

ImOK: A Civilian Emergency Messaging Framework

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Abstract—One of the first actions survivors take after a disaster strikes is to try to contact their families and friends to let them know their status. However, a disaster can wipe out or severely impact commercial communication infrastructure, making it impossible for people to communicate. This paper introduces a low-cost, low-bandwidth messaging framework called ImOK that integrates a user-friendly Wi-Fi captive portal with amateur radio-based communication. ImOK enables users to connect to a local Wi-Fi hotspot and submit short messages to a server, which are then encoded, and transmitted over amateur radio frequencies. A receiving station then decodes the messages and deliver them to recipients via an email gateway. We have implemented and tested a prototype that demonstrates the viability of the ImOK framework. By leveraging low-cost hardware, open source software and amateur radio technologies, this work demonstrates a practical approach to enabling communication during disasters, specifically to support emergency messaging when conventional communication infrastructure is unavailable.

Index Terms—Amateur radio, Emergency communications, Automatic Packet Reporting System (APRS)

I. INTRODUCTION

In the aftermath of a disaster, whether caused by nature or humans, one of the first things survivors typically do is attempt to contact friends and family to let them know that they are safe. For example, after the Great East Japan Earthquake (March 11, 2013), NTT DOCOMO reported that voice traffic spiked 50 - 60 times greater than normal [1]. However, in many crises, communication infrastructure is significantly disrupted or unavailable at precisely the moment when its need is greatest. Natural disasters such as hurricanes, floods, and earthquakes can destroy cellular and power infrastructure, while man-made events such as terrorist attacks can overwhelm or congest existing networks. Survivors are left without reliable means of communication and communities are isolated at the time of disaster.

In Puerto Rico, the devastation caused to the island's communication and power infrastructure by Hurricane Maria (September 2017) highlights the seriousness of this problem. According to FEMA reports [2] [3], over 95% of cellular sites were destroyed and most of Puerto Rico's residents did

not have power for several months. Despite the lack of fuel and hazardous driving conditions, many residents drove great distances in search of one of the few operating cell towers, just so they could let loved ones know that they were okay [4]

More recently, floods caused by Hurricane Helene (2024) destroyed almost three-quarters of cell sites [5] and destroyed 1,700 miles of fiber optic cables [6]. In this communication void, amateur radio became a vital lifeline for communication. Radio operator Thomas Witherspoon distributed handheld radios and enabled community-level messaging for needs like supplies and urgent care [7]. This amateur radio network facilitated essential communication across communities in North Carolina, carrying messages ranging from urgent medical needs to notes reassuring family that loved ones were safe.

During events such as the September 11 attacks, network congestion and infrastructure strain hindered individuals' ability to contact others, even when physical systems remained partially intact [8]. Similarly, immediately after the Boston Marathon Bombings [9] [10], local cellular sites were overly congested and people were unable to make calls or send text messages. Network congestion remains a significant challenge during more recent disasters as well. The scale of this problem was evident during the 2017, 2018, and 2019 California wildfires, where network congestion was estimated to have affected nearly two million customers and produced approximately 15 million blocked calls [11].

Our goal is to demonstrate the viability of using low-cost / low-distance (Wi-Fi) and low-bandwidth / high-distance (amateur radio) technologies to enable civilian messaging when commercial infrastructure is not available. Much of the current work in emergency communications focuses on contacting emergency services to ask for help or supplies. Our framework, called *ImOK*¹, empowers disaster-stricken communities to be able to stay connected with loved ones in the absence of communication infrastructure.

¹An abbreviation of *I am okay*

To illustrate the utility of the ImOK framework, consider the aftermath of a disaster in which cellular networks and internet access are disrupted across the affected region. In these conditions, individuals may be unable to contact loved ones, leaving their safety and well-being uncertain. In response, a local amateur radio operator deploys a temporary communication bridge that advertises messaging services using Wi-Fi, as shown in Figure 1. Individuals connect to the Wi-Fi hotspot to compose messages (email or SMS). The messages are then translated to a digital amateur radio mode. In a local scenario,

