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A DECENTRALIZED INTERNET OF THINGS (IOT) SENSOR NETWORK WITH AN ESP CONTROLLER FOR INTELLIGENT MONITORING OF NATURAL DISASTERS AND RISK ANALYSIS

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Abstract - Many lives, buildings, crops, and public safety are at risk during earthquakes, floods, and other severe weather occurrences. Unfortunately, continuous monitoring in distant and catastrophe-prone locations is frequently not possible with conventional catastrophe monitoring systems due to their centralization, high costs, and restricted geographic coverage. A Distributed Internet with Things (IoT) sensor infrastructure for smart emergency monitoring & risk analysis utilizing an ESP-based controller is presented in this research to overcome these shortcomings. Diverse sensor nodes placed in strategic areas throughout the world would gather data on vibrations and the surrounding environment in real time under the proposed system. The gyroscopes, temperature sensors, and precipitation analyzers that come standard on every node allow for the detection of unusual ground vibrations, environmental monitoring, and tracking of precipitation. A central Internet of Things (IoT) server is used for monitoring, analysis, & risk assessment after the ESP controller processes the acquired sensor data locally. The technology detects out-of-the-ordinary occurrences and sends out warnings to users in the event of possible catastrophes based on established thresholds and trends in sensor data. To help with decision-making and being ready, the system also shows environmental conditions & risk levels graphically via a web-based dashboard. Scalability, affordability, and applicability to either remote or high-risk regions, thereby supporting early warning, distributed monitoring, and improved disaster management.

Keywords - Disaster monitoring, the Internet of Things, early warning systems, risk analysis, distributed sensor networks, earthquake detection, and rain monitoring are all part of the DSN.

I. INTRODUCTION

Among the most grave dangers to human civilization and ecological harmony are natural catastrophes. Earthquakes, landslides, cyclones, cloudbursts, and other severe weather events may interrupt vital services, kill countless people, ruin crops, and devastate infrastructure on a massive scale. The effect of disasters may be reduced and preparation can be enhanced by the early detection of unusual environmental circumstances. The increasing frequency of severe weather occurrences, together with the effects of climate change and urbanization, have led to a rise in the need for sophisticated catastrophe monitoring systems in recent years.

Conventional catastrophe monitoring systems typically include a network of specialized sensors, government-run monitoring centers, and centralized observation stations. The deployment and maintenance costs of these systems are high, notwithstanding their use for large-scale observation. Rural, hilly, wooded, maritime, and geographically scattered disaster-prone areas are also less served by centralized systems because of the limited monitoring sites they typically provide. A lot of older systems can't provide local communities real-time warnings since they rely on delayed data collecting and offline processing.

Thanks to the proliferation of wireless connectivity, inexpensive embedded sensors, and cloud-based data platforms, distributed monitoring of the environment systems are now within reach, all thanks to the Internet of Things (IoT). Internet of Things (IoT) catastrophe monitoring systems allow for the simultaneous deployment of several sensor nodes in various geographic areas to keep tabs on the surrounding environment and relay that data to an analytic hub. Improved geographical coverage, monitoring in real time, remote access, and rapid alarm creation are all benefits of such systems. When environmental sensors, rainfall sensors, and vibration sensors are all part of a decentralized system, it becomes feasible to spot irregularities that might signal impending calamity.

Internet of Things (IoT) smart irrigation system design for automated water control comprises the bulk of the published works. Using Internet of Things (IoT) sensors to track field conditions and activate irrigation in response to crop needs, Istiyono et al. developed an intelligent agricultural monitoring & automated irrigation system [1]. By creating a smart irrigation surveillance system for agricultural settings that relies on Wi-Fi, Patankar et al. [2] shown how important wireless connection is for allowing remote access and real-time monitoring. A smart irrigation module was presented by Nawandar and Satpute [4] that prioritizes affordability while yet offering automated irrigation assistance via choices guided by sensors. Similarly, Veerachamy and colleagues et al. demonstrated how smart agriculture may use IoT to automate irrigation, showing how field conditions can be monitored constantly to regulate irrigation more effectively [9]. An irrigation system that integrates inexpensive hardware with Internet of Things connectivity for agricultural purposes was also covered by Srivastava et al. [10]. The system is built on ESP8266 Wi-Fi modules. Based on the findings of these research, irrigation systems that are connected to the internet are starting to be a viable option for farmers looking to cut down on water waste, increase precision, and decrease the amount of work required to irrigate their crops [1, 2, 4, 9, 10].

