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Technology of Internet of Things Responding to Natural Disasters

Shu-Wen Chen[1,2 *], Jia-Qi Shao[1], and Hui-Sheng Zhu[1]

[1] School of Math and Information Technology, Jiangsu Second Normal University, Nanjing 211200, China

[2] State Key Laboratory of Millimetre Waves, Southeast University, Nanjing 210096, China

Abstract

Numerous countries have been affected by natural disasters, the seriousness of which consequences is self-evident, such as power failure, building collapse and communication interruption. With the rapid development of science and technology, the Internet of Things (IoT) has become one of the most important part of current information technology. More and more countries and regions have realized the significance of IoT in dealing with natural disasters and are making efforts to put IoT into use. This paper summarizes the latest progress of IoT with fog computing, swarm robots and other advanced technologies in coping with natural disasters on four aspects. It focuses on how the IoT and other information technologies can solve problems encountered in natural disasters to a certain extent.

Keywords: IoT, natural disaster, monitoring, early warning

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1. Introduction

Natural disaster, generally speaking, refers to the degree of human and biological survival of the environment suffered light or heavy damage. Common natural disasters include meteorological disasters, geological disasters, marine disasters, biological disasters and so on.

Compared with man-made disasters, natural disasters have a greater impact range. In February 2021, winter storms hit North America, leaving 9.27 million homes without power and 176 people dead. In March, Mongolia was hit by sandstorms and blizzards

*Corresponding author. Email: chenshuwen@126.com

that killed dozens of herders. In April, 104 victims were injured in a 6.1 magnitude earthquake off the Indonesian island of East Java. China's Yunnan province was also hit by a 6.4 magnitude earthquake in May. In order to reduce the losses caused by natural disasters, more and more countries in the world have begun to use the most updated technologies such as the IoT to respond to natural disasters quickly and accurately.

The IoT is an emerging paradigm that enables real life objects to connect to the Internet [1]. With its rapid development, it has become one of the most important technologies of the 21st century. Therefore, the IoT is gradually becoming an indispensable part of our daily life and work. In addition, it can also help the same or different types of devices work together, and has made achievements in smart home, medical care and other aspects [1]. The technology of heterogeneous hardware and network together constitute the IoT system, which can process massive data and extract useful information. The IoT has a variety of implementation technologies, such as radio frequency identification (RFID), wireless sensor network, machine-to-machine (M2M) communication [2]. Wireless sensor network (WSN) is an important part of the IoT, whose role is to deploy various IoT sensor nodes to monitor environmental conditions [3] and help us obtain real-time data of the target environment. It can be used for path planning during disasters and resource management after disasters [4]. Whatever technology the IoT uses, getting access to large amounts of raw data is the first step. Only with the support of data, can the subsequent data analysis, processing, modeling work. At present, the IoT has made great achievements in the monitoring, early warning and post-disaster recovery [9]. These technologies are not only targeted at natural disasters in cities, but also can achieve effective communication through the IoT and its related technologies, which are often characterized by energy saving, weather resistance and the ability to withstand harsh natural environment [5]. Considering the shortcomings of IoT devices in information resource sharing and data processing, the integration of fog computing, cloud computing, machine learning, data analysis with IoT can improve the efficiency and reliability of the system, and achieve better communication and computing performance during and after disasters [6][7].

This paper mainly discusses the application of the IoT technology in natural disasters, focusing on the application of the IoT technology in disaster management, based on the documents related to the IoT before August, 2021. Then the characteristics of IoT technology in different disaster situations are discussed. Finally, the challenges faced by IoT technologies in the context of natural disasters and the prospects of it for the benefit of mankind are highlighted. The rest of this article is organized as follows. Part 2 introduces in detail the application of the IoT in the monitoring of natural disasters. Part 3 introduces the early warning technology of the IoT in disasters. Part 4 clarifies the role of the IoT in disaster management. Part 5 describes the characteristics of IoT applications under specific disasters. Finally, Part 6 gives a summary and prospect of the IoT technology. With the help of these technologies, we can calmly make natural disaster in control.

2. IoT Applied to Natural Disaster Monitoring and Prediction

There is no denying that the IoT is a new field with huge potential. As researchers devote themselves to the exploration of the IoT, it has developed into the Internet of Anything and Everything [7]. The IoT contributes to information exchange and communication through radio frequency identification (RFID), multiple sensors and other devices. Although no one can know when and what disasters will happen ahead of time, the combination of the IoT and other updated technologies can monitor the natural environment in real time and identify natural disasters in a short time when abnormal data is detected, which can reduce human response time to some extent. This will give us more time to evacuate people in an orderly and smooth way and reduce the loss of life before the disaster threatens them. The key factor supporting disaster monitoring is the acquisition and analysis of data, which is often generated by distributed sensors and services [8]. As Pointed out by P. P. Ray et al. [9], disasters require special interventions based on protocols. Because each disaster has a different premonition, destructive capacity and length of time.

This section focuses on how the IoT and other advanced technologies can be used to solve problems encountered in natural disaster monitoring. Several reliable and effective methods based on the IoT and other related technologies are described in detail. Table 1 shows the comparison of these approaches.

Table 1. The comparison of IoT and other technologies for disaster monitoring

Authors	Technologies	Results	Features
L. G. Greco et al. [8]	IoT and Semantic Web	The response time does not exceed 17 seconds.	Data can be annotated.
A. R.Rauniyar et al. [10]	IoT and Fog Computing	Can minimize the delay greatly.	Able to analyze key data for the IoT.
G. F. Furquim et al. [11]	IoT and ML	The prediction power can reach 95%.	The prediction can be made even in the case of node loss.
Y. C. Lin et al. [12]	IoT and UVA	The accuracy of monitoring is relatively high.	Different devices use different communication technologies.

2.1. Semantic web technologies

The semantic web is an intelligent network that can make judgments based on semantics to achieve barrier-free communication between people and computers. Every computer connected to the Semantic web can understand not only words and concepts, but also the logical relationships between them. And it can find the information needed in the massive resources, so as to develop the existing information islands into a huge database. The architecture of the semantic web is shown in Figure 1. IoT sensors provide a large amount of data for natural disaster monitoring. Faced with such a large amount of data, the meaning of each data often be confused, however, the application of semantic web technology can solve this problem. In the paper [8], authors argue that semantic web can understand not only words but also their logical relationships. For example, these data are identified as geographic location, while those are about weather conditions. Furthermore, in order to facilitate different algorithms to access and analyze data, the semantic web also allows all data to be organized in the form of machine understanding to reduce the chance of errors.

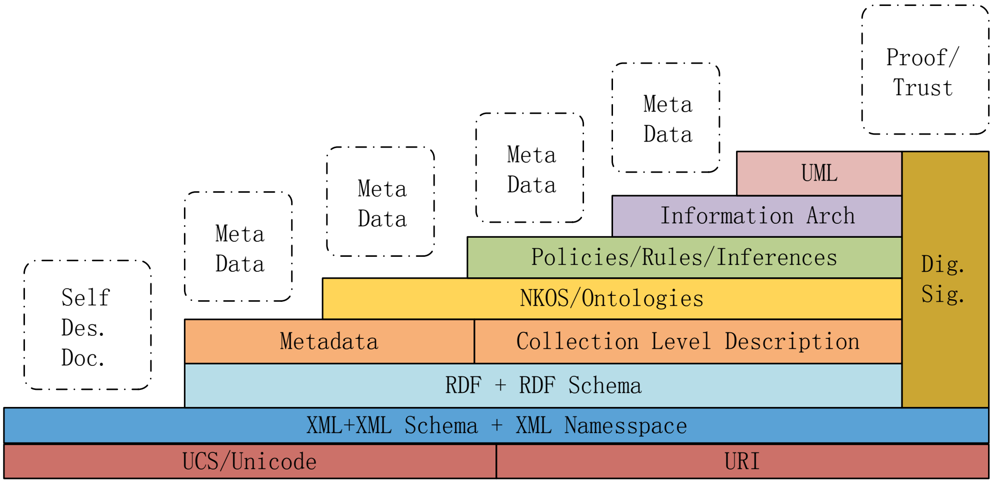

Figure 1. The architecture of the semantic web

Luca Greco et al. in the paper [8] demonstrate how IoT and semantic web technologies can be effectively employed for abnormal natural disaster monitoring. Abnormal data can be detected in a timely way after a disaster occurs but does not pose a fatal threat to human beings. A prototype system is proposed in this article, aiming to retrieve the data streams from web services which are used to collect IoT sensors data. In order to contextualize and give the meaning to the data obtained, it is helpful to apply semantic web technologies for data annotation. What`s more, these data will be stored in a triple store lying on a computer that communicates with lightweight nodes via MQTT protocols between the server and raspberry pi. Much essential information including time, sensors position, weather condition is contained in the triples, which can be easily queried by SPARQL language. Figure 2 shows the design of this architecture. The system is designed in four aspects：1) including the network connected devices such as wireless sensors and actuators which collects data from the environment or object under measurement. 2) including sensor data aggregation system and analog-to-digital data conversion. 3) analyzing the aggregated and digitalized data before sending them to the data center. 4) analyzing, manage data and store the data on traditional back-end data center system. Finally, the authors evaluate the performance of the system in disaster monitoring scenarios by measuring response times and other parameters. Satisfactory results have been obtained in the simulation experiments of the earthquake. It is turned out that this method is suitable for disaster scenarios with low power consumption and short response time.

