ESP32, and device B is SX1278, which together form end nodes. These clusters of Wi-Fi modules will spread in the vicinity of the disaster as the first response

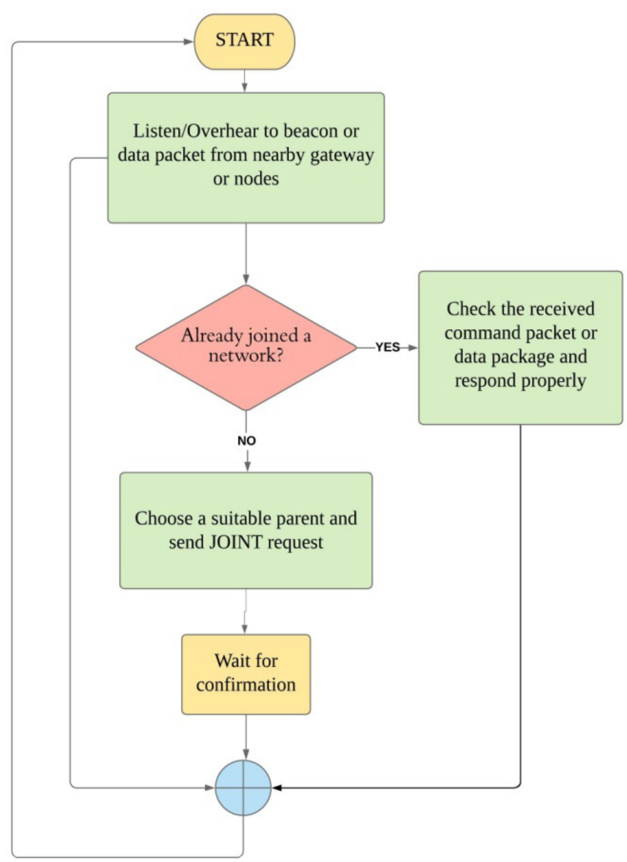

Figure 3: Flow chart

during a calamity. The spreading act would be carried out with the help of a rescue team, or it may already be installed in disaster-prone areas. As these nodes are temporary network providers/hotspots, any user can be connected to the network using a smartphone. Once a user is connected to the network, he/she can share critical information, such as, location, medical emergency fire, etc (Figure 5).

As information is filled and submitted, this is where LoRa comes into the picture. LoRa has a vast range of Wi-Fi, which helps in communication between nodes and gateway.

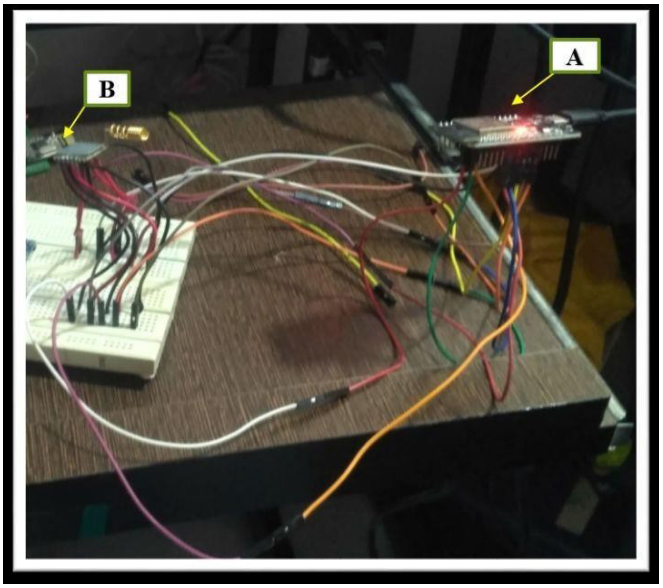

Figure 4: End node

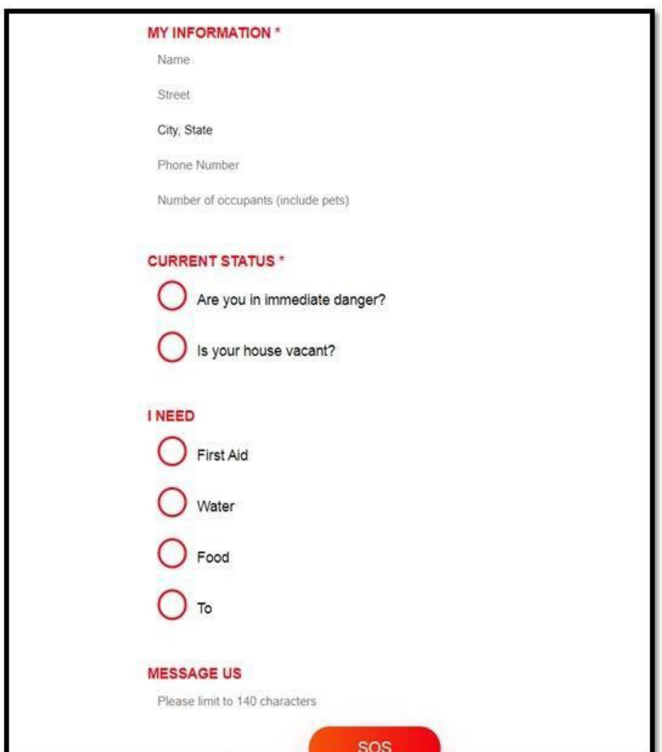

Figure 5: HTML interface

Gateway

The hardware setup shown in Figure 6 consists of Device D i.e Arduino Nano together with device C, i.e., SX1278 (LoRa module) forms a gateway. The data transferred from the end nodes is received at the gateway. The implemented gateway has the capability of 16/32 channels. Raspberry Pi/ Arduino Nano[7] and Semtech SX1278[6] are used in this section to increase channel handling capacity. The data received includes information about the victim, such as, location, message, etc. The data is also sent to the computer/ command center.

