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Augmented IoT Model for Smart Agriculture and Farm Irrigation Water Conservation

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Abstract

In Northern Nigeria, irrigation systems are operated manually. Agriculture has over the years been practiced primitively by farmers, especially in sub-Saharan Africa. This is due to the absence of intelligent technological know-how where its practice could be leveraged upon. Agricultural practice is constrained by some major challenges ranging from traditional way of farming, understating of concepts, practices, policy, environmental and financial factors. The aim of this study was to optimize an IoT-based model for smart agriculture and irrigation water management. The objectives of the study were to: design, implement, test and evaluate the performance of the optimized IoT-based model for smart agriculture and irrigation water management. The method used in the study was the prototyping model. The system was designed using balsamiq application tools. The system has a login page, dashboard, system USE-CASE diagrams, actuators page, sensor page and application interface design. Justinmind tool was used to show the flow of information in the system, which included data input and output, data stores and all the sub-processes the data moves through. The Optimized IoT model was implemented using four core platforms namely, ReactJS Frontend Application development platform, Amazon web services IoT Core backend, Arduino Development platform for developing sensor nodes and Python programming language for the actuator node based on Raspberry Pi board. When compared with the existing system, the results show that the optimized system is better than the existing system in accuracy of measurement, irrigation water management, operation node, platform access, real-time video, user friendly and efficiency. The study successfully optimized an IoT-based model for smart agriculture and irrigation water management. The study introduced the modern way of irrigation farming in the 21st century against the traditional or primitive way of irrigation farming that involved intensive human participation.

Keywords

Irrigation Systems, Water Management, Smart Agriculture, Model, Optimization

1. Introduction

The world is transitioning from analogue to digital, from manual to automated processes. This is due to the demonstrable effects of scientific hypotheses. In addition to the Internet of Things, smart agriculture, and irrigation water management might all benefit from this technological development. One such technology that man has developed in the fields of communication and IT is the Internet of Things (IoTs). IoTs is a gadget that was established in the field of information distribution and was either introduced or discovered in 1999 [1]. Its rapid rate of coverage, notably in radio coverage, was created by a member of the Radio Frequency Identification Development Community (RFIDC) to expedite communication in the fields of cloud computing and data analytics. The Internet of Things may be broken down into three distinct types: 1) human-to-human interaction; 2) human-to-thing or machine interaction; and 3) human-to-thing or machine interaction. In each case, the Internet of Things (IoTs) is responsible for facilitating communication between a wide variety of devices.

Increasing population means that there will always be a need for more food. In 2050, the estimated global population is expected to reach 9.7 billion, an increase of nearly 33 percent from its current level [2]. The world's food supply would need to expand by at least 70% if it were to keep up with the expansion of its population at this rate. However, owing to factors such as temperature, climate, terrain, soil quality, and technology, only a tiny fraction of the earth's surface can be used for agricultural purposes. Land tenure patterns, environmental restrictions, and population density are all examples of political and economic issues that influence agricultural land usage. In reality, during the last several decades, there has been a steady decline in the amount of land utilized for farming and food production. About 37% of the Earth's surface area, or about 18.6 million square miles, was utilized for agricultural purposes in 2014. These figures were 19.5 million and 39.47% back in 1991. Thus, the world is confronted with the formidable task of how to feed more people on less land.

There would be no Nigerian economy without agriculture. Agriculture consumes a significant portion of the world's freshwater supply. Northern Nigeria relies on manually operated irrigation systems. Farmers, particularly in sub-Saharan Africa, are notorious for their use of antiquated farming methods. Unfortunately, this is because there is now a dearth of sophisticated technical know-how upon which its application may be based. Western and developed-country agriculture is heavily influenced by technological advancements. In Africa, and Nigeria in particular, this is not the case. Africa as a whole, and Nigeria in particular, face food shortages as a direct consequence of farmers' refusal to adapt to new technologies in agriculture.

Smart agriculture may be defined as a methodology for comprehending how the fundamental utilization of cutting-edge technology and networks is leading us to a more sophisticated society. The idea of "smart agriculture" is to move away from problem-solving specialization and toward problem-solving problem-generalization. The goal of this study was to find the optimal configuration for an IoTs-based model that makes use of both a Device-to-Gateway (D2G) and a Gateway-to-Cloud (G2C) communication structure. Through a Long Range (LoRa) radio module, sensor nodes are able to send data to the gateway, which then immediately syncs the information to the cloud over an HTTP/TCP connection. The system is comprised of four nodes, each of which is placed in a separate section of the farm. Irrigation the gateway acts as a central point of control for the whole water management system. The farm may be seen and controlled by the farmer in two different ways: As long as the system is up, the farmers can log in from any network. On a smaller scale, the farmer may hook up to the system using a wireless LAN (WLAN). After developing a prototype of the whole model and deploying it to the farm for testing, the robust model for optimizing IoTs-based smart agriculture is put through its paces. The prototype's results are then compared against those of established models.

Many issues, including adherence to antiquated methods of farming and a lack of familiarity with modern agricultural ideas, practices, policies, and economics, pose serious limitations on agricultural output. When antiquated farming equipment is used, agricultural fields like irrigated farming lose productivity. The ancient techniques of irrigation farming are still widely used, despite the poor crop yield they produce. Scientists and engineers have been criticized for not doing more to improve upon the tried-and-true method. Especially in Nigeria and the rest of Sub-Sahara Africa, conventional farming methods that prioritize yield above food security are no longer viable. Thus, IoTs is one such Internet-based technology developed by scientists to address the persistent issues plaguing this vital part of the business. In order to enhance and save battery life, the research suggests a system in which sensor nodes read and broadcast temperature, humidity, and soil moisture content every two seconds. A raspberry Pi operates an electrical relay driver, which in turn connects the pump to an actuator node. The controller mediates communications between sensor nodes and the remote server.

The aim of the research was to develop an optimized IoTs-based model for smart agriculture and irrigation water management. The study intended to:

1) survey and evaluate agric-based IoTss models,

2) optimized an agric-based IoTss model,

3) implement the optimized agric-based IoTss model on the python programming platform,

4) test and evaluate using real-life performance metrics the results of the optimized agric-based IoTss model.

2. Related Literature

Embedded System Theory

A special-purpose computer system, as suggested by [2] is one that serves just one or a few distinct purposes. The theory of embedded systems is concerned with both the hardware and software sides of system development. Therefore, the development of an embedded application will include tasks like definition, design, implementation, validation, deployment, and maintenance. Ideas in people's heads are the starting point for the creation of every system. These concepts must be written down in requirements specification papers, which outline the system's essential features and functions. After identifying what needs to be accomplished, the system design procedure decides which parts of the system can do those tasks. A well-designed system begins with well-articulated and well-documented requirements. Predictably, there is a plethora of ways in which the needs of a basic system might be expressed. Once the system's needs have been well specified and documented, the first stage in the design process is to create the architecture for the whole thing. A system's architecture is a high-level description of the individual parts and how they interact with one another. After a software's architecture has been determined, it may be put into action. This may be accomplished by making use of an operating system or scheduler, two examples of lower-level system representations. It's common for embedded systems to include several jobs that coordinate their use of the hardware and software and exchange data with one another and their surrounding environment. Since the Internet of Things is an embedded system, this idea is relevant to the work at hand.

Actor Network Theory

While most network theories focus only on human actors, actor-network theory (also known as "actor-network theory" or "ANT"), is established by [3] and recognizes the importance of non-human actors, such as objects and institutions. These components are sometimes referred to as "actors" or "actants." According to actor-network theory, the heterogeneous network is the most important notion, which is to say, a system with many distinct parts. The social and technological components of these networks coexist seamlessly. Indeed, this is one of the justifications for using this hypothesis in the current investigation. The Internet of Things makes use of technological and social methods. Since the farmers learned that IoTs can be used in smart irrigation via communication, the method of utilizing IoTs in smart irrigation is the technical component of it, while the farmers who utilize smart irrigation are the socializing portion.

Additionally, ANT views the social and technological as intertwined. The current researcher may apply this theory to the realization that all the components of smart agriculture and irrigation water management are actors. Sensors, gadgets, mobile phones, computers, and the cooperative effort of the supervisor and supervised all play a role. These participants are essential to the research itself. According to actor-network theory, all nodes in a social network are equally significant, regardless of whether they are human, inanimate, or digital in nature.

Society's order is an outcome of a well-functioning actor network. When key players are taken out of the equation, the established order starts to collapse. The loss of telephones, for instance, might cause serious disruptions to societal order.

Schultz Theory of Traditional Agriculture

Schultz put forward his theory of conventional farming in 1964. To put it simply, Schultz's thesis is a theory concerning conventional farming [4]. By the latter, we mean agriculture "based entirely on the types of forces of production that farmers have employed for centuries," which often (but not always) yields disheartening results in the form of extremely low earnings. The issue that Schultz seeks to address is how conventional farming may be made into a highly productive system of food production. Schultz sees this issue as a financial one. The answer, however, is not as simple as pumping money into farming; rather, it requires deciding on the best course of action for agricultural investments. Schultz argues that the conventional agriculture industry cannot expand using just traditional production variables, or at least only at a significant cost.

There has to be new, diverse production variables. Therefore, Schultz's idea may be seen as a theory of progress. This research was conceived as a means of bringing the rudimentary agricultural industry into the contemporary era. Schultz claims that conventional farming often (but not always) yields disheartening outcomes, such as little financial returns. This issue may be remedied by using smart agricultural practices, in particular water irrigation. The sensor's ability to monitor environmental factors including temperature, soil moisture, and humidity will have a direct impact on crop yields. This is because IoTs has been fine-tuned for use in smart farming and irrigation.

