IOT BASED FLOOD MONITORING
AND
EARLY WARNING

A project report submitted in partial fulfilment

Of the requirments for the degree of B.E in

COMPUTER SCIENCE AND ENGINEERING

BY

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INTRODUCTION

Amongst natural disasters, floods represent one of the great global challenges harming humankind. This phenomenon leaves tens of thousands of victims worldwide. In terms of lives lost and property damaged, floods are ranked just behind tornadoes as the top natural disaster in the United States. According to studies by the United Nations Office for Disaster Risk Reduction (UNDRR) [1], since 1995, floods represented 47% of all weather-related disasters and are continuously listed first among natural disasters worldwide. In recent years (2008–2017), approximately 73.1 million people were affected by floods. The total number of people affected grew significantly in 2018 to 34.2 million people [2]. The data show a trend that the number and severity of floods may be increasing, thus making it more important for persons to better anticipate floods, according to experts within the United Nations Climate Change Conference (COP21). As the phenomenon of a dynamic range of energy in weather systems increases, effects are increasingly noticeable in the hydrological cycle and associated river system catchment areas.

Flood prediction models may be tuned using historical hydrological data concerning fluvial floods [3,4]. However, due to climate change and the increased levels of energy in weather systems, flash flooding is becoming more common and therefore, when considering flood alerting systems, historical data are less useful than real-time data [5,6]. Flash floods concentrate their waters in small geographic areas within six hours of the rains or other events that spawned them and are characterized by a rapid rise of fast-moving water. Water moving at 10 m per second, a common speed for flash floods, can move rocks weighing almost a hundred pounds. Flash floods carry debris that elevates their potential to damage structures and injure people.

(1)
Internet of Things (IoT) technology in each of the nodes.

(2)
LORA (LOng RAnge) technology to communicate between drifters, RiverCore nodes, and the hardware located in the sniffer.

(3)
MQTT (MQ Telemetry Transport) protocol to carry out the communication between the fixed and mobile nodes with the server in the cloud, making efficient handling of data acquisition.

(4)
JSON (JavaScript Object Notation) protocol for data exchange.

(5)
Low Energy Consumption Telemetry.

2. Materials and Methods

The components of the system include a fixed node (RiverCore), a mobile node (Drifter), a drone mountable sniffer, and weather stations, along with a web-based data acquisition platform, all integrated with IoT techniques to retrieve data through 3G cellular networks.

The developed architecture uses the Message Queuing Telemetry Transport Protocol (“MQTT is an OASIS standard messaging protocol for the Internet of Things (IoT)” [17]), to send real-time data packages from fixed nodes to a server that stores retrieved data in a non-relational database. From this, data can be accessed and displayed through different customizable queries and graphical representations, allowing future use in flood analysis and prediction systems. The parts of the system can be seen in Figure 1.

Figure 1. Elements of the early warning system (RiverCore, weather station, drifter, and sniffer).

2.1. System Components

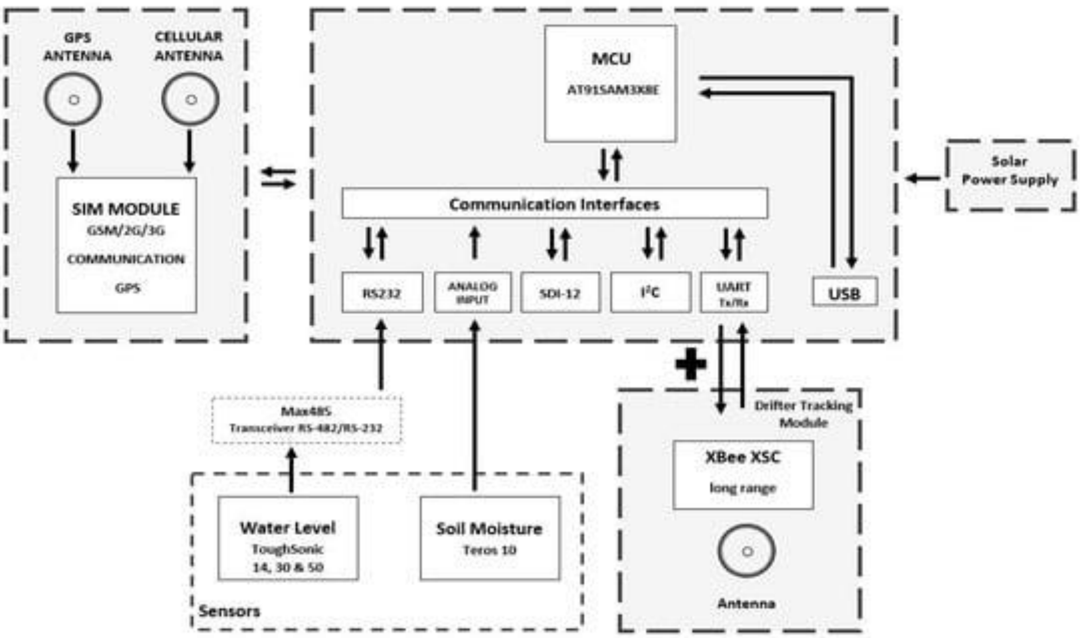


Figure 2. RiverCore hardware block diagram.

