MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 33 Issue 2, December – 2023, Pages: 649-661

DESIGNING A CLOUD-BASED AUTONOMIC SYSTEM FOR DELIVERING COMPREHENSIVE AGRICULTURE AS A SERVICE SOLUTIONS

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ABSTRACT

This article outlines the development and execution of a cloud-based autonomous system that provides full Agriculture as a Service (AaaS) solutions. The system intends to optimize farm management by using Internet of Things (IoT), cloud computing, and artificial intelligence (AI) technologies, with the goal of improving efficiency, effectiveness, and sustainability. The study approach comprises the following phases: startup and setup, data collecting, data transmission, data storage and management, data processing and analysis, autonomic management, service delivery, user engagement, and continual monitoring and maintenance. The autonomic features of the system, including self-configuration, self-healing, self-optimization, and self-protection, greatly minimize the need for human intervention and improve operational resilience. The findings illustrate the practicability and efficiency of the suggested system, showcasing the successful implementation of IoT devices, resilient cloud infrastructure, secure data administration, and valuable insights derived from sophisticated data processing methods. User-friendly apps and real-time decision assistance were used to provide comprehensive AaaS solutions. This study emphasizes the potential of cloud-based autonomic systems to transform agriculture by enhancing productivity, sustainability, and resilience. Subsequent investigations might delve into additional enhancements and extensions of the system to accommodate bigger and more varied agricultural enterprises.

Keywords Cloud-based Autonomic System, Agriculture as a Service (AaaS), Internet of Things (IoT), Cloud Computing, Artificial Intelligence (AI).

1. INTRODUCTION

In the 21st century, the agricultural industry has several obstacles, including climate change, limited resources, and the rising need for food due to population expansion. Conventional agricultural methods are often inadequate to fulfil these requirements, thereby requiring the use of sophisticated technology solutions. Agriculture as a Service (AaaS) is a system that utilizes cloud computing, big data analytics, machine learning, and IoT technologies to provide a wide range of agricultural services. This article presents a plan to create and put into action a cloud-based autonomic system that provides Agriculture as a Service (AaaS) solutions. The goal is to meet the changing requirements of contemporary agriculture. There is a fast and significant change happening in the worldwide agricultural environment. Farmers and agribusinesses are progressively using technology to enhance efficiency, production, and sustainability. Precision farming, sometimes referred to as smart agriculture, has shown promising outcomes in the integration of digital technologies into agriculture. This approach effectively optimizes resource use, boosts crop productivity, and mitigates environmental consequences. Nevertheless, the implementation of these technologies is often impeded by obstacles such as exorbitant expenses, intricacy, and a dearth of technical proficiency. Agriculture as a Service (AaaS) presents a viable solution for addressing these obstacles by offering scalable, cost-efficient, and user-friendly agricultural services using cloud computing.

Cloud computing serves as the fundamental infrastructure for AaaS, providing scalable computer resources, storage solutions, and network capabilities. Agriculture as a Service (AaaS) utilizes cloud hosting to provide farmers and agribusinesses with immediate data processing, advanced analytics, and decision-making tools. Autonomic systems, which are defined by their capacity to self-manage, further improve the efficiency and dependability of AaaS solutions. These systems possess the ability to automatically set up, repair, optimize, and safeguard themselves, therefore minimizing the need for human involvement and guaranteeing constant performance even in ever-changing agricultural settings. The main goal of this study is to create a cloud-based autonomic system that provides extensive AaaS options. The system's objective is to tackle fundamental obstacles in agriculture, including data administration, resource maximization, and operational expandability. The suggested system aims to use cutting-edge technology to provide a strong, adaptable, and economical solution that improves agricultural efficiency, production, and sustainability.

