Internet of Things (IoT) and its Contributions in Earthquake Disaster Management

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Abstract

Earthquake disaster management seeks to mitigate the potential harm caused by disasters, provide prompt and appropriate aid to the victims, and achieve efficient and swift recovery. Earthquake disaster management is one of the several applications of the Internet of Things (IoT), a highly promising technology. The IoT plays a crucial and widespread role in earthquake disaster management, with the capacity to potentially rescue lives. This article examines the contribution of IoT in the management of natural disasters, specifically focusing on its application in earthquake disaster management. The IoT enabled swift and efficient responses in the management of natural disasters. The main purpose of IoT is to detect earthquake disasters and provide advance notification to the general public. The implementation of IoT can be achieved by broadcasting messages in a more accurate and intelligent manner to effectively communicate with the public. Data is initially gathered from the surroundings by a vibration sensor, and subsequently communicated, evaluated, and received by a receiver. The essential message is then sent to smart and GSM mobile devices. This study provides substantial contributions to the establishment of suitable frameworks for the IoT in the field of earthquake disaster management.

Introduction

While it is impossible to forecast earthquake disasters, it is prudent to make necessary preparations in anticipation of such events. Earthquake disaster management involves the development of strategies to help communities minimize the risks associated with hazards and prepare them to effectively respond to disasters (Sinha *et al.*, 2019) Earthquake disaster management does not focus on preventing dangers, but rather on developing strategies to mitigate the impact of disasters (Aljumah *et al.*, 2021). There are two categories of disasters: natural and man-made. Natural disasters encompass seismic activity, volcanic eruptions, flooding, tsunamis, droughts, cyclones, forest fires, and landslides. Man-made disasters encompass events such as chemical leaks, nuclear releases, traffic accidents, structural damage, and terrorist strikes. The occurrence of disaster has increased in this century as a result of urbanization and globalization. Several early warning systems exist, but the management strategies are limited to following rigorous rules and regulations. In light of the rapid advancement of technology, it is imperative to prioritize the management process (Ding *et al.*, 2020).

The frequency of annual disasters in Nepal is steadily rising. The magnitude of the catastrophe's devastation is also escalating. Government entities have been established to mitigate the aftermath of calamities. The primary obstacles faced by them include financial constraints, inadequate IT resources, and a shortage of in-house knowledge. We can contribute to improving IT facilities and developing our expertise. By establishing connections between objects and linking them through a server, we may fulfill this criterion. With the rapid expansion of the Internet of Things (IoT), the field of embedded systems presents a vast research potential. This study focuses on the technological aspects that can be utilized to establish a highly effective management system. The IoT can be used to connect and integrate several departments' operations. The implementation of IoT technology can facilitate effective disaster management planning in the specific context of Nepal (Sharma & Shakya, 2020). While there are existing studies that explore the efficacy of IoT in disaster management, none of them specifically focus on the setting of Nepal. The approach to disaster management in foreign nations differs significantly from that in Nepal. Therefore, it is necessary to determine and give priority to the information needed for effective management of relief operations during natural disasters. This study presents a proposed IoT solution aimed at enhancing the effectiveness of disaster management. The provided solution is verified, therefore assessing the strategic worth obtained from implementing the offered solution for disaster management activities. This effort will establish the basis for the technical solutions that may be subsequently applied to achieve the advantages of IoT in disaster management. Technology has the potential to revolutionize the preservation of life and property during times of disasters.

A Review of Concepts

Internet of Things (IoT)

The Internet of Things (IoT), a relatively new concept for connectivity, envisions a future where there is a network of faulty products. The IoT refers to a system of interconnected things that are equipped with radio frequency identification (RFID) technology that can communicate with each other. The concept was invented by Ashton Kevin in 1999. The IoT is defined by IERC as a global network infrastructure that is dynamic and self-configuring. It operates using standard and interoperable communication protocols. In this network, both physical and virtual objects have distinct identities, physical characteristics, and virtual personalities. These objects interact with intelligent interfaces and seamlessly integrate into the information network (Villamil *et al.*, 2020).

The Internet of Things (IoT) will facilitate the utilization of devices to provide services across many applications, ensuring that security and privacy concerns are adequately addressed. This will be achieved by utilizing device identification, data gathering processing, and communication capabilities. From a broader standpoint, the IoT can be seen as a visionary concept that has significant ramifications for both technology and society (Kopetz & Steiner, 2022).

