



RelayRescue: The Offline Emergency Network

¹Harshali Raundal, ²Vaibhav Pawar, ³Smt. Y.D. Salunke

¹Research Scholar, ²Research Scholar, ³Assistant Professor and Research Guide

Department of Computer Science, K.A.A.N.M.S College, Satana

Abstract

RelayRescue is an Android application designed to provide a method of communication in instances when cell towers and the internet are unavailable. RelayRescue uses Wi-Fi Direct and Bluetooth to form a device-to-device mesh network via direct connections. This network can then be used to send SOS messages across multiple devices, transmit messaging, and transmit location data.

The app had a big SOS button for instant alert activation, and most interestingly, offline APK sharing. This allows the application to be shared as peer to peer, in the near future (ad-hoc network), to multiply the nodes of the network. All communications are end-to-end encrypted. It has power optimization also.

RelayRescue enables robust communication in simulated disaster scenarios, with 10-20 devices communicating over distances of about 100-200 meters over 4 to 6 hops. Compared to existing systems, the app emphasizes ease of use for end users while also supporting natural growth of the network through peer-to-peer propagation. RelayRescue can provide resilient, infrastructure-free mobile communication service to continue community resilience.

Keywords: Emergency mesh networking, Wi-Fi Direct, Bluetooth, Peer-to-peer, Disaster response

1 Introduction

Natural or manmade disasters—the big earthquakes, floods, hurricanes, and wildfires—share a single common trait: the systematic destruction of the communications infrastructure in the affected area. Cell towers are knocked out or overwhelmed, fiber optic cables are cut, and internet links are disrupted—and when people need to reach emergency services or friends and family the most, their phones are rendered useless.

The implications of this communication blackout are devastating. It blocks any effort of rescue or coordination of help and induces panic and chaos among the devastated populations. Being able to say “I’m here,” “I’m OK,” or “Please help” can be crucial. It is vital to develop a communications system entirely airdeliverable and independent of the terrestrial infrastructure that can be immediately set up and use the one tool that 99.9% of the population is already carrying: the smartphone.

Modern phones contain a wide range of wireless radios, including Bluetooth and Wi-Fi Direct. While we generally use Wi-Fi to connect to the Internet, Wi-Fi Direct allows two devices to connect directly without an access point or other router. Bluetooth works in a similar fashion with a far lower power requirement, but over shorter distances. The basic principle of this project is to use the two technologies to form a flexible, robust “wireless mesh network” (WMN). Essentially, this means that each phone in the system acts as both a user host and a data relay point in the network. If one phone can’t talk directly to another, it can route the message around, hopping from one device to another. This will provide a network to connect far more phones than Wi-Fi or Bluetooth can reach.

The problem that I will focus on for this project is the absolute failure of existing emergency networks and applications. Almost every disaster application that exists—whether it be government alerts or just high-profile messaging applications—is completely reliant on an active and functioning internet connection. The second, there is no network, they’re a bunch of dead icons—and as far as the user is concerned, functionality is completely absent. While Android phones have had Wi-Fi Direct and Bluetooth, both of which could be used to create a mesh network, for over ten years, no major emergency application has figured out how to set up a sustainable, intuitive mesh, specifically for an emergency where things like “please don’t spam” and “can I leave?” are crucial to the network working, and the network needs to be flexible despite the time of day or the angles of the sky.

This project suggests developing and introducing RelayRescue, an Android application that will be used to overcome the above limitation. RelayRescue will be a hybrid communication platform intelligently exploiting Wi-Fi Direct for bandwidth and power-hungry data transfers and Bluetooth for low-power device discovery and communication. The main features of the application will be

One-Tap SOS Alert: A visually distinct, prominent button that will automatically send a high-priority distress signal with location information over the entire mesh network.

Multi-Hop Text Messaging: Ability to forward traffic in the mesh and to contain broadcast messages to all users. If I want to draft a message to a user directly. Will automatically route between devices that are between two users.

Loop Prevention with TTL (Time-to-Live): TTL of each message will be attached and reduced by 1 at each hop. Messages with a TTL equal to 0 will be ignored, so the message will be susceptible to network flooding.