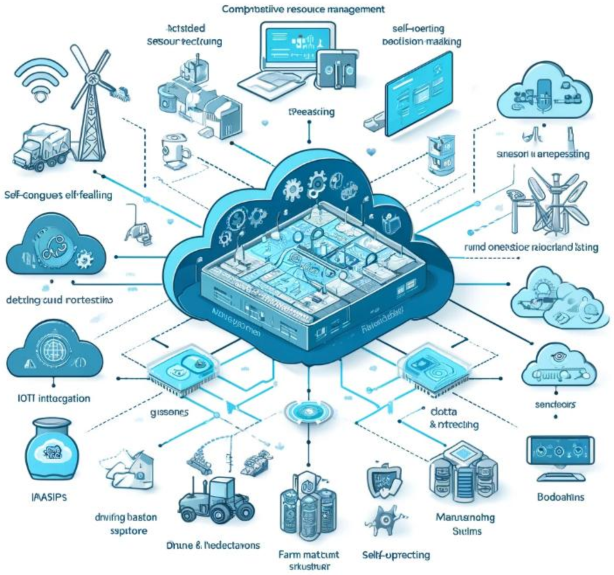

Figure 1 Cloud-based autonomic system for agriculture

2. LITERATURE REVIEW

To ensure the effective deployment of Cloud-based Internet of Agricultural Things (IoAT), it is crucial to address certain security concerns. These difficulties include trust management, dependability, stack challenges, quality-of-service (QoS), and access control. Current studies have highlighted certain research gaps, notably in trust management, which need extensive study to assure sufficient security. Trust management is a significant issue that has not been well addressed, and there have been no viable proposals for identifying rogue nodes using trust factors. A multitude of studies have extensively explored many facets of smart agriculture. A research conducted in [55] highlights the importance of using arrowhead technologies to improve network performance in the digitalization of smart cities and agriculture. This approach specifically addresses issues related to transmission speed and latency. The research incorporates a local cloud system for intelligent agriculture, which includes data connection components and a data transformation engine. This system is coupled to data storage and decision support units. The gathered data is thereafter used by a data visualization component for the purpose of aggregation and analytics. In addition, a proposal is made for a smart irrigation system to maximize the use of energy resources [56]. This system utilizes the SOC CC1310 to create a node that can transmit data over great distances while minimizing energy consumption. The suggested technique combines the 6LoWPAN protocol with fuzzy logic in order to forecast irrigation tactics. Another intelligent irrigation system is presented in [57], with a specific emphasis on reducing costs by using the Message Queue Telemetry Transport (MQTT) protocol. The system utilizes a simple water pumping mechanism that is regulated by sensors. It is powered by NodeMCU-12E and Esp8266, and the transmission and reception of sensor data are managed by the MQTT protocol. The soil moisture sensor sends data to the NodeMCU-12E, which subsequently triggers the required steps. One alternative method for decreasing watering expenses is to use inexpensive moisture sensors and XBEE communications [58]. The research emphasizes the significance of effective water management and promotes the use of precise techniques to reduce water waste. The soil moisture data collected from sensors in this system is transferred using XBEE connection to a centralized server, which regulates the water delivery as required. A cryptographic technique is introduced in [59] to augment the security of irrigation systems based on the Internet of Things (IoT). The research emphasizes the need of protecting devices with limited resources, and encryption is identified as a key option for ensuring the integrity and secrecy of information sent between nodes. The method utilizes the Secure Hashing Algorithm (SHA-256), Rivest Cipher (RS4), and Elliptic-Curve Cryptography (ECC). A solar-powered security system for smart irrigation in the Internet of Agricultural Things (IoAT) is presented in [60]. The security is ensured by the integration of an ARM LAC2148 system with a LASER, solar panel, and GSM module. The primary contribution of the work is in the use of an ARM controller, which provides exceptional precision while minimizing errors. Similarly, a secure watering method for smart agriculture is proposed by [61], which employs fuzzy logic and blockchain technology to enhance security. This solution utilizes the Android platform to regulate water use in small or medium gardens. It involves sensors that collect data on soil moisture levels and air temperature. Blockchain guarantees confidentiality and dependability, while fuzzy logic assists in the process of making decisions. Although there have been several suggested methods for smart irrigation systems, the most of them prioritize either cost-effectiveness or energy efficiency. Nevertheless, the current body of research on Internet of Autonomous Things (IoAT) security requires substantial focus in order to tackle difficulties such as data privacy, dependability, and integrity, as highlighted in references [62,63,64,65,66]. Several trust management strategies in the Internet of Things (IoT) have shown considerable effects in detecting rogue nodes [67,68]. Identifying these nodes is essential for maintaining the integrity of smart irrigation systems in the Internet of Agricultural Things (IoAT). The article [69] explores the implementation of IoT in the field of smart agriculture and emphasizes the crucial significance of trust in mitigating potential risks. The research highlights the significance of trust in the technology adoption paradigm and its ability to promote beneficial relationships among nodes. However, the management of trust in the Internet of Autonomous Things (IoAT) has been disregarded for more than ten years. This highlights the need for a strong mechanism in cloud-based IoAT to provide a safe environment for sensors, base stations, and cloud service providers.