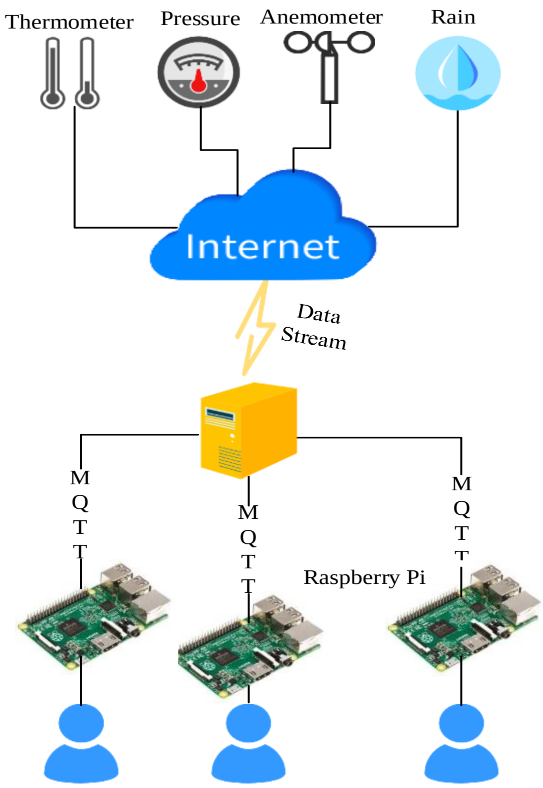

Figure 2. The design of the architecture based IoT and semantic web technologies

2.2. Fog computing system

Fog computing is a distributed computing infrastructure for the IoT that extends computing power and data analytics applications to the "edge" of the network, enabling users to analyze and manage data locally and gain instant insights via connectivity. Fog computing is a large-scale sensor network with a large number of network nodes and can realize direct communication between mobile phones and other mobile devices, without the signal to the cloud or even the base station to go around, supporting high mobility. The ultimate result of the development of the IoT is to connect all electronic devices, mobile terminals and other things, these devices are not only a huge number, but also widely distributed, only fog computing can meet. In contrast to cloud computing focusing on the way computing, fog computing pays more attention on the calculated location. Because fog computing is closer to the edge of the network than cloud computing, low delay, low congestion, and high mobility make fog computing more suitable for the response to time-sensitive and real-time events, such as the management of natural disasters. Apart from this, fog computing provides time support for analyzing critical crowdsourced IoT data of disasters. The system integrating fog computing and IoT can partly compensate for the weak infrastructure.

In the paper [10], a crowdsourcing-based disaster management using fog computing (CDMFC) model in IoT is introduced to monitor the natural disaster process. In addition, given that fragile infrastructure is more likely to be damaged in a disaster, they propose a mechanism for data offloading in the CDMFC model, even if there is no direct connection to the fog. Compared with traditional cloud-based disaster management models, the system can detect disasters in real time and release public safety information early. CDMFC consists of perception layer, crowdsourcing layer, CDMFC layer and cloud computing layer. The perception layer is used to sense different such events as fires, earthquakes, floods. The crowdsourcing layer is dedicated to crowdsourcing all the sensing data generated by the sensing layer and transferring critical data to the CDMFC layer. CDMFC layer makes full use of the advantages of fog computing and analyzes the crowd-sourced critical data of IoT disasters through crowdsourcing and data unloading mechanism. The final layer is the cloud computing layer, which analyzes non-critical data from the crowdsourcing layer and other data from the CDMFC model layer, and then stores the data in the cloud computing layer. Figure 3 shows the hierarchical structure of the CDMFC model for natural disaster management.

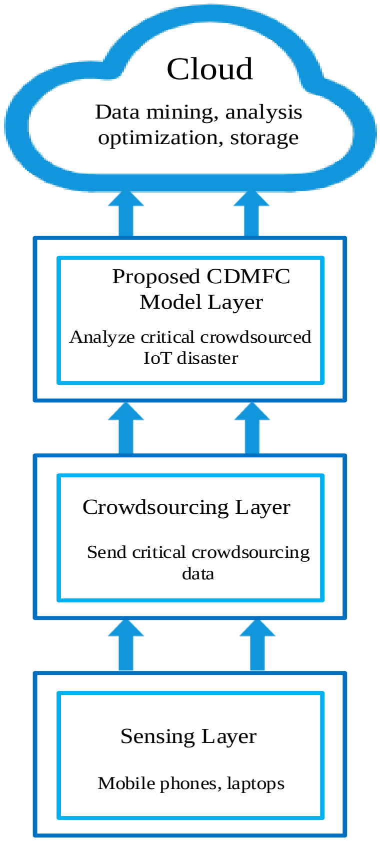

Figure 3. The hierarchical layered structure of CDMFC model for natural disaster management

2.3. A fault-tolerant system based on machine learning

Machine learning (ML) is now in an essential stage of informatization development. Machine learning theory is about designing and analyzing algorithms that allow computers to "learn" automatically. Machine learning algorithm is a kind of algorithm that obtains rules from data analysis and uses the rules to predict unknown data without human intervention. The application of machine learning can reduce the time spent on natural disaster monitoring. Furthermore, it can reduce the loss of fortune and life. In the existing IoT response to natural disasters, machine learning helps IoT systems to analyze sensors data and response timely.

SENDI is a fault-tolerant system based on IoT, ML and WSN which is used to monitor of natural disasters and issue the alerts [11], authors also clarify the feasibility of SENDI. This system is realized by applying emerging IoT standards and machine learning, plus collecting data by means of REDF system. All these data are collected by wireless sensor network in a real environment. When confronted to natural disasters, the fault-tolerance is embedded in the system by anticipating the risk of communication breakdowns and the destruction of the nodes during disasters. Even encountering the extreme weather, it can also be operated by adding smart nodes to carry out the data distribution. SENDI is made up of three layers. The first layer as the basis of SENDI, consists of a WSN. This layer accounts for collecting and transmitting data from the monitored environment. In the second layer (fog computing), the fog computing nodes are successively responsible for calculating the data collected by the convergence sensor node, and distribute the data to the third layer thus leaving the computing resources closer to the end-user so that it can contribute to the latency of the services. The third layer is composed of cloud, providing the necessary resources for the data storage. The combination with other information makes it successful to handle the monitoring environment by virtue of forecast model created by ML. Finally, the cluster system is used to solve the system fault, making the SENDI becoming fault-tolerant. However, the limitation of SENDI is the great demand for a flood of nodes. As a consequence, the next task is to study how many nodes are demanded to create a robust version of the system which is not easily degraded.

2.4. Drone technology

UAV relies on visible light cameras, motion picture cameras, standard or low-light TV cameras, infrared scanners and radars installed on the aircraft to complete various reconnaissance and surveillance tasks. Generally speaking, a UAV can carry one or several reconnaissance equipment, then work according to predetermined procedures or ground instructions, and finally transmit the obtained information and images back to the ground at any time for the use of relevant departments. It can also record all the information obtained and use it at a time when the drone is recovered. The tasks undertaken by UAV in the process of nature monitoring include real-time image detection and environmental information collection [12].

In the paper [12], the authors present a monitoring system based on drones and the IoT, which is set up in places that are difficult for staff to reach. The system consists of UVA flight system, natural environment monitoring device, and ground monitoring station. Different applications use different frequency band communication technologies. Firstly, ground-based sensors collect environmental such data as temperature, humidity and PM2.5. The drone is then controlled by VHF communication technology, and the sensor device transmits data stored in the solid-state memory to the drone via the LoRa communication module. Figure 4 shows the structure of this natural environment monitoring device. Wireless communication technology of the IoT is used to transmit data collected by sensor equipment and UVA flight system to monitoring stations. The 4G communication technology enables the flight information, monitoring environmental data and real-time images of the drone to be sent to the cloud, and then downloaded and received by staff on the ground. The automation of the system and real-time monitoring of UVA flight status will improve the accuracy of natural disasters.

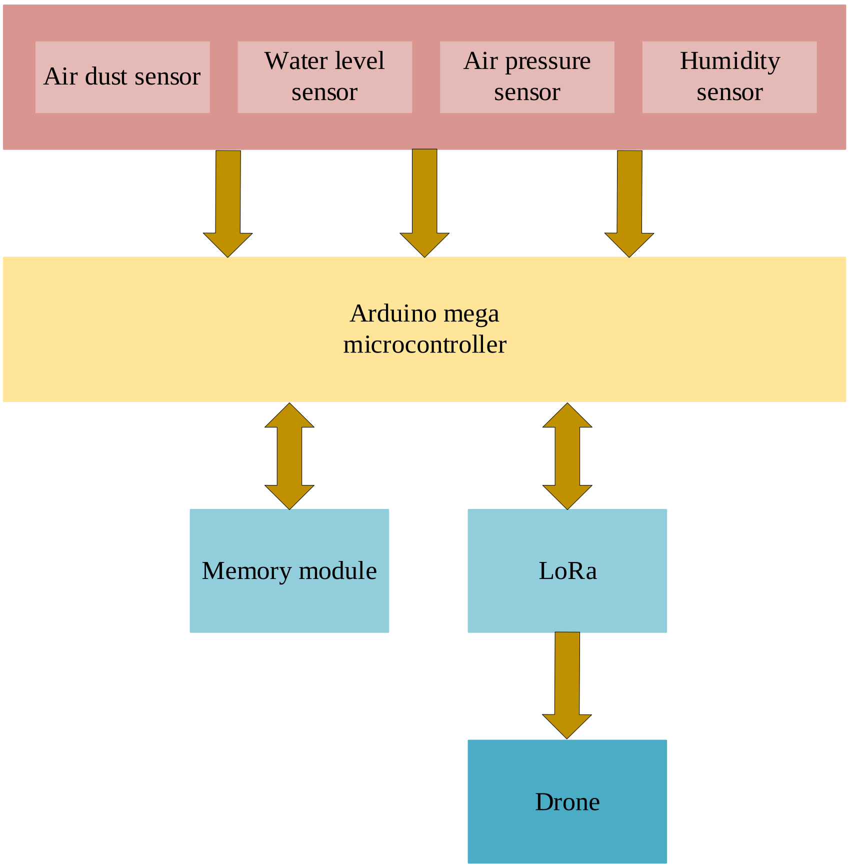

Figure 4. The structure of this natural environment monitoring device

3. IoT- Based Different Technologies for Natural Disaster Early Warning

In the reference of this paper, three methods of realizing natural disaster warning relied on IoT are listed. Forecasting means the monitoring of signals when natural disasters occur. For most countries around the world, early warning of natural disasters plays an outstanding role in reducing disaster risk, but it is also a huge challenge. Most importantly, the main idea of an ideal natural disaster early warning is to minimize disaster prevention costs and improve disaster prevention efficiency [13]. From this point of view, it is very necessary to carry out natural disaster monitoring and early warning. Table 2 compares these early warning methods.