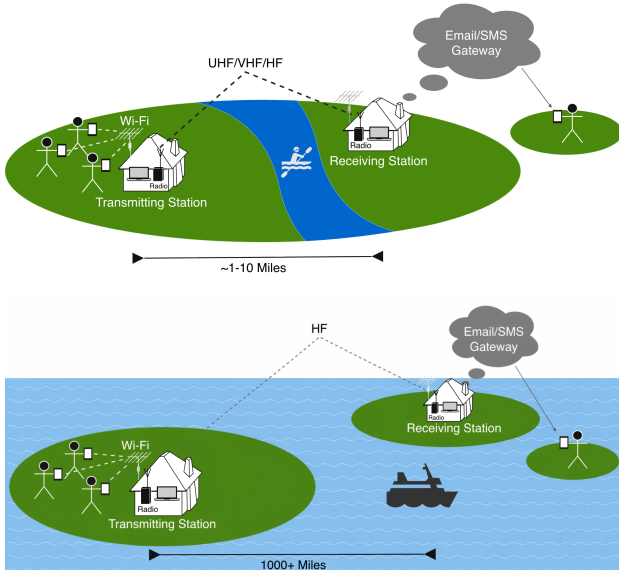


Fig. 1. Use Cases: Short range (top) vs. Long range (bottom) messaging

these messages may be transmitted over short distances to a nearby receiving station with internet access. This station might be on the order of tens of miles away and outside the most severely affected area. From there, messages can be delivered through available communication channels, allowing individuals to connect with loved ones in neighboring areas. In a longer-range scenario, messages may either be relayed over multiple radio links or transmitted directly over a single link and travel hundreds or even thousands of miles to reach a receiving station in an unaffected area. From there, messages can be delivered via email or text to recipients anywhere in the world. In both cases, individuals are able to communicate their status without relying on conventional communication infrastructure, restoring a critical form of connection during emergencies.

II. RELATED WORK

Traditional amateur radio messaging systems such as ARRL radiograms [12] demonstrate long-distance communication without centralized infrastructure, but rely on paper-based transcriptions of messages, which can introduce delays and

potential for transcription error. Raspberry Pi-based platforms [13] and [14] demonstrate how affordable hardware and amateur radio can send messages, but either lack full end-to-end delivery or have steep learning curves for untrained users. ROGER [15] focuses on emergency coordination for authorities rather than civilians. The ClusterDuck Protocol [16] and RNode [17] approaches provide off-grid mesh networking over extended distances. However, ClusterDuck is constrained by limited communication range, and RNode only supports one user at a time, creating bottlenecks. Satellite messaging, for example on iPhone [18], often imposes device compatibility restrictions or paywalls [19]. Facebook Safety Check [20] depends entirely on internet access, making it unusable when networks are down.

Overall, no existing solution combines multi-user, off-grid messaging with easy, smartphone-based access without reliance on subscriptions or current infrastructure. This paper addresses shortcomings of previous works by demonstrating an end-to-end system enabling civilian communications during disasters.

III. APPROACH

The ImOK framework is designed to enable communication in environments where commercial communication infrastructure is unavailable or severely limited. The framework enables users to send short status messages (e.g., *I'm OK*) using commonly available consumer devices, bridging local Wi-Fi networks with long-range radio communication and eventual internet-based email delivery.

At a high level, the framework utilizes low-cost consumer-grade technologies, amateur radio infrastructure, and open source software. Users connect to a local wireless Wi-Fi access point, submit messages via captive portal interface [21], and have those messages transmitted over amateur radio frequencies to a receiving amateur station with internet connectivity. This receiving station then forwards the message to the intended recipient via communication channels like email or even SMS.

Communication Background and Concepts

To understand the design of ImOK, several foundational concepts in networking and radio communication are outlined.

Captive Portal Interfaces: A captive portal is a network access mechanism commonly used in airports, campuses, etc., where users are automatically redirected to a web page upon connecting to a Wi-Fi network. The web page requires user to enter personal details such as an email address to gain access to the Wi-Fi network. ImOK uses a captive portal to present a message submission interface without requiring users to manually navigate to a specific IP address and the captive portal serves as the primary user interface for message input.

