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A Review on Disaster Relief with the Aid of UAVs with WSNs: Utilizations and Challenges

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***Abstract*:-**The fast development of Unmanned Aerial Vehicles (UAVs) has led to their use in various fields, including natural disaster management. UAVs can assist in disaster management by surveying affected areas and establishing communication networks between disaster survivors, rescue teams, and nearby cellular infrastructure. This paper highlights the different applications of UAV networks in disaster management and discusses some of the research problems associated to the use of UAVs in this context.

***Keywords:* -** Unmanned Aerial Vehicles; Wireless sensor networks; Early warning systems; Unmanned ground Vehicles

1. Introduction

It's great to see that there is a growing recognition of the importance of disaster resilience in the face of natural disasters. Leveraging advanced technologies such as WSNs and UAVs could potentially improve disaster prediction, assessment, and response capabilities [1]. WSNs can be used to observe environmental factors such as temperature, humidity, and seismic activity in real-time. This information can be used to create early warning systems that alert people in advance of natural disasters, giving them time to evacuate and prepare. UAVs can also be used in disaster response efforts, such as delivering medical supplies and other essential goods to disaster-stricken areas, conducting search and rescue operations, and providing real-time aerial footage of affected areas to aid in assessment and response efforts [2]. Overall, the integration of WSNs and UAVs can potentially improve disaster resilience and response efforts, ultimately helping to save lives and minimize the impact of natural disasters on communities [3].

It's true that natural disasters pose significant challenges to human response efforts due to their large physical scale and unpredictability [4]. In recent years, efforts have been made to improve disaster management systems by utilizing UAVs. UAVs can be equipped with various sensors and cameras that can collect data and images of the disaster-affected areas in real-time, which can be used to assess the extent of damage and plan rescue and recovery efforts [5]. UAVs can also be used to transport essential supplies and equipment to affected areas, as well as to perform search and rescue operations in areas that may be inaccessible to ground-based teams. However, there are still various open concerns and research issues in UAV-assisted disaster management systems [6]. One of the key challenges is the need to develop efficient and reliable communication systems that can facilitate real-time data transmission between the UAVs and ground-based teams. Another challenge is the need to ensure that UAVs can operate effectively in challenging environments, such as areas with high wind speeds or in areas with limited visibility [7]. Overall, the usage of UAVs in disaster management systems has the impending to ominously improve response efforts and reduce the impact of natural disasters on communities. However, it's important to continue to research and develop these systems to ensure they can operate effectively in a wide range of disaster scenarios [8].

This paper is divided into several sections:

Section II: Disaster Management Stages - This section likely gives an overview of the different stages of disaster management, such as prevention, preparedness, response, and recovery.

Section III: UAV-Assisted Disaster Management Applications - This section is probably dedicated to discussing the different ways UAVs can be used in disaster management like for search and rescue operations, damage assessment, and supply delivery.

Section IV: Open Issues and Challenges - This section may cover the various challenges and limitations of UAV-assisted disaster management systems, as well as potential areas for further research and development.

Section V: Conclusions - This section is likely a summary of the key points and findings presented in the paper, as well as any recommendations for future work in the field.

2. Disaster Management Stages

Understanding the nature of natural disasters and their phases is crucial for developing effective disaster management techniques and methods [9]. Natural disasters can take many forms, such as earthquakes, hurricanes, floods, wildfires, and more. Each type of disaster has unique characteristics that must be taken into consideration when developing disaster management plans [10]. For example, earthquakes can produce substantial damage to buildings and infrastructure; on the other hand hurricanes can cause widespread flooding and power outages. The phases of disaster management typically include prevention, preparedness, response, and recovery [11].

In the prevention phase, efforts are made to reduce the risk of disasters occurring in the first place, such as through building codes and land use planning. In the preparedness phase, plans and resources are put in place to respond to disasters if they do occur [12]. This can include things like emergency response plans, stockpiling essential supplies, and training first responders. In the response phase, emergency teams are deployed to the disaster area to provide aid and support to affected communities [13]. Finally, in the recovery phase, efforts are made to rebuild and restore affected areas to their pre-disaster state. By understanding the nature of natural disasters and their phases, disaster management teams can develop effective strategies and plans to minimize the impact of disasters on communities and promote quick recovery [14].

In this paper we propose a three-stage operational plan for using UAVs in natural disaster management [19].

