Enhancing Irrigation Systems in Edge-enabled IOT Environments

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***Abstract*—Agriculture is an important sector in human life nowadays. It is expected that population reach to 10 billion by 2050. Providing enough food for this vast population will be a significant challenge. Classical methods of agriculture cannot meet these demands. Instead, smart farming techniques which are a combination of the Internet of Things and machine learning should be relied upon. Irrigation is one particular sector within modern agriculture, but only 10% of the research has focused on water management, and more than 61% of their research has been focused on crop management. Consequently, it is imperative to contemplate the adoption of technological advancements for the enhancement of irrigation management practice. While good irrigation management has a direct impact on crop management, we manage irrigation crops using Internet of Things devices and sensors. Our agricultural field is equipped with a network of IOT devices capable of gathering and transmitting real-time information regarding temperature, humidity, illumination levels, and soil moisture levels to an edge server. This server is then responsible for making autonomous decisions about the irrigation of crops based on predefined parameters in real-time. All the sensors' data will be sent to the farmer's mobile to know the farmer that the irrigation can be happening or not.**

***Keywords*— Internet of things, Edge Server, Smart Irrigation.**

I. INTRODUCTION

Agriculture constitutes a significant share of the Gross Domestic Product (GDP) in countries at various stages of development. Projections indicate that by 2050, the global population is expected to reach approximately 10 billion [11]. To consistently meet the dietary needs of this expanding population, it is essential to boost food production by at least 70% [16]. There is a noticeable gap in the advancement of smart farming techniques, highlighting the urgent need for further research and development (R&D) to fulfill the objectives of sustainable farming [17]. Irrigation is one particular sector within agriculture that demands significant attention, as it accounts for 70% of the world's freshwater usage [18]. Traditional irrigation techniques are not compatible with today's human development. While, water management play an important role in crop management only 10% of the research has focused on water management, and more than 61% of their research has been focused on crop management [1]. Consequently, it is imperative to contemplate the adoption of technological advancements for the enhancement of irrigation management practices. This approach is anticipated to yield a significant influence on augmenting agricultural production while concurrently diminishing water usage [14]. Although many automated water management systems have been designed using electrical devices. But farmers need system which is the most cost-effective. IoT systems are so quick and efficient. As a result, IoT technology will be the best option for implementation of water management systems [12],[13]. In the context of our scholarly inquiry, we have engaged in the development of an advanced irrigation mechanism, utilizing the Internet of Things (IoT) within an Edge Server. This server is tasked with the acquisition of data transmitted from the IoT-enabled devices. The dataset encompasses a range of environmental factors including temperature, humidity, and illumination levels, and ground parameter including soil moisture content. The proposed system is real time and after the reception of this data, employing a series of conditional statements to determine the appropriateness of initiating irrigation processes operates in.

We consider this conditional statement based on situation of environment such as temperature, humidity, soil moister sensor upon reception of data from the agricultural sensors. The Internet of Things receives data from the sensors and transmits the information to the edge server, utilizing the C programming language. With in the server's programming, we have implemented protocols to abstain from irrigation activities during daylight hours. Furthermore, the system is designed to refrain from irrigation if the temperature within the agricultural domain is above the standard threshold for the cultivated crops. In the absence of these conditions, the server initiates the irrigation process at a designated optimal time and subsequently notifies the farmer via Short Message Service (SMS) before the commencement of irrigation activities. A distinguishing aspect of this research involves the storage of

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data on edge servers and the execution of conditional statement therein to formulate an intricate yet fundamental irrigation timetable for crop watering. As a result, decision latency in the irrigation system will be reduced. This approach facilitates a proactive response to real-time data, obviating the necessity for data transmission to cloud services for processing and irrigation decision-making. The Edge-enabled proposed system saves money on equipment and energy by allowing farmers to optimizing water usage and increasing yields without manual procedures.

