IOT BASED IRRIGATION MANAGEMENT SYSTEM

Abstract

Agriculture is one of the major activities in developing countries to sustain the life by providing food and other essentials to the living organism. Also, agriculture is a major water consuming sector in which irrigation practice utilizes major percentage of water of about 70-80 percent. Thus, a method is required to use water in agriculture effectively. In comparison to conventional methods, the modern irrigation system significantly reduces the amount of water used and assists irrigation scheduling mainly in some crops, like rice, require varying amounts of water as they develop. This chapter discusses about IoT based irrigation management system and suggests automating irrigation through the use of a smart phone that measures moisture content and periodically communicates data to a microcontroller via a connectivity unit. The microcontroller makes irrigation decisions and notifies the farmer through text message when the field is in good condition. This technology will raise agricultural yield because it is non-contact and non-invasive property. It can also help farmers decide how much irrigation to use in order to enhance crop cultivation. By utilizing this new age agricultural technologies, the crop's overall production costs will be reduced and also saves the time by decreasing the need for human intervention during irrigation. By integrating wireless sensor networks in the agricultural fields, the work can be expanded in the future to a huge scale.

Keywords: IoT (internet of things), sensors, microcontroller, automated irrigation

Authors

Ayushi Jha
Soil and Water Engineering
Punjab Agricultural University
Ludhiana, Punjab, India
ayushi-2031002@pau.edu

Simranpreet Kaur
Soil and Water Engineering
Punjab Agricultural University
Ludhiana, Punjab, India

Sadhani Kumari
Divison of Agricultural Engineering
ICAR-Indian Agricultural
Research Institute
New Delhi, India

Mahima Sharma
National Institute of Hydrology
Roorkee, Uttarakhand, India

I. INTRODUCTION

Utilization of modern technology in agriculture sector is not a new concept as agriculture industry depends largely on the innovative ideas to meet the steadily increasing food demand. Various technologies like Machine Learning (ML), Deep Learning, Artificial Intelligence (AI) and the Internet of things (IoT) are helping farmers to get task done with least efforts [9]. The internet of things or IOT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. IOT based sustainable agriculture is helping the farmers to deal with challenges such as to increase their yield and decrease the costs as well as improving the process of decision making with accurate data. IoT contributes in number of ways in the agriculture sector. IoT helps in efficient use of water, optimize the input resources like electricity, fertilizers, insecticides etc along with it help to maximize the earnings and allows farmers to delivers better products at low cost [11]. IoT based devices allows to collect large amount of real-time data on crucial factors like weather conditions, crop growth, soil quality, livestock health etc. that can help the farmers to plan staff, equipments and effective use of resources. Along with that this real-time data enables the farmers to monitor their crops and livestock and to detect any inconsistencies and anomalies in crop production and health of livestock. Hence farmer can plan to minimize the wastage of resources and eliminate any risks in bud to prevent crop loss. Moreover, with the help of IoT devices various time consuming and repetitive farm processes like fertilization, irrigation pest control can be automated. It can get rid of dependency on human labour which reduced the labour cost, less chance of error and increases overall efficiency of the crop production [8]. All the above factors enable IoT to maintain high quality along with increase in yield of the crop to meet the increasing demand of the population [11]. The field which requires immediate implementation of IoT technology is irrigation management as continuing water scarcity and growing population made a need of hour to utilize a technology which not only enable efficient use water but also enhance the crop productivity to ensure food safety in coming years. IoT based smart irrigation systems are able to automate the irrigation process by analyzing the climate condition and soil moisture hence allows sensible application of irrigation water to reduce water consumption in the agriculture sector and also to improve water use efficiency. This chapter aims to provide an insight on the use of IoT in irrigation system and general idea of structuring the IoT system that can be utilized efficiently by the farmer.

II. APPLICATION OF IOT IN AGRICULTURE

Sensors are leveraged in agriculture from long time but the issue with using traditional approach for using sensors was, not able to get the live data from the sensors. The sensors were used to store data into to their attached memory device and later on it was utilized. With the introduction of the internet of things sensors are now connected to the cloud via satellite or cellular network which enables to get the real-time data from the sensors and enabling decision making more effective. Thus, more advanced sensors are now utilized in the field of agriculture [2]. With the advancement of IoT technology in agriculture sector, sensors are used in every step of farming process such as calculating the number of resources and time required by a seed to become fully grown vegetable or a crop. Smart Farming utilizing IoT enables real-time monitoring of the field hence improving entire agriculture

system. The internet of things with the help of interconnectivity and sensors in farming saves the time of farmers as well as reduce the wasteful use of resources like electricity and water [7]. Below are some applications of IoT applications in the field of agriculture.

