

# An Open, Verifiable, and Performant Architecture for Resilient Mobile Communication

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# Chapter 1

## Introduction and Background

### Abstract

This project proposes an open and verifiable architecture for resilient mobile communication that continues to function during infrastructure failures or network censorship. The system integrates a multi-hop local mesh network with an opportunistic gateway mechanism to bridge offline nodes to the internet when connectivity becomes available. Through protocol-agnostic design, the architecture ensures adaptability across diverse mobile platforms while providing auditability and performance transparency. Our approach addresses the fragility of centralized communication systems by emphasizing decentralization, openness, and hybrid connectivity modes.

### 1.1 Background

Modern communication networks are largely dependent on centralized infrastructure such as cellular towers and internet backbones. In scenarios of network outage, disaster response, or deliberate censorship, these centralized channels fail to provide continuity of service. Mesh-based and device-to-device (D2D) technologies have emerged as promising alternatives, allowing devices to form ad-hoc networks that can operate independently of the internet. However, existing solutions often suffer from limited scalability, vendor lock-in, or lack of openness.

### 1.2 Motivation

Recent events, including large-scale internet shutdowns and natural disasters, highlight the urgent need for resilient and verifiable communication systems. Most available mobile applications such as Bridgefy or FireChat are either closed-source or highly dependent

on specific conditions (e.g., dense user clusters). Our motivation stems from the goal of creating an open, transparent, and reproducible communication framework that can operate across heterogeneous devices without reliance on centralized infrastructure.

### 1.3 Scope

The project focuses on the design and implementation of a hybrid communication system that enables:

- Peer-to-peer communication via multi-hop mesh networking using Bluetooth and Wi-Fi Direct.
- Gateway bridging for connecting isolated mesh networks to the wider internet.
- Protocol-agnostic and modular architecture, allowing future transport layers to be integrated seamlessly.
- Experimental validation on small-scale Android devices with realistic mobility conditions.

### 1.4 Research Gaps

While several projects have demonstrated local peer-to-peer communication or offline messaging, they often fail to:

- Integrate mesh and internet-based communication in a unified architecture.
- Provide open and auditable implementations for performance evaluation.
- Maintain stability under dynamic conditions such as mobility or churn.

These gaps motivate the need for a verifiable, performant, and extensible system capable of functioning under real-world constraints.

# Chapter 2

## Literature Review

The literature on resilient mobile communication encompasses both decentralized architectures and device-to-device (D2D) communication systems. This review summarizes key contributions and identifies the remaining limitations that shape the direction of our proposed work.

### 2.1 Dolphin: A Cellular Voice-Based Internet Shutdown Resistance System (2023)

Dolphin introduces an innovative approach to bypass internet shutdowns by transmitting data through standard cellular voice channels. The system uses a TCP-like protocol with encryption and compression to ensure reliable data transfer. Its strength lies in leveraging existing telephony infrastructure for connectivity when data services are unavailable. However, the system does not integrate with ad-hoc networking approaches, limiting its ability to function without cellular coverage. Our work extends this idea by combining voice-based resilience concepts with mesh-based connectivity for broader coverage.

### 2.2 A Framework for Multi-Hop Ad Hoc Networking over Wi-Fi Direct with Android Smart Devices (2021)

This framework enables multi-hop routing over Wi-Fi Direct, allowing devices to communicate without internet access. It demonstrates that Android smartphones can serve as intermediate routers to relay data between peers. The study, however, lacks mechanisms for automatic peer discovery, dynamic topology updates, and integration with online gateways. Our architecture builds on this foundation by incorporating adaptive peer discovery and transition between offline and online modes.

## 2.3 Device-to-Device Communications with Wi-Fi Direct: Overview and Experimental Evaluation (2013)

This work provides an empirical analysis of Wi-Fi Direct, focusing on discovery latency, connection setup delay, and power consumption. The results establish Wi-Fi Direct as a viable option for local communication but reveal challenges in scalability and delay. The experiments are limited to single-hop communication and controlled environments, without addressing message persistence or integration with cloud services. Our project addresses these shortcomings by building a hybrid communication model that supports multi-hop routing and data synchronization through internet gateways.

## 2.4 Comparative Analysis of Offline Communication Apps

A comparative review of existing mobile ad-hoc messaging applications provides context for our solution:

- **FireChat:** Enabled Bluetooth and Wi-Fi-based offline messaging but relied heavily on dense user clusters. Message reliability was low in sparse regions.
- **Bridgefy:** Offered a developer SDK for Bluetooth mesh communication but suffered from scalability and battery efficiency issues.
- **Briar:** Emphasized privacy and end-to-end encryption using Bluetooth, Wi-Fi, and Tor, but exhibited synchronization delays and poor usability for general audiences.
- **Serval Mesh:** Created Wi-Fi-based peer-to-peer networks for voice and file sharing, yet required complex setup and lacked modern mobile integration.

These systems highlight the trade-offs between usability, privacy, and connectivity. None of them achieve a unified, open-source architecture that seamlessly bridges offline and online communication—a gap that our work aims to fill.

## 2.5 Summary

The existing literature collectively emphasizes the importance of decentralized communication, yet there remains a disconnect between academic frameworks and practical,

user-friendly implementations. Our project contributes by proposing an open, protocol-agnostic system capable of both offline operation and opportunistic online synchronization, ensuring performance transparency and real-world resilience.