Flash Flood Monitoring and Forecasting System

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***Abstract*: Traditional flood forecasting methods often fail to predict these events due to their rapid onset and localized nature. To address this challenge, the development of an advanced Flash Flood Monitoring and Forecasting System is essential. A cost-effective, low-powered flood monitoring and forecasting system based on IoT is considered. Here, the system consists of a water level sensor (HC-SR04), rainfall sensor, soil moisture sensor, water flow sensor, and temperature and humidity sensor (DHT 11). A solar power source is used as the main power source for the functioning of sensors. The power bank is used as the secondary power source in this setup. By integrating ESP-NOW with the Blynk app, real-time flood monitoring data from remote sensors can be wirelessly transmitted and displayed on a user-friendly mobile dashboard. The setup ensures low-power communication for sensors while providing instant updates and alerts through the app.**

***Keywords*: ESP8266, Hydrological data, Meterological data, Sensors, Wireless sensor network.**

1. Introduction

Flash floods are sudden and rapid floods that occur due to heavy rainfall, often overwhelming drainage systems and causing significant disruption, particularly on roads. These floods pose a severe threat to public safety, cause major traffic disruptions, and create discomfort for passengers traveling on affected roads. In many urban and rural areas, roads can become impassable, leading to delays, accidents, and potential harm to individuals. To mitigate the impact of flash floods and provide real-time monitoring of flood-prone areas, our project integrates various environmental sensors, including ultrasonic sensors, rainfall sensors, soil moisture sensors, flow sensors, and temperature and humidity sensors. The ultrasonic sensors measure water levels on roads, while the rainfall sensors detect the amount of precipitation in the area. Soil moisture sensors help determine the saturation level of the ground, which is crucial in predicting potential flooding. Flow sensors measure the movement of water in drainage systems, and temperature and humidity sensors provide additional data to understand weather conditions that contribute to flooding. By collecting and analyzing data from these sensors, our system can predict flash floods, provide early warnings, and help authorities manage flood risks. This integrated sensor-based approach aims to improve public safety, minimize inconvenience, and enable timely interventions to prevent accidents and disruptions caused by flash floods on roads.

2. Hardware Setup

A. System Requirements

The system has the development and implementation of a wireless sensor network utilizing ESP-NOW communication protocol, integrating key components such as the DHT11 temperature and humidity sensor, the HC-SR04 ultrasonic distance sensor, soil moisture sensor, rain fall sensor and flow sensor.The environmental parameters like temperature and humidity is measured using the DHT11 sensor, while the HC-SR04 ultrasonic sensor is employed for accurate distance measurement. Ground saturation is measured by the soil moisture sensor, which signals the possible flooding hazards when the soil is too saturated. By measuring the amount of precipitation, the rainfall sensor can indicate periods of intense rain that could cause floods. Water movement speed and volume can be tracked with the use of a flow sensor, which detects water flow rates in pipes or open channels. The sensors interface with the ESP-NOW protocol. ESP-NOW enables low-latency wireless communication between ESP8266 modules without requiring traditional Wi-Fi networks, making it highly efficient for IoT applications. This system demonstrates a reliable, low-power, and wireless sensor network, ideal for real-time monitoring and data collection in smart homes, industrial automation, and environmental sensing applications.

B. Components Required

The flash flood monitoring system required the components that include the solar panel as a power source, a lead acid battery for backup, temperature and humidity sensor (DHT11), Water level sensor (HC-SR04), ESP8266 as Wi-fi module, rainfall sensor, soil moisture sensor and water flow sensor. The ESP-NOW protocol enables efficient wireless communication between ESP8266 modules, allowing real-time data transmission.

1) Power Source

Here a 10W solar panel is employed as the primary power source, a compact and efficient renewable energy solution. The 10W solar panel, in particular, is designed for small-scale energy needs, making it ideal for powering low-power devices, off-grid systems, and small electronic equipment such as sensors, lighting, and battery chargers. The power bank is used as the secondary power source in this setup.

Fig. 1. Solar pannel

Fig. 2. Powerbank

2) Temperature and Humidity Sensor (DHT11)

The DHT11 is a low-cost, reliable sensor used to measure temperature and humidity in the surrounding environment. It is widely used in various weather-monitoring, IoT, and home automation applications due to its simplicity, affordability, and ease of integration with microcontrollers like Arduino and ESP8266. The operating Voltage is about 3.1V-5±.5V DC. The temperature Range is up to -40°C to 80°C. Temperature threshold is Below 20. Humidity Range is from 0% to 100%. Humidity threshold is above 80. If the value gets above the threshold value notification will be given to blynk.