Table 2. Different techniques, test results and application directions for early warning

Authors	Technologies	Obtained results	Highlights
George et al. [13]	Time-critical IoT on Elastic Cloud	The warning accuracy is high and the time delay rate is low.	Any kind of disaster.
Fatin Hasnath et al. [14]	IoT and Swarm Robots	Ultrasonic sensors showing data perfectly according to its range which 2-400 cm.	Flood.

Akram et al. [15]	IoT and GIS	No experiments have been carried out.	Meteorological disaster.

3.1. Time-Critical IoT on elastic cloud workbench

The main idea of elastic disaster early warning system is to solve the problem of early warning with "cloudified". The integration of such IoT devices as sensors and cloud platforms can respond quickly when disasters occur.

In the paper [13], authors propose an architecture for time-critical IoT disaster warning on an elastic cloud platform. This software platform is designed for time-critical, interactive and adaptive disaster warning cloud applications. Sensors deployed in the telemetry station measure water level, pressure, temperature, air quality, and other parameters. Then they will transmit information to IP gateway through GPRS/GSM/Radio. Finally, the data will be transmitted to the database server. In addition, the function of the notification server in the system as the call center is to periodically check the data in the database. If the data is abnormal, the notification is sent over a different channel to the available operator, who then determines whether or not to issue an alert. The advantage of the system is that it can collect, analyze and process the data in real time. So that relevant officers can make quite rapid response to emergency and provide early warning service for the public through on-site event broadcasting and collaborative communication with IoT technology. Figure 5 basically shows the activities of disaster early warning using Time-Critical IoT on elastic cloud workbench.

3.2. Swarm robots-based system

Swarm robotics is a method of coordinating many robots as a system consisting of a large number of simple physical robots. Unlike general distributed robot systems, swarm robotics emphasizes a large number of robots and improves scalability, such as using only local communication. It is expensive to regional mapping using satellites. Therefore, it makes sense to use swarm robots to communicate and map areas. The combination of swarm robots and IoT offers hope for early warning systems for natural disasters.

Fatin Hasnath Chowdhury et al. [14] believe that the combination of the IoT, swarm robots and mobile applications will greatly facilitate victims' lives. As a result, they propose the prediction hub system. The concept of forecasting hubs is developed to protect innocent victim from natural disasters. The predictive connectivity system consists of robots, sensors, a network of portals, and mobile applications. The swarm robot is employed to perform real-time data mapping for a specific area. In the perform process, the sub bot will send signals to the mother bot. The process of sending and receiving signals is accomplished through a network created with the NRF transceiver module. When the sub bot completes its task, it returns to the mother bot and can use the portal to send emergency messages when it detects a natural disaster. Users can control the sensors and see real-time data via a mobile app, which is accessed by an ultrasonic sensor and a raspberry pi camera module mounted inside the robot. The prediction hub system is modeled and designed using HTML, CSS, MySQL, PHP, JAVA, Android SDK, VOLLEY, XML, NRF TRANCEIVER, and wireless sensors. Through the actual research and simulation data, the feasibility and reliability of the system are determined. Predictive connectivity systems are controlled by portals, mobile applications, sensors, and robots. The prototype system is very useful for flood-affected areas, but it also has its limitations, such as having to find the right area for the sensors.

3.3. Sysnergy of GIS and IoT

Geographic information system (GIS) is a special and important spatial information system. It is a technical system that collects, stores, manages, calculates, analyzes, displays and describes the geographical distribution data in the whole or part of the earth surface (including the atmosphere) space with the support of computer hard and software systems. A computer- based tool that can analyze and process spatial information, integrating the unique visual effects and geographic analysis functions of maps with general database operations. The Geographic information system (GIS) is primarily used to provide spatial information on disasters, which is beneficial to manage large amounts of vulnerability and risk data, particularly in the area of weather forecasting. GIS plays a prominent role in monitoring and early warning by interpreting data to help users understand spatial relationships, patterns and trends. At the same time, the IoT, as a wireless sensor network technology, plays an indispensable role in disaster warning.

In the paper [15], authors propose an early warning system based on GIS and the IoT, which will automatically initiate an alert system in case of severe weather or extreme environment, to protect the public in disaster areas. At the same time, the process from detection to warning integrates the IoT technology, so that GIS can play a more valuable role. The advantages of the system can be reflected from two aspects. On one hand, the system can operate with any available weather station. On the other hand, GIS combined with the IoT can also develop multi-layer geographic database, greatly shortening the time of spatial analysis and accurately locating the affected areas. The system has six integrated components, namely, weather sensor, data logger, data collection server, database server, alert server, and GIS server. What is special about this system is the way in which the data is obtained. The required data is provided by IoT sensors located in such different locations as weathervane sensors, barometers, hygrometers rather than a fixed sensor infrastructure as in other studies. After the data is collected, it can be stored in the SQL database on the server. The early warning server of this system is built in the form of a modular computer program. For early warning purposes, they propose a weather alert algorithm, which uses data from SQL database. If the measured value exceeds a certain threshold limit, both the government entity and the public are alerted by the system through multiple delivery mechanisms. The alert can be sent through such various channels as SMS, email, and online social media. On the other hand, the type of new alert can be changed by modifying the alert function.

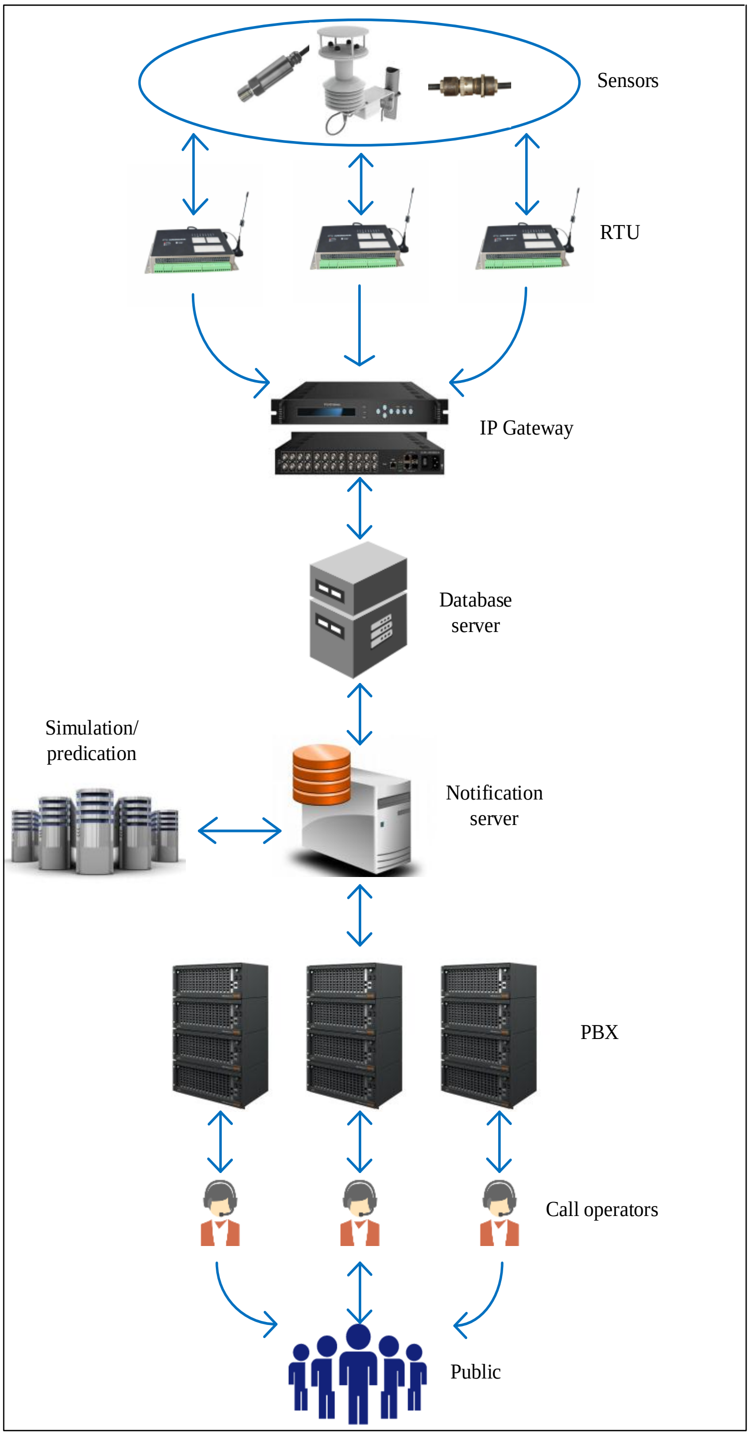

Figure 5. The activities of disaster early warning using Time-Critical IoT on Elastic Cloud Workbench

4. IoT Applied to Natural Disaster Management

Emergency evacuation, resource allocation, timely treatment and a series of work against time after the disaster makes the establishment of disaster management become a necessary task. It can be seen as a combination of interrelated processes that provides effective methods for analyzing and monitoring the occurrence of disasters [16]. The IoT has formed a huge network system in disaster management, which can be connected with satellite communications to closely monitor the occurrence of disasters and timely rescue work, providing scientific guidance for disaster management.

In disaster management, the IoT enables various departments to be connected. Through the cooperation of various disaster-related departments, decision-makers can send more rescue workers to the front lines of disasters within 24~48 hours according to the collected field data. Then they can formulate the best evacuation route, and dispatch resources according to the priority. In addition, in the previous major natural disasters, there have been such many problems. When traditional communication networks fail during emergencies, communication between emergency services is severely hampered [17]. Rescue centers require manual help and large-scale self-evacuation, but rescue work is not as efficient as expected [18]. The search has been slowed by a lack of information about the whereabouts of the victims [19]. In densely populated disaster areas, how to allocate resources reasonably and effectively is also a thorny problem [20].

In order to solve the problems left over from the previous disasters, a disaster management system has been designed and applied based on the increasingly mature IoT technology, big data analysis (BDA), crowdsourcing and other updated technologies to further reduce risks and impacts. In this section, several solutions are presented to improve disaster management, aiming to improve the current disaster management system and realize the integration of "sky - air - ground – site".

