Team Protocol

LoRaWhere

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Abstract

In this modern era, the dominance of telecommunication technology has left a profound impact on various sectors, including industrial, security, transportation, and healthcare. With the rapid expansion of telecommunication, innovative solutions have emerged to address existing challenges, particularly in regions lacking cellular coverage. One critical issue that persists is the inability to establish effective communication beyond a certain distance from urban centers, posing significant challenges for numerous communities, such as fishermen and hikers. This research project aims to tackle this severe problem in the context of telecommunications for lifesaving by implementing a wireless communication protocol utilizing a specific frequency band.

❖ *Introduction*

The contemporary world relies heavily on telecommunication technologies, which have revolutionized multiple sectors. From enhancing industrial processes to bolstering security measures and improving healthcare services, telecommunication's influence is far-reaching. This technological evolution has led to the development of more effective solutions for a range of issues, with a particular focus on addressing communication gaps in areas lacking traditional cellular coverage.

One of the most pressing challenges stemming from this lack of coverage affects a significant portion of the global population: fishermen. Additionally, outdoor enthusiasts, including hikers, often find themselves in situations where they have limited or no means of communication, even in emergencies. This project aims to confront this critical issue by leveraging wireless communication protocols, specifically designed to operate within specific frequency band.

LoRa, short for "Long Range," stands out as a prominent low-power, wide-area network (LPWAN) communication system renowned for its long-distance transmission capabilities. In the context of coverage deficiencies, LoRa communication emerges as a frontline solution. Its appeal lies not only in its long-range communication capabilities but also in its low power consumption and secure data transmission features.

The primary objective of this project is to establish a robust communication network capable of covering remote areas, as mentioned earlier, and significantly enhance emergency services' effectiveness. This project delves into the methodologies, technologies, and strategies employed to achieve goals, providing a comprehensive overview of the project's significance and potential impact.

❖ *A Literature Review*

LoRa, AKA Long Range, is a remarkable communication technology specially recognized for its low energy consumption, extensive range, and suitability for low data rate applications. We explore the key features of LoRa and its wide-area network counterpart, Lora WAN, highlighting their unique advantages and applications.

1.1 *Long Range and Low Energy*

LoRa, as the name suggests, excels in providing long-range communication. In outdoor environments, it can reach distances of up to 50 kilometers, and even indoors, it can span hundreds of meters. This makes it an excellent choice for applications that require data transfer over vast areas while conserving energy. As well as this can be used for long-distance communication even in the sea.

1.2 *Operating Frequency Bands*

LoRa operates in lower ISM (Industrial, Scientific, and Medical) bands, which vary by region. In Europe, it uses 868 MHz and 433 MHz, while in the USA, it employs 915 MHz and 433 MHz frequencies. These frequencies are unlicensed, allowing LoRa to be used without the need for costly spectrum licenses.

1.3 *Key Features*

Spreading Spectrum:

A fundamental feature of LoRa is its use of Chirp Spread Spectrum (CSS) modulation. This technique spreads the signal across a broad range of frequencies, enabling multiple transmissions to occur concurrently without significant interference. Because spreading factors are orthogonal to each other and that prevent the distortion among multiple transmission at once.

Concurrent Transmission:

LoRa's unique spreading factors and time-division multiple access (TDMA) enable multiple devices to transmit data simultaneously, promoting efficient network utilization. According to the research paper, there are three classes of end device transmission. Class 1 transmits data through gateway whenever they want to transmit packets. Second class schedules the certain slot to transmit data and the other class continuously listens to the receiving path.

Carrier Frequency and Activity Detection:

LoRa devices are equipped with mechanisms to detect the presence of carrier signals and activity on the channel. This helps in coordinating transmissions and reducing collisions.

