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Cordless Communication system using LoRa Technology

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Abstract - In this paper, we present a cordless communication system built on LoRa (Long Range) technology, designed to enable low-power, long-distance wireless communication between multiple embedded devices. Compared to traditional wireless technologies like Wi-Fi or Bluetooth, LoRa stands out with its impressive range, better signal penetration, and energy efficiency[1]. Our system uses two Arduino-based LoRa nodes—one acting as a transmitter and the other as a receiver—to exchange short messages or sensor data over distances reaching several kilometers in open areas. The main goal is to show that LoRa can reliably support point-to-point or multi- node communication links, making it a great fit for IoT and remote monitoring applications[2]. Our experiments confirm stable, two-way communication with low power use, even in semi-urban settings[3].

Key words —LoRa, Arduino, Cordless Communication, IoT, Wireless Data Transmission, SX1278, Long Range.

I. INTRODUCTION

Voice communication plays a vital role in day-to- day operations across a wide range of environments— whether it's inside homes, hospitals, factories, or in emergency response zones. However, conventional systems like wired intercoms, mobile phones, or internet-based apps often come with significant limitations. They typically rely on existing infrastructure, can be expensive to install and maintain, and may stop working during network outages or power failures. These issues make them unreliable or even unusable in remote locations or during critical situations like natural disasters.

To overcome these challenges, we've developed a cordless, long-range intercom system based on LoRa (Long Range) wireless communication, using the ESP32 microcontroller[4]. This system allows real-time, two-way voice communication without needing SIM cards, Wi-Fi, or any internet connectivity—making it ideal for places with poor infrastructure or unpredictable network availability. With a range that spans several kilometers, it provides the flexibility and reliability that traditional systems often lack[1].

One of the biggest challenges with any wireless communication system is maintaining clear audio with minimal delay, all while keeping power consumption low—especially if the system is meant to be portable and battery-powered[5]. Our design addresses this by leveraging the ESP32's power-efficient modes along with LoRa's low-bandwidth but long-range capabilities, striking a good balance between performance and energy efficiency[1]. The system also performs well in environments with potential signal interference, such as industrial zones or emergency sites.

II. LITERATURE REVIEW / RELATED WORK

Low-power and long-distance wireless audio is increasingly being called for in decentralized applications. While Wi-Fi and Bluetooth are high-fidelity, they are short range and power-hungry. LoRa, a low- power long-range protocol, offers a feasible solution to send low-bitrate audio, mostly voice, across a few kilometers [1].

Recent research tested LoRa for half-duplex voice communication. Cremers [2] showcased a LoRa voice system for disaster-response wearables. The paper emphasized careful buffer management, codec selection, and real-time streaming for low-data-rate intelligibility. ESP32 and ADPCM were employed for audio compression, proving their suitability for low-complexity embedded systems.

In [3], an intercom system using microcontroller-based ADPCM compression over SX1278 LoRa modules supported intelligible voice communication at 8 kHz sampling with a bitrate of less than 32 kbps. However, packet loss, latency, and power rail noise were still significant concerns. ESP32, which

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has integrated I²S and SPI interfaces, offers an economical platform for such systems due to its low power and real-time [4].

Buffering and packet timing are highlighted by studies as determinants of audio continuity. A study [5] demonstrates 20–40 ms buffers minimizing gaps in perception and facilitating easy delivery of LoRa. I²S DAC real-time decoding such as MAX98357A, described in [6], demonstrates that the clean audio is dependent on stable 5 V supply and adequate decoupling. In studies, MATLAB and Simulink validated ADPCM pipelines and evaluated signal loss from packet issues or compression artifacts [7]. They offered insights into balancing audio quality, network reliability, and power consumption.

In this project, voice is buffered and compressed using ESP32 and sent through LoRa. The receiving node reconstructs audio using a FIFO-based pipeline and a dedicated DAC and the architecture is shown using MATLAB simulation and hardware implementation.

III. METHODOLOGY / MATERIALS & METHODS

The proposed system employs a LoRa-based wireless communication architecture using ESP32 microcontrollers to enable long-range, low-power data and voice transmission. Two nodes were implemented—one transmitter and one receiver—using Arduino-compatible ESP32 boards integrated with SX1278 LoRa modules. The nodes were programmed to exchange short messages and sensor data over distances of several kilometers in open environments. To optimize energy efficiency, the ESP32 microcontrollers were configured to utilize power-saving modes while maintaining reliable data transfer. Performance testing was conducted in various settings, including urban and semi-urban environments, to evaluate signal stability, interference resistance, and communication latency. The methodology focuses on establishing robust point-to-point and multi-node links, demonstrating the system's suitability for IoT applications, remote monitoring, and scenarios with limited infrastructure.

