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MO-DI-FI: Alternative Communication Application for Search and Rescue Operation using Wi-Fi Direct Technology

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ABSTRACT

This study developed MO-DI-FI, an Android-based alternative communication system for search and rescue operations utilizing Wi-Fi Direct technology. The project aimed to address the lack of reliable communication during disasters, particularly in Sultan Kudarat, by enabling real-time peer-to-peer voice communication and GPS tracking without requiring internet access. Using a constructive research method, the system was iteratively designed, developed, and tested in collaboration with the Provincial Disaster Risk Reduction and Management Office (PDRRMO). The application consists of three modules: Rescuer, Stranded User, and Admin. Key findings demonstrated that the system effectively supports device discovery, offline voice communication, and location sharing. Despite limitations such as range constraints and device compatibility issues, the application significantly enhanced communication efficiency during simulated rescue operations. Furthermore, the system allows rescue data to be collected and stored offline during field operations, which can later be synchronized, reported, and visualized through the admin dashboard once an internet connection becomes available. The contribution of MO-DI-FI lies in its ability to provide offline, real-time, and structured communication support for disaster response teams operating in areas without network connectivity. Future research is encouraged to focus on expanding cross-platform compatibility and optimizing outdoor signal relay capability to further enhance its effectiveness in disaster scenarios.

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INTRODUCTION

Natural disasters have long been a global concern, contributing to significant mortality and injury rates worldwide (Delforge et al., 2023). Over the past decade, an average of 45,000 people have died annually due to such events, accounting for approximately 0.1% of global deaths. While some years witness fewer than 10,000 deaths, catastrophic events like the 1983–1985 Ethiopian famine, the 2004 Indian Ocean tsunami, Cyclone Nargis in 2008, and the 2010 Haiti earthquake have each resulted in death tolls exceeding 200,000, highlighting the severe impact of such disasters (Ritchie et al., 2024).

According to Dyvik (2024), the United States recorded the highest number of natural disasters globally in 2022, with 26 events, making it the most disaster-affected nation that year. Indonesia ranked second, reporting 20 disasters during the same period. Among these, storms and floods were the most frequent and destructive, contributing to global economic damages exceeding 130 billion U.S. dollars. Meanwhile, the 2011 earthquake and tsunami in Japan remain the most financially devastating natural disaster in recorded history, with total damages estimated at approximately 210 billion U.S. dollars.

The Philippines is globally recognized as one of the countries most vulnerable to natural disasters due to its geographic location along the Pacific Ring of Fire and within the western Pacific typhoon belt. As a result, the country frequently experiences typhoons, floods, landslides, earthquakes, volcanic eruptions, and droughts (Cordero, 2023). In 2021, the damages caused by various natural disasters amounted to over 60 billion Philippine pesos, predominantly due to severe storms that struck during that year. Furthermore, a powerful 7.0-magnitude earthquake that hit Abra in August affected more than 155,911 families, resulted in 11 fatalities, injured over 600 individuals, and caused damage valued at around 74.896 million pesos in agricultural products and over 9.732 million pesos in livestock and fisheries. In 2022, the Philippines faced tropical cyclones that led to damages totaling approximately 25.03 billion pesos, while earthquakes accounted for around 3 billion pesos in losses. The country's susceptibility to these hazards is primarily attributed to its geographical position, which places it at a higher risk for both seismic and meteorological events (Balita, 2024). According to the World Risk Index report, the Philippines ranked first worldwide in terms of disaster risk, reflecting its high levels of exposure and vulnerability. India ranked second with an index score of 42.31, followed by Indonesia at 41.46, and Colombia at 38.37. Other countries included in the top ten most at-risk nations are Mexico, Myanmar, Mozambique, China, Bangladesh, and Pakistan (Valmonte, 2022).

According to the Department of Social Welfare and Development (DSWD, 2022), several municipalities in Sultan Kudarat experienced flash flood due to heavy rains

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caused by the Southwest Monsoon and localized thunderstorms which had the total of six (6) houses were damaged, four (4) are totally damaged and two (2) are partially damaged in Sultan Kudarat.

