Intermittent Edge Computing for Green Agricultural Automation

Hui-Xin Shih
Academia Sinica & National Taiwan University, Taiwan
b09901091@ntu.edu.tw

Yu-An Lin
Academia Sinica & National Taiwan University, Taiwan
b06204039@ntu.edu.tw

Hsu-Huai Tsai
Academia Sinica & National Taiwan University, Taiwan
b08902016@ntu.edu.tw

Yuan Lin-Huang
Academia Sinica & National Taiwan University, Taiwan
b09901013@ntu.edu.tw

Chih-Yu Wang
Research Center for Information Technology Innovation, Academia Sinica, Taiwan
cywang@citi.sinica.edu.tw

***Abstract*—In recent years, there has been a notable shift towards automation in agricultural technology. Furthermore, driven by environmental concerns, green energy is gradually replacing conventional power sources. However, green energy sources are vulnerable to external environmental factors, resulting in an unreliable power supply. Such instability can disrupt the functioning of monitoring systems which are critical for agricultural automation, leading to operational issues. To address these challenges, we propose an intermittent edge computing system for agricultural automation. It consists of battery-less intermittent computing devices, wireless intermittent communications, and deep-capable edge computing. Our demo illustrates the process of tomato monitoring including reliable on-device tomato detection and Bluetooth Low Energy (BLE) image data transmission, even in the absence of stable power conditions. Upon receiving the data, we employ edge computing to detect the location, color, and quantity of tomatoes.**

I. Introduction

In recent years, there has been a notable trend towards agricultural automation. Smart agricultural management systems are increasingly utilized on farms, enhancing both productivity and efficiency. These systems rely heavily on continuous environmental monitoring, data transmission, and analysis [1]. Thus, stable energy supplies are needed. However, it is challenging to deploy wired power line in all areas of farms. Plus, as the adoption of green energy grows, many farms are turning to renewable sources like solar panels for their power needs [2]. Despite its environmental benefits, green energy is sensitive to external factors, resulting in power interruptions. Battery-based solutions, on the other hand, require occasional battery recharging and replacements, which are considered unsustainable. Several research studies have proposed to enhance power supply efficiency [3][4]. However, the instability in power supply due to external factors remains inevitable. Therefore, it's essential to ensure that data, computing, and communication loss are prevented even during power interruptions.

This demonstration introduces a smart agriculture system capable of functioning seamlessly under unstable power conditions through intermittent computing, intermittent communication, and edge computing [5][6]. We showcase wireless data transmission and deep learning model inference for tomato monitoring.

II. Prototype Description

We propose an intermittent edge computing system which includes intermittent MCU, BLE-based intermittent communication interfaces, and an edge server. In this system, intermittent MCU handles the local inference task for the captured photo, intermittent communication is employed to handle the transmission of photos, and the edge server is in charge of the final processing of the received photos. The architecture of the demonstration is illustrated in Fig. 1.

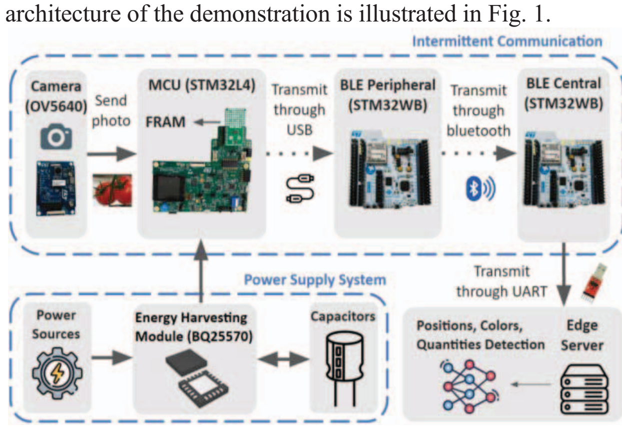

Fig. 1. The prototype overview

MCU(STM32L4): The MCU (STM32L4) is interfaced with a camera(OV5640) and a Ferroelectric RAM(FRAM). The STM32L4 is capable of storing image data received from the camera in the FRAM to prevent data loss during power interruptions. Additionally, the STM32L4 retrieves data from the FRAM and utilizes the pruning method for intermittent inference. Subsequently, the model determines the presence of tomatoes in the photos.

