"A Self-Adaptive Wi-Fi Direct Framework for Infrastructure-Free Communication" Networks"

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ABSTRACT

In recent years, local communication systems have gained significant attention for enabling efficient, short-range data exchange without reliance on external networks or internet connectivity. This paper presents the design and implementation of a Local Communication System over Wi-Fi Direct, which facilitates peer-to-peer communication between devices in close proximity. Unlike traditional Wi-Fi networks that require a central access point, Wi-Fi Direct allows devices to connect directly, forming an ad-hoc network with minimal setup. The proposed system enables fast, secure, and energy-efficient communication for applications such as file sharing, instant messaging, collaborative work, and device synchronization. By leveraging Wi-Fi Direct's capabilities, the system offers high data transfer rates, low latency, and scalable group communication, making it ideal for scenarios where internet access is unavailable or restricted. The paper also addresses connection establishment, device discovery, data transmission protocols, and security mechanisms to ensure reliable and protected communication. Experimental results demonstrate the effectiveness of the system in achieving seamless local connectivity with robust performance.

Keywords: - Wi-Fi Direct, Local Communication System, Peer-to-Peer Communication, Ad-hoc Network, Device-to-Device Communication, Wireless Data Transfer, Short-Range Communication, Connection Establishment, Secure Data Exchange, Offline Communication.

Introduction

In the present digital world, interactions between electronic devices that are smooth and effective have become significantly necessary. Usually, these communications are done via infrastructures, which are network-based systems like cellular networks or Wi-Fi networks that have central access points. However, there are a lot of real-life situations where such infrastructures are inaccessible. These situations are remote areas, places that have been affected by disasters, and areas with limited or no internet connectivity. To overcome such a disadvantage, local communication systems have become a feasible means of facilitating direct device-to-device communications without going through a network. Wi-Fi Direct is an innovative solution that makes peer-to-peer (P2P) communication possible. Hence, devices may interconnect to each other directly without a central device, thereby creating an ad-hoc wireless network. A network that employs Wi-Fi Direct is not like the traditional ones that use routers or access points. The control of the connection as well as the possibility of granting other devices access to the group quickly and securely is handed over to a device called Group Owner (GO). Therefore, Wi-Fi Direct is a perfect candidate to be the underlying technology of a local communication system as it is capable of providing an internet-independent connection with high speed and low latency. The major benefit of using Wi-Fi Direct to establish local communication systems is that it can achieve high-speed data transmissions, which are good for sharing large files, streaming multimedia in real-time, and instant messaging while at the same time keeping the setup simple. Wi-Fi Direct has other features apart from these that make it attractive. Such features are privacy, low power consumption, and the fact that it is meant for a local area. Also, Wi-Fi Direct can be used on any modern smartphone, tablet, laptop, or IoT device. As such, this paper is mainly concerned with the development of a local communication system using Wi-Fi Direct for the purpose of data exchange between close devices to be reliable, secure, and efficient. The system is aimed at supporting different applications through direct peer-to-peer connectivity that includes offline file sharing, collaborative work, real-time chat, and device synchronization. Moreover, through the use of authentication protocols and data encryption, the system guards not only against unauthorized access but also from data interception. The proposed system is Wi-Fi Direct communication addressing the issues such as device discovery, connection management, data integrity, and efficient resource utilization. A practical approach and an experimental evaluation were undertaken to show that the system fulfils its goal of fast, reliable, and user-friendly local communication even when there is no presence of traditional network infrastructure. This paper articulates the system architecture, communication protocols, security features, performance evaluation, and potential local communication system applications, which are the next sections after the abstract. The following table1 illustrates the traditional techniques and their limitations.

Table1Traditional Techniques Local Communication Over Wi-Fi Direct

Technique	Application	Limitation
Wi-Fi Direct Protocol	Enables direct peer-to-peer communication without an access point	Limited range; requires manual connection management

Group Owner (GO) Negotiation	Establishes leadership in a Wi-Fi Direct group for connection control	Single point of failure; may lead to connection drops if GO leaves
Service Discovery	Allows devices to find available services before establishing a connection	Discovery can be time-consuming; prone to false positives
Push-based File Transfer	Enables fast sharing of files between connected devices	May face compatibility issues across different device brands
Real-time Communication (Chat/Sync)	Supports instant messaging and device synchronization in local networks	Performance degrades with increasing number of connected devices
Security Protocols (WPA2, WPS)	Ensures secure communication and data encryption	Vulnerable to certain Wi-Fi Direct specific attacks (e.g., brute force)
Power Management Techniques	Reduces energy consumption during idle or low-activity states	Complex to manage without impacting communication reliability
Multi-Device Connectivity	Supports group-based communication and broadcast messages	Limited by the device's ability to handle multiple simultaneous connections
Offline Communication Systems	Enables communication without internet connectivity	Limited to close-range communication; not suitable for wide-area use
Cross-Platform Compatibility Solutions	Facilitates communication between different operating systems (Android, Windows, etc.)	Varying levels of protocol support can hinder seamless interoperability