The RiverCore fixed node is physically composed of a 32-bit microcontroller unit, a 3G cellular modem electronic board, an XBee (802.15.4) ("modules seamlessly interface with compatible gateways, device adapters and range extenders, providing developers with true beyond-the-horizon connectivity.” [19]), or LoRa radio, shield/daughterboard, an RS-485 transceiver, a regulated power supply, a solar charge controller, and a 12 v 80 A h battery.

- **Radio link budgets**
    - XBEE XSC PRO
        - Transmit power 20 dBm.
        - Receiver sensitivity −106 dBm.
        - Spread spectrum FHSS.
        - Outdoor/line-of-sight range 6 mi.
        - Urban range 1200 ft.
    - SIM5320A
        - Receive sensitivity −106 dBm.
        - Transmission power 33 dBm.

The weather station will be an important part of the forecasting model in the future, adding the variables it measures to be able to predict floods with more time.

It is intended to study the variables and compare them with the historical data of past hurricanes that have caused the overflow of rivers in the city. They are presented as part of the early warning system solution so that it is fully known.

This node (diagram shown in Figure 3) integrates a series of electronic components that the ATMOS 41 (all-in-one weather station [20]) weather station employs. Its high-performance, low-power Microchip 8-bit AVR RISC-based microcontroller handles the data of the 12 weather sensors included on ATMOS 41. The data are packed and sent to the platform via a wired internet connection. They also get stored with a timestamp on a Micro SD card as a backup.

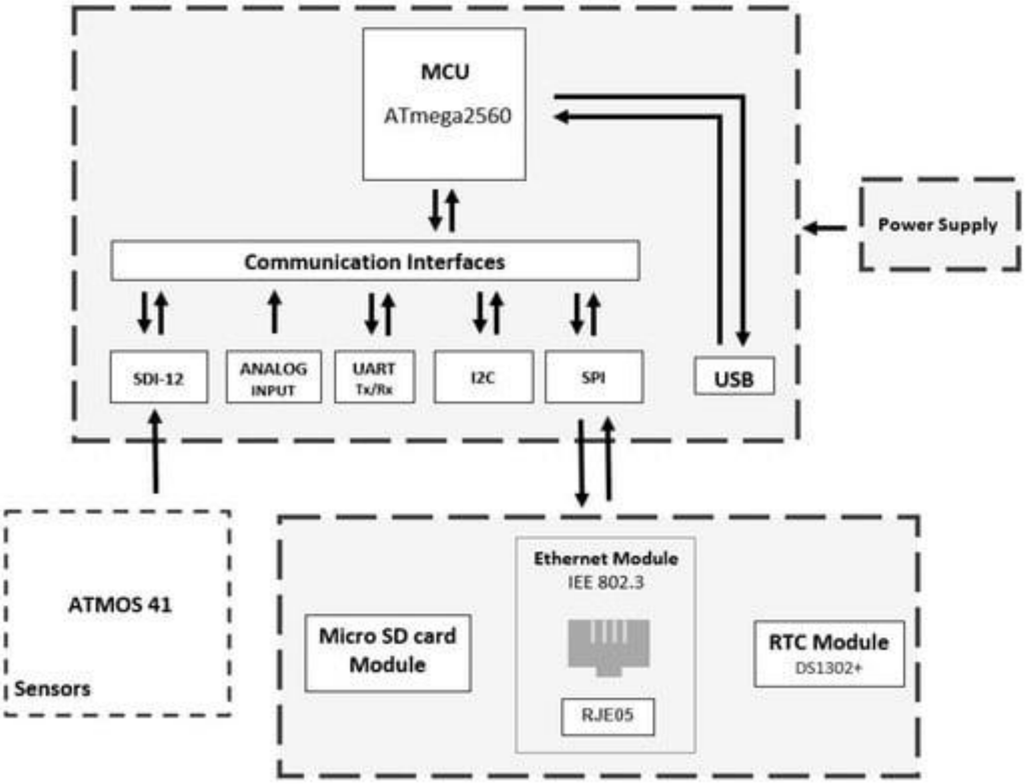


Figure 3. Weather station hardware block diagram.

- ## Weather Station Specifications

Solar radiation: Range: 0 to 1750 W/m^2; resolution: 1 W/m^2; accuracy: ±5% of typical measurement.

Precipitation: Range: 0 to 400 mm/h; resolution: 0.017 mm; accuracy: ±5% of measurement from 0 to 50 mm/h.

Vapor Pressure: Range: 0 to 47 kPa; resolution: 0.01 kPa; accuracy: varies with temperature and humidity, ±0.2 kPa typically below 40 °C.

