Disaste Resilience Through IoT Based Flood Warning Systems

A. Prof. SujataHelonde[1], B. Ajay Rahangdale[2], C. Divyanshu Bhondekar[3], D. Pranay Gedam[4], E. Prajwal Rewatkar[5]

[1,2,3,4,5] *J. D College of Engineering & Management, Nagpur*

***Abstract*—Environmental disasters such as floods, droughts, and extreme weather conditions are becoming increasingly frequent and severe. This research, "Predicting Environmental Disasters Using IoT," presents an innovative real-time monitoring and alert system designed to mitigate disaster impacts. The system utilizes advanced sensors, including ultrasonic, temperature, and water flow detectors, to collect and analyze environmental data. Using ZigBee and GSM communication modules, the collected data is transmitted to a centralized platform for processing and decision-making. The Arduino Uno serves as the core processing unit, programmed in C and C++ within the Arduino IDE, ensuring optimal data management and rapid alert dissemination.**

By continuously analyzing key environmental parameters, the system effectively forecasts potential hazards, issuing timely warnings to minimize damage to life and property. The scalable design of the system allows for the integration of additional sensors, enabling broader monitoring of environmental variables such as air quality, soil moisture, and seismic activities. The GSM module further enhances the system's efficiency by facilitating real-time notifications to relevant stakeholders.

Future upgrades to the system include incorporating renewable energy sources for sustainable operation and utilizing machine learning algorithms to refine prediction accuracy based on historical data trends. This project highlights the transformative role of IoT in enhancing disaster preparedness and contributes to the broader initiative of integrating technology into environmental protection efforts.

***Index Terms*—Internet of Things (IoT), Disaster Prediction, Real-time Monitoring, Arduino Uno, ZigBee, GSM Communication, Early Warning System, Sustainable Development, Machine Learning, Environmental Protection.**

I. INTRODUCTION

Natural disasters such as floods, earthquakes, and wildfires pose significant risks to communities and ecosystems. Conventional disaster prediction and response strategies often suffer from inefficiencies, leading to delayed action and increased damage. The Internet of Things (IoT) offers a cutting-edge solution by enabling real-time data acquisition, processing, and alert generation. This research, "Predicting Environmental Disasters Using IoT," aims to harness IoT technology to predict environmental hazards and issue timely alerts for disaster mitigation.

The proposed system incorporates a network of sensors, including temperature, water flow, and ultrasonic sensors, integrated with ZigBee communication modules for seamless data transmission. The collected data is processed by an Arduino-based platform, analyzed in real-time, and relayed to a central monitoring unit. If the system detects any anomaly indicating potential disaster conditions, a GSM module triggers immediate alerts to relevant authorities and stakeholders, facilitating prompt action.

Unlike traditional methods, IoT-driven disaster management systems offer continuous and precise monitoring of environmental factors, enabling early anomaly detection and accurate disaster forecasting. The adaptability of these systems to various geographical and climatic conditions enhances their effectiveness. This project underscores the potential of IoT in transforming disaster management by fostering proactive risk mitigation and resilience-building strategies.

II. LITERATURE REVIEW

The urgency of addressing environmental disasters has driven extensive research into early warning systems and predictive analytics. Conventional disaster prediction approaches, though effective to an extent, often fail due to their reliance on outdated data, manual collection methods, and slow response times. The emergence of IoT has revolutionized this field by enabling real-time data acquisition, rapid transmission, and advanced analytics.

Gubbi et al. (2013) emphasized the pivotal role of IoT in environmental monitoring, illustrating how interconnected sensor networks enhance real-time decision-making. Zhou and Liu (2020) introduced an IoT-powered hazard prediction system that effectively utilized sensor data and communication protocols to improve disaster forecasting. Similarly, Patel and Patel (2019) investigated IoT-based flood prediction models, demonstrating how real-time analytics significantly improve emergency response efficiency.

Recent advancements have focused on integrating machine learning with IoT to refine disaster prediction accuracy. Sinha and Srivastava (2017) explored the benefits of combining predictive analytics with IoT frameworks, concluding that such integrations enhance system efficiency and reliability. However, challenges remain in areas such as energy optimization, cybersecurity, and large-scale implementation, which require further research and development.