Based on the disaster reports provided during the interview conducted with Ms. Lovely Joy Hallegado, Head of the Provincial Disaster Risk Reduction and Management Office (PDRRMO) of Sultan Kudarat, the province experienced multiple disaster incidents between January 2023 and December 2024, including flooding, strong winds, dry spells, and landslides, which severely impacted numerous municipalities. Flooding remains the most frequent and damaging hazard, with significant incidents affecting municipalities such as Palimbang, Kalamansig, Tacurong City, President Quirino, and Bagumbayan. A major flooding event occurred on July 24, 2023, in Palimbang, affecting 2,407 households across 20 barangays, while another large-scale flood on October 25, 2024, impacted 1,786 households in Kalamansig, along with concurrent incidents in Lutayan, Lebak, and SNA. In addition, a prolonged dry spell in Tacurong City on April 9, 2024, affected 701 households across 19 barangays, demonstrating the widespread vulnerability of the area to varying disaster types. These recurrent events continue to strain the capabilities of the SAR teams, particularly because existing communication methods rely on internet-based applications that become unusable in remote or disaster-affected areas. This situation highlights the critical need for an offline-capable communication system, such as the MO-DI-FI application, which facilitates real-time voice communication and device location discovery using Wi-Fi Direct technology to support faster and more coordinated disaster response efforts.

According to Ms. Lovely Joy Hallegado, Head of the Provincial Disaster Risk Reduction and Management Office (PDRRMO) of Sultan Kudarat, current rescue operations begin with coordination through local authorities, such as barangay officials, to gather preliminary information about the victims. However, the actual search heavily relies on manual inspection using limited equipment like kayaks, rubber boats, and lifelines. This process often results in significant delays, risking the lives of stranded individuals due to the lack of precise information regarding their locations. At present, the PDRRMO team utilizes the Buzz application, an online walkie-talkie communication tool, to assist in coordination. However, this solution depends entirely on internet connectivity, which becomes unreliable or completely unavailable during disasters, particularly in remote or severely affected areas. Consequently, the process of locating and rescuing victims can take several hours or even days, greatly affecting operational efficiency. Geographical barriers, challenging terrains, unpredictable weather conditions, limited manpower, and the absence of real-time location information further exacerbate these challenges. These limitations highlight the urgent need for a robust, offline-capable communication system that allows rescuers and stranded individuals to establish real-time voice communication and location tracking

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without reliance on internet infrastructure. Given this context, the core problem addressed by this study is the lack of an effective offline communication tool that enables search and rescue teams to locate and communicate with stranded individuals efficiently. The proposed solution aims to develop an Android-based application utilizing Wi-Fi Direct technology, which allows real-time peer-to-peer voice communication and device discovery, enabling both rescuers and stranded individuals to identify each other's locations within Wi-Fi range, without depending on cellular networks or internet connectivity.

Geological disasters such as earthquakes, floods, and mudslides frequently cause widespread destruction of critical infrastructure, resulting in the loss of life and property. When major disasters strike, mobile communication networks are among the most affected, leading to significant challenges in coordinating rescue operations. The disruption of communication networks slows down the restoration of emergency services, which are vital for effective disaster response and recovery (Zhou et al., 2021).

Mobile solutions play a crucial role in facilitating emergency medical responses. These applications provide rapid access to humanitarian aid by enabling users to contact nearby responders and share essential information, including GPS-based location and medical status. Android-based m-health applications enhance disaster relief efforts by connecting operators directly through Wi-Fi Direct technology without relying on conventional internet-based communication (Agomuo et al., 2024).

Accurate location tracking is an essential component of search and rescue (SAR) operations, especially in remote or disaster-stricken areas where communication infrastructure is compromised. Global Positioning System (GPS) technology allows rescuers to pinpoint the coordinates of individuals in distress, thereby facilitating timely interventions. Recent studies highlight the integration of GPS with mobile systems to improve situational awareness and operational efficiency. For instance, the Smartphone Disaster Recovery System (SDRS) utilizes Wi-Fi Direct to transmit both text messages and GPS coordinates between victims and responders without the need for internet connectivity. Similarly, UAV-assisted systems, as explored in the Feasibility Study of Mobile Phone Wi-Fi Detection for UAV Search, utilize GPS and passive Wi-Fi signals emitted from smartphones to locate victims effectively (Al-Jaberi et al., 2021). Additionally, real-time location data sharing between field agents and command centers enables data-driven rescue decisions, enhancing the overall efficiency of SAR operations (Chou et al., 2020).

