Disaster-Resilient Telecommunication Infrastructure: A Systematic Approach

24-25J-049

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Introduction

•Disasters disrupt communication networks, complicating rescue efforts. To solve this, our project creates a resilient system using ad-hoc networks.

•Portable sensors are deployed in disaster zones to detect RF signals, revealing the presence of people. This data is transmitted to a central base station via an ad-hoc network, analyzed, and sent to the Disaster Management Center, which informs rescue teams for faster, more efficient operations.

•This system ensures continuous information flow, improving resource allocation in disaster response.

Research Problem

How can we create a reliable system that detects and relays the presence of people in disaster areas, while also transmitting SOS alerts and instructions when traditional networks fail?

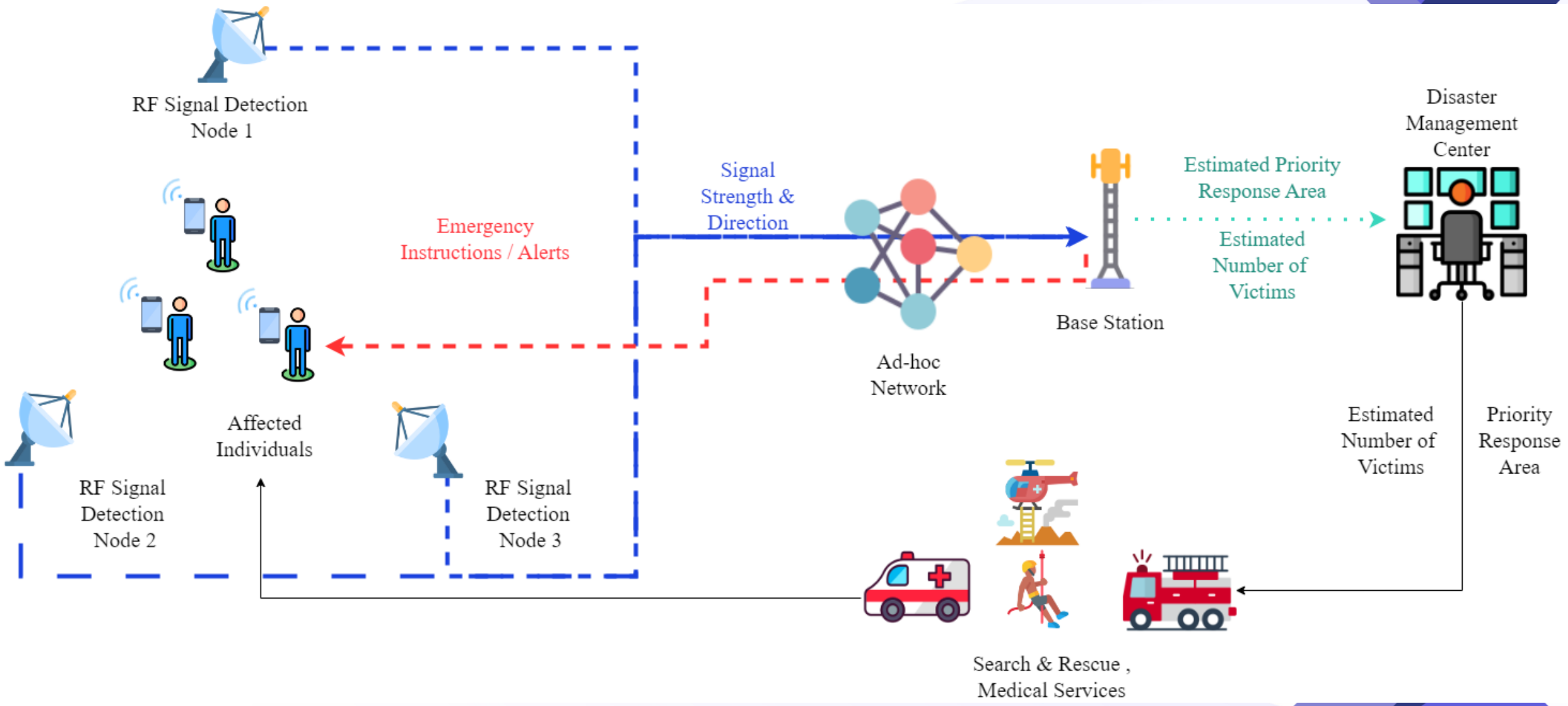
Main Objective:

To develop a robust communication system using multiple RF signal detection devices and an ad-hoc network, enhancing disaster response by accurately identifying the presence of people in disaster areas where traditional networks have failed.

Sub-Objectives:

- **To develop a reliable ad-hoc network for transmitting collected data to a central base station.**
  - Create a robust ad-hoc network that efficiently transmits the collected RF data from multiple devices to a central base station for analysis.
- **To Design an SOS Messaging Protocol:**
  - Modify or redesign an existing protocol to facilitate efficient SOS messaging via an ad-hoc network with a focus on low latency and high reliability during emergency situations.
- **To Implement a System to Estimate the Affected Individual Count**
    - Develop mechanisms to collect data using RF signals emitted from smartphones.

