A Review on Ad-hoc Networks: Application of Ad-Hoc Wireless Network in Disaster Scenarios.

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***Abstract*— Wireless ad hoc sensor networks are becoming more common in wireless data transmission infrastructure, and they can be particularly effective in disaster management systems. The globe is a disaster center, with disasters happening almost daily. These acts of mass destruction, whether natural or man-made, resulting in massive loss of money, property, and life due to a lack of planning on the part of governments and management agencies. As a result, steps must be done to avert these scenarios by recognizing the causes of disasters and implementing rapid rescue techniques after a disaster occurs. Wireless ad hoc sensor networks are an important part of the wireless data transmission infrastructure and can be quite useful in certain scenarios. When a disaster strikes, wireless sensor networks use technologies that can trigger an alert for an urgent rescue operation to commence. Our goal with this article is to look at technological solutions for disaster management using an ad hoc wireless network, as well as disaster detection and alerting systems and search and rescue operations. We've gone over the basic ad hoc network topologies that can be used in disaster management and the wireless sensor network models that can be used in different disaster scenarios. In this article, we discuss what are the four main ad hoc wireless networks, how these networks can be useful in real-world disaster scenarios in the world, and wireless network advantages.**

Keywords*— Ad Hoc Networks, MANET, WMN, CRAHN, Disaster Management, Rescue Operations, Wireless Sensor Networks.

I. INTRODUCTION

A **wireless ad-hoc network** is a type of wireless network that is decentralized. Because it does not rely on pre-existing infrastructures, such as routers in wired networks or access points in managed (infrastructure) wireless networks, the network is ad hoc. Instead, each node participates in routing by forwarding data to other nodes, and which nodes forward data is determined dynamically based on network connectivity. Ad hoc networks can use flooding to forward data in addition to traditional routing. Any set of networks where all devices have equal status on the network and are free to associate with any other ad hoc network devices in link range is known as an ad hoc network. Ad hoc networks are particularly valuable in a variety of industries, including the military, health care, disaster relief, etc. They are self-organizing, self-repairing, and simple to use. [1]

Ad hoc networks are ideal for emergency cases such as natural disasters or military conflicts since they require less configuration and can be deployed quickly. Ad hoc networks can be quickly constructed because of the presence of dynamic and adaptive routing technologies. The importance and applications of ad hoc networks in disaster management are discussed in detail in this paper.

Since the dawn of time, disasters have had a significant impact on human life. Irrespective of whether these disasters are natural or man-made, they result in the deaths of hundreds of people and significant property damage. Furthermore, in the case of a disaster, there is a great likelihood that the entire infrastructure will be damaged, causing the entire communication system to collapse. While many lives are lost in these scenarios, many people are stuck inside disaster zones due to fallen buildings, roadsides, bridges, rising water levels, and other factors. According to [2,] if these stranded people are recovered within the "Golden 72 Hours," they have a good chance of survival. As a result, rescuing these stranded people as soon as possible is essential. [2],[3],[11]

The loss of the communication system, on the other hand, makes the rescue mission extremely difficult. Many people die because of this, even before they had a chance to be saved. Different governments have devised a variety of methods based on ad hoc networks to address this issue. Because no infrastructure is required to construct a wireless network, ad hoc networks are suitable for disaster scenarios. [1]

The applications of ad hoc networks are used to classify them into distinct networks. Different systems that can be employed in disaster management have been proposed under each network. In this study, we will look at systems that fall into four categories of ad hoc networks.

II. Application Of Ad-Hoc Wireless Network In Emergency Cases

Since the beginning of time, the world has been plagued by disasters. Every year, natural and man-made calamities strike most countries. Hundreds of thousands of people are killed, and millions of homes are destroyed, because of these calamities. Each country has made several efforts to deal with these disasters. Some of these efforts are manual, while technology has been used in some situations to deal with disasters. During disasters, many individuals become trapped in dangerous situations, such as under collapsed buildings, bridges, or landslides. These persons have a good chance of surviving if they are rescued as soon as feasible. But, because of the collapsed buildings, fallen trees, flooded rivers, and other barriers, finding the victims becomes increasingly difficult. As a result, the rescuing officers require the victims' help in locating them and learning about their conditions to give them better rescue services. It is critical to have a stable communication network to do this. However, communication systems are frequently damaged because of calamities. This situation puts the rescuing mission in danger.