4.1. IoT and DMT-based system

DMT refers to disaster management team. The main work of DMT is to conduct long-term planning of the information and data collected at different stages. The IoT, with its interoperability, heterogeneity, soft weight and flexibility, has greatly improved the work efficiency of DMT.

The taxonomy of DMS based IoT is shown in Figure 6. This system works in five aspects. The first step is to view the affected areas and collect needed data for rescue work. Secondly, confirming the major problems which are confronted by the administers and individuals. Thirdly, trying to find out where the infrastructure of IoT technology should be deployed and how to apply IoT technology to solve current issues. Specially, when a natural disaster occurs, the collected sensor data and satellite data are first sent to the disaster management team (DMT). The collection of the data is divided into two steps. The first step is to send the data obtained from the different sites to DMT. After deploying the first team, they begin to analyze the original data. The data is used to examine necessities such as new update on topological conditions, recognition of the order of magnitude of the explosion, and necessities of correct amount of medicine and drinking water etc. to make long-time schedules. All activities of the planning are shown in Figure 7 at length.

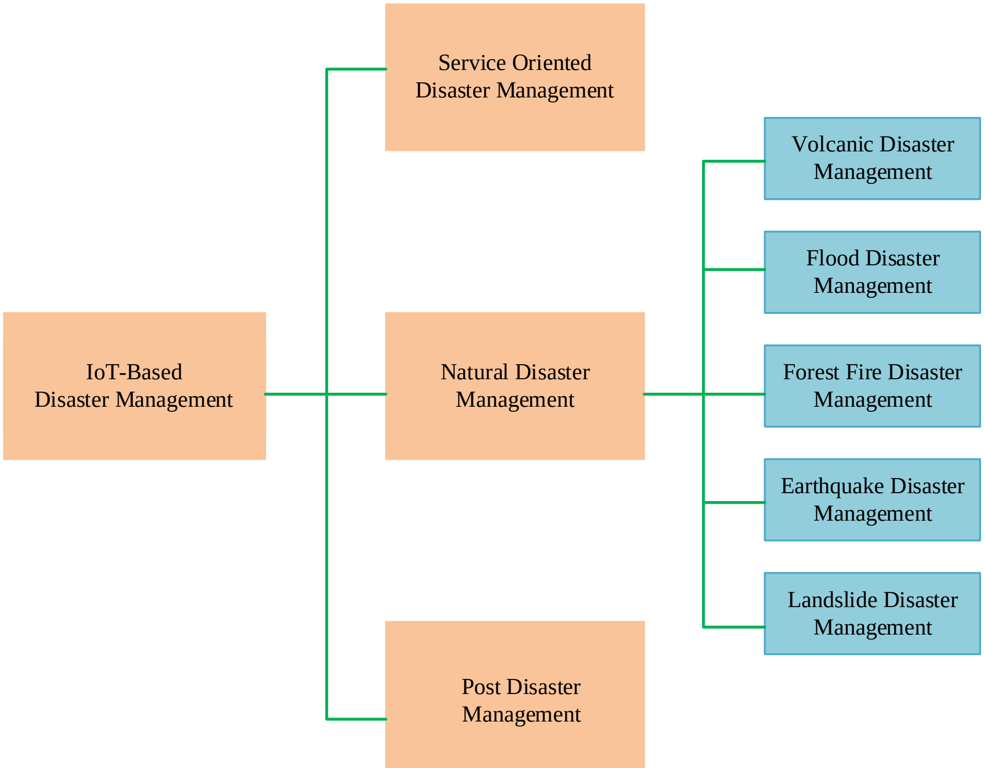

Figure 6. The taxonomy of DMS based IoT

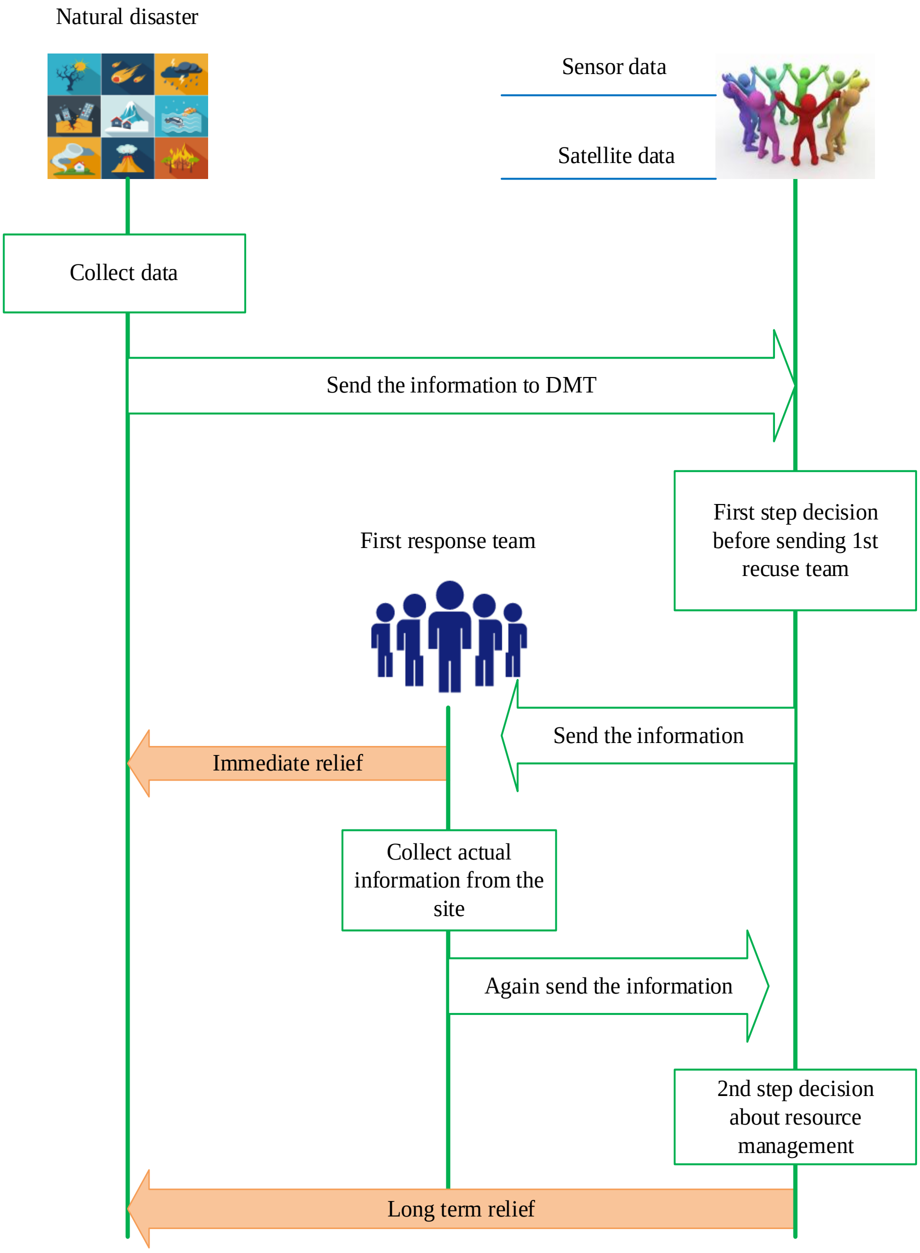

Figure 7. All activities of the planning

4.2. Other technologies for disaster relief

The purpose of disaster management is to provide relief and help to victims in disaster areas, quickly recover damaged areas, and minimize the damage caused by disasters [22]. Advanced technologies such as the IoT, deep learning, big data analysis and computed tomography (CT) have brought opportunities for disaster relief. In the process of disaster relief, the application of these technologies can recover important data and applications in a timely manner. In addition, technology has greatly improved the efficiency of medical staff.

In the paper [23], Chest CT technique and chest X-ray fusion are used to improve AI diagnosis. The authors also create an end-to-end input deep Convolutional Attention network (MIDCAN) and use multimodal. It was about 98 percent accurate in treating patients. In the paper [24], A model called depth fraction maximum pool neural network is proposed. The model was designed to more effectively treat patients who developed pneumonia and tuberculosis. In the paper [25], authors introduce a new deep learning method to improve the accuracy of computer vision in automatic intelligent diagnosis. In order to overcome the problem of over-fitting, multi-channel data enhancement is used in the scheme. Compared with deep learning, transfer learning plays an important role in medical image processing due to its high efficiency and low cost [26]. In the paper [27], in order to make full use of the large amount of biomedical data generated in the treatment process, the author proposed a data fusion method to increase the consistency and accuracy of the information. On the other hand, the development of sensor technology enables machine learning and artificial intelligence to be applied to multi-data source analysis, reducing the workload of medical staff, but the cost of sensor hardware and data maintenance, and the high complexity of data denoising are still challenges.

As a result, in the paper [28], the author proposes an IOTDRMF to create decisions for disaster management and risk reduction. Figure 8 vividly depicts the IOTDRMF. The IOTDRMF divides the population involved in the crisis into several categories and establishes a signalized intersection. For any node switching between these areas, the probability of entering different areas is also different, and big data is used to determine the shortest distance from the current path to the destination, to provide immediate rescue.