This Paper is structured as follows. Section 2 related work. Section 3 introduces our proposed method, encompassing its implementation and advantages. Section 4 concludes with summary of the experiments and their corresponding results

II. RELATED WORK

This section provides an in-depth analysis of the current state of academic inquiry regarding intelligent irrigation systems, which utilizing the Internet of Things technologies within the agricultural domain. Throughout this discourse, we will reference several pertinent studies that contribute to our understanding of this subject matter. Asmae et al. [2] proposed an automated system includes soil moisture, temperature, and water flow sensors integrated with an Arduino microcontroller and pumping motor components. This setup enables the system to autonomously regulate the water pumping motor based on soil moisture levels and temperature. The sensors strategically placed within the plant's root zone provide real-time data, allowing the system to activate or deactivate the pumping motor as needed. Mayarui et al. [3] presented an irrigation infrastructure necessitating minimal human involvement, ensuring environmental stability, and utilizing non-conventional energy sources. It integrates hardware and software interfaces, offering a user-friendly mobile device interface. Jolan et al. [4] proposed IoT system for monitoring Eruca sativa growth and development under various lighting conditions. Khondget et al.[5] presented an IoT and cloud-based smart irrigation system to predict optimal water usage for specific crops, enabling significant conservation of freshwater resources.Ismael et al.[6] proposed a sensor-equipped system, comprising soil moisture and temperature/humidity sensors, is integrated with an Arduino Uno microcontroller, GSM/Wi-Fi module, and relay switch to control a water pump. The system autonomously regulates the water pump based on soil conditions sensed by the sensors, while transmitting farm data to the farmer via GSM/Wi-Fi connectivity. Vinay et al.[7] proposed IoT-driven smart agriculture using devices like Arduino and Raspberry Pi for efficient data processing and irrigation, collection, and crop yield control. Aim to implement a system for automated irrigation, and data collection and reduce manual labor, enhancing productivity. Sumathi et al. [8] a proposed system that farmers will be able to monitor and control irrigation by using a smartphone or PC from anywhere at any time, to monitor the water parameters and reduce their efforts also to optimize the use of water. Abidkadir et al. [9] presented a smart irrigation system, revolutionizing modern agriculture by enhancing water management, crop productivity, and sustainability through advanced technology and data-driven control. Subudhi et al. [10] proposed a NodeMCU-based smart farming system. The system is designed using Blynk and Thing Speak cloud for an automated irrigation system. Statistics of different parameters such as temperature, rain, moisture content in the air as well as soil and motion are collected using Thing Speak Cloud using the NodeMCU. Tace et al. [15] introduced an intelligent and adaptable irrigation methodology characterized by minimal resource usage and cost-effectiveness, suitable for diverse agricultural settings. The methodology hinges on the utilization of a cloud-based algorithm tailored for enhancing agricultural practices. Huque et al. [19] proposed an Internet of Things (IoT)-enabled intelligent irrigation framework employing cloud computing infrastructure, a diverse array of sensors, and a microcontroller. The primary objective of this system is to streamline the monitoring of agriculture field conditions. Thaer et al. [20] presented a conceptual framework for intelligent irrigation leveraging Wireless Sensor Network infrastructure integrated with Internet of Things cloud-based services. This framework comprises three primary constituents: the WSN, responsible for data collection, the control unit for decision-making, and cloud services for data processing and management.

The preceding investigations have delineated systems with a focus on data processing occurring within the microcontroller, facilitating the implementation of irrigation decisions. In contrast, our system's design entails the transmission of data to an edge server, facilitating real-time irrigation decision-making.

III. PROPOSED METHODOLOGY

This study describes the creation of an Edge-enabled smart agricultural system that uses a range of variables, including temperature, humidity, illumination levels, and soil moisture to calculate the amount of water that crops would require. It is the goal of the implementation to show off intelligent capabilities so that watering decisions may be made based on constant monitoring of field conditions. Figure 2 depicts the mechanism in action.

- Data Collection IoT sensors will be deployed across the agricultural field to collect data on soil moisture levels, temperature, humidity, and other relevant parameters. The collected data will be transmitted to the Edge computing nodes using Ethernet shield for processing.

- Edge Computing (edge Server)

Edge computing nodes will be strategically placed to enable real-time data processing. This layer will handle data preprocessing, feature extraction, and the initial stages of ML model inference, reducing the need for centralized cloud processing.