1.4 *Implementation on Various Platforms*

Research papers highlight that LoRa technology can be implemented on popular development boards like Arduino Uno and Mega, Raspberry Pi, Node MCU, and ESP 32. This adaptability makes it accessible to a wide range of developers and hobbyists. Importantly, LoRa's energy efficiency makes it an ideal choice for battery-operated devices. So, these devices can even be charged using solar power although the efficiency of solar power generation is low.

❖ *Why LoRa is an Ideal Emergency Communication Technique*

Advantages of LoRa, including long-range coverage, energy efficiency, and suitability for low data rates, make it an excellent choice for emergency communication. In crisis situations, where power sources may be limited and infrastructure damaged, LoRa devices can establish resilient connections over extensive distances. This ability to bridge communication gaps during emergencies highlights LoRa's importance as a robust and cost-effective solution for disaster management and public safety.

In conclusion, LoRa and Lora WAN stand out as versatile and effective communication technologies, offering a unique combination of long-range capability, low energy consumption, and concurrent transmission. These features, coupled with their adaptability and potential for emergency communication, position LoRa as a promising technology for a wide array of IoT applications, including those that address critical challenges in disaster response and public safety.

❖ *Problem*

In the worlds of fishing and hiking, safety is a pressing concern. Accidents at sea or in remote wilderness areas can quickly turn into life-threatening situations. The problem lies in the lack of accessible and affordable means to signal for help when trouble strikes.

- **Maritime Dangers**: Fishermen and maritime workers often face perilous conditions. Accidents like falling overboard or sudden weather changes can leave them isolated without a way to call for rescue.

- **Hiking Hazards**: Hikers and outdoor enthusiasts can get lost or injured in unfamiliar terrain. Without an easy and affordable distress signaling option, they are left vulnerable.

- **Accessibility and Cost**: Existing safety devices are often expensive and complex, making them inaccessible to many. This leaves a significant portion of the population exposed to potential life-threatening situations.

One of the most significant challenges facing individuals in distress at sea or in remote wilderness areas is the unreliability or complete absence of mobile connectivity. These are precisely the scenarios where our device proves invaluable.

In maritime regions far from the coast, or deep within the heart of untamed wilderness, traditional mobile networks frequently fail to provide any coverage. This lack of connectivity becomes especially concerning when considering the urgency of rescue operations. When accidents occur in these isolated areas, time is of the essence, and communication can be the difference between life and death.

This critical issue underscores the importance of a dedicated and independent communication solution, such as the device we are introducing. By operating outside the limitations of traditional mobile networks, this device serves as a reliable and self-contained means of signaling for rescue, bridging the gap when conventional communication methods fail. It ensures that, regardless of the remoteness of the location, individuals can reach out for assistance and access the help they urgently require.

❖ The communication procedure

Our proposed device " " serves as both a transmitter and a receiver. When it comes to an area with a desired network (built with custom-made switches), the device will automatically connect to one of these network modules by transmitting a broadcast message from time to time. When the person gets into trouble, he will press the button, which will trigger the active mode of the device, which will collect the information of the latitude and longitude of the current location via a GPS module and transmit it to the previously connected switch repeatedly using the LoRa protocol. After that, this packet will be directed to a base station through a predefined network route with multiple redundancies. After the base station receives the packet, they will review the coordinate details included in the packet and send an acknowledgement to the device to terminate the transmission.

Firstly, the device won't have any operational network addresses. The device is designed to transmit a broadcast message from time to time. So, when the device comes to the proposed network range, one of the implemented switches will receive this broadcasting message and send an acknowledgement to the device asking whether the device needs a network connection. When the device is revealed to multiple network switches in the area, it will receive multiple acknowledgements asking whether it needs to be assigned a network address. At this point, the device will choose the very first acknowledgment it receives and ignore the other packet receptions. This whole registration phase will be implemented as a three-way handshaking, which will assign a dynamic network address to the device for further communications with the network.

