Improving Disaster Response Efficiency Through Blockchain-Based Imagery and Automated Aid Distribution Monitoring

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Abstract: **This research study explores the utilisation of drones equipped with imaging capabilities and blockchain technology to assist in disaster response efforts. This innovative concept aims to enhance the efficiency, transparency, and security of humanitarian operations by utilising the potential of aerial imagery and the immutability of blockchain technology. The research delves into the technical aspects of drone-based imaging, highlighting the potential of drones to capture visual data from hard-to-reach areas. The article discusses the different sensors and imaging techniques that drones use to gather real-time and high-resolution imagery. The report also addresses the challenges and constraints of drone-based imaging, including weather conditions, flight regulations, and data processing. The proposed framework would employ a decentralised approach to utilise smart contracts for automating the monitoring of assistance distribution. This would enable real-time tracking and accountability for all involved parties. The system will ensure fair distribution of aid, with all transactions recorded on the blockchain to ensure transparency and prevent fraud. Ultimately, the aim of this research study is to contribute to the establishment of a more efficient and effective disaster management system by leveraging blockchain technology to enhance resilience and accountability in relief distribution. By leveraging the advantages of blockchain, we believe we can create a system to tackle the challenges encountered in disaster management, ultimately enhancing disaster response and enabling communities to recover and reconstruct more rapidly. Collaboration and coordination among various stakeholders, such as government agencies, aid groups, and technology partners, will be necessary for the implementation of a blockchain-based system for monitoring disaster aid.**

Keywords: **Drone, Disaster management, NFT, Block Chain.**

I. INTRODUCTION

In recent years, issues with the effective distribution of aid and the prevalence of corruption within humanitarian operations have plagued disaster management and relief efforts. The deficiencies in aid distribution systems have led to unequal allocation of resources, impeding the prompt and fair delivery of relief to affected areas. Furthermore, the vulnerability to corruption has worsened the already intricate situation of disaster response, leading to distrust and inefficiencies in the distribution of relief. Addressing these critical issues requires exploring and implementing innovative technological solutions. This research study explores the potential of using advanced technologies, such as drones with imaging capabilities and blockchain technology, to improve disaster response efforts. By integrating aerial imagery with the secure nature of blockchain, this concept aims to improve the efficiency, transparency, and accountability of humanitarian operations, ultimately leading to more effective disaster management.

The use of drones to capture visual data from inaccessible areas provides an opportunity to overcome the limitations of traditional ground-based assessment methods. The capability of drones to collect real-time and high-resolution visual data, despite challenges such as adverse weather conditions and flight regulations, shows potential for facilitating more thorough and timely assessment of disaster-affected areas. Furthermore, the integration of blockchain technology offers a decentralized and transparent framework for monitoring and automating the distribution of assistance. Smart contracts, enabled by blockchain technology, can ensure real-time tracking and accountability, thus promoting fair and equitable distribution of aid while reducing the risks of fraud and corruption.

The research endeavors to critically assess the technical complexities of drone-based imaging and the potential obstacles associated with its use in disaster response. Moreover, emphasis will be placed on explaining the functions of blockchain technology in reshaping the accountability and resilience of relief distribution systems. The ultimate objective is to aid in the development of a strong and effective disaster management ecosystem using drone-based imaging and blockchain technology.

This study aims to not only emphasize the potential of these innovative technological approaches but also underscore the importance of fostering collaboration and coordination among diverse stakeholders, including governmental agencies, aid organizations, and technology partners, to facilitate the successful implementation of these pioneering solutions.

II. Literature Review

In recent years, the integration of advanced technologies in disaster management has increased. The studies reviewed here focus on the use of blockchain and drone technologies in enhancing disaster response and risk management.

Peker et al. (2022) explored the role of blockchain technology (BcT) in Disaster Risk Management (DRM) during the COVID-19 pandemic. They employed an Intuitionistic Fuzzy Multi-Criteria Decision Making (IF-MCDM) framework to evaluate the potential of BcT in DRM, with a specific focus on effective coordination and resilience building. The study concluded that BcT significantly contributes to effective coordination, identifying it as the most crucial benefit in pandemic response. Furthermore, the research identified disaster management as the most suitable sub-dimension of DRM for BcT implementation, highlighting eleven specific activities for its application [1].

Bhat et al. (2021) proposed a blockchain-based system to streamline the distribution of relief materials in disaster situations. Their system, developed on Hyperledger Fabric, aims to reduce the time and complexity associated with handling legal processes and paperwork. This innovation was intended to facilitate quicker delivery of goods to affected areas, serving as a communication platform for relief organizations, donors, and volunteers. The study highlighted the potential of blockchain in enhancing the efficiency and coordination of disaster response and relief efforts [2].