Power Supply System: The power source or energy harvesting devices charge the capacitor. When the capacitor is adequately charged, the Energy Harvesting Module discharges

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it to the STM32L4. If the power generated by the source is less than the power consumed by the MCU, it will be offline.

BLE Peripheral(STM32WB55): The BLE Peripheral receives the image data sent by the STM32L4, divides it into several packets, and calculates the cyclic redundancy check (CRC) for each packet. Upon completing these processes, the BLE Peripheral functions as a General Agreement on Tariffs and Trade (GATT) server, responding to requests from the GATT client to establish a Bluetooth connection and transmit data.

BLE Central(STM32WB55): Acting as a GATT client, the BLE Central sends requests to the GATT server (BLE Peripheral) to establish a connection. The BLE Central checks for packet loss and recalculates the CRC to prevent data errors. Then, it transmits the data to the Edge server via UART.

Edge Server: The Edge Server receives photo data from the BLE Central and reconstructs it into an RGB image. The Single Shot MultiBox Detector (SSD) model in the Edge server is employed for object detection, facilitating the identification of the location, color, and quantity of tomatoes in the photo.

III. DEMO OVERVIEW

The objective of this demo is to showcase a system capable of handling unexpected power interruptions in agricultural automation. We visualize the entire process, including image storage, transmission, processing, and tomato detection.

In the first part, we demonstrate the scenario when there are no tomato images stored in the FRAM. As depicted in Fig. 2, when the power is stable and the system is initialized, the camera module captures an image and stores it in the FRAM. The STM32L4 then analyzes the image to detect any tomatoes. If no tomatoes are detected, the camera retakes a photo. If tomatoes are detected, the transmission system is activated.

Fig. 3 illustrates the complete process from the initiation of image transmission to the completion of detection. The process consists of seven steps: each time the power is restored, if there are tomato images stored in the FRAM, the BLE Peripheral retrieves the incomplete image data from the STM32L4 (steps ① & ②). This is necessary because the BLE Peripheral and STM32L4 share the same power supply system. When a power interruption occurs, the BLE Peripheral loses power, leading to the data in the buffer being cleared. Therefore, it is essential to retrieve the data from the STM32L4 again after each power loss.

After retrieving the data, the BLE Peripheral responds to the request from the BLE Central, establishes a connection with the BLE Central (steps ③ & ④), and starts transmitting the data (step ⑤). Upon receiving the data, the BLE Central verifies the correctness of the data in each packet and detects any packet loss. The system operates on a block-by-block basis, with 6 packets in a block. BLE Central responds to the BLE Peripheral when all the data in the block are received correctly (step ⑥). This process enables rapid transmission while ensuring that BLE Central receives complete and correct data under wireless conditions. Once the Central receives the image data, it passes the data to the edge server (step ⑦). After the edge server completes receiving the entire image data, it converts the data back to the original photo and performs detection analysis on it. Finally, the detection results are displayed on the Edge server.

ACKNOWLEDGEMENT

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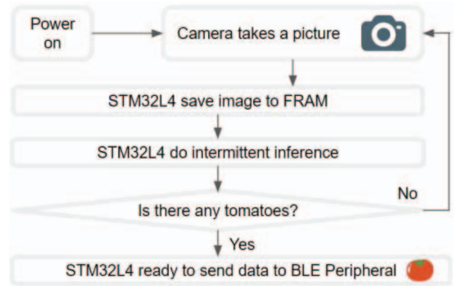

Fig. 2. Demonstration flowchart

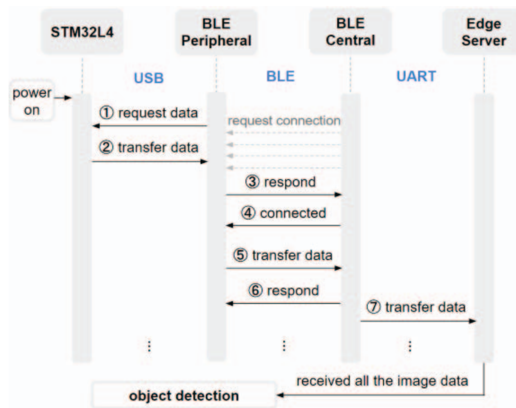

Fig. 3. Intermittent communication process

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