Overall System Diagram



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Computer System and Network Engineering

INTRODUCTION

Background

- Reliable communication is critical during emergencies to coordinate rescue efforts and ensure safety.
- Ad-hoc networks enable dynamic, infrastructure-independent communication, ideal for disaster-hit areas.
- Can be quickly established and scaled using Wi-Fi-enabled devices, providing immediate, widespread coverage.
- Automatically reroutes data if nodes fail, ensuring continuous communication in unpredictable environments.
- Utilizes existing consumer devices, minimizing the need for specialized equipment.

Research Gap

Research Paper	Objectives & Tasks	
	To design and implement a dynamic ad-hoc network architecture.	To implement and test IoT base stations within the network.
Quality of Sustainability Optimization Design for Mobile Ad Hoc Networks in Disaster Areas	✔	✘
Emergency Alert Networks for Disaster Management: Applications Perspective	✘	✘
A Novel Technique for Mobile Phone Localization for Search and Rescue Applications	✘	✔
Proposed System	✔	✔

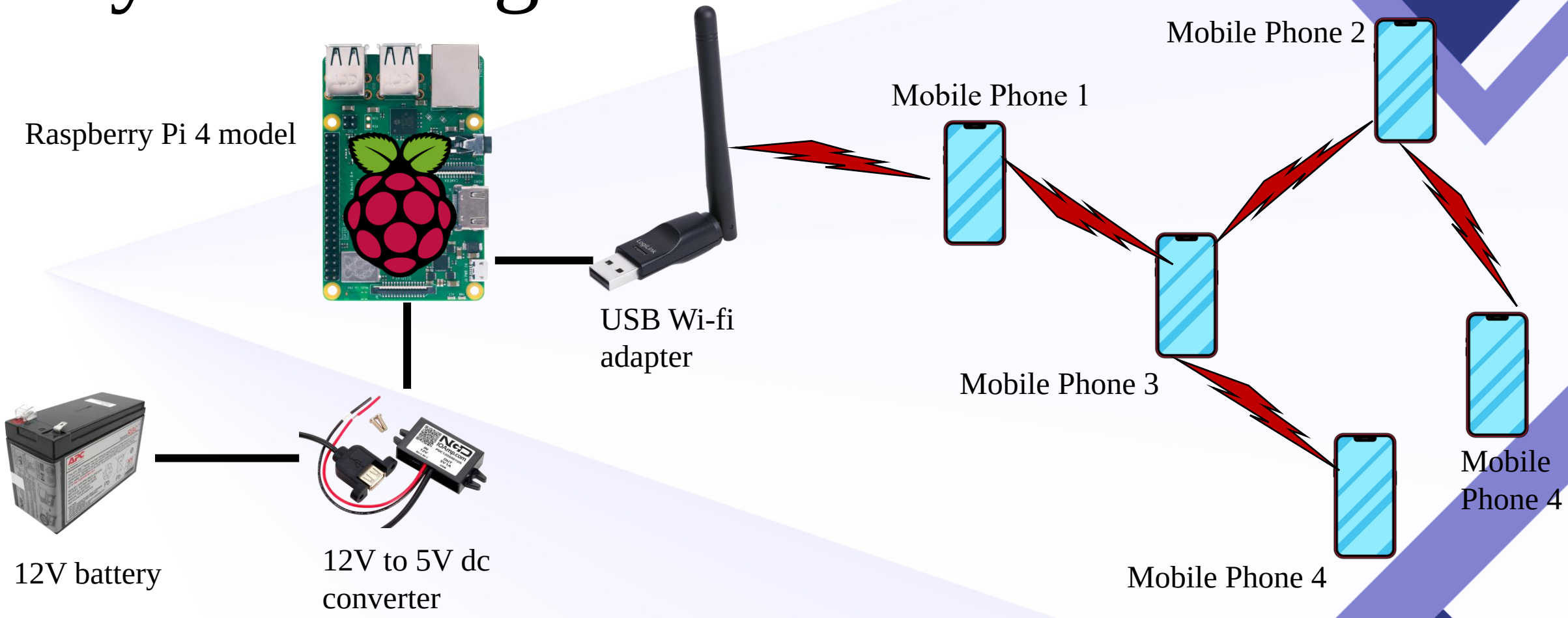
Research Question

- How can a dynamic ad-hoc network architecture be designed and implemented to facilitate reliable emergency communication in disaster-affected areas without relying on existing infrastructure?

- **Main Objective**
  - To develop a disaster-resilient telecommunication infrastructure to ensure continuous communication during natural disasters.
- **Sub-Objectives:**
  - Establish an ad-hoc network for emergency communication.
    - To design and implement a dynamic ad-hoc network architecture.
  - Utilize IoT base stations to enhance the ad-hoc network.
    - To implement and test IoT base stations within the network.