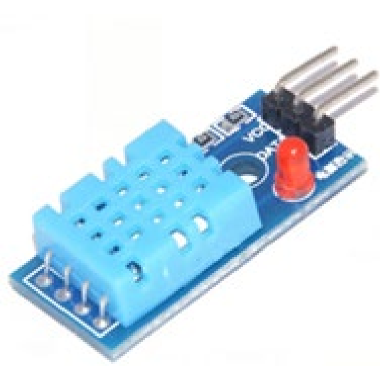

Fig. 3. Temperature and humidity sensor

3) HC-SR04-Water Level Sensor

The HC-SR04 is an ultrasonic sensor commonly used for distance measurement applications, including water level detection. It operates by emitting ultrasonic sound waves at a frequency of 40 kHz, which travel through the air, hit an object (such as the water surface), and then reflect back to the sensor. The time taken for the echo to return is measured and converted into distance. The sensor uses a straightforward trigger and echo mechanism with digital pins, making it easy to integrate with microcontrollers like Arduino, ESP8266, or ESP32.The Operating voltage is 5V DC. The Frequency is 40kHz. Measuring Range is considered as 2cm-400cm. Accuracy is ±3mm. Interface are 4-pin interface (VCC, Trig, Echo, GND) and the threshold value is 10 cm.

Fig. 4. Water level sensor

4) ESP8266-WiFi Module: IoT Device

The ESP8266 is a low-cost, highly integrated Wi-Fi module used in a wide range of Internet of Things (IoT) applications. This module allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections. With its built-in Wi-Fi capabilities and ease of use, the ESP8266 has become a popular choice for IoT projects. Hence it is a low power device it's ideal for battery powered devices. This plays a crucial role in sending real time data to the blynk.

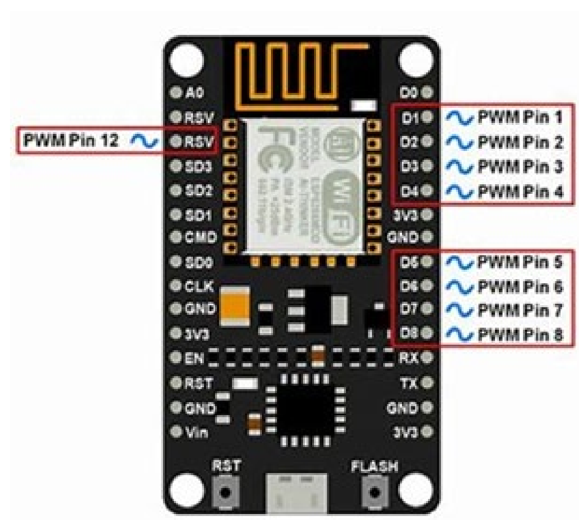

Fig. 5. Wi-fi module

5) Rainfall Sensor

A rain sensor is one kind of switching device which is used to detect the rainfall. It works like a switch and the working principle of this sensor is, whenever there is rain, the switch will be normally closed.it includes the electronic module as well as a PCB. Here PCB is used to collect the raindrops. When the rain falls on the board, then it creates a parallel resistance path to calculate through the operational amplifier. This sensor is a resistive dipole, and based on the moisture only it shows the resistance. For example, it shows more resistance when it is dry and shows less resistance when it is wet.

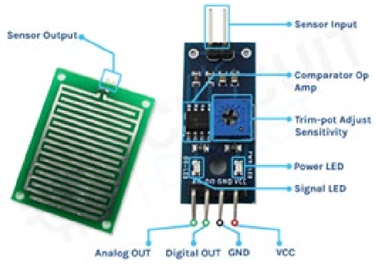

Fig. 6. Rainfall sensor

6) Soil Moisture Sensor

The soil moisture sensor is one kind of sensor used to gauge the volumetric content of water within the soil by the interaction with neutrons, and replacement of the moisture content. This sensor mainly utilizes capacitance to gauge the water content of the soil (dielectric permittivity). The working of this sensor can be done by inserting this sensor into the soil and the status of the water content in the soil can be get in the form of digital value as 0 and 1. The resistance-based devices have two electrodes. When inserted into the soil, these sensors measure the electrical resistance between the electrodes. As the soil moisture increases, its conductivity also increases, so the resistance between the electrodes goes down. Then, this change in resistance is converted into a moisture reading.