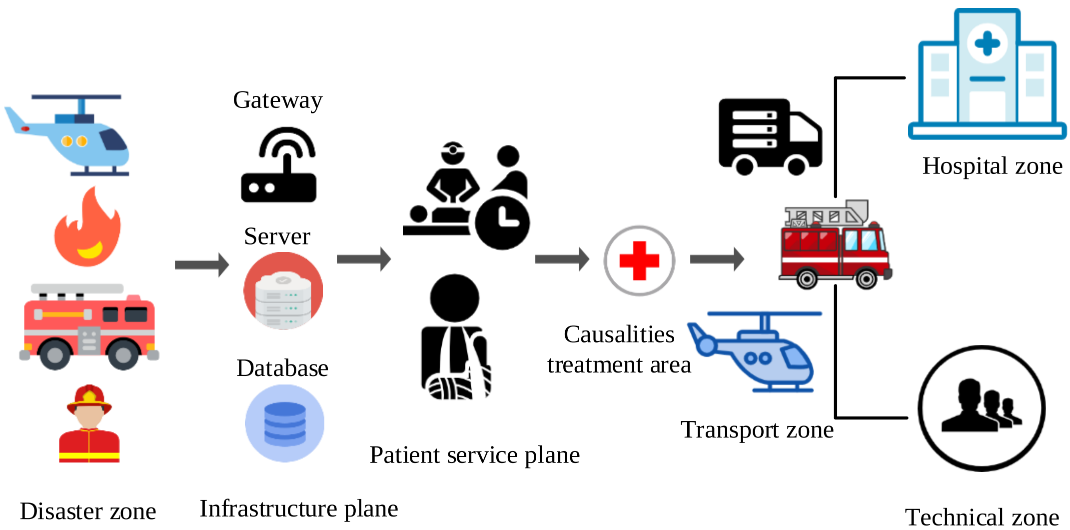

Figure 8. The architecture of IoT DRMF

In previous papers, there are researches on crowdsourcing for disaster relief and IoT for disaster relief, but few papers combine crowdsourcing and IoT to analyze their effects on disaster relief.

In the paper [22], the author believes that the IoT can meet the needs of natural disaster relief planning, and proposes an efficient disaster management solution based on the IoT. The scheme has three key functions, which are information collection, information transmission and information processing. Information is the basis for disaster management units to plan all kinds of early rescue activities, and it is impossible to carry out rescue work without the support of a large amount of information. In addition to topological data, weather conditions in the affected area also determine the types of supplies needed to plan effective relief operations. A common problem in disaster management is communication between disaster areas. In this scenario, the gateway is used to control the locally deployed coordinator, summarize the data provided by the satellite and local residents, and then transfer the data to the central database maintained by the DMU through the Internet.

In the paper [29], the author opens up a new perspective to try to develop an integrated model of crowdsourcing and IoT to improve disaster relief capabilities. In the age of information explosion, the boom of social media has enabled people to generate data all the time, and these data have been incorporated into the category of social media-based crowdsourcing. When a disaster occurs, people in the disaster area can post distress signals and locations online as long as they have a working device. The more accurate the location data of the victims, the more effective the disaster response will be. The role of the IoT is to connect disaster relief materials as an IoT system. For example, when disaster relief workers know where a victim is, they can attach RFID (radio frequency identification) devices to the supplies, so that the victims can use the available supplies to find other victims who have access to the supplies, and the victims can be grouped together and have a better chance of surviving, or even saving themselves, before the rescuers arrive. But user access module.

Next, an agent-based evacuation guidance these are ideal levels, and in the real world, there are factors like trust between people and ease of use of IoT devices that need to be taken into account.

4.3. Related technologies for self-evacuation in disasters

When lack of planning evacuation management system, often appear the following questions. In the process of evacuation, the untimely dissemination of information led to the negative emotions of panic, tension and worry of the evacuees, and the evacuation site was out of control for a time. Sometimes the evacuation process is affected by factors such as the location of the shelter or traffic conditions [20].

In order to achieve mass evacuation after a disaster, the authors of this paper [20]. The authors propose a paradigm based on the IoT and mobile cloud computing, where the collaboration between mobile terminals and cloud servers is realized。The core of the solution is an evacuation planning algorithm of APF(APF-RAS) based on relational attraction, which greatly simplifies the difficulty of complex disaster scene modeling. This scheme makes evacuation more humanized and allows related evacuees to be evacuated to the same place, which can relieve anxiety, depression and other bad emotions to a certain extent. The authors again propose to people life and help to optimize system (CLOTHO) the general architecture, there are four different modules to CLOTHO efficient evacuation planning, collecting evacuees, position information of the data acquisition module, two-way communication between mobile devices and cloud servers of the network transmission module. A cloud service module that provides personalized evacuation solutions, and finally a system for the IoT is proposed in the paper [30]. The system consists of two parts: scenario recognition and evacuation path planning. In the case of disaster, although there are signs and other facilities to inform people of the direction of evacuation, it is hard to avoid the collapse of the signs and other facilities, which cannot give people the correct evacuation route. Therefore, this paper uses information and communication technology to study the disaster measure support system. The AOT system platform consists of IoT devices, device agents and management agents. Specifically, the agent controls sensors deployed in the field, and sensors such as drones work with actuators to identify disasters. situation recognition agent and evacuation guidance agent are managed by the device agent. The main task of situation recognition agent is to identify UAV and other actuators and then transmit the recognized sensor information to the control actuator. After

4.4. Resource scheduling in IoT environment

In simple terms, resource management is through like resource scheduling and monitoring problems to deal with the task of rescue and recovery. Disaster management is the most critical stage of disaster management. A little neglect will cause irreversible consequences [32]. Resource management includes two important tasks, namely resource allocation and resource management [32]. When disasters occur, resource management requires efficient resource allocation [32]. Relatively, important activities should be given sufficient attention during resource scheduling.

In the paper [33], the authors propose a scheduling algorithm based on the IoT to deal with the dependencies of various activities. In addition, in order to estimate waiting times for various activities, queuing theory is studied and used, which helped to determine optimal resource centers. Resource utilization is

the disaster occurs, the dispersal guidance agent will automatically generate the evacuation guidance plan, which is guided by UVA and UGV, and the evacuation plan will also be changed according to the development situation of the disaster on site.

In the paper [31], the authors propose an IoT based infrastructure to support self-evacuation in large-scale processes. Decision makers, first responders, and evacuees do not interact directly in order to prevent information overload on nodes and communication links. The user evacuation system and the interaction between the infrastructure components are based on services that use encoded structured information to transmit and process events. The emergency command center is the core of the entire evacuation system, where all available information and most processing takes place.

maximized by scheduling resources according to the priority of activities. For example, under the condition of insufficient resources, equipment and time, there are many sick and wounded waiting to be treated. Medical workers need to make decisions quickly according to the order and priority of emergency treatment and implement treatment for patients [34].

In response to this typical scenario, the authors propose in this paper [34] an e-health IoT solution that essentially helps decision makers make decisions faster by providing appropriate priorities, and does not provide a complete recovery solution. Figure 9 depicts the architecture of the IoT eHealth solution for disaster emergencies。The main ideas of the architecture are different from the traditional approach, the small wearable biosensors attached to the patient, the patient's body temperature, heart rate, will scan through such equipment and related parameters as small distance of dew said server communication, transmission equipment to doctors, the doctor again according to the severity of the injury, priority arrangement seriously injured patients.

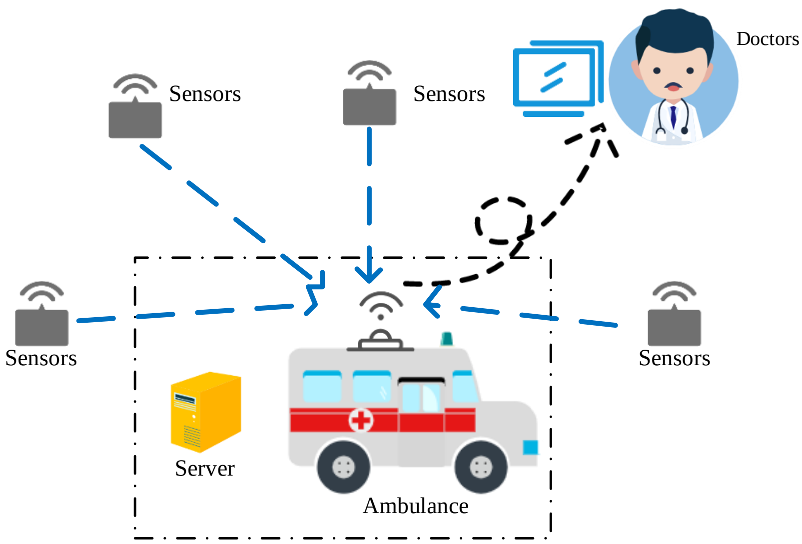

Figure 9. Architecture of IoT eHealth

In the paper [33], in order to deal with excessive and insufficient resources, a multi-objective resource allocation technique with different constraint sets is proposed. Using IoT devices, Raspberry Pi, Arduino, and a variety of sensor dust. And resource scheduling algorithm based on different parameters. The first parameter is proportional priority, the second is transportation cost, the third is resource utilization, and the fourth is scheduling time. Efficient resource allocation and optimal allocation can achieve twice the result with half the effort. The system proposed by the author uses IoT devices, Raspberry pi, Arduino, and various sensor dust. An IoT device could be a Raspberry PI, an Arduino, or an Intel Galileo. After a large number of tests, the feasibility of the scheme is relatively high, so that more people's lives and property security can be guaranteed.

4.5. Disaster communication in IoT environment

When major natural disasters occur, communications infrastructure is vulnerable [34]. In the paper [35], the author explains how the AD hoc D2D network based on the IoT can still maintain effective communication during a disaster, and suggests that we integrate the disaster mode into all mobile phones. When the traditional communication network crashes, D2D communication is initiated to form an AD hoc network, and some of the devices will act as relay agents, which can be selected according to the following cost functions: device surplus energy, calculated power, channel quality index (CQI) or signal-to-noise ratio (SINR), and bandwidth availability. But when IoT coverage is damaged [35], drones (UAVs) are used as flight base stations based on their mobility and flexibility. In the paper [35], the authors propose a multi-antenna transceiver design and multi-hop device-to-device (D2D) communication aimed at expanding the coverage of UAVs in the IoT in disasters. In natural disasters, the existence of emergency communication networks provides survivors with a chance of survival, through which they can keep in touch with their families and rescuers, tell them where they are and wait for rescue. The architecture of the UAV and D2D communication system is shown in Figure 10. In addition, the authors also designed the SPR algorithm (shortest path by) to quickly establish multi-hop D2D links with the minimum hop count. In the simulation experiment, the transmission performance of UAV is optimized. Finally, the throughput and interrupt probability of the scheme are improved.

