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CRISISSYNC: Smart Disaster Management System

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Abstract: *This paper presents CRISISSYNC as a solution to overcome the limitations of the traditional disaster management system. This presents the disadvantages of centralized command structures that depend heavily on uninterrupted communication and infrastructure. Due to this, incidents like delayed response can occur, resulting in loss of many lives. We propose a decentralized and intelligent disaster management framework that transforms traditional crisis handling into an adaptive, self-healing process. It integrates five innovations, which are a Predictive Digital Twin for proactive forecasting, a Crowdsourced Sense-Making AI for trusted real-time insights, a Trustful Mesh Network for resilient communication, an Autonomous Swarm Intelligence for collective decision-making, and a Dynamic Task Marketplace for optimal resource allocation. By combining all these innovations, we remove the risk of a single point of failure and move towards a Smart Disaster Management System.*

Keywords: *Disaster Management, Swarm Intelligence, Digital Twin, Mesh Network, Artificial Intelligence, Blockchain, Internet of Things (IoT)*

I. INTRODUCTION

Natural or Artificial Disasters, like floods, earthquakes, wildfires, etc., expose the limitations and weaknesses of traditional disaster management systems. The traditional system relies on the hierarchical command structure and sequential decision-making. It can lead to slow responses and a bottleneck, which can result in many lives. Also, the problem of sequential decision-making becomes inefficient in large-scale disaster management processes. With all these problems in the traditional system, there arises the need for an updated and more advanced system for Disaster Management. The recent advancements in emerging technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), Blockchain, and decentralized networks have now enabled new ways for an advanced and smart disaster management system. The main objective of CRISISSYNC is to combine all these technologies to create an intelligent, self-healing ecosystem that will be capable of functioning even under severe disruptions. This paper introduces the CRISISSYNC, a Smart Disaster Management System that combines five innovations which are Predictive Digital Twin for proactive forecasting, a Crowdsourced Sense-Making AI for trusted real-time insights, a Trustful Mesh Network for resilient communication, an Autonomous Swarm Intelligence for collective decision-making, and a Dynamic Task Marketplace for optimal resource allocation. The novelty of this work lies in the holistic integration of multiple emerging technologies into a single operational ecosystem that transforms disaster management from a reactive process to a proactive, autonomous, and resilient mechanism. CRISISSYNC presents an intelligent self-healing approach that dynamically changes based on data feedback and system learning. This thing is different from traditional systems that depends on central control and fixed protocols.

II. LITERATURE SURVEY

A. Previous Research Articles

Didem Cicek and Burak Kantarci (2021), in their paper titled “Use of Mobile Crowdsensing in Disaster Management: A Systematic Review, Challenges, and Open Issues,” published in MDPI (Turkey/Canada), conducted a detailed review of mobile crowdsensing (MCS) applications for disaster management. In this study, they showed how MCS used data from citizens during both manmade and natural disasters. Nonetheless, certain issues like faulty data, privacy issues, and low crisis participation rates can arise. They highlighted how AI can be used to filter faulty data. They proposed a crowdsensing-based disaster management system addressing data reliability and user participation.

Maurilio Matracia, Nasir Saeed, Mustafa A. Kishk, and Mohamed Slim Alouini (2022), in their review paper titled “Post-Disaster Communications: Enabling Technologies, Architectures, and Open Challenges,” published by CoLab (Saudi Arabia), studied and examined some emerging communication technologies—such as IoT devices, UAVs, and mesh networks—for post-disaster recovery. The authors studied and examined how the mentioned technologies help people reconnect in the event that traditional infrastructure or systems fail and cannot connect. The study also covered the issues that are unresolved with these networks’ energy efficiency, scalability, and interoperability in harsh environments. The study highlighted the importance and necessity of hybrid architectures that integrate terrestrial and aerial networks, which guarantee constant communication and real-time information flow in disaster situations.

Haolang Luo, Yifan Wu, Gang Sun, Hongfang Yu, and Mohsen Guizani (2023), in their article “ESCM: An Efficient and Secure Communication Mechanism for UAV Networks,” published on arXiv (USA/China), proposed a unique UAV-based communication mechanism for operation related to disaster management. According to the results of the simulation, the performance of ESCM was better than traditional UAV communication models in terms of transmission reliability and energy efficiency, which makes it ideal for urgent disaster management tasks.

Zesong Dong, Wei Tong, Zhiwei Zhang, Jian Li, Weidong Yang, and Yulong Shen (2023), in their paper titled “Blockchain-Based Identity Authentication Oriented to Multi-Cluster UAV Networking” (arXiv, China), introduced a decentralized blockchain-based identity authentication framework for UAV networks that are deployed in zones affected by disasters. Multiple UAV clusters operating in dynamic environments with high risk can communicate securely and without tampering. The study showed how blockchain improves trust management, authentication, and data security in independent UAV operations, which results in a low risk of data manipulation and spoofing. According to the findings of this study, by combining or integrating blockchain technology with UAV swarm communication, disaster management networks’ resilience and integrity can be considerably increased.