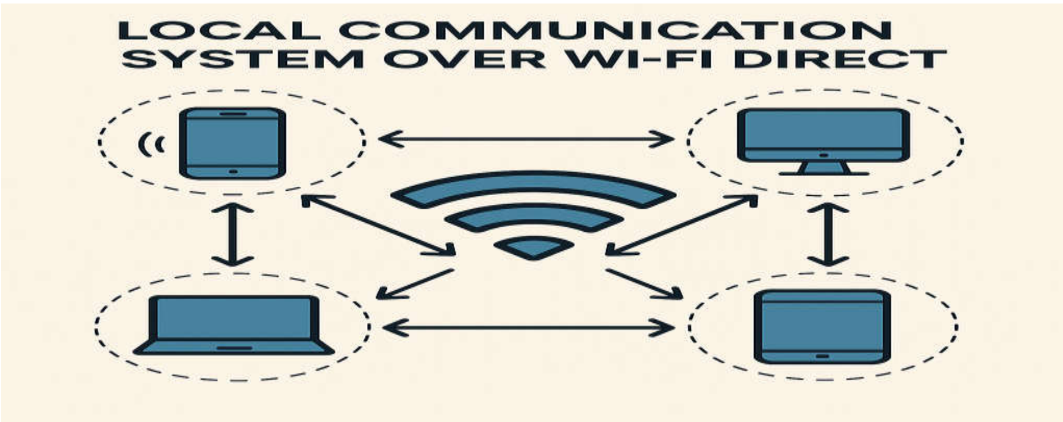

Figure 1 Overview Diagram.

The main contributions of this study are as follows. The figure 1 shows the overview diagram of the local communication system over Wi-Fi direct.

- **Development of a Local Communication System:** This research presents a reliable and efficient local communication system utilizing Wi-Fi Direct technology to enable peer-to-peer device communication without the need for internet or centralized access points.
- **Design of Secure and Real-Time Data Exchange:** The system supports real-time communication and file sharing between devices with integrated security mechanisms to ensure safe and private data transfer.
- **Implementation of Multi-Device Connectivity:** The system effectively manages connections among multiple devices in a Wi-Fi Direct group, facilitating seamless communication and synchronization.
- **Evaluation Across Multiple Scenarios:** The proposed system has been tested in various real-world environments, including offline, cross-platform, and group-based communication settings, demonstrating robust performance and user-friendly operation.

Literature Review

This paper presents a comprehensive study of Wi-Fi Direct for device-to-device (D2D) communication, focusing on the processes of device discovery and group formation. Through both real-world Android device experiments and OMNeT++ simulations, the study evaluates the performance of three operational modes: Standard, Persistent, and Autonomous. The results show that the Autonomous mode significantly reduces discovery time, although the overall process is still delayed by Wi-Fi Protected Setup (WPS) handshakes and channel contention. The paper identifies substantial performance gaps between simulated models and real-world behavior and suggests refining simulation protocols to better mirror actual device responses. It provides practical recommendations to improve responsiveness in Wi-Fi Direct systems, especially for real-time applications where quick device discovery is essential [1].

This research addresses the challenges of content sharing across multiple Wi-Fi Direct groups, proposing a content-centric routing mechanism that operates both within and between groups. The authors develop a novel Content Routing Table that maps available data to specific devices in the network, bypassing traditional IP-based routing. By implementing transport-layer tunneling, they enable bidirectional data transfer across separate groups, even in the absence of a common backbone. Real-world tests on Android devices demonstrate that the approach enhances scalability and flexibility for peer-to-peer communication. The system outperforms Bluetooth in throughput, providing a viable solution for content dissemination in decentralized environments like mobile ad-hoc networks (MANETs) [2].

Focusing on improving the efficiency of device discovery in Wi-Fi Direct communication, this paper introduces a global channel randomization technique to reduce discovery latency. The method involves periodically switching listening channels to increase the probability of prompt device detection. Testing on Android smartphones and via simulation confirms that the proposed strategy significantly reduces the average time required for device discovery without compromising reliability or requiring hardware modifications. The solution is particularly beneficial for applications where fast connection setup is critical, such as real-time chat and data synchronization. This lightweight and backward-compatible enhancement can be easily integrated into existing Wi-Fi Direct implementations to improve user experience [3].