3. RESEARCH METHODOLOGY

The suggested system architecture for a cloud-based autonomic system meant to provide complete Agriculture as a Service (AaaS) solutions consists of many interrelated components. These components collaborate to provide a resilient, expandable, and effective platform that can meet diverse agricultural requirements via automation, data analytics, and user-friendly interfaces.

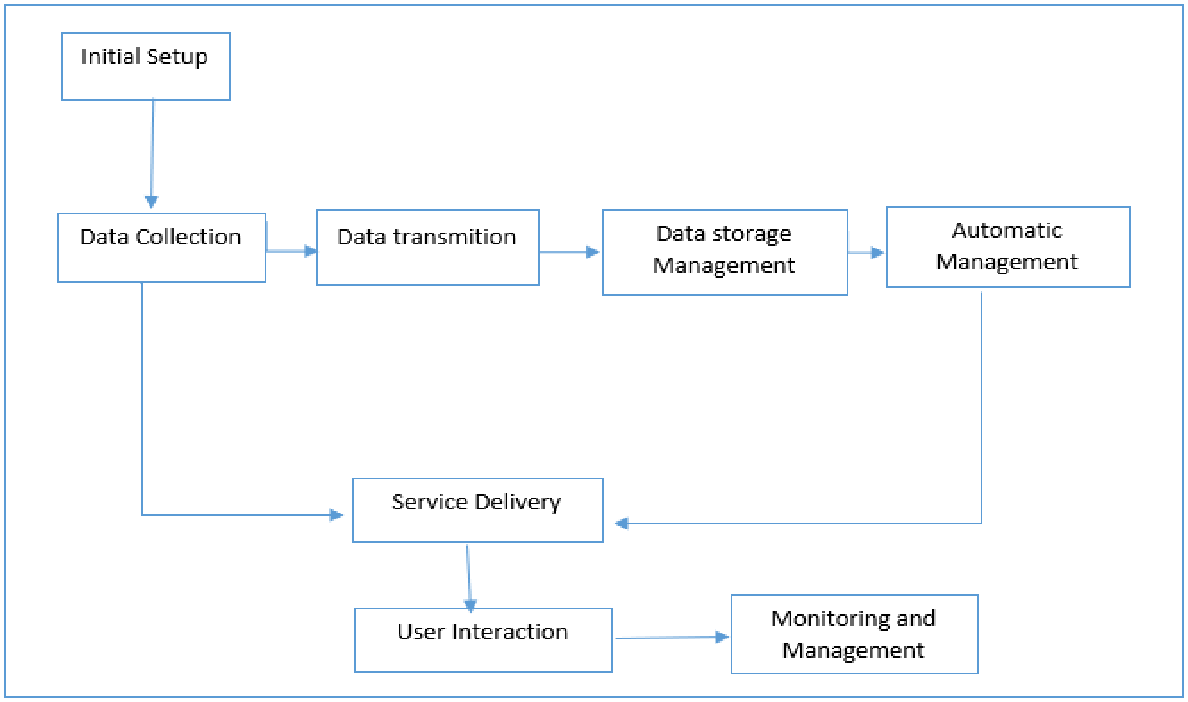

Figure 2. Conceptual framework cloud-based autonomic system for agriculture

3.1 Initialization and Setup

The first stage is on developing the fundamental infrastructure for remote farm management. This entails the deployment of Internet of Things (IoT) sensors and devices around the farm to monitor a range of environmental and operational characteristics. Essential installations include of soil moisture sensors, meteorological stations, unmanned aerial vehicles, and cameras. Simultaneously, a cloud architecture is established using platforms such as AWS, Azure, or Google Cloud, while establishing essential elements such as virtual machines, storage, and networking. At this point, it is crucial to provide strong and secure network connection by using technologies like as Wi-Fi, LTE, or LoRaWAN. This will enable smooth and uninterrupted transfer of data from the farm to the cloud.