Reliable communication is a cornerstone of effective disaster response. Voice-based communication systems, particularly those employing peer-to-peer or mesh networking technologies via LAN or Wi-Fi, provide a practical solution in environments where internet or cellular networks are unavailable. Recent literature explores mobile

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applications designed to facilitate offline voice communication, including features like multilingual translation and secure message logging using blockchain technology (Benamar et al., 2024). These technologies support coordination in infrastructure-deficient environments, ensuring real-time or asynchronous audio interactions among responders. Furthermore, voice communication systems play a critical role in field coordination, victim status updates, and tactical exchanges during SAR operations (Al-Fuqaha et al., 2021). Zhang and Wang (2020) stated that several studies also examine offline push-to-talk models and walkie-talkie–style applications as viable alternatives to traditional radio systems in disaster situations.

Several applications leverage Wi-Fi Direct technology to maintain communication in disaster scenarios. The HelpMe application provides essential chat-based communication when traditional networks fail. It forms an opportunistic ad-hoc network among smartphones, offering features such as direct communication, intelligent request matching to nearby users, energy efficiency for extended use, and GPS-based location sharing. Furthermore, it includes cloud-based user profiling for assistance with missing persons when connectivity is restored (Caliston & Tabia, 2022).

FireChat is an offline messaging application that enables users to communicate without an internet connection through mesh networking. It allows message transmission between nearby devices using Bluetooth and Wi-Fi Direct, supporting both private and group messaging. This makes FireChat a reliable tool in contexts where internet access is unavailable, such as natural disasters, mass gatherings, or remote areas (Dymenko, 2024).

Briar is another offline messaging platform that uses a combination of Bluetooth and Wi-Fi Direct within a mesh network. It is designed for environments with no or unreliable internet access. Briar places a strong emphasis on privacy and security, utilizing robust encryption protocols, including Authenticated Encryption (AE) and Authenticated Encryption with Associated Data (AEAD) algorithms. These methods generate both ciphertext and a Message Authentication Code (MAC) simultaneously using a single key, such as AES-CCM and AES-GCM, providing both confidentiality and integrity (Yang, 2021).

Although HelpMe, FireChat, and Briar share the common goal of enabling communication during emergencies, they differ significantly in their focus. HelpMe is designed to assist humanitarian operations and facilitate medical aid, FireChat provides flexible offline messaging, and Briar prioritizes secure and private communication. Despite their strengths, these applications lack SAR-specific features such as integrated voice communication, real-time GPS mapping, and centralized rescue dashboards. Several additional systems address communication gaps in SAR operations. The Smartphone Disaster Recovery System (SDRS) enables victims to send distress signals and GPS locations via Wi-Fi Direct, supporting communication without internet

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infrastructure (Lee et al., 2024). Similarly, Android-based Mobile Ad-hoc Network (MANET) applications establish decentralized peer-to-peer networks for disaster scenarios. These systems support both text messaging and GPS location sharing, improving field coordination (Patel & Patel, 2020).

The Feasibility Study of Mobile Phone Wi-Fi Detection for UAV Search demonstrates that smartphones can serve as passive distress beacons, allowing UAVs to detect Wi-Fi signals emitted by mobile devices and locate individuals without requiring them to run a specific application (Lodeiro-Santiago et al., 2022). Additionally, the scoping review by Lee, Gardner-Stephen, Mohamad Ali, and Sulaiman (2024) explores how Wi-Fi Direct's Service Discovery Protocol can form Wireless Collaboration Networks (WCNs), which are crucial when conventional communication infrastructure is compromised (Lee et al., 2024).

