Poster: Photovoltaic Agricultural Internet of Things - the Next Generation of Smart Farming

Fan Yang*, Lei Shu*†, Ye Liu*, Kailiang Li*, Kai Huang*, Yu Zhang† and Yuanhao Sun*
* College of Engineering, Nanjing Agricultural University, China
†School of Engineering, University of Lincoln, UK
yangfan@jsnu.edu.cn, {lei.shu, yeliu, kailiang_li, kai_huang}@njau.edu.cn
YZhang@lincoln.ac.uk, yhsun.nau@outlook.com

Abstract

In the poster, a new paradigm of smart farming is proposed for the first time. It is named as Photovoltaic Agricultural Internet of Things (PAIoT). We envision the scenarios of PAIoT in terms of energy supply, communication method and computing models. In addition, PAIoT's advantages are presented. Finally, the open research issues are discussed for the PAIoT.

1 Introduction

The rapid development of industrialization and urbanization process leads to high demand of energy. The International Energy Outlook, published by the U.S. Energy Information Administration, estimates that global energy consumption will rise 28% from 2015 to 2040. However, energy production by burning fossil fuels has serious impact on climate change. Solar photovoltaic power [1], which harvests energy from sunlight and generates electricity power, is the fastest-growing renewable energy technology. It is considered as a key approach for low carbon economic development.

Although solar photovoltaic power has many advantages, such as cleanness, silentness and availability at almost anywhere, one limitation is that it needs to occupy a lot of space. To solve this problem, photovoltaic agriculture [4] is introduced where electricity production of solar power system and agricultural production activities can work simultaneously in the same area. As shown in Figure 1, many activities such as planting, breeding and irrigation occur on the land while solar panels are equipped on top of it to generate electricity. This promising model is beneficial for both economic and ecological development.

Furthermore, the deployment of Internet of Things into agriculture enables smart farming [3]. Real-time agricultural information is collected by embedded sensing systems. After that, these data are stored, processed and managed on a cloud platform. Finally, the big data analytics guides farmers to perform precise agricultural operations.

Figure 1. The scenarios of photovoltaic agriculture.

The aforementioned background motives us to think about one question: "*What will happen when Internet of Things meet the new photovoltaic agriculture?*" In this poster, this question is answered: Photovoltaic Agricultural Internet of Things (**PAIoT**) – the next generation of smart farming. We envision that in the PAIoT: (*i*) Sensor nodes, actuators, robotics and unmanned aerial vehicles could be supplied by solar photovoltaic power via wireless power transfer; (*ii*) These embedded systems could communicate with each other using active transmission, wireless backscatter and wired-backscatter communication techniques [2]; (*iii*) Real-time feedback and actions could be available since these devices are able to process and analyze data locally with the benefit of sufficient power supplement. Figure 2 shows an example of Photovoltaic Agricultural Internet of Things. In the following, the advantages of PAIoT compared with the traditional Internet of Things for agriculture will be presented in Section 2, and discussion of the open research issues in Section 3.

2 The Advantages of PAIoT

Stable Energy Supplement. Energy harvesting technology is a promising method for embedded systems powering themselves in a sustainable way. However, peer-to-peer am-

International Conference on Embedded Wireless Systems and Networks (EWSN) 2019
25–27 February, Beijing, China

ISBN: 978-0-9949886-3-8

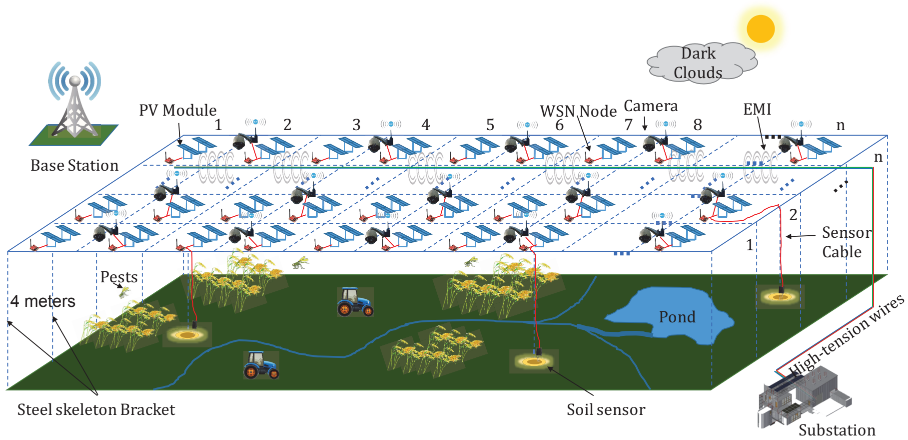

Figure 2. An ecosystem example of smart farming with Photovoltaic Agricultural Internet of Things.

