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SMART SYSTEM ARCHITECTURE DESIGN IN THE FIELD OF PRECISION AGRICULTURE BASED ON IOT IN BANGLADESH

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Abstract. *Despite being the largest production sector, agriculture in Bangladesh is still backdated. Applying a technology-based smart system architecture in precision agriculture can better smoothen Bangladesh's traditional farming activities. This study aims to introduce a smart system architecture in precision agriculture based on IoT in Bangladesh. The study combines several sensors compatible with the microcontroller unit, IoT cloud platform, and mobile application. The system is simulated in Cisco Packet Trace (Version 7.3.1) software. The sensors collect environmental data from the fields and process them in a cloud platform to produce information. Based on the information, farmers can access the information through a mobile application and make smart decisions to improve crop production. The system supports remote monitoring and control. The simulated result showed that the system could maintain a suitable environment for the crops.*

Keywords: Internet of Things, Precision agriculture, Bangladesh, Irrigation, Simulation

1. **Introduction.** Bangladesh is one of the most densely populated countries in the world. With a current population of 161.36 million since 2018 [1], Bangladesh's population is expected to exceed 200 million by 2050. Despite the population increase, the economy of Bangladesh mostly depends on the agricultural sector. 14.7% of its GDP comes from agriculture, and 40.6% are directly and indirectly connected to agricultural activities [2]. Consequently, agricultural land areas are shrinking annually due to the rapid growth rate of the population. Unfortunately, there are limited scopes to expand the available cultivable land. Thus, there will be inadequate food production for this large population shortly in the long run. Therefore, a technology-based smart system architecture can improve food production, reduce production costs, and increase sustainability [3].

In developing countries like Bangladesh, farmers feel more comfortable using traditional methods rather than adopting new technologies due to a lack of proper knowledge, high costs, and uncertainty of the effectiveness of the new technologies [4]. However, these traditional manual cultivation methods are not enough to get the full potential from the cultivable lands. Yet, it is possible to achieve significant potential from the developing countries' food production sector by adopting digital technologies. Recently, the Internet of Things (IoT) has gained much popularity and attention among researchers and practitioners due to its diverse application fields and numerous benefits. However, the application of IoT in the field of farming activities is still a new concept. Ongoing studies have found significant possibilities of using IoT technology in precision farming [5,6]. IoT is a dynamic global network infrastructure where the smart objects are connected virtually with self-configuring ability. Gubbi et al. [7] identified the trending application

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environments of IoT as – smart home/office, smart retail, smart agriculture/forest, smart transportation, smart grid and power management, smart healthcare, smart city, smart natural resource, and utility management. Like so many other application domains, IoT has started to dominate in the agricultural sector. Today's agricultural practices achieved many positive impacts in different agricultural areas using modern technologies and methods such as wireless sensor networks, blockchains, artificial intelligence, big data, edge computing, and cloud computing [6,8-12]. Islam et al. [13] developed and implemented an Arduino Nano-based smart monitoring system for agricultural practice in Bangladesh. The study showed that farmers could monitor their fields in real time and thereby make the necessary decisions. Maha et al. [14] developed an IoT-based automated smartboard system that reduces complexity in farming activities. Samawi [15] developed an IoT-based secure multi-crop irrigation system to reduce water consumption in farming. However, this study's system architecture will use different microcontroller platforms and sensor devices, which will serve different purposes.

This study, therefore, aims to design a smart system architecture in the field of precision agriculture based on IoT in Bangladesh. The smart architecture focuses on introducing environmental monitoring and automated controlling system using IoT and cloud technology. The system uses several interconnected sensor devices (e.g., temperature, humidity, and water level sensors) to detect environmental parameters and a cloud platform to monitor and analyze data in real time. The cloud platform allows the users to monitor and control several actuators such as drip systems, water spray systems, and water drainage systems. The proposed system architecture functionality is simulated using the Cisco Packet Tracer software. The automated smart system architecture reduces human effort in the agricultural field and maintains a suitable environment for crop production.

This research is organized into the following sections – The first section describes the study's background and aim, including a literature review. The second section describes the problem statement of the study. The third section gives an overview of the proposed system architecture. The fourth section describes the application area of the smart system architecture, the simulation of the system, how the simulation works, and evaluates the data from the simulation. The final section contains a summary of the research.