Relative Humidity: Range: 0 to 100% RH (0.00–1.00); resolution: 0.1% RH; accuracy: varies with temperature and humidity, ±3% typical RH.

Air temperature: Range: −50 to 60 °C; resolution: 0.1 °C; accuracy: ±0.6 °C.

Humidity sensor temperature: Range: −40 to 50 °C; resolution: 0.1 °C; accuracy: ±1.0 °C.

Barometric pressure: Range: 50 to 110 kPa; resolution: 0.01 kPa; accuracy: ±0.1 kPa from −10 to 50 °C, ±0.5 kPa from −40 to 60 °C.

Horizontal wind speed: Range: 0 to 30 m/s; resolution: 0.01 m/s; accuracy: greater than 0.3 m/s or 3% of measurement.

Wind gust: Range: 0 to 30 m/s; resolution: 0.01 m/s; accuracy: greater than 0.3 m/s or 3% of measurement.

Wind direction: Range: 0° to 359°; resolution: 1°; Accuracy: ±5°

Tilt: Range: −90° to +90°; resolution: 0.1°; accuracy: ±1°.

Lightning strike count: Range: 0 to 65,535 strikes; resolution: 1 strike; accuracy: variable with distance, >25% detection at < 10 km typical.

Lightning average distance: Range: 0 to 40 km; resolution: 3 km; accuracy: variable [20].

Drifter—A free-floating sensor that takes local measurements and tracks the flow in water systems. Drifters compile water measurements to estimate the flow of a hydrodynamic system; however, it requires communication capabilities and a method to integrate the gathered data into an appropriate data structure.

The drifter architecture (Figure 4) includes a radio to communicate location information to the fixed node and RiverDrone (sniffer), thereby increasing the possibilities of finding and recovering them. It also incorporates an SD card module to store the location, speed, and potentially, any other data that are registered. Importantly, it can be equipped with additional modules or sensors. The system recovery method is explained in Section 3.2.

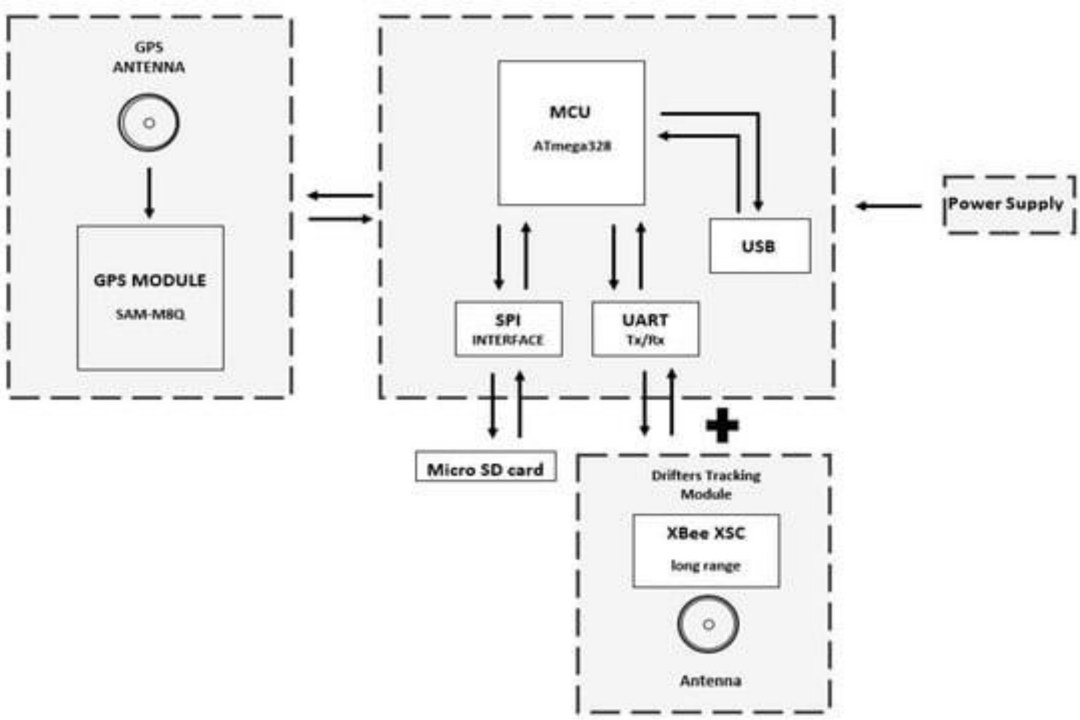


Figure 4. Drifter hardware block diagram.

The sniffer architecture (Figure 5) allows the device to work as a sniffer looking for drifters. Equipped with matching radio, cellular communication, and GPS, drifters can report their location to the EWIN platform, where the information is forwarded and displayed on a web page.