According to Slide2Talk Team (2022) and Murtaza (2023), other notable applications include Slide2Talk and Talkie Pro, which enable offline voice communication over Wi-Fi Direct. Slide2Talk functions as a walkie-talkie-style application providing push-to-talk features without internet access, while Talkie Pro supports real-time voice calls and group chats via Wi-Fi Direct. These applications showcase the feasibility of peer-to-peer voice communication during emergencies, offering alternatives similar to walkie-talkie systems (Daniel, 2021).

Research on Bluetooth-based push-to-talk (PoB) communication examines how Bluetooth technology can enable immediate voice interaction during emergencies. While Bluetooth facilitates real-time voice communication, it is constrained by a limited range of approximately 10 meters and scalability issues, which reduce its effectiveness in large-scale SAR operations (Martínez & Rodríguez, 2023).

PoB systems form ad-hoc networks by connecting devices into scatternets—networks composed of interconnected mini-networks. This structure allows for message relaying through intermediate devices, extending the communication range slightly beyond that of standard Bluetooth connections. Communication and broadcasting occur via Bluetooth's PAN (Personal Area Network) profile, allowing devices to exchange messages within each piconet while designated nodes bridge communication between piconets. Floor control mechanisms ensure organized communication by granting users permission to speak, preventing message collisions and maintaining order during group interactions (Al Nahas et al., 2020).

Ensuring secure communication in Wi-Fi Direct-based networks is critical, particularly during disaster situations where sensitive information, such as victim locations, is transmitted. Establishing a secure session key during the group formation stage is a fundamental approach to protecting device-to-device (D2D) communication. This key exchange process prevents unauthorized

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devices from joining the network and safeguards against external threats. Wi-Fi Direct typically employs WPA2-Personal security with AES-CCMP encryption, providing confidentiality and integrity of the transmitted data (Arnaboldi et al., 2023). Studies have demonstrated that WPA2-PSK combined with AES-CCMP effectively defends against eavesdropping and man-in-the-middle attacks in mobile communication environments (Rashid & Bilal, 2021). Furthermore, Chen et al. (2021) emphasize that while Wi-Fi Direct enables efficient peer-based communication, its security depends heavily on proper session key negotiation and consistent use of encryption protocols, especially in offline or ad-hoc deployments.

METHODS

Study Participants/Research Subject

The participants in this study were personnel and technical staff from the Provincial Disaster Risk Reduction and Management Office (PDRRMO) of Sultan Kudarat, who are directly involved in conducting search and rescue (SAR) operations during disaster events. These participants were selected because they have substantial experience in flood response, rescue operations, and emergency coordination within the province. Their insights were critical to understanding the operational challenges related to communication breakdowns during disasters. Additionally, technical testing involved multiple Android smartphone users from the research team, representing both rescuers and simulated stranded users, to validate the functionality of the MO-DI-FI application in real-world scenarios.

Materials/Instruments

This study employed both system development tools and validation instruments. The primary material is the MO-DI-FI Android application, designed for offline communication using Wi-Fi Direct technology. Development was conducted using Android Studio, with programming languages Java and XML, along with tools like SQLite for local databases, Firebase for web-based administration, and OSMDroid for offline mapping. Testing was carried out using Android smartphones equipped with Wi-Fi Direct, GPS, and compass sensors to ensure functionality in real-world scenarios.

For data gathering, the study used a semi-structured interview guide during consultations with PDRRMO personnel to collect operational feedback and requirements. An observation checklist and screen recording tools were also employed to document app performance during testing. The interview questions were reviewed and validated by disaster communication practitioners to ensure their relevance and

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appropriateness. Feedback gathered was instrumental in refining the system's usability and operational reliability.

Design and Procedure

This study utilized a Constructive Research Design, which is commonly applied in information technology research that aims to develop practical solutions to real-world problems. The research involved the development of the MO-DI-FI Android application, an offline communication system designed for search and rescue operations using Wi-Fi Direct technology.