The first stage is pre-disaster preparedness, which involves conducting surveys to identify potential events before a disaster occurs. This stage also involves setting up EWS using static WSNs and setting threshold levels for sensing.

The second stage is disaster assessment, which involves providing real-time situational awareness during the disaster and conducting damage studies for logistical planning.

The third stage is disaster response and recovery, which includes Search and Rescue (SAR) missions, forming the communications backbone, and conducting insurance-related field surveys.

Each stage requires UAVs to perform different tasks, has varying priority levels, and lasts for different lengths of time.

3. UAV-Assisted Disaster Management Applications

This section discusses a study that categorizes WSN and UAV applications in disaster management that depends on their objectives. Six types of applications are reviewed, including monitoring, forecasting, and EWS, disaster information fusion, situational awareness and logistics, damage assessment, standalone communication systems, and search and rescue missions. The purpose of the study is to give insights into the potential usage of WSN and UAVs in disaster management and to identify gaps and challenges in their application. By classifying and reviewing related works, the study aims to develop more effective and efficient disaster management strategies to reduce the impact of disasters on people and the environment [20].

a) Monitoring, forecast, EWS

This section discusses the use of WSN and UAVs in predicting disasters through structural and environmental monitoring and data analysis for forecasting and EWS. These applications are primarily focused on the preclusion and readiness stages of the disaster management progression. For instance, [21] describes a EWS for natural disasters that utilizes available WSN based technologies and focuses on reliable information transmission, large amounts of information from different types of sensors, and minimal energy depletion. [22] presents a methodology for designing and implementing a web-based platform that continuously monitors the landslide in the Eastern Italian Alps using various techniques and integrated services. [23] Outlines an elucidation that employs UAVs to address issues that rise from accountabilities in a sensor network during natural disasters.

b) Standalone communication systems

The applications that are receiving the most attention in disaster management are focused on establishing or restoring communication infrastructure during and after disasters. These applications propose various approaches, such as standalone communication systems, integrated emergency communication systems that rely on wireless sensor networks (WSN), and networks of unmanned aerial vehicles (UAVs) that act as a backbone for communication networks. In addition, there are proposals for flexible network architectures that provide a common networking platform for heterogeneous multi-operator networks, as well as distributed mobility algorithms for re-establishing connectivity among disconnected end-users in post-disaster scenarios [38]. These proposed solutions aim to provide reliable and efficient communication channels for disaster victims and rescue teams, enabling them to exchange critical information and coordinate their efforts. Furthermore, some of the proposed solutions use available resources, such as mobile devices, to extend Internet connectivity to disaster victims and facilitate their access to vital services and information. In summary, these applications demonstrate the potential of wireless technologies in addressing

communication challenges that arise during and after disasters. They also emphasize the importance of developing robust and adaptable communication infrastructures that can withstand and recover from disruptions caused by natural or man-made disasters [39].

c) Search and rescue missions

WSNs and UAVs have proven to be powerful tools in disaster search and rescue operations. These technologies can be used to quickly and efficiently search for survivors in disaster zones, especially in urban areas where access can be limited. The architecture proposed in [40] focuses on using a sensor suite and sensor fusion algorithm for victim detection. This approach allows for the aggregation of sensor readings from various sensors on multiple robots, which can improve the accuracy and efficiency of the search and rescue operation. Additionally, the authors propose a methodology for testing the system, which involves a combination of real-world and simulation-based testing. Similarly, [41] presents an ad-hoc sensor network for disaster relief applications that provides rescue teams with a quickly deployable and reliable tool to collect information about the presence of people in a collapsed building. The system uses wireless sensors that are placed in the building and communicate with a base station to provide real-time data on the location of survivors. [42] takes a different approach to WSN deployment by using mobile robots for human enter. Overall, the use of WSN and UAVs in disaster search and rescue operations has the potential to significantly improve the efficiency and accuracy of these operations as shown in Table 1. These technologies can provide rescuers with real-time information on the location of survivors, which can help save lives and reduce the time and resources needed for the rescue operation.

d) Other applications

Ensuring the health and wellbeing of individuals is a top priority for an effective disaster management system. As such, various medical interventions are utilized before, during, and after disasters to address issues such as disease prevention, emergency medical care, and supply delivery. Additionally, WSN and UAVs plays a crucial role in the reconstruction of infrastructure during the recovery phase. This includes leveraging prior disaster knowledge to improve the construction process and enable "smart" infrastructure development [43]