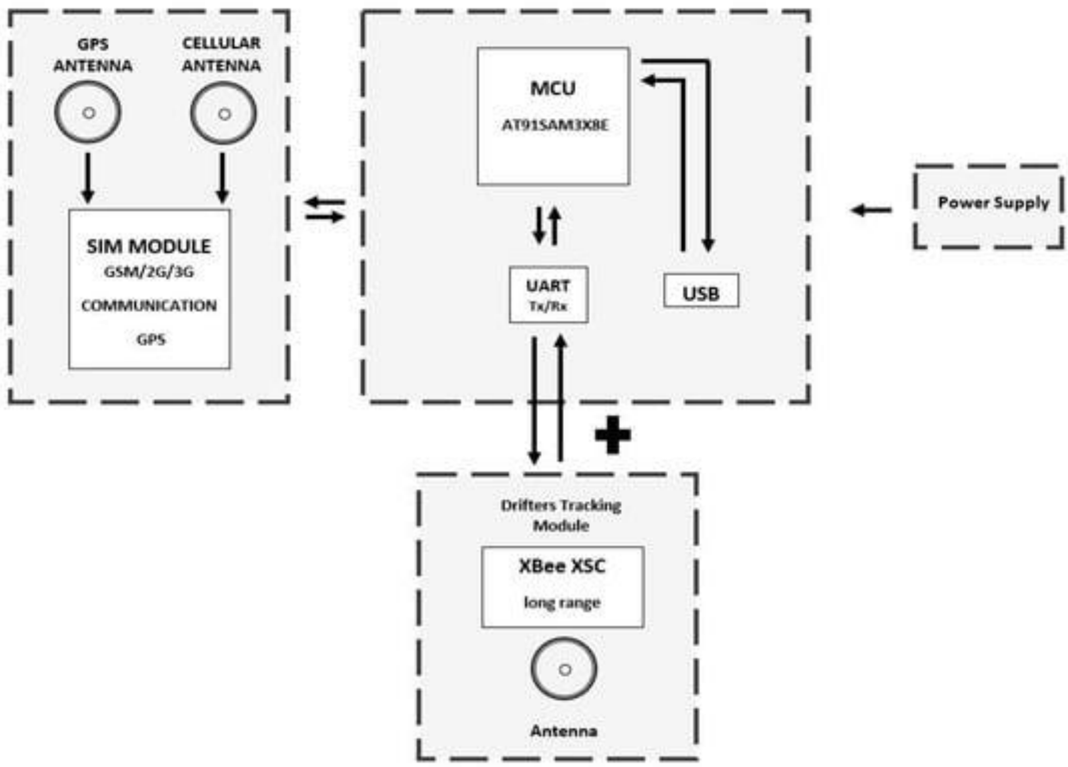
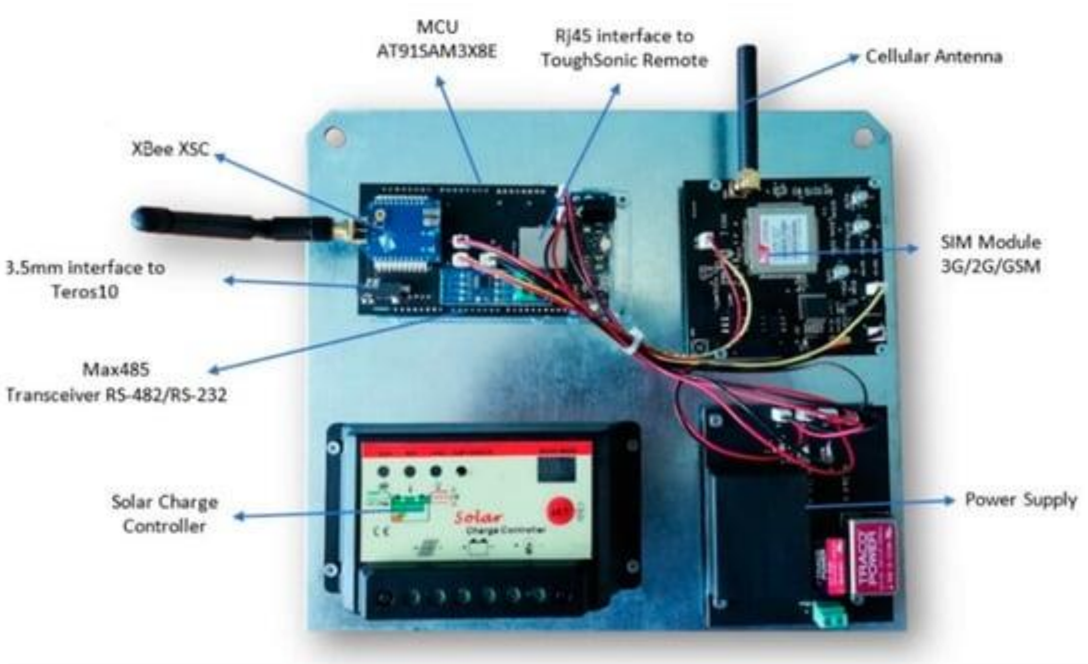


Figure 5. Sniffer hardware block diagram.