The procedure started with problem identification through interviews and consultation with the Provincial Disaster Risk Reduction and Management Office (PDRRMO) to understand the communication gaps experienced during disaster response. The system requirements and specifications were formulated based on the information gathered, followed by the design of the system architecture, interface, and functional modules. Development was carried out using Android Studio with Java and XML, integrating tools such as Firebase for database and authentication, SQLite for offline data storage, and OSMDroid for offline mapping functionalities. Key features implemented include peer-to-peer voice communication, GPS-based location sharing, radar-based direction detection, and a rescue status logging system. The application underwent functional testing conducted by the researcher to ensure that each module operated as intended, followed by beta testing with PDRRMO personnel to validate its performance in simulated disaster scenarios. The testing process focused on critical features such as device discovery via Wi-Fi Direct, push-to-talk communication, GPS tracking, and synchronization of rescue logs to the admin dashboard. An iterative development approach was employed, allowing continuous refinement based on the results of each testing cycle and user feedback from PDRRMO. This ensured that the application met both technical standards and the operational needs of rescue teams. The entire development adhered to ethical standards, including obtaining formal permission from the PDRRMO and the University of Mindanao Ethics Review Committee under Protocol No. UMERC-2025-293.

RESULTS AND DISCUSSION

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Test Case Name: Wi-Fi Direct Signal Strength and Connectivity Test (Outdoor Open Line of Sight Scenario)
Environment: Outdoor open line of sight (flood scenario, no obstructions)
Stranded User: Trapped across water, full visibility
Distance: Rescuer ↔ Repeater ↔ Stranded (Equal per test case)
Rescuer Device: Android 13 (Tiramisu) Redmi Note 13 Pro
Repeater Device: Android 13 (Tiramisu) Redmi Note 13 Pro
Stranded User Device: Various Android Versions (4.4 to 14)

Table 1
Outdoor Line of Sight Testing Result

Android Device	0–60m	60–120m	120–180 m	180–240 m	240–300 m	Beyond 300m
Huawei Y635 (Android 4.4)	Stable	Stable	Weak	No Signal	No Signal	No Signal
Samsung Galaxy Note 8 (Android 7)	Stable	Stable	Stable	Weak	Weak	No Signal
Samsung Galaxy Note 9 (Android 8-9)	Stable	Stable	Stable	Weak	Weak	No Signal
Redmi Note 9 Pro (Android 10)	Stable	Stable	Stable	Weak	Weak	No Signal
Samsung Galaxy A52 (Android 11)	Stable	Stable	Stable	Stable	Stable	No Signal
Samsung Galaxy S22 (Android 12)	Stable	Stable	Stable	Stable	Stable	No Signal
Redmi Note 13 Pro (Android 13)	Stable	Stable	Stable	Stable	Stable	No Signal
Samsung Galaxy A55 (Android 14)	Stable	Stable	Stable	Stable	Stable	No Signal

Table 1 depicts the Wi-Fi Direct signal strength test results under the Outdoor Open Line of Sight Scenario, where the environment simulates a flood scenario with no physical obstructions between devices. The table summarizes the performance of different Android devices based on distance ranges, showing how signal stability is affected as the distance increases between the rescuer, repeater, and stranded user. The

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results indicate that all devices maintain a stable signal from 0 to 120 meters. As the distance increases beyond 120 meters, older devices such as Huawei Y635, Samsung Galaxy Note 8, and Note 9 begin to experience signal degradation, resulting in weaker connections and noticeable voice delays. Devices like Redmi Note 9 Pro show a slightly better range but still encounter weak signals beyond 180 meters. In contrast, newer devices such as Samsung Galaxy A52, S22, A55, and Redmi Note 13 Pro maintain stable signal strength up to 240–300 meters, providing reliable communication with minimal delay within this range. However, all devices uniformly experience signal loss and radar failure beyond 300 meters, indicating that the maximum functional limit for the Wi-Fi Direct connection in this scenario is capped at approximately 300 meters, depending on the device capability.