METHODOLOGY

System Diagram



Technologies to be used

- Ad-hoc Network Technologies:
  - Mesh networking, Dynamic Source Routing (DSR), Optimized Link State Routing (OLSR).
- IoT Devices:
  - Sensors and communication devices for IoT base stations.
- Software Integration:
  - Middleware for seamless communication between mobile devices and the ad-hoc network.

Requirements

- Hardware
  - Wi-Fi Enabled IoT Base Stations
  - Mobile devices
  - Wi-fi adapters
  - Power supply units
- Software
  - Custom Firmware

Gantt Chart

Process	Months											
	May	June	July	August	September	October	November	December	Janurary	February	March	April
Requirement Gathering & Initial Planning												
Network Design												
Middlewre Development & Hardware Setup												
Integration & Testing												
Final Deployment												
Project Review & Documentation												
Final Presentation												

References

[1] T. P. Peethambaran and A. H. Lashkari, "A survey on development of an architecture of integrated VANET-cloud computing and design of trust management model," *2015 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT)*, Kumaracoil, India, 2015, pp. 57-63, doi: 10.1109/ICCICCT.2015.7417093.

[2] S. K. S. Kouadri and M. Yaghmour, "Toward a new architecture based on SDN and NFV for an optimized and flexible VANET," *2018 7th International Conference on Computers Communications and Control (ICCCC)*, Oradea, Romania, 2018, pp. 270-275, doi: 10.1109/ICCCC.2018.8509072.

[3] B. Altayeb and I. Mahgoub, "A survey of vehicular ad hoc networks routing protocols," *International Journal of Innovation and Applied Studies*, vol. 3, no. 3, pp. 829-846, Sept. 2013. doi: 10.1109/IEEECONF.2014.6844624.

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BACKGROUND

- Disasters can severely damage traditional communication infrastructure, leaving affected areas without reliable means of communication.
- Ad-hoc networks are crucial in these scenarios as they can form spontaneously and operate independently of existing infrastructure, maintaining communication links.
- In disaster situations, the ability to send and receive SOS messages is critical for coordinating emergency response and ensuring the safety of individuals.

- My role focuses on modify and enhance an existing SOS messaging protocol to enable the transmission of SOS messages within the ad-hoc network.
- The protocol is designed to ensure low latency and high reliability in delivering SOS messages, tailored specifically to the dynamic nature of ad-hoc networks.[1]

Research Gap

Research Paper	Objectives & Tasks			
	Modification of Existing SOS Protocol for Ad-Hoc Networks	Focus on Low Latency in SOS Message Delivery	Enhancing Reliability in SOS Message Delivery	Integration with Mobile Devices
Wireless Ad Hoc Networking: The Art of Networking Without a Network	✗	✗	✗	✗
Routing Mechanisms in Ad Hoc Networks	✓	✗	✗	✗
Building a Disaster Rescue Platform Utilizing Ad-Hoc Networks	✓	✓	✓	✗
Proposed System	✓	✓	✓	✓

Research Question

- How can the existing SOS messaging protocol be redesigned to better integrate with mobile devices and other technologies used in disaster response scenarios, ensuring seamless communication?[2]