This study evaluates the feasibility of using Wi-Fi Direct for Vehicle-to-Pedestrian (V2P) communication in urban mobility scenarios. The authors conduct both field tests and OMNeT++ simulations to assess performance indicators like packet delivery ratio (PDR) and latency at varying distances and speeds. The findings reveal high reliability (near 100% PDR) at distances up to 100 meters, but a noticeable drop at longer ranges or higher speeds. The connection setup time is identified as a major limitation for safety-critical applications. To mitigate this, the paper proposes the use of beacon-stuffing techniques to transmit safety messages before the connection is fully established. Overall, the study demonstrates the potential of Wi-Fi Direct for short-range vehicular safety communication but suggests further optimization to meet stringent real-time requirements [4].

This paper presents a mobile application framework that leverages Wi-Fi Direct for peer-to-peer communication in disaster-affected areas where traditional networks may be unavailable. Developed using the App Inventor platform, the framework enables non-technical users to quickly build and deploy emergency communication apps. The system supports offline messaging and the synchronization of emergency updates across nearby devices without relying on cellular or Internet infrastructure. It is designed to support role-based information dissemination, ensuring that messages reach relevant personnel such as rescue teams or civilians efficiently. The proposed solution was tested in controlled lab environments and mock disaster scenarios, demonstrating its robustness and applicability for real-time, local communication during emergencies [5].

Shen et al. propose a lightweight yet secure Diffie-Hellman-based key agreement protocol to enable encrypted D2D communication without any prior share. It combines commitment schemes to prevent man-in-the-middle attacks with minimal computational overhead. The protocol integrates seamlessly with Wi-Fi Direct, complete with Android implementation and experimental validation. Real-world tests indicate efficient key generation within milliseconds, making it suitable for quick peer-to-peer sessions. Their security analysis confirms robustness against replay and impersonation attacks. This work effectively bridges a critical gap in Wi-Fi Direct by introducing built-in, user-transparent encryption. It strengthens both confidentiality and integrity in local communications. The contribution lays groundwork for secure, ad-hoc D2D systems. A valuable addition for developers needing fast and secure encryption in peer-to-peer apps [6].

Iskounen et al. present a complete implementation of Wi-Fi Direct functionality within the OMNeT++/INET simulation framework. The work covers key procedures including device discovery, Group Owner negotiation, and group formation. The module is validated against official Wi-Fi Direct specifications through test scenarios. Simulation results align closely with expected protocol behavior, affirming the model's accuracy. The implementation provides an accessible platform for future protocol analysis and performance testing. Researchers gain the ability to simulate large-scale ad-hoc networks under varied conditions with reproducible results. This simulation tool streamlines the evaluation of enhancements like channel randomization or multi-group routing. It is a fundamental contribution to Wi-Fi Direct research infrastructure. Also aids in protocol extension exploration without hardware dependencies [7].

Tueno et al. introduce a distributed, file-sharing protocol enabling automatic peer-to-peer networking of Android devices using wifi. The system features a two-layered architecture: a low-level peer maintenance kernel and a higher-level application layer for catalog-based file discovery. The kernel forms and manages ad-hoc subnets, delegating file retrieval tasks to appropriate nodes across subnets. The protocol's design allows hop-by-hop file sharing across devices without centralized coordination. A proof-of-concept implementation demonstrates reliable file search and download in dynamic mobile environments. The hybrid architecture supports scalable, multi-hop communication over Wi-Fi. This work extends Wi-Fi Direct functionality by enabling mesh-like capabilities without modifying core standards. It's a significant step towards fully decentralized P2P file exchange systems [8].

Shahin & Younis propose a robust Android-based framework that supports scalable group formation and management in sensor-rich smart environments. The framework addresses limitations in Android's native Wi-Fi Direct API, such as its inability to support concurrent multi-group scenarios. It includes modules for service discovery, group maintenance, and automated fallback handling. A chat application built on top of the framework is demonstrated, seamlessly managing peer arrivals and departures. Experimental evaluation indicates stable group operation across mobility and device churn. This work enables developers to build more resilient, connected ecosystems without needing low-level platform modifications. It also highlights strategies for integrating sensor data aggregation in local ad-hoc networks. An important building block for smart crowd-sensing and collaborative mobile applications [9].

