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# Solar-Powered IoT-Enabled Weather Monitoring System with AJAX-Based Webserver for Data Visualization

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**Abstract –** *Internet of Things (IoT) devices are being very popular nowadays in various application areas in multiple industry sectors. The web application to interact with these IoT enabled devices is primarily done through web applications that run on mobile and PCs. The web applications must provide real-time dynamic information and interacts with sensors and environment to get the request or data. AJAX technology enables dynamic data loading in the IoT web applications with auto-updation of sensor information.*

*This paper presents an innovative approach for developing a Solar powered intelligent weather station based on Internet of Things (IoT) using AJAX-based web server technology. The proposed system leverages the asynchronous communication capabilities of AJAX to enable real-time data updates, dynamic content loading, and interactive user interfaces, providing a seamless and responsive user experience. The system utilizes AJAX Technology to create a web-based interface that allows users to access and monitor weather data including Temperature, Humidity & Rain from the sensors. The proposed solution has been implemented and the prototype of the smart weather station is tested, demonstrating the real-time sensor data visualization, real-time data updation, solar based battery charging and IoT based sensor integration. ESP8266 based webserver is being used in the proposed solution along with the sensors to sense the weather parameters. The results show the web application with real-time sensor data displayed; Real-time AJAX based data updation etc.*

***Key Words***: **Internet of Things (IoT), AJAX, Sensor, ESP8266**

## 1. INTRODUCTION

Internet of Things (IoT) encompasses a network of interconnected devices integrated with sensors and software, enabling them to gather, exchange, and analyze data. These devices can include everyday objects like household appliances, wearable devices, machines, healthcare devices, and more. In the recent years, the significance of IoT has surged as it holds the potential to revolutionize industries by digitizing processes and enhancing productivity and efficiency.

A Smart weather station based on the Internet of Things (IoT) and solar energy can be used to sense various weather parameters and send it to IOT based server for real-time monitoring. Furthermore, to enable real-time data updates, asynchronous data retrieval, and an interactive user experience, AJAX technology is integrated with the webserver.

### 1.1 AJAX Technology

AJAX (Asynchronous JavaScript and XML) is a web development technology that allows for asynchronous communication between a web browser and a web server without the webpage refreshing. It enables web experiences by allowing web applications to update parts of a webpage without fully refreshing the entire page. With AJAX, innovators can build web applications that can send and receive data from a server in the background without interrupting the user's interaction with the webpage. This asynchronous communication allows for faster and more interactive web experiences, as only the updated portions of the page need to be refreshed, reducing the amount of data transfer and processing required.[4]

AJAX is widely used in modern web development for a variety of purposes, including dynamic content loading, form submissions, real-time data updates, and interactive user interfaces. It has become a popular technology in building rich and interactive web applications, providing a smooth and responsive user experience. It has several advantages, including improved user experience, increased performance, reduced server load, and the ability to build complex web applications with dynamic content.

The benefits of using AJAX technology are mentioned below:

1. **Efficient Data Retrieval:** The smart weather station uses AJAX Technology to asynchronously retrieve weather data from various sensors. When a user requests any information, AJAX can send a request to the server to fetch the latest data without reloading the entire page. This allows for efficient and asynchronous data retrieval, ensuring that the system remains responsive and doesn't block the user interface.

2. **Real-time Data Updates:** The use of AJAX Technologies enables real-time data updates without refreshing the complete webpage. This can provide users with up-to-date and relevant weather information without requiring them to manually refresh the page.

3. **Data Visualization:** AJAX can be used to dynamically update weather data visualizations, such as charts, maps, or graphs. AJAX can also be used to update weather charts or graphs to provide users with visual representations of weather trends.

4. **User Interaction:** AJAX can enable user interaction in the system. For example, users can customize their weather preferences, set up weather alerts etc. by giving inputs through forms, text fields etc.

5. **Performance Optimization:** AJAX optimizes the performance of the weather station. By asynchronously retrieving data and updating the user interface, AJAX also reduces the amount of data transfer and processing required, resulting in a more efficient and responsive system.

### 1.2 Features of Smart Weather Station

Here are some key reasons why IoT is considered important nowadays:

1. **Connectivity:** IoT enables devices to connect and communicate with each other, allowing seamless data exchange. This data can be further processed for better decision-making, process optimization, and improved outcomes.

2. **Efficiency:** IoT can automate tasks, processes, reducing human intervention and minimizing errors. This can lead to increased efficiency, cost savings, and improved productivity in industries.

3. **Enhanced User Experience**: IoT enables the development of innovative products that can provide personalized user experiences. For example, smart home devices, wearable devices, connected cars etc.

4. **Security:** IoT can enhance security through real-time monitoring, predictive analytics, and automation of safety protocols. For example, smart surveillance systems, smart home security etc.

5. **Environmental Sustainability**: IoT can contribute to environmental sustainability by enabling efficient management of resources, such as energy, water, and waste. For example, smart grids, smart agriculture, smart city solutions etc.