2. **Problem Statement and Preliminaries.** Agriculture and the rural non-farm economy are the main sources of livelihood for rural people in Bangladesh. When the world is advancing in agricultural activities by utilizing technological innovations, Bangladeshi agriculture is still backdated compared to the developed countries. In most cases, farmers of Bangladesh use traditional farming methods. However, the difference between the amounts produced and the potential for production remains large as farmers fail to maximize land use. According to the World Bank [16], Agriculture in Bangladesh is characterized by small, rice-dominated farms, which have greatly increased food self-sufficiency over the last 30 years. However, this self-sufficiency is continuously threatened by an increasing population and stagnating yields. At the heart of the problem is the "yield gap", the difference between the amounts produced and the potential for production, which remains significant as farmers fail to maximize land use. Weak technology carries much of the blame. Farmers lack the machinery and information systems to store their products postharvest or process them into high-value commodities such as fruit juice and jam. Lack of crop diversification, deteriorating and declining cultivable land, and poor linkages to markets also play a crucial part. As a result, a lot of sale potential is lost.

The basic technologies used in Bangladeshi agriculture are mostly based on farm machinery such as power tiller, tractor, diesel engine, water pump, combine harvester, rotavator, rice, and wheat reaper some locally developed machinery. Farmers also use cattle-based farming activities like weeding and grinding. These manual techniques and technologies alone cannot achieve the full potential of the agricultural sector. For using manual technologies, farmers cannot make a precise decision where digital technologies and methods can help to increase production. Agriculture is also vulnerable to many climate-changing issues and natural disasters. As a result, crop production cannot meet the desired expectation of the farmers. An IoT-based system architecture can be a smart solution for agricultural activities in Bangladesh to handle these problems.

3. **Proposed System Architecture.** The Agro-industry can be classified into four major sub-sections, i.e., 1) Crops, 2) Livestock, 3) Fisheries/Aquaculture, and 4) Forestry [17]. In this study, the proposed smart system architecture focuses on crop production. In the proposed system architecture, various sensor devices are placed in the crop fields to collect environmental data. These sensor devices are compatible with a microcontroller unit. A WiFi module is used to send data to the Internet. The information passes through a gateway and a router to connect to the cloud. Users can monitor the system through cloud service using smartphones.

Figure 1 shows the layered view of the proposed smart system architecture. The total system architecture is divided into four layers – the things layer, gateway layer, cloud layer, and application layer. The things layer consists of sensor devices that are implanted in the agricultural field, the actuators to control the environment, and a microcontroller unit to read data from the sensors and manipulate the actuators' status. The sensor devices and the actuators are programmed using JavaScript in Cisco Packet Tracer. The microcontroller unit also uses JavaScript to read environmental data from the sensors and control the actuators. The monitoring devices from the same network or the same place as smartphones or laptops are also placed in the things layer.