This paper proposes specialized protocols for reliable unicast communication across disjoint Wi-Fi Direct groups. Dual-connected devices act as relays, enabling inter-group message forwarding without infrastructure. The design includes buffering strategies and acknowledgment schemes to ensure message delivery despite group topology changes. Simulations and real tests show improved delivery probability and reduced latency compared to standard broadcast approaches. The work enhances the scalability of Wi-Fi Direct by enabling mesh-like extensions. Particularly effective in emergency response scenarios, where information must propagate across device clusters. It opens avenues for robust multi-hop peer-to-peer communication using only Wi-Fi Direct [10].

Fogue et al. present hybrid solutions combining Wi-Fi Direct ad-hoc groups with infrastructure access. Devices bridge peer networks and traditional LANs by negotiating subnets and relaying Internet connectivity. Their protocols dynamically assign gateway roles and ensure seamless switching between offline and online states. Tested in VANET-style scenarios, the framework supports alert distribution and data retrieval in mixed environments. This work demonstrates that Wi-Fi Direct can extend infrastructure-backed networks without sacrificing flexibility. It's applicable to rural connectivity, disaster zones, or bandwidth-constrained urban settings. It exemplifies the convergence of ad-hoc and managed networks to provide resilient connectivity [11].

This survey and experimental study dives into performance profiling of Wi-Fi Direct parameters like discovery time, group formation delay, throughput, and range. Results confirm autonomous mode offers faster discovery (~1 s) but group setup remains between 3–6 s. The paper also explores channel randomization (LCR), client-aided GO caching, and loss modeling. Simulation experiments using NS3 show discovery delays may be reduced by up to 72%. The authors advocate sharing GO history and channel data among peers to speed reconnections. They additionally compare Wi-Fi Direct vs Bluetooth for multimedia delivery, revealing higher bandwidth and range. Comprehensive in both analysis and applied enhancements, it offers actionable protocol-level optimizations [12].

Pawal et al. describe the implementation of a high-speed Android file-sharing tool using Wi-Fi Direct-based ad-hoc networking. They report transfer speeds up to 250 MBps—significantly outperforming traditional MANET approaches. The paper discusses implementation constraints, including lack of multi-hop support and cross-device compatibility. Developers propose workarounds for host-client communication barriers inherent in the API. The paper provides benchmarks on large file transfers under various conditions. Although preliminary, their solution offers a practical blueprint for high-throughput ad-hoc data exchange on Android. It highlights both the promise and limitations of real-world P2P file-sharing using Wi-Fi Direct [13].

This framework leverages Android and Wi-Fi Direct to support emergency communications when conventional infrastructure is unavailable. It defines procedures for local alert dissemination, service discovery, and opportunistic message forwarding. Trials in disaster scenarios reveal resilience to interference and device churn, though communication scheduling remains critical. The system includes optimization for data synchronization and offline message queuing. It foregrounds reliability and fault tolerance under challenging conditions. The design integrates with broader resilience frameworks and lightweight alert protocols. It is particularly envisioned for community-driven disaster relief applications. Emphasizes the critical role of ad-hoc messaging in emergency coordination [14].

"FileLinker" introduces an intuitive NFC-triggered Wi-Fi Direct file-sharing mechanism. By tapping devices together, NFC initiates the connection, then Wi-Fi Direct handles high-speed transfer. This hybrid approach reduces manual pairing steps and accelerates connection setup. The system is evaluated in field tests, showing faster and more reliable transfers compared to manual Wi-Fi Direct pairing. It combines user convenience with secure, short-range authentication—the NFC tap acts as proximity check. Resulting transfer speeds surpass Bluetooth by an order of magnitude. The proof-of-concept underscores how multi-technology integration can improve UX in ad-hoc communication services [15].

Material and methods.

Dataset and key consideration

In the case of creating and assessing a local communication system over Wi-Fi Direct, a standard dataset is hardly ever available, if at all. Consequently, most papers depend on experimentally generated datasets through real-world experiments of the Wi-Fi Direct-enabled devices. Such datasets usually come from the observation and recording of peer-to-peer interactions between several devices in closed and open area scenarios. To get the necessary data, the following tools are often used: Android Debug Bridge (ADB), Wireshark for packet analysis, and custom-built Android logging applications. The datasets normally keep track of the main performance metrics, such as device discovery time, the formation of the group's success rate, connection setup times, data transfer speeds, packet delivery ratios, battery consumption, and disconnection rates. During the creation of such datasets, one should also think about the factors which include the number and types of devices that are involved, the distance between devices, the presence of physical obstacles, different user behaviors, and possible interference from other wireless networks. To gauge the system's stability and effectiveness, it is crucial that performance metrics, such as latency, throughput, packet loss, and energy efficiency, are measured with great care. On the ethical side of things, the research community should make sure that data privacy and reproducibility of experiments are considered alongside the other issues in order to be responsible and reliable in research practice. To sum up, a Wi-Fi Direct dataset for local communication has to be technically and practically sound in terms of challenges of real-world communication to be able to offer a significant evaluation and valuable insights for the system enhancement.