1. **Monitoring climate conditions:** Climate is one of the major factors affecting crop production. Requirement of climate conditions vary from crop to crop and inaccurate or improper knowledge of climatic conditions can drastically affect the quality and yield of the crop. IoT technology helps to know the real-time weather conditions of any given area. The sensors are placed in agriculture field to collect data from the environment which enables the farmer to select the right crop according to the suitability of the climate conditions [7]. The whole IoT system consists of different sensors that can identify real-time weather conditions such as temperature, humidity, solar radiation, rainfall etc which plays a crucial role in crop productions. Moreover, real-time access to satellite images and cloud-based algorithm calculations facilitates the farmers to forecast and track the weather conditions, hence allows farmer to take necessary measures to protect the crop.

2. **Smart greenhouses:** All aspects of greenhouse operation can be monitored and controlled using IoT sensors. Operations such as irrigation, lighting, fertilization, pest control and air humidity are controlled by the sensors and this eliminates the need of human intervention, thus making the process of crop production cost-efficient and more precise. It also gives the chance to identify any fluctuation beforehand in the environment of green house and provide enough time optimize the growth conditions for plants decreasing any risk of loss of crop. The IoT enables to create a remote access to the greenhouse by connecting the system to the cloud which eliminates the need of constant manual monitoring. The amount of water spent of irrigation can be controlled by integrating it with smart irrigation system, thus optimizing the crucial aspect of greenhouse production [2].

3. **Precision farming:** Precision farming is enhancing crop monitoring and assisting management decision using high technology sensor and analysis tool. Precision farming is one of the most famous applications of internet of things. Precision agriculture enables the farmer to create data using sensors and analyze the data to take smart and quick decisions. The IoT based smart agriculture field monitoring system with different sensors like soil and moisture sensors enables to track the chemical and humidity characteristics of the soil and also indentifying any pest infestation. This helps the farmers to optimize the use of water and fertilizers according to the present conditions of the field and also taking necessary measures to shut down the pests to improve the crop yields [1], [9].

4. **Livestock monitoring:** The IoT based applications and livestock collars having smart sensors are used by the farmers to monitor the health, location and well-being of the cattle by gathering data on each livestock's temperature, nutrition regime, blood pressure and various other parameters. It enables farmer to identify any disease affected animal and separate it from herd to prevent further spread of the diseases and to take necessary measures [9]. As the farmers can locate the animal using smart IoT based sensors it reduces the labour-cost. The IoT system enables the famer to optimize the milk production by providing nutrition according to the requirement of the animal and also to monitor cattle reproduction. Overall, it helps the dairy farmers in efficient management of dairy farm.

5. **Irrigation management:** The IoT based smart irrigation system is one the most useful application of IoT it enables the farmer to use water in sustainable manner. There are different smart irrigation systems like weather based and soil-based systems [5]. Weather based irrigation systems utilize the local weather information through sensors or form historical data to make decisions on irrigation scheduling. In this system decisions are made by analytical assessment of different weather parameters such as rainfall, humidity, temperature, wind and solar radiation [11]. Whereas in soil-based irrigation system decisions is made on the basis of the soil moisture data collected from the sensors installed in the field and also according the crop health, age of crop. The smart irrigation system controls and manages the water storage pump of groundwater, tracking soil moisture, pressure and temperature conditions of crop production area through various IoT-based sensors.