Disaster

An event that causes damage to the environment, injuries to people, or a decrease in medical services. It requires an exceptional reaction from anyone in the affected neighborhood or region. The definition of a disaster can vary among experts. A catastrophe, as defined by several public health practitioners, is an abrupt and exceptional event that has an impact on health or presents a risk to it (Ray *et al.*, 2017). A disaster is commonly defined as an event resulting from either natural or human causes, which leads to significant physical damage, loss of life, and destruction of property. A disaster refers to any catastrophic event resulting from a hurricane, flood, fire, explosion, or similar calamity. Through this method, catastrophe has the potential to devastate individuals' livelihoods, residences, financial systems, as well as their cultural and societal existence. Future attributes of a catastrophe may include rapidity, exigency, perplexity, capriciousness, peril, and the demise of human beings, fauna, and assets. While it is not possible to completely avoid disasters, there are some emergency recovery programs specifically created to mitigate their impact (Kadam *et al.*, 2018).

Disaster Management

According to the Global Disaster Preparedness Center, there are four phases of emergency management: Mitigation, Preparedness, Response, and Recovery. Through the use of, among other things, sensors, robots, and unmanned vehicles, IoT helps minimize risks and improve response by transforming disaster management from reactive to proactive. And the data generated by these devices minimizes the risk of being taken off guard while helping everyone to make more informed decisions. Additionally, enhanced communications systems assist in rescue work (Sharma *et al.*, 2021).

Table 1. Phases of Disaster Management System

Mitigation	Minimizing the effects of disaster, such as implementing building codes and zoning, vulnerability analyses, public education.
Preparedness	Planning response, including preparedness plans, emergency exercises and training, warning systems.
Response	Minimize hazards created by disaster, such as search and rescue, emergency relief
Recovery	Return the community to normal, through things like temporary housing, grants, medical care, and IoT can be a game changer in a number of ways.

Earthquake Disaster Management

Earthquake is one of the natural events that occur almost every day in different parts on the earth. It causes millions of people death and homeless. The latest event was recorded in Nepal in April 2015. It took 8,979 human lives and injured 22,300 people (Adhikari *et al.*, 2015). According to Global Report on Disaster Risk, Nepal ranks in the 11th position in terms of earthquake risk. Historical data and ongoing seismological studies have indicated that the entire region of Nepal is prone to earthquake and it lies in the active seismic zone V. There is regular earthquake activity along the major active faults in east-west alignment. The seismic pattern has geographically divided into three clusters of events: western, central, and eastern Nepal. Siwalik, lesser Himalaya, and frontal part of the Higher Himalaya are the most vulnerable zones. The country has had major earthquakes in the 20th century; namely Bihar-Nepal earthquake (1934), Bajhang earthquake (1980) Udayapur earthquake (1988) and the Gorkha earthquake (2015) (Khanal, 2020). Nevertheless, researchers are consistently engaging themselves to design and i novel forms of IoT-based systems that may help to notify the prospective remotely located victims before the incidence takes place. `Nerve Net', implemented at Onagawa, Japan, is one of the most recent advancements toward the IoT integration with earthquake monitoring. It is based on the concept of bypass network which is proven to be disaster-resilient. This network is geographically distributed over several kilometers of a region where local and remote communications take place by involving Wi-Fi, satellite, optical Ethernet, and Unmanned Aerial Vehicle (UAV) (Hadiana *et al.*, 2020).

Some Solution of Earthquake EW System

(Tariq *et al.*, 2019) proposed and tested a Seismic Wave Event Detection Algorithm (SWEDA) to achieve milliseconds earthquake detection and warning and optimizing computational costs using inclinometer nodes for Industry 4.0 and the CANOpen communication protocol for industrial IoT. (Fauvel *et al.,* 2020) proposed a distributed edge computing approach for earthquake EW which uses GPS stations and seismometers to run the ML model. It reduces the amount of data to be transmitted towards the cloud and provide a more resilient system in case of wide earthquake. (Khedo *et al.*, 2020) simulated an on-site WSN model to predict and detect earthquakes in the island of Mauritius, and they analyzed how different WSN parameters such as synchronization protocol, sampling frequency and node density at location of the epicenter. (Fu *et al.*, 2019) proposed a development and testing of sensor node for dense earthquake EW networks, achieving low costs using MEMS sensors and standalone TCP/IP module. MyShake smartphone earthquake monitoring application developed (Allen *et al.*, 2020) and that has been working as a phone application since 2016. Alerts can be generated by either detecting p-waves embedded in user's smartphones or mining data from regional seismic networks.

Table 2. Review Paper in Earthquake EW System.