In the realm of field monitoring or crop-environment observation, there is an important current of study involving the use of IoT systems for both irrigation management and the collection of data pertaining to soil moisture, humidity, temperature, or crop conditions. The Internet of Things (IoT) was suggested by Karanam as a means to track environmental variables and aid in the improvement of agriculture management choices [11]. An agricultural domain field monitoring and automated framework was created by Mohanraj et al. [13]. This framework integrates sensing and actuation to enhance the creativity and productivity of farm operations. Along with their presentation of an Internet of Things (IoT)-based irrigation automation system, Rajalakshmi and Mahalakshmi demonstrated how to integrate continuous monitoring with automatic watering to keep crop conditions favorable [14]. In contemporary smart agricultural systems, these studies show that integrated monitoring platforms are more common, with irrigation being only one part of a larger real-time field management approach [11], [13], [14].

The idea of smart agriculture has been developed in many research to include cloud computing, wireless networking, and larger Internet of Things (IoT) ecosystems. Interconnected sensing technology, communication networks, or digital platforms may turn conventional farms towards data-driven agricultural settings, as described in detail by Ayaz et al. [5] in their article on Internet of Things (IoT) based smart agriculture. Scalability, interdependence, power efficiency, & the practical installation of sensor networks in farms were key difficulties highlighted in Tzounis et al.'s analysis of current advancements and future obstacles in agricultural IoT [12]. Importance of these contributions lies in their contextualization of irrigation automation within smart agriculture, a field that combines sensing, communication, storage, and analysis to facilitate precision farming. Additionally, they emphasize the need of dependable, scalable, and ecologically diversified agricultural IoT systems that can function in rural network environments [5, 12].

Modern irrigation designs have been studied, including both stationary sensor nodes and those that rely on aerial monitoring and analytics hosted on the cloud. By combining an Internet of Things (IoT) cloud infrastructure with unmanned aerial vehicles (UAVs), Karar et al. performed a pilot research on smart irrigation in agriculture [3]. By collecting spatial crop data and enhancing irrigation planning across larger agricultural regions, their research implies that airborne monitoring may supplement ground-level sensing. When it comes to precision farming, these kinds of research are crucial since a limited number or fixed sensors can't always capture field variability. More and more, agricultural monitoring systems are becoming multi-layer, with the ability to integrate ground data, aerial views, and remote decision support, all via the use of UAVs or cloud-connected platforms [3].

Agricultural monitoring or irrigation management using machine learning and cognitive data analysis has also been a significant area of study in the last several years. An Internet of Things (IoT) smart irrigation administration system was created by Goap et al. [6]. This system uses open-source technology and machine learning to help with irrigation choices. With the ability to intelligently monitor environmental trends, these systems can optimize water distribution rather of depending just on predefined threshold levels. Agricultural activities including crop monitoring, crop

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forecasting, water scheduling, and disease diagnosis are being handled more and more by learning-based systems, according to a review by Liakos et al. [7]. An analysis of deep learning's function in farming by Kamilaris and Prenafeta-Boldú showed that sophisticated data-driven methods are playing an increasingly important role in precision farming [8]. Research shows that farming is moving away from rule-based automation and toward adaptive and predictive systems that can learn from field data and help with better decisions [6]-[8].