2.2. Hardware Development

Hardware requirements have been defined according to the specific needs of the application, which has resulted in the development of fixed, weather station nodes, and drifter nodes, along with a data acquisition process that uses IoT techniques to retrieve data through the 3G cellular network.

Power management, the cellular communication method, and other components described in a previous paper [21] remain unchanged. Their initial design effectively handles the extra load and demands of the new hardware now incorporated on the fixed node. The main hardware modules or the fixed node c



an be seen in Figure 6.

Figure 6. RiverCore hardware modules.

2.3. Sensor and Processing Considerations

The ultrasonic water level sensors ToughSonic Remote 14, 30, and 50 are used to measure the distance between the water surface and the sensor location. The data generated are then processed within the microcontroller and encapsulated in a JSON ("JavaScript Object Notation is a lightweight data exchange format") structure, along with an identification string. These data are then transmitted to the server through the 3G cellular network and stored into the NoSQL ("No Structured Query Language") database to carry out future calculations that can later be used for flood forecasting.

Several versions of this sensor are available, each of which possess different ranges and communication interfaces. Three different models were considered (ToughSonic Remote 14, 30, and 50), each with a different range, although all of them communicate through the RS-485 standard. The RiverCore processor board does not support this standard. Consequently, a Max 485 transceiver was employed to handle the communication between the microcontroller and the sensor. Before connecting to RiverCore, each sensor needs to be configured employing the manufacturer's software, ASCII ("American Standard Code for Information Interchange") streaming, with a 57,600 baud rate, which is the default configuration the fixed node accepts for this sensor. Some calculations to determine the distance between the ToughSonic sensor and the water occur in RiverCore (fixed node). The water depth is then calculated at the EWIN server with the characteristics of each site. Each sensor and site are treated differently since the formula varies between Remote 14, 30, and 50, and every physical site has its characteristics and topographic data.

Along with the ultrasonic water level sensor, every fixed node also incorporates a soil moisture sensor. The TEROS 10 is an analogue sensor, which makes its integration into the network simpler. However, an analogue sensor may also report some inconsistent values because analogue signals suffer from greater interference and other physical factors like the wiring length.

The TEROS 10 reports an output of 1000 to 2500 mv, which the microcontroller translates into voltage accordingly to its 12-bit resolution. These data are then transmitted, as is, and the server transforms the data into usable information regarding soil conditions.

The information from the humidity sensor is used to calibrate the hydrological model, since the soil has an antecedent humidity before a heavy precipitation episode. If the soil moisture is low, it has a greater capacity to absorb water volume and the opposite is true if the soil has a high moisture content. In this last scenario, it is easier to generate runoff. Therefore, the humidity sensor data are used to calibrate the hydrological model to know the response of the basin and to use these variables in the forecast model.

There are two types of fixed nodes on the EWIN network: RiverCore and weather stations. The weather station node retrieves the weather information from the ATMOS 41 weather station which packages 12 weather sensors. It features a 3-wire interface following the SDI-12 protocol for communicating sensor measurements.

The weather station measures 12 weather variables including air temperature, relative humidity, vapor pressure, barometric pressure, wind speed, wind gusts and direction, solar radiation, precipitation, lightning strikes, and lightning distance. The data are backed up internally by the weather station node and sent to the server unmodified to be stored and displayed.

The RiverCore main processing board is based on the AT91SAM3x8E, which can communicate with different protocols; this allows it to be compatible with different sensors and devices, with optimum efficiency.

The compatible communication protocols are listed below:

- I2C;
- SDI-12;
- SPI;
- RS-232/RS-485;
- USB;
- Analogue input.

The actual implementation of the RiverCore fixed node, which has been deployed in the experimental network, has inbuilt libraries for RS-232, Analog, I2C, and SDI-12 devices; however, different libraries can be developed to include compatibility with a wide range of hydrologic devices.

The drifter node integrates a GPS module, which retrieves location, time, and speed variables. It also contains a physical storage card slot to retrieve measured data. This device is sealed inside a waterproof enclosure that holds a magnetic switch, which powers the data logging mechanism while it flows through the river basins. These data are stored inside the MicroSD card and can be analyzed by the EWIN data acquisition platform. Drifter nodes add radio communication capabilities to transmit information to other devices like a fixed node and a sniffer. The above-depicted hardware components are shown in Figure 7.