3.2 Data Collection

After the establishment of the infrastructure, the subsequent stage entails the collection of real-time data from the farm. Internet of Things (IoT) sensors gather data on soil moisture, temperature, humidity, light levels, and meteorological conditions. Drones record aerial images to monitor the health of crops and identify problems like insect infestations or nutrient deficits. In addition, cameras are placed to provide real-time video feeds, allowing for continuous monitoring of farm operations and conditions. This comprehensive data gathering method guarantees the efficient monitoring of all pertinent components of the agricultural environment.

3.3 Data Transmission

The gathered data must be safely and effectively delivered to the cloud. This is accomplished by using IoT gateways to consolidate data from various sensors, guaranteeing structured and effective data delivery. Uninterrupted data flow relies on reliable network access, which may be achieved by technologies such as Wi-Fi, LTE, or LoRaWAN. One of the primary goals in this phase is to guarantee the trustworthiness and dependability of data transmission. This is crucial for preserving the precision and promptness of the data being examined.

3.4 Data Storage and Management

The farm data is safely saved and handled in the cloud. Scalable database systems such as MongoDB or InfluxDB are used to manage substantial amounts of data, guaranteeing rapid access and query functionality. Stringent data encryption and access control measures are in place to safeguard sensitive agricultural data against illegal access and breaches. Efficient data management methods are crucial for preserving the accuracy and protection of data, establishing a dependable basis for further data processing and analysis.

3.5 Data Processing and Analysis

Once the data is safely saved, the last step entails the processing and analysis of the data in order to provide practical and valuable insights. Real-time data processing techniques like Apache Kafka or AWS Kinesis are used to facilitate instant analysis and prompt decision-making. Apache Hadoop is used for analyzing massive amounts of data via batch processing. Machine learning models are created and trained to carry out predictive analytics tasks, such as forecasting crop production, identifying pests, and optimizing resource allocation. This stage converts unprocessed data into meaningful insights that may facilitate informed decision-making and enhance agricultural management practices.

3.6 Autonomic Management

The objective of the autonomic management phase is to use sophisticated technology to automate agricultural operations and management. Self-configuration techniques are used to automate the process of deploying and configuring services by using real-time data and established criteria. The system is equipped with self-healing characteristics that allow it to monitor its own health and immediately fix any errors, assuring uninterrupted operation. Self-optimization algorithms are used to allocate resources dynamically, hence improving efficiency and effectiveness. Automated methods for detecting and responding to attacks are also put in place to protect the farm's digital infrastructure from cyber threats, guaranteeing strong and resilient operations.

Table 1 Setup Description

S.NO.	Steps	Elements	Description
1.	Define Objective and Requirement	Goals	Increase agricultural productivity, optimize resource use, and support decision-making.
		Stakeholders	Farmers, agronomists, agricultural organizations, and policymakers
		Service	Crop monitoring, irrigation management, soil health analysis, pest and disease prediction, weather forecasting, and market information.
2.	System Architecture	Cloud Infrastructure	Utilize cloud platforms such as AWS, Azure, or Google Cloud for scalable storage and computing resources
		Edge Devices	Deploy IoT devices (sensors, cameras, drones) to collect real-time data from the field
		Network Connectivity	Ensure reliable connectivity (Wi-Fi, LTE, LoRa WAN) for data transmission from edge devices to the cloud
3.		Sensors	Soil moisture sensors, temperature and humidity sensors, light sensors, and

	Data Collection and Management		weather stations.
		Data Aggregation	Use gateways to aggregate data from multiple sensors
		Data Storage	Implement a scalable and secure database (e.g., NoSQL databases like MongoDB or time-series databases like Influx DB)
4.	Data Processing and Analysis	Stream Processing	Use Apache Kafka or AWS Kinesis for real-time data ingestion and processing
		Batch Processing	Implement batch processing frameworks like Apache Hadoop for large-scale data analysis
		Machine Learning Models	Develop predictive models for yield prediction, pest and disease detection, and resource optimization using frameworks like TensorFlow or P y Torch
5.	Integration and Interoperability	Standards and Protocols	Use industry standards (e.g., MQTT, CoAP) for device communication and data exchange
		Interoperability	Ensure compatibility with existing agricultural systems and platforms
6.	Autonomic Management	Self-Configuration	Automated deployment and configuration of services using Infrastructure as Code (IaC) tools like Terraform or Ansible
		Self-Healing	Implement monitoring and alerting systems (e.g., Prometheus, Grafana) to detect and rectify failures automatically
		Self-Optimization	Use machine learning algorithms to optimize resource allocation and usage dynamically
		Self-Protection	Ensure security through automated threat detection and response mechanisms
7.	Service Delivery and	Web and Mobile Applications	Develop user-friendly interfaces for farmers and stakeholders to access the