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Figur-1 Edge Server

In the depicted scenario In the Figure-1, after the acquisition of data concerning temperature and humidity, soil moisture, and light intensity within the field by the Internet of Things (IoT) devices, the data is transmitted to the edge server, Formulates a comprehensive irrigation timetable for agricultural fields. In our analysis, we consider a conditional statement that responds to various environmental factors, including temperature, humidity, and soil moisture, as detected by agricultural sensors. These sensors transmit data to the Internet of Things (IoT) infrastructure, which then relays the information to an edge server programmed in C. Within this server, specific protocols are established to prevent irrigation during daylight hours. Additionally, the system is configured to abstain from irrigation if the ambient temperature exceeds the optimal threshold for the crops being cultivated. In the absence of these inhibiting conditions, the server triggers the irrigation process at a predetermined optimal time and subsequently sends a Short Message Service (SMS) notification to the farmer prior to the onset of irrigation activities.

System Integration The developed system design models and Edge computing capabilities will be integrated into the existing IoT-based irrigation system, creating a comprehensive and adaptive solution.

Figure-2 System Design

The diagram provided in Figure-2 depicts the architectural blueprint of our system, delineating its key components and functionalities. At its core, the system revolves around a Raspberry Pi serving as the focal point, operating as an edge server tasked with data reception and processing. This Raspberry Pi, functioning as an edge server, orchestrates the decision-making process regarding irrigation activities, generating predictions at intervals of ten minutes. Concurrently, it maintains a repository of our dataset within a MySQL database, ensuring data integrity and accessibility.

Complementing the Raspberry Pi's functionalities, the system incorporates Internet of Things (IoT) devices, specifically Arduino Uno microcontrollers strategically positioned across the agricultural expanse. Leveraging the ubiquity and versatility of Arduino Uno, these devices facilitate data aggregation from disparate points within the farm, transmitting it seamlessly to the edge server. This distributed data acquisition framework enables comprehensive monitoring and analysis of environmental conditions critical for informed irrigation decisions.

Integral to the IoT ecosystem are the array of sensors deployed throughout the farm terrain. These sensors encompass a suite of parameters including temperature, humidity, soil moisture, and light intensity. Strategically situated across various locations within the farm, these sensors continuously gather pertinent environmental data, transmitting it to the Arduino Uno units. Subsequently, this sensory data is relayed to the edge server, furnishing real-time insights crucial for precision agriculture practices.

Moreover, the system is fortified with a proactive notification mechanism to alert the farmer in exigent situations. Leveraging SMS communication, the edge server promptly notifies the farmer of any emergent issues or anomalies detected within the farm premises, enabling timely intervention and mitigation measures. In summary, the elucidated system architecture embodies a sophisticated amalgamation of hardware components, IoT devices, and data processing infrastructure, culminating in an integrated framework designed to optimize agricultural operations through data-driven decision-making and proactive monitoring.

Figur-3 our system design in a real environment

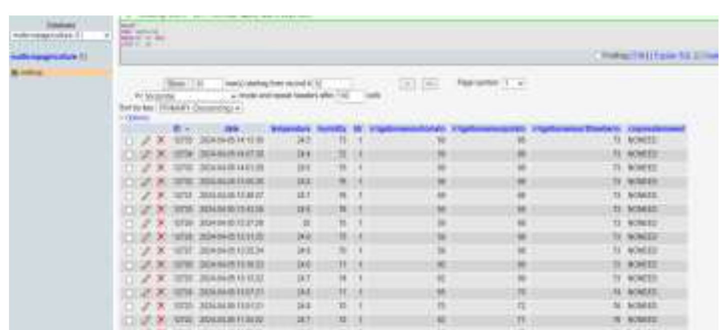

Figure-4 Data Collection and Prediction On local server

Figure- 4 illustrates the primary relational database table within, functioning as a repository for data acquired from Internet of Things (IoT) devices. The server orchestrates the transmission of this data at ten-minute intervals, ensuring regular updates to the database. Within this database, intricate details regarding the environmental parameters of the

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agricultural site are meticulously archived and organized, serving as a comprehensive record of the farm's conditions over time.

