Cloud-Powered Agricultural and Weather Forecasts in Tanzania: Zeomancer's Microservices Approach

Katz School of Science and Health

Gagan Preet Singh and Karina Thapa, M.S. in Data Analytics and Visualization

Faculty Advisors: Andrew G. Catlin

ABSTRACT

In Tanzania, millions of subsistence farmers lack access to localized weather forecasts and agricultural best practices, which are crucial for optimal crop management. Zeomancer, an IoT device, collects data directly from the soil and receives weather data from external sources. Both data sets are stored, processed, and analyzed through an advanced weather forecasting model, all within a microservices-based, cloud-native architecture. The purpose of this project was to develop this microservices-based architecture to enhance the flexibility and reliability of the Zeomancer device to deliver real-time, localized weather and health forecasts and actionable agricultural and health insights directly to locals' mobile devices. This initiative is expected to facilitate more informed decision-making, maximize productivity, and boost crop yields by up to 40%, highlighting its potential to transform agricultural practices and increase food security and health in Tanzania.

INTRODUCTION

Tanzanian farmers frequently confront challenges due to unpredictable weather and insufficient access to agricultural data, complicating effective crop management (Rowe, 2023a).

Zeomancer utilizes tiny, sophisticated weather stations (IoT Regional Sensor Devices, Fig. 1) scattered across farms to collect weather data from the European Centre for Medium-Range Weather Forecasts and local ministries of health and agriculture. This data is swiftly and efficiently sent through a minimal-internet-use system (MQTT Broker) to a secure storage system (PostgreSQL Database). An advanced in-house AI weather forecast model then analyzes this data to predict future weather conditions accurately, coordinated by Node-RED, which ensures all parts of the system work together seamlessly.

The entire setup operates on a microservices architecture, allowing for easy updates, scalability to thousands of devices, robust data security, and cost efficiency, making advanced weather predictions accessible and sustainable for farmers.

The purpose of this project was to develop a containerized cloud-based architecture to enhance the flexibility and reliability of the Zeomancer device.

Figure 1. First Zeomancer prototype deployed at the University of Dar es Salaam demo farm with Dr. Moses Ismail and two crop scientists. This device also has a soil moisture sensor installed and is mounted on a water bottle. *Photo: Brian Rowe.*

APPROACH

Development of the containerized cloud-based architecture was designed to be **as cost-effective and efficient as possible**, supporting sustainable operations in resource-constrained environments (Rowe, 2023b).

The following steps were taken:

Data Collection and Storage:
- Identified secure, scalable, low-cost cloud object-type data storage solution – Amazon Web Services (AWS) S3.

Containerization of the Application:
Each system component functions as an independent microservice, allowing updates without system-wide disruptions:
- **MQTT Broker:** Utilized lightweight messaging protocol to transmit sensor data, ensuring low bandwidth consumption.
- **PostgreSQL Database:** Stored received data in a robust, scalable database system.
- **AI-Enhanced Weather Forecasting:** Applied machine learning models to predict weather conditions accurately.
- **Node-RED:** Implemented for integrating and visualizing different system components and managing data flows effectively.

Scalability:
- Used Docker containers managed by cloud cluster nodes, ensuring seamless performance scaling and efficient scaling from 10 to over 1000 IoT devices.

Privacy:
- Implemented powerful services to ensure data isolation and protect privacy.

OUTCOMES

Cloud Architecture Concept:

- A full cloud architecture concept was developed for the Zeomancer device.
- The architecture is under review and modification by the Zeomancer team.
- Figure 2 illustrates the components of the Zeomancer cloud architecture interconnected within the Amazon Web Services (AWS) cloud environment.

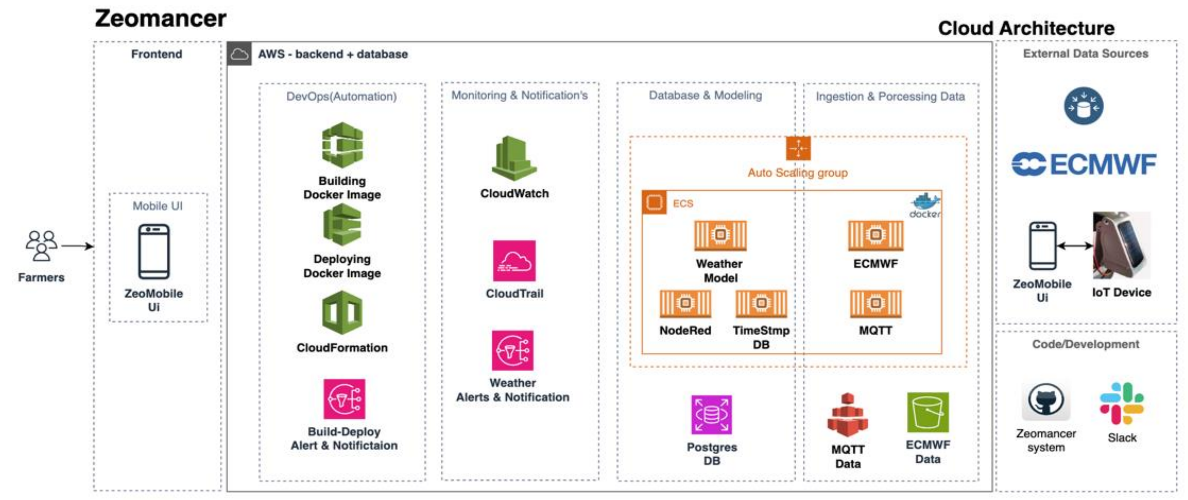

Figure 2. Zeomancer Cloud Architecture Conceptual Diagram

Key Features:

- **AWS Elastic Container Services (ECS) with Fargate:** Managing and scaling containerized applications without having to manage servers or clusters.
- **AI-Weather Forecasting and Amazon Simple Notification Service (SNS):** Processing data and sending notifications, ensuring real-time updates are delivered efficiently.

CONCLUSIONS & RECOMMENDATIONS

The Zeomancer project demonstrates how integrating microservices with cloud can offer scalable, efficient solutions tailored to local needs (Rowe, 2023c). This model not only supports agricultural development but also serves as a blueprint for similar initiatives in other sectors and regions like health and science.

Expected outcomes for locals:
- **Enhanced Decision Making:** Access to real-time data allows farmers to make informed decisions about planting, harvesting, irrigation, pest control, etc.
- **Increased Crop Yields:** Better agricultural practices, informed by accurate forecasts, potentially increase yields up to 40%.
- **Risk Reduction:** Timely weather and health updates help locals take preventive actions.

Recommendations:
- Expand the IoT network to cover more regions and gather more granular data.
- Develop community training programs to help farmers maximize the benefits of the technology.
- Incorporate additional data sources and analytics features to provide more comprehensive advice.

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