The Technology Acceptance Theory

According to [5] Technology Acceptance Theory (TAT), when people are given a novel technological tool, they take into account a variety of criteria before deciding whether or not to incorporate it into their daily lives. One's "perceived usefulness," or "the extent to which a person feels that employing a given method will improve his or her performance," The degree to which a user "believes that utilizing a certain system would be devoid of effort" is known as the "perceived ease-of-use" (PEOU).

Acceptance of new technologies is explained by the theory of technology adoption, which considers the social influences (subjective norms, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality, result demonstrability, perceived ease of use) that contribute to how people evaluate and plan to implement new technologies. Using this idea, we can foretell whether or not a given tool will be well-received by its intended audience, as well as what adjustments need to be made to the system to make it more palatable to those target demographics. As the authors of the Technology Acceptance Theory explain it, a person's attitude toward the usage of the system and their author's judgment of its value are what ultimately decide whether or not they will make use of an information system. Even if a worker is resistant to a new information system at work, there is a good chance they will end up using it if they believe it would boost their productivity. This study used the theory because it provides insight into how computer science students and researchers would respond to and make use of IoTs services.

IoTs Systems Theory

According to [6], these three characteristics—reduction, repeatability, and retaliation, are what set science apart. Science's proximity to the physical world is a key factor in that field's ability to successfully use the technique. According to the Internet of Things (IoTs) systems theory, a company is a complex social system with interconnected components. The article also said that the Internet of Things system is defined as a collection of interconnected devices that share information and resources. Any system's integrations, both vertical and horizontal, are designed to bring about the desired outcome. Any disruptions to the proper functioning of a system are known to be disastrous. Systems thinking is the theoretical basis of this research. The Internet of Things (IoTs) is a system in which many people, each operating at a different level, collaborate toward a common goal: the connectivity of sensors for the purpose of information sharing. The theory is an important part of this research since it has to do with scientific techniques and the connection of networks, nodes, and the exchange of data in the cloud as they pertain to the adoption of smart agriculture in Nigeria and the thriving IoTs professional.

Concept of Internet of Things

Data acquired from devices that detect and interact with the physical world drives applications and services in the Internet of Things, according to the Ministerial Meeting on the Digital Economy [7]. Connectivity to the internet, either directly or through a middleman in the form of a local or wide area network, is a necessary component of the Internet of Things. According to the GSM Association [8] IoTs are the use of data collected by embedded sensors and actuators in machines and other physical things via the usage of intelligently linked devices and systems.

Internet of Things Key Features

Below is a quick overview of the most significant aspects of the Internet of Things, including artificial intelligence, connection, sensors, active involvement, and the utilization of tiny devices.

Connectivity: With the advent of new networking and Internet of Things (IoTs) networking enabling technologies, networks are no longer reliant on a few dominant service providers. Networks don't need to be massive and expensive to be useful. Connected gadgets in an IoT system form their own mini-networks.

Without sensors, the Internet of Things would be just another network. They are the defining tools that change the Internet of Things from a simple network of devices into an interactive system that can be seamlessly integrated into real life. The majority of people's interactions with modern linked technology are performed in a receptive or "passive" mode. The Internet of Things ushers in a brand-new standard for interactive information, consumer goods, and services.

Miniature Electronics: As was foreseen, electronic gadgets have shrunk in size while also decreasing in cost and increasing in functionality. The accuracy, scalability, and adaptability that make up IoTs are all the result of the use of tiny devices designed specifically for the task.

Based on existing and developing interoperable information and communication technologies, the Internet of Things (IoTs) was seen by [9] as a global infrastructure for the information society, allowing for advanced services to be provided through the linking of disparate "things" (both real and imagined) (ICT).

In the context of the Internet of Things, "things" refer to any recognized and networkable physical or digital item in the real or virtual worlds. Information on an item may either be fixed or change over time.

Internet of Things Hardware

The sensing module coordinates the collection of data through various active and passive sensors. Some of the measuring tools used by the IoTs include the following:

The desktop computer, the tablet computer, and the mobile phone all play crucial roles in IoTs as the hub and remote controls, respectively. The desktop gives the user the most freedom to customize their computer.

Tablet: Like a desktop, it lets you get to the system's most important functions, and it doubles as a remote.

The mobile phone gives convenient remote access and the ability to adjust critical settings. Routing and switching hardware are also key components of the network infrastructure.

Internet of Things Technology and Protocol

As a standard technology with built-in compatibility across platforms, Low Energy Bluetooth satisfies the long-term, low-power requirements of IoTs applications.

Low Energy Wireless: This innovation swaps out the IoTs system's most power-hungry component. Communication lines, such as wireless, must remain in listening mode even if sensors and other components may be powered off for extended periods of time. Low-energy wireless not only saves money by reducing energy usage, but it also helps devices last longer.

ZigBee, Z-Wave, and Thread are all examples of radio protocols that may be used to set up low-speed local area networks. In contrast to many comparable solutions, these technologies need less power to operate while yet providing a high data rate. As a result, this boosts the capabilities of low-cost, locally-operated networked devices.

The major improvements brought forth by LTE A, also known as LTE: Advanced, are an expansion of coverage, a decrease in latency, and an increase in throughput. It greatly strengthens the capabilities of the Internet of Things by increasing its reach, with the most major uses being in car, UAV, and similar communication.

WiFi Direct: Without an access point, users may make low-latency peer-to-peer (P2P) connections at WiFi speeds. Unlike other methods of boosting network performance, WiFi-Direct doesn't reduce your connection speed or data transfer capacity.

The internet of things is a system composed of several components. Things like sensors, biochip transponders for farm animals, and plant heart rate monitors fall under this category. In addition, there are sensors for monitoring electronic coastal waters, agricultural crops, and environmental food sources. These sensors monitor preexisting equipment and relay that data to the devices in question for enhanced efficiency and responsiveness.

Internet Network Facilities for IoTs

Network facilities, such as those provided by the Internet, are what is required to create or join a computer network for the purpose of exchanging information or data [10] Hubs, switches, bridges, routers, gateways, CSU/DSUs (Channel Service Unit/Data Service Unit), NICs (Network Interface Cards), ISDN (Integrated Services Digital Network) adapters, WAPs (Wireless Access Points), modems, transceivers (media converters), and firewalls are just some of the devices used in modern networking. Here is how [11] describes each of these network features:

Hub: When it comes to the hierarchy of networks, hubs are at the very bottom. Twisted-pair cabling networks need the usage of hubs to link devices. Larger networks may be built by connecting many hubs together. Simply said, hubs are devices that forward data packets to all other devices on the network regardless of whether or not the data package is intended for that specific device. Because of this, they are inefficient gadgets that might slow down overloaded networks. A hub's only function is to act as a conduit for electric currents to flow through. This kind of equipment is known as a passive hub. These days, it's far more typical to use an active hub, which not only routes data signals but also regenerates them before sending them on to all of the linked devices. A hub does not modify the data it sends, and it does not check for errors. There is a wide range of sizes and forms that hubs may take. The term "workgroup hub" is widely used to refer to small hubs having five or eight connection ports. Some others can hold more gadgets (normally up to 32).

Internet-Enabled Electronic Devices for Smart Agriculture and Irrigation Water Management

Electronic gadgets that can connect to the internet are called "web-enabled devices" [12]. Internet-enabled gadgets are any electronic gadgets that can connect to the internet, the vast majority of which are mobile. The term "mobile Internet device" (MID) refers to any wirelessly connected, multimedia-enabled mobile device that can connect to the Internet. In the context of this investigation, the term "Internet-enabled device" refers to any electronic gadget, large or little, fixed or portable, that may connect to the Internet by wireless means or an Ethernet connection in order to collect and/or transmit data. Devices with Internet access (IED) provide two-way dialogue and data collaboration in real time. They're made to let people connect with one another and access useful data, content, and services depending on their current location. When these devices are linked (sometimes referred to as "logged on"), they allow for the transmission and retrieval of a wide variety of signals and data [13]. IEDs include mobile phones (mostly smartphones), computers (desktops and laptops), tablets, e-book readers (like the Kindle), netbooks, gaming consoles, and many more, and allow anybody to access the Internet [14] [15] [16] [17]. In the "Internet of Things", however, when every item is integrated into and made Internet-enabled, IED includes objects like TVs, automobiles, and household appliances [18].

Internet Network for Smart Agriculture and Irrigation Water Management

A computer network, often known as a network, is a collection of computers and often additional devices (such as printers, external hard drives, modems, and routers) that are interconnected so that they may talk to one another and share information and resources [19]. Connecting two or more computers so they may exchange and store information is called "networking" in the computer industry. A network is a collection of interconnected computer systems and other computing gear devices that allow users to share information and resources [20]. To rephrase, a network consists of two or more computers that are interconnected in some way. Computers that are part of a network are referred to as nodes, and according to [21], networks allow for the connection and communication between two or more computers. The author defined servers as the computers and devices that dole out network resources, and clients as the end users that make use of those services.

Concept of Smart Agriculture

There has been a shift in the 21st century from conventional farming methods to "smart agriculture", which makes use of Internet of Things (IoTs) sensors, contextually aware computing, and the pervasive computing idea. There is a proliferation of uses for the word "smart", from "smart farm" to "smart workplace" to "smart education" to "smart hospital", and so on. These occurrences motivate researchers to start work on systems that, depending on their complexity, can make at least some decisions. Smart agriculture relies heavily on data collected by sensors, which play a crucial role in decision-making. Smart agriculture, as demonstrated by [22], is a systematic involvement subject to the following steps: 1) collecting and transferring information from the field of agriculture to the station control for making decisions; 2) sensing local agricultural parameters; 3) making decisions based on local data; 4) gathering and identifying data from sensing location; 5) analyzing history, knowledge, and domain to determine the basis on decisions.