III. PROBLEM STATEMENT

Existing disaster prediction mechanisms have critical shortcomings in terms of accuracy, timeliness, and scalability. Traditional methods rely on static datasets and manual processes, leading to delayed detection of hazardous conditions and ineffective disaster response strategies. While IoT-based solutions have been introduced, they frequently lack comprehensive sensor integration, restricting their capability to monitor multiple environmental parameters simultaneously.

Additionally, many existing systems do not incorporate robust communication frameworks, leading to delayed emergency alerts and response times. High implementation costs and technical complexities further hinder the widespread adoption of these solutions, particularly in rural and disaster-prone areas.

IV. RESEARCH GAP

Absence of Real-Time Monitoring and Forecasting – Traditional disaster management methods often depend on pre-existing datasets, resulting in slow response times. IoT-enabled real-time monitoring can significantly enhance prediction accuracy.

Limited Multi-Sensor Integration – Most existing solutions focus on monitoring a single environmental factor rather than providing a holistic disaster detection approach.

Inefficient Early Warning Mechanisms – The absence of robust, real-time communication networks often delays disaster alerts, necessitating the integration of GSM-based alert systems.

Sustainability Challenges – Many IoT-based disaster monitoring systems rely on conventional power sources, making them vulnerable during extreme weather conditions. Renewable energy integration is a key area requiring attention.

V. PROPOSED SYSTEM

Comprehensive Sensor Network – The system integrates ultrasonic, temperature, and water flow sensors to monitor key environmental parameters, identifying anomalies that could indicate impending disasters.

Processing Unit – An Arduino Uno microcontroller processes real-time sensor data using optimized C and C++ algorithms.

Communication Modules – ZigBee facilitates local data transmission, while GSM modules ensure real-time alert notifications to authorities and disaster response teams.

Scalability and Adaptability – The modular design of the system allows seamless expansion by incorporating additional sensors for diverse environmental monitoring needs.

Automated Alert Mechanism – When predefined safety thresholds are exceeded, the system triggers immediate notifications to relevant personnel, facilitating prompt intervention.

Renewable Energy Utilization – The system incorporates solar-powered energy solutions, ensuring uninterrupted functionality even during disaster-induced power failures.

Data Logging and Pattern Analysis – Historical data is logged for future trend analysis, improving prediction models over time.

User-Friendly Interface – A real-time monitoring dashboard provides stakeholders with an intuitive and accessible interface to track environmental conditions.

Cost-Effective Implementation – The system is designed using affordable, easily available components to ensure feasibility and scalability, particularly in disaster-prone regions.

VI. METHODOLOGY

Flood monitoring and alert system using WSN is designed and built for monitoring, predicting and alerting of the flood disaster in the Perak Tengah Region. The system can be divided into three parts (refer Figure 3.2):

- Sensor node 1

Part 1 consists of the transceiver, microcontroller, water flow sensor and water level sensor. These two sensors will be installed at the riverside to measure the parameter.

- Sensor node 2

Part 2 consists of a transceiver, a microcontroller, and temperature sensor. The receiver will retrieve the information transferred by the transceiver in sensor node 1. Temperature sensor will record the values and the microcontroller will compare the values with the threshold value. All of the data will be transferred to sensor node 3.

- Sensor node 3

microcontroller, a phone and the Personal Computer to monitor the data. The staff can monitor all the parameters via the computer. The phone will receive the alert signal if the measured value exceeds the threshold value.

All nodes will be installed at the Perak River area as presented in Figure 3.3.