Test Case Name: Voice Communication Test Results– Outdoor Open Line of Sight

Table 2

Outdoor Line of Sight Testing Result

Android Device	0–60m	60–120 m	120–180 m	180–240 m	240–300 m	Beyond 300m
Huawei Y635 (Android 4.4)	0.5–2 sec	2–4 sec	4–6 sec	6–8 sec	8–10 sec	No Signal
Samsung Galaxy Note 8 (Android 7)	0.5–1.8 sec	1.8–3 sec	3–5 sec	5–7 sec	7–9 sec	No Signal
Samsung Galaxy Note 9 (Android 8–9)	0.4–1.5 sec	1–2.8 sec	2.8–4 sec	4–6 sec	6–8 sec	No Signal
Redmi Note 9 Pro (Android 10)	0.3–1.2 sec	0.8–2 sec	2–3.2 sec	3.2–5 sec	5–7 sec	No Signal
Samsung Galaxy A52 (Android 11)	0.2–1 sec	0.5–1.5 sec	1.5–2.5 sec	2.5–4 sec	4–5.5 sec	No Signal
Samsung Galaxy S22 (Android 12)	0.2–1 sec	0.5–1.5 sec	1.5–2.5 sec	2.5–4 sec	4–5.5 sec	No Signal
Redmi Note 13 Pro (Android 13)	0.2–1 sec	0.5–1.5 sec	1.5–2.5 sec	2.5–4 sec	4–5.5 sec	No Signal
Samsung Galaxy A55 (Android 14)	0.2–1 sec	0.5–1.5 sec	1.5–2.5 sec	2.5–4 sec	4–5.5 sec	No Signal

Table 2 shows the voice communication delay results for the Outdoor Open Line of Sight Scenario using Wi-Fi Direct. The test measures how voice communication is affected as the distance increases between the rescuer, repeater, and stranded user across different Android devices. The results indicate that all devices maintain low voice delay (0.2 to 2 seconds) within 0–120 meters, providing smooth, real-time communication. As the distance increases to 120–180 meters, voice delays become noticeable, ranging from 2.8 to 4 seconds depending on the device. Communication remains functional but starts showing minor lag. Beyond 180 meters up to 240 meters, delays increase further to 4 to 6 seconds, with some devices experiencing intermittent breaks or

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degraded quality. At distances between 240–300 meters, voice delay peaks at 5 to 10 seconds, heavily affecting communication quality, especially for older devices like Huawei Y635 and Samsung Note 8. All devices uniformly experience complete voice communication failure beyond 300 meters, where Wi-Fi Direct connection drops entirely, resulting in a No Signal status. The test clearly shows that device generation plays a significant role in voice communication performance. Newer devices such as Samsung A52, S22, A55, and Redmi Note 13 Pro handle voice communication more efficiently at longer distances compared to older devices. However, the maximum effective range for acceptable voice communication is generally capped at around 240–300 meters under open line-of-sight conditions.

Test Case Name: Wi-Fi Direct Signal Strength and Connectivity Test (Indoor Rescue Scenario)

Stranded User: Inside the bedroom with 2 obstacles (1 concrete wall and 1 wooden door) to the repeater.
Distance from Stranded User to Repeater: 10 meters (fixed)
Repeater: The repeater device is placed outside the house, in front of the front door.
Distance from Rescuer to Repeater: Variable (tested from 0 meters up to maximum distance) with partially open line of sight, there are scattered obstacles such as trees, poles, and distant walls.
Rescuer Device: Android 13 (Tiramisu) Redmi Note 13 Pro
Repeater Device: Android 13 (Tiramisu) Redmi Note 13 Pro

Table 3
Indoor Rescue Scenario Testing Result

Android Device	10–18m	18–25m	25–35m	35–45m	45–55m	Beyond 55m
Huawei Y635 (Android 4.4)	Stable	Stable	Weak	Weak	Very Weak	No Signal
Samsung Galaxy Note 8 (Android 7)	Stable	Stable	Stable	Weak	Very Weak	No Signal
Samsung Galaxy Note 9 (Android 8-9)	Stable	Stable	Stable	Weak	Very Weak	No Signal
Redmi Note 9 Pro (Android 10)	Stable	Stable	Stable	Weak	Weak	No Signal
Samsung Galaxy A52 (Android 11)	Stable	Stable	Stable	Weak	Weak	No Signal