Proposed System

The system being proposed sets up a local communication network with the help of Wi-Fi Direct technology to provide quick, dependable communication that does not need any kind of infrastructure between devices that are close to each other. The system is structured in such a way that peer-to-peer file sharing, sending short messages, and real-time data transfer can be done without the need for internet access or the use of a third-party router. The next figure 2 depicts the architecture of the system being proposed.

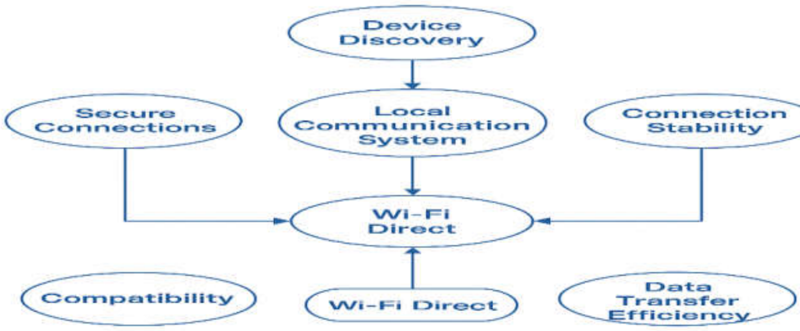

Figure 2 Proposed System Architecture

Components

- **Device Discovery Module:**
  Enables nearby devices to find each other using Wi-Fi Direct's peer discovery mechanism. It continuously scans for available peers within communication range.
- **Group Formation Module:**
  Facilitates the automatic creation of Wi-Fi Direct groups by dynamically assigning one device as the Group Owner (GO) and connecting peers efficiently.
- **Connection Management Module:**
  Manages session setup, maintains stable communication links, and handles reconnection in case of disconnection or mobility.
- **Data Communication Module:**
  Supports reliable transfer of different types of data (files, text messages, and media) between connected peers with minimal latency.
- **User Interface (Android Application):**
  Provides an intuitive interface for users to discover devices, send/receive files, and monitor communication status.

3. **Workflow of the System**

1. **Initialization:** Devices enable Wi-Fi Direct and open the application.
2. **Peer Discovery:** Devices search for nearby peers and list available devices.
3. **Group Formation:** Upon user selection or auto-connect logic, a Wi-Fi Direct group is created.
4. **Data Transfer:** Users can exchange files, text, or real-time data over the established peer-to-peer connection.

5. **Connection Maintenance:** The system ensures stable links and attempts reconnection if interruptions occur.
6. **Session Termination:** Users can disconnect after successful communication or upon leaving the communication range.

Peer to Peer Connection

A peer-to-peer (P2P) connection is a type of network communication where two or more devices (peers) connect and communicate directly with each other without relying on a central server or network infrastructure like routers or access points.
In a P2P setup:

- Each device acts as both a client and a server.
- Devices can initiate, receive, and manage communication equally.
- There is no hierarchy—all peers have the same privileges in the network.

Direct Communication: Data is exchanged directly between devices.

Decentralized: No dependency on external infrastructure (like routers or internet).

Dynamic Connections: Devices can join or leave the network without disrupting the overall system.

Resource Sharing: Peers can share files, media, or services among themselves. The figure 3 shows the peer to peer communication between clients.

