Blockchain and High-Performance/Low-Cost Ambient Sensors Mounted on Open Field Servers-Based IoT-Oriented Information-Sharing System for Agricultural Fields

Shinji Kawakura, Masayuki Hirafuji, and Ryosuke Shibasaki

Abstract — Our research group focuses on creating various application systems of these systems tends to focus on agricultural (agri-) advancement and security issues. First, we monitor agriculture and related environments (e.g., rice fields, meadows, and gardens) and obtain environmental agri-information (e.g., temperature, moisture, and the quality of soil) over extended periods. To do so, we use an existing Japanese high-performance/low-cost field server (FS) system, which operates sensor units uniformly. Furthermore, we develop and implement a blockchain and Twitter-based record sharing system connecting with the FS for the benefit of traditional agri-researchers, workers, and their respective managers. In regard to the study results, presenting the accuracy data quantitatively is difficult; we are unable to show the success and error rates for the systems’ data transmitting and receiving, nor the examination operation time. We believe the holistic system holds the potential to improve not only agri-businesses but also agri-skills and overall security levels.

Keywords — agricultural field, ambient sensor, blockchain, field server, Twitter.

I. INTRODUCTION

Various software and hardware agricultural (agri-)systems have been developed to help manage risks, such as security issues and the increasing impact of severe disasters. Obtaining and sharing real-time information is a crucial factor for success in practical modern agri-management. Across multiple projects, we have focused on two main directions.

First, to monitor outdoor fields (such as rice fields, meadows, and gardens) and obtain environmental information over long periods, we developed a high-performance/low-cost field server (FS). National Agriculture and Food Research Organization (NARO), Tsukuba, Japan)-based system that uniformly operates sensor units. This is a diverse ambient sensor cloud system using Open FS. Our system was designed based on the assumption that some components can be accessed via the Internet. Thus, the system can monitor values from many kinds of units and dynamically adjust managing schedules according to detected conditions. FS approaches have been experimentally validated [11]-[15].

Second, we developed wearable measuring systems, combining diverse components, such as advanced sensors, and gadgets that incorporate 3-axis-acceleration sensor(s) and gyro-sensor(s). We analyzed users’ motions according to dynamics and statistics [16]-[19]. We also connected isolated nodes via Digi-Mesh. These approaches can improve users’ agri-jobs’ skills and enhance security in agri-fields. The expansion and complexity of agri-management, including social requirements and methodologies, have exceeded those systems [11]-[19]. Many fixed FS(s) systems have been developed by various facilities and companies [1]-[3].

Recent promising studies in diverse research and business fields have investigated blockchain-based networks and similar systems [4]-[11]. Kamilaris, Fonts, and Prenafeta-Boldó [4] presented the latest blockchain technology-based trends in agriculture and food supply fields, focusing on food science and technology. Omar et al. [5] and Cichosz, Stausholm et al. [6] constructed and presented concrete examples of blockchain technology-based platform systems for health care, and practical treatments for diabetic patients. Regarding blockchains for diverse vehicles, Liu et al. constructed and presented blockchain-enabled security systems according to electric vehicle clouds and edge computing [7], and Cebe et al. looked at a lightweight blockchain framework for forensic applications of network-connected vehicles [8].

Internet of things (IoT)-based blockchain security and integrity have been considered in the literature. Yu et al. presented blockchain-based solutions to enhance the security and privacy levels of the IoT [9]. Machado and Fröhlich used blockchain-based systems to verify the IoT data integrity of cyber-physical systems [10]. With respect to robotics, Strobel et al. managed byzantine robots with blockchain technology for a swarm robotics decision-making scenario [11].

Cases more closely related to our focus include past studies of the (mesh-shaped) network system for agri-research and business-based management [1]-[3], [12]-[15]. Fukatsu, and Hirafuji [12] designed, developed, and handled web-based sensor network systems with FSs for practical agricapplications. The systems obtained diverse data, such as humidity, temperature, and soil components (e.g., nitrogen (N), phosphoric acid (H₃PO₄), and potassium (K)), from real
outdoor agri-fields.

Brun-Laguna et al. demonstrated a GR-PEACH (Renesus Inc., Japan) IoT-based frost event prediction system for agri-fields with consideration of recent precision agriculture techniques [13]. Karim and Karim [14] constructed and managed a monitoring system using the Web of Things (WoT) for precision agriculture.