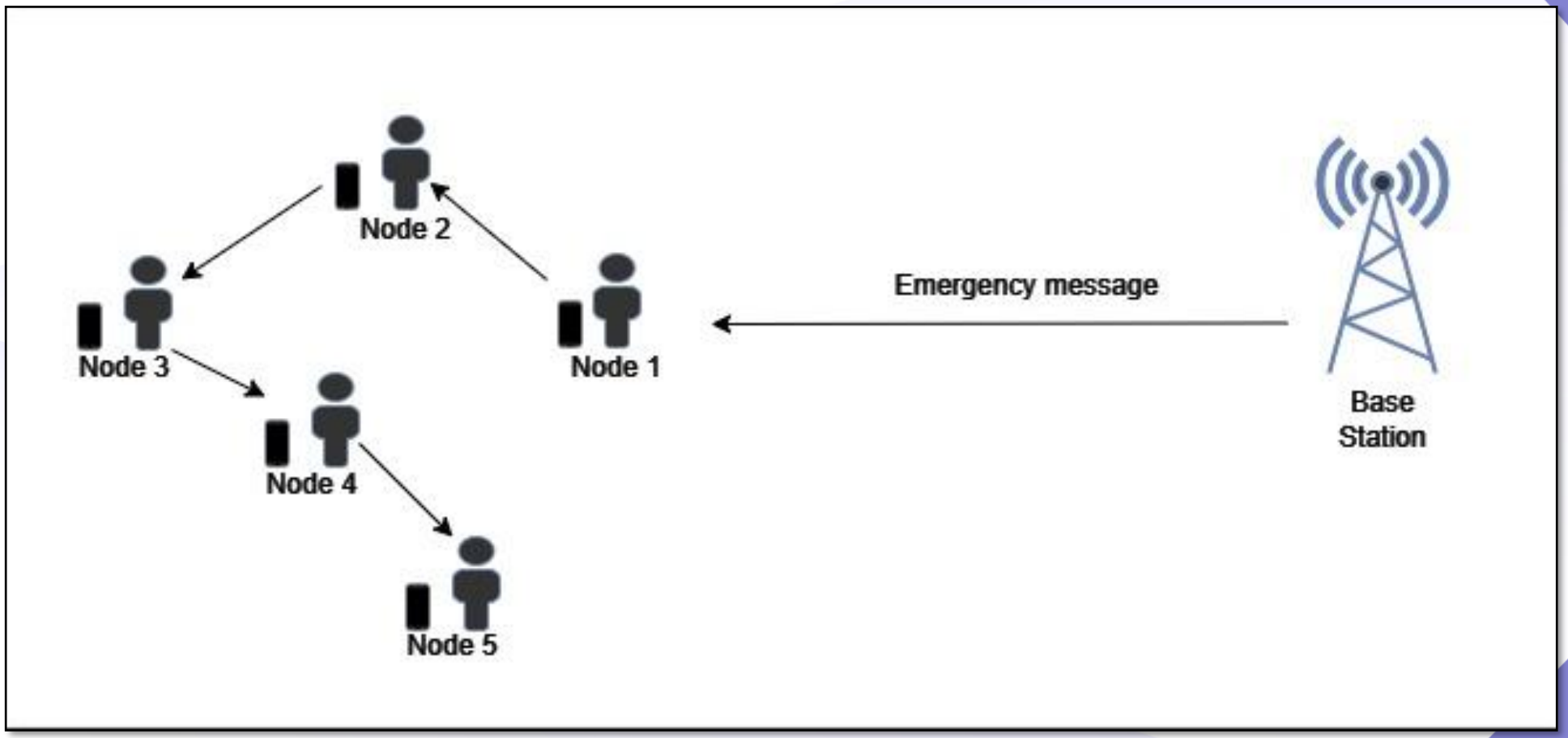
Main Objective

- To develop and enhance a dedicated SOS messaging protocol that ensures low latency and high reliability for communication within ad-hoc networks during disaster situations.

Sub Objectives

- To identify the limitations of the existing SOS messaging protocol, particularly in terms of latency and reliability within ad-hoc networks.
- To develop specific modifications to the SOS messaging protocol that address the identified limitations and optimize performance in dynamic, infrastructure-less environments.
- To adapt the enhanced protocol for seamless integration with mobile devices and other technologies used by rescue teams, ensuring effective communication during disaster response efforts.

System Diagram



Methodology– Technologies to be Used

1.Existing Protocol Analysis:

- Begin with a comprehensive analysis of existing SOS messaging protocols used in ad-hoc networks.
- **Tools:** Network simulators (e.g., NS-3, OMNeT++) to evaluate the current protocol's performance in terms of latency, reliability, and scalability.

2.Protocol Redesign:

- Modify the existing protocol to optimize message delivery in disaster scenarios.

Epidemic Routing Protocol , SPIN (Sensor Protocols for Information via Negotiation)

3. **Simulation and Testing:**
    - **Tools:** Use network simulation tools (e.g., NS-3,Omnet++) to test the modified protocol in various disaster scenarios, evaluating its performance against key metrics like latency, reliability, and message delivery rate.
4. **Integration with Mobile Devices:**
    - ➢Ensure the redesigned protocol is compatible with existing mobile devices and ad-hoc network infrastructure.
    - ➢**Technologies:**
        - **Android SDK** for testing protocol integration with mobile applications.
5. **Field Testing and Validation:**
    - ➢Conduct field tests in controlled environments to validate the protocol's performance in real-world disaster scenarios.

Gantt chart


Process
June
July
August
September
October
November
December
Janurary
February
March
April
Literature Review
Requirement Analysis
Protocol Design
Simulation and Testing Setup
Initial Testing and Refinement
Testing
Data Analysis and Optimization
Final Report and Presentation Preparation

References

[1] I. Chlamtac, M. Conti, and J. J.-N. Liu, "Wireless ad hoc networking: The art of networking without a network," *IEEE Communications Magazine*, vol. 17, no. 5, pp. 48-54, May 2003.

[2] M. Mauve, J. Widmer, and H. Hartenstein, "A survey on position-based routing in mobile ad hoc networks," *IEEE Network*, vol. 15, no. 6, pp. 30-39, Nov. 2001.

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Computer Systems & Network Engineering

Background

- During natural disasters, traditional communication networks are often disrupted, making it challenging to coordinate rescue operations. To address this, our project utilizes RF Signal Detection & Analyze to gather critical data on Wi-Fi and Bluetooth signals in affected areas.
- These portable devices are equipped with sensors and communication modules which detect and measure RF signal strength, providing insights into the presence of people within the disaster zone.
- The data collected by these nodes is transmitted to a central base station using an ad-hoc network. This approach allows for the continuous relay of information, even in the absence of conventional communication infrastructure. By focusing on the collection and transmission of RF signals, this aims to enhance disaster response capabilities, ensuring that rescuers have the information they need to prioritize their efforts and improve outcomes.