Amateur Radio Communication: Amateur radio is a decentralized communication system that allows licensed operators to transmit signals over specific radio frequencies and bands. Unlike cellular or internet-based systems, amateur radio operates independently of centralized infrastructure, making it particularly useful in emergency or off-grid scenarios.

Frequency ranges include Ultra High Frequency (UHF), Very High Frequency (VHF), and High Frequency (HF). These frequency bands differ in their propagation characteristics and typical communication distances. UHF (300-3000 MHz) and VHF (30-300 MHz) are commonly used for short to medium range communication with line-of-sight propagation. The typical distance ranges from a few kilometers to tens of kilometers under normal conditions. With favorable conditions or elevated antennas, this range can be extended further. In contrast, HF (3-30 MHz) supports long-distance communication through ionospheric propagation, where signals bounce off the ionosphere and travel hundreds to thousands of kilometers. This enables communication across regions or between continents without requiring intermediate infrastructure.

Transmission on amateur radio frequencies requires a valid license issued by a regulatory authority. In the United States, amateur radio licenses are divided into Technician, General, and Amateur Extra [22]. Each level grants increasing privileges, such as access to additional frequency bands and greater transmission capabilities.

Digital Communication Modes: In addition to voice communication, amateur radio supports digital communication modes that encode structured data into audio signals. These signals are transmitted over radio frequencies and decoded by receiving systems. Protocols such as Automatic Packet Reporting System (APRS) enable short message transmission in low-bandwidth environments [23]. Other digital modes, such as JS8Call, as well as analog techniques like continuous wave (CW), are other methods for communication under constrained conditions. JS8Call provides reliable long-distance messaging under weak signal conditions [24]. CW uses Morse code to transmit information with minimal bandwidth and power.

Figure 2 presents a high-level view of the ImOK framework. A user interacts with the system through a smartphone connected to a local Wi-Fi hotspot. The user submits their desired message and recipient via the captive portal. The transmitting station collects, queues and processes the submitted message for radio transmission. The message is then sent over the appropriate amateur radio frequency to a receiving station. The receiving station captures the transmission, processes the message, and forwards it through internet-based services to the intended recipient.

ImOK Framework Design

The ImOK framework emphasizes the separation between three major stages of the system: local user access, radio-based

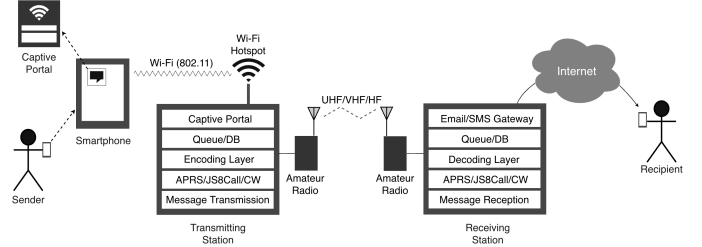


Fig. 2. ImOK Framework Design

message transport, and internet-based delivery. At the local access layer, the system uses familiar consumer technologies such as smartphones, Wi-Fi, and captive portals to simplify user interaction. At the transport layer, amateur radio enables communication without direct dependence on cellular or internet infrastructure. At the delivery layer, an internet-connected receiving station transports the received message to standard digital services such as email.

Overall, this combines accessible local networking with radio-based transport to provide end-to-end communication in constrained environments. Overall, the approach is designed to support multiple radio frequencies and communication modes, rather than being limited to a single protocol. Depending on the deployment scenario, the system can operate across different frequency bands, including UHF/VHF for short-range communication and HF for long-distance transmission, as well as across multiple communication modes such as APRS, JS8Call, and continuous wave (CW).

IV. AN IMOK PROTOTYPE

To demonstrate the viability of the ImOK framework, we have implemented a fully operational prototype. The prototype is composed of two primary components: a transmitting station and a receiving station. The transmitting station performs message collection, encoding, and radio transmission. The receiving station performs radio reception, message decoding, processing, and final delivery via email.

The transmitting station is implemented on a Raspberry Pi, as shown in Figure 3.