In this trial, considering past technical concepts and trends, we developed and implemented a blockchain-based agri-record sharing system for common agri-workers and managers. Specifically, we selected Hyperledger Fabric Certification (CA, Hyperledger Fabric CA Project), handled with the Go language, which we determined to be a promising infrastructure that allows for the sharing of basic text and numerical data at various organizations. We can achieve quick data-sharing approaches for FS data.

II. METHOD

A. Outline

First, we reviewed past academic and companies’ results and accomplishments, and met with some predecessors who have engaged in primary industries. Then, we selected some promising techniques and electronic gadgets. We developed approximate schedules, designed, and mechanically constructed the systems, and scripted various command codes for processing. Although similar fixed FS-based systems exist, they are not optimized for network formation(s) with mobile systems, and do not cooperate with wearable sensing systems (WSs).

Thus, we aim to create new integrated structures to support these options and enhance their utility and flexibility against sudden accidents in real situations. As preliminary trials, we conducted indoor and outdoor experiments to estimate their utilities to some extent. We used typical FS constructions surrounded by small solar panels to supply constant and stable electricity. The panels were attached to the solid frames surrounding the FS to allow for balance adjustment. Twitter (Twitter Inc., California State, the U.S.) is one of the most robust, user-friendly SNS in diverse aspects and worldwide reviews. That’s why we selected, trust, and utilize Twitter and its peripheral services in this successive study.

B. System

In Figs. 1-4, we present the main structure of the blockchain-based and oriented system. This study consists of three phases: (1) designing and confirming the validity of the entire system, (2) constructing and tuning various minor system settings, and (3) conducting experiments in indoor and outdoor settings. To inform Phase (1), we performed a literature review to identify achievements and similar research and tools. Then, we designed systems to be practically executed in outdoor farmlands. During this phase, we incorporated the opinions of farmers with about 10 or more years of professional agri-experience. In Phase (2), we built the system and verified the parts judged to be the essentials of the operation. In Phase (3), we performed operational experiments in indoor and outdoor settings.

In Fig. 1, vector 1 indicates datasets sent from WiFi-routers installed on Arduino microcomputer boards to general cloud servers of Twitter (Twitter Inc., USA). We utilized a commonly distributed Twitter-API for general Arduino-developers. For vector 2, after we open the source codes of Twitter’s website, we search the intended tab codes indicating uploaded FS data with Twitter using Python-3 codes and extract the datasets. For vector 3, we upload the datasets to the private blockchain-based networks. Fig. 2 illustrates the present study’s construction of Hyperledger Fabric [20]-[24]. Fig. 3 presents the deploying model of hierarchical CAs, and Fig. 4 shows the construction and flowchart of the blockchain-formed applications. Fig. 5 broadly illustrates the FS (main body unit). We use Arduino UNO3 (Arduino Inc., Italy), and code in ”Arduino 1.0 language” or ”Processing language.” Target measures included temperature, humidity, location of users and FS, strength of natural light (including sunlight), and distance between FS (in the future, including WS) and obstacles.

Fig. 1. Model of sending datasets from WiFi-routers installed on Arduino-microcomputer boards to Twitter cloud servers, and then to private blockchain-based networks.
Hyperledger is based on a different information-sharing style than other formats (e.g., Bitcoin Core, Lightning Network, Ethereum, or Quorum). This setup makes the information-sharing process much safer. Unlike other blockchain infrastructures, Hyperledger-based systems cannot broadcast datasets extracted from Twitter to outsiders. For example, a notary-based system prevents double dealings and ensures the uniqueness of a transaction.

For the data-uploading obtained from FSs, we first set the following two formats, noting a set threshold for long sentences: (1) For longer sentences than the threshold, we present long sentences of obtained data from sensors (e.g., generated voltage value, time, temperature, or humidity) as comma separated values (CSV)-format sentence-datasets. For instance, a data row could be “Battery 4.5 [V], Board-T 24.4 [deg-C], S-Moist 0 [Hz], Soil-T 60.0 [deg-C], Top-FD 0, Bottom-FD 0” (Fig. 6, 7, and 8). (2) For shorter sentences than the threshold, we use small, relatively simple datasets, output from the aforementioned Arduino.

III. Results

In this study, motivated by improving the skills and conditions of agri-workers in primary industries, we created FSs, WSs, and real-time wireless networking-based systems. We incorporated a blockchain-based methodology, Twitter cloud services, and private databases to accumulate and store a variety of promising data. Based on our results, the proposed approaches can improve the detection of critical or fatal situations and the stability of the overall system. Although we applied the integrated system with a certain level of accuracy, we were unable to quantify the accuracy data because we did not define appropriate trial time ranges, and the error data were rather random. Thus, we are unable to report success and error rates (%) for the data transmission and reception or the operation time. However, from our experimental ranges for these errors, we suggest that the errors were not due to the characteristics of the Hyperledger-infrastructure.
Fig. 7. Uploaded dataset on Twitter.