Smart agriculture also acknowledges the significance of analysis of data and precision farming informed by meteorological conditions. Using weather predictions as a case study, Bendre et al. investigated the use of big data for precision agriculture [15]. Their findings emphasize the importance of weather patterns, rainfall likelihood, and environmental variability in determining irrigation & crop management options. Improving irrigation planning and reducing wasteful water consumption may be achieved by integrating IoT sensors with analysis of data and predicting weather information. Where water shortage and climatic unpredictability have a direct impact on agricultural production, this viewpoint becomes even more pertinent [15].

II. RECOMMENDED MODEL

A. Block Diagram

Using a distributed Internet of Things (IoT) sensor network, the suggested system can monitor and analyze risks associated with natural disasters in real-time. Several dispersed sensor nodes based on ESP are linked to a single centralized Wifi monitoring platform in the design. Environmental or vibration-related data is collected and sent by each sensor node from its immediate vicinity for analysis and alarm production.

Every node has its own sensor unit that comprises a gyroscope, temperature sensor, and precipitation sensor. Unusual vibrations or abrupt changes in motion may be detected by the gyro sensor, which might indicate structural instability or seismic disturbances. There are a number of potential applications for the temperature sensor, including the identification of climate-based anomalies and the monitoring of weather-related disasters. Heavy rains that might cause floods or storm-related danger can be detected by the rain sensor, which detects the amount of precipitation.

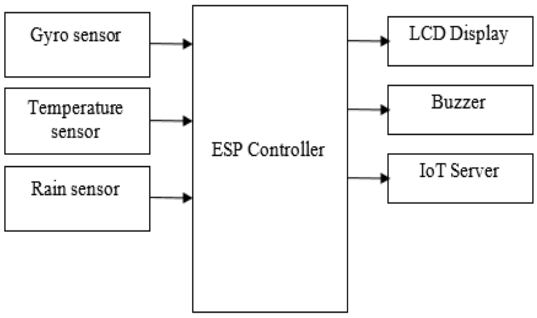

Fig. 1. Layout of the system for monitoring and analyzing risks associated with natural disasters

A local processing & communication device, the ESP controller is linked to all sensor outputs. The ESP controller is always reading data from the sensors, comparing it to certain thresholds, and then decides whether the current state is safe or dangerous. In order to monitor the sensor values while network status locally, a 16×2 LCD screen is linked, and a noise generator is used to immediately provide an auditory alarm in the event that aberrant readings are discovered. An Internet of Things (IoT) server receives the processed data over Wi-Fi and uses it to aggregate, display, and analyze readings from various nodes in order to do risk assessments.

The following is the function flow of a block diagram. The sensors report back to the Esc controller in real time any changes in vibration or ambient conditions. After collecting data from the sensors, the controller checks the results against predetermined limits. In addition to being sent to the IoT platform, the measured data is shown locally on the LCD. The system notifies the online platform and triggers the buzzer in the event that rainfall level, temp value, and vibration pattern suggests a potentially dangerous condition. This allows for remote notice and risk analysis.

Therefore, the suggested block diagram depicts a distributed sensor architecture for intelligent catastrophe management that integrates wireless connectivity, centralized monitoring, early warning capabilities, and local processing.

B. First Version of Hardware

Figure 2 shows the hardware prototypes of the proposed catastrophe monitoring system. It includes an Internet of Things (IoT) communication interface, a local display, an alarm clock, and several environmental sensors that are combined with an ESP-based controller. Building a distributed

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catastrophe sensing node as a small, inexpensive embedded monitoring device for use in the field in real time is shown by the prototype.

The ESP controller is the brains of the operation, collecting data from sensors, analyzing it locally, controlling alerts, and communicating wirelessly. A temperature sensor measures the ambient temperature, a gyro sensor detects anomalous vibrations, and a rain sensor measures the amount of rainfall or the presence of water; all of these sensors are interfaced with the ESP controller. When it comes to tracking environmental changes caused by things like earthquakes, weather, and floods, these sensors are the mainstays.