III. NEED OF AUTOMATED IRRIGATION SYSTEM

Agriculture sector is the biggest consumer of freshwater in whole world accounting for 70% total water use [4] and In India, agriculture consumption accounts for 83 % of total water consumption [10]. Moreover, due to steadily growing population, natural resources like water and land under huge pressure. The possible risks of climate change have given rise to various problems such as decline in quality of water, increase in water scarcity, the increase in soil and water salinity, the biodiversity loss and the increase in irrigation requirements. It gives rise for the need of smart water management system to ensure food water security of world's population. Type of irrigation system used, amount of irrigation along with method of application plays a crucial role in water management. Sometimes farmers apply or spray more water than needed (over-irrigation) in order to avoid any loss of productivity due to water stress (under-irrigation) this not only affects the yield of crop it also leads to wastage of water and electricity. The IoT based precision irrigation system utilizes data from the soil sensors to provide irrigation to the crops in order to avoid over irrigation or under irrigation of soil. It provide opportunity to the farmers to monitor the whole process online through a website or application .The rise in use of IoT based systems is mainly due to various factors such as low-cost devices, availability of cloud data centers for storage and processing, low-power wireless technologies, management frameworks for dealing with unstructured data from social networks, high-performance computing resources in goods platforms, and computational intelligence algorithms to handle large amount of data amount of data (aka big data analytics). IoT based automated irrigation system in agriculture plays crucial role in increasing water productivity along with in decreasing the extra labor requirement, fertilizer use and water requirement in the field. Therefore, this system is prospective solution to the issue faced in manual and cumbersome irrigation process by enabling affective use of water resources and also eliminates human intervention in farming process [9]. The IoT based smart irrigation system is a way to solve the issue of water crisis along with the automated system which enables the farmer to control and monitor the farms located at different location through mobile or website from remote place and fulfill the aim of increasing the farmer's profit and overall income.

IV. COMPONENTS INTEGRATED IN THE SYSTEM

The IoT based system is a natural choice when thinking of automation in any field. The degree of success of the developed system depends on the precision and effectiveness

with which the integrated components work. An IoT based system is mainly the integration of three units viz. transmitting unit, connectivity and receiving unit.

1. **Transmitting unit:** Transmitting unit of any system compile together to create a whole thing that transmits together to create an entire system Circuit termination hardware is always present in a transmission system at both the transmit and receive ends of a transmission channel. The transmitting section of IoT system consists of sensors, relay, light dependent resistor (LDR), microcontroller that functions all together to transmits data in form of signal with is further processed in the processing unit.

    - **Sensors:** Sensors collect certain information from the environment around them. Because a sensor's main function is to identify even the minute changes in its environment, so they are also referred to as "detectors" in general. This allows an IoT device to gather pertinent data for post-or real-time processing. This small piece of hardware can measure anything, depending on the type of sensor. Even while specialized sensors can measure a variety of complexity, some IoT devices combine numerous sensors to be able to collect a variety of data or carry out a number of tasks. For example, mobile phones have some inbuilt sensors such as GPS, fingerprint lock and various other sensors bundled in one serving several purposes. From irrigation management point of view sensors such as soil moisture sensor, temperature sensor, pressure sensor, pH sensor, light sensor, rain sensors and many others are used when working with IoT based irrigation management system and some of them are described below are mainly used.

        - **Soil moisture sensor:** It measures the moisture underneath the soil and can be used to calculate how much water is trapped in the soil horizon. In order to calculate how much water is needed, soil moisture sensor insert a sensor underground in the root zone of crop fields. Water in the soil is not immediately measured by soil moisture sensors. Instead, they track changes in another soil characteristic that is predictably connected to water content.

        - **Temperature sensor:** In experiments and scientific study, soil temperature sensors are used to measure the temperatures of the soil, atmosphere, and water. Ground temperature, the collective term for surface temperature and ground temperature, is the abbreviation for soil temperature. The temperature of the soil has a direct impact on the development and growth of plants, the breakdown of fertilizers, and the deposition of organic matter. Soil temperature sensors come in a variety of designs using thermistors, thermocouples, thermocouple wires, and averaging thermocouples. The electrical signals transmitted from the sensors to our data loggers can be converted to different units of measurement, including °C, °F, and °K. The temperature sensors convert physical parameter to electrical signal. The temperature sensor LM35DZ can be used with IOT based system that produces an analog output. Temperature ranges between −55 °C (-1 V) to + 150 °C (6 V) and Voltage required between 4 V to 30 V for operation.