Authors (Year)	**Focus and Objectives**	**Results**
Tariq *et al.* (2019)	Proposal and testing of an SWEDA earthquake algorithm to achieve milliseconds earthquake detection and warning and optimizing computational costs, also designing and producing 2 kinds of sensor nodes.	The solution was tested with three different systems installed in SHM sites at Qatar University, and it identified p-waves 11 s before a second trigger for s-waves was generated, showing good Earthquake EW capabilities.
Fauvel *et al.* (2020)	Proposed a distributed edge computing approach for earthquake EW to run the ML model. It reduces the amount of data to be	The paper presents the results of the Distributed Multi-Sensor Earthquake Early Warning

	transmitted towards the cloud and provide a more resilient system in case of wide earthquake.	(DMSEEW) system. The paper also presents experimental results that validate the effectiveness of the DMSEEW system on a real-world dataset.
Khedo *et al.* (2020)	simulated an on-site WSN model to predict and detect earthquakes in the island of Mauritius, and they analyzed how different WSN parameters such as synchronization protocol, sampling frequency and node density at location of the epicenter	The results of the paper showed that the proposed Wireless Sensor Network (WSN) system for monitoring seismic activity using primary waves (P-waves) was efficient in estimating the location of the hypocenter and the local velocity.
Fu *et al.* (2019)	Development and testing of a sensor node for dense Earthquake EW networks, achieving low costs using MEMS sensors and standalone TCP/IP units to handle communications, so that the device can be controlled by a simple and cheap MCU.	The paper presents the results of the field testing of the proposed low-cost seismic sensor integrated with a Class C MEMS accelerometer. The tested dynamic range (over 87 dB) and useful resolution (over 14.5 bits) are completely in conformity with the designed parameters.
Allen *et al.* (2020)	My Shake smartphone earthquake monitoring that has been working as a phone application since 2016. Alerts can be generated by either detecting p-waves embedded in user's smartphones or mining data from regional seismic networks.	The paper describes the development of the MyShake Platform. The MyShake project has shown that earthquakes can be detected, located, and the magnitude estimated in 5 to 7 seconds after the origin time, and alerts can be delivered to smartphones in 1 to 5 seconds.

Our work is different from the previously discussed work in the sense that we combine different characteristics of the available research discussed above and develop a dedicated IoT-based sensor which can sense the natural environmental signals and perform the detection algorithm simultaneously. In addition, our model does not simply rely on natural disaster detection mechanism. Instead, we use both a machine-learning technique and a traditional STA/LTA algorithm to reduce the chance of false alarms. The developed system's cost is very low compared to existing systems.

Methodology

There are various methodologies that can be used in IoT for early warning systems for earthquake disaster that can play a significant role in providing real-time data to predict and alert for disasters. Some of them are:

Risk Assessment

Risk assessment is an essential first step in disaster management and IoT-based early warning systems. Before implementing any IoT solution for early warning systems, it is important to conduct a risk assessment to identify potential hazards, vulnerabilities, and risks, and assessing their likelihood and impact. This process involves identifying critical assets and infrastructure that require monitoring and develop models for predicting disasters (Poljansek *et al.*, 2019).

Predictive Analytics

Predictive analytics can be used in IoT to analyze historical data and real-time sensor data to identify potential disasters. Machine learning algorithms can be used to develop models that predict the likelihood and severity of disasters based on various parameters, such as weather conditions, seismic activity, and environmental factors (Akbar *et al.*, 2017).

Agile Methodology

Agile methodology can be used to develop IoT solutions for early warning systems in an iterative and incremental manner. The focus is on delivering value to users quickly and adapting to changing requirements. The development process is broken down into small sprints, with each sprint delivering a working solution (Pandit *et al.*, 2021).

Real-time Monitoring

Real-time monitoring is critical for early warning systems in IoT. This involves using sensors and other devices to monitor environmental conditions, such as temperature, humidity, and air quality, and alerting users to potential disasters based on thresholds (Chaduvula *et al.*, 2023).

Continuous Improvement

Early warning systems in IoT require continuous improvement based on feedback and data analysis. Continuous improvement involves gathering feedback from users and stakeholders and using that feedback to improve the solution. It also involves analyzing data from sensors and other sources to identify areas for improvement (Damasevicius *et al.*, 2023).

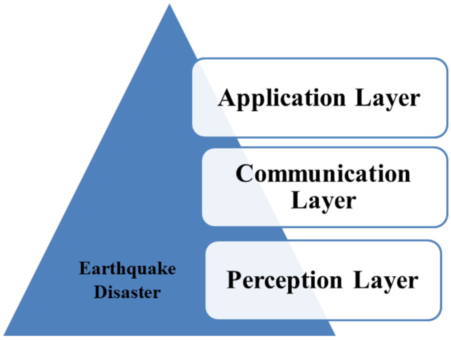


Fig. 1. IoT Architecture for Earthquake Early Warning Model.