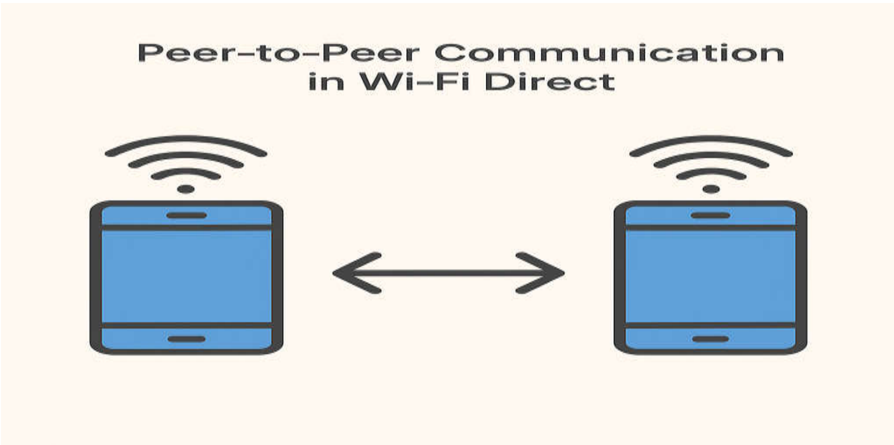

Figure 3 Peer to Peer Communication

Result and discussion

1. Server Starting

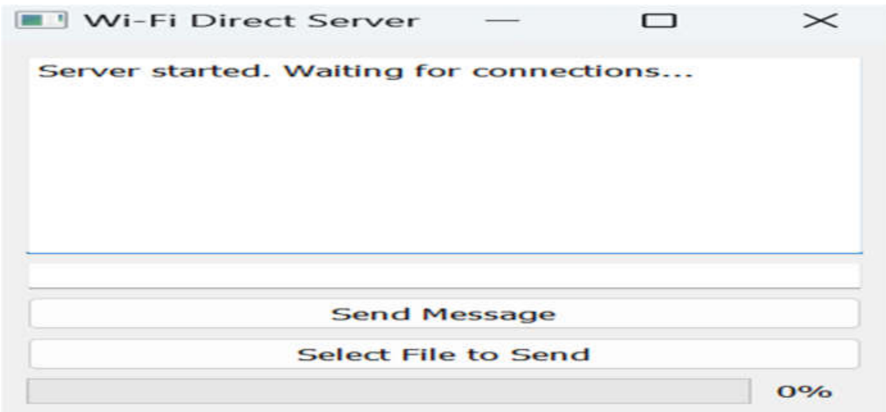

Figure 4 Server Starting
The figure 4 shows the server starting window.

2. Client Starting

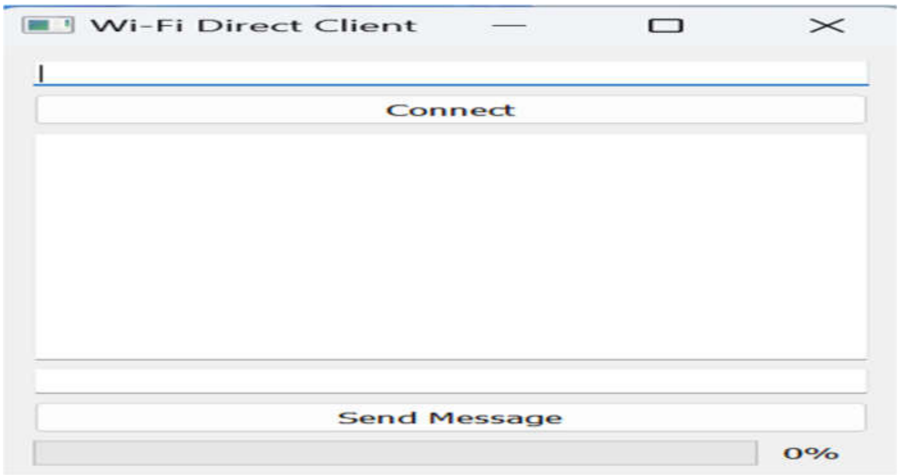

Figure 5 Client Starting
The figure 5 shows the client starting window.

3. Client Initiating Communication

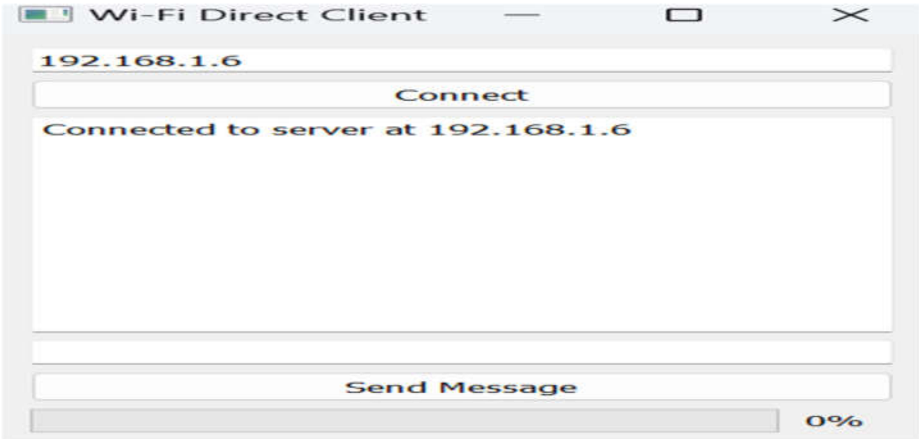

Figure 6 Client Initiating Communication
The figure 6 shows the Client Initiating Communication