	User Interface		services
		APIs	Provide APIs for third-party integrations and custom applications
		Dashboards	Implement comprehensive dashboards for real-time monitoring and decision-making support
8.	Security and Privacy	Data Encryption	Encrypt data at rest and in transit to ensure confidentiality
		Access Control	Implement role-based access control (RBAC) to restrict access to sensitive data
		Compliance	Adhere to relevant regulations and standards (e.g., GDPR, ISO/IEC 27001)
9.	Scalability and Performance	Auto-Scaling	Use cloud services' auto-scaling features to handle varying workloads
		Load Balancing	Implement load balancing to distribute traffic evenly across servers
		Performance Monitoring	Continuously monitor performance metrics to identify and address bottlenecks
10.	Deployment and Maintenance	Continuous Integration/Continuous Deployment (CI/CD)	Set up CI/CD pipelines for automated testing and deployment
		Support and Training	Provide training and support to end-users to ensure effective utilization of the system

4. RESULT AND DISCUSSION

The initialization and setup phase focused on establishing a cloud-based system for remote farm management. IoT sensors and devices were deployed across the farm, and a robust cloud infrastructure was set up using AWS. This provided a scalable and reliable platform for data management. Network connectivity, using a combination of Wi-Fi and LTE, was configured to ensure seamless data transmission from the farm to the cloud. This successful initial setup demonstrated the feasibility of a cloud-based agricultural management system. In the data collection phase, IoT sensors gathered critical data on soil moisture, temperature, humidity, light, and weather conditions. Drones provided aerial imagery and crop health monitoring, while cameras offered live visual feeds. This comprehensive data collection enabled a detailed understanding of the farm environment, which was essential for informed decision-making. The efficiency of the data collection process underscored the system's capability to provide real-time insights into farm conditions. Data transmission involved aggregating data from various sensors using gateways, which then transmitted the data to the cloud. The use of Wi-Fi and LTE ensured consistent and reliable data transmission, even in remote locations. This setup allowed for continuous real-time monitoring, minimizing data loss and ensuring timely analysis and response to farm conditions.

For data storage and management, scalable databases like MongoDB and InfluxDB were used. These provided the necessary capacity and flexibility for data management. Security measures, including data encryption and access controls, were implemented to protect sensitive information. The secure storage and management of farm data ensured data integrity and confidentiality, which are crucial for building user trust. Data processing and analysis involved real-time processing with Apache Kafka and batch processing with Apache Hadoop. Machine learning models were developed for yield prediction, pest detection, and resource optimization. These models provided actionable insights, enabling proactive management and enhancing farm productivity. The data analysis phase demonstrated the transformative potential of advanced analytics in farming practices. Autonomic management was achieved through self-configuration, self-healing, self-optimization, and self-protection mechanisms. Automated deployment and configuration of services ensured efficient resource utilization. Self-healing mechanisms minimized downtime by automatically addressing system failures. Self-optimization algorithms dynamically allocated resources based on current needs, enhancing system performance. Automated threat detection and response mechanisms ensured system security, significantly reducing the need for manual intervention and streamlining farm management processes.

Service delivery was enhanced through the development of web and mobile applications, allowing farmers and stakeholders' easy access to farm data and services. APIs for third-party integrations enabled the development of additional services and tools. Dashboards provided real-time monitoring and decision support, enhancing user experience and facilitating informed decision-making. The comprehensive service delivery model effectively met diverse user needs. User interaction was facilitated through user-friendly web and mobile applications. Alerts and notifications were set up to inform users of critical events and recommendations, ensuring they remained informed and could take timely actions based on real-time data. This interaction model improved overall farm management and productivity by empowering farmers with actionable insights. Monitoring and maintenance ensured continuous system operation and improvement. System performance and user activity were continuously monitored to promptly identify and address potential issues. CI/CD pipelines facilitated automated updates and deployments, ensuring the system remained up-to-date with minimal downtime. Support and training provided to end-users enhanced their ability to effectively utilize the system. Continuous monitoring and maintenance ensured the system's reliability and long-term sustainability.