The victims are unable to call the rescue officers or any other authorized personnel to record their location, request help, or provide any other information about the disaster due to the damaged communication system. As a result, locating and rescuing these victims has become more difficult and time-consuming. Furthermore, due to the damaged communication equipment, it has become difficult for rescue officers to connect with their colleagues and superiors. This is a life-or-death situation for the rescue operation. The rescue officers must communicate with each other, with their supervisors, with the medical instructors, and with the victims to rescue the trapped people and assist the innocent victims.

Several systems based on ad hoc networks have been implemented to resolve this concern. From all those scenarios, we'll be focusing on four systems in this evaluation, which were developed using four different sorts of scenarios.

Before moving into the systems, it's important to understand the background of the four most common wireless ad hoc networks.

1. Mobile Ad Hoc Network (MANET)
2. Wireless Mesh Network (WMN)
3. Wireless Sensor Network (WSN)
4. Cognitive Radio Ad-hoc Network (CRAHN)

A. Mobile Ad hoc Network (MANET)

Broadcast communications and multi-hop communications via routing protocols are the two types of communications that can be considered in classical MANETs.

In broadcast communications, a node sends the same data to all its one-hop neighbors at the same time. When nodes use routing protocols to construct a communication path to a destination node, they should maintain routing tables to decide which node is the best next hop for routing the information. Regarding the relevance of routing protocols in disaster scenarios, consider a scenario in which a rescue team needs to retransmit information to a data unit. From a crew member to the central unit, a multi-hop route can be built. The routing protocol would oversee deciding which nodes to use to retransmit data packets from the crewmember to the central unit. [1],[4]. Figure 1 illustrates how MANET works.

Figure 1- MANET network

B. Wireless Mesh Network (WMN)

The Wireless Multi-Hop Ad-hoc Network (WMN) is a wireless multi-hop ad-hoc network made up of mesh nodes arranged in a mesh topology. Mesh clients and mesh routers are both referred to as "mesh nodes."

Traditional wireless routers are fundamentally different from mesh routers in a wireless mesh network. [6]. A constant connection is maintained through a wireless mesh network. If one of the nodes in the path fails to transfer data for a certain transmission, the remaining nodes dynamically choose another path to send data to the right destination.

Furthermore, because each WMN node can operate as a router for forwarding packets, it is feasible to establish wireless networks that can span a large area. WMN has several advantages, including a low initial cost, ease of network maintenance, robustness, and consistent service coverage [5], [12]. Enterprise networking, healthcare, medical systems, and security surveillance systems can all benefit from WMN. Furthermore, because they can be quickly configured without any wired infrastructure, WMN is considered one of the most viable choices for communications networks during disasters.