Fig. 8. Example illustration of a plan derived from the system.
IV. DISCUSSION, CONCLUSION, AND FUTURE TASKS

Over several years of research, we have accumulated basic data from several digital gadgets. However, their accuracy, endurance, and validity should be confirmed. We were unable to present numerical sets of fixed quantitative data concerning blockchains and databases, so we must seek more suitable and valid methods to assess the systems’ operations (Fig. 8).

For the FS’s main body unit, we could attach more robust frames, digital video cameras, small edge-computers to deal with various data four-solar panels, and mechanisms to automatically adjust their positions.

Another remaining problem is attaining more data from diverse settings and situations (such as breeding farms, plastic farms, construction sites, or more intense or sudden natural impacts). We may consider combining machine learning and quantum computing technologies to support data collection and stability over longer experiment times.

Moreover, we could perform desktop analyses and interview key experts and users. The results of these investigations could be incorporated into computer systems and fed back to experimental users. We could also undertake further experiments and practical applications of the system to understand how to enhance the system for use in real settings. We have been planning consultation and supporting projects to improve the security and productivity of real agri-workers. Above all, we hope to start launching practical consulting and proposals to real users within 10–20 years, both in Japan and globally.

Furthermore, as these techniques are economically robust, scalable, and distributed flexibly, they could be applied to other fields and settings, such as factories or residential districts, to identify sudden accidents or crimes. Considering various non-fixed factors, such as installation locations, outdoor field conditions, and different approaches to various incidents, such as systems’ tumbling, sudden halting, or other irregular accidents, we can solve diverse social problems.

ACKNOWLEDGMENT

Our heartfelt appreciation goes to the members of Mitsui Fudosan Co., Ltd., Kashiwano-Ha Farm Inc., Kashiwa-shi, National Agriculture and Food Research Organization (NARO, Tsukuba-shi, Japan), and The University of Tokyo who provided considered support, feedback, and comments.

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Shinji Kawakura
Place of birth: Toyama Pref., Japan. Date of birth: July 14, 1978. Ph.D. in Environmentology, University of Tokyo, 2015, Bunkyo-ku, Tokyo, Japan. B.A. in Control System Engineering, Tokyo Institute of Technology, 2003, Meguro-ku, Tokyo, Japan. M.A. in Human-Factor Engineering, Tokyo Institute of Technology, 2005, Meguro-ku, Tokyo, Japan.
Career: Systems engineering, research for private companies. Development and verification of sensing systems for outdoor agricultural workers.

Dr. Kawakura, Research Center for Artificial Photosynthesis (ReCAP) at Osaka City University/Osaka City, Osaka, Japan. IEEE senior member, Hong Kong Chemical, Biological & Environmental Engineering Society (HKCEES) senior member.

Masayuki Hirafuji
Place of birth: Kawasaki-shi, Kanagawa Pref. Japan. Date of birth: Oct. 29, 1956. Dr. in Agriculture, the University of Tokyo, 1983, Bunkyo-ku, Tokyo, Japan. B.A in Agriculture, the University of Tokyo, 1981, Bunkyo-ku, Tokyo, Japan. M.A. in Agriculture, the University of Tokyo, 1979, Bunkyo-ku, Tokyo, Japan. Career: National Agriculture and Food Research Organization (NARO), The University of Tokyo.

Dr. Hirafuji, Project Professor at Field Phenomics Research Laboratory, Bunkyo-ku, Tokyo, Japan.

Ryosuke Shibasaki
Place of birth: Fukuoka, Pref. Japan. Date of birth: March 1, 1958. Dr. in Engineering, the University of Tokyo, 1987, Bunkyo-ku, Tokyo, Japan. B.A in Engineering, the University of Tokyo, 1980, Bunkyo-ku, Tokyo, Japan. M.A. in Engineering, the University of Tokyo, 1982, Bunkyo-ku, Tokyo, Japan. Career: Professor at the Center for Spatial Information Science, University of Tokyo.

Dr. Shibasaki, Center for Spatial Information Science (CSIS), The University of Tokyo, Meguro-ku, Tokyo, Japan, and Department of Socio-Cultural and Socio-Physical Environmental Studies, The University of Tokyo/Kashiwa-shi, Chiba, Japan.