End-to-end encryption will be used so that all private messages will be encrypted to prevent other devices (like the ones relaying the message) from viewing the message.

Offline APK Sharing: Critical for network resiliency, this feature enables an already installed app to transmit the APK (installation file) to a new nearby device that does not have the app installed and does so in a peer-to-peer manner, allowing the network to snowball on the ground without requiring an internet connection.

Battery Optimization: Background services used to discover peers will be optimized in order to not consume much of the precious battery power.

This project has defined its parameters. This application will be written and developed for the Android Operating System version 21 to inform us of the development being for mobile smartphones and tablets running this version of the OS or greater—this now encompasses most current Android hardware. Secondly, the testing environment will primarily be tested on a simulated disaster by the use of 10 to 20 mobile devices in close radiated range (up to 00 meters).

Of course, this project is limited by its many assumptions and challenges. A mesh network thrives on high node density, and, depending on how many devices participate in it and how they are dispersed over the mesh, it is quite likely that it will be poor most times. If the number of devices are too few, the mesh will be broken into several disconnected sub-meshes; messages cannot go beyond them. Another limitation is that this project will be highly platform-specific; it will not be able to communicate with a bunch of iOS devices, which face a whole new set of connectivity limitations. To summarize, this project is most definitely the beginning of a long journey that involves structural intricacies of routing, interference, device heterogeneity, and real-world limitations that would require huge refinements of research assumptions and idealism.

2 Related Work

Smartphone-Based Ad Hoc and Mesh Systems

Several systems use Wi-Fi Direct and Bluetooth to build mobile ad hoc networks (MANETs) among survivors' smartphones. **Conecta2** forms ad hoc networks over Wi-Fi Direct or Bluetooth, enabling the exchange of text, photos, audio, and coarse localization of nearby devices, demonstrating feasibility in simulated post-disaster scenarios [1]. **MO-DI-FI** provides Wi-Fi Direct-based voice communication and GPS tracking between rescuers and stranded users, with offline data storage and later synchronization [2]. A “local communication system” over Wi-Fi Direct implements intra-group and inter-group forwarding plus mobility-aware handover, achieving up to 31.7 Mb/s intragroup throughput and robust multi-group communication [3].

LifeBeacon extends this paradigm by combining BLE and Wi-Fi Direct in a decentralized, self-healing MANET with encrypted SOS messaging and Wi-Fi probe-based victim localization; experiments show scalability, energy efficiency, and accurate RSSI-based trilateration under simulated disaster conditions [4]. A Wi-Fi Direct-based emergency scheduling scheme further optimizes device duty cycles, ensuring bounded joining time, connectivity, and energy savings via centralized and distributed scheduling algorithms [5].

A more recent mesh P2P implementation, **PeerDrop**, uses Wi-Fi Direct discovery and AES-256 encryption in a decentralized topology, achieving high bandwidth over single and multi-hop routes and targeting offline messaging in disaster or rural areas [6].

Bluetooth / BLE Mesh and IoT-Assisted Networks

Bluetooth Low Energy and Bluetooth Mesh are explored for public safety and IoT-backed emergency networks. The **BLE Mesh** framework implements proactive multi-hop routing with RSSI-assisted path selection and provides a reusable API layer for proximity services; its QuoteSendApp example disseminates emergency information without Internet access, illustrating the rapid development of public safety apps on commercial devices [7].

Bluemergency leverages Bluetooth Mesh across IoT devices in “digital cities,” using smart home and office nodes as relays for smartphone communication when infrastructure fails; the approach exploits the ubiquity and backward compatibility of BT Mesh to build large-scale, battery-powered multi-hop networks without jail-breaking phones [8]. Hybrid architectures also combine LoRaWAN and Bluetooth Mesh, using BM as

a redundant short-range mesh to transparently carry critical LoRaWAN traffic and improve delivery success by nearly two orders of magnitude in harsh indoor conditions [9].

