Voice Communication over Meshtastic Networks

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***Abstract*—Voice communication is essential in post-disaster scenarios where users may be unable to type due to injury, stress, or environmental constraints. While Meshtastic provides a decentralized LoRa-based mesh network for long-range messaging, it does not natively support voice and is limited by low data rates and strict regulatory duty-cycle requirements. This paper investigates two methods for enabling voice over such networks: waveform-based audio packetization and a semantic speech-to-text (STT) / text-to-speech (TTS) approach. Preliminary experimental evaluations demonstrate that waveform-based methods, even when using low-bitrate codecs like Codec2, are impractical for urgent communication; delivering a 3-second voice message requires hundreds of packets and several minutes due to transmission latency and duty-cycle constraints. In contrast, the proposed offline STT/TTS method transcribes speech locally, transmits it as a standard text payload, typically in a single packet and reconstructs the audio at the receiver. This semantic approach reduces delivery time from minutes to seconds, while maintaining high reliability and regulatory compliance. The study concludes that semantic communication is the most viable solution for voice interaction in bandwidth-constrained LoRa mesh environments.**

***Index Terms*—Meshtastic, LoRa, Voice, STT, TTS**

I. Introduction

Communication methods that are simple and fast to use are critical in disaster situations. Voice communication is particularly valuable when victims or responders cannot type messages due to injury, stress, or environmental constraints. Equally important are alternative means of communication in post-disaster scenarios where public communications infrastructure may be damaged.

Meshtastic is an open-source communication platform that enables long-range messaging using LongRange (LoRa) radios. Devices form a decentralized mesh network where packets are forwarded between nodes without requiring cellular or internet connectivity [1].

As shown in Fig. 1, mobile user devices such as smartphones or laptops connect to Meshtastic nodes through Bluetooth or serial interfaces which act as gateways that exchange packets among themselves over the mesh network, enabling long-range communication in license-free frequency bands.

The system supports short text messages with payload sizes of approximately 255 bytes. Devices operate under region-specific radio configurations that define channel bandwidth, spreading factors (SF), and transmit power [2]. Regulatory duty-cycle constraints for license-free frequency bands also prevent nodes from continuous transmission, significantly affecting the feasibility of transmitting large volumes or continuous streams of data such as voice over the network.

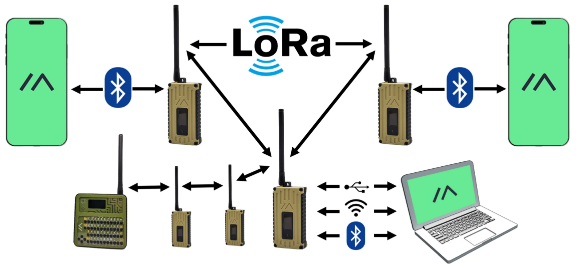

Fig. 1. Interaction between user devices and Meshtastic nodes. Mobile phones and laptops connect to LoRa nodes via Bluetooth or serial interfaces, enabling message transmission over the decentralized LoRa mesh network.

Typical uses of Meshtastic include disaster recovery support, messaging and location tracking in areas without cellular coverage by hikers and explorers and location tracking of children by their families during outings. It is also becoming a popular technology for low-power, wide-area (LPWA) Internet of Things (IoT) applications.

The main contribution of our work is to investigate how Meshtastic with its technical and regulatory limitations may be extended for two-way voice communication, as typically required between victims and rescue operators in a post-disaster situation.

II. Literature Review

Cremers [3] explores LoRa-based bidirectional voice communication systems for rescue applications, highlighting both feasibility and severe bandwidth limitations.

Practical implementations of audio transmission over the Meshtastic platform have also been demonstrated using chunk-based packetization approaches [4]. The paper presents proof-of-concept audio transmission over Meshtastic using a chunk-based packetization approach, where raw PCM audio is compressed, encoded, and divided into size-constrained packets to satisfy the 255-byte payload limitation of Meshtastic. The processed audio data is then sequentially transmitted over the mesh network for end-to-end delivery. On reception, incoming packets are buffered and reassembled based on their chunk identifiers to reconstruct the original encoded payload. The

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reconstructed data is then Base64-decoded, decompressed, and parsed to recover the original PCM audio stream, as a *.wav* file. The overall architecture in [4] is summarized in Fig. 2 and Fig. 3.