Research Gap

Research Paper	Objectives & Tasks		
	Integration with Disaster Management Centers	Non-Intrusive Operation	Use of multiple devices for increased accuracy.
A Novel Technique for Mobile Phone Localization for Search and Rescue Applications	✗	✗	✗
A Doppler Effect Based Framework for Wi-Fi Signal Tracking in Search and Rescue Operations	✗	✓	✗
A Smartphone-assisted Post-Disaster Victim Localization Method	✗	✓	✗
Proposed System	✓	✓	✓

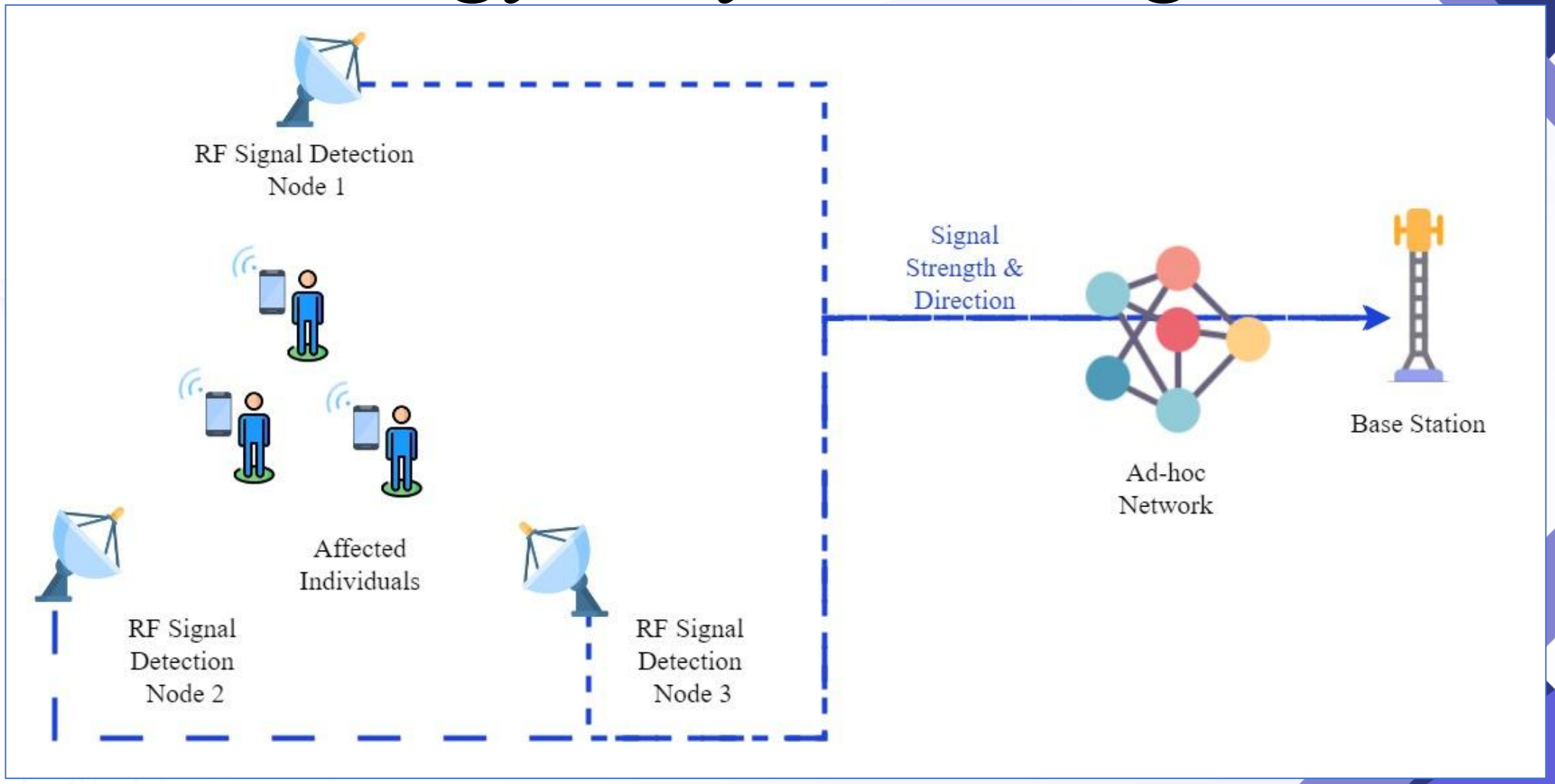
Research Question

- How can RF technologies be utilized to collect data & estimate the number of individuals in a disaster-affected areas effectively?

- Objective
  - To develop a system that uses RF technologies to collect data and estimate the number of people in disaster-affected areas.