        - **pH sensor:** Soil pH sensors are used to measure the whether the soil is acidic or alkaline in nature. To grow healthy, vibrant plants, soil must be at right pH level. Soil pH meter must be used correctly in order to obtain accurate measurements. A

soil's acidity or alkalinity can be measured with a soil pH meter. They operate by monitoring the hydrogen ion activity, which is represented by the hydrogen potential or pH. The pH scale has a range of 0 to14, where 0 is very acidic, 7 is neutral, and 14 is alkaline.

- **Humidity sensor:** In order to function, humidity sensors must be able to detect changes in electrical currents or air temperature. Capacitive, resistive, and thermal humidity sensors are the three most common types. To determine the air's humidity, all three types will keep an eye on even the smallest alterations in the environment. Humidity Sensors aid in water level management without being present in the area, greatly enhancing farmers' efforts and lowering expenses. HR 202 humidity sensor is commonly used with IOT based system. It is resistive type humidity sensor.

- **Relay:** Relays are switches designed to close and open circuits both electronically and electromechanically. It regulates whether the circuit connections in an electronic circuit are opened and closed. The relay is not energised with an open contact when the relay contact is open (NO). In contrast, if it is closed (NC), the relay is not powered up because of the closed contact. The states are prone to shift, nevertheless, when energy (electricity or charge) is applied. Relays are typically used in control panels, manufacturing automation, and building automation to switch smaller current levels in control circuits and control electricity. Different types of relay modules are used with IoT based systems such as Grove relay operating at a voltage of 3.3-5V, Grove-two channel SPDT relay operating at voltage of 5V, Grove-four channel SPDT relay 5V.

- **Light dependent resistor:** A photo resistor, also known as a light-dependent resistor, is a light-sensitive electrical component. The resistance alters as beam hits it. The resistance of the LDR can vary by orders of magnitude, with the resistance decreasing as the light intensity rises. When connected to VCC (5V), the LDR emits an analogue voltage whose magnitude varies in direct proportion to the amount of input light it receives. In other words, the voltage coming from the LDR will increase in proportion to the brightness of the light.

The components in the transmitting unit transmit the data in form of signal to the heart of the IoT system that is microcontroller. The microcontroller controls the entire system automatically and acts as brain of the system.

- **Microcontroller:** A microcontroller is a compact integrated circuit that controls a single process in an embedded system. A typical microcontroller is a single chip that houses a CPU, memory, and input/output module. To control a single device function, a microcontroller is integrated into a system. It accomplishes this by utilising its core CPU to evaluate data that it receives from its input/ output module. The microcontroller receives temporary data that is stored in its data memory, where the processor accesses it and employs programme memory instructions to interpret and apply the incoming data. It then communicates and takes the necessary action using its input/output modules. The brain of the device is supposed to be a CPU. It interprets and reacts to several commands that control how the microcontroller

operates. This calls for doing elementary logic, input/output, and arithmetic operations. Additionally, it carries out data transmission activities that send commands to other embedded system parts. A microcontroller's memory is where it stores the information that the processor needs to process commands that have been programmed into it. There are two main memory types in microcontroller viz. Long-term and Data memory. Long-term information about the instructions that the CPU executes is kept in programme memory. Since programme memory is non-volatile, it can store data indefinitely without a power supply. Data memory is needed to store temporary data while instructions are being carried out. Data memory is volatile, which means the information it stores is only kept current if the device is plugged into a power source. Then comes about the choice of microcontroller out of two popularly used that is arduino or raspberry pi.

- **Arduino:** It is one of the simplest microcontrollers that can be used in any IoT based system. It is an open-source hardware system, that can be operated and make in use by the desiring users. It includes an ATMEGA microcontroller, which processes data and supports the IoT system's efficient operation. The Arduino's versatility makes it feasible to create a variety of Internet of Things projects by simply altering a little amount of code. Arduino programmes can simply be written in C++ programming language using IDE software. Also, ESP-8266 WiFi module can be installed to establish the WiFi communication between the Arduino and cloud platform.

  Because of the Arduino board's extreme versatility, anything is possible. Various modules, including obstacle sensors, presence detectors, fire sensors, GSM modules, GPS modules, etc., can be linked to this board fairly quickly. The Arduino board's primary purpose is to control electronics by reading inputs and converting them into outputs since it behaves like a tool. There are different types of arduino boards available with different memory availability and processor units such as Arduino Uno, Arduino Due, Arduino Mega etc.