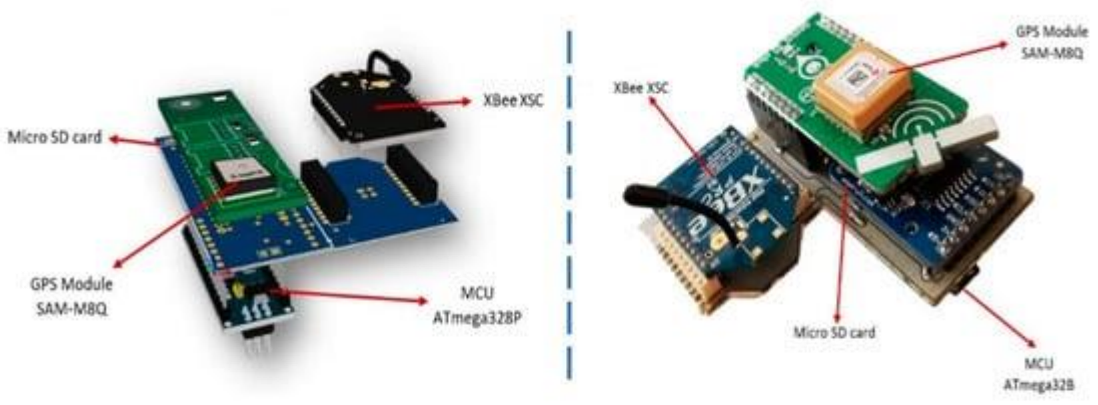
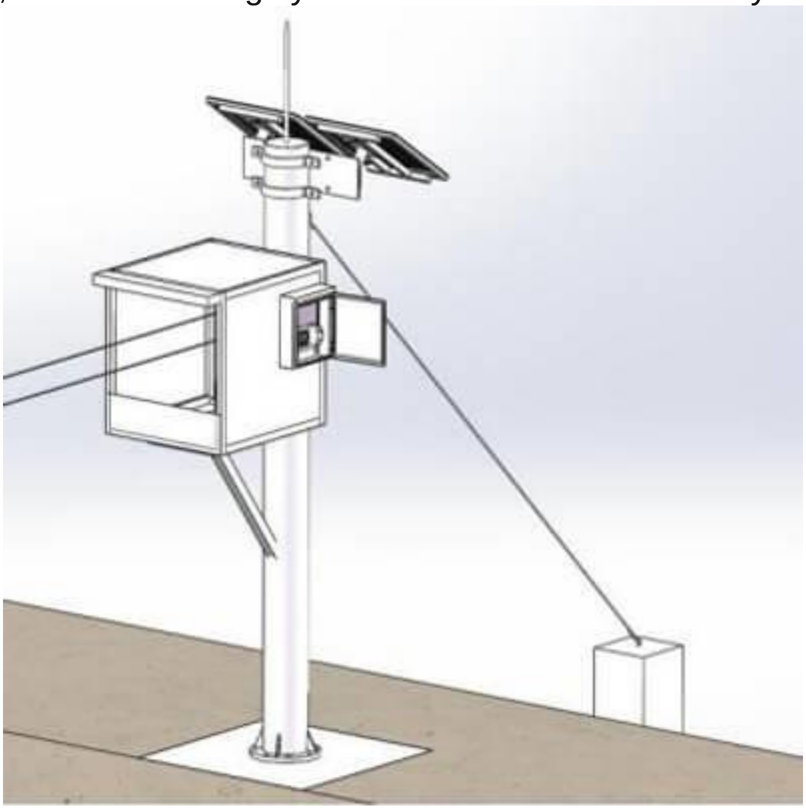


Figure 7. 3D model and picture of drifter electronic components.

2.2. Hardware Development

2.3. Sensor and Processing Considerations

In view of the frequency and severity of floods, many technology companies use the Internet of Things to propose many solutions and countermeasures. Among them, flood monitoring systems with sensors are widely used.