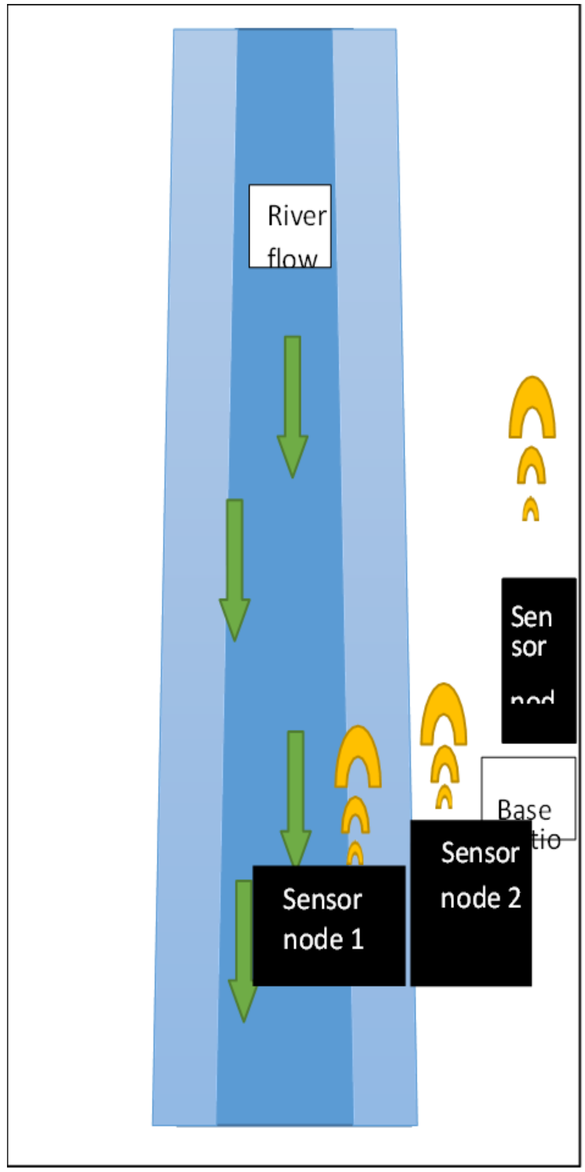


Figure 3.3 Sensor node installation location in Perak River

A. Materials and Apparatus

The apparatus for flood monitoring and alert system using wireless system are selected by some factors which are low in cost, able to measure various flood parameters such as the water level, water velocity and temperature in real time.

B. Microcontroller

A microcontroller is a compound of microchip which are able to do read – write, store information by having the memory and can take input to synthesize or produce output and all of these parts are in one board which is the Arduino as shown in Figure 3.4. It can even drive motor or read information through the sensor, but the specification of the item must meet the basic need of an Arduino [33].

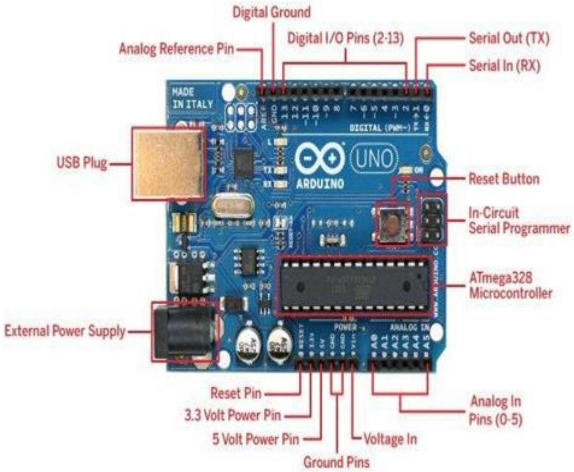


Figure 3.4 Arduino Uno

C. Sensors

Sensors are crucial in measuring the flood parameter. In this paper, the parameters are the water level, temperature level and velocity or water flows. The sensor used are Ultrasonic sensor, temperature sensor and water flow sensor.

Figure 3.5 Ultrasonic sensor

For this project, the sensor used to measure water level is Ultrasonic sensor as shown in Figure 3.5. This sensor measures the distance from the sensor to the object. It works like a simple communication and have both transmitter and receiver. The working principle of ultrasonic sensor starts with the transmitter emitting an ultrasound with the frequency of 40 kHz with the timer simultaneously on. When emitted ultrasound bounces back to the receiver the timer will stop. The distance can be calculated using:

$$Distance = time\ x\ velocity$$

D. Wireless data transfer

Data need to be transferred quickly and wirelessly. In this project the wireless system used are ZigBee module and GSM module.

Figure 3.8 GSM module

The aim of this project is to alert the community toward the upcoming flood disaster. SIM900 is the selected mechanism that will be used in this project. The system will alert the end user in real time. The GSM module as in Figure 3.8 will send an alert via SMS when the measured values of parameters exceed the threshold values set.

Figure 3.9 ZigBee modul

The system uses ZigBee module as in Figure 3.9 is the medium to transfer the data from one node to another.