A Wi-Fi hotspot provides access to the open source Splines Raspi Captive Portal [25]; the local DHCP and DNS service automatically assigns IP addresses and redirects HTTP requests to a locally hosted portal page that includes form input containers for the recipient email address and message content, as shown in Figure 4. The captive portal facilitates ease of message collection. No knowledge of the device's IP address is required and the captive portal is the only visible component of the system to end users. As a result, this presents a simple, user-friendly, and intuitive user interface.

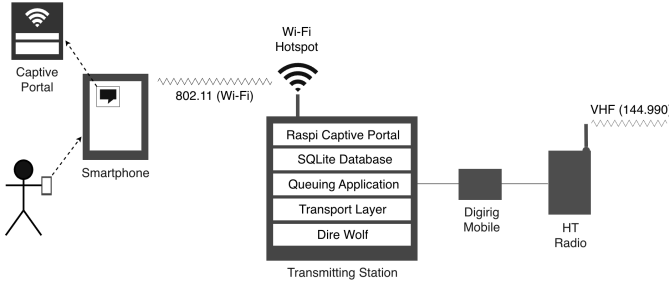


Fig. 3. Transmitting Station

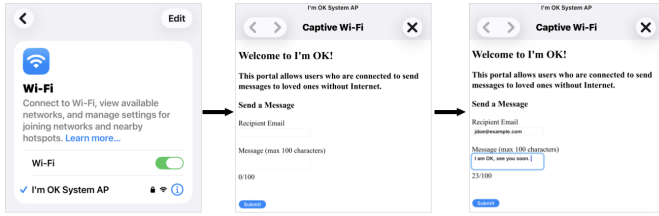


Fig. 4. Captive Portal User Interface

The transmitting station hosts a backend service that accepts user messages, stores them in a local SQLite database, and queues them for processing. The backend formats each message as an APRS payload, decomposes messages into fragments, and encodes the data as AX.25/KISS frames. Dire Wolf is a software terminal node controller (TNC) for transmission [26]. It accepts the KISS frames from the backend, modulates the APRS data into an audio signal, controls the radio's push-to-talk function, and sends the audio to the radio through the Digirig interface [27]. The Digirig converts the digital audio into an analog waveform, which the handheld radio transceiver then transmits over VHF. This system sends packets directly to a dedicated receiving station, which decodes, reassembles, and forwards for email delivery.

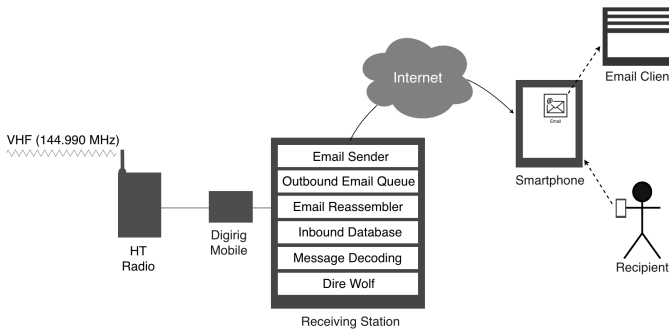


Fig. 5. Receiving Station

The receiving station, shown on Figure 5, is implemented using a radio, a Digirig interface, and a computing device that is connected to the internet. Processing begins with

packet decoding in Dire Wolf and progresses through message parsing, storage, reassembly, queuing, and final email delivery via the Gmail API. The receiving station is responsible for processing incoming APRS transmissions and completing message delivery. It uses Dire Wolf to capture and decode incoming transmissions. A backend processing service stores received transmissions and reconstructs messages that may have been split across multiple APRS packets. Once a message has been decoded, it is added to a queue for delivery. Queued messages are then retrieved, formatted into MIME-compatible email format, and forwarded to an email delivery service. The Gmail API is used to send the final message to the intended recipient over the internet.

Summary End-to-End Messaging Pipeline

To summarize, the following outlines the end-to-end workflow of ImOK, highlighting how data moves between components from submission to final delivery:

- 1) A user connects to the Raspberry Pi's Wi-Fi hotspot. The captive portal displays a message submission form. The user enters the recipient email address and message.
- 2) The submission is sent to the server on the transmitting station.
- 3) The server validates the input and stores the message into a local database.
- 4) The message is stored with a pending status, forming the sending-side transmission queue.
- 5) A worker process retrieves the message and formats it into one or more APRS packets.
- 6) The payload is embedded in AX.25 frames, encapsulated using KISS, and transmitted via radio.
- 7) On the receiving station, Dire Wolf decodes the incoming APRS packet.
- 8) The system parses the decoded packets, extracts message fragments, and reassembles into the original message.
- 9) The reconstructed message is stored in a local database and the message is queued for delivery.
- 10) A worker processes retrieves the queued message and formats it as an email.
- 11) The email is sent to the recipient via the internet using the Gmail API.

