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# **CHALLENGE NAME:**

# **Next-Gen TinyML Smart Weather Station Challenge 2024**

**PROPOSAL**

**Team: AI4D**

**Team Members:**

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**February 2024**

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1. **Introduction**

In today's rapidly changing climate landscape, the need for accurate and reliable weather data has never been more pressing. Extreme weather events are becoming increasingly frequent and severe, posing significant challenges to communities worldwide. Smart weather stations offer a beacon of hope in this turbulent environment, providing real-time environmental data with unparalleled accuracy and reliability. By embracing tinyML, we are poised to revolutionize weather monitoring, enhancing community resilience and adaptation to climate change.

This challenge marks a pivotal moment in the evolution of weather monitoring, as we harness the transformative potential of Tiny Machine Learning (tinyML) technology. Our mission is to inspire and drive the development of smart weather stations that are not only innovative but also energy-efficient and cost-effective. This competition serves as a catalyst for creativity and collaboration, as we will design, build, and deploy weather stations capable of delivering real-time environmental data with unparalleled accuracy and reliability.

1. **Problem statement**

The main objective of this challenge is to develop weather stations that demonstrate exceptional qualities in terms of cost-effectiveness, energy efficiency, and mechanical durability. Our objective is to design systems that avoid the need of mechanical components while achieving high levels of accuracy in various weather conditions. We primarily concentrate on accurately measuring rainfall and wind using advanced machine learning techniques that are implemented at the edge with ultra-low power consumption. This weather station holds immense potential for agricultural applications, serving as a vital resource for farmers in making informed decisions regarding planting schedules. To facilitate our endeavors, we are privileged to access a comprehensive dataset provided by the Swiss Technology Innovation Center (CSEM), encompassing environmental sensor data and ground truth information from mechanical weather stations.

1. **Literature Review:**

For quite some time, accurate weather forecasting has been an essential application for the use of machine learning strategies. [1] [2] provided a noteworthy case study that took place in the state of Tennessee and focused on the application of machine learning algorithms to improve the accuracy of weather forecasts. The findings of this study highlight how important it is to make use of historical data on the weather and to apply machine learning algorithms in order to produce more accurate forecasting systems. The results of the study show that such approaches have the potential to optimize decision-making processes in a variety of fields, including agriculture and disaster management, among others.

An intelligent weather forecast system based on the Internet of Things (IoT) was proposed by [3][4]. This cutting-edge system exemplifies how the landscape of weather monitoring and prediction is constantly shifting, with an emphasis on the use of Internet of Things technology. In order to give accurate real-time forecasts, the research investigates how Internet of Things sensors and machine learning models can work together. The study sheds light on the significance of accurate data as well as the part that weather stations equipped with internet of things capabilities play in improving the standard of data collecting. This is in line with the goal of our proposal, which is to implement TinyML in intelligent weather stations in order to increase the accuracy of real-time weather predictions.

Recent developments in the field of weather monitoring and prediction have shown the possibility of merging machine learning and internet of things technologies. An Internet of Things (IoT)-assisted weather prediction and information monitoring scheme that is based on an intensive learning strategy was introduced by [5] This method represents the rising realization of the significant role that techniques that include intense machine learning play in weather forecasting. In addition, [4] [6]investigated the possibility of creating a weather monitoring and forecast system that is underpinned by machine learning and the internet of things. These studies highlight the revolutionary impact of merging sensors that are enabled by the internet of things (IoT) with machine learning algorithms in order to produce weather forecast systems that are more accurate and flexible. This type of research provides useful precedents for the integration of TinyML into smart weather stations, which is one of the main focuses of our proposal, which aims to improve the capabilities of real-time weather monitoring and forecasting.