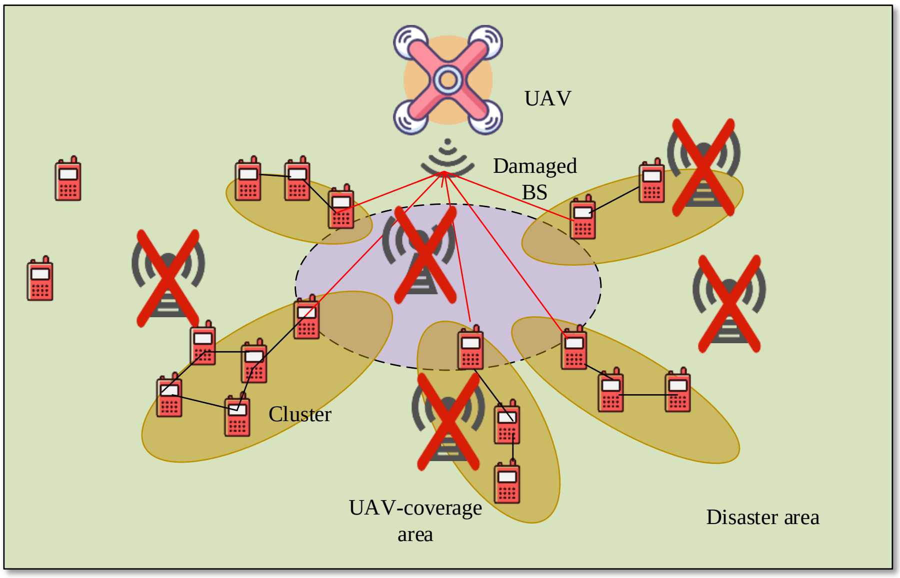

Figure 10. Architecture of the UAV and D2D communication system

In addition to the above methods, in the paper [18], the authors think that the WSN, DTN and NVIS technologies can be combined in the access network and backbone network by deploying a unique integrated heterogeneous system using high-frequency communication as a new method of emergency communication network. Different interconnections between multiple nodes are also built. The channel delivers data collected from the disaster site to the NVIS network of the operation center as the physical layer in the absence of any power infrastructure. To obtain better network performance, the ionospheric spectrum is divided into multiple channels. A specific channel is located in the nodes of multiple hops to communicate to the central node, and another channel is used for digital voice transmission to ensure emergency communication.

In the paper [37], in order to overcome the problem of information transmission delay, the author proposes a P2P cloud network service of disaster information based on the IoT, which combines the IoT, M2M network and P2P cloud service to facilitate better disaster management. The disaster information system consists of the local security information server, the central disaster Information Center integrated Disaster Server, and the high-speed network server. The decentralized nature of P2P networks allows nodes to find data without relying on the index server, even if the data transmission fails in the event of a disaster. In addition, disaster information components, which consists of collection module, processing module and distribution module, are also configured to ensure the continuity of disaster information. Finally, users can learn about the situation in disaster areas in a timely manner on the central disaster Information Platform.

In a disaster, network infrastructure is damaged and communication channels are congested with increased data traffic. In the paper [38], the authors present an emergency information platform specialized in where IoT technology, fog computing, cloud computing, point-to-point computing and delay tolerant networks are used to solve problems where traditional communication modes fail or perform poorly. For example, a link that allows delay Tolerance network (DTN) is used for data propagation. In the event of a disaster, first responders will deploy more fog servers at the disaster site that have process, storage, and network transmission capabilities. IoT devices at the edge of the network sense and collect disaster data, which is then first sent to the fog node for pre-processing. But when the Internet connection is damaged, the authors suggest using the movement of people, vehicles or even drones to create an opportunity network to support the continued work of interrupted communications. The advantage of this system lies in the use of the active computing components of the system for information collection and dissemination, coupled with the unstructured IoT coverage network combined with the existing communication facilities in disaster areas, enabling rapid deployment of disaster communication systems. In addition, the multi-dimensional overlaying routing method implements the routing tolerance mechanism and enhances the robustness of the platform.

In the paper [21], to solve the problem of network load balancing between backbone nodes, the author presents an IoT based data aggregation backpressure routing (DABPR) scheme for disaster management. By aggregating overlapping routes, the data transmission efficiency is improved and the network life cycle is prolonged. The program has five phases that complement each other, Including cluster head selection phase, maximization of event detection reliability phase, data aggregation phase, scheduling phase, and route selection with multi attributes decision making metric phase. To organize the network in a hierarchical manner, nodes are divided into clusters. Nodes called cluster heads perform the task of aggregating data and forwarding it to sink nodes. The optimal route from the source node to the sink node is related to the intermediate node to some extent, and the optimal route will be selected according to the estimated parameter values. Data aggregation tools exist to reduce the size and rate of information exchange. In addition, in order to achieve the stability of network queues and throughput maximization, the scheme also uses the congestion gradient function to solve the dynamic traffic demand problem. The final simulation experiment shows that the outstanding performance that all nodes can be evenly distributed energy can make the proposed algorithm provide more set cost.

4.6. Big data analysis and IoT-based disaster management

The combination of big data analytics (BDA) and the IoT as a valuable platform to support a variety of new data sources and real-time big data processing tools. The platform has demonstrated its value in enhancing data management and visualization of disaster management systems, as well as accurate decision-making in a short period of time.

Disaster management systems rely on the environment which supports multiple data sources. In the paper [16], the authors propose the overall architecture deployment of disaster management environment based on BDA and IoT. Specifically, it is made up of five layers.

The first layer is the data generation layer. Data sources include not only traditional sensor or GIS-based factual data, but also a wealth of valuable crowdsourced data from human and social media streams. In disaster management, the expansion of data sources is of great help in forming new insights. The second layer is data harvesting. When a distributed data source is identified as relevant to disaster management, the distributed system receives tasks assigned by the delivery network and sends the processed information to IoT devices. At the same time, the data dispatcher will send alerts and arrange preventive measures in time. The third layer is data communication, which is a core layer. It is responsible for efficient, secure transmission across all layers using existing advanced communication technologies. The fourth layer is data management and analysis. The data is filtered from the collection of data sets from heterogeneous data sources, and the unstructured data is classified with a semantic engine to further reduce the time and computational overhead of data analysis. In addition, the Hadoop ecosystem, which is an open-source software platform supporting massive data storage and processing, and Spark analysis engine, which is an in-memory data processing framework suitable for interactive data query, are combined as the programming model. Data analysis can be achieved by using machine learning algorithms, natural language processing to facilitate the decision-making process. The fifth layer is applications. The application layer has a large number of valuable data resources as the cornerstone, and a web-based access control API that allows information visualization and interactive reporting operations to emergency responders.

4.7. Crowd sensing and IoT-based framework

The identification of areas where disasters are occurring or are imminent will reduce the workload of rescue teams. In order to achieve this goal, in the paper [39], the author proposes a disaster management framework based on IoT communication technology based on crowd sensing clustering algorithm. The developed system uses embedded system, cellular network and other different IoT technologies to transmit two important information - the state of the building and the density of residents, hoping to use the size of the crowd density to provide information about the state of the building damage. The IoT unit, which is composed of cellular and Wi-Fi networks, is generally deployed on large buildings such as hospitals and Bridges. During a disaster, the state of the building is detected by building damage programs and the collected data is sent to the cloud through the message queue telemetry Transmission (MQTT) protocol. The framework then runs the resident density clustering mechanism to determine the resident density of each region. Through the decision support system based on fuzzy logic, the rescue team can know where to go after considering the building damage and the density of residents. The structure of disaster management framework based on IoT technology is shown in the Figure 11.

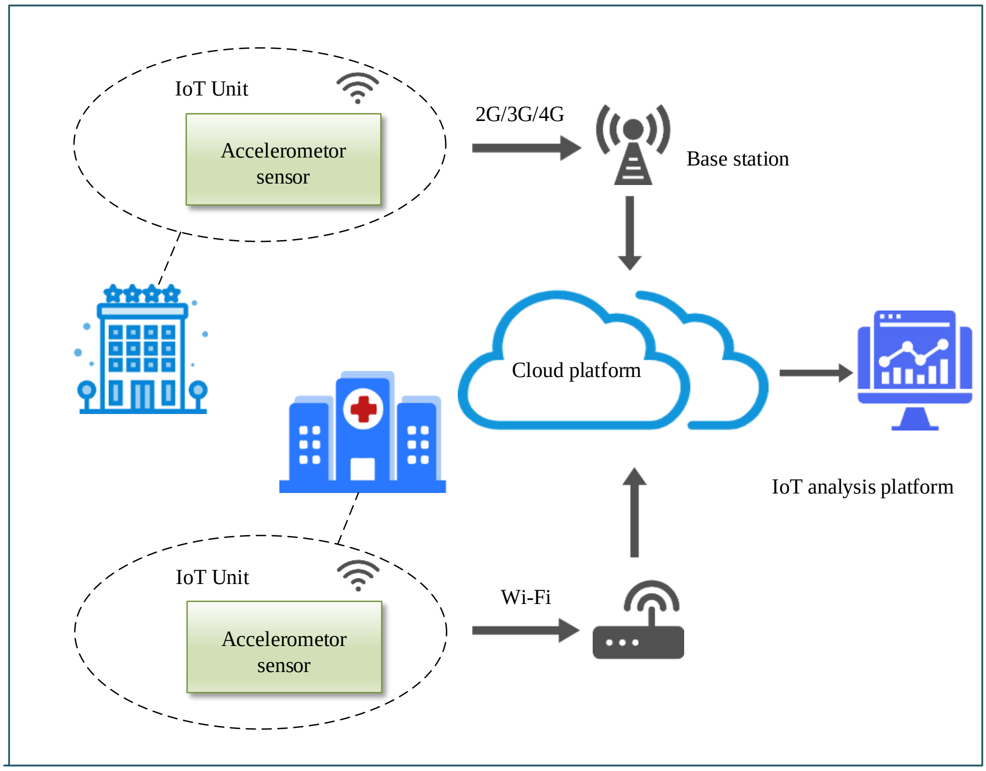

Figure 11. The structure of disaster management framework based on IoT technology

4.8. IoT technology for disaster recovery

Disaster recovery (DR) refers to the recovery of important data, applications, hardware, etc., after a disaster occurs. Communication and staying in touch are an important aspect of a disaster, both for those who are currently in the disaster area and for others who are paying attention.