4. Server Receives Communication

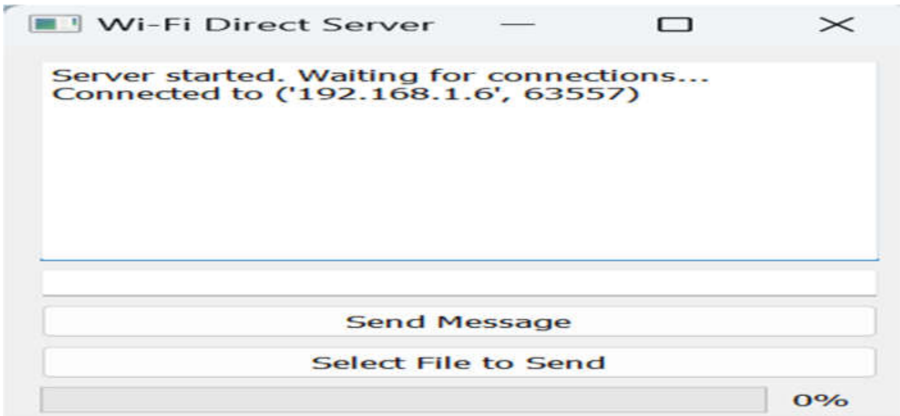

Figure 7 Server receives communication
The figure 7 shows the server receives the communication using ip address.

5. Client Send Message

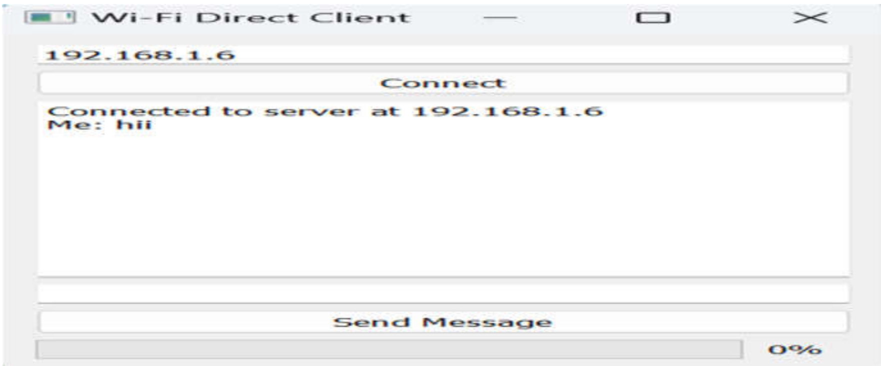

Figure 8 Client Send Message
The figure 8 shows the Client Send Message.

5. Server Receive Message

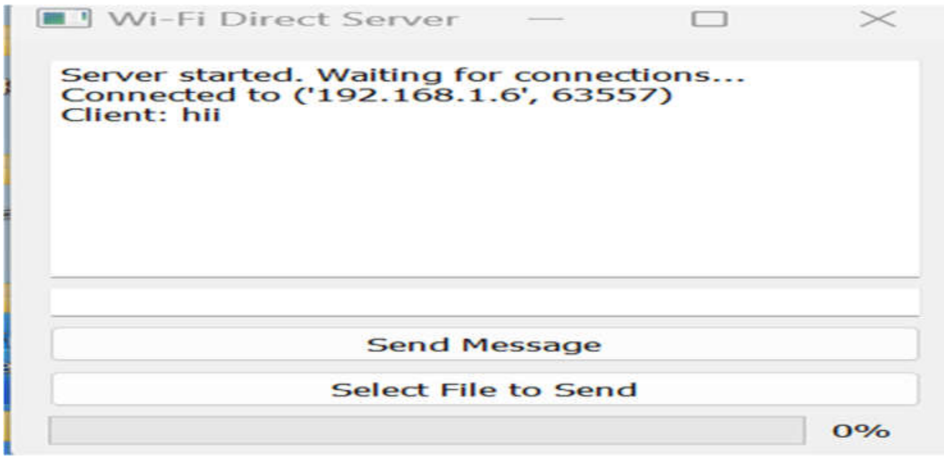

Figure 9 Server Receive Message
The figure 9 shows the Server Receive Messages.