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Samsung Galaxy S22 (Android 12)	Stable	Stable	Stable	Weak	Weak	No Signal
Redmi Note 13 Pro (Android 13)	Stable	Stable	Stable	Weak	Weak	No Signal
Samsung Galaxy A55 (Android 14)	Stable	Stable	Stable	Weak	Weak	No Signal

Table 3 presents the Wi-Fi Direct signal strength test results conducted under the Indoor Rescue Scenario, where the rescuer plays a critical role in establishing communication links. In this setup, the stranded user is inside a bedroom with two obstacles (a concrete wall and a wooden door) between them and the repeater device. The repeater is positioned outside the house in front of the door, while the rescuer moves away from the repeater at varying distances. The rescuer's distance from the repeater is the primary changing factor in this test, while the distance between the stranded user and the repeater is fixed at 10 meters. This scenario simulates a real-world rescue situation where the rescuer may need to move further from the repeater while maintaining communication with the stranded user. The results show that all devices maintain a stable signal within 10 to 25 meters total distance (Rescuer ↔ Repeater plus the fixed 10m Stranded ↔ Repeater). As the rescuer moves beyond 25 meters, signal degradation begins, especially for older devices like Huawei Y635, Samsung Galaxy Note 8, and Note 9, which experience weak to very weak signals between 35 to 55 meters, and complete signal loss beyond 55 meters. Newer devices such as Samsung Galaxy A52, S22, A55, and Redmi Note 13 Pro perform better but still encounter signal weakening beyond 35 meters, with radar failures and no signal beyond 55 meters. This confirms that indoor obstacles combined with increasing distance from the rescuer to the repeater significantly impact Wi-Fi Direct communication reliability.In summary, the test demonstrates that the rescuer's position relative to the repeater is critical for maintaining stable communication with the stranded user. Reliable signal is generally maintained up to 35 to 45 meters, but signal drops and failures occur beyond 55 meters in this indoor scenario with obstacles.

Test Case Name: Voice Communication Test Results – Indoor Rescue Scenario

Table 4

Voice Communication Testing Results Indoor Rescue Scenario

Android Device	10–18m	18–25m	25–35m	35–45m	45–55m	Beyond 55m
Huawei Y635 (Android 4.4)	0.5–2 sec	1–3 sec	2–4 sec	4–6 sec	5–8 sec	No Signal

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Samsung Galaxy Note 8 (Android 7)	0.5–1.8 sec	1–2.5 sec	2–3.5 sec	4–5.5 sec	6–8 sec	No Signal
Samsung Galaxy Note 9 (Android 8–9)	0.4–1.5 sec	1–2 sec	2–3 sec	3.5–5 sec	5–7 sec	No Signal
Redmi Note 9 Pro (Android 10)	0.3–1.2 sec	0.8–2 sec	2–3 sec	3–5 sec	5–6.5 sec	No Signal
Samsung Galaxy A52 (Android 11)	0.2–1 sec	0.8–1.5 sec	1.5–2.8 sec	2.8–4 sec	4.5–6 sec	No Signal
Samsung Galaxy S22 (Android 12)	0.2–0.8 sec	0.5–1.2 sec	1.2–2 sec	2–3.5 sec	3.5–5 sec	No Signal
Redmi Note 13 Pro (Android 13)	0.1–0.5 sec	0.4–1 sec	1–2 sec	2–3 sec	3.5–5 sec	No Signal
Samsung Galaxy A55 (Android 14)	0.1–0.5 sec	0.3–1 sec	1–1.8 sec	2–3 sec	3.5–4.5 sec	No Signal

Table 4 shows the voice communication delay results for the Indoor Rescue Scenario using Wi-Fi Direct. The test measures how voice delay increases as the distance grows between the rescuer, repeater, and stranded user, with indoor obstacles present (1 concrete wall and 1 wooden door). The results show that all devices maintain low voice delay (0.1 to 2 seconds) within 10 to 25 meters, providing smooth communication. As the distance extends to 25–45 meters, voice delay becomes noticeable, ranging from 2 to 5 seconds depending on the device. Beyond 45 meters up to 55 meters, most devices experience higher delays (4.5 to 8 seconds), making voice communication less reliable. Older devices like Huawei Y635 and Samsung Note 8 show higher delay compared to newer devices. All devices eventually experience complete voice communication failure beyond 55 meters, where Wi-Fi Direct connection drops entirely. The results confirm that voice communication is functional and acceptable within 35 to 45 meters for newer devices, but older devices experience degraded performance at shorter distances.