- **Raspberry pi:** It is much more complicated type to work with in comparison to arduino. It can be thought as a mini computer which is small size, lost cost with some exhaustive capabilities. It has input and output ports arranged in different patterns in different type of raspberry boards. Several sensors can be connected at a time on the board of this tiny computer that further connects with the outside world. The coding/programming for raspberry pi can be done using python programming language. There are different types of raspberry boards available with different memory availability and processor units such as Raspberry Pi 4 B, Raspberry Pi 3 B+, Raspberry Pi Zero W, Raspberry Pi Zero WH etc.

2. **Connectivity:** The aim of any IoT based system is to make the data available to the end user, which can be redeemed through a platform, but the data transmitted through sensors and other input devices and further fed as a memory in the microcontroller. To make this information available at user interface a connection is needed that connects the transmission unit to the user interface. Cellular, satellite, WiFi, Bluetooth, low-power wide-area networks (LPWAN), connecting via a gateway or router, or connecting directly to the internet via ethernet is just a few of the ways that the sensors/devices can be

connected to the cloud. There are compromises between each option's bandwidth, range, and power usage. The ideal connectivity method depends on the IoT application in question, but they all achieve the same goal that is sending data to the cloud.

To get to the cloud, incoming, unprocessed data from the sensors must travel through gateways. Gateways translate network protocols to ensure that all networked devices can communicate with each other without interruption. In essence, this makes the gateways an important communication center and is what allows for simple data traffic management. Additionally, gateways provide security by shielding the network from intrusive and harmful attacks. As the data passing through it is secured by the most recent encryption techniques, it can also be seen as an additional layer of protection. Prior to transferring sensor data to the cloud, gateways can preprocess the data. In other words, they reduce the significant amounts of data that were "sensed" in the earlier stage. Some intelligent IoT gateways have the capacity to evaluate and average data.

The acquired data must be processed after it has been transported to the cloud. This high-performance facility plays a key role in connecting the IoT ecosystem's parts. It manages the data, keeps it in storage, and makes choices that can make or break a contract. All of this is accomplished for enormous amounts of data in only a few milliseconds, which is crucial for IoT because latency cannot be compromised, especially in essential areas like health and safety. While providing and acting on real-time information is the primary function of IoT solutions, there needs to be a component that can manage vast amounts of data to accommodate the time-sensitive nature of the IoT model. Cloud computing platforms are useful in this situation. As they are often in charge of processing, controlling, or taking analytics into account for the gathered data, they serve as the brain of the IoT ecosystem. For effective real-time data analysis, a combination of devices, protocols, gateways, and storage is used.

3. **User interface:** The processing is further followed by making the data available and utilized by the end user. This may be done by sending the user a warning (email, text, notification, etc). For instance, a text message alarm when the cold storage facility's temperature rises too high. A user may have access to an interface that enables them to routinely monitor the system. It's not necessarily a one-way street, though. The user might also be able to take action and influence the system, depending on the IoT application. By using an app on their phone, the user might, for instance, remotely change the temperature in the cold storage. In terms of irrigation management, a person/ farmer can control the irrigation schedule from remote location without actually existing on the field. Additionally, certain tasks are carried out automatically. The system could modify the temperature automatically using predetermined rules, as opposed to waiting for you to do so. The IoT system might automatically notify security professionals or the appropriate authorities rather than notifying about an intrusion. The interface should be user-friendly enough to prevent any complications for the user, even though an attractive design is important.

4. **Automated irrigation system:** It is quite evident that the water sources are getting exploited day by day, the groundwater level has gradually decreased over the previous ten years, and that there have also been bad monsoons. This creates a necessity to automate the irrigation system for efficiently using water resources, and the majority of researchers

are currently focusing on irrigation system automation. A block diagram representing the general layout of IoT based irrigation system is presented in figure 1. According to the need the complexity of the system can be varied by choosing highly efficient devices.