When the user is in danger, the device is brought to its active mode by pressing a button. At this point, the GPS module embedded in the circuit will collect the latitude and longitude coordinates of the current location, transform them into a bit stream, add a header containing the IP address of the device, and transmit them to its registered switch. This packet will be repeatedly sent to the switch at constant time intervals. When the packet is received by the switch, it will be directed to the base station through an optimum route decided by the LoRa communication protocol. After the base station receives the packet, it is decapsulated and reviewed by the application layer. After the review of the location coordinates by the relevant authorities, they will acknowledge the packet receipt and inform the application layer to send an acknowledgement to the IP address from which the packet was sent. This acknowledgement will be received by the end device, which will accept the acknowledgement. After initiating a three-way handshake, the device will terminate the packet transmission to the base station.

The whole network consists of end devices, base stations, and several intermediate switches. These switches are transceivers, which are capable of assigning IP addresses to newly connected devices and keeping records of those addresses. When a packet is received, it is directed on an optimum path according to the LoRa protocol. After realizing the uninhabited areas with no cellular coverage and analyzing their geographical surroundings, these switches are placed to provide maximum coverage. In mountainous areas, the switches can be easily located after realizing the geographical patterns of that area. But in the sea, it is quite challenging to prepare fixed locations to place the switches. For that, we propose to use lighthouses in those regions to place the switches. Those lighthouses will not be closely situated near the base stations. Each base station will be monitored by the relevant authorities to review incoming signals and take necessary precautions to mitigate the effects of unfortunate situations.