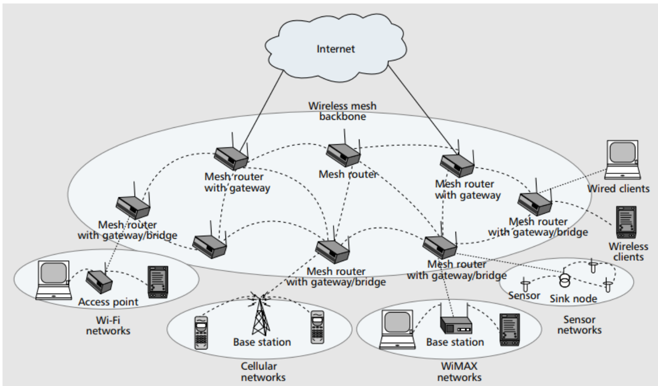

Figure 2 - wireless Mesh Network

C. Wireless Sensor Network (WSN)

Wireless sensor networks are centralized networks in which nodes are often clustered. In general, one node serves as the central node, cluster head, or sink node, while the others collect data from the environment and transfer it to the central node. When it comes to disaster circumstances, WSNs should be used for detection, warning, and alerting. They are suitable for deployment in locations that are prone to natural disasters. Consider a WSN placed in a location to sense earth vibrations to detect possible earthquakes, or a WSN placed in a forest to monitor and detect fires. Wireless sensor networks are also expected to play a crucial role in the Future Internet and the Internet of Things (IoT), both of which could help with disaster response. [20]

D. *Cognitive Radio Ad-hoc Network (CRAHN)*

The nodes of CRAHN are equipped with cognitive radios that can switch their communication spectrum. The nodes naturally assemble themselves in an infrastructure-less fashion. These networks are useful for disaster management because of their flexibility, ease of deployment, and ability to use spectrum efficiently.

CRAHN has been proposed for disaster management in recent suggestions. An innovative cluster-based method for post-disaster management has been presented in recent years in this direction. The system uses CRAHN and a three-tier resource management approach, and it claims to provide reliable communication in the event of a crisis. [7],[13]

III. Review Of Existing Works On Ad Hoc Networks For Disaster Scenarios

Be This review will discuss disaster management systems proposed using MANET, WMN, WSN, and CRAHN, respectively.

A. *Disaster Response System Using Mobile Ad hoc Network (MANET)*

Infrastructure and communication networks are frequently damaged by both natural and man-made disasters. This condition complicates rescue operations because it is vital for rescue and emergency personnel to interact with one another to give better service to the victims. The authors of [4] proposed a MANET-based communication system that makes extensive use of text messaging functionality. Emergency responders can use this system for search and rescue missions.

The search and rescue officers can send messages to the Local ERS command, and the Local ERS command can respond to the rescue officer, according to [4] and figure 3. The Mobile Hospital Coordinator can interact with the rescue and search officers and obtain necessary information.

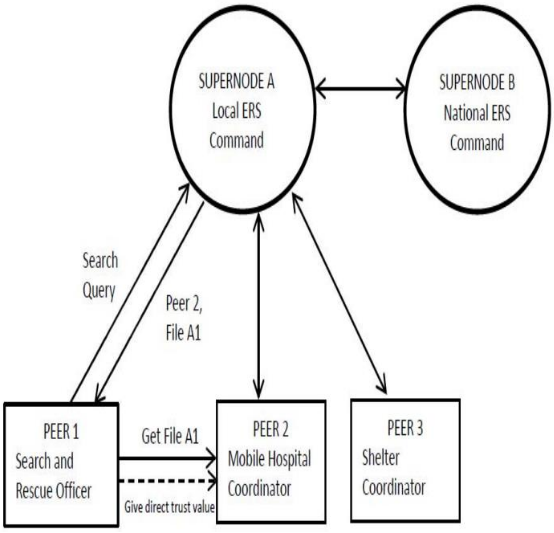

Figure 3 - Emergency Response System

Because this suggested approach inherits peer-to-peer features, all MANET mobile devices are treated equally in this network. Furthermore, this approach allows devices to use GPS to identify their location. These positions will be broadcast to all mobile devices and will allow all surrounding devices to be recognized. Moreover, messages sent by mobile devices are broadcast so that other nearby linked devices can read them.

According to [4,] this method supports communication between mobile devices over up to 50 meters.