Experimental work on **Bluetooth 5.0** assesses performance through fire, showing only ~2 dB additional loss for P2P and mesh links and highlighting the suitability of Bluetooth-based wearables and mesh safety systems in fire-prone disasters [10].

Wireless Mesh Networks for Emergency Infrastructure

At the infrastructure level, wireless mesh networks (WMNs) are proposed as backup communication backbones for emergency response organizations. A WMN-based architecture aims to guarantee secure communication and reliable text-based information sharing when conventional networks are overloaded or broken, highlighting common interoperability and coordination challenges among first responder agencies [11]. A classic work on creating Wi-Fi/Bluetooth mesh networks for crisis management explores energy and throughput-efficient integration of Wi-Fi ad hoc and Bluetooth piconet/scatternet segments, enabling devices to bridge between radio technologies for continuous routing in earthquake-like scenarios [12].

Complementary work on **LoRa-based emergency systems** (LOCATE) underscores the limits of short-range D2D (e.g., Wi-Fi Direct) for large-scale coverage and proposes phone-to-LoRa transceiver links via BLE to achieve long-range multi-hop dissemination and GPS-free localization, outperforming Wi-Fi Direct-only approaches in wide-area emergencies [13].

Synthesis and Research Gaps

Collectively, the literature demonstrates that **Wi-Fi Direct and Bluetooth/BLE meshes can provide neighborhood-scale, infrastructure-less communication** for text, voice, and SOS messages, with emerging support for localization and victim tracking [4] [7] [5] [2] [3] [1]. **IoT-assisted and heterogeneous meshes** (Bluetooth mesh with LoRaWAN, smart city IoT, convergence devices, drones/robots) extend coverage and survivability beyond what phones alone can offer [14] [15] [8] [9] [13] [16] [17].

Key gaps remain in large-scale real-world deployments; interoperability across platforms and OS restrictions (especially for multi-hop Wi-Fi Direct); usability and adoption in actual disasters; and systematic evaluation of energy consumption, routing robustness, and security in heterogeneous meshes. These gaps provide fertile ground for new research into protocol design, cross-layer optimization, and user-centered system evaluation for offline emergency communication.

3 Problem Statement and Motivation

Disaster events regularly take out cellular towers and internet connections, leaving the community without that vital link at the worst possible time. Emergency apps in current use depend completely on an available internet connection, making them useless during a need when there is no connection. Phones have Wi-Fi Direct and Bluetooth features that can work without infrastructure between phones, but there is yet to be a solution that combines these elements into an emergency mesh network solution for Android devices.

Picture this: an earthquake hits, you have no cell service, and the building collapses on your family members. You have no means of contacting rescue services or neighbors a few feet away. Imagine a rescue team gets to your place and finds that they cannot get anyone to respond because the rescue team has no way to find survivors scattered around the area. These situations happen in real disasters, yet the technology to avoid such catastrophes exists and is waiting inside the pockets of billions of people today. Android has been including Wi-Fi Direct and Bluetooth in its phones for years, the ability to have a direct connection from one device to another without infrastructure. The idea behind RelayRescue is that we shouldn't lose people or make them suffer longer because disaster relief applications cannot use the tools that are already owned by a phone in their own pocket. We aim to fill that gap with this project.

4 System Architecture and Methodology

RelayRescue is founded on a modular four-layer architecture for infrastructure-free emergency communication. Each layer is devoted to a few important duties, and the interaction between layers can be controlled within predefined rules.

4.1: User Interface Layer

- **SOS Button:** a big, red button located in a prominent position for quick, emergency alerts. Clicking once on the big, red button instantly sends an SOS alert throughout the whole mesh network.
- **Broadcast Message:** Broadcasting messages to all accessible devices in the network.
- **Direct Message:** Starts a private chat with one other person by sending a message directly to his or her device.
- **Location Sharing:** Broadcasts the user's real-time location to the mesh at regular intervals.
- **Chat Interface:** A single screen for peer discovery/discoverable devices, composing messages, and viewing/conversing. Opens when the choice of broadcast or direct message is made.