Smart Agriculture and Irrigation Water Management with IoTs

In order to increase agricultural output and keep up with rising food demands, IoTs is predicted to play a crucial role. Internet of Things (IoTs) based advanced technologies and solutions are used in smart agriculture to increase operational efficiency, increase output, and decrease waste by collecting data from fields in real time, analyzing that data, and deploying control mechanisms. Various Internet of Things (IoTs) applications, including as variable rate technology, precision farming, smart irrigation, and smart greenhouse, will be crucial to the improvement of agricultural operations. With the help of IoTs, farms may become more connected and intelligent, which in turn improves both the quality and quantity of agricultural output. The current agricultural boom may be attributed in large part to the Genome project and other genetics-related developments. The Internet of Things (IoTs) has the potential to fuel yet another economic upswing as more and more cutting-edge breakthroughs in fields like geo-positioning systems, big data, drone technology, remote sensing, and robots are launched to the market.

Many academics think that the anticipated boom will be driven by the widespread adoption of the aforementioned technologies, which are gradually making their way into production and practical usage and which, when "cemented together" by IoTs (Internet of Things), represent a strong force. An agricultural Third Green Revolution is imminent, thanks to the aforementioned new technological advancements and capacities. It's important to understand that "smart farming" refers to farmers who actually put the aforementioned technology and advances to use in their operations. Simply put, "smart farming" refers to the widespread use of interconnected information and communication technologies in agricultural contexts. There has been an exponential rise in the usage of Information and Communication Technologies (ICTs) over the last two decades, making this phenomenon more than just a passing fad in established economies like the United States and the United Kingdom but also in developing nations like Nigeria. Many academics and IT professionals believe that "IoTs and Smart farming are the future of the World's agriculture," and this is not surprising.

Structure of IoTs in Smart Agriculture

First, the sensing layer: Obtaining automated and real-time transformations of the figures of real-world agricultural manufacturing into digital transformations or information that may be handled in the virtual world through varied or various ways is one of the issues of the sensor layer. The information they gather consists of; Humidity, temperature, gas concentrations, pressure, etc. are examples of a. sensor information.

Applications of IoTs in Smart Agriculture

Several Internet of Things (IoTs) based applications in smart agriculture, as stated by [23], are meant to raise output. The Internet of Things has several important uses in smart farming. With the use of the Internet of Things (IoTs) and information and communication (ICT) technology, precision farming is a method of agricultural management that maximizes profits while also protecting scarce natural resources. Acquiring real-time data on the conditions of crops, soil, and air is essential for precise farming. Goals of this strategy include environmental protection, long-term success, and profit maximization. Drones for Farming: Monitoring crop health, taking photographs of agricultural sites for use in development, applying fertilizer at varied rates, and keeping track of animals are just few of the many uses for unmanned aerial vehicles (UAVs) in agriculture. Unmanned aerial vehicles (UAVs) have the potential to quickly and cheaply survey large areas using a variety of sensors to collect a wealth of data. The need for more effective irrigation methods that waste less water has led to the development of "smart irrigation". More and more people are realizing the need to conserve water by using modern, effective irrigation methods. By monitoring factors like humidity, soil moisture, temperature, and light intensity, IoTs-based smart irrigation can determine how much water is really needed. Such a strategy has been shown to increase irrigation productivity.

In order to prevent soil deterioration, farmers may benefit from soil monitoring devices that let them keep tabs on soil quality and make necessary improvements. A variety of physical, chemical, and biological characteristics, such as texture, water-holding capacity, and absorption rate, may be tracked with their help. Degradation of soil quality may be caused by a number of factors, including erosion, densification, Stalinization, acidification, and contamination by poisonous substances.

Problem of IoTs in Smart Agriculture

IoTs is plagued by a few major issues. As a result, these concerns must be addressed before to the widespread use of IoTs. Among the obstacles to widespread use of IoTs in smart agriculture are the ones listed below. Before the Internet of Things (IoTs) can be widely adopted throughout the world, significant progress must be made in the area of security. The proliferation of IoTs devices and services for information and communication has created new challenges for the administration of technological resources, particularly in the world's poorer countries.

Price: The Internet of Things relies on connected gadgets to open up new channels of online data exchange. Sensors, Wi-Fi, and control mechanisms, among other necessities, will need to become more affordably available in the not-too-distant future if IoTs use is to increase.

Managing data is a crucial part of the Internet of Things. The procedure involved in processing this data becomes a crucial problem when contemplating a worldwide interconnection and interchange of all types of data, information, or the created information.

Power: Power is crucial in the Internet of Things. It is becoming more difficult to get electricity for the correct usage of the Internet in certain nations due to energy restrictions.

Challenges of Conventional Agriculture

The regular agriculture is massively constrained with poor access to farmland, insufficient financial support, poor transport system, poor road network, aging farmer population, education ineffective farming system and techniques. And generally poor security system within and outside the farm territory poses a major challenge to agricultural activities [24].

Benefits of IoTs in Smart Agriculture

The following be below are some benefits of the Internet of Things in smart agriculture and irrigation.

1) The Internet of Things (IoTs) allows for the streamlined collection and management of vast amounts of information gathered from sensors, and the integration of distributed evaluation services means that this data can be accessed from anywhere at any time, facilitating real-time monitoring and end-to-end connectivity.

2) Experts have predicted that by using sensors and other smart technology, farmers will be able to increase their yield by 72 percent by 2050.

3) Reduced costs made possible by Internet of Things (IoTs) innovations will significantly improve productivity and longevity.

4) Fourth, the Internet of Things will allow for even greater efficiency in the use of water, soil, fertilizers, pesticides, and so on.

Intelligent IoTs-Based Irrigation System

With their study titled "Smart Agriculture in Karachi, Pakistan," [25] provide some interesting insights. The study of how people use technology in many contexts to reap multiple advantages is instructive in and of itself. As a technology, sensor networks are not novel in the field of agriculture. However, several research groups are working on and proposing a variety of solutions to the problem, since local weather, soil, water, and land conditions might vary greatly. This necessitates the exploration of alternative strategies, with a focus on agriculture that may aid in the discovery of answers to problems in a range of contexts. The techniques for handling a wide range of settings, situations, and challenges are being brought to light by the rise of ubiquitous computing and context-aware computing. The problem of combining multiple technologies and applying them to a specific sector has always been difficult. Using a sensor network and other developing technologies, such as ubiquitous computing, context-aware computing, and grid computing, may make farming more efficient and effective. In this research, we define "Smart Agriculture" and show how various cutting-edge technologies might be used in the field of agriculture. In addition, the ways in which various forms of cutting-edge technology have facilitated agriculture's steady development are detailed. In addition, this research includes a brief discussion of the process followed in creating a smart agriculture prototype for use in controlling irrigation systems. The new investigation is connected to previous work on "smart agriculture."

Sensor-Based Automated Irrigation System with IoTs: A Technical Review

Sensor-based automated Irrigation System with IoTs: A Technical Review was conducted by [26] in India. With a population of over 1.2 billion and rising, India's agriculture has to be developed to prevent a catastrophic food shortage in the next 25 - 30 years. The farmers of today are really feeling the effects of the dry weather and the water shortage. In order to help farmers save time, money, and effort, this research is focused on developing automated irrigation systems. Traditional methods of irrigating farmland include human labor. Reduced need for manual labor thanks to irrigation automation technologies. These sensors pick up any changes in ambient temperature and humidity and provide an interrupt signal to the micro-controller. In contrast, the current study, which is dubbed the optimal IoI-based model for smart agriculture and water management, is not the same as the aforementioned investigation.

IoTs-Based Smart Irrigation System

According to research by [3] [8] using an Internet of Things-based Smart Irrigation System at the University of Colorado Boulder. The agricultural domain may be transformed from manual and static to intelligent and dynamic by automation of farm operations, allowing for increased output with less human monitoring. In order to keep the soil at the ideal moisture level, this research suggests using an autonomous irrigation system. The brains of the operation are microcontrollers, namely the ATMEGA328P running on the Arduino Uno platform. Soil moisture sensors are included in the system in order to get an accurate reading of the soil's moisture content. By setting this value, the system may prevent either over- or under-irrigating. Through the use of IoTs, farmers can monitor the health of their sprinkler systems in real time. A farmer may see whether or not the water sprinklers are on at any particular moment by visiting a website that displays real-time data collected from the sensors using a GSM-GPRS SIM900A modem. Sensor data is also sent to a Thing Talk channel where charts may be generated for further study. In order to save a significant amount of water studied the implementation of an automated microcontroller-based rain gun irrigation system. An operating system, middleware, and critical apps known as Android were created for use with these systems, ushering in a new era in the administration of field resources. The Android Software Development Kit (SDK) contains the resources needed to create Android apps in Java. Cell phones have grown indispensable, fulfilling a wide range of human requirements. This program uses a mobile phone's global positioning system (GPRS) to provide an answer to the problem of controlling irrigation systems. These systems spanned the less valuable, lower-priced agricultural area.