1. **Methodology**

Our journey begins by leveraging the dataset provided by CSEM, enabling us to gather local rain and wind audio alongside other sensor measurements using embedded devices devoid of moving components. In parallel, we get on curating our own local datasets, enriching our training data to capture the diverse nuances of weather patterns. With data in hand, we dive into the development of the tinyML models tailored to extract rain and wind intensity from sound measurements. Our focus then shifts to optimizing these models, meticulously fine-tuning memory footprint and power consumption to meet the stringent demands of edge deployment. Armed with refined solutions, we venture into real-world deployment, rigorously assessing performance and reliability across varied environmental conditions. Finally, we document our journey, weaving together insights, challenges, and triumphs into a comprehensive report, complemented by compelling video demonstrations that showcase the ingenuity and efficacy of our prototypes.

**4.1 Edge Impulse**

Initially, historical weather data from a variety of sources will be compiled to serve as the basis for training machine learning models. Edge Impulse, which offers a user-friendly interface for data preprocessing, model development, and evaluation, will serve as the primary training platform. By leveraging key environmental parameters such as temperature, humidity, wind speed, and precipitation, we will use this platform to train machine learning models to recognize intricate weather patterns. The TinyML methodology will be adopted to facilitate the deployment of these compact models on microcontrollers with limited resources that are embedded in our intelligent weather stations.

Utilizing Edge Impulse serves the primary objective of our project, which is to improve the precision and timeliness of weather forecasts in an edge computing paradigm. By using Edge Impulse, we are able to efficiently process and analyze sensor data, resulting in the production of highly accurate predictive models. The TinyML framework assures that these models can be deployed directly onto the smart weather stations, enabling them to independently perform real-time inference in areas with limited connectivity. This strategy maximizes the system's autonomy and dependability while minimizing latency. In addition, we will include stringent testing and validation procedures to ensure the accuracy and dependability of the trained models under actual meteorological conditions.

The project will use the following phases;

**Data Pre-processing phase:** Once the data is collected, it will be pre-processed to ensure that the data is of high quality and ready for use in training the AI model. This will include tasks such as text cleaning, text normalization, and feature extraction.

**Model Training phase:** The pre-processed data will be used to train the AI-powered model using supervised and reinforcement learning techniques.

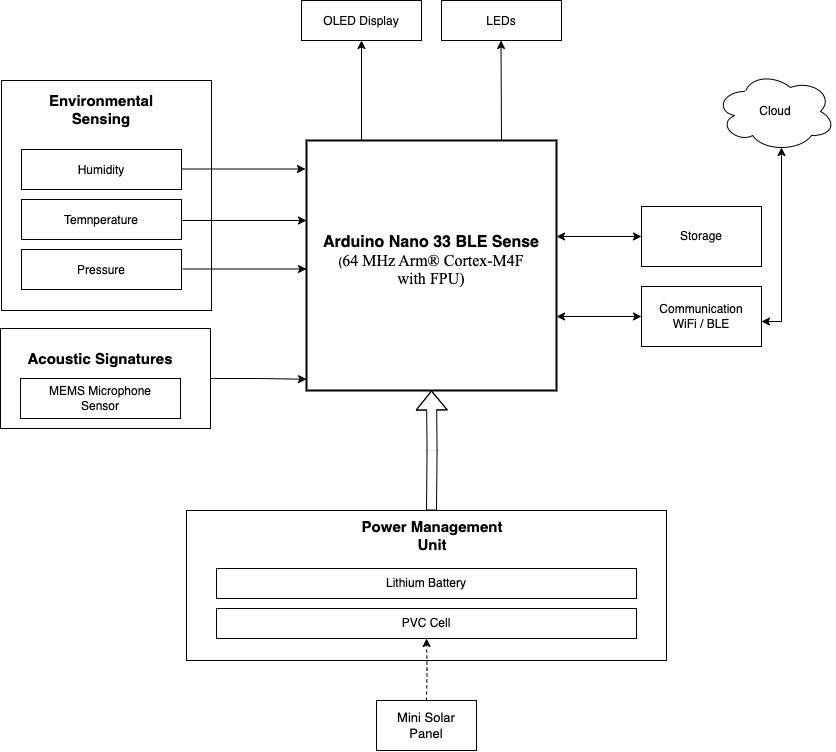
Model Validation phase: Once the model is trained, the study will conduct a rigorous validation process to ensure that the model is effective, reliable, and user-friendly. It will use a combination of quantitative and qualitative methods to evaluate the model's performance and gather feedback from users and mental health professionals. This will include tasks such as model testing, user testing, and expert review.

