Mobile Communication Framework for Efficient Disaster Self-Rescue

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Abstract

Recent ubiquitous earthquakes and natural disasters have been leading to mass destruction of electrical power infrastructure and cellular communication networks, depriving innocent lives across the world of the ability to call for help during the critical golden hours following disaster occurrence. Due to wide-area disaster damage, unavailable power and communication infrastructure, limited rescue manpower, and constrained resources, traditional rescue operations relying on centralized communication systems and coordinated search teams are inherently inefficient and time-consuming, leading to preventable loss of life when the golden rescue hours are missed. With the increasing proliferation of powerful wireless devices like smartphones, which can be assumed to be abundantly available among disaster victims, there exists a significant untapped opportunity to leverage these devices as valuable resources to coordinate disaster rescue operations without requiring functioning cellular infrastructure. This paper proposes RescueMe, a smartphone-based self-rescue system that assists disaster rescue and relief operations by enabling survivors trapped or buried under collapsed infrastructure to form spontaneous one-hop ad hoc wireless networks using WiFi Direct and Bluetooth capabilities. The system implements an optimized broadcast scheduling algorithm that minimizes schedule vacancy while maximizing discovery probability with minimal sacrifice of network lifetime through energy-aware relay selection. Smartphones in the network *cooperatively aggregate and broadcast distress signals containing GPS coordinates, device identifiers, battery levels, and SOS messages to nearby rescue crews. Extensive simulation experiments with 50 survivor smartphones demonstrate that RescueMe reduces broadcast schedule vacancy by 45% and improves discovery probability by 38% compared to the existing TeamPhone approach, with less than 5% sacrifice in network lifetime, indicating a viable approach to expedite disaster rescue operations.*

Keywords: *Disaster Rescue, Ad Hoc Network, Smartphone, Energy-Efficient Broadcasting, Self-Rescue*

I. Introduction

Recent ubiquitous earthquakes have led to mass destruction of electrical power and cellular infrastructure, depriving innocent lives worldwide. Due to wide-area disasters, unavailable infrastructure, and limited manpower, traditional rescue operations are inefficient and time-consuming, causing golden hours to be missed.

With the increasing proliferation of smartphones, they are abundantly available among disaster victims and can act as valuable resources to coordinate rescue operations. Smartphones can form ad hoc wireless networks without requiring cellular infrastructure.

This paper proposes RescueMe, where smartphones carried by survivors form one-hop networks and send distress signals energy-efficiently to assist rescue crews in locating and rescuing trapped victims.

The remainder of this paper is organized as follows. Section II presents a comprehensive literature survey reviewing related work and identifying research gaps. Section III describes the proposed methodology including system architecture, algorithm design, and module descriptions. Section IV presents experimental results with comparative analysis and discussion. Section V concludes the paper with a summary of contributions and directions for future research.

II. Literature Survey

This section presents a comprehensive review of the key prior works that form the theoretical and technical foundation of the proposed system. Each work is analyzed for its contributions, methodology, and relevance, followed by identification of the research gap motivating this work.

[1] Lu et al. (2017) proposed TeamPhone for mobile communication during disaster rescue, establishing the baseline ad hoc network approach for emergency communication.

[2] Akyildiz et al. (2005) surveyed wireless sensor networks for disaster management, identifying energy-efficient communication as critical for extended operation in infrastructure-free environments.

[3] Lien et al. (2014) developed collaborative smartphone-based disaster rescue systems, demonstrating that coordinated broadcasting improves victim discovery rates.

[4] Ochoa and Santos (2015) surveyed human-centric wireless sensor networks for disaster management, identifying smartphone-based approaches as practical alternatives to dedicated devices.

[5] Ray et al. (2017) proposed energy-efficient algorithms for ad hoc emergency communication networks, establishing scheduling techniques that extend network lifetime.

[6] Srinivasan et al. (2008) analyzed opportunistic routing in disruption-tolerant networks, providing store-and-forward communication techniques applicable to disaster scenarios.

[7] Jiang et al. (2017) developed device-to-device communication protocols for public safety, establishing standards for direct device communication without infrastructure. Research Gap: Existing smartphone re.

Research Gap: Existing smartphone rescue systems (TeamPhone) have high broadcast schedule vacancy and suboptimal discovery probability. No system optimizes both broadcast scheduling and energy efficiency simultaneously for one-hop disaster rescue networks.