For greenhouses, SIMCOM Company's SIM900A module was used to create an Internet of Things (IoTs) alarm system described in IoTs SMS alarm system based on SIM900A. Air temperature and humidity are only two of the environmental characteristics that may be measured by the device. At the same time, the AT command allows the system to achieve automated SMS sending and receiving, as well as alarms for environmental parameter overshoot and inadequate balance. When an alert is activated, the system may immediately notify the user's chosen mobile phone, regardless of their physical location. As an example of the Internet of Things being put to good use in the agricultural sector, this technology has shown promising results in practice.

Water Management in Smart Agriculture

Monitoring, modeling, exploring, assessing, designing measures and strategies, implementing policy, operating and maintaining, and evaluating are just a few of the many tasks that [27] [28] list as being part of water management. Institutional change and similar supplementary efforts are included as well. Both immediate and far-reaching plans are necessary for managing water resources effectively. Therefore, the area of water resources management is rather broad. Planning, developing, operating, and managing water resources encompass a wide range of specialized fields and disciplines. Two-tiered management is a part of water resource management. The first level of management encompasses the water manager's day-to-day responsibilities and overarching goals.

According to [22] [23] [24] [25] [26] irrigation water management encompasses a wide variety of tasks, including planning, analyzing, designing, modeling, exploring, implementing, operating, maintaining, and evaluating irrigation systems. This concept is all-encompassing since it includes all of the procedures and strategies that go into water management. Smart farming and irrigation cannot be achieved without first establishing efficient water management practices. The smart irrigation system policy's impact on the agricultural sector's economy may be mitigated by inefficient and wasteful water management.

The following are some examples of why irrigation is so crucial:

1) Farming suffers when there is not enough rain. With an irrigation system, yields may be raised despite rain's capriciousness.

2) Land that is irrigated is more productive than land that is not.

3) Irrigation infrastructure allows for the cultivation of different crops in Northern Nigeria, which is otherwise unable to do so due to the region's limited rainy season.

4) Most of the unused land has been brought into agriculture thanks to irrigation.

5) Irrigation increases the quantity of water available, which boosts agricultural output and farmer income.

Types of Irrigation Systems

There are different types of irrigation systems, depending on how the water is distributed throughout the field. Some common types of irrigation systems include:

Surface Irrigation: This is the process where water is distributed through and across the land by gravity, no automated pump is involved.

Localized Irrigation: Water is distributed under low pressure, through a pipeline and applied to each crop.

Drip Irrigation: A type of localized irrigation in which drops of water are delivered at or near the root of crops.

Sprinkler Irrigation: Water is distributed by overhead high-pressure sprinklers or guns from a central location in the field or from sprinklers on moving platforms.

Manual Irrigation: This is where water is distributed across land through manual labor and watering cans. This system involved human participation and was labor intensive.

Methods of Irrigation

Irrigation can be carried out by two different methods: Traditional Methods and Modern Methods.

Traditional Methods of Irrigation: In this traditional method of irrigation, irrigation is carried out manually with the help of human beings. Therefore, the farmers fetch water from canals or wells or use carries and cattle to the fields farming. These methods depend on the region. The main advantage of this method is that it is cheap. But its efficiency is poor because of the uneven distribution of water. Also, the chances of water loss are very high.

Modern Methods of Irrigation: The modern methods of irrigation are done automatically with the help of irrigation devices and sensors. The modern method involves two systems: Drip system and Sprinkler system.

Challenges of Smart Irrigation Water Management

IoTs smart irrigation water management is not without challenges:

Hacking: There is the problem of inter-connectivity. There is a challenge in linking major devices in IoTs to irrigation.

Interconnectivity: This is a challenge of linking major devices in IoTs to irrigation.

Compatibility and Duration: The life expectancy of some devices is short to continue servicing irrigation.

Cultural Barriers: Cultures of certain people do not agree with the irrigation system.

Food security is a concern on a global scale and in the division of international waterways. Since agriculture uses the most water, governments should begin to understand that achieving food self-sufficiency is not always attainable and is often very uneconomic. Modern ideas lean toward food security, which entails producing food in regions of the globe with the best economic and environmental circumstances, and then exporting this food to nations that are able to generate enough wealth to pay for its purchase. There should be sufficient and trustworthy market mechanisms in place for nations that import food. Opportunities to create activities that bring in foreign currency are particularly important for low-income nations.

Internet of Things-Based Smart Agriculture

Smart agriculture in Nigeria was examined by [8] [9] This research looked at the advantages and disadvantages of using IoTs in smart agriculture, as well as its definition, characteristics, and agricultural applications. As a consequence, it seems that agriculture is only one of many industries that has benefited greatly from the advent of the Internet of Things. Smart agriculture has emerged as a result of the widespread use of Internet of Things (IoTs) apps and sensors to boost yields and enhance crop quality. Agricultural output is boosted along with food security when IoTs is correctly adopted. If the measures needed for widespread adoption of IoTs are adopted, it might have an impact on a wide range of nations. The goal of this research is to address this issue by developing a more effective model for the Internet of Things to be used in smart irrigation water management in Nigeria.

IoTs-Based Smart Irrigation Systems: An Overview of the Recent Trends on Sensors and IoTs Systems for Irrigation in Precision Agriculture

What are existing IoTs solutions in smart irrigation for agriculture? This is the question that drove research. How do current methods for creating Internet of Things irrigation systems compare to the ones that have come before? The authors conducted extensive manual searches of search engines and digital libraries to identify articles of interest for this study. Google Scholar 24, IEEE Explore 25, Scopus 26, and the Sensors Digital Library 27 were mined for a total of 283 articles. IoTs irrigation, IoTs irrigation system, and smart irrigation were used to get the total number of publications for this review. We also made sure that irrigation, water, Internet of Things, and smart were all included in every single article we reviewed. Answers for existing Internet of Things (IoTs) solutions in smart irrigation for agriculture in Nigeria might be found with the aid of this new study.

IoTs-Based Smart Sensors Agriculture Stick for Live Temperature and Moisture Monitoring Using Arduino, Cloud Computing and Solar Technology

Using Arduino, Cloud Computing, and Solar Energy, [10] developed an IoTs-Based Smart Sensors Agriculture Stick for Real-Time Temperature and Moisture Monitoring. In this paper, an Internet of Things (IoTs)-based "smart stick" for real-time monitoring of agricultural factors is introduced; the stick may assist farmers in collecting information such as current temperatures and moisture levels. By simply placing an agricultural IoTs stick in the field and connecting it to various smart devices (smartphones, tablets, etc.), farmers can immediately implement a smart monitoring system, and the data collected by the stick's sensors can be easily analyzed and processed by agricultural experts located in far-flung areas thanks to cloud computing. The work being done now will aid in the development of a model with several sensors and interfaces, leading to a more effective wireless sensor network.

IoTs-Based Agriculture Monitoring and Smart Irrigation System Using Raspberry Pi

While [13] proposed collecting data from several sensors and doing real-time monitoring, the focus of this study is on automating such processes. The authors of this research set out to find ways to boost agricultural productivity using various technological approaches. Furthermore, a low-cost WSN for collecting data from soil moisture, humidity, and temperature sensors is shown. The research indicates an automated approach might improve agricultural productivity. The authors offer a smart irrigation system and a technique for efficient data sensing. The goal of this study is to create a system for gathering and archiving information from the cloud.

Smart Irrigation Water Management Using the Internet of Things

The study by [29] evaluated IoTs-enabled irrigation water management (IoTs-sIWM) and methods, IoTs applications in relation to irrigation water management, deliverables of IoTs in irrigation farming, challenges and practicality of the IoTs in smart irrigation water management, and prospects of IoTs in smart irrigation water management.

3. Methodology and Model Design

The study employs a prototyping methodology. It started with the most important parts of the project and gradually worked its way to the rest. The project was broken down into smaller prototypes so that it could optimize each element separately.

The Existing System the Study Evaluated

Several IoTs-based smart agricultural models were compared and contrasted in this study. These included an IoTs-based smart agriculture monitoring system and an intelligent IoTs-based automated irrigation system.

Yuthika investigated India's automated irrigation system, which is based on the Internet of Things. There is a connection between agriculture and the national economy. Lots of study has gone into using wireless sensors and mobile computers to automate the irrigation system [29] [30]. Agricultural systems that use machine learning have also been the subject of study. The term "machine to machine" (M2M) refers to the burgeoning field of technology that enables machines, objects, and other devices to exchange data with one another and with the server/cloud/etc. in the background, through the core network. As a result, we have created an Intelligent IoTs-based Automated Irrigation system, which collects sensor data on soil moisture and temperature and uses a KNN (K-Nearest Neighbor) classification machine learning algorithm to analyze the data in order to make a prediction about whether or not the soil needs to be irrigated. It's a semi-automated system in which the devices exchange data and use their collective intelligence to control the water flow. This is not 21st century smart since it was built using expensive embedded devices like Arduino Uno and Raspberry Pi3. This method is both expensive and unwelcoming. At 30-minute intervals, sensors spread over an agricultural field capture data, which is then uploaded to a cloud server and kept indefinitely.

Using a web-based interface provided by a companion application, users can keep tabs on and make adjustments to the system from anywhere. However, due to their centralized design, these systems are vulnerable to hacking, data transmission to the cloud is cumbersome, and a faulty component can have far-reaching effects.