**Deployment phase:** After validating the model, the study will deploy the mental health conversation AI platform, making it accessible to Tanzanians through mobile devices. It will also provide training and support to mental health professionals who will be using the platform in their practice

**4.2 Hardware Design**

The hardware design for our smart weather application is a crucial ensuring the robust functionality and reliability of our system. To assemble the intelligent weather station, we will use a combination of specialized parts. The Arduino Nano 33 BLE Sense development board, a compact and feature-rich microcontroller with Bluetooth Low Energy (BLE) capabilities, will serve as the foundation of our design. This makes it suitable for data transmission and connectivity. In addition, Mini Solar, PV cell and Lithium battery (1S 3.7V 18650, 5200mAh) will serve as the main source of power, the ESP-01 ESP8266 (Espressif 8266EX) WIFI and LoRa Module SX1278 Modules will be integrated to facilitate internet connectivity and data transmission to remote servers, and SD Card for keeping data temporarily. To provide a user-friendly interface, a Grove - OLED Display 1.12'' V2 that enables real-time data visualization will be incorporated.

Multiple environmental sensors will be incorporated into the design to collect vital weather-related information. These sensors include the BMP380 for measuring atmospheric pressure, Adafruit AHT20 for measuring Humidity and Temperature, and the ADMP401 MEMS Microphone for monitoring sound and noise levels. Two LED status indicators will provide visual feedback on the operational status of the weather station. Through meticulous hardware selection and integration, we intend to create an all-encompassing and adaptable smart weather station capable of collecting diverse environmental data.



*Fig 3: Proposed Smart Weather Station Block Diagram*

1. **Bill of Materials**

The following is the list of materials with their relative prices per one smart weather device.

|  |  |  |  |
| --- | --- | --- | --- |
| S/N | Components | Quantity | Price (USD) |
| 1 | Arduino Nano 33 BLE Sense | 1 |  |
| 2 | BMP380 Barometric Pressure sensor module | 1 |  |
| 3 | ADMP401 MEMS Microphone | 1 |  |
| 4 | Adafruit AHT20 - Humidity and Temperature sensor module | 1 |  |
| 5 | ESP-01 ESP8266 (Espressif 8266EX) | 1 |  |
| 6 | LoRa Module SX1278 | 2 |  |
| 7 | Grove - OLED Display 1.12'' V2 | 1 |  |
| 8 | Mini Solar & Voltage regulator | 2 |  |
| 9 | Lithium battery (1S 3.7V 18650, 5200mAh) | 1 |  |
| 10 | Connecting cables | 20 |  |
| 11 | Prototype case | 1 |  |
| 12 |  |  |  |
| **Grand total** | | |  |

1. **Reference**

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[3] M. Sadhukhan, S. Dasgupta, and B. Indrajit, “An Intelligent Weather Prediction System Based on IOT,” Sep. 2021, pp. 528–532. doi: 10.1109/DevIC50843.2021.9455883.

[4] N. Kumar, S. Keshari, A. Rawat, A. Chaubey, and I. Dawar, “Weather Monitoring and Prediction System based on Machine Learning and IoT,” Sep. 2023, pp. 1–6. doi: 10.1109/ICAIA57370.2023.10169428.

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[6] K. Ioannou, D. Karampatzakis, P. Amanatidis, V. Aggelopoulos, and I. Karmiris, “Low-Cost Automatic Weather Stations in the Internet of Things,” *Information*, vol. 12, no. 4, 2021, doi: 10.3390/info12040146.