- Sub-objectives
  - To Implement a Data Collection System:
    - Develop mechanisms to collect data using RF signals emitted from smartphones and compatible devices. Utilize Wi-Fi or Bluetooth technology to gather data from devices within proximity.
  - To Data Filtering for Accuracy:
    - Implement filtering techniques to ensure data accuracy and eliminate redundancies or false positives in estimating the number of affected individuals.
  - To System Evaluation and Optimization:
    - Evaluate the system's performance in real-world simulations or pilot projects. Optimize the system based on feedback and results to improve data collection accuracy.

Methodology – System Diagram



Methodology - Technologies to be Used

1.Microcontroller-Based Platform

- Utilize a flexible and programmable embedded system for building the RF signal detection devices.
- Support integration with various sensors and communication modules.

2.Wi-Fi and Bluetooth Modules

- **Wi-Fi Module:** Employed to detect and measure Wi-Fi signal strength and facilitate data transmission.
- **Bluetooth Module :** Utilized to detect and measure Bluetooth signal strength for short-range communication.

3.Data Transmission Protocols

- Efficient methods for transmitting RF signal data to the base station

System, personal, and software Requirements specification

- Hardware Requirements

  - Microcontrollers / Microprocessors.
  - Wi-Fi and Bluetooth modules & antennas for RF signal detection.
  - Power supply components for device operation in the field.
  - Enclosures and mounting hardware for device protection and deployment.

System, personal, and software Requirements specification

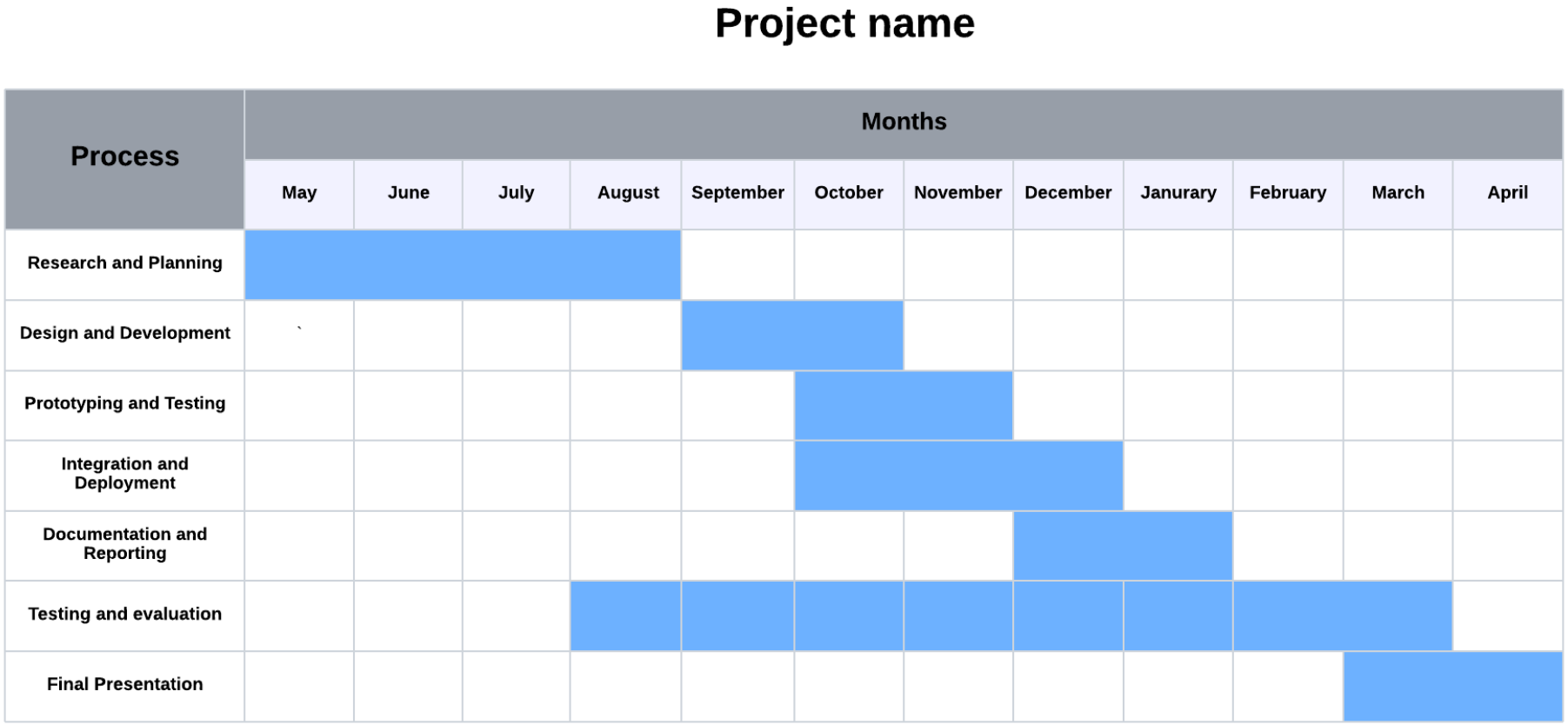
- Personnel Requirements
  - **Required Skills and Knowledge:**
    - **Embedded Systems:**
      - Understanding of embedded system design and development for building RF signal detection devices.
    - **Microcontrollers:**
      - Proficiency in programming and interfacing with microcontroller-based platforms for data collection and transmission.
    - **Sensors and Modules:**
      - Experience with integrating and configuring Wi-Fi and Bluetooth modules to detect and measure RF signal strength.
    - **Networking:**
      - Knowledge of networking protocols and configurations to detect networking devices.