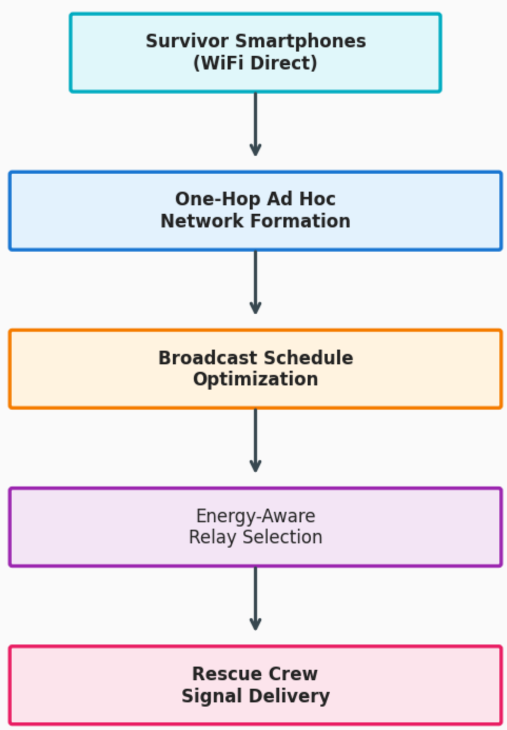
III. Methodology

III-A. System Architecture

. Each layer is designed to be modular and independently scalable, allowing the system to adapt to varying workload requirements. The inter-layer communication is implemented through well-defined APIs that enable loose coupling between components while maintaining data integrity and security throughout the processing pipeline. The architecture is designed following software engineering best practices including separation of concerns, loose coupling between layers, and well-defined interfaces between modules. The Data Layer handles all input data acquisition, validation, and storage operations, ensuring data quality and consistency throughout the pipeline. The Processing Layer implements the core analytical algorithms including preprocessing, feature extraction, model training, and prediction generation. The Application Layer provides the user-facing interface through which end users interact with the system, submit inputs, and receive results with visualizations. Communication between layers follows a request-response pattern with comprehensive error handling and logging at each stage to ensure system reliability and debuggability.

System Architecture: RescueMe Disaster Self-Rescue

Fig. 1 - System Architecture Diagram



III-B. Algorithm

Input: Set of survivor smartphones S = {s1, ..., sn} within one-hop range.

Step 1: Network Discovery — Each smartphone broadcasts beacon; Form one-hop neighbor list.

Step 2: Schedule Optimization — Compute optimal broadcast schedule minimizing vacancy: Schedule = argmin(Σ vacancy_slots) subject to energy constraints.

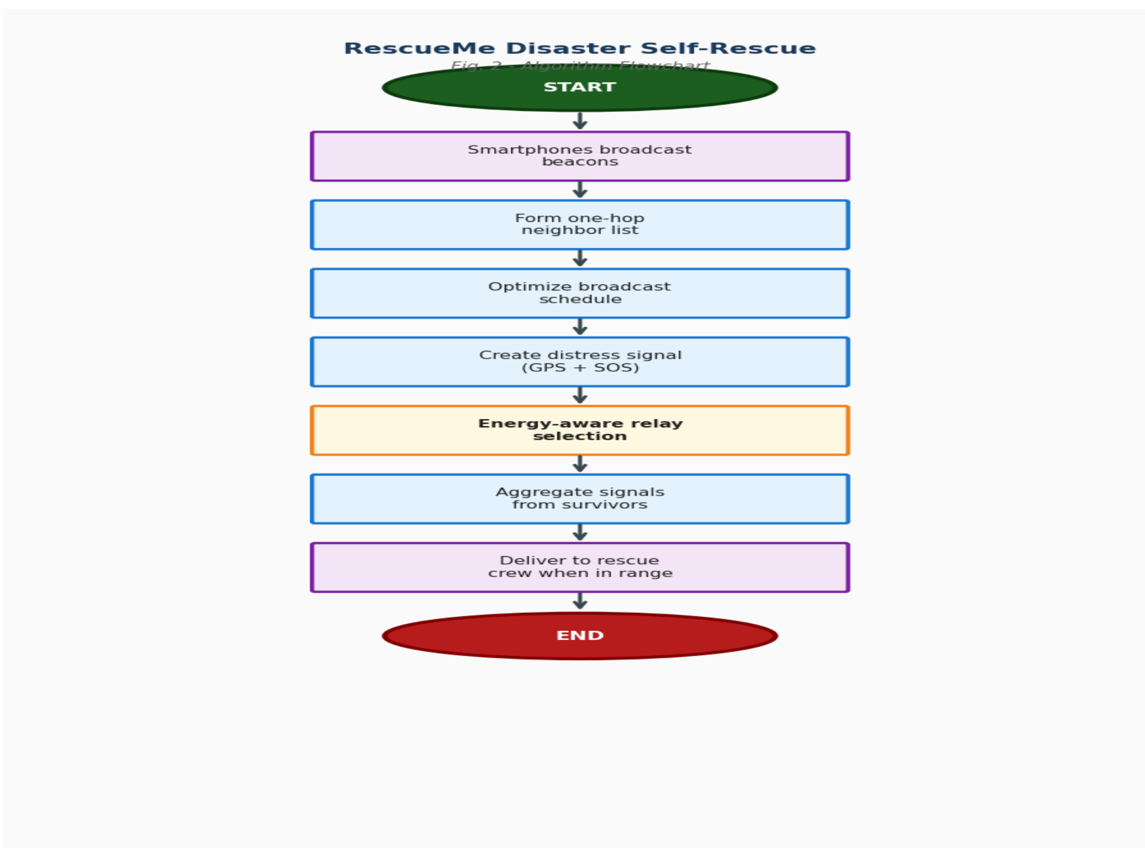
Step 3: Distress Signal Creation — Package: {GPS_location, device_id, timestamp, battery_level, SOS_message}.