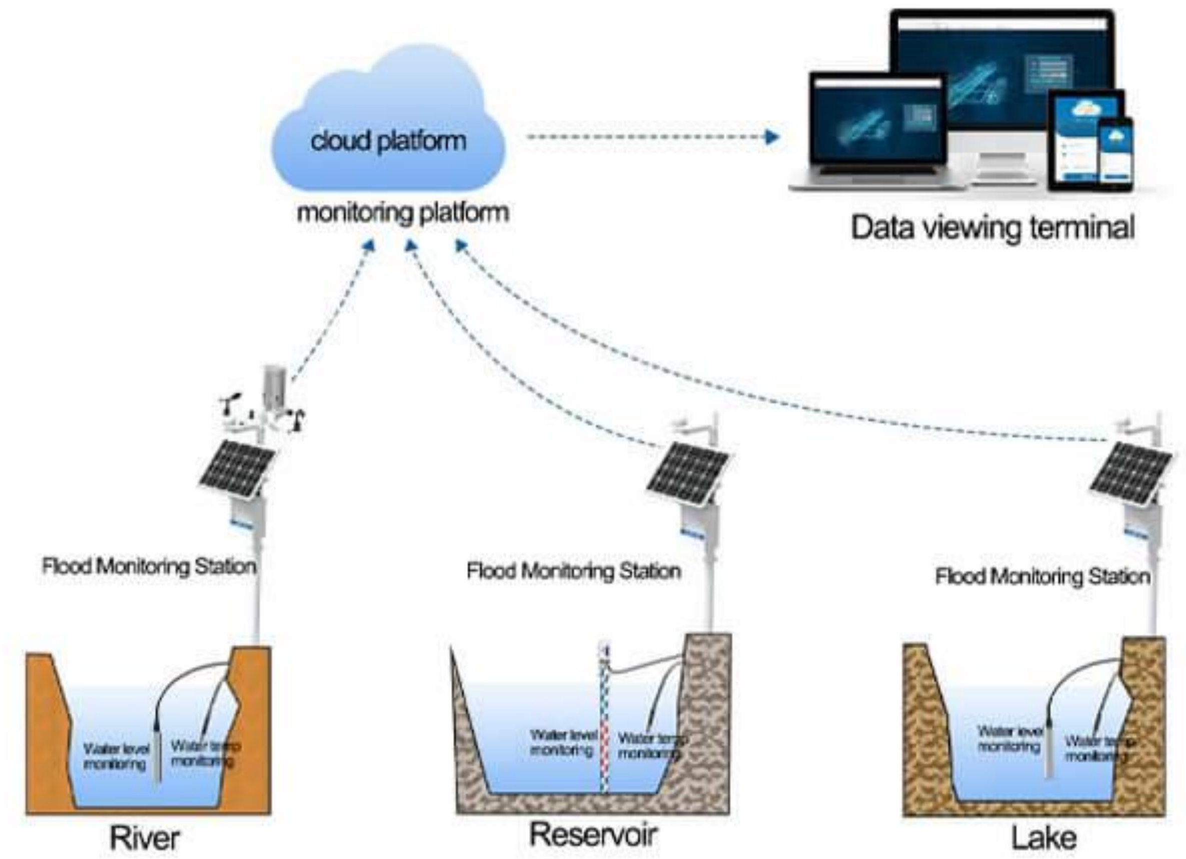


Data viewing and analysis

The data collected by the flood monitoring system is finally transmitted wirelessly to the free cloud platform or the customer’s own platform. Staff can not only view real-time data by logging in to the platform, but also set alarm values and check the working conditions of various sensors through the platform. Choose a platform that can log in on a computer and view data remotely through the mobile APP. In this way, the staff can grasp the data even when they are moving, and react in time.

Renke flood monitoring system

Technological innovation and digital empowerment are effective ways to improve the level of flood and drought disaster prevention. To scientifically and effectively respond to changes in the natural environment, geological disasters, and flood disasters, Renke has independently developed a flood monitoring system in response to government requirements. The system consists of a data acquisition system, a solar power supply system, an all-weather protective box, a weather observation bracket, a video monitoring system, and an environmental monitoring platform. Through the deployment of sensor collection terminals, intelligent data collection and integrated uploading are realized, combined with the back-end environmental monitoring platform, the flood prevention and disaster reduction monitoring system is improved, analysis and judgment are strengthened, and warning information is released in time to provide comprehensive and comprehensive guarantee for its safe and stable operation.