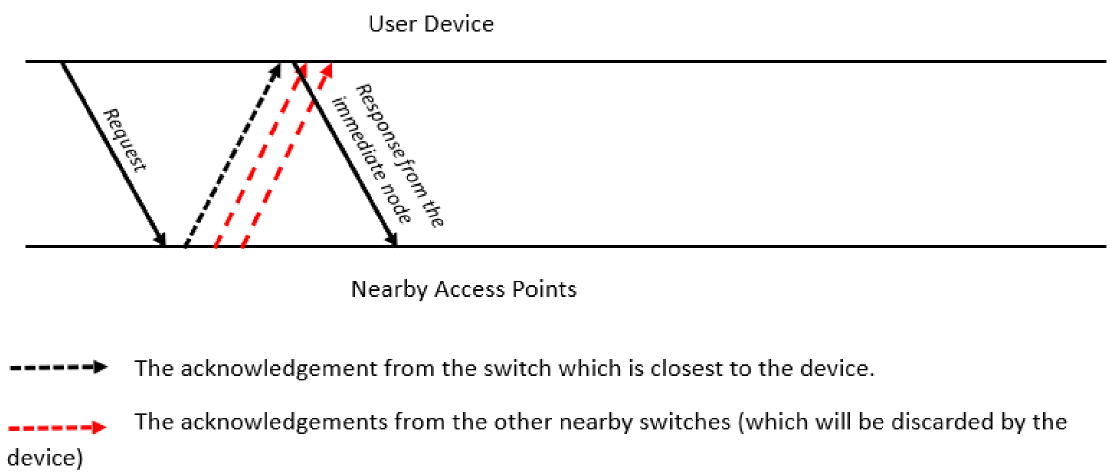


Figure 1:Identification Nodes

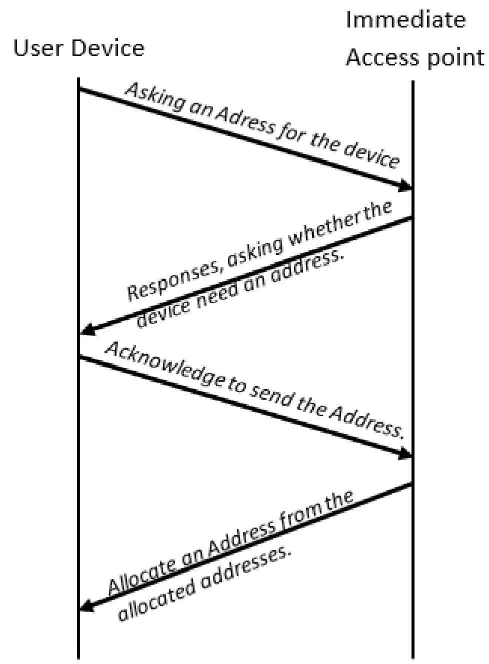


Figure 2:Setup Phase

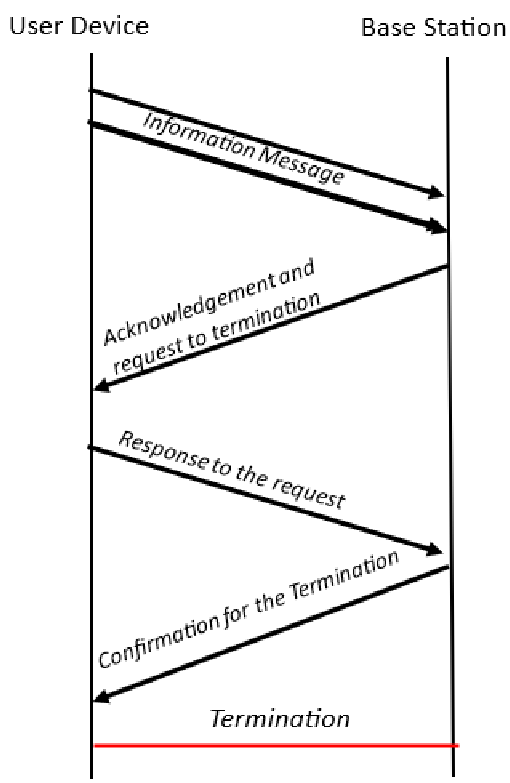


Figure 3:End to end communication.

❖ Functionality

BCON is a reprogrammable device that boasts a versatile capability: it can be programmed to operate as a source device utilized by individuals in distress or as a repeater strategically positioned in areas devoid of cellular connectivity. This ingenious approach allows us to extend the communication range of our device, making it even more effective in remote and challenging environments. This device comes with a programmable microcontroller (ESP32), antenna, power management circuitry, Lora communication, Wi-Fi and Bluetooth which makes this an ideal muti communication device that can be configured to fulfill different requirements at different places in the network. It can be configured as a small, embedded device at user side and detecting device at the base stations. Using the same module for different purposes makes it cost effective in production and provides more flexibility to users or organizations to customize the network in a way that it caters their requirements well.