	Disaster stages			Technology		UAV assisted applications					
Authors	Pre,disaster preparedness	Disaster assessment	Post,disaster response & recovery	WSN	UAV	Monitoring , forecast, EWS	Information fusion	Situational awareness	Damage assessment	Standalone comm. system	SAR missions
[11]	•			•		•					
[30]	•		•	•	•	•				•	
[8]	•	•		•	•	•		•			
[5]	•	•		•		•	•				
[3]	•	•		•			•				
[16]		•		•	•		•		•		
[20]		•		•	•		•				
[27]		•	•	•			•				•
[14]		•			•			•			
[13]		•		•				•			
[25]		•	•	•				•			•
[21]		•	•		•			•			•
[31]		•			•				•		
[9]		•			•				•		
[15]		•	•		•				•		•
[12]			•	•						•	
[2]			•	•						•	
[10]			•	•						•	
[22]			•		•					•	
[29]			•	•	•					•	
[19]			•		•					•	
[6]			•		•					•	
[17]			•		•					•	
[18]			•	•						•	
[4]			•	•						•	
[7]			•		•					•	
[26]			•		•					•	•
[23]			•	•							•
[28]			•	•	•						•

TABLE I: - UAV-ASSISTED DISASTER MANAGEMENT APPLICATIONS

4. Open Issues

Below are some of the research challenges related to networking that arise when using UAVs in disaster management.

A. UAV Localization

It is true that UAVs (Unmanned Aerial Vehicles) have limited flying time and requires time-critical action in disaster scenarios. In such situations, allowing UAVs to autonomously scout the disaster area and select their locations with self-learning techniques using repeated trials may not be the most efficient approach. To address this, the use of partial external inputs to guide the UAVs in establishing the last-hop connectivity to users as well as establishing a relay network is recommended [44]. This can be done by leveraging last recorded information from cellular network location databases and pings from mobile devices to estimate the density of affected people and their geographical distribution. New signalling protocols between operators may need to be established to facilitate this process. Additionally, ant-foraging algorithms that reinforce paths based on availability/number of mobile pings can be used to drive the UAVs towards the locations with high density of survivors. By incorporating these approaches, the UAVs can be guided more efficiently towards locations where they are most needed, potentially improving the overall effectiveness of disaster response efforts [45].

B. UAV-assisted system sustainability

To extend the network lifetime of UAVs, they can alternate network responsibilities among them. This is similar to how networked nodes are managed in the Bluetooth standard, where the master node places selected slave nodes in parked mode once the number of active connections increases beyond a certain number. However, in the UAV scenario, parking action is more complex and involves identifying safe stationary locations for the UAV to land on-ground and perform other non-aerial tasks, such as serving as ground-relay nodes or fixed base stations [49]. Charging points must be optimized to minimize UAV travel time, and magnetic-induction based charging plates installed on supporting ground vehicles is a feasible option. This raises new possibilities for joint optimization and practical applications of existing research on target tracking [50].

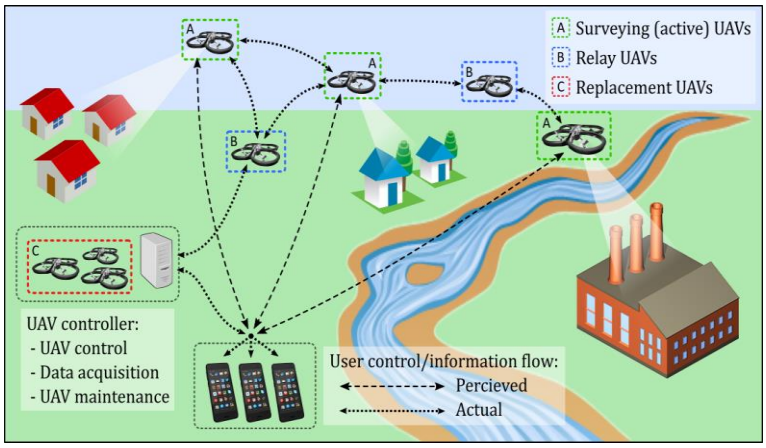

Fig 1. Illustration of a UAV-assisted disaster management system [51]

5. Conclusion

The article highlights the primary ways in which UAV networks can be used for disaster management and examines various research topics that are relevant to their use. It has been concluded based on the reviewed studies that the integration of UAV networks with wireless sensor networks and cellular networks has potential to become an effective technology for disaster management applications in the future.

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