bient energy harvesting suffers the problem of unstable energy supply since the storage element of each sensing device is limited. In PAIoT, solar power could be firstly scavenged into distributed energy substations. Then the energy is used to supply sensor nodes through wireless energy transfer or wireline. Distributed energy substations could store enough energy in daytime or good weather condition, and then power sensor nodes in the nighttime or adverse weather time.

High Resolution Multimedia Sensing. Traditionally, remote sensing is widely used for crop growth monitoring because of the advantages of large coverage area and low acquisition cost. But the resolution of remote sensing image is not good enough. Due to the shade of photovoltaic panels, remote sensing technology is not suitable in photovoltaic agriculture. Instead of using remote sensing technology to monitor crop growth, high-resolution multimedia sensor nodes are available to provide precise agricultural sensing without concerning the power hungry problem.

Computing at the Edge. Due to the limited computational capability, low data storage and battery storage, sensor nodes traditionally equip only one or two types of sensors to monitor the farms. Then they report the result to a gateway. Although the sensor nodes are connected in a multi-hop routing way, they do not actually collaborate with each other in view of data processing and analysis. Since the power supply is no longer an issue in PAIoT, multiple types of sensors could be integrated into one node with powerful microprocessor control unit. The node is able to perform real-time data analysis and actions, so that adaptive environment adjustment is available for various agricultural products. Moreover, since most of the data do not need to transmit to the cloud, the bottlenecks of network traffic are largely reduced.

Flexible Sensor Node Deployment. Sensor deployment in the Agricultural Internet of Things needs to consider not only the stable sampling service in key area but also the stability of sensor supports. Bad weather such as gusty winds and torrential rain can seriously affect data acquisition, especially for image sensing. Photovoltaic panels and steel skeleton in PAIoT are the "protector" for sensors, which can ensure that the nodes work stably without being affected by the environment.

3 Open Research Issues

Power Conversion Efficiency and Energy Coverage. High-efficiency power conversion by novel antenna and integrated circuit design is an open research issue for the blueprint of long-distance wireless power transmission. Distributed stations deployment based on energy transfer model is also a direction for full energy coverage.

Optimal Scheduling of Wireless Power Transfer. Different kinds of sensor nodes and actuators are usually deployed in the farm. Some of them are low power while others are power-hungry. The diverse tasks allocation also leads to different energy consumption among these nodes. To save the harvested energy, wireless power transfer should not work continuously. Therefore, optimal scheduling is needed.

Reliable Communication. Electro Magnetic Interference (EMI) exists in solar photovoltaic power system. How the EMI affects active or backscatter communication and which communication is more suitable in PAIoT are the two questions to be answered.

Lightweight Artificial Intelligence. Resource-efficient machine learning is also an issue in PAIoT although the power supply limit is relaxed.

4 Acknowledgments

This work is supported by the International Cooperation Program of Nanjing Agricultural University under grant number 2018-AF-23. Lei Shu is the corresponding author.

5 References

[1] R. Fu, D. J. Feldman, R. M. Margolis, M. A. Woodhouse, and K. B. Ardani. Us solar photovoltaic system cost benchmark: Q1 2017. Technical report, National Renewable Energy Lab.(NREL), Golden, CO (United States), 2017.

[2] N. Jayasuriya, A. Sayakkara, C. Suduwella, C. Keppitiyagama, K. De Zoysa, and K. Hewage. "wire is not dead": Wired-backscatter communication for breakage detection in electric fences. In *Proceedings of the 2017 International Conference on Embedded Wireless Systems and Networks*, pages 300–304, USA, 2017. Junction Publishing.

[3] S. Wolfert, L. Ge, C. Verdouw, and M.-J. Bogaardt. Big data in smart farming – a review. *Agricultural Systems*, 153:69 – 80, 2017.

[4] J. Xue. Photovoltaic agriculture - new opportunity for photovoltaic applications in china. *Renewable and Sustainable Energy Reviews*, 73:1 – 9, 2017.