V. RESULTS AND DISCUSSION

To evaluate the ImOK prototype, we performed the following tests:

- 1) bench testing under short-range conditions; and
- 2) longer-distance transmission with 2 meter receiving antenna.

Bench testing was conducted with the transmitting and receiving stations placed approximately 10 feet apart. As shown in Figure 6, the transmitting station included a Quansheng UV-K6 handheld transceiver (HT) and was flashed with the

TABLE I
BENCH TESTS

Test Name	Number of messages	Interval (seconds)	Size (characters)	Fragments
Short Messages	10	2	20	1
Medium Messages	10	2	80	2
Long Messages	10	2	140	4
Burst Load	10	1	10	1
Heavier Burst	20	1	10	1
Count of 50 Burst	50	1	10	1
Count of 100 Burst	100	1	10	1

Egzumer v0.22 firmware [28]. Power was set to 1 to 2 watts and a stock antenna was used. The radio was connected to a Raspberry Pi 5 running on Bookworm OS through a Digirig Mobile as the digital mode interface.

On the receiving station, the equipment included a Baofeng UV-5R HT using the out-of-box firmware. Power was 1 to 2 watts. The HT was connected to a Macbook Pro running on an Apple M4 Pro chip via a Digirig Mobile as the digital modes interface. We conducted several tests under different

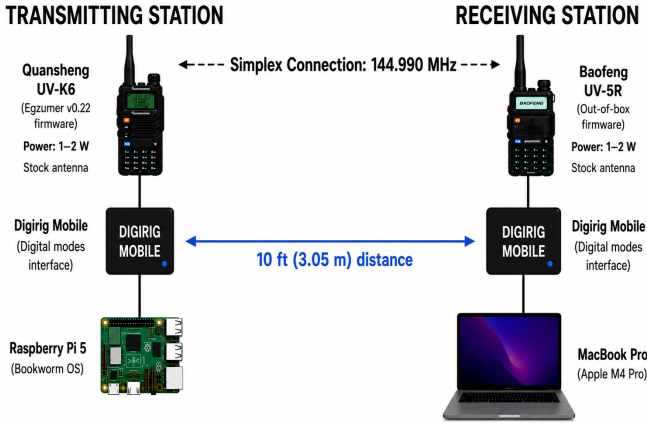


Fig. 6. Bench Testing Equipment

loads, as shown in Table I. All test categories achieved 100% end-to-end completion rate, with the exception of the highest-load scenario (100-message burst), which achieved 99% completion.

The single failure observed in the 100-message burst test occurred despite all messages being successfully recorded in the transmission-side database, indicating that the loss happened during radio transmission or reception rather than message generation or queuing.

We also performed several field tests using a mobile transmitting station configuration and fixed receiving station configuration. As shown in Figure 7, the transmitting station was a Quansheng UV-K6 handheld transceiver (HT), flashed with the Egzumer firmware [28], and configured to transmit at 4 to 5 watts. A TWAYRDIO RH770 SMA-Female Telescopic antenna was used. The Quansheng HT is connected to a Raspberry Pi 5 (Bookworm OS) using a Digirig interface.