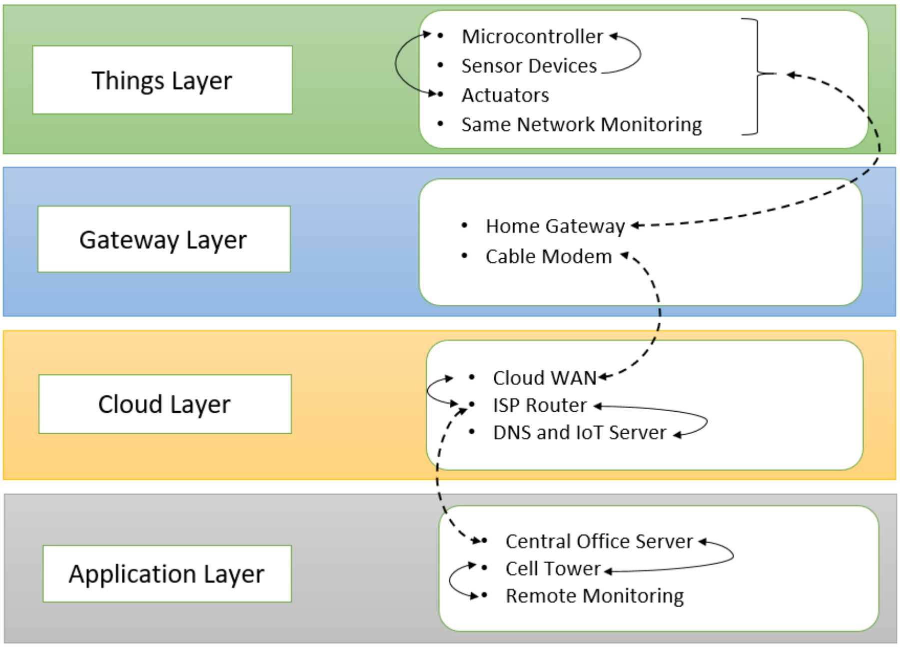

Figure 1. Layered view of the proposed smart system architecture

The gateway layer consists of a gateway device (Cisco DLC-100 wireless controller) and a cable modem. All the sensor devices, actuators, and microcontroller units are connected to the gateway device using WiFi (IEEE802.11n). The gateway device is connected to the cable modem and the cable modem is connected to the Internet. The cloud network consists of an ISP router (Cisco 2911), a Wide Area Network (WAN), a DNS server, and an IoT server. All the devices in the things layer are registered to the IoT server, allowing the user to monitor and control the system remotely. The IP addresses for the connected devices are obtained through the DHCP service configured in the cloud layer. The cloud layer connects the gateway layer and application layer through the Internet. The ISP router is connected to the central office server in the application layer. The central office server is connected to the cell tower which allows the users' remote monitoring of the system using mobile Internet. In the application layer, the users can remotely monitor and control the system from a smartphone or laptop.

4. Simulation and Result.

4.1. Application area.

In this study, a real-life scenario is considered for the simulation regarding Boro rice cultivation in the Dinajpur district located in northern Bengal. According to the Agriculture Information Service (AIS) of Bangladesh, Boro is a highly productive rice category (5-6 t/ha), and it covers most of the total produced rice in Bangladesh. Boro rice is mainly irrigation dependent, and it requires a suitable environment for maximum productivity. Boro rice takes 145-150 days from plantation to harvest and needs more resources and care for a longer period. During the early stage of its plantation, Boro rice requires 4-6 cm of standing water in the crop field [18]. During middle age, the plants need 10-13 cm of standing water in the field. A temperature of 27°C to 32°C and relative humidity of 60%-80% is suitable for rice cultivation [19]. This study aims to simulate these environmental parameters and maintain a suitable environment for Boro rice production. The simulation also supports remote monitoring and control of the system.

4.2. Simulation.

The primary objective of the simulation is to maintain a specific range of water and suitable humidity levels in the crop field for the Boro rice. The simulation is performed using Cisco Packet Tracer (Version 7.3.1) software. Cisco Packet Tracer is a networking simulator software that supports IoT simulation [20]. Apart from using the built-in IoT devices, this software also allows the users to program their custom sensors and actuators using JavaScript and Python programming language, which added extra flexibility for IoT simulation. Figure 2 shows the simulated network in Cisco Packet Tracer software.