Fig. 7. Soil moisture sensor

7) Water Flow Sensor

Water flow sensors have an inlet and outlet pipes to flow water to inside and from outside of the device. The sensor is installed at the water source or pipes to measure the rate of flow of water and calculate the amount of water flowed through the pipe. It consists of a plastic valve from which water can pass. A water rotor along with a hall effect sensor is present in the middle of inlet and outlet valve that help to sense and measure the water flow. When water flows through the valve it rotates the rotor. When water flow is in lower rate then the sensor shows lower value as the volume of water flow. By this, the change can be observed in the speed of the motor. This change is calculated as output as a pulse signal by the hall effect sensor. Thus, the rate of flow of water can be measured.

The main working principle behind the working of this sensor is the Hall effect. The water flow sensor can be used with hot waters, cold waters, warm waters, clean water, and dirty water also. These sensors are available in different diameters, with different flow rate ranges. he sensor contains three wires. Red wire to connect with supply voltage. Black wire to connect to ground and a yellow wire to collect output from Hall effect sensor. For supply voltage 5V to 18V of DC is required.

Fig. 8. Water flow sensor

3. Experimental Setup

This circuit is designed as a comprehensive flood detection and monitoring system by integrating multiple sensors with an ESP-based microcontroller. An ultrasonic sensor is used to monitor water levels, such as in rivers, reservoirs, or drainage systems, by measuring the distance between the sensor and the water's surface. If water levels rise beyond a safe threshold, the system can trigger alerts. Temperature and humidity are measured by the DHT sensor, which adds to environmental data that aids in forecasting flood-causing weather. If the soil is too wet, the soil moisture sensor's detection of ground saturation levels can reveal the possibility of floods. The rainfall sensor helps identify heavy rainfall that may cause flooding by providing real-time precipitation data. An essential tool for determining how quickly water is moving or accumulating is a flow sensor, which measures the water flow rates . The central processing unit is an ESP-based microcontroller that gathers, processes, and perhaps transmits data from all sensors to a cloud platform for real-time monitoring and analysis. When flooding conditions are identified, the microcontroller triggers notifications.

A. Distance Measurement

Ultrasonic sensor-HC-SR04 is employed for distance measurement. They provide accurate and precise measurement making them useful for wide variety of applications. Low cost and easy adaptation are other advantages. In this circuit the sensors are integrated with NodeMCU, through Arduino the results are obtained in the Blynk application. NodeMCU initializes the trigger pin making them emitting the pulse. The time taken by the Echo ins to receive the signal is calculated and converted into distance.