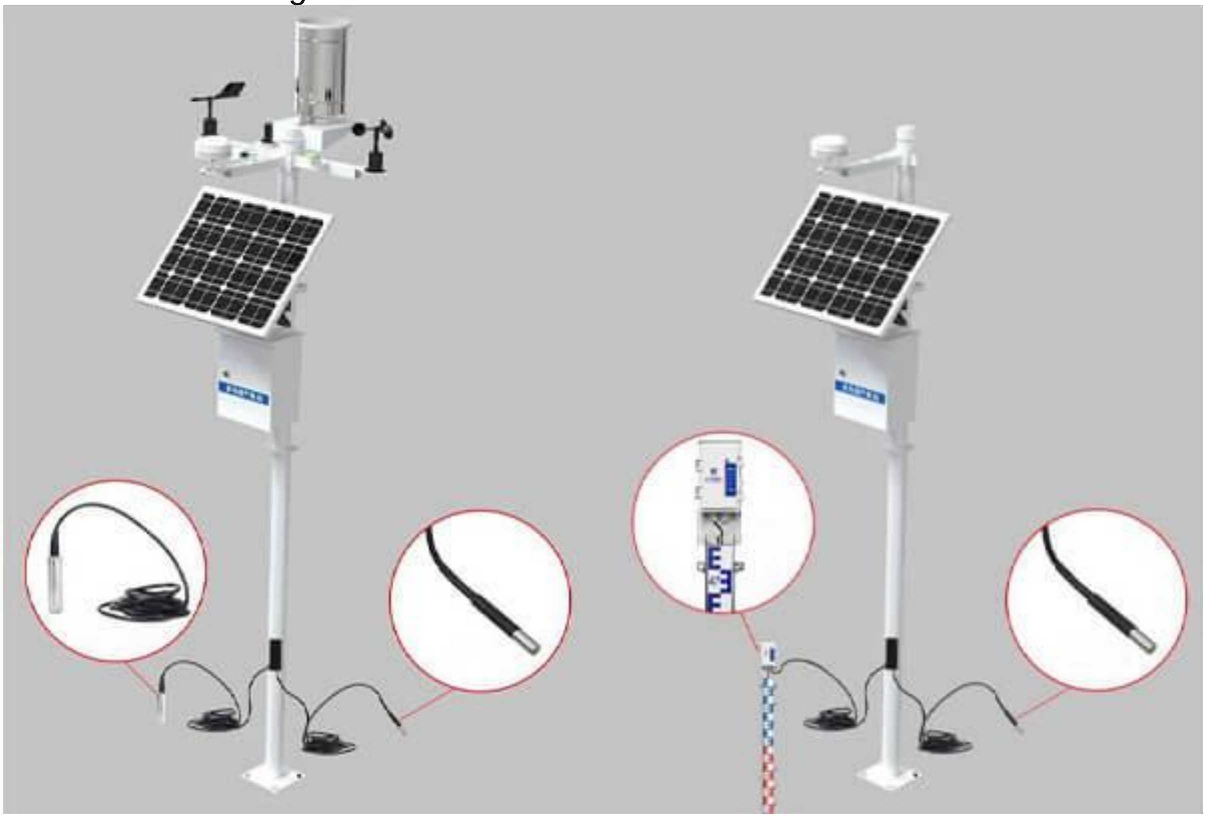
Among them, water level monitoring and rainfall monitoring are the key parts of the flood monitoring system. Through the monitoring of water level, total rainfall, instantaneous rainfall, daily rainfall, current rainfall and other data, it provides timely services for the integrated management of floods and water resources. In addition, it also supports a variety of environmental monitoring terminals such as temperature and humidity sensor, wind speed sensor, wind direction sensor, illuminance sensor, carbon dioxide sensor, and PM2.5 PM10 sensor.

Tipping bucket rain gauge

The rain gauge consists of a funnel and a small container fixed on a tipping rod. Before the container is tipped, a certain amount of precipitation is collected, all the collected water is dumped and the electrical signal is sent to the data transmitter. Our tipping bucket rain gauge can read the day's rainfall, instantaneous rainfall, yesterday's rainfall, total rainfall, hourly rainfall, last hour's rainfall, 24-hour maximum rainfall, 24-hour maximum rainfall period, 24-hour minimum rainfall, and 24-hour minimum rainfall period.

Liquid level sensor

The liquid level sensor is a device used to measure the liquid level, which converts the height of the liquid level into an electrical signal for output. The measuring range can be customized, and it can work in rivers, lakes, and reservoirs for a long time.



The whole system can be powered by solar energy, with large-capacity lead storage batteries, and can work continuously for seven days on rainy and cloudy days to ensure the normal operation of the equipment. At the same time, it supports wireless 4G signal or RS485 signal upload mode, which effectively reduces the overall cost of the system, improves system reliability, and is suitable for a variety of outdoor environments. The system is simple to install, easy to operate, without wiring, and effectively solves the construction problems of no electricity and no network cables in the field. The system design complies with national and industry standards and meets the needs of networking and sharing. It is widely used in hydrological departments for real-time monitoring of hydrological parameters such as rivers, lakes, reservoirs, channels, and groundwater.

Features of Renke Flood Monitoring System

1. **Remote monitoring**: The flood monitoring system can remotely view the temperature, humidity, rainfall, water level, water temperature, illuminance, wind speed, wind direction, and other monitoring data in the current environment and the operating status of the field equipment in real-time.
2. **Real-time monitoring**: The video image captured by the camera synchronizes data to the environmental monitoring platform through the video character overlay. Through video monitoring, the current water level, rainfall situation, and current environmental information can be monitored in real-time, which is convenient for remote control.
3. **Over-limit alarm**: When any monitored data exceeds the upper limit set by the administrator, the platform will send alarm information to the administrator in the form of SMS, phone, email, etc.
4. **Historical data query and analysis**: The flood monitoring system supports querying the historical data of one or more water and rain monitoring stations in the jurisdiction. Select the corresponding site, time range, and data type (hourly data, daily data, monthly data, quarterly data) according to your needs for query, support data comparison and analysis, and export historical data reports in PDF and Excel format.
5. **Data storage**: The weather monitoring host is used in the data acquisition system, with built-in data storage, which can store 520,000 records. When the communication fails, the device will automatically store it, and the stored data can be uploaded after the communication is restored.
6. **Multiple terminal viewing**: The system supports multiple methods such as computer PC and mobile phone clients to view data anytime and anywhere.
7. **Large-screen visualization**: Centralized scrolling display of environmental monitoring data of each monitoring point, real-time display of the dynamic curve of water level, rainfall, and other elements, the data is clear and intuitive, which is convenient for management personnel to view the system.