In the above analysis, a centralized system was used to describe the current system. Professionals depend on simple rules that have been consolidated for data collection and calculation. Massive amounts of time, effort, and resources are spent on important data processing, delaying the transfer of signal data to the central server. In this age of technological advancement and streamlined processes, it lacks the intelligence it needs to function effectively. Several sensors are put on a farm as part of centralized IoTs for smart agriculture to measure things like monitoring. An Internet Protocol (IP) address will be given to each gadget on the network. The collected agricultural field data is then sent to a cloud through a gateway that is linked to the internet by WiFi or some other communication network. The information is sent from the cloud to the farmers' mobile devices or desktop PCs. Farmers may make informed choices with the help of this information. One significant problem is that the aforementioned approaches are expensive, centralized, and slow to convey data. Moreover, the aforementioned study's models are quite intricate. Developing and deploying a decentralized system that is as smart as it should be in the 21st century is made easier by the suggested optimal IoTs-based architecture for smart agriculture and irrigation water management.

Architecture of the Existing System

In the current design, which is a centralized Internet of Things (IoTs) based smart agricultural architecture, all connected nodes (devices) in the system transmit data directly to a remote/local server through a specific gateway/network router. Since all traffic must go to or from a centralized server, nodes cannot have a direct dialogue with one another. If the farm has an Internet connection, the owner can check in from anywhere in the globe, while the farmer can use a wireless LAN to keep tabs on things from the comfort of his or her own backyard (WLAN). Their current sensor-based irrigation monitoring system has a two-tiered architecture: a foundation layer and a display layer. The sensor nodes in a hierarchical network are dispersed widely in the lowest layer. Using a wireless local area network (WLAN), these nodes transmit their data to a central location. The upper layer consists of the following modules: business module, alarm/network status display module, network management module, and acquisition module. The sensor network's data-gathering modules capture both real-time and delayed data, which is then stored in a database and used to trigger decisions and alerts. The Alarm/Network status display module is responsible for sending out alert alerts and showing relevant information to end users. To facilitate communication between users and other modules and networks, an interface is provided by the Alarm/Network status display module. **Figure 1** is a description of the old system's architecture.

1) Unreliable gateways: The gateway device in an Internet of Things network may represent a single point of failure. In a centralized IoTs system, the inactivation of a gateway disables fundamental features including decision-making, analytics, and data storage. This prevents the user from remotely monitoring sensed data from the farm and controlling moisture levels. Considering the gateway makes this crucial decision for the smart farm, even local automation is impossible.

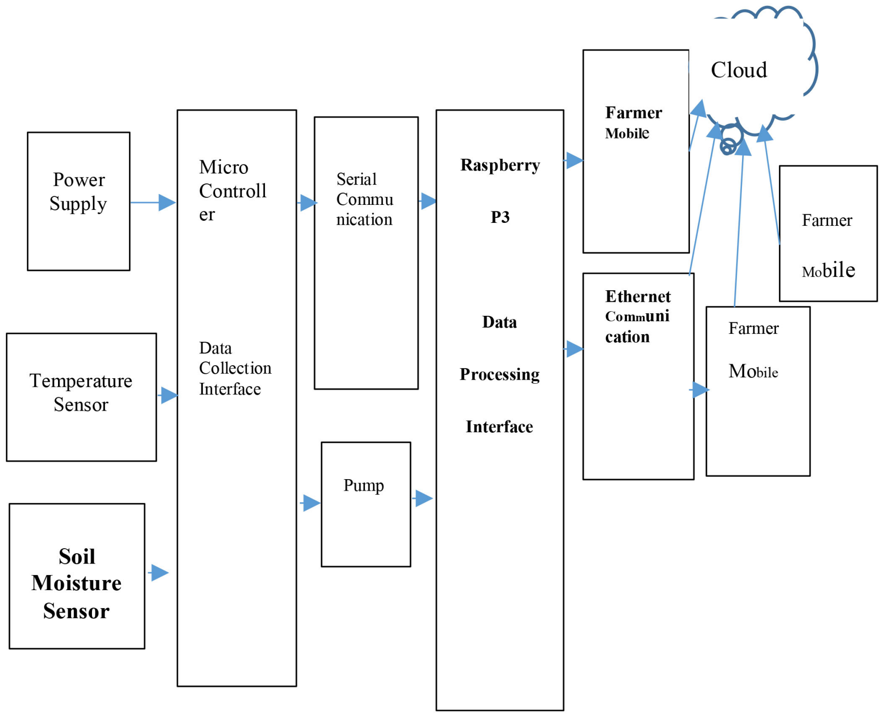

Figure 1. Architecture of the existing system [29].

2) Unreliable network: owing to limited resources and spotty connection, particularly in rural regions, the network is more likely to lose sensor readings or create inaccurate sensor readings, making it difficult to rely on the data for decision-making and analytics. Given that IoTs infrastructure is typically tasked with handling mission-critical applications, the idea that measurements might be discarded owing to the intrinsic nature of IoTs networks is cause for worry.

3) The public's acceptance and trust are crucial to rolling out the loT, but this raises concerns about privacy and security. Data entering the network that will be utilized by many different apps simultaneously is the main source of worry when it comes to loT security and privacy (service providers). Therefore, it is necessary to establish tiers of policy and permissions. When it comes to personal information, we must provide each user the option to choose who has access to their information. In a nutshell, the user has to be in charge of her or his own data. With that said, new security mechanisms and encryption technologies are crucial for energy-constrained devices. There will be constraints on authentication and authorization in a network of that magnitude.

4) The human element and the amount of manual labor required to complete this process are disadvantages. Since water is distributed in such an inefficient manner, its effectiveness is low. There is also a substantial potential for water loss.

5) A significant issue is the system's expensive model proposals.

6) In addition, the models used in the research are rather complex. No decisions or actions are made in the model. Nitrogen, phosphorus, and potassium are all quantified in the model, however, the rising complexity of soil pre-treatment

and compound inspection is increasing the average testing time for NPK. High-tech solutions often have their drawbacks.

The Proposed Optimized IoTs-Based Model

In order to better manage irrigation water for smart farming, the suggested system uses an improved model based on the Internet of Things. It's a decentralized technology that allows for efficient data transfer to a central server. Lighting, humidity, temperature, and soil moisture sensors are used for this purpose. Specifically, it is designed to keep an eye on the agricultural field and control the irrigation system mechanically. The gateway is responsible for transmitting data collected from all sensors to the cloud for further analysis and storage. The gateway is responsible for the local automation, while the farm's state is kept in constant sync with the cloud. The architecture of the system permits two distinct users, one of whom acts as the farm administrator and the other as the farm manager. The farm administrator is responsible for adding sensor and actuator nodes to the system and configuring them for either fully automated or user-managed operation. The farmer's job is to manage the farm's sensor and actuator nodes and to get updates on the farm's status by text message or email. The sensor data may be seen by the farm manager through a dynamic, adaptable web application, and the irrigation system can be activated either on-site or remotely. A (main) intake structure or (main) pumping station, conveyance, distribution, application, and drainage are the major components of the irrigation system.

The use of a node, gateway, and sensors allows for fully automated irrigation. Taking into account factors like soil moisture, humidity, and temperature, it adjusts the amount of water applied accordingly. In order to determine whether the landscape needs watering, the smart irrigation controls are in constant communication with wireless moisture sensors. Saving time and effort when watering plants is a major benefit of the irrigation optimized IoTs-based model. Consequently, financial restraint is essential. It may reduce your water and electricity costs, depending on how many pumps you have and how long you need to water. If you want to save time and effort, just fill the water tank once and let the irrigation system take care of itself. Irrigation systems may now be optimized with the help of a vibratory plow, allowing for quick installation with little damage to the grass and leaving almost no evidence of the soil being disturbed. Every year before winter, it will blow out all of the water in your pipes and sprinkler heads and then provide a spring restart and other annual checks.

Advantages and Limitations of the Optimized IoTs-Based Model

This research will be very useful for agencies responsible for overseeing agricultural and water irrigation systems. This study will be helpful to the government via the Ministry of Water Resources because it provides a framework for using ideas like Fischan's theory of talent and context to fulfill the sector's goals. The need for one's expertise in the given situation is emphasized by this competency. Farmers will also gain from the research since it will encourage them to switch to the new or contemporary way of irrigation, which is more efficient and saves time compared to the old approach. Additionally, research institutions like the Crop and Root Research Institutes in Ibadan and Umuahia, Nigeria, would benefit from this cutting-edge approach to Internet-era water irrigation management. The findings would also be helpful to researchers and other Internet and agricultural students. It would encourage research and further education on agricultural practice. Nigerian policymakers and other interested parties would create a condensed course of study in the IoT. Knowledge capacity will be increased, and this will aid in documenting and archiving that information.

The system is limited to irrigation water evaluation and control. Without the CCTV cameral integrated into the IoTs, the system cannot do surveillance and monitoring effectively. Without which data cannot be read from every sensor to the cloud through the gateway for processing, analytics and storage. Local automation is only achieved at the gateway level while the farm state is instantly synchronizes with the cloud.

Design Tools

The Arduino was used to create an Internet of Things (IoT) model. Microcontroller with eight bits of memory transmits serial data representing temperature and humidity. The four main platforms used by the Optimized IoT-based model are the ReactJS Frontend Application development platform, the Amazon Web Services platform, the Google Cloud Platform, and the Azure platform. Arduino as a platform for creating sensor nodes, along with the Python programming language for creating Raspberry Pi-based actuator nodes is a core infrastructure for the Internet of Things. Volts are used to power the device.

System Design

A program called balsamiq was used to sketch out the proposed system. An Actuators page, a Sensors page, a Login page, a User Case Diagram, and an Application Interface Design would all be part of the system. The information flow of the system, including data input and output, data storage, and all the sub-processes the data moves through, was visualized using the Just in Mind tool. To do this, we used figma symbols and notation to represent the many things being described.