B. *Disaster Response System Using Mesh Network (WMN)*

A Wireless Mesh Network (WMN) is a multi-hop wireless ad hoc network made up of radio nodes with a mesh topology. The WMN is made up of mesh clients (nodes), mesh routers, and gateways. Because they are self-organized, self-configured, and easy to deploy without requiring any physical connections between nodes, wireless mesh networks are the best option for disaster recovery applications. There are several advantages to using WMN, including consistent coverage and topology. Aside from that, because each WMN node may act as a router for packet forwarding, it can be used to build larger wireless networks. The authors of [5] presented a system that can auto-detect an Emergency Relief State (ERS) due to a disaster and auto-configure itself to stay up and running, regardless of the nature of the disaster, using this Wireless Mesh Network technique. A WMN network's nodes discover neighboring nodes automatically and establish and maintain connectivity ad hoc, using ad hoc routing protocols [14],[15],[5]. The self-configuring characteristic of WMNs, according to [5,] enables a simple and quick network implementation.

Figure 4 is an example of a wireless multi-hop access infrastructure in a smart city's Public Safety and Disaster Response Scenario. Typically, several tenants use IoT devices to transmit messages for their purposes, such as ambulances, public lighting, and semaphores. Devices belonging to a tenant are isolated from the others, as seen in Figure 4. However, in the event of an emergency, as shown in Figure 5, all communication channels are automatically reconfigured to offer PSDR with a federated communication environment.

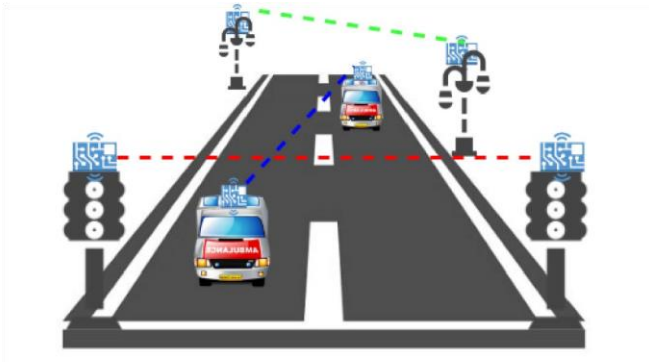

Figure 4 - Scenario before the emergency

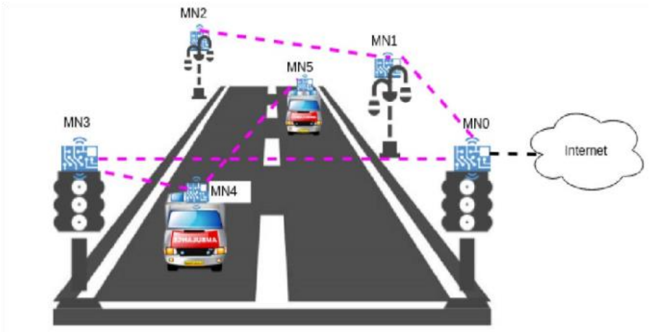

Figure 5 - Scenario after the emergency

The author has identified two types of victims using this system: passive and active victims. Each type of victim is treated differently by the system. Active victims are those who have access to their phones and can use Wi-Fi to connect to the nearest access point. They will be sent to a web page where they can share their location and safety status after they have joined. Passive victims are those who are unable to utilize their mobile devices to alert rescuers of their location because they have been injured or have lost their gadgets during the disaster. To deal with these situations, the system will use Bluetooth to search up to 15 meters [16] for victims' mobile devices and collect data so that rescuers may assist the injured.

Thanks to this technology, there is no longer any need to waste time compiling statistics on the number of persons present in the disaster area. The promptness with which this matter was addressed allowed the number of deaths and missing persons to be reduced.

C. Disaster Response System Using wireless sensor Network (WSN)

The primary focus of research on wireless sensor networks in disaster scenarios was on two factors. First, how can a WSN be utilized to detect, warn, and notify about a potential calamity in disaster prediction and alert systems? Second, because WSN node mobility is minimal, by supporting post-disaster search and rescue missions by installing nodes in the catastrophe area. A disaster alert system that uses WSN and Analytic Network Process (ANP) to predict any possible landslides disasters is proposed. In [**17**] the authors proposed a flashflood alerting system based on a WSN in a rural area. Regarding the work done for post-disaster scenarios, in [**18**] the authors proposed a multi-agent system-based WSN approach for crisis management. In [**19**] the authors evaluated using autonomous mobile robots to deploy a WSN in a disaster area. Figure 6 shows various phases used for a monitoring system.