In order to establish a comprehensive and integrated model-based approach to the analysis of disaster recovery indicators, the author presents a scheme in the paper [40], which is a stochastic Petri (SPN) modeling strategy. This IoT infrastructure disaster recovery solution uses device sensors to collect environmental information and send it over a wireless or 4G connection to a private cloud that serves as the primary site where the data is stored and processed. However, when services on the primary site are interrupted, traffic is sent back to the disaster recovery cloud until the primary site is available. The status and data created on the secondary site are migrated back to the primary site. This approach was successfully applied to evaluate disaster recovery solutions for healthcare IoT infrastructure.

5. Specific application of the IoT under different natural disasters

At present, the application of IoT in natural disaster prediction and early warning has become a research hotspot at home and abroad [41]. Different natural disasters also require different IoT technologies to deal with. In this section, several specific approaches for different disasters are introduced. Table 3 shows a comparison of several approaches.

Table 3 . A comparison of several approaches

Authors	Models/Systems	Field	Regions
Z. L. Li et. al [37]	A monitoring and forecasting system based on 5G and the IoT.	Landslide	Fujian, China
R. D. Dhanagopal et. al [38]	IoT based Energy Efficient Early Landslide Detection (EEELDS) model.	Landslide	Mountain areas in India
M. T. A. Abraham et. al [39]	Landslide early warning system based on IoT and MEMS.	Landslide	Himalayas, India
B. B. Basnyat et. al [40]	Mountain flood monitoring model based on Internet of Things.	Flash flood	Streams in Ellicott City, Maryland
A. A. Alphnsa et. al [41]	Early warning system based on IoT.	Earthquake	India
M. K. Klapez et. al [42]	Earthquake warning system.	Earthquake	Medium-high seismic zone in Italy.
N. G. Germenis et.al [43]	Earthquake early warning system based on IoT.	Earthquake	Greece

5.1. The role of IoT in geological disasters

As the production activities have expanded, geological disasters caused by slope instability happens more frequently [42].

Landslide usually occurs in mountainside villages. It is difficult for people living in mountainous areas to perceive subtle abnormal changes in the mountain, but the IoT can help detect the landslide. The rise of 5G offers hope for monitoring landslides. In the paper [42], the IoT, 5G communication technology, and landslide warning technology are combined to develop a new monitoring and prediction system, which can track the movement and change of the landslide in real time. It can also issue warnings in time, so that relevant departments can take disaster prevention measures in advance. The system supports GNSS based IoT automatic monitoring devices, which regularly transmit the monitored rainfall, water table, cracks and other data to the equipment-side server through 5G communication channels. In addition, the system also adopts the dual communication mode of BeiDou satellite and GPRS (BD/GPRS) to transmit the collected data to the indoor monitoring center. Wireless sensor network technology connects each monitoring position to ensure the stability and security of data transmission. The monitoring and early warning platform provides comprehensive analysis of monitoring data, introduces the early warning criterion based on tangent Angle, and gives different levels of early warning according to slope deformation and crack development degree. The system has been successfully applied to the long-term creep slope of a terraced field in Youxi County, Fujian Province, realizing the automation and digitalization of geological disaster monitoring and warning.

Considering the cost and maintenance issues, a model for IoT based landslide detection mechanisms is proposed in the paper [43], the proposed design is named as IoT based energy efficient early landslide detection (EEELDS) model. Once the precursory of the landslide occurs, it can send emergency messages and related data to the disaster management departments in a minute. It is universally acknowledged that the landslide tends to come with the movement of the rock mass, so authors use various objects to sense the anomalies. For example, vibration sensor is used to detect the movement of bedrocks. Rainfall sensor will change its resistance according to the droplets on the surface. Whether the rainfall sensor will be activated is dependent on the weather conditions. If these sensors are activated, the sensor information will be acquired by node 1 and be sent to IoT Hub frequently. Then the information received is forecast to respective nodes. At critical moments, the government sends text messages to residents. To further reduce the maintenance costs, solar cells are used as renewable energy to improve the energy efficiency of the model. After a series of experimental operations, the tested accuracy is 30% higher than existing accuracy.

The Himalayas in India are one of the most landslides prone regions. In the paper [43], in order to develop a more effective landslide warning system (LEWS), the authors use a micro-electromechanical system (MEMS) based which is a small integrated system consisting of electronic and mechanical components. A tilt sensor and a volume-water content sensor to monitor slope activity, which are placed at a depth of 30 cm on the slope. IoT based networks use wireless modules to communicate between sensors and between data recorders and databases. In particular, the study is carried out in a sunken zone of the Darjeeling Himalayas. The study uses six units embedded with volumetric water content sensors as a monitoring system to measure the dielectric constant of the soil and indirectly calculate the moisture content in the soil. Data collected by six sensors can provide a landslide warning, which is transmitted to a data logger. The researchers compare the monitoring data with field measurements and find that it is important to consider both long-term and short-term rainfall when setting rainfall thresholds for the region.

Flash flood is a common disaster and sometimes occur on tranquil surroundings. In the paper [45], authors present a detailed architecture and design three different kinds of flash flood detection based on IoT. The first IoT deployment is based on on-premise IoT solutions, named Smart Security P&S Unit. The preceptor of the Gen-1 IoT is a float switch. When flash flood happens, the water rises continuously until the water level reaches the switch and then turns off the circuit. At this point, the CPU receives the binary signal sent in. And the floating switch automatically remains deactivated when the threshold is reached. The disadvantages of Gen-1 deployments include data limitations, predictive power, and cost. The Gen-2 uses a camera unit that continuously shoots the riser structure for positioning areas and images. Use digital identification technology to determine flood level. This generation has low availability and moderate overall performance. In Gen-3, there is a perceptron that is connected to the central processing unit. The collected data is transmitted to the cloud for subsequent access and machine learning. Compared with the previous two generations, the third generation has a great improvement, but there is still a lack of practicality and stability of equipment. As a result, further improvements are needed in flood monitoring.

Wireless sensor network has the advantages of low cost, easy maintenance and strong robustness. It is a network that distributes sensors in space and monitors physical and environmental conditions in real time [46]. The hardware part of the IoT is responsible for detecting and reading signals, and the software part is responsible for sending timely warnings to the public. In theory, P waves reach the ground before S waves, so wireless sensors can predict surface tremors ahead of time, giving the public seconds or minutes of advance warning. Somewhat reducing the rate of casualties.

In the paper [46], besides the vibration sensors that detect ground motion, accelerometers detect ground motion and send alarm signals to the microcontroller. The microcontroller makes decisions based on pre-programmed characteristics and follows the ZIGBEE protocol to deliver early warning signals to the IoT PC. Eventually, through the IoT, the alert message will be sent to the public's mobile phones. For those who do not use smartphones, alerts are sent to nearby base stations via GSM modules.

In the paper [47], the authors mention the earthquake warning system (SAS). The role of SAS is to detect the earthquake in progress as soon as possible and issue an alarm during the coming S waves. It has the advantage of being the first to detect earthquakes and send alerts further afield. But the disadvantage is that there is no way to respond quickly near the epicenter or in the right place. Earth cloud consists of two parts: sensor system and cloud service. The Earth cloud sensor system consists of three parts: Raspberry PI 3 Model B V1.2, the Adafruit ADS1115 analog to digital converter, and a set of 4.5Hz detectors enclosed in a rugged structure. Considering the cost, the sensor element of the earth element is a geophone rather than an accelerometer. The sensor-generated data is encapsulated in an MQTT message, which is sent to the AWS IoT before Amazon Kinesis processes it in real time. Two of the three sensor devices deployed in Italy's medium-high seismic zone successfully sent data to the cloud, achieving the desired results.

In the paper [48], the authors describe the design and implementation of a seismograph, which is characterized by low cost and intelligent embedded. Advanced IoT technology can help the seismometer configure response devices that support typical seismic and geophysical data acquisition networks and earthquake early warning. Considering rural and remote installation sites, the equipment must take the form of an integrated compact system, even buried underground. The high-level design of intelligent embedded seismograph operation software consists of eight components. The sampler is used to assign different sampling rates to all different sensors, with a range of sampling rates up to 500sps. The raw data converter is designed to receive uncomplex data streams. Triger detector is responsible for detecting signals of abnormal sequences or states which are propagated to other components. Stream server and triggered stream server are used to transmit continuous data streams and trigger data streams serving earthquakes, respectively. The function of the local storage controller is to store data, but it can also retrieve historical data. Data forwarder can work with other devices in the network to create a mechanism which acts as a link between various data processes. System manager can access the parameters in each component remotely at any time. The selections of P wave detection algorithm and control signaling communication protocol are important parts of this system.

5.2. The role of IoT in forest fire

Forest fires tend to spread across many geographical areas. IoT offers the possibility of reducing damage caused by disasters through intelligent monitoring, diagnosis and repair [49].

In the paper [50], a complete IoT based microcontroller control system is proposed with the aim of detecting forest fires with sensors. Once the exact location of the fire is detected, it will direct the location to a nearby forest worker. Additionally, for deeper management of the forest, the activities of the system are monitored in real time, and relevant information as well as data are stored for regular viewing by the staff. Given that transmission lines are not available in forests, solar panels and batteries are a good choice for powering the system. The Arduino, as one of the main components where the entire control operation takes place, is connected to the temperature sensors and the smoke sensors. When there is a disaster, the Arduino monitors the scene until it exceeds a certain level, and then transmits the alarm of a forest fire. At the same time, the GPS module connected in the system is used to locate the fire, accurate to the latitude and longitude. The ESP8266 contained in Wi-Fi module is used to transmit the information to officers by virtue of cloud. IoT related devices monitor and record specific information about the fire, and the system is linked to office computers in a chain reaction. This system has been successfully implemented in small forest areas with high fire incidence, but it is still difficult to implement in large forest areas.