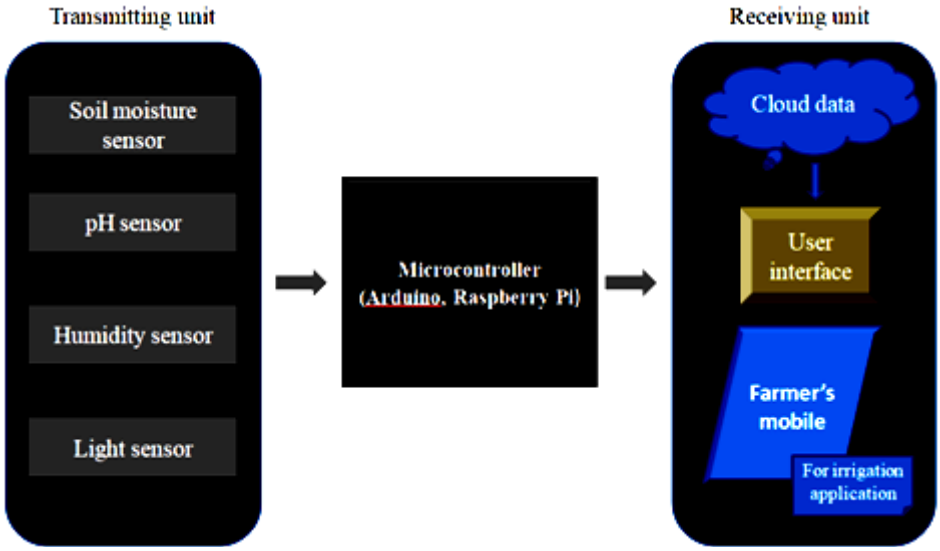

Figure 1: Layout of IoT Based Irrigation Management System

An IoT based irrigation system mainly consists of the sensor unit that includes soil moisture sensor, pH sensor, humidity sensor, rain sensor, light sensor. The data in form of signals through each sensor that is installed in a irrigated crop field will be transmitted to the microcontroller unit. The sensor is plugged in the input port of the microcontroller unit, that will further process the data according to the program that has been feed into the microcontroller and produces an output in accordance to the necessity. Using the sensor values it will provide information in form of notification or SMS alert to the farmer's mobile phone or will automatically functions the irrigation unit as per the need.

Several efforts have been made in the field of irrigation automation that holds different number of successes. In [12], a site-specific irrigation controller with in-field data feedback was presented. This device uses Bluetooth connectivity to help with irrigation decision-making and real-time task monitoring. [13] With the aid of suitable sensors, a low-cost microcontroller prototype system was created to track the status of the crop fields soil, canopy, air temperature, and soil moisture. By gathering information throughout the growing season, the PIC16F88 microcontroller was employed to monitor the agricultural conditions. In [14], the authors looked into how Australian irrigators could receive drip run time recommendations using mobile phone Short Messaging Service (SMS) to help plan irrigation schedules. A smart sensor was used in the construction of a microcontroller-based drip irrigation system [15] to keep track of the environmental conditions in the agricultural area. By continuously monitoring weather factors like temperature, relative humidity, and soil moisture, diseases' germination was discovered and alerted to via buzzer. Using the physical parameter values, it had acquired from the agricultural field, this system also performed a real-time analysis of the drip irrigation. Using the physical parameter values, it had acquired from the agricultural field, this system also performed a real-time analysis of the drip irrigation. To make use of the available water in the agricultural field, an automated irrigation

system [16], [17] was created. In this, soil temperature and moisture levels were assessed using sensors implanted in the root zones of the crops, and wireless information units were utilised to transfer the measured data to the web server over the public mobile network.

V. CONCLUSION

Water management is vital in countries facing water insufficiency. This also affects the agriculture sector as its major consumer of the water. The growing concerns about climate change have given rise to the need of water management measures to ensure the availability of water for food production. Thus, the researches on water efficient ways of irrigation have increased in years. The IoT based smart irrigation system provides an adequate solution for independent agricultural operations for economics, precision, decreased human effort and protection of environment. Although application if IoT provide number of benefits to agriculture but there many challenges faced by the farmers while implementing IoT for agriculture. One of the major one is its high cost, the equipments required to implement IoT in the agriculture required initial high investments as well as operation costs are also high, it is difficult of marginal farmers to adopt such technology. In addition to this it requires constant internet connection and right technology to ensure stable and timely transfer of collected data. Most of the farms are situated in rural and remotes areas which lacks in proper infrastructure and uninterrupted internet access. In order to regularly monitor its crop farmer needs to have secured access to crop data without any irregularity but communication problem will make this system in vain. Also, all the IoT systems are interconnected and they communicate over networks, various kinds of network attacks can take place as system enables little control despite any security measures and IoT systems collect large amount of data which is difficult to secure. In spite of all this challenges IoT based technology is one of the best solutions to overcome the problem of water scarcity so there is ample need of research to overcome the challenges faced in implementation of this technology. With advancement in research facilities and more and more scientists taking interest in this field along with many private companies and government is working on to provide reliable internet coverage across the globe it will enables the promising future of IoT based irrigation management.

