Development and field evaluation of a multichannel LoRa sensor for IoT monitoring in berry orchards

Redmond R. Shamshiri [1] and Cornelia Weltzien[1]

Abstract: Evaluation of long-range wireless transceivers with respect to their power consumption, network connectivity, and coverage under extreme field conditions is necessary prior to their deployment in large-scale commercial orchards. This paper reports on the development and field performance of an affordable multi-channel wireless data acquisition for IoT monitoring of environmental variations in berry orchards. A connectivity board was custom-designed based on the powerful dual-core 32-bit microcontroller with WiFi antenna and LoRa modulation at 868 MHz. The objective was to verify the possibility of transmitting multiple sensor readings with lower power consumption while increasing the reliability and stability of wireless communication at long distances (over 1.7 km). Collected data from the wireless sensor was compared and found to be consistent with measurements of a data logger installed in the same locations. The presented paper highlights the advantages of LoRa sensors for digital agriculture and the experience in real-time monitoring of environmental parameters in berry orchards.

Keywords: wireless sensors, IoT monitoring, digital agriculture, LoRa gateway, datalogger

1 Introduction

Digital agriculture offers a better yield and quality for crop production. Wireless sensing technology and the Internet-of-Things (IoT) solution reduces data collection errors, improves the accuracy of remote monitoring, and more importantly evaluation of the microenvironment through dynamic assessment. To that end, sensing technology allows the best quality of growth environment with the capability of yield prediction. The trend of environmental monitoring in modern farming is towards shifting from offline systems to wireless and cloud-based data collection architecture. Various remote systems, either by means of prototype or commercial, are being investigated for their functionalities and limitations in high-density orchards. Examples include field server-based and distributed field router systems for real-time monitoring and processing [Vi20, Re20]. A remarkable advantage of these platforms is the power management capability that allows the system to continuously operate in large coverage areas where connection stability and power sources are a concern [Sh20]. The main justifications for the deployment of IoT infrastructure in agriculture can be summarized as (i) to provide real-time monitoring of the variations in the fields, (ii) to feed data to cloud-based decision support systems, and

[1] Leibniz Institute for Agricultural Engineering and Bioeconomy, Max-Eyth-Allee 100, 14469 Potsdam-Bornim, Germany, rshamshiri@atb-potsdam.de, https://orcid.org/0000-0002-5775-9654, CWeltzien@atb-potsdam.de

(iii) to send instant responses to the wireless actuators in agricultural robotic applications [Sh18]. It is expected that this process embraces the uncertainties, especially in the remote areas, and consequently contributes to a higher yield with lesser inputs. However, in most studies, raw data are first collected via wireless sensor network-based systems and are processed afterwards [YYC20, SSK19]. A drawback of this approach is that because the collected data is not processed in real-time, they cannot immediately determine the temporal and spatial variations in the environmental parameters, as well as their deviation from optimal conditions. An effective IoT-based solution should incorporate the use of wireless sensors and mobile applications for displaying, processing, and analyzing data from remote locations using cloud services which together provide new insights and recommendations for better decision-making [SHJ19]. The presented paper introduces the architecture of an affordable multichannel wireless sensor node (WSN) with LoRa modulation at 868 MHz that was custom-designed for real-time monitoring of variations in the microclimate, light condition, soil temperature, soil moisture, and leaf wetness inside berry orchards. Performance evaluation of the WSN was carried out by different means, including comparing the collected data with a data logger that was installed in the same location.

2 Architecture and communication protocols

The wireless communication and the architecture of data transmission from sensors nodes to the end-users are demonstrated in Figure 1, showing the collection of data inside the field, transmission of data to an edge node (gateway) via LoRa 868 MHz, and data transfer to cloud storage via the available WiFi connection in the farm office. Figure 1 also shows a total of four layers, including the farm layer (with sensor nodes), the backend layer, the wrapper later, and the frontend layer integrated in a way that end users can access data from their phone or desktop applications for real-time monitoring of the sensor measurements. The farm layer has the role of (i) provider, in which wireless sensor nodes in the farm collect data and transmit to a gateway device that has access to the internet using WiFi protocol, or convert the data packet to JSON format before sending the data to the backend layer using HTTPS protocol, (ii) client, in which each wireless node sends requests to the backend and receive responses in JSON format via HTTP protocol. The backend layer consists of a middle layer between the backend server and the farm layer. A middle device or server in the backend layer that uses WiFi and REST API providers first receives data from the farm layer and then transfers the packets to the backend layer. Received data are pre-processed, analyzed, and can be categorized using queries, crop models, and artificial intelligence algorithms, and are then saved in the database using controllers that have been implemented in the C# frameworks. The wrapper layer includes the cloud storage in which processed data from the backend are sent to IoT servers and are saved. This gives the user the advantage of having a secure backup of the collected data. The provider receives data from the backend layer and for further real-time assessment of the field conditions. The input of this layer is the transferred data which are collected every 5 or 10 minutes by the field layer (sensor nodes in the farm). The frontend layer, also called the presentation layer, provides data visualization by means of real-time plots, control buttons, and indicators on mobile apps, webpages, or other platforms.