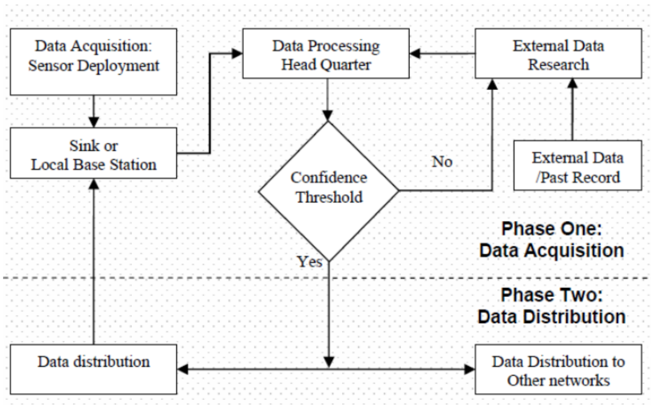

Figure 6 - Smart System aided with Wireless Sensor Network

D. Disaster Response System using CRAHN

In recent years, the use of technology for disaster management has been investigated. People trapped in a disaster situation have a good chance of surviving if they are rescued within the first 72 hours, according to [2.] As a result, many lives can be saved if proper communication infrastructure is provided sooner, and people are evacuated as soon as possible.

The authors suggest a novel disaster response system based on cognitive radio ad-hoc networks in [3]. (CROHN). The CRAHN nodes are equipped with cognitive radios that can switch their communication spectrum. The nodes dynamically organize themselves in an infrastructure-free manner. Because of their flexibility, ease of implementation, and ability to use spectrum efficiently, these networks are suitable for disaster management. [7],[13],[3]

There are four basic aspects to this system, according to [3].

a. **Disaster Detection** - The area that is prone to disaster is fitted with sensors such as smoke detectors, seismometers, and radar systems in this sector to identify any disaster circumstances. The sensor data is first provided to a context manager, after which an Artificial Neural Network (ANN) determines whether a disaster is expected based on the data.
b. **Spectrum sensing** - For communication, the nodes in the region will form a CRAHN. The system will execute at every node during a disaster, as shown in Figure 7. Spectrum holes will be detected by the cognitive radios that have been deployed in the network. Furthermore, this system can identify the best spectrum hole, and each node maintains a scenario database that describes the catastrophe site's overall situation.

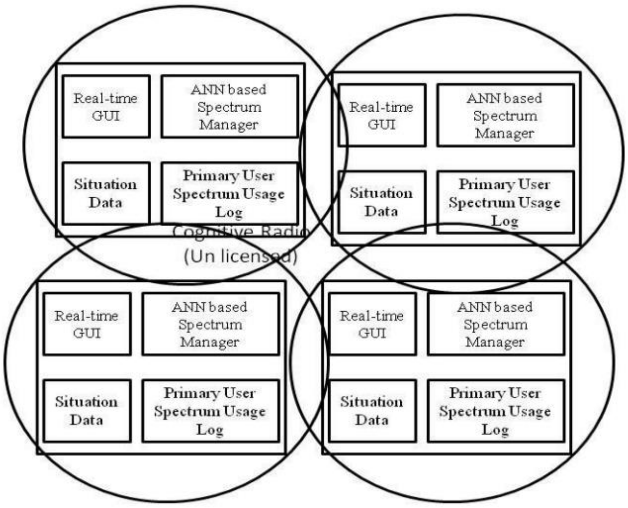

Figure 7 - Cognitive Radio Based Communication

- **c. Initiating the response** - As soon as the system detects a disaster, the response state is engaged. Then, in the event of a disaster, an appropriate call tree is used to notify the proper person. According to the proposed method, a request for gateway service discovery is floated over the network until a node that provides gateway service is discovered. That gateway node is then utilized to communicate with the appropriate person. [3]
- **d. Managing disaster** - Rescue services are dispatched as soon as the catastrophe response is activated. These services can be used by injured people to alert rescuers about themselves, and service workers can use the service discovery algorithm to learn about the present position of another rescue worker [3].