Fig. 2. Transmitting end flow in [4]

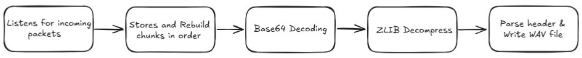

Fig. 3. Receiving end flow in [4]

In addition, low-bitrate speech codecs have been proposed to improve speech quality while reducing transmission time [5].

Recent work has explored efficient on-device speech synthesis models capable of running locally without cloud connectivity [6]. In addition, semantic communication approaches that transmit linguistic information instead of waveform data have been proposed for bandwidth-constrained networks [7], [8]. These works motivate the voice communication approaches investigated in this paper.

III. Preliminary Experiment Design

In Test Round 1, we reproduced and evaluated the proof-of-concept in [4] under real Meshtastic network conditions. These experiments follow Fig. 2 and Fig. 3.

Motivated by the findings in [3], our **Test Round 2** extends the proof-of-concept by integrating the Codec2 low-bitrate speech codec. The experiment repeated the same setup used in Test Round 1 while evaluating the impact of Codec2 compression on transmission performance.

In **Test Round 3**, inspired by semantic communication concepts [7], [8], as an alternative to waveform transmission, a semantic voice communication approach using Speech-to-Text (STT) and Text-to-Speech (TTS) is evaluated. In this approach, a user records voice through the Meshtastic mobile application connected to a device via Bluetooth. The recorded speech is transcribed locally into text and transmitted as a standard Meshtastic message. At the receiver, the text message is converted back to audio using an offline TTS engine. The overall architecture of this experiment is shown in Fig. 4.

Two STT approaches were evaluated. Cloud-based transcription using Google APIs was rejected because it requires internet connectivity and is unsuitable for disaster scenarios. Instead, the Android *SpeechRecognizer* API was used for offline transcription. The voice input is converted locally into text, transmitted with a voice identifier flag [VR], and reconstructed at the receiver using an on-device TTS engine.

The above preliminary experiments were conducted using two Meshtastic nodes communicating directly over a LoRa link. The following configuration was used throughout all experiments.

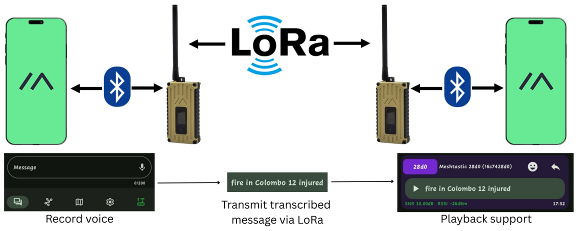

Fig. 4. Offline STT/TTS integration within Meshtastic mobile application enabling fully off-grid voice interaction.

- Device Type: Heltec LoRa V3
- Device Config: CLIENT
- Region: EU 868 MHz
- Spreading Factor: SF12 (Long Fast)

The proof-of-concept implementation allows several compression and packetization parameters to be configured from its built-in user interface as shown in Fig. 5. In particular, the *zlib* compression level can be adjusted between *Low*, *Very Low*, and *Ultra Low*. Additionally, the audio payload can be divided into different packet sizes (*Small*, *Medium*, and *Large*) to satisfy the Meshtastic payload constraint.

Experiments were performed by varying the node separation d, compression level, and chunk size using these controls. Approximately 3-second voice messages were transmitted for each configuration to observe packet delivery reliability and transmission latency.

Fig. 5. Experimental setup consisting of two Meshtastic nodes communicating directly over a LoRa link while transmitting voice messages generated by the proof-of-concept application.

IV. Preliminary Results

A. Test Round 1

Table I summarizes the results obtained from the first experimental evaluation using two Meshtastic nodes.