Architecture of the Proposed System

The layers of a well-designed IoTs-based architecture are the cloud, the IoTs, and the physical. Without a centralized system, devices in the physical layer of an efficient IoTs system may freely exchange data with one another (gateway). An actuator node may begin or end the irrigation system in response to a command from the user, the gateway, or another sensor node. Drip irrigation systems use data gathered from water level sensors to help save water. The environment is monitored using a variety of sensors. As a result, the system becomes more secure and less reliant on the network (Internet). Using a radio communication network called Long Range (LoRa), the nodes may talk to one another and the gateway. That is, communication between the physical layer and the IoTs layer may occur independently of a TCP/IP infrastructure. This framework also makes it simple to automate many tasks on farms. The smart agricultural system is controlled by the physical layer, which is an automation layer. Its purpose is to monitor and regulate the system's sensors and actuators. A soil moisture sensor, a temperature sensor, and a humidity sensor are all employed in the automation process. These sensors are used to monitor environmental conditions such soil moisture, plant temperature, and humidity. Actuators regulate the flow of water in an agricultural irrigation system. The Internet of Things (IoTs) layer collects information from the physical world and transfers it to the Cloud for analysis. At this stage, a system controller acts as a gateway to the cloud and as a local storage/server. In addition to communicating with the underlying physical layer through the LoRa radio network, this layer also establishes a connection to the cloud via a private TCP/IP network. IoTs gadgets provide the controller with data and alarms at regular intervals. The information is sent to a remote server for further examination. Information sent between cloud services is encrypted using security-level protocols while in the cloud layer. It processes data, stores it, and provides access to the system through an API for use by desktop and mobile apps. It offers analytical services and an email/SMS alerting system as well. Figure 2 highlights the schematic structure of a smart agricultural system.

Mathematical Model of Performance of the Optimized IoTs Model

$$\text{Water Flow Rate} = \frac{Q_{wi}}{Q_{wu}} \times \frac{100}{1} \tag{1}$$

where

Q_{wi} = quantity of H_2O in the source;

Q_{wu} = quantity of H_2O used from the source;

H_2O = water.

Irrigation H_2O Management

$$\text{Quantity of } H_2O \textbf{ Reserved} = Q_{wi} - Q_{wu} \tag{2}$$

$$\text{Quantity of } H_2O \text{ reserved from sprinkle} = Q_{wi} - Q_{w} \tag{3}$$

Q_{ws} = quantity of H_2O sprinkeld.

$$\text{Quantity of } H_2O \text{ reserved from drip} = Q_{wi} - Q_{wd} \tag{4}$$

Q_{wd} = quantity of H_2O dripped.

$$\text{Quantity of } H_2O \text{ served from sprinkle} = Q_{wi} - Q_{wst} \tag{5}$$

Q_{wst} = quantity of H_2O at sprinkle time.

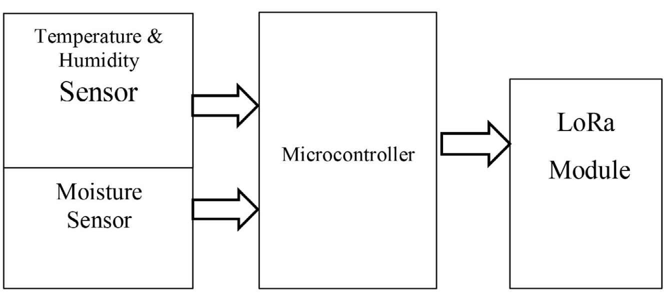

Figure 2. Smart agriculture sensor node gateway.

The Hardware Configuration of the IoTs System

This system measures of five quantities namely; irrigation, surveillance live feed, humidity, temperature and soil moisture level. These quantities are relatively measure using sensor modules. DHT11 sensor module was used to measure temperature and humidity at the sensor node. It has 0˚C - 50˚C temperature range and 20% - 90% relative humidity range with an accuracy of plus or minus 1%. Moisture sensor was employed to measure soil water contain. It consists of two gold coated probes that are used to detect soil moisture. The probes measure the resistance of the soil by passing electric current through it. The smart farm was equipped with an electric pump that acts as an output of the system to irrigate the farm. These help to archive water management in the farm and ultimately avoid over irrigation and under irrigation. The pump will only be activated automatically to water the farm when the sensor nodes reads low moisture content on the soil and can also be activated by the use either remotely or locally using web interface. Figure shows typical electric motor. Data read from every sensor is send to the cloud through the gateway for processing, analytics and storage. Local automation is achieved at the gateway level while the farm state is instantly synchronizes with the cloud.

The Schematic Optimized IoTs Model

Figure 3 shows the block diagram of the overall process including the irrigation control system, surveillance live feed, water tank, sensor node, actuator node wireless sensor network, the cloud and user terminal. An edge device is used to collect data from the environment. The sensors sense the physical parameter and collect the data, which then relays to the microcontroller for further processing. It is a central hub of the IoTs system that acts as a bridge between the nodes and the Internet. The actuator, an edge device that acts on the environment upon receiving the inputs (e.g. humidity, soil water level) can autonomously take decision based on the program installed. It turns ON or OFF (e.g. the pump) depending on the need of the moment.

where

$$\text{Drip time} = \text{time of sprinkle;}$$

$$\text{Quantity of } H_2O \text{ saved from drip} = Q_w - Q_{wdt};$$

$$Q_{wdt} = \text{quantity of } H_2O \text{ at sprinkle time,}$$

where drip time is the time the sensor trigger off, which is the time at which the crops are saturated with water.

Quantity of H_2O reserved from mean the balance of H_2O in the source.

Quantity of H_2O saved simply means the amount of H_2O managed from either the sprinkle or drip irrigation method.

$$\text{Total } H_2O \text{ saved} = Q_{wi} - (Q_{wst} - Q_{wdt}) \tag{6}$$

where T_{H2O} – saved = total H_2O saved which is the actual water management.

$$\text{User Friendly: } U_f \; H_2O \; \frac{NT}{NP_t} \times \frac{100}{1} \tag{7}$$

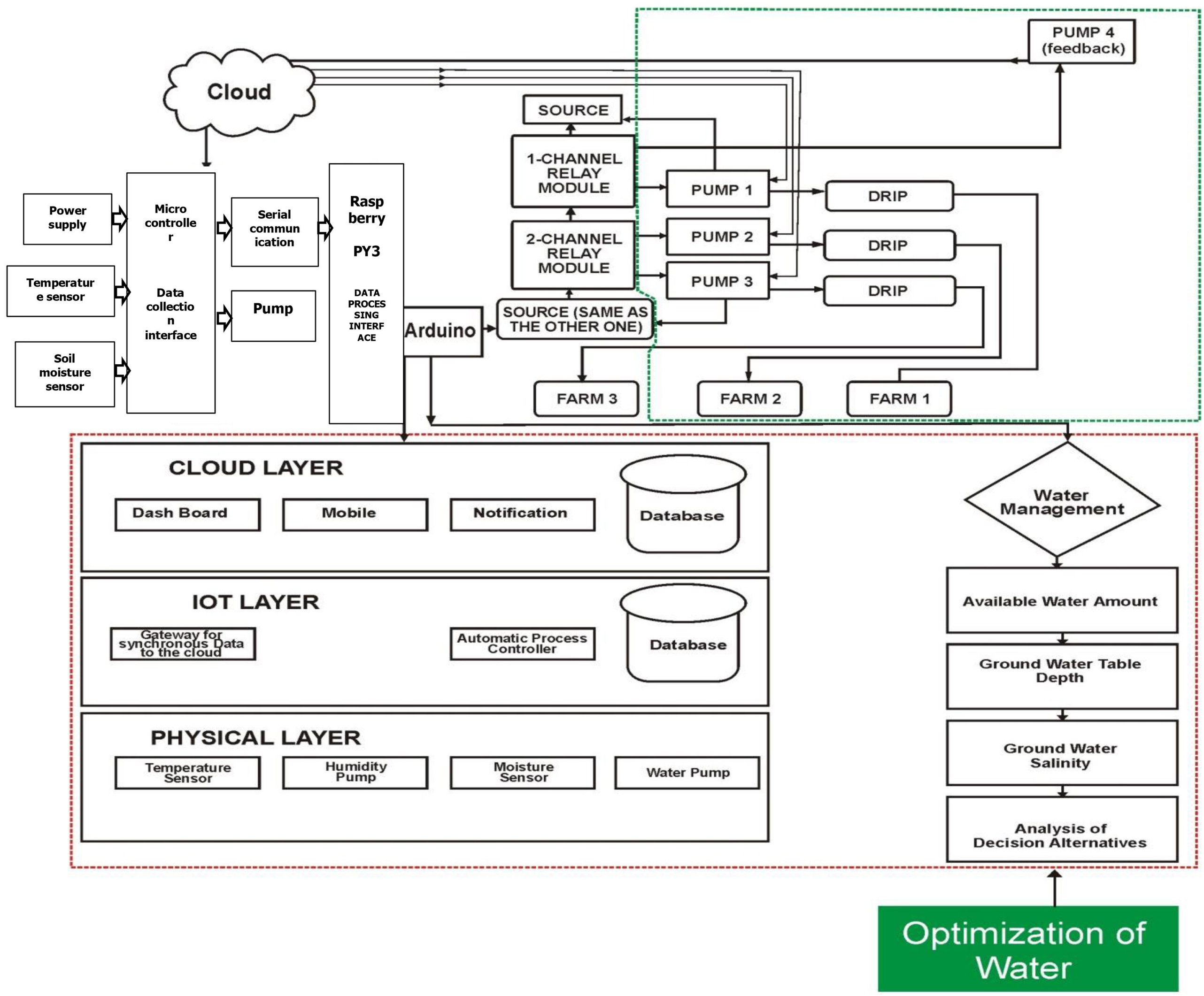

Figure 3. Architecture of the proposed system.