Radar-based location detection, which relies on the built-in compass and directional calculations, was tested under the same conditions. In outdoor open line-of-sight environments, compass and radar direction detection remained accurate and stable up to 120 meters. Beyond this distance, location detection began to show inconsistency and occasional instability, especially on older devices. Newer devices managed to maintain directional accuracy up to 240 to 300 meters before radar-based location detection started failing. In indoor scenarios, radar-based location detection was reliable up to 25 meters. Beyond this, detection

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became inconsistent at 35 to 45 meters and completely failed beyond 55 meters, matching the limitations observed in signal strength and voice communication.

GPS detection was evaluated separately under various conditions. The system consistently acquired GPS signals in most outdoor environments, including under tree cover, cloudy weather, and even when the device was placed in airplane mode, demonstrating that GPS functions independently from cellular or data networks. GPS detection was reliable when the device was located near a window indoors, regardless of the floor level. However, the system consistently failed to acquire GPS coordinates when the device was positioned deep indoors, far from any windows or satellite line of sight. This aligns with the well-known limitations of GPS technology, which requires a clear line of sight to satellites in order to function effectively.

Device-based performance differences were evident throughout testing. Newer devices operating on Android versions 11 to 14 performed better in terms of signal strength, voice communication delay, and location detection accuracy. Older devices experienced signal degradation, higher latency in voice communication, and earlier failure in both radar-based and GPS-based location detection when compared to newer models.

The overall testing demonstrated that the MO-DI-FI system was effective for outdoor rescue operations, offering stable communication and accurate location detection across distances ranging from 240 to 300 meters, depending on the device's capabilities. Indoor rescue scenarios showed significant limitations due to obstacles such as walls and doors, restricting the effective operational range to between 25 to 45 meters. Voice communication, signal strength, radar-based direction detection, and GPS functionality were all directly impacted by environmental factors, especially the presence of physical barriers and the availability of satellite signals.

CONCLUSION/IMPLICATIONS

The results of the testing conclude that the MO-DI-FI: Alternative Communication Application for Search and Rescue Operations successfully achieved its objective of providing a reliable alternative communication tool during emergency situations without the need for cellular networks. The system demonstrated full functionality across its core features, including Wi-Fi Direct device discovery, push-to-talk voice communication, GPS-based mapping, radar-based direction detection, and rescue log management. Testing across multiple Android devices confirmed that the application performs reliably, however, performance varies based on device generation. Newer Android versions from 11 to 14 delivered more stable connections, lower voice delays, and more reliable location detection compared to older

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devices. In outdoor open line-of-sight scenarios, the application maintained stable connectivity and voice communication at distances up to 240 to 300 meters for modern devices, with older devices showing limitations beyond 120 meters. Indoor environments with physical obstacles significantly reduced the system's effective range, limiting stable communication and location detection within 25 to 45 meters, and failing completely beyond 55 meters. GPS functionality was consistent in outdoor and near-window indoor conditions but failed when used in deep indoor locations without line-of-sight to the sky.

Based on the results, it is recommended that the MO-DI-FI application be primarily deployed in outdoor search and rescue operations, where it performs with maximum efficiency. For indoor scenarios or locations with significant obstacles, the use of outdoor repeater devices is highly recommended to extend the signal range and maintain stable communication. It is advisable for rescuers to use newer Android devices, preferably those running version 11 or higher, to ensure optimal system performance in terms of signal strength, voice clarity, and location accuracy. While the current system is developed for Android, it is also recommended that future development considers cross-platform compatibility with iOS devices, enabling the application to function on both Android and iPhone, thereby enhancing its usability and accessibility for a wider range of users in various rescue environments.

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