TABLE I
AUDIO TRANSMISSION TEST RESULTS AT DIFFERENT DISTANCES AND COMPRESSION SETTINGS FOR A APPROXIMATE 3 SECOND VOICE MESSAGE

Distance	**Compression**	**Chunk**	**Received Without Loss?**	**Time to Receive**
2m	Low	Small	Yes	14 min
2m	Very Low	Small	Yes	10 min
2m	Ultra Low	Small	Yes but not intelligible	2 min
2m	Low	Medium	No	Payload too big
2m	Low	Large	No	Payload too big
80m	Low	Small	Yes	12 min
80m	Very Low	Small	Yes	9 min
80m	Ultra Low	Small	Yes but not intelligible	3 min
150m	Low	Small	No	Some chunks were missing

The results show that successful transmission is possible when small chunk sizes are used together with higher compression levels. However, increasing the chunk size beyond the payload limit results in transmission failure. Additionally, increasing the communication distance introduces packet loss, which prevents successful reconstruction of the original audio message.

B. *Test Round 2*

Table II summarizes the results obtained from experiments conducted using two Meshtastic nodes. The same experimental configuration used in Test Round 1 was applied, with the addition of Codec2 compression.

TABLE II
AUDIO TRANSMISSION TEST RESULTS FOR A APPROXIMATE 3 SECOND VOICE MESSAGE - WITH CODEC2 COMPRESSED

Distance	**Compression**	**Chunk**	**Received Without Loss?**	**Time to Receive**
2m	Low	Small	Yes	11 min
2m	Very Low	Small	Yes	8 min
2m	Ultra Low	Small	Yes but not intelligible	1 min
2m	Low	Medium	No	Payload too big

The introduction of the Codec2 low-bitrate speech codec improves transmission efficiency compared to the original implementation. The results indicate that higher compression levels reduce the total transmission time while maintaining successful packet delivery, although aggressive compression may significantly degrade audio quality.

C. *Chunk Reception Behavior*

While reproducing the proof-of-concept, chunk reception behavior was observed. A voice message typically contains several kilobytes of data and must therefore be divided into hundreds of packets due to Meshtastic payload limitations. For example, a 3-second message using very-low compression required nearly 380 chunks. Missing chunks prevent correct reconstruction of the original audio message. This behavior was observed when nodes were placed approximately 150 m apart, where partial packet reception resulted in incomplete message reconstruction. Figures 6 and 7 illustrate successful and failed chunk reception cases.

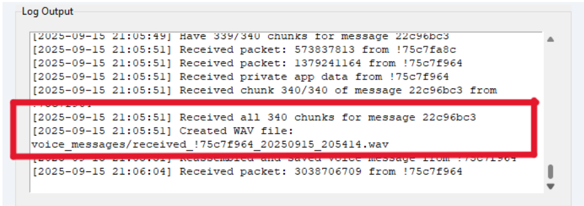

Fig. 6. Successful full chunk reception.

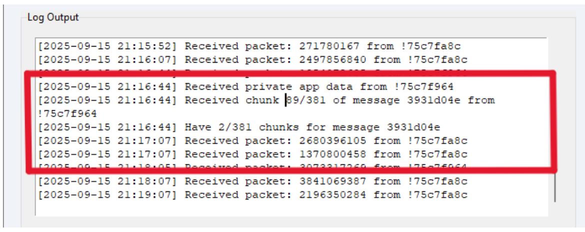

Fig. 7. Partial chunk reception causing incomplete reconstruction.

D. *Regulatory Constraint Impact*

European Union's (EU) LoRa regulations impose:

$$T_{silence} = 99 \times T_{transmit} \quad (1)$$

This indicates that only 1% of the time may be used for transmission, while the remaining 99% must remain idle. Similar duty cycle restrictions exist in other parts of the world except in the US, where full channel occupancy is allowed. To evaluate the effect of the duty cycle, transmission time for a 3-second voice message was evaluated using simulations based on the Meshtastic Python utilities with several codec configurations. The results are shown in Fig. 8.