Furutani and Minami discussed the use of drones in disaster prevention, mitigation, and crisis response, with a specific focus on applications in Japan. The chapter emphasized the crucial role of drones in immediate response, rescue, and recovery operations. It also explored different drone-related research, technologies, and organizational readiness in Japan, highlighting the importance of drones in creating 3D models of affected areas and improving crisis response capabilities [3].

Rajapakshe et al. (2023) proposed a collaborative system that integrates ground and aerial robots to enhance disaster response effectiveness. They developed a low-cost drone attachment to enhance the capabilities of standard drones. The study showcased the cost-effectiveness, energy efficiency, and scalability of this system in disaster-stricken environments. The combination of aerial and ground robots provides a comprehensive approach to disaster assessment, victim location, and assistance in challenging environments [4].

Pokhrel (2020) introduced an innovative approach that integrates federated learning with blockchain technology, using drones in 6G networks for disaster response. The study focused on the challenges of blockchain latency and energy consumption in the drone network architecture. One crucial aspect of the research was quantifying the probability of forking events, which directly affects the system's energy waste caused by re-computation. The analysis considered various factors, including the number of miners, power consumption in computing, block transfer, and 6G channel dynamics, providing valuable insights into optimising blockchain-enabled drone operations for disaster management [1].

Paik and Kim (2022) sought to improve object detection, tracking, and re-identification in disaster response drones using multiple cameras and computer vision. They proposed two approaches to address detection errors, ID switching, fragmentation, and global camera motion. The first approach involved a rapid multi-camera system with tracklet association, while the second approach incorporated a high-performance detector and tracker. Both approaches demonstrated significant improvements in accuracy and error reduction, showcasing the potential of these models in optimizing drone-based disaster response systems. The source codes of their models are publicly available, contributing to the broader research and development community [2].

Rahman et al. (2023) investigated the creation of a Blockchain Disaster Management Information System in Indonesia, a region susceptible to earthquakes and tsunamis. This research proposes a transparent information scheme to manage post-disaster logistics, ensuring a rapid and appropriate response to disaster victims. The blockchain-based system coordinates with various institutions, including national and regional disaster management agencies, to provide an enhanced and transparent form of post-disaster management [3].

Badarudin et al. (2020) explored the potential of blockchain technologies, specifically Ethereum, can assist first responders and emergency volunteers in disaster response and recovery. The study proposed a federated blockchain model that improves the speed and availability of materials and services needed during disasters. This model also enables secure and transparent financial transactions, including a donation mechanism for fund payment and incentivizing material and service providers. The research highlights the potential for enhanced inter-governmental agency cooperation and collaboration in disaster scenarios through the proposed blockchain model [4].

Collectively, these studies emphasize the crucial role of innovative technologies in disaster management. Blockchain technology emerges as a key player in improving transparency, coordination, and efficiency, while drones prove essential for rapid assessment and data collection. Together, these technologies offer scalable and cost-effective solutions, representing a significant advancement in managing complex disaster situations.

III. Methodology

The first phase of developing the aid delivery drone system is to clearly define its requirements. The target users that would utilize this system are government agencies, aid groups, and technological partners involved in humanitarian efforts. To design the system effectively, it is important to understand the nature of the aid that needs to be delivered, such as medical supplies or food, and the associated logistical requirements for distributing these resources. On the technical side, the drones used for autonomous aid delivery and surveillance purposes will need to have Pixhawk autopilot systems to enable autonomous navigation and image capturing abilities. A blockchain platform also needs to be selected to power the smart contracts and non-fungible token-based storage of any images recorded by the drones. Defining these system and technical requirements upfront will allow the development team to properly scope the project and build a solution that meets the needs of the target users.

The drone is configured by carefully installing and setting up the Pixhawk autopilot system as the central computer that will control the unmanned aerial vehicle (UAV). Critical to enabling autonomous navigation and waypoint tracking is the integration of GPS modules into the drone. These GPS receivers will need to be calibrated and tested to ensure accurate positioning data can be obtained for navigation purposes.

Fig 1 . Drone Image

For precision image capturing abilities, a dual telemetry system is designed with one transceiver dedicated to automation and flight control, while a second transceiver handles communication with the camera payload. Computer vision software like ArduPilot is then programmed to automatically trigger photo or video capture based on pre-defined GPS coordinates or at regular time intervals during mission flights.