$$Distance = \frac{Time \times speed\ of\ sound}{2}$$

Cae1: Distance measured at 64 cm

Fig. 9. Measuring distance using ultrasonic sensor at 64cm

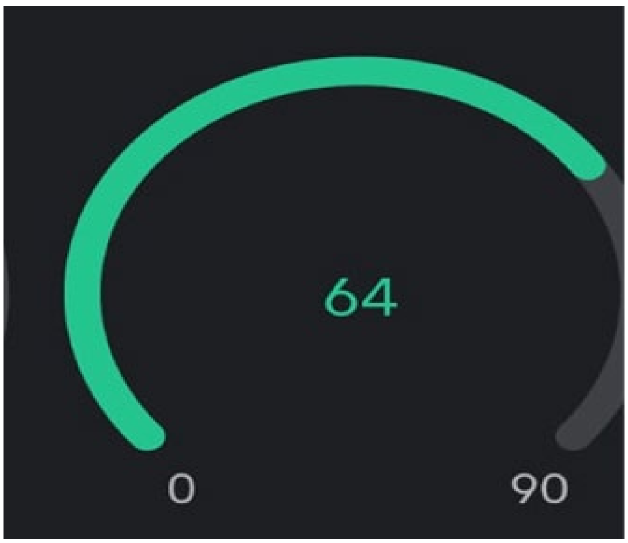

Fig. 10. Real time data on blynk application

Case:2 Distance measured at 75cm

Fig. 11. Measuring distance using ultrasonic sensor 75cm

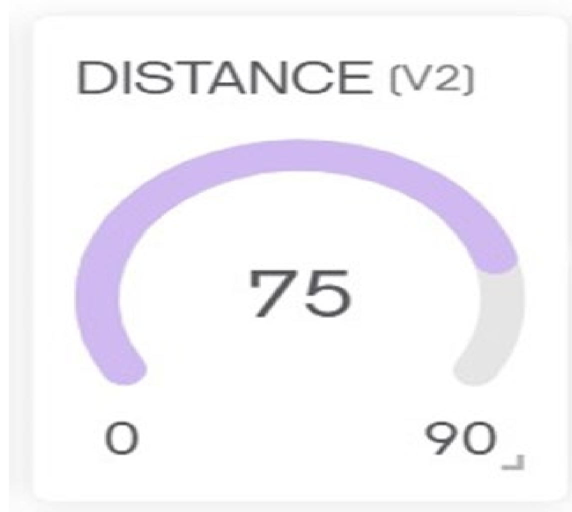

Fig. 12. Real time data on blynk application

B. Rainfall Measurement

Rainfall sensor measures the amount of rainfall obtained in a particular area. It measures the change in resistance caused by the presence of water,.It works by detecting the change in resistance as water droplets falls on the conductive plates, lower the resistance more the water collects.

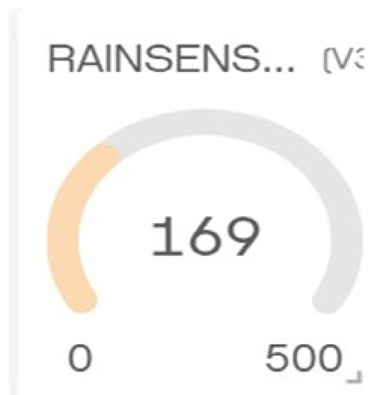

Fig. 13. Rainfall sensor measurement

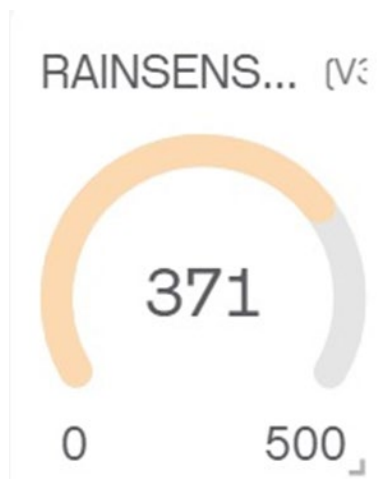

Fig. 14. Rainfall sensor measurement

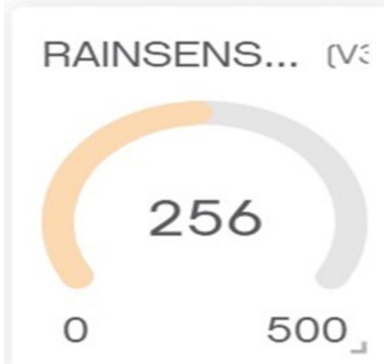

Fig. 13, 14, 15. shows rainfall measurement at different intensities shown in Blynk application

4. Alert System

Step 1: Start the Sensor System
Begin the execution of the program.
Step 2: Initialize System
Initialize Serial communication.
Configure DHT sensor, input/output pins, and interrupt settings.
Connect to Wi-Fi network.
Step 3: Check Wi-Fi Connection
If Wi-Fi is connected, proceed to the main loop.
If Wi-Fi is not connected, wait and retry connecting until successful.
Step 4: Enter Main Loop
Continuously read sensor values and update Blynk.
Step 5: Read Sensor Data
Read water level sensor data.
Read DHT sensor data (temperature and humidity).
Read Water flow sensor.
Read rainfall sensor.
Read soil moisture sensor.
Step 6: Send Data to Blynk
Update sensor readings in the Blynk app.
Check if Wi-Fi is connected before sending data.
If Wi-Fi is not connected, attempt to reconnect.
Step 7: Delay for Stability
Wait for 2 seconds before the next loop cycle to ensure stable readings.
Step 8: Repeat Process
Return to Step 4 (Main Loop) and continue monitoring continuously.

A. Alert notification

Integration of sensors to the Blynk application enables real time data accessibility. The sensor data is processed and transmitted to the Blynk application using a microcontroller ESP8266. Blynk application enables the suer to visualise real time data through smartphone. Through Blynk application customizable alerts can also be provided. Here we have classified the alerts into “Red”, “Orange”, and “Yellow”. If the condition exceeds the threshold value alerts will be generated accordingly.

In the flash flood monitoring system, there provide the Google Map widget within the Blynk app to set and track the desired flood prone area. This allows users to know about the specific area where flood monitoring crucial, ensuring real time updates and alerts. When the water level exceeds the threshold value, the system sends notifications while marking the affected location on the map. By integrating Google Maps with Blynk, users can easily visualize flood risks, enhancing preparedness and response efforts. This improves situational awareness, helping individuals and authorities take timely action to mitigate potential flood impacts.

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