System, personal, and software Requirements specification

- Software Requirements

  - **Development Environment:**
    - Programming tools and environments suitable for developing code for microcontroller-based platforms.
  - **Custom Firmware:**
    - Software to control the detection of RF signals and manage data transmission.
  - **Networking Libraries:**
    - Libraries for handling Wi-Fi and Bluetooth communication and ad-hoc network formation.

Gannt Chart


Project name
Process
Months
May
June
July
August
September
October
November
December
Janurary
February
March
April
Research and Planning
Design and Development
Prototyping and Testing
Integration and Deployment
Documentation and Reporting
Testing and evaluation
Final Presentation

References

- “A novel technique for mobile phone localization for search and rescue applications,” *IEEE Conference Publication | IEEE Xplore*, Sep. 01, 2010. https://ieeexplore.ieee.org/document/5647107
- “A Doppler effect based framework for Wi-Fi signal tracking in search and rescue operations,” *IEEE Journals & Magazine | IEEE Xplore*, May 01, 2018. https://ieeexplore.ieee.org/document/8038804
- “A Smartphone-Assisted Post-Disaster victim localization method,” *IEEE Conference Publication | IEEE Xplore*, Dec. 01, 2016. https://ieeexplore.ieee.org/document/7828505

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Computer System and Network Engineering

BACKGROUND

- Transmit gather data to the base station through ad-hoc network.
- Develop algorithms to analyse RF and device count, identifying population density and movement patterns.
- Generate real-time insights for emergency response teams.
- improve disaster management operations through accurate and timely information.

RESEARCH GAP

Research Paper	Objectives & Tasks		
	Implementing energy-efficient data transmission techniques.	Real-Time Data Transmission and Processing for Disaster Management	Focus on Predicting Population Density
New Ordered Policy Routing Protocol for Active Data Transmission in Mobile Ad-hoc Networks	✗	✗	✗
Estimating Crowd Density in an RF-Based Dynamic Environment	✗	✗	✓
A Novel Technique for Mobile Phone Localization for Search and Rescue Applications	✗	✓	✗
Proposed System	✓	✓	✓

Research Question

- How can data be effectively collected through an ad-hoc network in disaster-affected areas?
- How can the collected data be analysed in real-time to determine population density to enhance emergency response efficiency?