IV. How the Ad Hoc Wireless Networks Operate in the Events of a Real-World Natural Disaster

A. Forest Fire Detection

Thousands of unusual animal, bird, and insect species live in the forest. Forest fires not only destroy people's homes but also wreak on flora and fauna. Lightning, high heat, or carelessness on the part of residents are all common causes of forest fires. Although putting out raging fires is difficult, the disaster can be avoided if information about the fire's location is instantly given to the nearest control center and suitable actions are made to control it before it consumes everything. In the forest, there are a lot of sensor nodes. These sensor nodes are grouped into clusters, with a cluster header for each node. Temperature, relative humidity, and smoke can all be measured by sensor nodes. They are also supposed to be aware of their current location using devices such as the Global Positioning System GPS. The associated cluster head receives measurement data as well as location information from each sensor node. The cluster header uses a neural network approach to determine the weather index and transmits it to the manager node via the sink. A wired network connects the sink to the manager node. To detect wind speed, a few wind sensor nodes are manually put around the forest and connected to the sink via wired networks [21].

Users can get two types of information from the manager node:

1. An unusual event requires an emergency report (e.g., smoke or extremely high temperature is detected).
2. A real-time forest fire danger rate for each cluster is based on weather indices from the cluster header and other forest fire parameters.

B. Tsunami Detection

The pains are still fresh in the hearts of all those who lost families in the 2004 Tsunami that decimated the whole island of Sri Lanka. It is estimated that tens of thousands of people died in the disaster, which occurred not only in Sri Lanka but also in other Asian countries.

When an earthquake measuring 8.9 on the Richter Scale struck in the Indian Ocean, nearly 32 countries around the world were put on high alert. An alert was issued because of the effective monitoring system, and more coastal areas were evacuated. Though tsunamis are not as regular in Sri Lanka as they are in Japan, Indonesia, Vietnam, and Thailand, it is better to be prepared than to be sorry after a disaster. Three types of nodes are defined in a system for tsunami detection and mitigation using a wireless ad hoc sensor network: sensor, commander, and barrier. Across a coastline area, a huge number of sensor nodes collect underwater pressure readings.

C. Flood and Water Level Detection

Thousands of lives and property are lost each year in Sri Lanka due to floods. Last year, the floods in Sri Lanka claimed many human lives, cattle, and businesses. Although none of these losses can be eliminated, the loss of lives and property can be minimized to the bare minimum if simple procedures are done before the disaster in the form of flash floods occurs. This can be accomplished with the use of wireless sensor networks and communication technology. The system development phase is split into phases, each of which is equally significant. Level one begins with the physical placement of sensing devices along riverbanks and the construction of an effective localization mechanism based on the situation and environment. The positioning of the wireless sensors is influenced by the river's flow path, records of water flow, and future trends of the river's route. To communicate with the local base stations, these sensors create clusters. Local base stations are powerful enough to communicate directly with one another via wireless communication. The data from the sensors is collected in the local base stations and fed into the data processing centers as inputs. [22]

The second level is involved with the installation of local base stations as well as data communication at the district level. To process acquired data, Level three could be involved with the central monitoring system at headquarters. The data is subsequently analyzed either in-house or at independent research organizations that specialize in high-risk flood analyses.

D. Earthquake Detection

When an earthquake strikes, it causes massive loss of life and property. Fortunately, earthquakes do not affect Sri Lanka; however, earthquakes do impact India, our neighboring country, regularly. The most powerful earthquake to strike India occurred on January 26, 2001, and it shook not only India, but also neighboring countries such as Pakistan, Afghanistan, and Iran. Thousands of people lost their lives, limbs, and cattle, and the damage to the property was unquantifiable. Although property loss cannot be ruled out, prompt action can save many irreplaceable human lives. The system architecture for our approach is depicted in Figure 8, where each sensor detects an earthquake event per sample period using the seismic frequency spectrum.