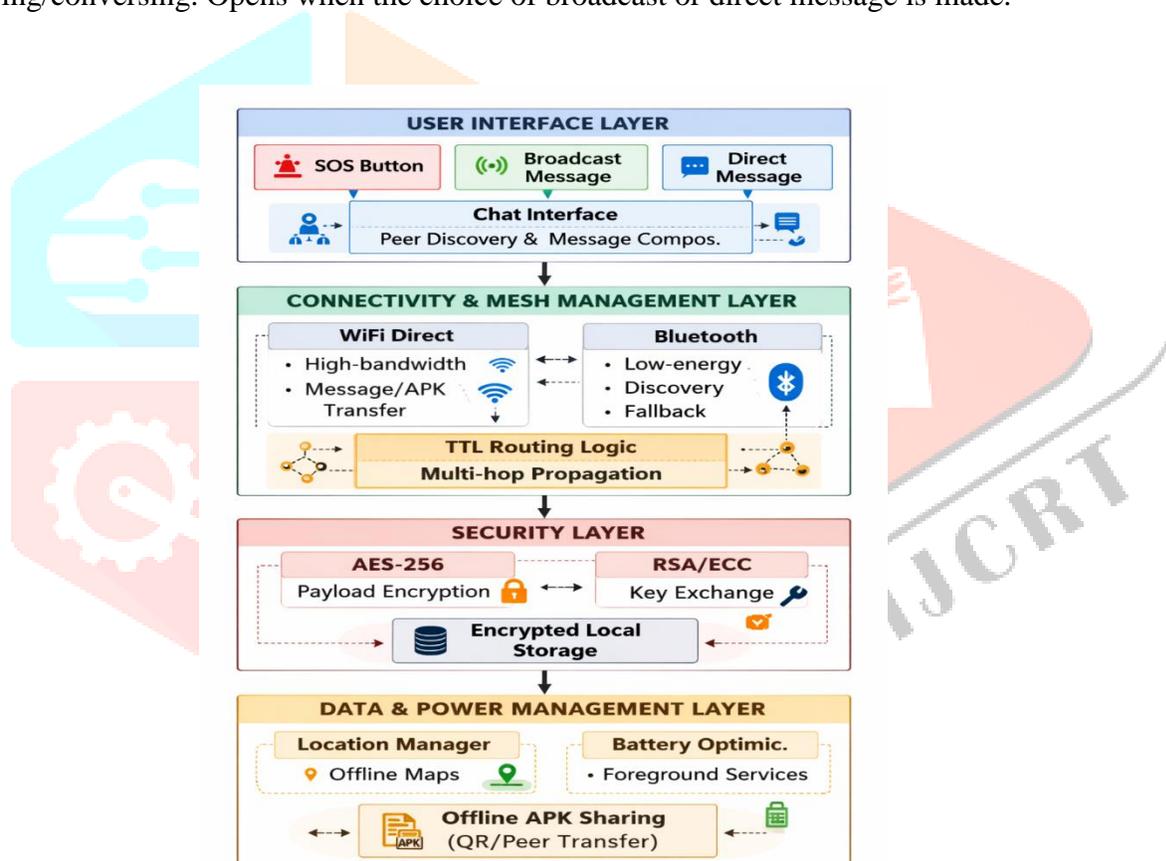


Fig. 1. RelayRescue layered architecture for offline peer-to-peer emergency messaging.

4.2: Connectivity and Mesh Management Layer

This layer handles all device-to-device communication and network topology. The hybrid communication protocols applied in the system are given in Table 1.

Table 1. Hybrid Communication Protocols

Protocol	Role	Characteristics
Wi-Fi Direct	Primary data transfer	High bandwidth, suitable for messages, images, and APK files.
Bluetooth	Discovery & fallback	Low energy consumption, peer discovery, backup when Wi-Fi unavailable.