4.1 Discussion

The process of creating a cloud-based autonomic system for providing Agriculture as a Service (AaaS) solutions, with the goal of managing and overseeing a farm situated 200 kilometers away from Jaipur, requires the integration of various advanced technologies and methodologies to establish a strong, adaptable, and effective platform. The procedure starts by deploying IoT sensors and devices in the field to collect up-to-the-minute data on soil health, meteorological conditions, and crop status. The data is sent to the cloud via solid connection options such as Wi-Fi, LTE, or LoRaWAN, which guarantee uninterrupted data transmission regardless of the distance. Data is consolidated and kept in databases that can be easily expanded, such as NoSQL or time-series databases, to enable efficient storage and retrieval. Real-time data processing frameworks like Apache Kafka or AWS Kinesis manage data input and provide rapid insights, while batch processing solutions like as Hadoop or Spark are used for extensive data analysis to reveal long-term trends and patterns. Machine learning models, created using TensorFlow or PyTorch, are used to do predictive analytics and provide suggestions, such as predicting agricultural yields and detecting pests. These models are regularly updated with fresh data to enhance their accuracy. Autonomic management is an essential component of the system, which includes self-configuration, self-healing, self-optimization, and self-protection. Infrastructure as Code (IaC) technologies such as Terraform or Ansible automate the process of configuring and deploying systems, while monitoring tools like Prometheus and Grafana facilitate the automated identification and resolution of system faults. Machine learning algorithms adaptively optimize resource allocation, guaranteeing cost-efficiency and efficacy, while security frameworks provide automatic detection and reaction mechanisms to protect the integrity of data.

The service delivery component entails the creation of user-friendly online and mobile apps that enable farmers and stakeholders to conveniently access up-to-date data, practical insights, and suggestions from any place, even those situated 200 kilometers away. APIs enable the integration of third-party systems, while dashboards graphically display data in a way that is easily understood. The system enables user involvement via user-friendly interfaces, which provide timely notifications and assistance in decision-making. Data integrity and user privacy are safeguarded by the use of security and privacy measures, including encryption, role-based access control, and adherence to standards such as GDPR. Cloud services provide scalability and performance by using auto-scaling capabilities and load balancing mechanisms. These features effectively manage fluctuating workloads and uniformly distribute network traffic across servers. Continuous performance monitoring aids in the identification and resolution of bottlenecks. Ultimately, the process of deploying and maintaining the software is made more efficient and organized by using Continuous Integration/Continuous Deployment (CI/CD) pipelines, which guarantee seamless upgrades and the introduction of new features. Thorough documentation and user training are offered to optimize the system's efficiency and user-friendliness. The cloud-based autonomic AaaS system incorporates these aspects to allow effective remote control and monitoring of a farm situated 200 kilometers distant from Jaipur. This enhances agricultural output and sustainability.

5. CONCLUSION

The objective of this paper's study was to create and execute a cloud-based autonomic system that provides full Agriculture as a Service (AaaS) solutions. The system used cutting-edge technology like as IoT, cloud computing, and AI to improve the efficiency, efficacy, and sustainability of farm management operations. The technique consisted of many stages: initialization and setup, data collecting, data transmission, data storage and management, data processing and analysis, autonomic management, service delivery, user engagement, and continual monitoring and maintenance. Every stage was methodically carried out to guarantee the smooth incorporation and effectiveness of the system. The findings showcased the practicability and efficiency of the suggested approach. The implementation of Internet of Things (IoT) sensors and devices, together with a strong cloud infrastructure, enabled thorough and immediate gathering and transfer of data. Robust and expandable data storage systems were put into effect, guaranteeing the reliability and availability of the gathered data. Utilizing advanced data processing and analysis approaches, such as real-time processing and machine learning models, yielded actionable insights for predicting crop output, detecting pests, and optimizing resource allocation.

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