NT = total number of tests or triers;

NP_t = total number of positive test or triers, where a positive test is a test where the saturated used for the reports friendliness.

High-Level Input Model

The input design of the proposed system highlights the segment or input from where the user of the system adds information to the system. In the input form, the system administrator has the privilege of adding new user to the system or updating existing user information in the system. Other users fill an input form that enables them to view upload. Figures 4-6 highlight four input quantities of the model namely, humidity, temperature, soil moisture level and irrigation. These quantities are relatively measured using sensor modules. Arduino sensor module was used to moisture temperature and humidity at the sensor node. Figure 3 contains a vivid outline of the components of the Optimized IoTs Model.

It has 0˚C - 50˚C temperature range and 20% - 90% relative humidity range with an accuracy of plus or minus 1%. Moisture sensor also employed to measure soil water content. It consists of two gold coated probes that are used to detect soil moisture. The probes measure the resistance of the soil by passing electric current through it. The sensors are embedded in the farm to collect the environment data which then relays to a microcontroller for processing and is transmitted through a LoRa module to other sensor/actuator nodes. Figure 5 shows the input model while Figure 6 shows the sensor connection dashboard. Figures 4-6 outline the sensor activities in an IoT setup in measuring the geo-information of a farm.

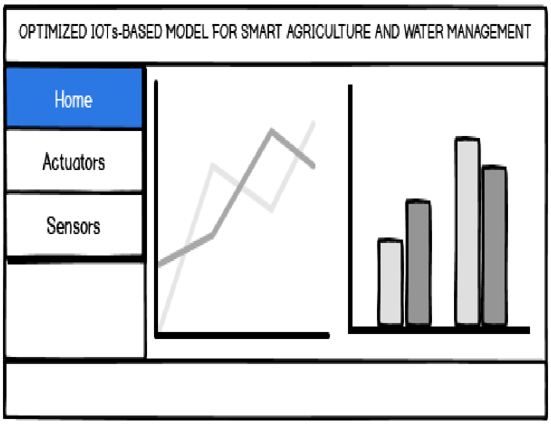

Figure 4. Dashboard page.

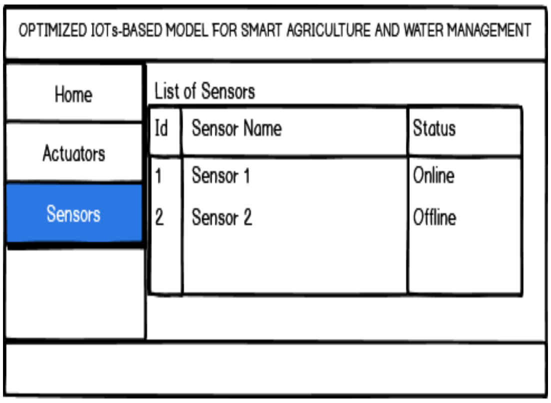

Figure 5. Sensors page.

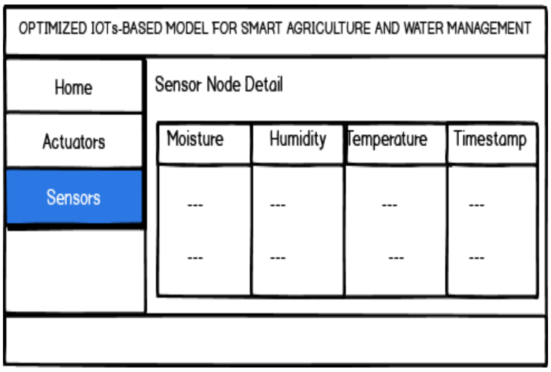

Figure 6. Sensor detail page.

High-Level Output Model

The output of the proposed design system is the product and information that the device produces. The output design demonstrates the proposed system's overview of the configuration of the model. The output designs have the following features, Moisture Humidity, Temperature, timestamp, surveillance live feed and water pump.

A dynamic responsive web application is designed to serve as the interface for viewing readings from the sensors and also provides farm manager access to locally or remotely activate the irrigation system of the farm. Figure 7 highlights the output profile from a sensor communication setup.

High-Level Process Design

Data read from every sensor is sent to the cloud through the gateway for processing, analytics and storage. Local automation is achieved at the gateway level while the farm state is continuing sly synchronized with the cloud. The system is design in such that two (2) different authorized user one as a farm admin while the other serves as farm manager. Farm admin has role of adding both sensor and actuator nodes to the platform and setting operation mode from automated operated or operated by farm manager user. The farm manager user has the role of controlling both the sensor and actuator nodes as well as receiving either SMS or Email notifications about any changes made in the farm's operation. Figures 8-13 display the design setup of the Optimized IoTs Model.

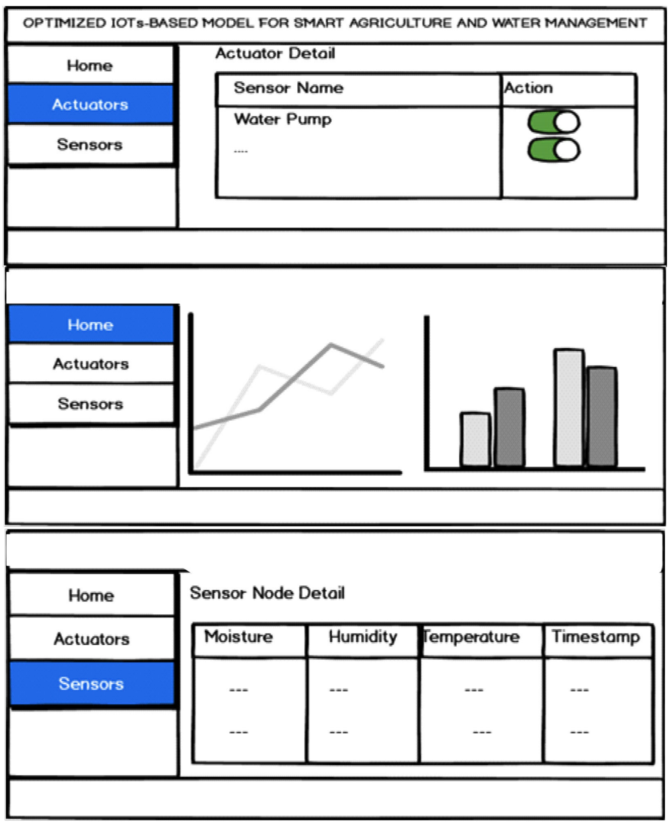

Figure 7. Output design.

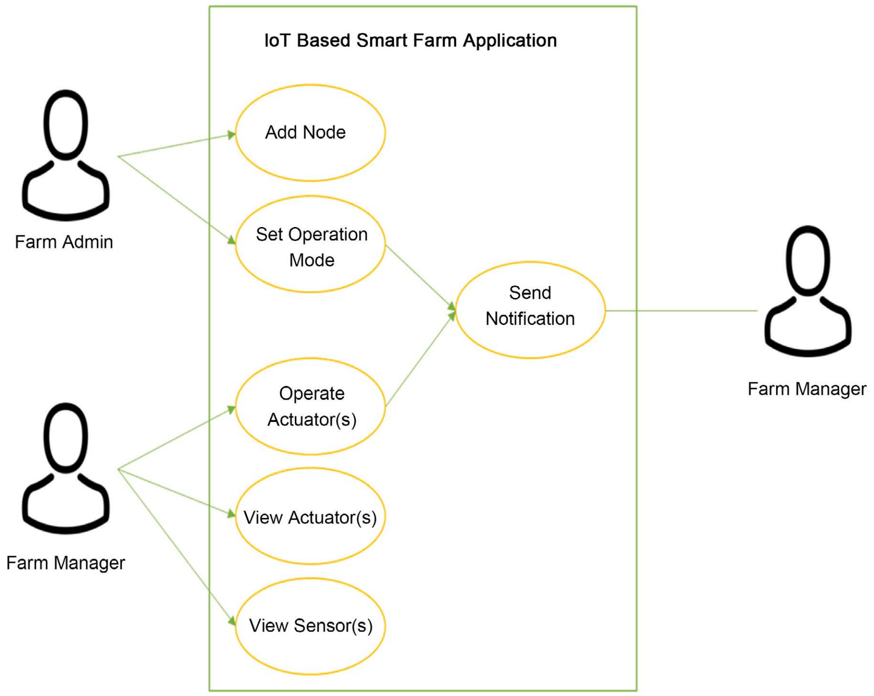

Figure 8. System use case diagram.

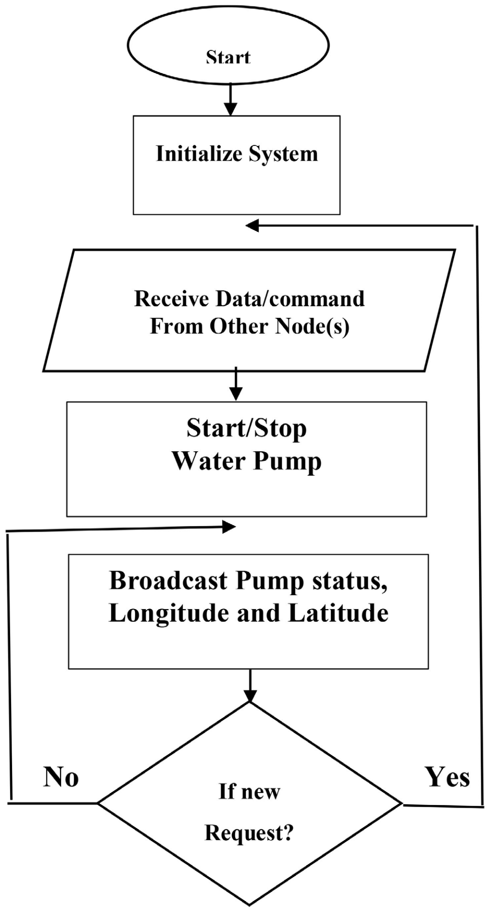

Figure 9. Actuator Node flowchart.