IoT Architecture for Earthquake Early Warning Model

We proposed a straightforward IoT architecture that may be used to define IoT-based disaster management. A Perception layer, a communication layer, and an application layer make up the core components of the typical IoT design.

Perception Layer: The perception layer has the task to sense and collect data from the environment, usually through sensors.

Communication Layer: The communication layer transmits the data acquired and processed by the perception layer to a server, cloud service or application. This layer is responsible for routing, communication between heterogeneous networks, and reliable data transmission. There are different communication technologies that can be used to transmit data, both wireless and wired.

Application Layer: The application layer is at the top of the IoT layered architecture. It uses the data received from the communication layer to provide services or operations, possibly combining collected data with historical data, and satellite or weather forecasting data from other sources.

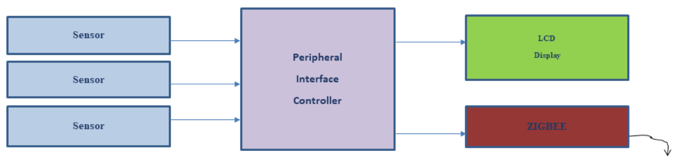


Fig. 2. Block diagram of Transmitter.

Sensors and sensing units can monitor environment vibrations and ground movement to create alarms and to alert people in certain places before the disaster occurs. Even a few seconds or minutes of warning can prove essential in saving lives.

Proposed Earthquake Early Warning Model

The main purpose of this paper is to detect the earthquake disaster and to alert the public earlier. It can be done by sending warning message by means of IoT, the more accurate and smart way for transferring message to the public. Thereby the smart phones are hinted with the alert message by IoT and thus the human are aware.

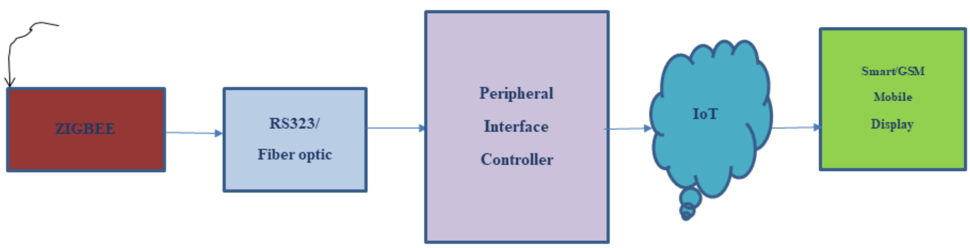


Fig. 3. Block diagram of Receiver.

Results and Discussion

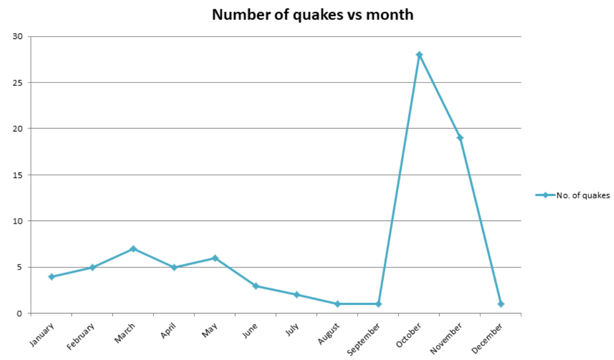
Table 3 lists the earthquake detail with month wise and magnitude, many and earthquakes occurs in October.

Table 3. Earthquake (>=4) detail in Nepal in 2023.

	Months												
Magnitude	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	**Total**
>=6	0	0	0	0	0	0	0	0	0	2	1	0	**3**
>=5	1	1	0	2	0	0	0	0	0	9	1	0	**14**
>=4	3	4	7	3	6	3	2	1	1	17	17	1	**65**
Total	**4**	**5**	**7**	**5**	**6**	**3**	**2**	**1**	**1**	**28**	**19**	**1**	**82**

Figure 4 shows the earthquake occurs month wise using line chart which shows the variation of earthquakes in different months of year 2023.

The result from the experiment is to make "Early Warning Natural Disaster Model". This Model is expected to monitor disaster such as Earthquake, environment sensors vibration and generate alert sign with the help of sensor and send it to the public through smart phone and GSM mobile.



Conclusion

It is feasible to incorporate affordable wireless sensor network components for the purpose of detecting earthquake disasters and notifying the impacted population. The Internet of Things (IoT) facilitates the smooth connecting of diverse devices with varying functionality, hence reducing the risk of human mortality and damage caused by earthquake disasters. This article provides a comprehensive overview of IoT-based earthquake disaster management systems, focusing on their historical significance in research and their potential for future advancements. It aims to enhance awareness of past research contributions and identify areas for further investigation in order to handle the diverse challenges associated with earthquake disaster management systems.

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