In addition to choosing between protocols, the system also manages mesh network strategies to establish reliable connections:

- **Dynamic Peer Discovery:** Constantly searches for close-by peers and continues to use Wi-Fi Direct and Bluetooth.
- **Multi-Hop Message Propagation:** Messages are automatically passed through intermediate devices in order to extend the node's reach.
- **TTL (Time-to-Live) Routing:** The transporter includes a TTL in each message, which is decremented after each hop. Once TTL=0, messages cannot further propagate, avoiding message loops.
- **Connectivity Resilience:** Drops from one protocol are compensated for by the other, which kicks in automatically to provide seamless connectivity.

4.3: Security Layer

Makes sure all communications are kept confidential.

- **End-to-End Encryption:** All message payloads are encrypted using the AES-256 algorithm.
- **Secure Key Exchange:** RSA or ECC (Elliptic Curve Cryptography) is used to establish encryption keys during direct messaging sessions.
- **Encrypted Local Storage:** All the messages and data are locally stored on the device.
- **Zero Dependency on External Servers:** Security provided solely by a peer-to-peer architecture that requires no Internet or cloud infrastructure.

4.4: Data and Power Management Layer

The system now has a several features to simplify the usage or make it more robust:

- **Location Management**
The device coordinates are retrieved through the Android Location API. To preserve privacy, part of the location information is encrypted and sent as a special message type. These coordinates are bitmapped with maps on Google My Maps, which works offline as well.
- **Battery Optimization**
In order to maintain discovery and mesh connectivity, the application uses foreground services with low-power locks. An intelligent background service decreases the rate of peer discovery scans if the user stops moving or the application is no longer on top. This method saves a lot of power and delivers reliable connectivity.

- **Offline App Sharing**

APKs also support peer-to-peer transfer of other APKs over Wi-Fi Direct or Bluetooth. These APKs can be shared by simply scanning a QR code, so users can grow the network naturally without an internet connection. This feature is very useful during a disaster due to increased mesh coverage, allowing for even critical applications to be quickly served.

Table 2. Technology Stack Summary

Component	Technology Used
Platform	Android OS (Minimum SDK 21+)
Languages	Java
Frameworks	Android Jetpack, Material Design 3
UI Design	XML Layouts, ConstraintLayout, Animations
Connectivity	Wi-Fi Direct, Bluetooth Low Energy (BLE)
Security	AES-256, RSA/ECC, Encrypted Local Storage
Location	Android Location API, Offline Map Integration
App Sharing	Peer-to-peer APK transfer, QR Code

Figure 2 shows how the TTL message forwarding mechanism works within a multi-hop network. From the source device (A), an initial TTL value of 3 is set and is propagated through other intermediate devices. The

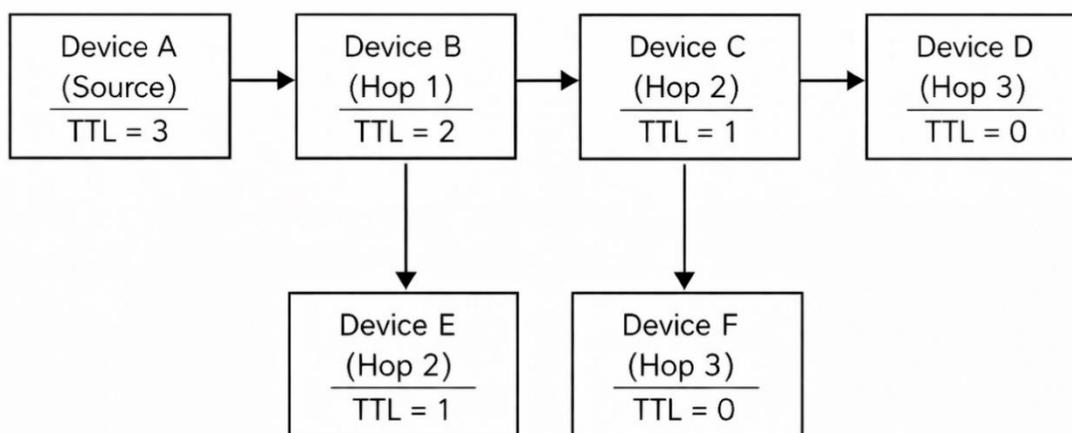


Fig. 2: TTL-Based Network Device Flow Diagram

intermediate TTL value decrements by 1 on each hop until the 0 value is reached, when forwarding stops. The diagram also depicts control of forwarding by branching off to other devices.