REFERENCES

[1] Burak, “Farming done right : Top 5 applications of IoT in agriculture,” Relvant. https://relevant.software/blog/top-applications-of-IoT-in-agriculture/
[2] A. K. Singh,"Application of IoT in agriculture system,” Agricultural Science and Food Technology, vol. 6, pp. 41-44, May 2020.
[3] Arpitha Shankar S. I. A. Shankar, “IOT based smart irrigation system using raspberry pi,” International Journal of Engineering Research & Technology, Vol. 7, 2019. ISSN: 2278-0181
[4] C. Kamienski , J. Soininen , M. Taumberger, R Dantas , A. Toscano , T. S. Cinotti, R. F. Maia, and A. T. Neto, “Smart water management platform: IoT-based precision irrigation for agriculture,” Sensors vol.19, 276, 2019. ; doi:10.3390/s19020276
[5] E. Nigussie, T. Olwal, G. Musumba, T. Tegegne, A. Lemma, F. Mekuria, “IoT-based Irrigation Management for Smallholder Farmers in Rural Sub-Saharan Africa,”
[6] Procedia Computer Science vol. 177, pp. 86–93 ,2020.
[7] K. Dane,” An overview of internet of things (IoT) for farming, challenges and benefits,” Agriculture goods, April 2020. https://agriculturegoods.com/an-overview-of-internet-of-things-IoT-for-farming-challanges-and-benifits/

[8] M. Hasan, "10 best advantages of IoT in agriculture and smart farming," Ubuntupit, July 2020. https://www.ubuntupit.com/best-advantages-of-IoT-in-agriculture-and-smart-farming/
[9] R. Pathak,"7 applications of IoT in agriculture," Analytic steps, December 2020. https://www.analyticssteps.com/blogs/5-applications-IoT-agriculture
[10] S. Rawal, "IOT based Smart Irrigation System ," International Journal of Computer Applications, vol 159, pp. 7-11, February 2017.
[11] S. V. Kumar, C. D. Singh, and K. Upendar, "Review on IoT based precision irrigation system in agriculture," Current Journal of Applied Science and Technology, 39(45): pp. 15-26, 2020.
[12] S. R. Barkunan, V. Bhanumathi, and J. Sethuram, "Smart sensor for automatic drip irrigation system for paddy cultivation", Computers & Electrical Engineering, vol. 1, pp. 180–193, 2019.
[13] Y. Kim , and R. G. Evan, "Software design for wireless sensor-based site-specific irrigation", Computer and Electronics in Agriculture, vol. 2, pp. 159–65, 2009.
[14] K. F. Daniel and K. Hirut, "A low-cost microcontroller-based system to monitor crop temperature and water status", Computer and Electronics in Agriculture, vol. 1, pp. 168–73, 2010
[15] J. C. Nicholas, W. C. Evan, W. H. John, and A. M. Graham, "Using a mobile phone Short Messaging Service (SMS) for irrigation scheduling in Australia – Farmers' participation and utility evaluation" Computer and Electronics in Agriculture, pp. 132–43, 2012
[16] R. P. Nilesh, B. L. Rahul, S. M. Swarup, and A. B. Ashwin, "Microcontroller based drip irrigation system using smart sensor", Annual IEEE India Conference (INDICON), pp. 1–5, 2013.
[17] G. Joaquin, F. V. M. Juan, N. G. Alejandra, and A. P. G. Miguel APG, "Automated irrigation system using a wireless sensor network and GPRS module", IEEE Transactions on Instruments and Measurement, vol. 1, pp. 166–76, 2013.