## 2. IMPLEMENTATION

### 2.1 Hardware Development:

#### 2.1.1 Introduction to ESP8266:

The Wi-Fi module known as the ESP8266 is frequently used in embedded applications, particularly Internet of Things (IoT) applications. It is a low-cost, low-power, and highly integrated module that combines a microcontroller unit (MCU) with built-in Wi-Fi connectivity. As a result, it is ideal for adding wireless communication capabilities to a variety of Internet of Things devices [1].

**Key Features:**

- **Clock Speed:** 80 MHz
- **Flash Memory:** 4 MB / 64 KB
- **Digital I/O Pins:** 11
- **ADC Pins:** 1
- **ADC Range:** 0-3.3V DC
- **UART/SPI/I2C:** 1
- **Wi-Fi built in:** 802.11 b/g/n
- **USB to Serial Interface:** CP2102

One of the critical highlights of the ESP8266 module is its capacity to run custom firmware, which takes into consideration programming and customization of its usefulness. Smart home automation, remote sensing, data logging, wireless sensor networks, weather stations, and numerous other IoT products all make use of the ESP8266 module.

#### 2.1.2 BMP280 barometric pressure sensor

The BMP280, an absolute barometric pressure sensor, is ideal for mobile and other measurement applications due to its compact dimensions and low power consumption. It is widely utilized in mobiles, smart watches, weather stations, and other devices. Bosch's proven Piezo-resistive pressure sensor technology forms the foundation of the BMP280, offering high accuracy, linearity, and long-term stability [1].

**Features of BMP280:**

- Pressure Range: 300-1100 hPa
- Temperature Range: -40-85°C
- Average typical current consumption:3.4 μA @ 1 Hz
- Interface: I2C and SPI
- Operating voltage: 1.71 V – 3.6 V

### 2.1.3 DHT11 Sensor:

The DHT11 sensor is designed for measuring the temperature and humidity of the surrounding environment. It consists of a capacitive humidity sensing element to measure humidity and an NTC thermistor to sense temperature. The capacitive element for humidity measurement contains two electrodes with a moisture-holding substrate acting as a dielectric between them. As humidity levels change, the capacitance value also changes accordingly. The circuit's integrated circuit (IC) then measures and processes these resistance values, converting them into a measurable digital signal.

**Features:**

- Operating Voltage: 3.3V-5.5V
- Temperature Range: 0-50 °C
- Temperature Accuracy: ±2% °C
- Humidity Range: 20-90% RH
- Humidity Accuracy: ±5% RH

### 2.1.4 Rain sensor:

The rain sensor is utilized to detect rainfall and finds applications in automatic wipers, weather stations, and more. It operates on the principle of variable resistance, where the two resistance coils are distant and the resistance is high when the surface is dry. Conversely, during rainy conditions, the resistance decreases. To process this variable resistance, a voltage divider network converts it into a variable voltage, which is then passed to the LM393 Voltage comparator to transform it into a digital signal [2].

**Circuit Diagram:**

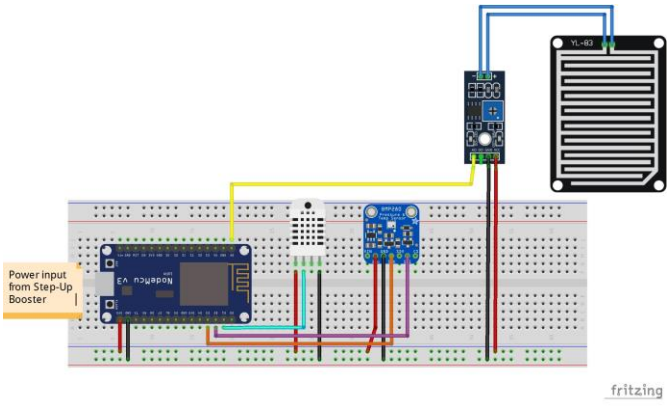


**Fig -1**: Circuit Diagram of Functional Prototype

### 2.2 Software Implementation:

### 2.2.1 ESP8266 Webserver:

A web server that can serve web pages, receive and process HTTP requests, and send HTTP responses can be built with the ESP8266 module. This empowers the module to collaborate with internet browsers and different gadgets over a nearby organization or the web, making it ideal for making IoT applications that require electronic connection points. The following is an overview of how to construct a web server based on the ESP8266 [1][2]:

- **Configure Wi-Fi connectivity settings:** The ESP8266 module needs to be configured with appropriate Wi-Fi settings, including the SSID (name of the Wi-Fi network) and password, in order to connect to a local Wi-Fi network.
- **Create a web server:** Creating a web server involves in setting up a listening socket on a specific port and handling incoming HTTP requests.
- **Handle HTTP requests:** The module needs to parse the HTTP request sent by a web browser to the ESP8266 web server, extract pertinent information like the URL, HTTP method, and request parameters, and process the request accordingly.
- **Send HTTP responses:** Post processing the HTTP request, the ESP8266 web server needs to generate an HTTP response, which typically includes an HTML page, images etc. The response is sent back to the client (e.g., web browser) in the form of an HTTP response message.
- **Implement desired functionality:** The web server running on the ESP8266 module can be altered to execute the ideal usefulness for the IoT application. This can incorporate controlling associated gadgets, gathering sensor information, communicating with data sets, and performing different undertakings in view of the prerequisites of the application.