Wildfires is considered as the one of the most dangerous types of forest fires. In the paper [51], authors propose an IoT-fog cloud collaborative framework based on soft computing technology and a real-time emergency warning generation mechanism based on time mining under adverse fire conditions. The framework consists of three layers. Sensors in the IoT are responsible for obtaining wildfire location attributes and impact attributes. The data is then transmitted to the fog layer. The holt-Winters model predicts future wildfire trends in the clouds where disaster management teams can retrieve and use data.

In the paper [52], the authors propose a remote monitoring system which is based on IoT, which uses solar energy system to monitor forest areas. Data about the current environment is collected through the gateway and displayed on the dashboard.

In the paper [53], the authors propose an energy-saving IoT framework supported by fog and cloud computing technologies. The architecture starts with IoT sensors to monitor wildfire cause parameters, and then utilizes the power of fog nodes to improve the life cycle of the sensor network. Using cloud computing to predict the occurrence of wildfires. Alarms are activated when wildfire vulnerability is high. Not only does it fulfill its mission of wildfire monitoring and warning, it also leverages energy efficiency.

5.3. The role of IoT in ocean disasters

The flood is a wave of powerful destructive power. Detecting waves in time could save many lives. In the paper [54], an overview of the work used for tsunami detection is given. The first is to deploy the sensors in the ocean. Once the values monitored by the subsea sensors exceed a certain level, the data is sent to a data acquisition center for pre-processing and analysis. Too high will trigger an alarm and evacuation.

In the paper [55], the authors focus on disaster response systems for fishermen performing marine operations on the ocean. It uses the IoT for information gathering, post-disaster search, and rescue during disasters and emergency response phases. In addition, an edge smart module is added to the IoT solution to define the smart part of the edge node. The components of the proposed IoT solution are shown in Figure 12. The solution consists of ocean-net architecture-based devices, mobile applications, technology acceptance models, edge layer intelligence, partial context-aware algorithms, mobile phones, computers, tablets, and other IoT devices, as well as community participation in the design phase.

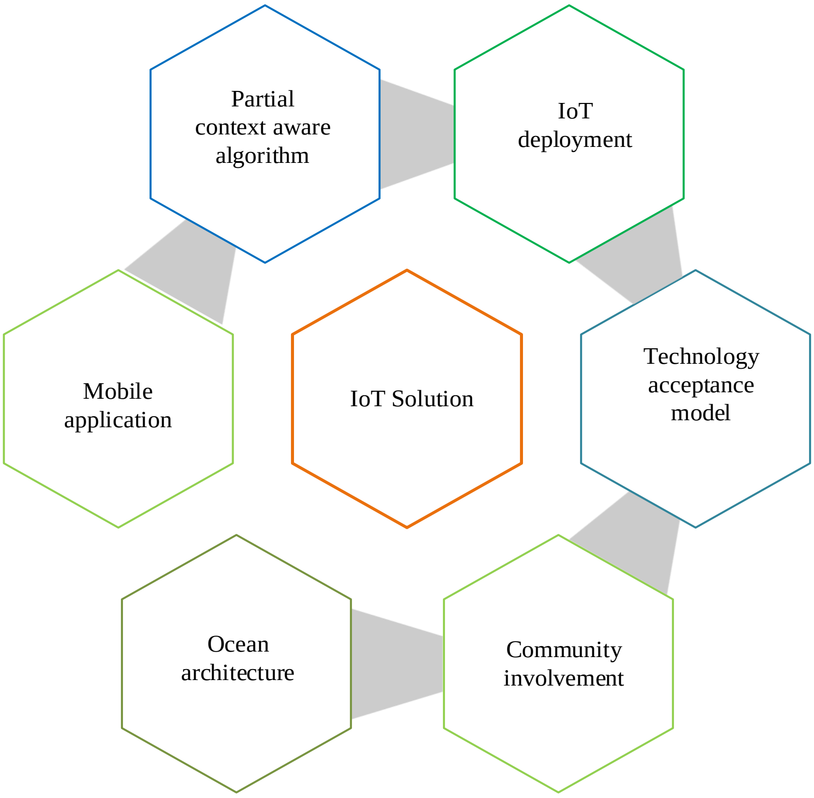

Figure 12. Components of the proposed IoT solution

5.4. The role of IoT in hydrological disasters

How to prevent floods is a challenge facing mankind. The combination of IoT devices, cloud services, geographic information systems (GIS), and other technologies has opened a new perspective on flood warning [55][57].

Although some researchers have developed flood prediction systems at the present stage, these systems are mostly oriented to cities, while for remote rural areas where there is a lack of funds, talents, and technologies, it is worth to think about how to deploy equipment to effectively monitor and warn the invasion of floods. In the paper [58], the authors propose a model calculated by multiple linear regression which can select any parameter type according to the demand. Any number of parameters can be added or modified. The water level is represented by a polynomial and an alarm is issued if the threshold is exceeded. But the drawbacks of the model are the lack of information about the frequency of the alerts, the distance they can travel, the high cost of using multiple sensors to detect the data needed, and the susceptibility of sensors to damage in extreme environments such as heavy rains. The main work of flood warning system is data processing, data representation, and data broadcasting. The water level is first measured by an ultrasonic sensor installed near the river, which is sent to a microcontroller. The microcontroller comes to compare the measured water level to a threshold that people have set in advance. If it exceeds, the warning message will be broadcast to everyone by ZigBee. In addition to water level monitoring, water velocity sensors are deployed to dynamically detect changes in water flow velocity and notify the server immediately of anomalies. The warning broadcast system does not rely on mobile towers to avoid information delays and complex calculations, taking into account the lack of Internet access during disasters.

Smart IoT flood monitoring system for rural deployment is also mentioned in the paper [59]. When ultrasonic sensors start measuring the river's water level, the whole system kicks in. The microcontroller will receive the data from the sensor. The data are analyzed and compared to determine whether to give the flood warning.

In the paper [60], the authors describe how computer vision and IoT sensors can play a role in flood monitoring and flood mapping. Accurate monitoring of water levels before early warning is required. Each point in computer vision's camera field of view (FOV) can be treated as a sensor, but with less accuracy than the IoT sensors, which provide only point-based readings. Using the two in a complementary way amplifies the advantage and achieves precision.

In the paper [61], the authors point out that in order to prolong the life of the system, an energy-saving method based on data heterogeneity can be adopted. A new pre-processing technology of flood detection system, principal component analysis (PCA), is proposed. Its main function is to reduce the dimension of nonlinear data, facilitate the data training of artificial neural network, and maintain the optimal bandwidth of the network. The data acquisition layer, fog layer, and cloud layer generally constitute the flood prediction and early warning model proposed in this paper. Rainfall sensors, water flow sensors, water level sensors, humidity sensors, and other sensors deployed in the natural environment are specifically responsible for data collection. The data acquisition layer then transmits the data to the transition layer, the fog layer, for data analysis, where PCA performs its function, and finally the data is stored in a cloud-based server for use by the disaster management team.

In the paper [62], the authors present a flood level detection model based on IoT. The modulator controls all tasks of the project, and the LCD visualizes the activities inside the microcontroller. Remote sensing sensors are used to quantify such different boundaries as temperature, wind speed, air pressure. These boundary values which are used to predict the possibility of flood occurrence can be refreshed on the web or displayed locally. The technology relies on a board and biometric framework connected to the IoT and delivers all sensor data to the cloud via the ESP8266 Wi-Fi module. The model gives a forecast of where and when floods will occur, thus people making preparations before the occurrence of the disaster.

In the paper [63], an integrated model using the IoT and machine learning is proposed to predict water level and flood severity. Machine learning algorithm is used to analyze the nonlinear and dynamic characteristics of the flood sensor data set. In order to solve the problems such as loss and damage of a large number of original data, data science method is adopted to analyze and extract the sensory data set which is characterized by class imbalance, noise, and lost value. The implementation of the system mainly consists of three stages. First, the IoT sensor is responsible for collecting data which serves as the input of ML technology and divides the data into three categories: normal, abnormal, and high risk of flooding. Second, after processing, the data is configured and trained for classification model. Third, the model is evaluated using data not tested.

Similarly, in the paper [64], the authors study the machine learning-based embedded flood prediction model which uses the data of IoT sensors to construct. The feature of this scheme is to model the regional mean flood forecast using the data set acquired by the sensor. Integrating IoT sensor data into ML model as input factor, and constantly updating model parameters can achieve the effect of reducing model error. The data set obtained by the sensor is used to model the regional mean flood forecast.

In the paper [65], the authors construct an ultra-low power IoT framework relied on artificial neural network to predict flood. Artificial neural network technology is used to build an artificial neural network flood prediction model using real-time data collected from a dashboard developed by Thing Speak. The interconnection of the Wi-Fi modules on the IoT board enables various low-power IoT nodes to communicate over the Internet. The model will provide information about impending disasters based on rapid increases in water levels and continued rainfall.

In the paper [66], the authors design a flood monitoring system which integrates flow and water level sensors. Using the artificial neural network to process the data obtained from the sensor, and through a laboratory test, it is concluded that there is a strong correlation between the flow rate under different pressures.

In the paper [67], the authors propose an embedded system based on IoT and machine learning, and introduced a prediction algorithm based on simple artificial neural network (ANN) model to predict the probability of flood occurrence. The wireless sensor network is responsible for collecting data, sending it to the Internet through GPRS module, and the artificial neural network is responsible for training and modeling the data.

6. Summary and Future Work

Through the integration of big data analysis, fog computing, cloud computing, machine learning, artificial neural network and other technologies with the IoT, it has played a lot of roles in disaster monitoring, early warning and management, improving the dilemma before the application of technology. As a feasible disaster management scheme, it plays an important role in resource scheduling and rescue path planning. This paper outlines the main implementation processes of IoT technologies that can be used in natural disaster prevention and relief. However, data security, scalability, robustness, cost of equipment, accuracy of alerts, and so on remain challenges. To sum up, the ultimate purpose of this paper is to help us understand the response schemes of the IoT that have been studied or proposed. In the future, more and more IoT or the IoT combined with other technologies will emerge to deal with natural disasters, so that more people will be saved from disasters.

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