5 Experimental Results and Discussion

Table 3. Specifications of the smartphones used in the performance evaluation experiments

Brand	Model	Android Version	Bluetooth Version
Infinix Smart 5	X657C	11	4.2
Moto	Moto g34	15	5.1

Table 4. Successful message delivery rates (with 0 being the lowest value and 1 the highest) between two Android devices running RelayRescue through Wi-Fi Direct at various distances without obstacles

Distance between devices (m)	10	20	30	40	50	60	70	80	90	100
Message (20 characters)	1	1	1	1	1	1	1	1	1	1

Table 5. Successful message delivery rates (with 0 being the lowest value and 1 the highest) between two Android devices running RelayRescue through Bluetooth at various distances without obstacles

Distance between devices (m)	10	20	30	40	50
Message (20 characters)	1	1	1	1	1

Table 6. Successful message delivery rates (with 0 being the lowest value and 1 the highest) between two Android devices running RelayRescue through Wi-Fi Direct at various distances with obstacles

Distance between devices (m)	5	10	15	20	25	30	35
Message (20 characters)	1	1	1	0.9	0.8	0.5	0.6

Table 7. Successful message delivery rates (with 0 being the lowest value and 1 the highest) between two Android devices running RelayRescue through Bluetooth at various distances with obstacles

Distance between devices (m)	5	10	15	20	25	30	35	40	45
Message (20 characters)	1	1	1	1	1	0.8	1	1	1



Fig 3. Main Screen of RelayRescue

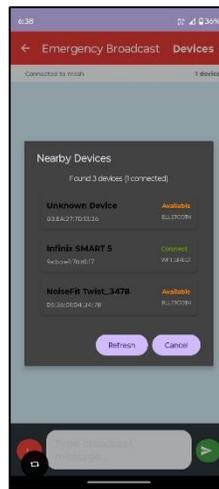


Fig 4. List of nearby devices.



Fig 5. Device 1's Chat Screen.



Fig 6. Device 2's Chat Screen.

The main screen of RelayRescue is shown in Fig 3; the list of the surrounding devices is depicted in Fig 4, the chat screen of the first device is represented in Fig 5, and the chat screen of the second device is exhibited in Fig 6.

6 Conclusion and Future Work

RelayRescue effectively validates infrastructure for less emergency communications through the use of Wi-Fi Direct and Bluetooth that are built into off-the-shelf Android devices. The hybrid mesh network proves effective, with 100% message delivery at 100 meters using Wi-Fi direct and at 50 meters using Bluetooth in open spaces. The four-layer architecture range provides a secure route through encrypted communication, TTL headers, and power control, while offline APK sharing allows for organic network growth. This project demonstrates that it is possible to rely on smartphones as an alternative, resilient communication node during a disaster, something the existing emergency applications fail to do.

In future work, we plan to port RelayRescue to iPhone (in addition to Android devices) to enable applications for further emergency scenarios. We will perform larger field tests involving dozens of devices to tune the routing algorithms and TTL provisioning further, and we research the application of machine learning techniques for power optimization. For deployment, we will work towards defining standardized APIs and pursuing certification processes with emergency response and humanitarian agencies.