### 2.2.2 Implement AJAX in ESP8266 Webserver:

Implementing AJAX in an ESP8266 web server involves using the ESP8266 module to handle incoming HTTP requests and send asynchronous responses to client-side scripts running in a web browser. The overview for setting up AJAX in ESP8266 webserver is mentioned below:[4]

1. **Set up the ESP8266 web server:** Make use of appropriate libraries like ESP8266WebServer to set up the ESP8266 module as a web server. This

involves configuring HTTP handlers to handle client-side incoming requests.

2. **Handle AJAX requests:** In the web server code running on the ESP8266 module, implement handlers for AJAX requests. These handlers should extract relevant information from the HTTP requests, such as the URL, HTTP method, and request parameters, and process the request accordingly.

3. **Send asynchronous responses:** The ESP8266 web server can generate data based on the request and send it back as an asynchronous response in a specific format such as JSON or XML instead of sending a complete HTML page in response to AJAX requests.

### 2.2.3 Programming the ESP8266:


**Fig -2**: Programming the ESP8266

### 2.3 Prototype Testing

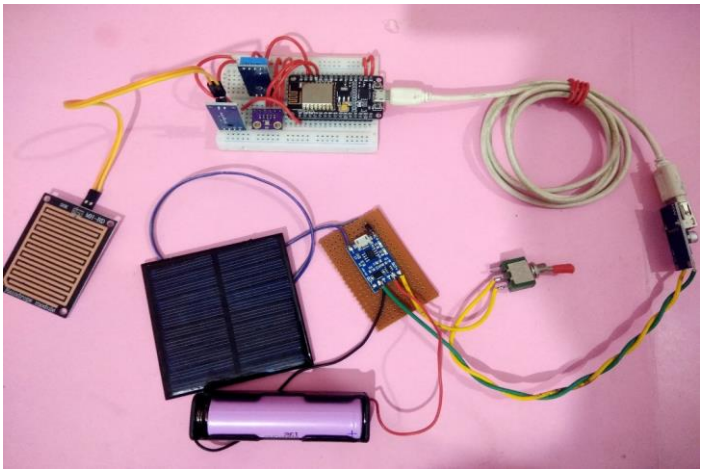

**Fig -3**: Prototype Testing Hardware Setup

### 2.4 Results

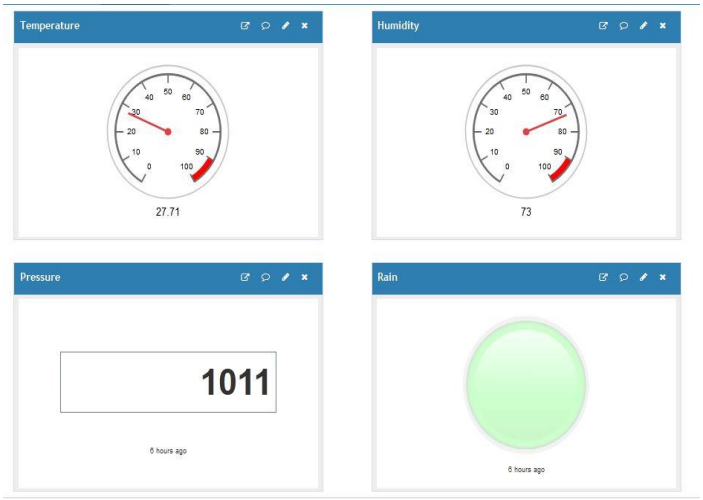


**Fig -4**: Results on the HTML Webpage

## 3. CONCLUSIONS

In conclusion, this journal paper presents the development of a solar-based weather station capable of monitoring multiple environmental parameters such as humidity, temperature, pressure, and rainfall. The key innovation lies in its ability to operate without any external power supply, the integration of a solar panel that harnesses solar energy used for charging the lithium-ion battery. The use of AJAX technology facilitates real-time monitoring and data visualization on a web-based IoT platform. This solar-powered weather station offers a sustainable and efficient solution for collecting crucial environmental data, making it a suitable device for various applications, including weather monitoring, research, and infrastructure management. The successful implementation of this project showcases the potential of renewable energy sources and IoT technologies in creating practical and eco-friendly monitoring systems. As climate change becomes an increasingly pressing global concern, the insights and findings from this research contribute to the advancement of environmentally conscious technologies, empowering us to make informed decisions for a sustainable future.

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## BIOGRAPHIES

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