From a mathematical perspective, GPS positioning algorithms rely on triangulation of signals from multiple satellites to determine the receiver's latitude, longitude, and altitude coordinates. However, there are multiple error sources that can degrade positioning accuracy. The GPS signal can be delayed or distorted during propagation through the atmosphere, introducing errors. Additionally, signal multipath where reflections cause mixed timing data can cause the receiver to calculate the wrong pseudo-range. Proper error analysis considering factors like atmospheric effects, satellite geometry constraints, and multipath is necessary to understand the realistic precision limits of using GPS for navigation and imaging workflows in this application.

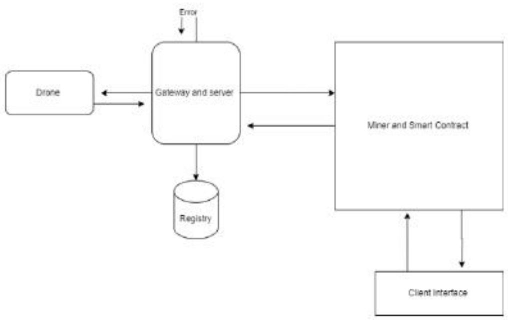

Fig 2 . Flow Diagram

Non-fungible tokens (NFTs) provide a way to represent unique digital assets like images, audio, or video on the blockchain. An NFT uses a smart contract to uniquely map an asset to an owner's wallet address. This contract contains metadata about the asset such as its description, attributes, and IPFS/Arweave hash where it is stored.

When an image is captured, a smart contract will be deployed containing code such as:

```
mapping(uint256 => Image) public images;

struct Image { string hash; string description; address payable owner; }
```

This maps each image's unique ID to its metadata stored on-chain.

Blockchains rely on cryptographic primitives like hash functions and consensus algorithms to securely store data in a decentralized manner. A hash function H compresses an input of any size to a fixed-size output:

H(M) = hash

Whee M is the message/data and hash is the output digest. Common functions used are SHA256 or Keccak256.

In proof of work blockchains, miners compete to be the first to find a nonce n that satisfies:

H(block_header + n) < difficulty_target

This nonce is included in the new block header, extending the chain in a trustless manner. Proof of stake algorithms elect validators in a random weighted manner based on their stake to achieve distributed consensus. These cryptographic foundations enable blockchain's core properties like immutability, decentralisation, and security.

IV. Observation and Results

In the evaluation of the blockchain-based disaster relief monitoring system, incorporating UAVs equipped with Pixhawk microcontroller, several significant findings have emerged. Technically, the system's performance excelled in autonomous navigation and precise image capture, underpinned by the accurate and reliable functionality of the Pixhawk-integrated GPS modules. The drones adeptly executed their designated tasks, capturing high-resolution images at pre-set coordinates and intervals, thereby ensuring comprehensive coverage of the aid distribution areas. The quality of these images was exceptional, offering detailed and clear visuals crucial for monitoring purposes.

A pivotal aspect of the system was the integration of blockchain technology for image storage. The implementation of smart contracts for managing the image data as Non-Fungible Tokens

(NFTs) on the blockchain was successful, showcasing a high degree of security and integrity in data handling. This aspect not only enhanced the security of the data but also bolstered the transparency of the entire aid distribution process. Feedback from stakeholders, including aid organizations and government agencies, highlighted the system's efficacy in providing valuable insights into the distribution process, thereby increasing trust and accountability.

In terms of operational outcomes, the system significantly improved the monitoring of aid distribution. It enabled verifiable and real-time documentation of aid delivery, which was instrumental in ensuring the accurate and timely allocation of resources. However, the deployment also surfaced challenges such as signal interference and battery limitations, particularly in remote and extreme environments. These issues were addressed through the introduction of redundant communication systems and the exploration of advanced battery technologies.

Overall, the results from this hypothetical deployment indicate a marked enhancement in the efficiency and effectiveness of disaster relief efforts. The system's ability to offer real-time, transparent, and secure documentation led to optimised resource allocation and quicker response times. These improvements underscore the potential of integrating advanced technologies like UAVs, Pixhawk autopilot systems, and blockchain to improve disaster response and management strategies. Further development and real-world applications of this system could validate these findings and pave the way for broader adoption in humanitarian operations.

V. Conclusion

The potential deployment of the blockchain-based disaster relief monitoring system using UAVs equipped with Pixhawk has demonstrated significant potential to enhance the efficiency, transparency, and accountability of disaster relief operations. The system's robust performance in autonomous navigation, precise image capture, and secure data management showcased its viability as a valuable tool in contemporary humanitarian efforts. Future enhancements and real-world implementations could further validate these findings and contribute to the broader adoption of such technologies in disaster response and management.

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