It is possible to utilize the gyro sensor to detect mechanical disturbances, earth tremors, or structural instability by watching for abrupt movements, angular shifts, or odd vibrations. When severe weather strikes, the temperature sensor keeps tabs on the air and helps trace any resulting environmental changes. We can utilize the data collected by the rain sensor to better prepare for floods and analyze disasters depending on the frequency and severity of rainfall.

With the help of a 16×2 LCD screen that is linked to the ESP controller, local information on node functioning, Wi-Fi connection condition, and live sensor data may be seen. This paves the way for monitoring at ground level independent of the online dashboard. The detected data may be quickly alerted via a buzzer if they rise over the predetermined safety limits. In the event that the weather becomes unusually wet, hot, or vibratory, the buzzer will go off to notify anybody in the area, whether they are users or field personnel.

One way the ESP controller links the hardware nodes to the main IoT server is via its integrated Wi-Fi functionality. Each node transmits its sensor data in real time to an online platform via this link, allowing for the simultaneous monitoring of several nodes. Environmental data, alert status, or risk trends may be shown on the IoT dashboard for various monitoring sites.

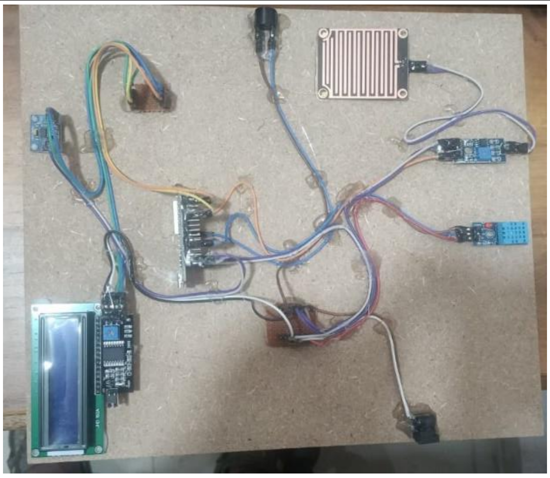

Fig.2. Analytical and monitoring hardware for potential natural disasters

By employing inexpensive components, the hardware prototype proves that a distributed catastrophe monitoring node can be built. Due to the system's small design and modular architecture, a bigger disaster-monitoring sensor network may be formed by deploying several similar nodes in various places. Because of this, the planned structure is appropriate for ecologically sensitive places, such as mountainous regions, the banks of rivers, coastal zones, forests, industrial safety zones, or rural villages.

III. Dynamic Graph

Sensing, decision-making, alert-generation, and web-based reporting are all shown in the flow diagram of the proposed distributed IoT catastrophe monitoring system. First things first: connect the system to Wi-Fi and turn on the ESP controller. The controller will initialize the gyro, rain, temperature, LCD, and buzzer modules when the network link is successful.

The controller will continually gather sensor data from all linked sensing devices after startup. The data that have been measured are shown on the LCD and sent to the the website server at the same time, allowing for remote monitoring in real-time. Afterwards, the data detected is compared to predetermined thresholds by the controller.

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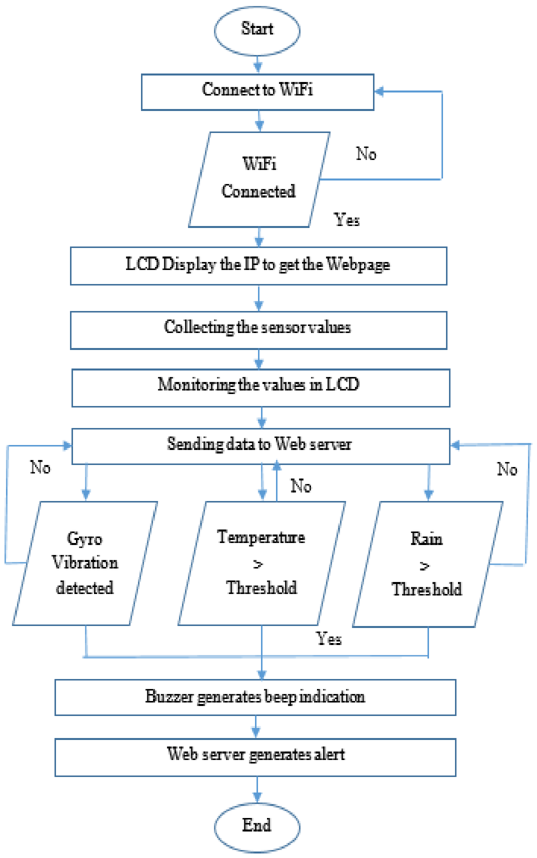