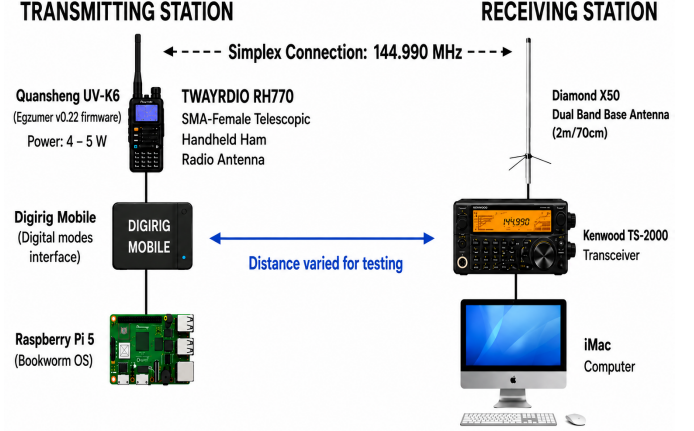


Fig. 7. Distance Testing Equipment

On the receiving station, the equipment used was a Kenwood TS-2000 transceiver that is connected to an iMac computer. The Kenwood transceiver is connected to a Diamond X50 Dual Band Base Antenna (2 meter/ 70 centimeter) and mounted on the roof of Jadwin Hall. The roof is about 60 feet above ground level on the campus of Princeton University and sits at about 125 feet above sea level.

We created a testing agent (in Python) that runs on a laptop and connects to the transmitting station Wi-Fi hotspot. The agent is used to emulate multiple users accessing the transmitting station to send short messages. The testing agent is able to programmatically access the captive portal message interface and is configured to send 25 random length messages at 10 second intervals with message sizes varying from 20 characters to 140 characters. Varying the message length allows us to test ImOK with different message fragments, which must be created on the testing station and reassembled in the receiving station:

- Messages sizes of 20 - 35 characters require 1 fragment
- Messages sizes of 36 - 70 characters require 2 fragments
- Messages sizes of 71 - 105 characters require 3 fragments
- Messages sizes of 106 - 140 characters require 4 fragments

An example of a randomly generated email, which has been successfully delivered, is shown in Figure 8.

The Quansheng HT and the Kenwood TS-2000 were each set to operate on a 2 meter VHF band using the frequency

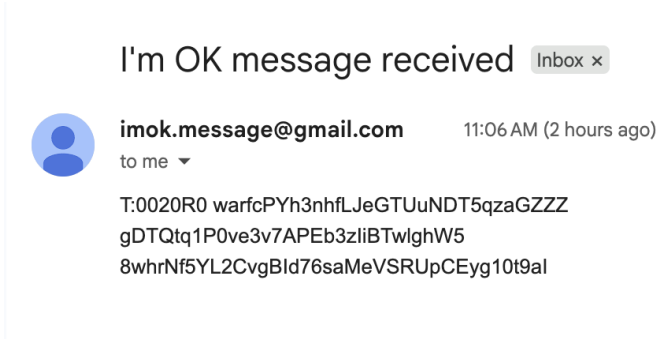


Fig. 8. Example test email message

144.990 MHz. Before conducting any experiments, we ensured the frequency was clear of any existing communication between amateur radio operators.

To demonstrate the viability of the ImOK framework, we traveled to several arbitrary locations and executed the test agent, as described. The results are shown in Table II.

TABLE II
DISTANCE TESTS

Distance Tx-Rx (miles)	Messages sent	Messages received
0.9	25	25
1.0	25	25
2.8	25	25
3.3	25	25
4.0	25	0

Our preliminary results show that ImOK can transport and deliver email using amateur radio bands, albeit over short distances. This essentially demonstrates use case in the top of Figure 1. However, there are a few factors that impact these tests.

First, we used the 2-meter VHF band (i.e., 144.990 MHz) with a portable HT configured for 4-5 watts. Having a portable device is useful for quickly setting up and deploying the test environment. However, portable HTs have the tradeoff of limited transmission power. In addition, the 2 meter band is generally limited to line of sight. Therefore, it is not surprising that for distances over 4 miles, this band is not adequate enough. In the future, we plan to utilize radios with higher power. We also intend to utilize different bands and digital modes that can support longer range communication.

Second, ideal testing conditions would include sending hundreds or thousands of messages to evaluate the system. However, for these tests, we used the Gmail API mail delivery service. This service restricts the number of emails that can be transmitted during a 24 hour period to 500 messages. Because actual emergency scenarios may require significantly higher message volumes, future implementations will use more scalable email delivery services that are less restricted.