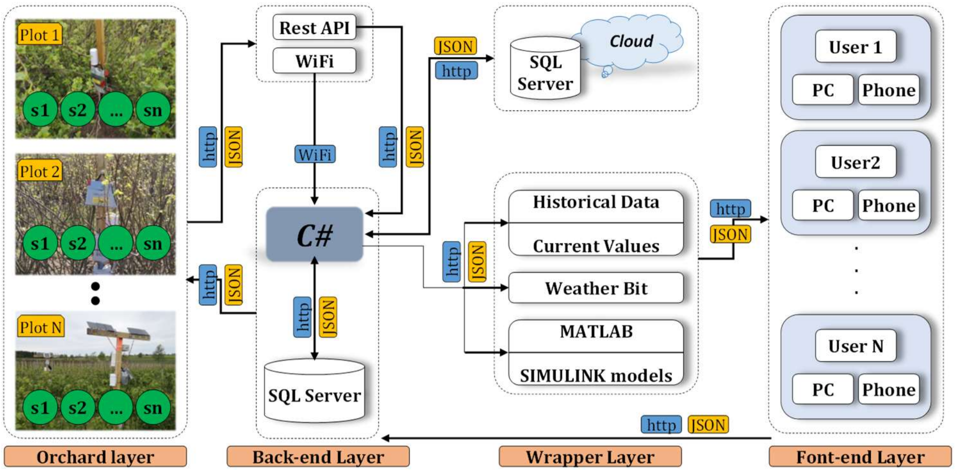

Fig. 1: Schematic view of the data collection and real-time monitoring

3 Data collection setup

The data collection was carried out based on the setup shown in Figure 2 at a commercial berry orchard namely Weggun (Bauernhof Weggun GbR, Germany) located in 53°19'24.9"N 13°33'41.0"E. Different models of 3.8V LiPo batteries and solar panels, as well as different sensor probes with different wire lengths were tested in order to compare and find the best configuration available. The accuracy and reliability of the sensors were verified in several official calibration phases at the Leibniz Institute for Agricultural Engineering and Bioeconomy (Potsdam, Germany). The wireless sensor board utilized a 32-bit microprocessor integrated with the hybrid ADP-WSN/LoRa connectivity board, and an external solar-charged battery module shown in Figure 2. Wireless communication with LoRaWAN gateway was realized via a LoRa Dual-Core 240MHZ CP2102 technology (868 MHz) capable of covering 2~10 km distance in rural areas. The LoRaWAN gateway consisted of three main components, including a concentrator board that was connected to an antenna, a Raspberry Pi Zero onboard computer that made possible all the connections between the concentrator and the LoRaWAN backend, and C++ codes that was custom-written to drive all the process. The gateway used the available WiFi network inside the farm office. All devices had waterproof IP68 cases, with GX16 aviation plug connectors. The plug-and-sense probes utilized DS1820 for soil temperature, BlueDot BME280 + TSL2591 for microclimate and light, ADP-LWS2020 for leaf wetness, and SKU capacitive sensor for soil moisture.

A hybrid multi-channel data logger shown in Figure 3 was installed in the same location for collecting ground truth data and storing it on a SD card. Finally, data from the WSN that were stored on the cloud-server were compared with the data that were stored in the SD card.

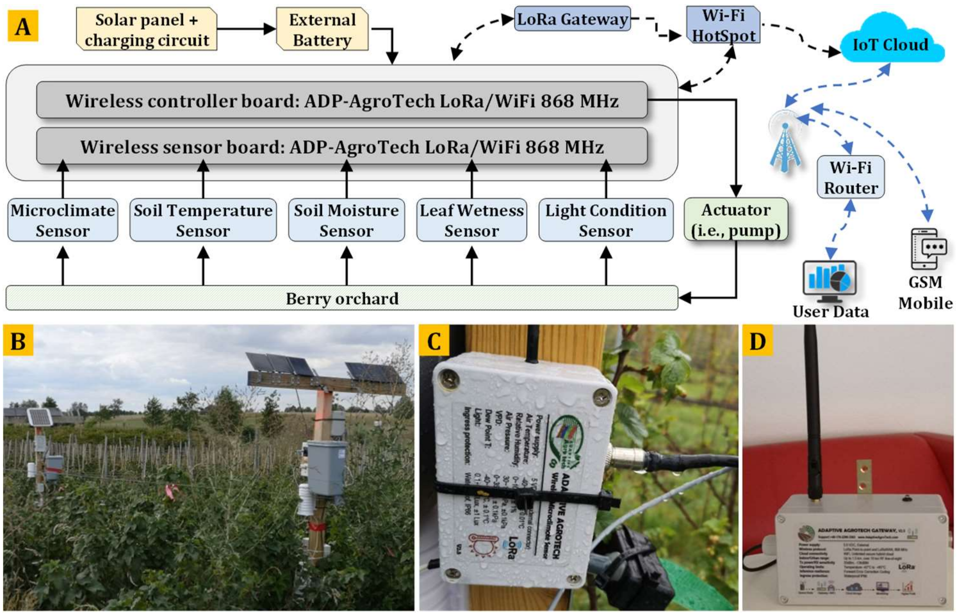

Fig. 2: Data collection setup showing (A) schematic view, (B) sensor locations and stands, (C) LoRaWAN wireless sensor nod, and (D) LoRaWAN gateway