6. Server Send Files

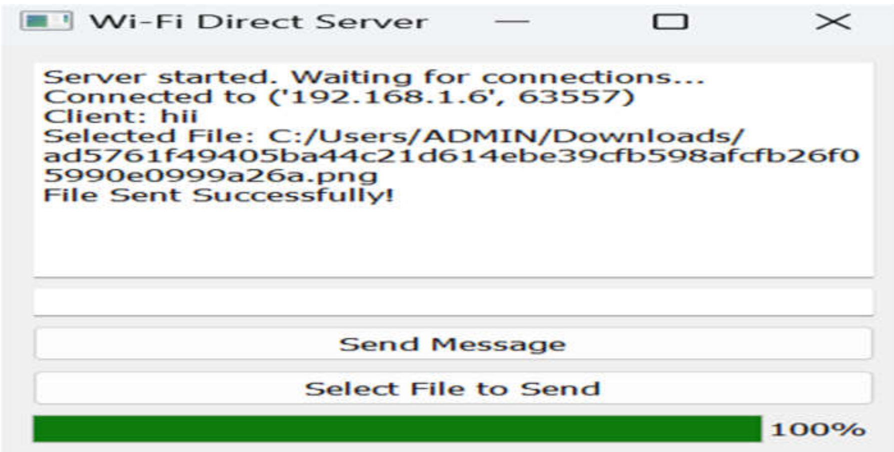

Figure 10 Server Send Files
The figure 10 shows the server sends the files to client using Wi-Fi direct.

7. Client Receive Files

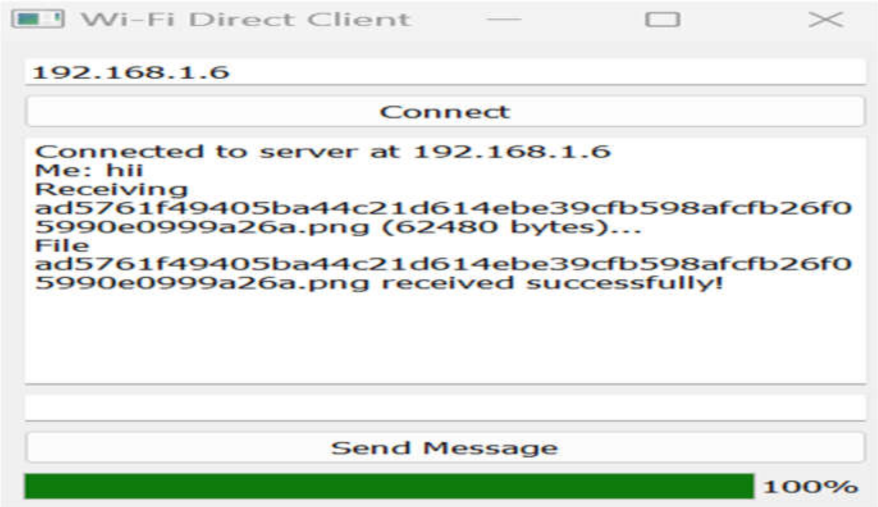

Figure 11 Client Receive Files

The Client Receive the files using wifi direct are shown in the figure 11.

Wi-Fi Direct is a peer-to-peer (P2P) communication technology that allows devices to connect directly without the necessity of traditional wireless access points or routers. Thus, it is a fast, secure, and efficient way of local communication between any combination of smartphones, tablets, laptops, IoT devices, and the like. Wi-Fi Direct, unlike traditional Wi-Fi networks, which depend on a central hub, creates a direct link between devices that are in the same vicinity. Local communication via Wi-Fi Direct can be extremely helpful in the case of such applications as file sharing, multimedia streaming, collaborative gaming, group messaging, and device synchronization. The technology can facilitate a communication link between two devices or between one device and several others, thus allowing the creation of dynamic groups in which the device that acts as the Group Owner (GO) communicates with clients. Wi-Fi Direct can be considered a strong alternative to Bluetooth for local communication due to the high data transfer rates and low latency it offers. Its main benefit is that it does not require internet access in order for devices to interact locally.

Conclusion

Local communication over Wi-Fi Direct is an effective, speedy, and adaptable way to directly connect two devices without the need for an external infrastructure. It allows for high data transfer rates and low latency, thus it can be used for file sharing, group messaging, and real-time media streaming, etc. The peer-to-peer architecture makes the connection processes easy and therefore user convenience is increased. Nevertheless, issues such as connection stability, limited multi-hop support, and higher power consumption, among others, are still the matters that need to be solved. Some solutions have been suggested by researchers, such as routing improvements, clustering, and multi-group extensions. Wi-Fi Direct is, in fact, very useful in scenarios that are constantly changing and where it is necessary to establish quick local connections. The fact that it can create ad hoc networks anytime, anywhere, is what makes it a potential communication system of the future, be it smart or mobile. There are still ongoing developments that will eventually lead to its performance and reliability being further enhanced. In fact, Wi-Fi Direct is an excellent device that can bridge the gap between different devices and thus enable smooth communication locally.

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