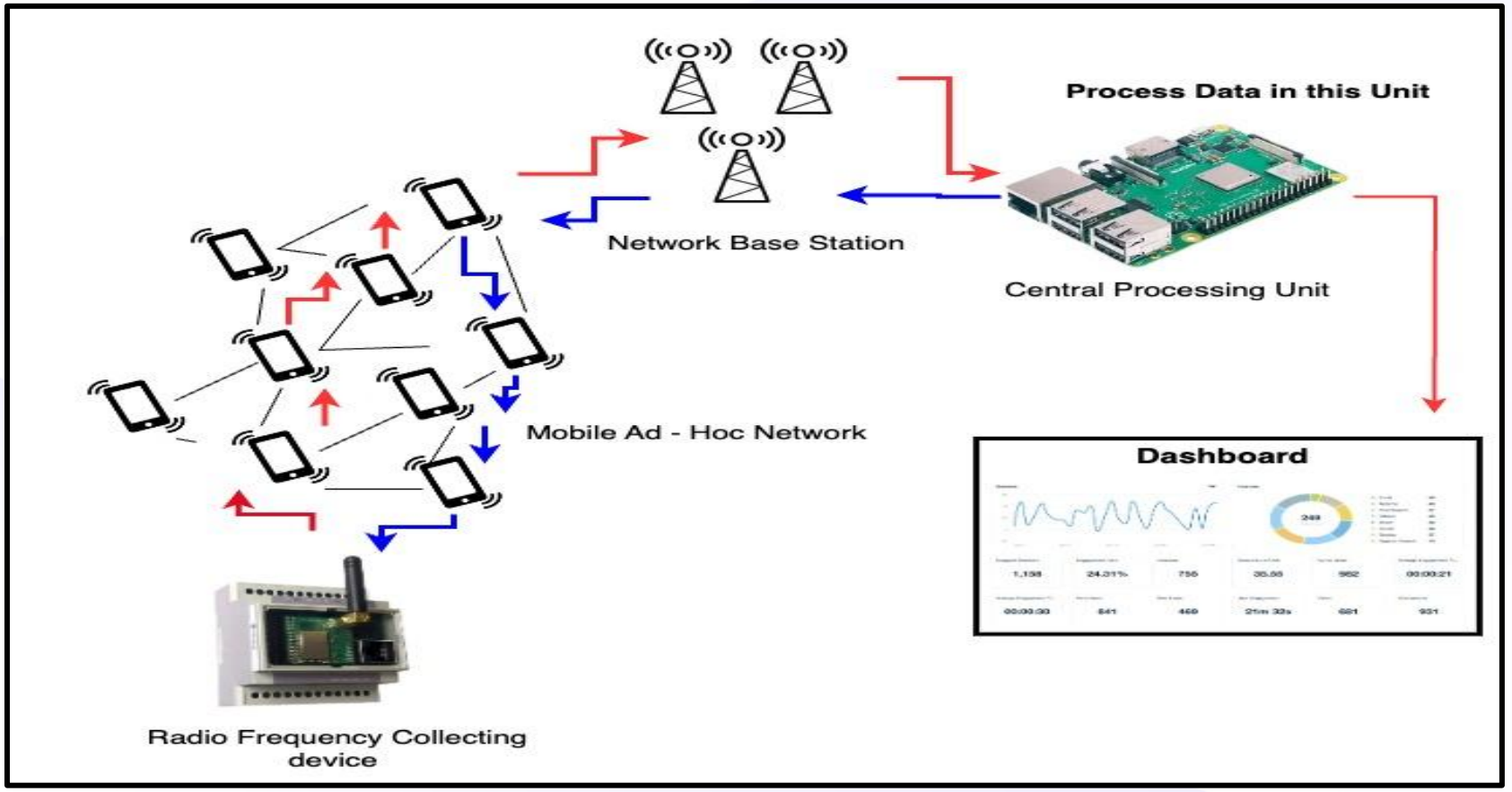
MAIN OBJECTIVES

- To Develop a reliable system for real-time transmission, analysis, and reporting of population density patterns in disaster-affected areas.

SUB OBJECTIVES

- To Transmit collected data seamlessly through the ad-hoc network to base stations.
- To Integrate the collected data for comprehensive analysis.
- To Develop algorithms to analyse the data and identify population density patterns.
- To Provide analysed data to indicate population density locations for rescue teams to move to.

METHODOLOGY – SYSTEM DIAGRAM



METHODOLOGY

- Connect IoT devices to the mobile ad-hoc network (MANET).
- Send the row data to the base station through a mobile ad -hoc network.
- Use routing protocols to establish a path to the base station.
- Create algorithms to analyse population density and movement patterns.
- Analyse data instantly to provide quick insights.
- Send a details about the high population density area to the rescue team.

METHODOLOGY - TECHNOLOGIES TO BE USED

1.Ad-Hoc Network Protocols
(AODV - Ad-hoc ondemand distance vector protocol)
1.Packet-Switching Technology
2.Low-Latency Communication Protocols
3.Data Analysis Tools
4.Data Aggregation Tools

SYSTEM, PERSONAL, AND SOFTWARE REQUIREMENTS SPECIFICATION

System Requirements

- Base Station Infrastructure:
- Ad-Hoc Network Components:

Personnel Requirements

- System Engineers
- Network Engineers
- Data Analysts

Software Requirement

- Communication Protocol Software
- Data Analysis Tools

GANTT CHART

Process	Months											
	May	June	July	August	September	October	November	December	Janurary	February	March	April
Reserch About The Task												
Planning and Design												
Finding and create Data Sets												
Create a data communication protocol												
Develop the algorithms												
Train modles												
Testing and evaluation												
Final Documentation												

REFERENCES

1. “A novel technique for mobile phone localization for search and rescue applications,” *IEEE Conference Publication | IEEE Xplore*, Sep. 01, 2010. https://ieeexplore.ieee.org/document/5647107
2. “New ordered Policy routing protocol for active data transmission in mobile ad-hoc networks,” *IEEE Conference Publication | IEEE Xplore*, Jun. 01, 2019. https://ieeexplore.ieee.org/document/8821864
3. “Estimating crowd density in an RF-Based dynamic environment,” *IEEE Journals & Magazine | IEEE Xplore*, Oct. 01, 2013. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6507544

SUPPORTING ITEMS

BUDGET

Item		Cost	
Hardware Costs	Microprocessors & Microcontrollers	LKR 37,000.00	LKR 67,500.00
	Wi-Fi / Blutooth Modules	LKR 8,500.00	
	Antennas	LKR 1,500.00	
	Power Supply Components	LKR 10,500.00	
	Enclosures & Mounting Hardware	LKR 10,000.00	
Software & Development	IDE	Free (Open Source)	LKR 15,000.00
	Libraries		
	Algorithm & ML Model Development	LKR 15,000	
Miscellaneous	Documentation & Reporting	LKR 3,000.00	LKR 3,000.00
Total			LKR 85,500.00

COMMERCIALIZATION

- Cost-effective, scalable, and adaptable solution.

Potential Markets

- Disaster management and emergency response.
- Telecommunications and smart city applications.

Thank You