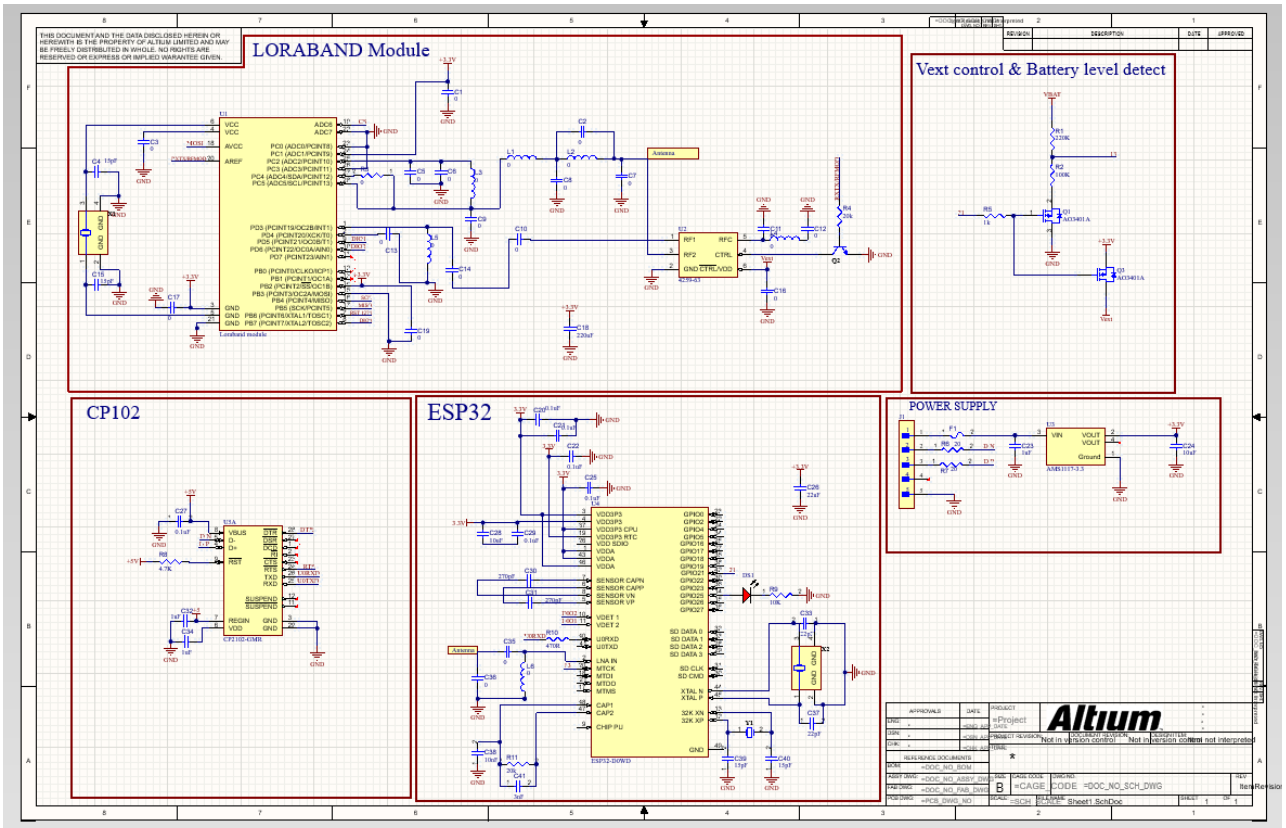
To illustrate, consider a scenario where we strategically place similar devices on buoys at sea or renowned hiking locations, areas notorious for their lack of reliable cellular coverage. In this setup, when an individual activates their BCON device to send an emergency signal, it can be intercepted and relayed by the devices already positioned in these strategic locations.

In essence, we can program the BCON device to function either as the source device used by the victim or as a repeater stationed at various key points. This capability enhances the device's effectiveness in bridging the communication gap between remote locations and the base station, ensuring that distress signals reach their destination even when conventional means of communication falter.

By programming and strategically placing multiple BCON devices at specific sites, we gain the ability to pinpoint the location of individuals in distress. This is achieved by meticulously mapping the time it takes for their distress signals to reach at least three BCON devices stationed in the vicinity.

In essence, when we deploy multiple BCON devices within a given area, we create a network that can triangulate the position of the person in need. By analyzing the precise arrival times of distress signals at these three or more BCON devices, we can calculate the victim's location with a high degree of accuracy. This innovative approach enhances our ability to respond swiftly and effectively to emergencies, providing crucial location information even in areas where traditional GPS or cellular tracking may be unreliable or unavailable.

Because our device is reprogrammable, we have the flexibility to determine how the victim's message is relayed and to confirm whether the base station has received it.



Schematic of the device

Enclosure of the device

❖ *Selection of a communication method*

Our selection of LORAWAN as the primary communication method for BCON is grounded in careful consideration of the following detail:

LORAWAN's exceptional long-range capabilities, reaching distances up to ten kilometers, are well-documented and validated through extensive field trials. This expansive coverage is pivotal for our device, particularly in scenarios such as maritime emergencies or remote wilderness situations where conventional networks falter due to limited infrastructure.