These modules use simple communication between the microcontroller, computer. The system can be set up whether to use it point to point or multi point networks. The power consumption for this module is around 0.15 Watt and the transfer rate is 250 kbps from a node to another node. The maximum range between two modules is 120 m and if the range is more than 120 m it will have disruption or no data is transmitted.

E. Alert system

The system will alert the subjected person via SMS received through the phone and the real time data is displayed on the computer at the base station. Table 3.1 summing the equipment used.

Equipment	Function
Ultrasonic sensor	To measure water level
Temperature sensor	To measure the temperature
Water flow sensor	To measure the water flows
Arduino UNO	As microcontroller to set the condition
ZigBee module	Transfer data via wireless network
GSM module	Alert by sending SMS
Computer	Base station and display data
Phone	To receive alert sent from GSM module

Table 3.1 Equipment and their functionalit

Program flowchart as shown in Figure 3.10 is the overall flow of how the flood monitoring and alert system works using the architecture shown previously in Figure 8. The program starts with the activation of all nodes. All of the sensors will measure the parameters which are water velocity, water level and temperature. The data in sensor nodes 1 and 2 will be transferred to sensor node 3. The data is then analyzed and the values will be compared with the flood parameter threshold value. All of the values will be displayed on the computer at the base station. If the value of measured parameters exceeds the threshold value, module will trigger and send an alert to the phone. If the value does not exceed the threshold value, the sensor will start measuring the new data.