U-LoRa Gateway Computer

After obtaining the victim's data, the command center will track the person's exact location and take the appropriate action with the rescue team's assistance.

Results

End module parameters are shown in Table 2. The proposed LoRa module was tested by setting the output power level to +22 dBm and the Bandwidth (BW) to 125 kHz at different transmission distances. Two nodes stood 1-meter above ground. The transmitter sends the recipient 200 packets. These two nodes were tested with moving objects between them, a line of sight distances. This experiment tested Packet delivery ratio (PDR) of two nodes at different Spreading Factor (SF) settings, i.e., 9, 12. With SF = 9, the PDR

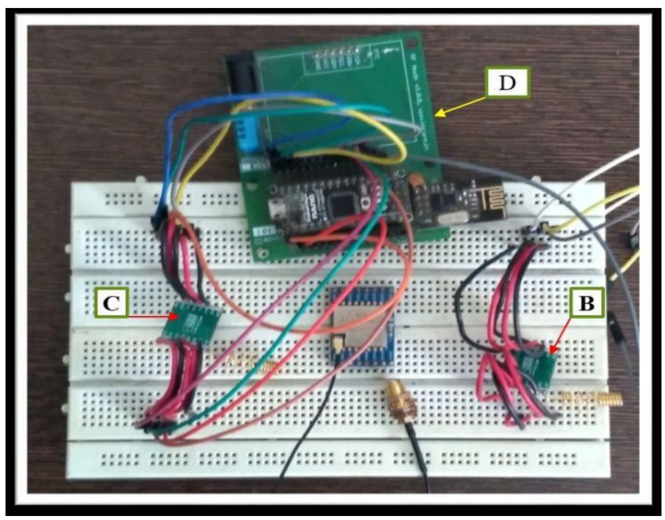

Figure 6: Gateway

Table 2: RFM95W analysis

Parameter	*RFM95W*
Frequency	868 MHz
Bit-rate	300 Kbps
Wi-Fi range	8/10 m
Power consumption	120 mA
Range	800 m
Packet delivery ratio	88.49%

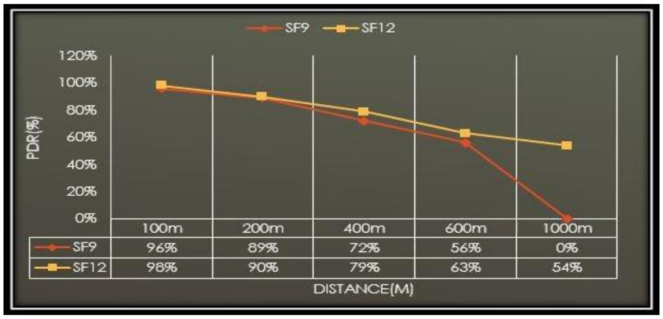

Figure 7: Graph of PDR *vs.* distance

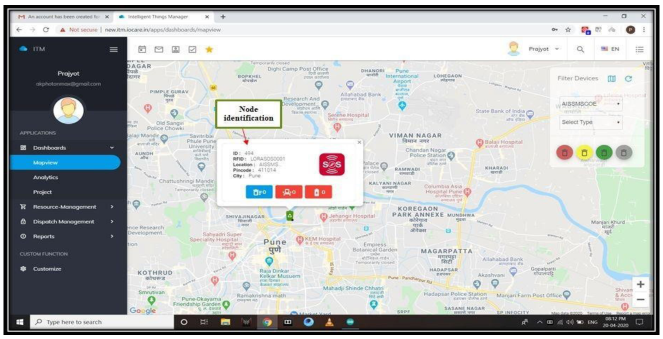

Figure 8: Result of node identification

was 96% at 100 meters and dropped to 0% at 1,000 meters. With SF = 12, the PDR was 98% at 100 meters, observably better than SF = 9. Even when the distance was extended to 1,000 meters, the PDR remained at 54%. This experiment confirmed that the transmission range and data delivery performance of large SFs can be increased, PDRs at BW = 125 kHz, particularly at SF = 9 on 100 meters. However, in both tests, the PDR of SF = 9 was still low compared with PDR at SF 12 settings. Although the PDRs were all almost 100% at SF settings from 9–12, the PDRs with SF = 9 ranged from 80 to 93%. as shown in Figure 7. We conclude that, if we want to increase the PDR, we should set the SF to a larger number and the BW to a smaller number. Eventually,the node placed at distant infrastructure was identified with the help of TTN(The Things Network) as shown in Figure 8.

Conclusion

This paper proposes LoRa's wireless mesh network system architecture collection of data from node modules, spread across a wide geographic region. LoRa is a long-range low-power telecommunication system for the "IoT." The physical layer uses the proprietary technology of LoRa modulation with a MAC protocol. LoRa WAN is an open standard with free-of-charge specification where intermediate devices forwarding end devices to a network server via an IP backhaul interface that allows for the larger performance. A LoRa deployment can have multiple gateways and more than one gateway can receive the same data packet. The current gateway is only a relay where it is linked to the fact that the packet sent by the devices has a destination address and there is no link between a device and a gateway. The only task to be dealt with by the gateways is the timing of the downlink message. The timing is accurate for the device to receive a message from its receiver window.

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