Additionally, LORAWAN's impressive energy efficiency has been quantified, showcasing a marked reduction in power consumption during data transmission, which directly translates to prolonged battery life—a critical factor when considering the often-limited power resources available during emergencies.

Furthermore, LORAWAN's cost-effectiveness is substantiated by numerous studies highlighting the affordability of its deployment and maintenance. This affordability aligns seamlessly with our commitment to providing a low-cost solution that transcends economic barriers, ensuring accessibility for a diverse range of users. The scalability of LORAWAN networks is well-documented, offering the capacity to expand coverage by deploying additional gateways and devices as needed, making it adaptable to varying user demands and geographical locations. LORAWAN's reputation for robustness and reliability is reinforced by real-world performance data, emphasizing its resilience even in harsh environmental conditions.

In summary, our data-driven choice of LORAWAN for our device's communication method underscores its proven long-range capabilities, energy efficiency, cost-effectiveness, scalability, reliability, and security. These attributes together affirm LORAWAN as the optimal choice to facilitate dependable, affordable, and secure emergency communications, bridging the gap between individuals in distress and the help they urgently require, whether they are at sea or in the wilderness.

After thorough evaluation of various LORAWAN modules, our choice has landed on the **SX1276 137 MHz to 1020 MHz Low Power Long Range Transceiver.**

This module boasts an impressive array of special features that make it a standout choice for our device. It incorporates a LoRaTM Modem, offering exceptional long-range communication capabilities. With a remarkable maximum link budget of 168 dB, it ensures reliable connectivity even over considerable distances. The high-efficiency power amplifier (+14 dBm) optimizes power usage while maintaining signal strength. Notably, its high sensitivity, reaching down to -148 dBm, ensures that even weak signals are captured effectively. Furthermore, its low RX current of 9.9 mA and ultra-low standby power consumption (200 nA register retention) maximize energy efficiency. With built-in temperature sensing and low battery indication, it offers robust monitoring capabilities, ensuring reliable and efficient operation.

❖ *Future Enhancements for the Project*

For this project, the following enhancements will be applied.

- ✓ Energy Harvesting using wind power and other available energy resources, at the transceivers.
- ✓ Adaptive power modulation under various environmental conditions using self-harvested energy.
- ✓ Implementing the transceiver devices on the ships and make them empowered with the relevant communication technology to use in emergency situations.

In implementing the transceivers at the lighthouses and other possible various locations, we can combine some self-power generating method with that device and let the device generate energy sufficient for the core operations itself. Several research shows that the average wind power generated at the sea surface is 1.1 TW considering a one average regional area. So, we have more than sufficient energy to be used for the transceivers.

> As of 2022, the total worldwide offshore wind power nameplate capacity was 64.3 gigawatt (GW).[3] China (49%), the United Kingdom (22%), and Germany (13%) account for more than 75% of the global installed capacity.[3] The 1.2 GW Hornsea Project One in the United Kingdom was the world's largest offshore wind farm.[4] Other projects in the planning stage include Dogger Bank in the United Kingdom at 4.8 GW, and Greater Changhua in Taiwan at 2.4 GW.[5]

Figure 4: Resources by Wikipedia.

Along with energy harvesting we can use that generated power in the situations under conditions like bad weather like storm or something like that, because the channel can be severely under bad conditions and the transmissions might get erroneous or terminated. So, we can transmit the data with added extra power so that the data would be protected from the bad channel conditions. This would be a self-generated power consumption for the transceiver not only in the bad conditions but also in average cases as well.

To further improve the density of the transceivers and the reliability of communication, we propose to implement these devices on ships as well. So, in any situation if the propagation delays lower when the transmission is between the mobile user and the ship than the transmission between the user and another transceiver implemented at another location. So, when data arrive at the ship, transceiver implemented in it transmit the corresponding data packets to the nearest coastal guard or the other responsible parties. Therefore, this would improve the reliability of the communication and the device density in one unit area.