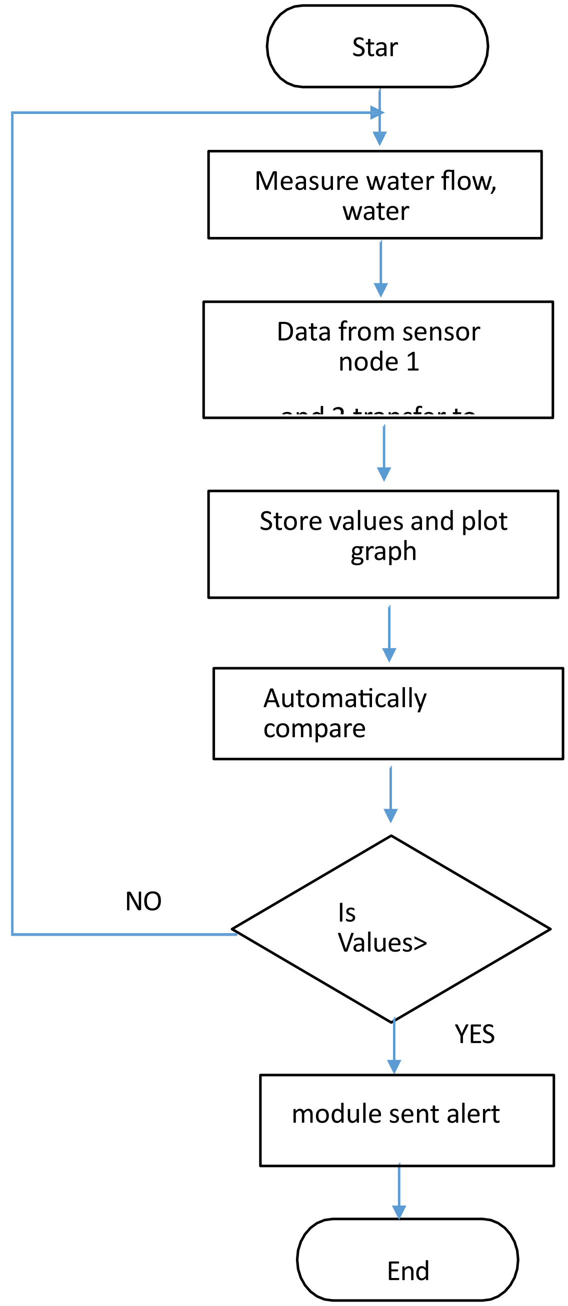


Figure 3.10 Program flowchart

VII. RESULT AND DISCUSSION

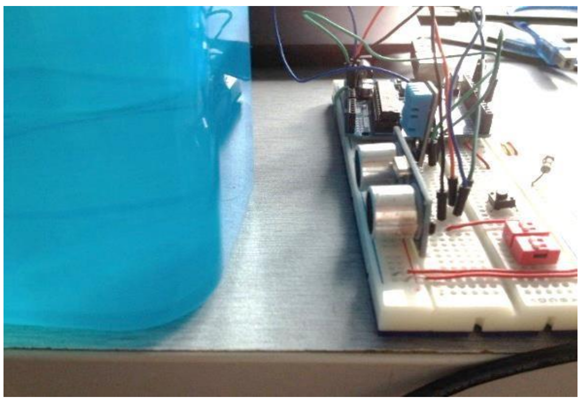
This chapter provides the results of the experiments. Three experiments were conducted. First experiment was done in indoor environment. Second experiment studies the system implementation in outdoor to observe the behavior of these sensors. The purpose of third experiment is to integrate all the sensors and proflood monitoring system using wired connection.

Indoor Sensors testing

In indoor experiment three experiment were done which are Ultrasonic sensor, Temperature sensor and Water flow sensor to test the functionality and accuracy of the sensors.

A. Water level via Ultrasonic Sensor

The purpose of the experiment is to check correction of the coding and test the operation of the sensor. Figure 4.1 shows the sensor is used to detect an object. The code operates well with the hardware and the output result is displayed on the serial monitor on the Arduino software as in Figure 4.2.

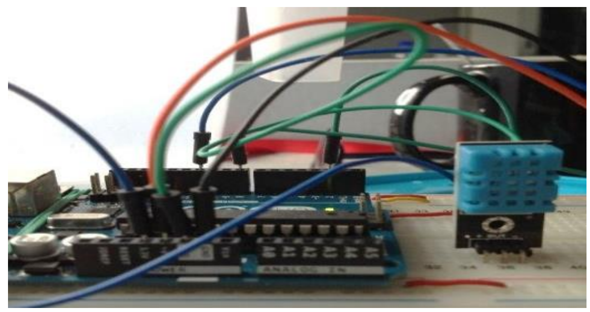


The Ultrasonic Sensor is then tested onto the surface of the water as shown in Figure 4.3. The experiment is done to show whether the sensor can be used to sense water level or not. The serial monitor can display the distance between the sensor to the water surface, proving that the Ultrasonic Sensor can be used to monitor the water level.

Figure 4.3 Ultrasonic sensor with water surface

The test is continued with different levels of water as in Figure 4.4. The same container is added with water to check the sensitivity of the Ultrasonic sensor with the water surface.

Figure 4.4 Different levels of water testing



B. sensor testing Result

The temperature data from the sensor were compared with the online source generated by google as shown in Figure 4.7 [23]. The experiment was conducted four times and the data is recorded in the Table 4.3.

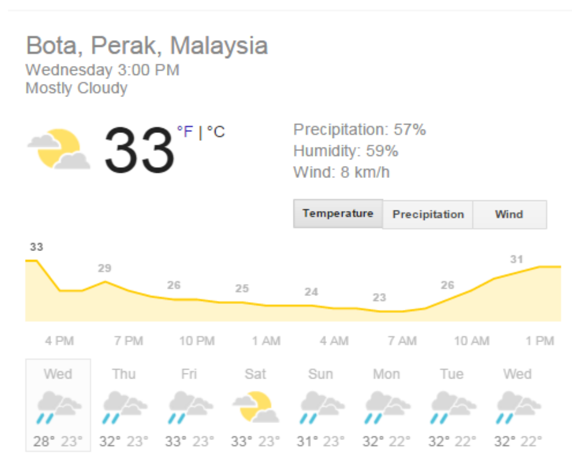


Figure 4.7 Weather forecast by google

C. Water Flow sensor

Some additional part needs to be modified at the original Water Flow sensor to make sure the wire does not immerse in the water. Somematerial (polystyrene) is stacked to the Water Flow sensor to make sure only the turbine part of the sensor is immersed in the water as in Figure 4.10. The modified sensor is tested on the water surface and the data are recorded.The data can be seen on the Serial monitor on the Arduino program on the computer. The outcome of the experiment shows that the system is able to deliver the data without damaging the sensor itself and the environment.