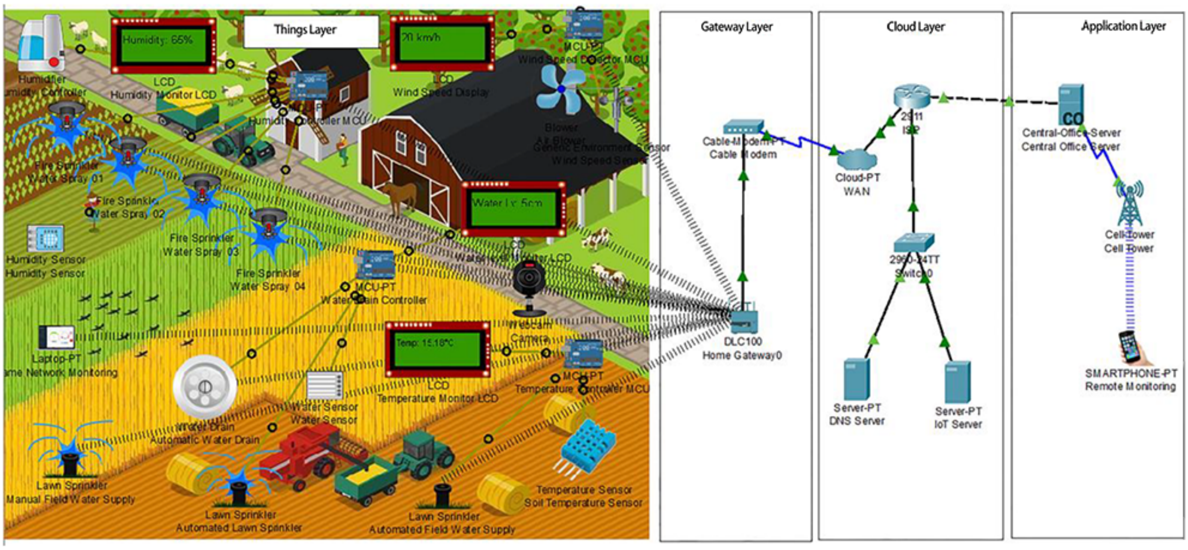

Figure 2. Simulated network

The total system architecture is divided into four layers – the things layer, gateway layer, cloud layer, and application layer. There are three main sensor devices in the things layer, i.e., humidity, water level, and temperature, all placed in the crop field. These sensors collect environmental data. The sensors are connected to their dedicated Microcontroller Units (MCU), which read the data from the sensor devices. Water spray, field water supply, and water drain act as the main actuators to control the environmental parameters. The water sprays are connected to humidity monitoring MCU. The humidity monitoring MCU is programmed using JavaScript to control the water sprays. The water spray system is active when the weather humidity is less than or equal to 60%. The water spray system increases the field humidity level and keeps it stable from 60% to 65%. There is an MCU-controlled water supply and water drainage system. A water level monitoring sensor is connected to the water level controller MCU. The MCU reads information about the water level in the field from the water level sensor. When the water level goes down to 5 cm, it turns ON the automated lawn sprinkler (field water supply) and increases the water level in the crop field. During this time, the water drainage system is programmed to turn OFF. Again, excess water level hampers the production rate for Boro rice. Thus, if the water level increases to more than 7 cm in the crop field, the MCU turns OFF the water supply and turns ON the water drainage system to maintain an optimum water level. A security camera is also used for remote visual monitoring purposes.

In the gateway layer, a Cisco DLC-100 device is used as a home gateway for the sensors, actuators, and microcontroller units placed in the things layer. The sensors, actuators, and microcontroller units in the things layer are equipped with a wireless module and connected to the DLC-100 using WiFi. The DLC-100 is connected to a cable modem that connects the cloud layer's Wide Area Network (WAN). A simple cloud is implemented to fulfill the requirements of this study. The cloud layer includes the wide-area network, Internet service provider router (Cisco 2911), a DNS server, and an IoT server. Services like routing, DHCP, and WAN are configured in the ISP router. Devices in the things layer get their IP addresses from the DHCP service. A DNS server is configured to map the IP address for remote monitoring. The devices in the things layer are registered to an IoT server in the cloud layer. The IoT server allows both the same network monitoring and remote monitoring of the system.

4.3. **Monitoring and control.** This smart system architecture allows remote monitoring and controlling services for the users. In this study, monitoring is classified into two types, i.e., the same network and remote monitoring. The goal is to monitor the environmental parameters, field environment, actuator status, and visual monitoring through a security camera. The same network monitoring can be performed from the crop field, where remote monitoring allows long-distance monitoring and control. A laptop device in the things layer is connected to the home gateway. A central office server is connected to the ISP router in the cloud layer in the application layer. A cell tower in the application layer is connected to the central office server, which provides 3G Internet service to remote users. Users from distance areas can monitor and control the system like the same network monitoring.

4.4. **Performance evaluation.** The simulation uses weather data of Dinajpur district in northern Bangladesh on Nov. 27, 2019, which is the early stage for Boro rice.

Figure 3 shows the water spray system's impact on the humidity level in the crop field. It shows that when the weather humidity is naturally in an optimum state, the water spray system is inactive. The state changes to active when the weather humidity level goes below 60%. The water spray system increases the humidity level gradually and keeps it stable within a suitable range for crops.

Figure 4 shows the water level in the crop field and the active or inactive state of the water drainage system and water supply system. The figure shows that the standing water level remains between 4-6 cm in the crop field.

The findings indicate that the system can maintain a suitable environment for the crops. However, the findings have some limitations as a complete real-life environment could not be implemented in the simulation, which provides a limited result in this study.