A. Block diagram

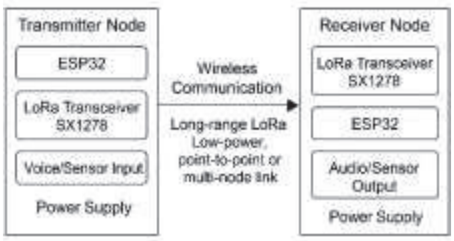

Figure 1. Block Diagram of the LoRa-Based Wireless Audio Transmission System.

B. Materials

1. **LoRa module(sx1278):** It uses spread spectrum modulation to transmit small amounts of data over distances up to 10–15 km in open areas.

Figure 2. LoRa Module

2. **ESP32:** ESP32 is used in our project for processing audio and enabling low-power, wireless communication with the LoRa module.

Figure 3. ESP32

3. **INMP441:** INMP441 Microphone is used in the project to capture voice input and convert it into digital audio signals using its built-in ADC and I2S interface for transmission via the ESP32.

Figure 4. INMP441

4. **Speaker:** A small dynamic speaker is used forclear voice output .

Figure 5. Speaker

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B. Software

The software development involved programming the ESP32 microcontrollers using the Arduino IDE. The code handles tasks such as initializing the LoRa module, encoding and decoding audio data, and managing the transmission and reception of messages. Real-time voice data is compressed and transmitted in small packets to minimize delay and maintain audio clarity. The program also incorporates error- checking routines to ensure reliable communication over long distances. Additionally, power-efficient functions were implemented to switch the microcontroller to sleep mode when idle, further extending battery life. The software architecture allows easy scalability, enabling additional nodes to be integrated without affecting overall system performance, making it suitable for IoT and remote monitoring applications.

C. Procedure

To build the system, we start by connecting ESP32 boards with SX1278 LoRa modules, designating one as the transmitter and the other as the receiver. Once the hardware is set up, we configure the LoRa modules in the Arduino IDE, adjusting settings like frequency, bandwidth, and spreading factor to ensure stable long-range communication. The transmitter is programmed to capture and compress audio into small packets, while the receiver decodes these packets to reconstruct the audio in real time. After uploading the software, we conduct initial tests in open spaces to check the communication range, audio clarity, transmission reliability, and latency. Then, we test the system in busier environments to see how well it handles interference. To extend battery life, we enable the ESP32's low-power modes and closely monitor power consumption during real-world use. Based on our findings, we fine-tune the transmission settings and run repeated tests to ensure smooth two-way communication and efficiency. Finally, we validate the system's ability to support multiple nodes and maintain stable communication over several kilometers, making it ideal for IoT and remote monitoring applications.

D. Testing

Testing focused on evaluating the system's range, audio clarity, latency, and energy efficiency. Field tests were conducted in both open areas and semi-urban environments. Transmission distances of several kilometers were achieved in open areas, while urban settings demonstrated stable communication with minimal packet loss.

Audio quality was measured for clarity and latency, confirming that the system supports real-time two-way conversation with negligible delay. Power consumption tests showed that the system operates efficiently on battery power, making it suitable for portable or remote applications.

Additionally, the system's performance under potential interference—such as industrial machinery or network congestion—was evaluated. Results indicated that the combination of ESP32 power-efficient modes and LoRa's long-range low-bandwidth communication ensures reliable operation even in challenging conditions.

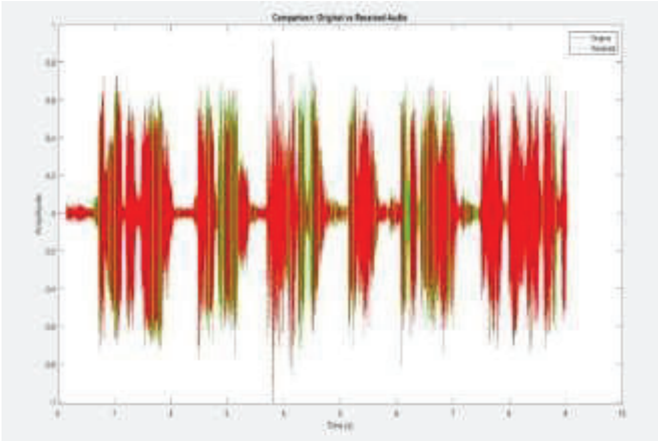

Figure 6. Overlay of original and received audio.