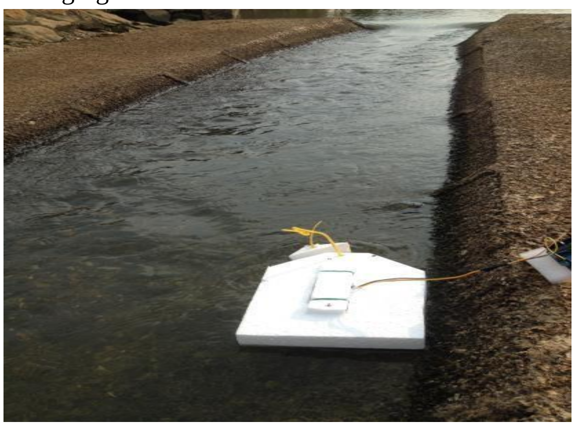
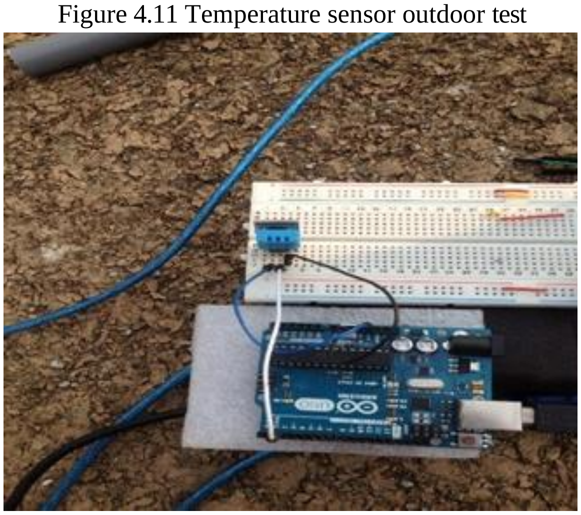


Figure 4.10 Water flow sensor outdoor test

D. Temperature sensor

The Temperature sensor can be used easily anywhere without any major modification to the sensor as long as the connection is correct and equipped with power supply as shown in Figure 4.11. Some protection is needed to protect the sensor from the water droplet because it may disrupt the sensor from sensing the temperature parameter.

Figure 4.11 Temperature sensor outdoor test



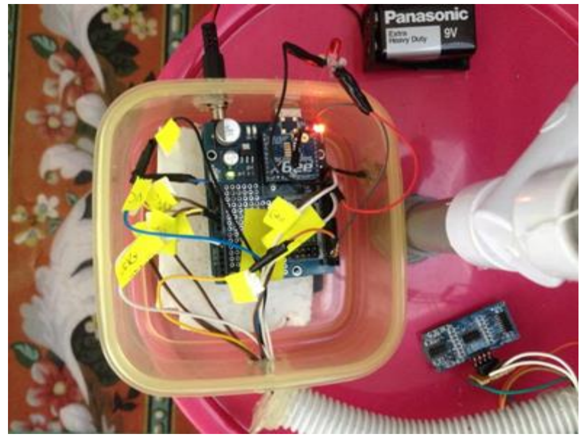


Figure 4.20 Router

E. Ultrasonic sensor

Ultrasonic sensor must be used on a dry place. It is because whenever the sensor made contact with the water or liquid in it will be malfunction. Thus, modification needs to be done to the sensor as shown in the Figure 4.12. A certain distance is kept between the sensor and the water surface and the transducer must be faced directly perpendicular towards the water surface. When flood happens, the water level can rise to 3 meters from the normal level of water. Thus, the sensor and the water surface must be more that that range for the system to operate well.

Figure 4.12 Ultrasonic sensor outdoor test

The outdoor experiment has been done for 4 days and the data are tabulated in Table 9. The experiment was conducted for 3 hours each day with the delay of 15 minutes between the recorded data. The data shown in the Table 4.4 is the mean for each day. The data then displayed in graph as shown in Figure 4.13.

Figure 4.14 Subsystem integration (wired)

Figure 4.15 Ultrasonic sensor (wired)

Subsystem Integration (Wireless)