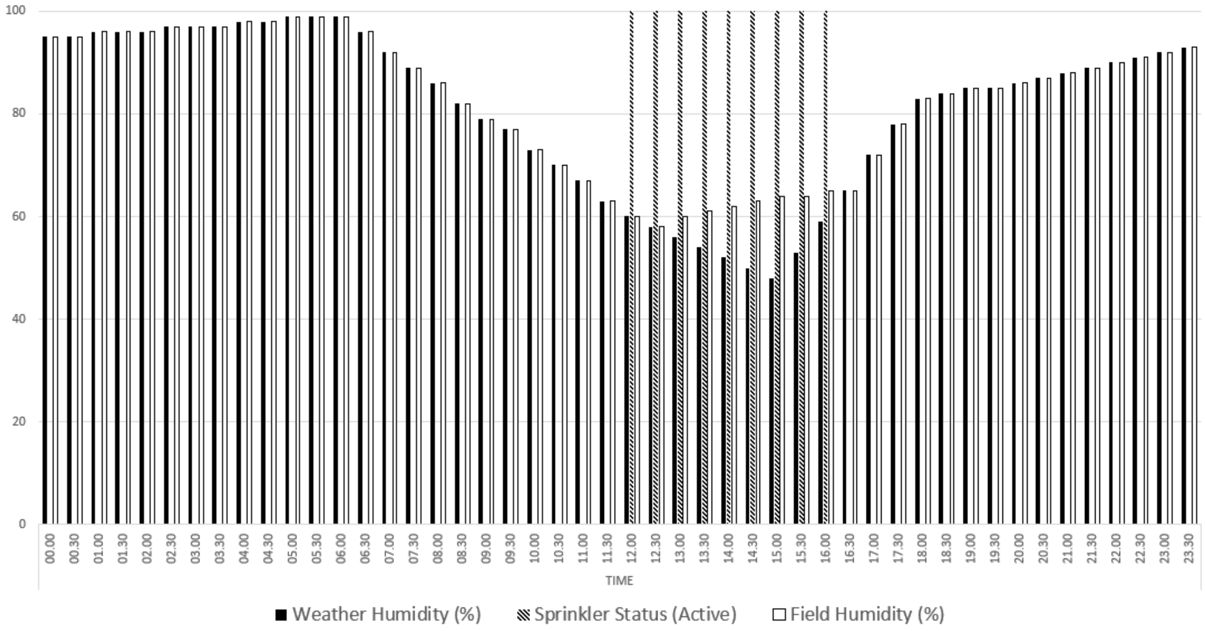

Figure 3. Water spray system impact on humidity

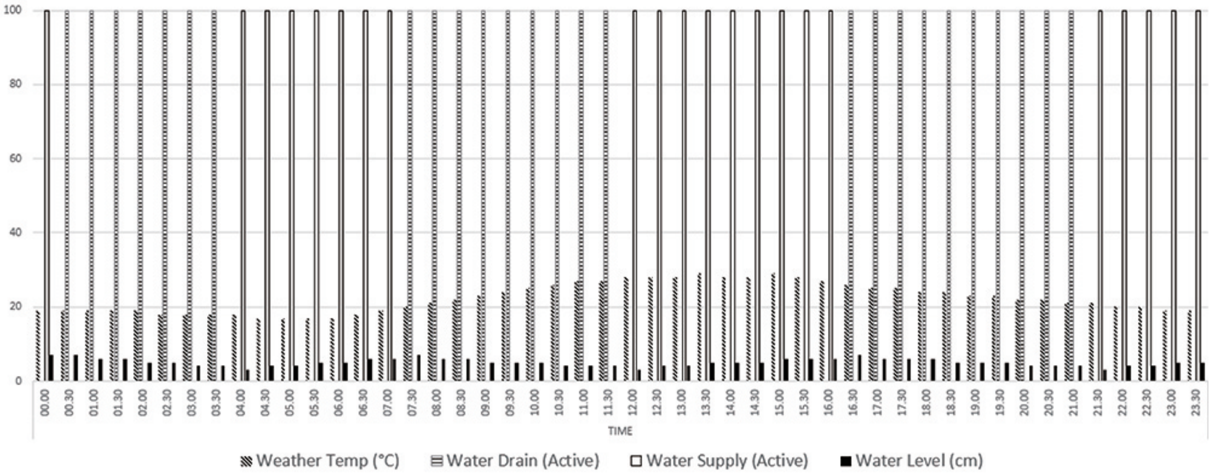

Figure 4. Water level maintenance

5. **Conclusions.** This study aimed to develop an IoT-based smart system architecture in the agricultural sector where monitoring and control are essential. The study focused on maintaining a specific suitable range of water and humidity levels for the crops in a rice field using IoT technology. A system architecture was designed to monitor environmental parameters such as temperature, humidity, and water level in the paddy field. Sensor devices placed in the rice field sense the environmental data. Microcontroller devices control actuator devices like water drainage, water supply, and water spray systems based on data from the sensor devices. The system architecture is simulated using the Cisco Packet Tracer software. The simulation result showed that the system could maintain water and humidity levels suitable for rice cultivation. The simulation also showed that the system allows the users to monitor and control the whole system remotely. As a future extension of this work, researchers can implement this system architecture in a real scenario and observe the production rate of the Boro rice or other related crops.

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