7 References

- [1] M. D. P. Salamanca, E. H. Cables, and J. C. Ramírez, “Conecta2: An Android App for Communication between Disaster Survivors through an ad hoc Network,” *Ing. e Investig.*, vol. 44, no. 3, pp. 1–9, 2024.
- [2] J. W. Lascaña and C. Barbosa, “MO-DI-FI: Alternative Communication Application for Search and Rescue Operation using Wi-Fi Direct Technology,” *Res. Front. Int. J. Soc. Sci. Technol.*, vol. 1, no. 2, pp. 1–16, 2025.
- [3] F. L. X. W. Z. W. J. C. X. L. Y. Bi, “A Local Communication System Over Wi-Fi Direct: Implementation and Performance Evaluation,” *IEEE Internet Things J.*, vol. 7, no. 6, pp. 5140–5158, 2020.
- [4] S. S. M. T. S. W. W. T. N. M. M. D. A. D. B. H. K. K. T. D. P. P. Abeygunawardhana, “LifeBeacon: Offline Emergency Communication and Victim Detection System for Disaster Areas,” *2025 Sixt. Int. Conf. Ubiquitous Futur. Networks*, 2025.
- [5] M. S. Pan and C. M. Wang, “A Group-Less and Energy Efficient Communication Scheme Based on Wi-Fi Direct Technology for Emergency Scenes,” *IEEE Access*, vol. 7, no. c, pp. 31840–31853, 2019.
- [6] P. Mrs. Meher Bhawnanim, Bhavesh Sukare, Ayush Jagdhane, Rohan Nishad, and S. B. Engley, “PeerDrop: Implementation of a Mesh-Based Peer-to-Peer Network for Secure Offline Communication,” *Int. J. Res. Publ. Rev.*, vol. 6, no. 5, 2025.
- [7] B. Zhang, Y. Wang, L. Wei, Q. Jin, and A. V. Vasilakos, “BLE mesh: A practical mesh networking development framework for public safety communications,” *Tsinghua Sci. Technol.*, vol. 23, no. 3, pp. 333–346, 2018.
- [8] H. R. and M. H. Flor ´ Alvarez, Lars Almon, and G. Secure Mobile Networking Lab, TU Darmstadt, “Bluemergency: Mediating Post-disaster Communication Systems using the Internet of Things and Bluetooth Mesh,” 2019.
- [9] E. Sisinni, A. Depari, A. Flammini, S. Rinaldi, and P. Ferrari, “Evaluating the Joint Use of LoRaWAN and Bluetooth Mesh to Improve Survivability for Critical Sensor Applications,” *IEEE Sens. J.*, vol. 24, no. 14, pp. 22992–23003, 2024.
- [10] B. Black, J. Rafferty, J. Santos, A. Ennis, P. Perry, and M. McKee, “Bluetooth 5.0 Suitability Assessment for Emergency Response within Fire Environments,” *Electron.*, vol. 12, no. 22, 2023.
- [11] N. A. Ahmad, K. Kidam, and R. Mohsin, “Wireless mesh network infrastructure and communication challenges in emergency response,” *AIP Conf. Proc.*, vol. 2401, no. 1, 2021.
- [12] N. A.-J. Safa Al-Tekreeti, Christopher Adams, “Creating wi-fi bluetooth mesh network for crisis management applications,” *Proc. SPIE - Int. Soc. Opt. Eng.*, vol. 7708, 2010.
- [13] L. Sciuillo and M. D. F., Angelo Trotta, “Design and performance evaluation of a LoRa-based mobile emergency management system (LOCATE),” *Ad Hoc Networks*, vol. 96, 2019.
- [14] J. Lohokare and R. Dani, “An Intelligent cloud ecosystem for disaster response and management leveraging opportunistic IoT mesh networks,” *2021 Int. Conf. Inf. Commun. Technol. Disaster Manag. ICT-DM 2021*, pp. 125–133, 2021.
- [15] Priyanshu Sutradhar, “Drone-Assisted Mesh Networks: A Framework for Emergency Connectivity in Remote and Low-Infrastructure Zones,” *Int. J. Adv. Res. Sci. Commun. Technol.*, pp. 113–119, 2025.
- [16] Ludovico Ferranti; Salvatore D’Oro; Leonardo Bonati; Francesca Cuomo; Tommaso Melodia, “HIRO-NET: Heterogeneous Intelligent Robotic Network for Internet Sharing in Disaster Scenarios,” *IEEE Trans. Mob. Comput.*, vol. 21, no. 12, 2021.

[17] A. M. M. C. M. Z. A. Phillips, “Convergence Communication over Heterogeneous Mesh Network for Disaster and Underserved Areas,” *2020 IEEE 17th Annu. Consum. Commun. Netw. Conf.*, 2020.