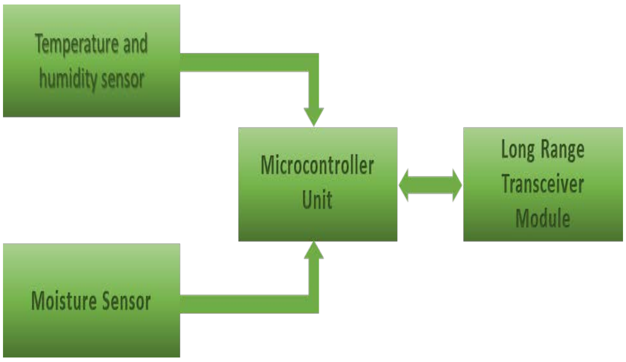

Figure 10. Sensor node architecture.

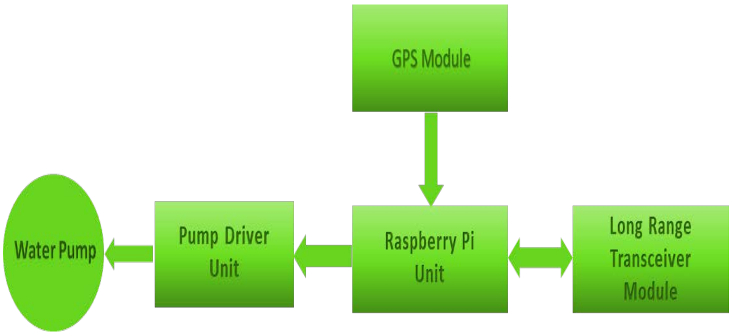

Figure 11. Actuator node architecture.

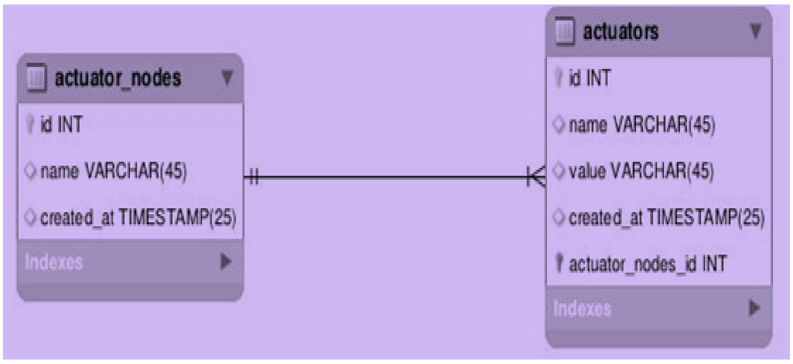

Figure 12. Actuator database design model.

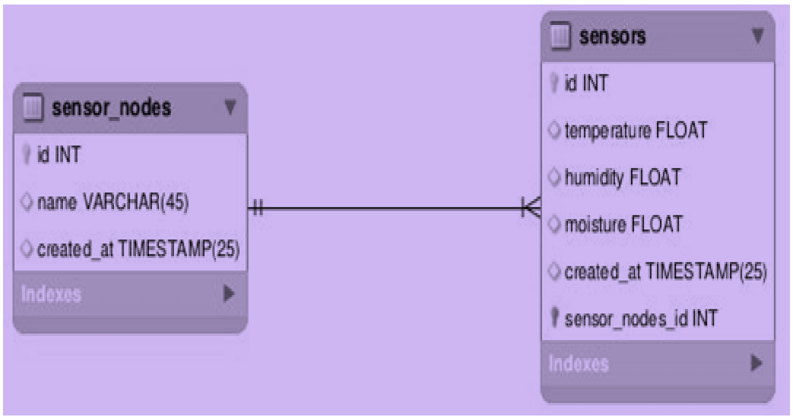

Figure 13. Sensor database design model.

When the data of different sensors that are humidity, temperature, soil moisture and location is acquired it is sent to the mobile app of the user and if the water content in the soil is less than the cut off value then an alert message is received on the app of the user and motor gets switched-on automatically using relay.

In the flowchart, a node waits for request from any of the nodes or from server and, if there is a valid request it process the request and wait for another request while If there is no request it reads sensor data and broadcast tit to other nodes in the network an d the server for processing. This give the possibility of automation at the physical layer of the architecture unlike the centralized approached where all request are routed to the IoTs layer or Cloud layer for processing. The decentralized approach increases the efficiency and **Sensor node flowchart**

Database Design of the Proposed System

The system's database structure will include the observed data in addition to the device information data. The information data is data about the devices that are installed in the field and provides the status of the device, whether it is active or not, while the observed data is the real-time sensor data which is communicated by IoTs data manager from IoTs layer and helps to process and monitor the crops observed data for further analysis. The smart agricultural and irrigation farm's database is built to hold both operational and observational data. Data from sensors and monitors is saved in the SENSORS and ACTUATORS tables, while ACTUATOR NODES and SENSOR NODES tables record every fundamental and vital information about the devices in the field. Node names, identifiers, sensor states, timestamps, dates, and settings were all kept in separate tables. The database structure is planned using the MySQL schemas workbench.

4. Results and Discussion

The study achieved the following results, it:

1) designed an optimised IoTs-based model for smart agriculture and irrigation water management.

2) implemented the optimised IoTs-based model for smart agriculture and irrigation water management with python programming language

3) tested and evaluated the performance of the optimised IoTs-based model for smart agriculture and irrigation water management.

Performance Evaluation of the Systems

Table 1 compared the existing method against the optimized model for farming and irrigation. The performance indices were selected to measure effectiveness of both existing and optimized methods.

Table 1 of this research show the comparative results for both the existing and proposed systems alongside their comparative analysis and parameters used in the comparison for both systems includes; water flow rate, irrigation water management, surveillance live feed and user friendly. The above comparative analysis of the existing system and the proposed system based on the aforementioned

Table 1. Performance evaluation of the old model and the optimized model.

Performance metric	Existing model	Optimized model
Water flow rate	0.19 L/S	0.98 L/S
Irrigation water Conservation	Uncertain	0.017 L/Ms
Surveillance live feed	Absent	Present
User Friendly	Semi friendly (49%)	Friendly (82%)

parameters, therefore, clearly shows that the optimized model is better than the existing system especially when it comes to the water flow rate, 0.98 L/S as against 0.19 L/S of the old system, irrigation water management, 0.017 L/Ms as against uncertainty in the old system, presence of surveillance live feed as against absent of it in the old system and 82% user friendliness as against 49% of the old.. Based on the performance evaluation above it can be stated that the optimized model outperformed the existing method of farming /irrigation by far.

Possible Promotion and Application Prospects

The results have the propensity to solving the palpable major agricultural concerns in relation to crop production, farm security, and effective water management in Ministry of Agriculture, River Basins, and the Environment Ministry. Irrigation units in the Agriculture Ministry would be the prime domain of users of the model. The major deliverable would certainly include major reduction in farm insecurity, reduction in cost of production occasioned by reduction in the quantity of water used for irrigation, increase in farmers' safety, and increase in the food supply chain.

5. Summary

Since all data must be sent to or received from a centralized server, automated smart agricultural monitoring encounters various challenges and hitches while trying to transfer data to the server. Since water is distributed in such an inefficient manner, its effectiveness is low. There is also a substantial potential for water loss. As a result of this difficulty, irrigation farming has grown less productive because of the usage of antiquated agricultural equipment. The poor yield of vegetables, fruits, and harvests is attributable, in part, to the fact that many farmers still utilize conventional/traditional methods of irrigation. In this investigation, the prototyping approach was applied. The prototype approach broke down the many steps required to maximize smart agricultural irrigation into linear, sequential stages, where the success of each step relies on the success of the preceding one and each phase is associated with a certain goal. A program called balsamiq was used to sketch out the proposed system. The four main systems used to implement the Optimized IoTs-based model are as follows: The purpose of this research was to fine-tune an existing IoTs-based model for smart agriculture and irrigation water management, put that model into practice, and then tested and assessed its efficacy. The study was improved by the use of empirical analysis.

We've looked at the downsides of the present system and recommended a better one, complete with a login menu and an admin panel. The farmer's login information is saved in a database and may be created from the manage menu.

6. Conclusion

The goal of this research was to develop an improved IoTs model for efficient water management in smart farms and irrigation systems in Nigeria. The system has the following features: a login page wireframe, dashboard wireframe, system user case diagram, actuators page wireframe, sensors page wireframe, and application interface design. The model was deployed to the farm after it was proven to be effective at its intended tasks.

Recommendations

The study recommends the following:

1) The farmers must be adequately trained in computer skills to comply with the management, maintenance and operation of the system.

2) The government through the Ministry of Water Resources should publicize the IoTs-based model for smart agriculture and irrigation water management.

3) Also, Research Institutes such as crop and Root Research institutes in Ibadan and Umuahia in Nigeria should adopt the IoTs-based model for smart agriculture and irrigation water management in this Internet era.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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