Our test results show that the system is capable of reliably transmitting and reconstructing messages under controlled conditions. The use of message fragmentation allows the system to handle larger message sizes. Additionally, the use of queue-based processing allows the system to maintain consistent operation even when packets are delayed or out-of-order.

VI. CONCLUSION AND RECOMMENDATIONS

The goal of ImOK is to address the urgent human need for communication when conventional communication infrastructure fails. This can be due to natural or man-made disasters that shut down conventional communication channels. As discussed in the introduction, disaster survivors almost instinctively seek to confirm their safety and reassure loved ones. While amateur radio can assist in emergencies, its direct use requires specialized knowledge and is not easily accessible to the general public. In the aftermath of a disaster, ImOK is not intended to replace a cellular network. Instead, its primary use is to enable survivors to notify loved ones of their status until cellular infrastructure can be restored.

To address this issue, we presented and evaluated ImOK, a civilian emergency messaging framework that combines local Wi-Fi access, low-cost computing, amateur radio communication, and open-source software. The system demonstrates an end-to-end pipeline for sending messages when conventional communication infrastructure is unavailable. The sending-side architecture provides an intuitive messaging platform, while also handling message persistence, fragmentation, and packet generation. The receiving-side architecture decodes the radio transmissions, reconstructs fragmented messages, and delivers them via the Gmail API. These components together form a store-and-forward system that tolerates intermittent connectivity and asynchronous communication.

While we demonstrated that we can reliably deliver email over amateur radio frequency, one serious limitation concerns distance. Enabling messaging between stations separated by few miles can certainly be beneficial in some emergency situations. However, we would like to support much larger distances, over hundreds or even thousands of miles. To achieve this objective, we are confident that the ImOK framework can be extended to support various HF bands, such as a 10 meter and 17 meter, 40 meter bands.

There are certainly other limitations that need to be investigated and addressed. APRS imposes strict payload constraints that require fragmentation and increased transmission time for longer messages. System performance is also influenced by environmental factors such as signal quality and distance. Additionally, the current implementation relies on a single receiving station for final delivery.

Future work can extend this system in several ways. Additional transport protocols such as JS8Call or other digital modes could be integrated through the modular transport layer

to improve reliability under weak signal conditions. JS8Call is of particular interest due to its capability for long-range text communication over HF bands, enabling transmissions across thousands of miles. One significant tradeoff of JS8Call is that due to its design it takes longer (than APRS) to transmit messages. Another possibility is to use CW (morse code) as a means of transmitting text-based messages.

An *intelligent transport multiplexer* would allow ImOK to examine current atmospheric conditions and weather conditions, distance requirements, etc., and automatically select the most appropriate transport frequency and protocol. This would offer great flexibility to ImOK operators.

Additionally, the current system relies on a single receiving station to perform message processing and email delivery, which limits scalability. Supporting multiple receiving stations or alternative transport mechanisms could distribute processing and reduce this bottleneck. Integrating other digital modes may also help address this limitation by enabling more flexible routing and delivery paths.

After developing and evaluating more comprehensive support of additional frequencies and operating modes, we envision making ImOK ready for use to the broader ham radio community. Additionally, we believe partnering with emergency agencies could be beneficial to help further test and eventually deploy ImOK. For example, the IEEE MOVE (Mobile Outreach using Volunteer Engagement) program deploys volunteer teams equipped with communications and power infrastructure to support communities affected by natural disasters [29]. Incorporating ImOK into these deployments could help support civilian messaging during a disaster. In addition, engaging with organizations like IEEE MOVE would provide valuable insight into how ImOK could be integrated into existing response operations and the practical limitations of operating in disaster environments.

Finally, incorporating message acknowledgment mechanisms and refining the user interface would improve both usability and delivery reliability. This would additionally provide users with greater confidence that messages have been successfully transmitted and received.

In conclusion, ImOK demonstrates that it is possible to make communication more accessible to the general public after disasters wipe out commercial communication infrastructure. The system enables individuals to send simple *I'm OK* messages without requiring internet connectivity or specialized expertise. In situations where uncertainty and feelings of isolation are high, the ImOK system helps individuals reconnect with others when it matters most. Our work to date provides a solid foundation for this mode of emergency communications. We expect our continued work in this area will lead to an even more robust solution.

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