

A Life Cycle Framework of Green IoT-Based Agriculture and Its Finance, Operation, and Management Issues

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The large-scale application of IoT systems in agriculture is facing challenges such as huge investment in agriculture IoT systems and non-tech-savvy farmers. To identify these challenges, the authors summarize the applications of IoT techniques in agriculture in four categories: controlled environment planting, open-field planting, livestock breeding, and aquaculture and aquaponics.

ABSTRACT

The increasing population in the world forces humans to improve farm yields using advanced technologies. The Internet of Things (IoT) is one promising technique to achieve precision agriculture, which is expected to greatly increase yields. However, the large-scale application of IoT systems in agriculture is facing challenges such as huge investment in agriculture IoT systems and non-tech-savvy farmers. To identify these challenges, we summarize the applications of IoT techniques in agriculture in four categories: controlled environment planting, open-field planting, livestock breeding, and aquaculture and aquaponics. The focus on implementing agriculture IoT systems is suggested to be expanded from the growth cycle to the agri-products life cycle. Meanwhile, the energy concern should be considered in the implementation of agriculture IoT systems. The construction of green IoT systems in the whole life cycle of agri-products will have great impact on farmers' interest in IoT techniques. With the life cycle framework, emerging finance, operation, and management (FOM) issues in the implementation of green IoT systems in agriculture are observed, such as IoT finance, supply chain and big data financing, network nodes recharging and repairing, and IoT data management. These FOM issues call for innovative farm production modes and new types of agribusiness enterprises.

INTRODUCTION

The development of the Internet of Things (IoT) has been reshaping various fields such as industry, transportation, and healthcare. In the literature, increasing attention is paid to both IoT techniques and their practical applications. The penetration of IoT in the agriculture sector is deepening. In practice, governments and companies are often reported to be applying some advanced IoT techniques into agriculture.

The potential and superiority of IoT in agriculture result in its current popularity. It is a challenging and must-be-solved task to sustainably feed the world's growing population, which is predicted to reach 9.6 billion people by 2050 [1, 2]. Precision agriculture aims to maximize crop yields while preserving resources, and is indeed proved

with high productivity [3]. To implement precision agriculture, farmers need to monitor the growth environment and make optimal production decisions. This is where IoT systems can help farmers. Through various sensors and actuators, farmers can know in real time the growth status and environment in their farms, and make timely actions to keep the optimal growth status.

However, the costs of implementing IoT systems in agriculture are huge. In current practice, most existing IoT devices are deployed in controlled environment agriculture such as greenhouses and livestock farms [4]. Large-scale promotion in open-field agriculture, which is the key to solving the world's food problem, is still not coming. Two aspects that probably limit the promotion are observed. First, IoT-based agriculture should be viewed from a life cycle of agri-products, not just a cycle of growth. Both the quality of agriculture ingredients and the circulation of harvested agri-products have important impacts on yields and production behaviors. Without a whole life cycle equipped with IoT systems, it is difficult to attract farmers' interest in deploying IoT devices. Second, the implementation of IoT systems in agriculture is not only a technical issue but also involves some challenging finance, operation, and management (FOM) issues. The costly investment is the first concern to consider. Neither large-scale nor small holder farmers are willing to undertake the costs without attractive benefits and conveniences. Unfortunately, most existing studies focus on the technical issues in the growth cycle.

Meanwhile, the energy concern should be considered in the implementation of agriculture IoT systems. Motivated by these observations, in this article we try to formulate a life cycle framework of green IoT-based agriculture, including ingredient supply, growth, processing and packaging, distribution and storage, and consumption. Through analyzing the applications of IoT systems throughout the life cycle, we identify some FOM issues that need to be solved to make IoT systems fully cover agriculture. These FOM issues such as IoT finance in agriculture, supply chain and big data financing in IoT-based agriculture, farm-to-door delivery optimization, IoT-based reception box layout, and agriculture IoT data management

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