**Summary of Emergency Response Drone System Report**

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The project addresses the critical challenges of communication breakdowns, limited access to affected areas, and delays in aid delivery during natural and human-made disasters such as floods, earthquakes, and wildfires. By integrating advanced hardware, real-time sensor data, and a LoRa-based mesh network, the Emergency Response Drone (ERD) system offers a scalable, resilient, and autonomous solution to enhance situational awareness, coordination, and resource delivery in high-risk environments. The report outlines the system’s objectives, technical components, methodology, experimental setup, and future development potential, emphasizing its role in revolutionizing disaster management. The primary motivation for the ERD system stems from the limitations of traditional disaster response methods, which often fail due to damaged infrastructure, lack of real-time data, and coordination difficulties. The project aims to develop an autonomous drone platform capable of rapid assessment, real-time environmental monitoring, and delivery of critical supplies like medical kits and communication devices. Key objectives include:

• Developing a quadcopter system with long-range mesh networking for enhanced performance..

• Providing real-time environmental data using onboard sensors to assist first responders.

• Minimizing power consumption to extend flight time and payload capacity.

• Creating a scalable, adaptable system for various disaster scenarios.

• Laying the foundation for future integration of advanced technologies like AI and improved communication protocols.

The system’s reliance on decentralized LoRa mesh networking ensures robust communication in infrastructure-deficient areas, making it a vital tool for first responders.

The ERD system is built around a robust hardware and software framework. The quadcopter, based on an F450 frame, is equipped with a propulsion system, an Arduino Mega 2560 flight controller, and a suite of MEMS sensors, including:

• MPU6050: A 6-axis accelerometer and gyroscope for flight stabilization and attitude estimation.

• HMC5883L: A 3-axis magnetometer for yaw heading calculation.

• MS5611: A barometric pressure sensor for precise altitude estimation.

• NEO-6M V2: A GPS module for real-time geolocation with 2.5-meter accuracy.

These sensors enable the drone to collect environmental data, detect hazards, and navigate autonomously. The Heltec WiFi LoRa 32 V3 module facilitates long-range, low-power mesh communication, allowing drones to act as mobile routers and relay data to ground stations and other drones.

The methodology integrates drones with LoRa-based mesh networking through a systematic approach. Drones are configured with dynamic routing and selfhealing capabilities, ensuring reliable data transmission in the absence of infrastructure. The flood fill algorithm, a key component of the mesh network, enables each node to rebroadcast packets to neighbors, ensuring broad data dissemination in dynamic environments. The algorithm’s simplicity and robustness make it ideal for unpredictable disaster scenarios, though it may cause redundant transmissions. Other algorithms include:

• **Motor Mixing Algorithm**: Adjusts motor speeds based on thrust, yaw, pitch, and roll for stable flight.

• **Complementary Filter**: Fuses accelerometer and gyroscope data for accurate orientation estimation.

• **PID Controller**: Corrects flight errors across roll, pitch, and GPS operations.

• **Failsafe Algorithm**: Ensures safe landing or motor shutdown during signal loss.

**Flood Fill Algorithm**:

1.Source node (e.g., drone or ground station) sends a data packet.

2. Each receiving node checks if it has seen the packet before.

3. If not, it rebroadcasts the packet to its neighbors.

4. If already seen, it discards the duplicate.

5. Repeat until all reachable nodes receive the packet.

The drones follow preprogrammed or dynamically adjusted flight patterns to maximize network coverage and respond to on-ground needs. The experimental setup focuses on constructing drones as mobile nodes within the LoRa mesh network. Each drone includes a carefully designed frame, propulsion system to optimize signal strength. The Arduino Mega handles data transmission and reception, while the ground station interface provides real-time telemetry, including GPS location, orientation, battery health, and payload status. Key features of the ERD system include:

• **Flight Modes**: Angle, Baro, Mag, GPS Home, GPS Hold, and WP Navigation

for versatile operation.

• **Mesh Network Capabilities**: Decentralized structure, energy efficiency, adaptability, data security, dynamic routing, and node discovery.

The system was tested under simulated disaster scenarios to evaluate range, latency, and reliability, demonstrating significant improvements in response times and communication integrity.

The LoRa-based mesh network is a cornerstone of the ERD system, offering reliability, scalability, and self-healing capabilities. Unlike traditional networks, the mesh topology allows nodes to connect dynamically, rerouting data through alternative paths if a node fails. LoRa’s low-power, long-range communication (0.3–5.5 kbps) is ideal for extended missions in remote areas. The report illustrates four scenarios for node connectivity:

• Optimum Scenario: Direct path from source to destination.

• Node Addition: Automatic rerouting when a new node is added.

• Node Removal: Self-healing by rerouting around lost nodes.

• Worst-Case Scenario: Drones act as airborne routers to restore connectivity.

These capabilities ensure uninterrupted communication, even in infrastructure damaged environments.

The report identifies key challenges in disaster-affected areas, including cellular tower failures, limited accessibility, coordination issues, and delayed infrastructure repair. The ERD system addresses these through:

• **Extended Range**: LoRa enables long-distance communication.

• **Decentralized Network**: Operates independently of traditional infrastructure.

• **Real-Time Coordination**: Enhances teamwork between drones and responders.

• **Efficient Resource Allocation**: Tracks and allocates resources dynamically.

• **Enhanced Situational Awareness**: Provides real-time environmental data.

The system’s cost-effectiveness, energy efficiency, and adaptability make it a practical solution for large-scale disaster management.

Future enhancements include integrating AI for real-time decision-making, developing advanced routing protocols to reduce network congestion, and implementing multi-drone coordination algorithms for swarm intelligence. The ERD system represents a significant advancement in disaster response, combining autonomous aerial mobility with decentralized communication to minimize response times, expand operational reach, and maintain connectivity in challenging environments. By addressing the complexities of modern disaster scenarios, the system lays a foundation for future innovations in autonomous coordination, smart monitoring, and humanitarian aid, promising faster, smarter, and more adaptive emergency management.