Y. Zhang and H. Lin (2022), in their study titled “Digital Twin-Enabled Smart Emergency Management in Cities”, explored how virtual digital twin environments can simulate events like disasters in real-time to predict and mitigate potential damages caused. By combining IoT sensor data with AI-based prediction models, the system offered specific scenario forecasting and response planning. The authors showed that by making use of a digital twin framework, better decision-making and coordination are allowed among the emergency units, which results in increased preparedness. The integration of digital twins into urban emergency management systems has the potential to convert reactive operations into frameworks that are proactive and self-organizing.

B. Resarch Gaps

Even if considerable progress has been made in technologies like AI, UAVs, blockchain, and MCS to be used for disaster management, there are many issues that still exist. Didem Cicek et al. (2021) and Matracia et al. (2022) identified the issues and expressed the need for improved connectivity between decentralized communication systems and mobile sensing platforms, as current frameworks often fail under high data bottlenecks or partial infrastructure collapse. Luo et al. (2023) and Dong et al. (2023) demonstrated the advantages of UAV-based communication and blockchain authentication, but also listed the limitations and issues in scalability, energy efficiency, and integration with heterogeneous IoT devices in complex urban environments. Additionally, Zhang and Lin (2022) explained the digital twins predictive model, but the mechanisms for integrating real-time crowd intelligence and decentralized coordination were missing. Most existing systems operate in isolation, which either focuses on secure communication and deployment of the sensors in real-time or prediction without establishing an integrated, self-adaptive ecosystem. There remains a gap in developing a fully decentralized, swarm-intelligent, and trust-driven framework that enables real-time collaboration among devices, agents, and citizens. Moreover, many challenges exist in achieving transparent data validation, adaptive learning from past events, and cross-network coordination during disasters, which can be either natural or man-made. The addressing of these issues forms the foundation of the proposed CrisisSync: Smart Disaster Management System, which integrates various emerging technologies like AI, blockchain, mesh networking, and swarm intelligence into a single decentralized architecture to enable autonomous, resilient, and self-healing disaster management.

III. METHODOLOGY

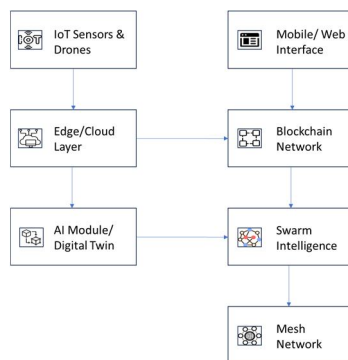


Figure 1. System Architecture of CRISISSYNC Framework

The CRISISSYNC combines and integrates various emerging technologies to ensure real-time prediction, communication, and coordination during natural or man-made disasters.

- 1) IoT Layer: This layer collects live data of the environment and infrastructure through sensors, drones, and smart devices available during times of disasters.
- 2) AI Layer: This layer performs tasks like predictive modeling, anomaly detection, and decision-making so that the actions to be performed can be given priorities.
- 3) Blockchain Layer: This layer ensures that the decentralized nodes can communicate with each other securely.
- 4) Swarm Intelligence Layer: This layer enables the system to coordinate independently and make collective decisions among various agents available during times of disasters.
- 5) Mesh Network Layer: This layer maintains peer-to-peer connectivity during infrastructure breakdowns in case of disaster.
- 6) Digital Twin Module: This layer simulates the conditions of the city during times of disasters so that we get a better idea of performing tasks in case of disasters.
- 7) Cloud & Edge Computing Layer: This layer provides scalable and fast processing, which is required for real-time data analysis.

Fig. 1 illustrates the overall system architecture of CRISISSYNC. It shows how various layers and technologies work together in the case of a disaster.

IV. CONCLUSION

The CRISISSYNC framework, which we proposed, introduced a major shift in disaster management. The main objective or idea lies in getting away from systems that have centralized commands towards decentralized systems. We have integrated various available technologies like Crowdsourced Sense-Making AI for gaining trusted real-time insights, a Trustful Mesh Network for flexible communication, an Autonomous Swarm Intelligence for collective decision-making, and a Dynamic Task Marketplace for maximum resource allocation. The integration of all of these technologies ensures faster prediction, trusted data exchange, and autonomous task execution without completely relying on a single point of control. The uniqueness and novelty of our idea lie in integrating all these technologies to form a disaster management system.

V. FUTURE SCOPE

- 1) Scalability to Smart Cities: We will soon be able to apply our concept to major cities in the near future.
- 2) Integration with 6G and Edge Computing: By integrating with 6G and Edge Computing, we can achieve secure and dependable communication and faster predictions.
- 3) Human-AI Collaboration: We can improve coordination between human and AI agents in case of a disaster.
- 4) Standardization and Policy Development: We can create interoperability and privacy standards for decentralized systems.
- 5) Cross-Disaster Adaptability: We can change our concept to handle situations like pandemics, wildfires, and floods.
- 6) Continuous Learning: We can merge reinforcement learning for evolving system intelligence based on past events.

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