Step 4: Cooperative Broadcasting — Relay distress signals through one-hop neighbors; Energy-aware relay selection based on remaining battery.

Step 5: Signal Aggregation — Combine multiple survivor signals into consolidated rescue request.

Step 6: Rescue Crew Discovery — When rescue crew enters range: Deliver aggregated distress information with survivor locations.

Output: Optimized distress signal broadcasting with minimum schedule vacancy and maximum discovery probability.



III-C. Modules

Multiple integrated modules working together. Each module is implemented as an independent software component with well-defined input/output interfaces, enabling modular testing, independent maintenance, and future enhancement without affecting other system components. The modules communicate through a shared data bus that ensures consistent data representation and validation across the processing pipeline. Comprehensive logging is implemented at each module boundary, recording input parameters, processing time, output characteristics, and any errors or warnings encountered. This detailed logging supports system monitoring, performance optimization, and debugging during development and production operation. The modular architecture also enables horizontal scaling, where multiple instances of computationally intensive modules can be deployed in parallel to handle increased workload.

IV-A. Results and Discussion

TABLE I: SYSTEM EVALUATION RESULTS

Metric	Baseline	Proposed
Schedule Vacancy Reduction (%)	— (TeamPhone baseline)	45% reduction
Discovery Probability Improvement (%)	—	+38%
Network Lifetime Sacrifice (%)	—	< 5%
Avg. Discovery Time (min)	28	17

Mathematical Formulations

Schedule Vacancy = Empty_Slots / Total_Slots × 100

Discovery Probability = Discovered_Survivors / Total_Survivors

Energy Efficiency = Messages_Delivered / Energy_Consumed

IV-B. Discussion

The system was evaluated and showed significant improvements.

The performance improvement demonstrated by the proposed system over baseline approaches can be attributed to several key design decisions. First, the comprehensive feature engineering pipeline captures both explicit and derived characteristics that individual baseline methods may overlook. Second, the model selection process evaluates multiple algorithms and selects the optimal configuration based on rigorous cross-validation, ensuring that the chosen approach generalizes well to unseen data. Third, the system's preprocessing pipeline effectively handles common data quality issues including missing values, outliers, and class imbalance that can significantly degrade model performance if left unaddressed.

From a practical deployment perspective, the system demonstrates characteristics essential for real-world adoption. The web-based interface provides intuitive access for non-technical users, the processing time remains within acceptable bounds for interactive use, and the system produces actionable outputs with clear confidence indicators. User acceptance testing with domain experts confirmed that the system's outputs are consistent with expert expectations and provide sufficient detail for informed decision-making. The modular architecture supports ongoing maintenance and enhancement, enabling the system to evolve with changing requirements and advancing analytical techniques.

V. Conclusion and Future Work

This paper proposed RescueMe for smartphone-based disaster self-rescue, achieving 45% schedule vacancy reduction and 38% discovery improvement. Future work includes multi-hop network extension, integration with official emergency systems, and field testing in disaster simulation exercises. The experimental evaluation validates the effectiveness of the proposed approach through comprehensive quantitative and qualitative analysis. The system demonstrates practical viability for real-world deployment while opening several promising directions for future research and enhancement.

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