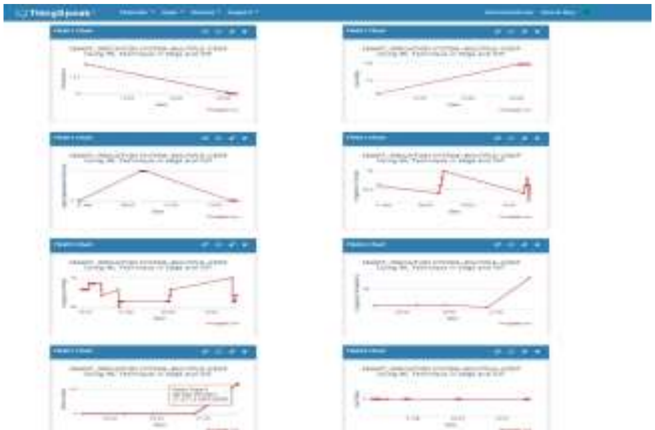

Figure6-Data Collection and Analysis on Thing Speak

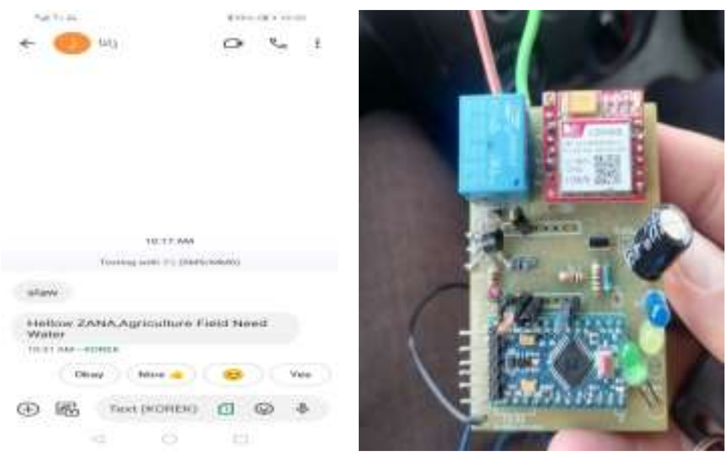

Figure-6 SMS Notifier from Edge Server

Here we designed a SMS-based notification mechanism. The hardware component depicted in the Figure 6, integrated with the edge server, constitutes a pivotal aspect of the system. Specifically, this component, identified as the GSM system, serves as the intermediary for transmitting instructions from the server to facilitate irrigation processes. Upon receiving directives from the server, typically communicated via Short Message Service (SMS), the GSM system promptly relays these commands to notify the relevant farmer. This mechanism ensures efficient and timely execution of irrigation tasks, thereby enhancing agricultural management practices.

IV. CONCLUSION AND FUTURE WORK

Addressing the projected 70% increase in global food demand by 2050, primarily driven by population growth, necessitates prioritizing enhancements in agricultural production as an imperative initial step. In light of this, the present study proposes the implementation of a composite irrigation strategy as a viable solution to confront this impending challenge. This paper introduces an innovative methodology for an edge computing-based irrigation system, designed to enhance decision-making processes regarding the scheduled watering of plants. The approach, which integrates the Internet of Things (IoT) with an edge computing framework, empowers the agricultural system to autonomously and efficiently adjust to fluctuations in environmental conditions. The procedure of automated irrigation modulates the irrigation system based on real-time meteorological parameters to prognosticate the irrigation schedule. To achieve our objective, we integrated edge computing technology with the Internet of Things in our system architecture. This technological approach facilitated the reception of data about environmental variables, such as temperature, humidity, and soil moisture, from Internet of Things (IoT) devices. Subsequently, utilizing this data in real time, our system executed precise decisions regarding irrigation management. Comparative analyses have demonstrated that the edge-centric methodology outperforms its cloud-based counterpart with respect to latency, response time, throughput, and bandwidth consumption. Our forthcoming endeavor entails the development of an irrigation timetable for various crops, leveraging the amalgamation of machine learning and Internet of Things (IoT) technologies. To accomplish this, it necessitates a transformation in the system architecture, alongside modifications in the methodology for data acquisition and the criteria for determining the optimal irrigation intervals for plants.

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