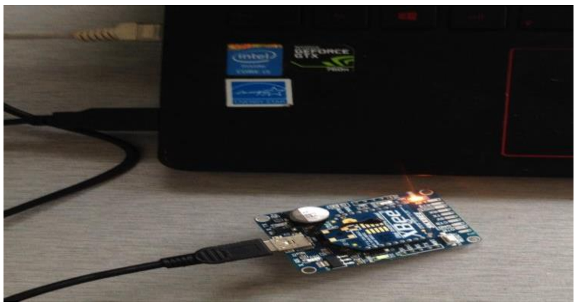


Figure 4.21 Coordinator

VIII. CONCLUSION & RECOMMENDATION

This study presents an advanced IoT-based framework for real-time environmental disaster prediction and monitoring. By integrating sophisticated sensors, efficient communication technologies, and renewable energy solutions, the system ensures high-precision disaster forecasting and rapid emergency response capabilities. Its modular, cost-effective design makes it an ideal solution for large-scale implementation in disaster-prone areas. Future research should focus on integrating artificial intelligence and machine learning to enhance predictive accuracy, as well as expanding the system's environmental monitoring capabilities. This project highlights the immense potential of IoT in modern disaster management, contributing to global efforts aimed at creating resilient and sustainable communities. solution for disaster-prone regions. It highlights the importance of leveraging technology to build resilient communities, reduce vulnerabilities, and save lives. While the current system lays a strong foundation, future enhancements, such as incorporating machine learning for predictive analytics and expanding the range of monitored parameters, can further optimize its performance. The project serves as a testament to the transformative potential of IoT in addressing global challenges and fostering a safer, more sustainable future for all.

REFERENCES

[1] G. Merkuryeva, Y. Merkuryev, B. V. Sokolov, S. Potryasaev, V. A. Zelentsov, and A. Lektauers, "Advanced River flood monitoring, modelling and forecasting," Journal of Computational Science, 2014.

[2] C.-Y. Lee and G.-B. Lee, "MEMS-based humidity sensors with integrated temperature sensors for signal drift compensation," in Sensors, 2003. Proceedings of IEEE, 2003, pp. 384-388.

[3] I. A. Aziz, I. A. Hamizan, N. S. Haron, and M. Mehat, "Cooperative flood detection using GSMD via SMS," in Information Technology, 2008. ITSim 2008. International Symposium on, 2008, pp. 1-7.

[4] I. Mohamed Shaluf and F. l.-R. Ahmadun, "Disaster types in Malaysia: an overview," Disaster Prevention and Management: An International Journal, vol. 15, pp. 286-298, 2006.

[5] L. Billa, S. Mansor, and A. Rodzi Mahmud, "Spatial information technology in flood early warning systems: an overview of theory, application and latest developments in Malaysia," Disaster Prevention and Management: An International Journal, vol. 13, pp. 356-363, 2004.

[6] M. R. A. Halim, "Flood Monitoring and Warning System," Universiti Teknologi PETRONASMay 2015.

[7] S.-M. Yu, P. Feng, and N.-J. Wu, "Passive and Semi-Passive Wireless Temperature and Humidity Sensors Based on EPC Generation-2 UHF Protocol," Sensors Journal, IEEE, vol. 15, pp. 2403-2411, 2015.

[8] C. C. Wing, "Managing flood problems in Malaysia," Buletin Ingeniur, 1971.

[9] A. Shafie, "A Case Study on Floods of 2006 and 2007 in Johor, Malaysia," Colorado State University, 2009.

[10] H. Varikoden, B. Preethi, A. Samah, and C. Babu, "Seasonal variation of rainfall characteristics in different intensity classes over Peninsular Malaysia," Journal of Hydrology, vol. 404, pp. 99-108, 2011.

[11] V. Sooryanarayana, "Floods in Malaysia," in Working Group on Tropical Climatology and Human Settlements of the 26th Congress of the

International Geographical Union. Sydney, Australia. August, 1988.

[12] M. Castillo-Effer, D. H. Quintela, W. Moreno, R. Jordan, and W. Westhoff, "Wireless sensor networks for flash-flood alerting," in Devices, Circuits and Systems, 2004. Proceedings of the Fifth IEEE International Caracas Conference on, 2004, pp. 142-146.

[13] N. W. Chan, "A contextual analysis of flood hazard management in peninsular Malaysia," Middlesex University, 1995.

[14] R. Seiler, M. Hayes, and L. Bressan, "Using the standardized precipitation index for flood risk monitoring," International journal of climatology, vol. 22, pp. 1365-1376, 2002.

[15] V. Vunabandi, R. Matsunaga, S. Markon, and N. Willy, "Flood Sensing Framework by Arduino and Wireless Sensor Network in Rural-Rwanda," in Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD), 2015 16th IEEE/ACIS International Conference on, 2015, pp. 1-6.