Fig. 3. Schematic for a system that monitors and analyzes risks associated with natural disasters

Before doing anything further, the system makes sure the rain sensor reading is higher than the predetermined limit. The system will consider heavy weather or flood warnings if it detects unusual rainfall or excessive water presence. The controller will next see whether the value of temperature is higher than the threshold; this may be an indication of unusually high or low temperatures, or other environmental issues. Simultaneously, the system keeps an eye on the gyro sensor for any structural problems or ground tremors that might cause vibrations or abrupt changes in motion.

The controller will trigger the buzzer and notify the web server if one or more of these settings go over the set limits or show suspicious activity. In order to show the current danger level or alert status, the IoT platform refreshes the monitoring dashboard. If nothing out of the ordinary happens, the system will keep uploading data to the server and monitoring in real time.

This process guarantees that in a distributed Internet of Things disaster-monitoring system, there is constant monitoring, quick event detection, remote reporting, and instant alert production.

IV. INDUSTRY-RANDOM FINDINGS

The prototype of the distributed IoT network of sensors that was suggested for monitoring natural disasters was put into action to test its capabilities in sensing changes in the environment, detecting abnormalities, and generating early alerts. A gyroscope, thermometer, rain gauge, LCD screen, and buzzer were all components of the hardware node, which was driven by an ESP controller. Through Wi-Fi, the prototype was linked to an Internet of Things server, allowing for remote monitoring along with data display.

Fig.4show the title on the LCD

While the experiment was running, the system was constantly reading the sensors and showing them on the LCD screen. Simultaneously, the data was sent to the online portal, allowing for remote observation of environmental factors and node status. The rain sensor, logic for temperature thresholds, and vibratory event detection were all tested under various simulated climatic circumstances to ensure they were functioning properly.

Fig.5. LCD display of sensor values

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The gyro sensor did not detect any unusual vibrations when the system was operating under typical environmental circumstances, and the readings from the rain and temperature sensors were also below the threshold. Here, the buzzer stayed off, and the system was shown as running normally on the online platform. Pictured in Figure 5 is the LCD's continual display of real-time sensor readings and connection status.

Fig.6. show on liquid crystal display

In order to test the warning mechanism, we inflated the temperature, introduced rain or water at the rain sensor, and induced vibrations at the sensor's gyro input. The ESP controller detected the threshold breach and set off the buzzer under these circumstances. All at once, the information was sent to the web host, which then refreshed the dashboard and showed a warning message, as seen in figure 7. This proved that the framework could notify users locally and remotely of any unusual occurrences in their surroundings.

Fig.7. Automated web-based dashboard for monitoring and analyzing risks associated with natural disasters

The suggested system is ideal for concurrent monitoring of several locations due to its distributed architecture. It is possible to install several sensor nodes in various places and then combine their readings at a single online platform. The ability to analyze environmental conditions across several locations and more accurately identify areas at danger is a boon to users or disaster control teams.

The following capabilities were effectively shown by the prototype that was created:

- • constant, real-time tracking of temperature, vibration, and rainfall,
- • LCD-based localization of environmental values,
- • Data visualization from sensors accessible remotely via the web,
- • detecting aberrant events based on thresholds,
- • early warning generating based on buzzers,
- • being suitable for dispersed deployment across several monitoring sites.