Fig. 3: The hybrid data logger with modular solar charged external battery and plug-and-sense probes used for validation of the wireless sensor

4 Results and conclusion

Sample results showing the performance of the WSN and the hybrid data logger collected every 10 minutes for 30 days in August 2020 have been plotted in Figure 4. For the purpose of this paper we have only provided plots of air temperature, soil temperature, and soil moisture, which are considered more important for farmers. It can be seen that except for the few minor interruptions shown in Figure 4.(A), the deployed WSN sensor has provided smooth and accurate air and soil temperature data collection, showing a consistent pattern with the plots of the data logger readings (Figure 4.(B)). In addition, plot of the soil moisture from the WSN shown in Figure 4.C is consistent with that of the data logger in Figure 4.D. Our preliminary results from other sensors deployed in the field revealed a similar performance in terms of data transfer, interruptions, and connectivity failures. It should be noted that signal strength of the wireless transmission can be affected significantly in high-density orchards, especially when fields are surrounded by tall trees.

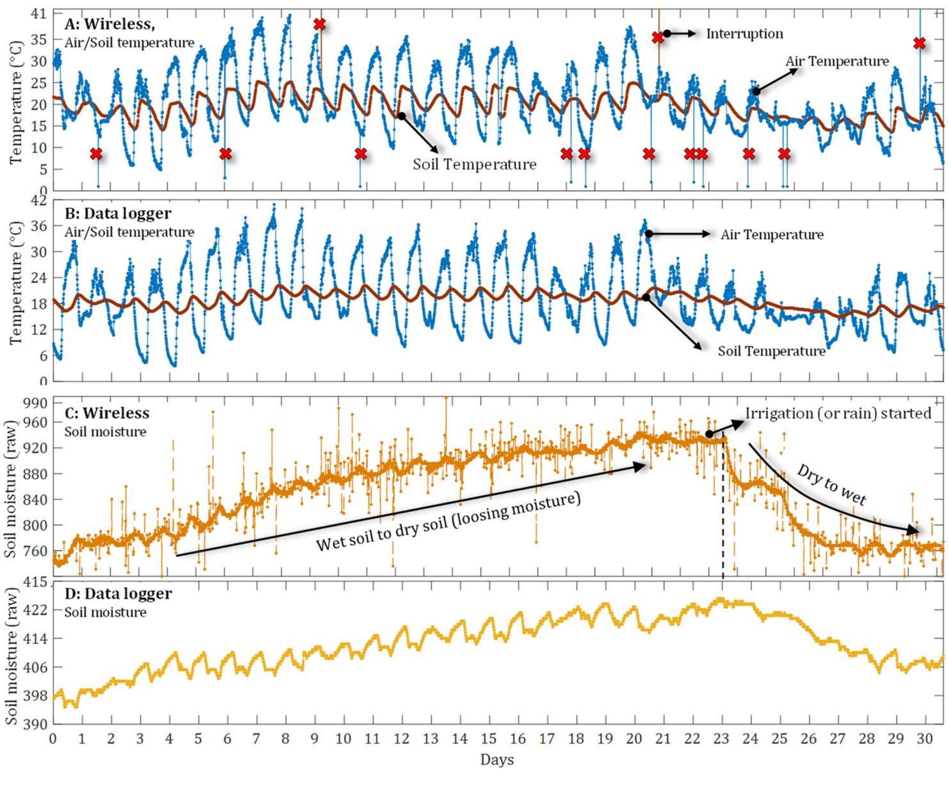

Fig. 4: Comparing the performance of the wireless sensor node with a data logger

It can be concluded that developing a robust and affordable WSN for field conditions should take into account the correct selection and combination of the battery and charging units, the electronic housing box, connectors and plugs, data wire and cables, wireless antenna, and the modularity and compatibility of the package components. The introduced WSN can be placed anywhere in the orchard and overcome cable wiring difficulties for the sensors and the LAN connection. Additionally, it is flexible in data sharing and can be upgraded with user experience. However, the major disadvantage of wireless sensor nodes is the repeated loss of connection even in mesh applications. The water in the high amount of biomass of the plants damps the radio signals and avoids communication distances over long ranges. This can be solved by using different techniques (that sometimes involve a huge amount of effort), including antennas with cable for higher positions, higher mesh density, multiple gateway nodes, and higher output power. In general, it is a good practice to store all measurement data using devices that benefits from local memory. Therefore, the asynchronous readout is enabled for the user, and the data is not missed which an efficient practice for IoT is monitoring in large-scale commercial berry production.

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