These results confirm the observations from Test Round 2. Even with Codec2 compression, transmitting a 3-second voice message requires approximately one minute under unrestricted transmission. When the EU duty-cycle constraint is applied, the transmission time increases significantly.

Although the 1% duty-cycle regulation primarily applies to LoRaWAN networks [9], Meshtastic also follows regional radio constraints [2]. Even considering the less restrictive 10% duty cycle, a transmission time of several minutes for a short voice message is unsuitable for urgent disaster communication. Therefore, waveform-based voice transmission is considered impractical.

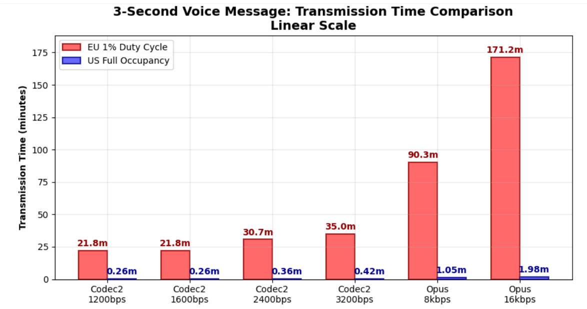

Fig. 8. Transmission time comparison for a 3-second voice message under EU 1% duty-cycle and unrestricted scenarios.

E. Test Round 3

Test Round 3 was conducted using two mobile devices running the updated Meshtastic Android application with offline STT and TTS support, each connected to a Meshtastic node with the same experimental configuration used in Test Round 1.

Although precise *Time-to-Receive* measurements were not recorded, practical observations showed that voice messages were delivered with playback support within a few seconds, representing a significant reduction in latency compared to waveform-based transmission.

F. Performance Comparison

Table III summarizes the performance differences between waveform-based transmission and the proposed STT/TTS approach when deployed over the Meshtastic network.

TABLE III
VOICE TRANSMISSION METHOD COMPARISON

Metric	Waveform-Based	STT/TTS-Based
3 s Message Latency	Several minutes	Few seconds
Message Size	Large (KB–MB scale)	Very small (text payload)
Number of Chunks	Hundreds	Typically single packet
Regulatory Compliance	Limited	High
Off-grid Operation	Yes	Yes
Network Congestion	Severe	Negligible
Scalability	Poor	High

The results show that waveform-based transmission is inefficient for LoRa mesh networks. Even with compression such as Codec2, short voice messages require hundreds of packets and several minutes for delivery. Duty-cycle restrictions further increase transmission latency.

The STT/TTS approach transmits only the semantic content of speech as a short text message. Since the payload size is very small, most messages are delivered in a single packet, reducing latency and network congestion.

V. Discussion

LoRa mesh networks are inherently designed for low-data-rate communication. Transmitting waveform-level audio conflicts with packet size limitations and duty-cycle regulations. This work evaluated the feasibility of enabling voice communication over the Meshtastic networks. Experimental results show that waveform-based voice transmission is impractical under the constraints as it becomes unreliable when the number of packets increases. Even small packet losses result in incomplete message reconstruction. Further, the time taken for transmission is unacceptably long.

In contrast, the STT/TTS-based semantic approach significantly reduces communication overhead and enables faster and more reliable message delivery. This is true despite the duty-cycle restriction. Therefore, from this preliminary investigation, we are able to establish that semantic-level communication is a practical solution for interactive voice communication in Meshtastic, although non-verbal cues such as emotional tone and environmental sounds are not preserved during transmission.

VI. Future Work

Future work will focus on semantic voice communication over Meshtastic and further improvements.

The experiments have been so far conducted using only two nodes and relatively short communication distances. Larger multi-hop deployments may introduce additional latency and packet loss effects that require further evaluation.

Further, we envisage lightweight semantic communication techniques that preserve essential contextual information while maintaining low transmission overhead [7], [8].

In addition, efficient on-device speech synthesis models [6] could be explored to further improve the quality and responsiveness of offline text-to-speech generation within the Meshtastic mobile application.

Intelligent network management, such as SDN-assisted routing and adaptive data rate control may further improve reliability and scalability in voice-enabled Meshtastic networks.

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