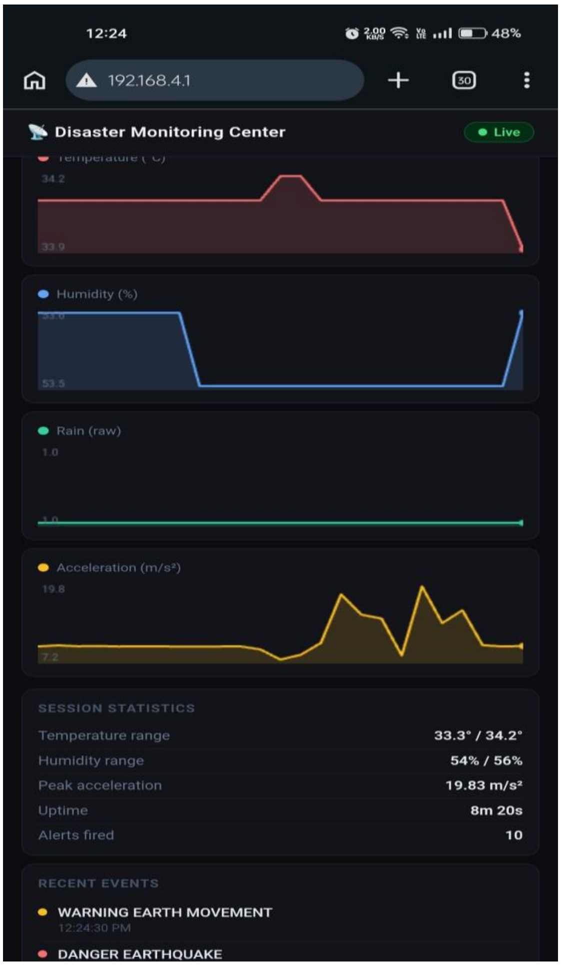

Fig.8. A online dashboard displaying a graph of all sensors

By seeing the system's experimental behavior, we may conclude that inexpensive IoT gear is capable of monitoring the environment and providing early warning in the event of a crisis. While this system is designed to be a realistic embedded monitoring solution and is based on thresholds, it lays a solid groundwork for more complex platforms that analyze catastrophe risk with several nodes.

V. Final Thoughts and Prospects

Smart monitoring & risk analysis of natural disasters utilizing a distributed internet of things sensor network controlled by an event-sensing PLC was described in this article. The suggested system was created to observe environmental and vibration-related metrics in real-time and to alert people to unusual situations that may be caused by natural catastrophes. The system makes use of dispersed ESP-based sensing nodes that are equipped with gyroscopes, thermometers, and rain sensors in order to track various environmental factors from various places. Online data visualization, analysis, and alert production are enabled by means of local processing and transmission to an IoT server.

Traditional centralized catastrophe monitoring systems have a number of drawbacks that the suggested paradigm seeks to address. Suitable for installation in areas prone to disasters or in distant areas, it is also scalable and comes at a reasonable cost. For better accessibility at field level, we included a small LCD screen and buzzer alarm; on the other hand, the Internet of Things dashboard allows for centralized monitoring remotely of numerous nodes. This experimental prototype showed real-time tracking, danger detection based on thresholds, local warning creation, and reporting over the web. Consequently, the system provides a workable answer to the problems of emergency readiness, environmental monitoring, and the capacity for rapid action.

Multiple avenues exist for expanding the reach of this work in the future. Integrating additional sensors like gas detectors, water level sensors, the barometric pressure sensors, moisture in the soil sensors, or GPS modules allows for more thorough catastrophe monitoring. Machine learning models and analytics stored in the cloud may improve the system's capacity to foresee when a catastrophe may occur. Users and authorities may get timely notifications via the integration of mobile applications. In large-scale deployments, a regional catastrophe intelligence network may be formed by spatially mapping several scattered nodes. This network can enhance public safety infrastructure and bolster the resilience of smart cities.

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