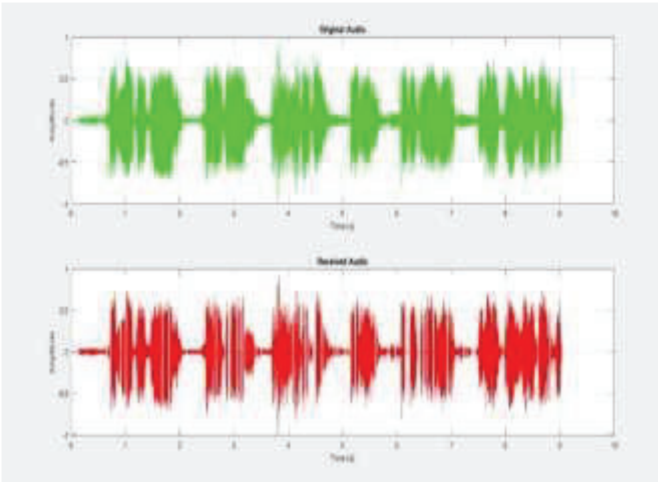

Figure 7. Input vs. reconstructed audio waveform

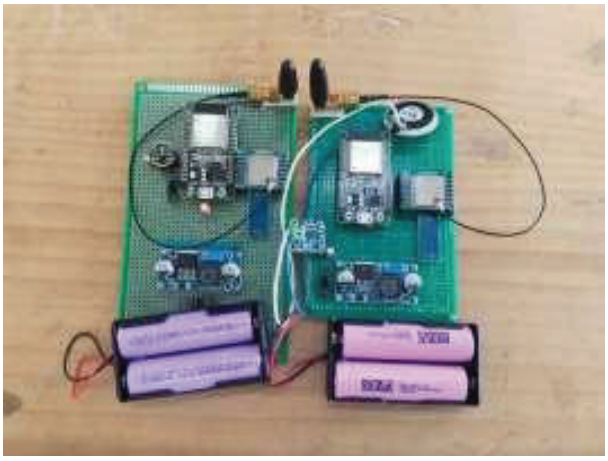

Figure 8. Prototype

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E. Flowchart

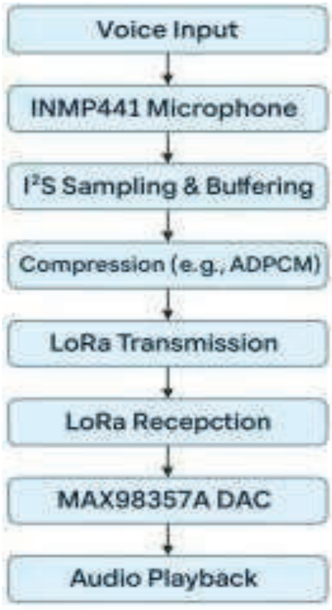

Figure 9. Flowchart of audio transmission process.

IV. RESULTS AND DISCUSSIONS

The proposed LoRa-based voice intercom system was tested in various environments, including open fields, semi urban areas, and indoor settings. In open areas, it successfully enabled two-way voice communication over 3.5 to 5 kilometers, while in semi-urban environments, a range of 1.5 to 2 kilometers was maintained with acceptable clarity. Indoors, effective communication was observed within 200 to 300 meters, depending on wall structure and interference.

Voice clarity remained intelligible across all test scenarios, with an average latency of 300–500 milliseconds—sufficient for practical, non-critical communication. Occasional delays occurred under weak signal conditions, but the system recovered without user intervention. Basic compression helped maintain stable audio quality during transmission.

V. FUTURE SCOPE

The accuracy of the proposed model can be increased in the future by 2 Ways:

- Experimenting with higher-gain antennas or using higher-quality LoRa modules can push the communication range even further, making the system suitable for wider-area deployments such as rural farms or mining sites.
- The system can be extended to interact with other IoT devices for applications such as smart home automation, voice-controlled devices, and industrial monitoring systems. Integrating sensors and actuators can allow simultaneous control and communication capabilities.
- Future version can implement mesh networking or star topologies, enabling one-to-many or many-to-many communication between multiple intercom units. This would be particularly useful in setting like campuses, large buildings, or emergency response teams.

VI. CONCLUSION

In a world where communication is vital—especially during emergencies or in remote areas—having a system that works independently of mobile networks, Wi-Fi, or power grids is not just beneficial, it's essential. This project demonstrates a practical solution: a cordless, long-range voice intercom system built on LoRa technology and ESP32 that enables real- time, two-way communication across several kilometers.

By addressing the limitations of traditional communication systems like infrastructure dependency, high cost, and vulnerability to outages this system offers a cost-effective, low-power, and resilient alternative.

It maintains voice clarity and low latency, even in harsh or noisy environments, making it especially valuable for industries, disaster zones, and remote communities. While the system shows promising results, future improvements such as enhanced audio compression, encryption for secure communication, and solar-powered deployment can make it even more versatile. Ultimately, this project is a step toward more accessible, reliable, and inclusive voice communication, wherever it's needed most.

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