Each sensor maintains independent statistical models of frequency spectrum for different scales of seismic signal energy acquired by the sensor to handle earthquake dynamics such as highly dynamical magnitude and changeable source location [24].

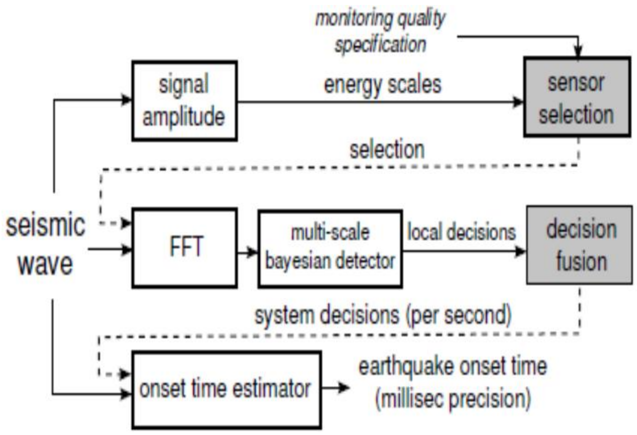

Figure 8 - System Architecture of sensor detects an earthquake

According to much research, when the sensor receives more signal energy, the frequency-based detector performs better. As a result, it is suggested that the base station selects a minimal subset of informative sensors based on the signal energies received by sensors while maintaining system sensing quality. The selected sensors then use the Fast Fourier Transform (FFT) to compute the seismic frequency spectrum and make local detection judgments, which are then sent to the base station for fusion. In addition to earthquake detection, node-level earthquake start time is crucial for determining earthquake source location. In this method, the base station first recognizes a single earthquake and calculates an approximate onset time [25].

V. Advantages Of Ad Hoc Networks

The rapid growth of disaster management systems in ad hoc technology is widely used in portable computing, such as laptops and mobile phones, to access online services to analyze disasters, get disaster sensor notifications, and so on. The growth of self-organizing networks lowers the cost of communication. In ad hoc networks, the advancement of wireless network technologies improves networking anytime, anywhere, and anyhow. It's easy to create and set up an ad hoc network. The following are some of the benefits of an ad hoc network:

- Divorce from the network's central administration.
- Routers are self-configuring nodes.
- Continuous re-configuration for self-healing.
- Scalability refers to the ability to add more nodes.
- Mobility enables the creation of ad hoc networks on the go in any situation involving many wireless devices.
- Flexible ad hoc can be set up at any time and at any location.
- Decentralized administration results in lower beginning costs.
- Ad hoc network nodes do not require any hardware or software. As a result, it may be instantly connected and communicated.

Conclusion

The use of ad hoc networks in disaster situations is still in its early stages. Most of the research on this topic is based on simulations rather than actual experimentation. The results of this survey's study, which are based on real-world experiments, show that using ad hoc networks in disaster scenarios is practical and could help save many lives and reduce the number of casualties. In this work, we have analyzed the key sectors of application for the many ad hoc paradigms identified in the literature, as well as the major contributions made by scholars in the recent decade. Because of their ability to self-configure and self-heal, ad hoc networks that are decentralized and do not rely on pre-existing infrastructure have shown to be very ideal for disaster situations. Apart from these, ad hoc networks have several other advantages in disaster scenarios, such as being a low-cost option and so on. Rescue officers can use Ad hoc networks to communicate with one other, victims, and even superiors. Furthermore, there is no need to waste time obtaining statistics on the number of persons killed or injured in natural disasters, and locating victims have become much easier. This approach makes the rescuing process much more efficient and allows for more lives to be saved.

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