5G-Enabled Automated Plant Watering System for Small Farmers Using srsRAN and Open5GS

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Abstract. Smart irrigation systems rely on sensing, automation, and communication to improve water-use efficiency and reduce manual intervention. In rural South Africa, however, small-scale farmers continue to face persistent constraints including water scarcity, prolonged dry seasons, limited digital connectivity, and increasing irrigation energy costs, which obstruct the adoption of precision irrigation technologies. This paper presents an automated plant watering system implemented over an open-source private 5G standalone (SA) network using srsRAN and Open5GS. The proposed system integrates soil moisture and environmental sensing, threshold-based irrigation control, and real-time communication between a low-cost sensing node and a Python-based edge application server. In the deployed architecture, the sensing and actuation node connects via Wi-Fi to a 5G user equipment (UE), which provides broadband access to the private 5G network. The system is experimentally evaluated using both network-level and application-level performance measurements. The private 5G testbed achieved round-trip time (RTT) between 19.557 ms and 159.896 ms, uplink throughput of 16.4 Mbps, downlink throughput of 50.9 Mbps, and zero packet loss during testbed evaluation. During application operation, end-to-end RTT ranged from approximately 60 ms to 170 ms for local operation and increased beyond 300 ms when a cloud-based monitoring platform was introduced. The results show that open-source private 5G SA infrastructure can support responsive smart irrigation services while providing a practical and affordable platform for experimentation and pilot-oriented deployment. This study contributes experimental evidence for broadband-based smart irrigation over private 5G SA, an area that remains relatively underexplored compared with low power wide area network (LPWAN) agricultural Internet of Things (IoT) approaches.

Keywords: 5G · Smart irrigation systems · Precision agriculture · Rural connectivity · Internet of Things (IoT) · Digital inclusion

1 Introduction

Agriculture plays an important role in sustaining rural communities in South Africa, where small-scale farmers contribute meaningfully to local food production [33],[17]. However, many of these farming environments continue to face persistent structural constraints, including limited broadband infrastructure, inconsistent mobile network coverage, scarce resources, and high connectivity costs [22],[27],[28]. These challenges restrict access to digital services and limit the adoption of connected technologies that could improve agricultural decision-making.

Water management remains one of the most serious challenges in such environments. Small-scale farmers frequently experience water scarcity, prolonged dry seasons, increased energy costs for pumping, and limited access to modern irrigation technologies [3],[30]. In many cases, irrigation decisions are still based on manual observation, fixed schedules, or basic gravity-fed techniques rather than measured soil conditions [23],[18]. As a result, farmers may over-irrigate, miss critical watering intervals, waste water, increase pump wear and energy consumption, and ultimately experience inconsistent crop growth or reduced productivity [23],[24],[19].

These challenges are particularly important in a water-scarce country such as South Africa, where efficient use of limited freshwater resources is essential for sustainable agriculture and for improving the resilience of small-scale farmers. The shift toward smart agriculture is therefore not only a technological opportunity, but also a practical response to environmental and socio-economic pressures [10],[6]. However, this transition depends on the availability of communication infrastructure capable of supporting timely sensing, monitoring, and control. For many small-scale farming environments, commercial cellular coverage may be unreliable or costly, while existing IoT solutions may not provide the responsiveness needed for time-sensitive irrigation control [29],[11].

Recent developments in communication technologies, particularly fifth generation (5G) networks, provide new opportunities for supporting Internet of Things (IoT) applications in agriculture [4]. Compared to earlier wireless technologies, 5G offers higher data rates, lower latency, improved reliability, and the ability to support large numbers of connected devices [16],[4]. These characteristics make 5G suitable for time-sensitive agricultural applications such as automated irrigation and remote monitoring [23],[8]. In particular, private 5G networks built on open-source platforms such as srsRAN [26] and Open5GS [20] offer a potentially affordable and replicable way to support experimental and pilot-oriented smart agriculture deployments.

Motivated by these challenges and opportunities, this paper presents an automated plant watering system implemented over an open-source private 5G standalone (SA) network. The proposed system integrates soil moisture and environmental sensing, threshold-based irrigation control, and real-time communication between a low-cost sensing node and an application server. In the deployed architecture, the sensing and actuation node connects locally over Wi-Fi to an industry-grade 5G user equipment (UE), which provides broadband access to the private 5G network. The hybrid design enables low-cost field devices to be integrated into a broadband mobile communication environment without the sensing node having native 5G capability. The system utilizes the Blynk IoT platform to develop a customizable cloud-based dashboard that enables remote monitoring and interaction with the irrigation system.

The system is evaluated experimentally using both network level and application level performance measurements. The private 5G testbed is assessed using latency, throughput, and packet loss measurements, while the irrigation application is further evaluated using round-trip time (RTT) measurements during operation under local and cloud-integrated configurations. RTT is a measure of network latency, defined as the total time it takes for a data packet to travel from a sender to a receiver and back again to the sender [13].

The remainder of this paper is organized as follows. Section 2 presents an overview of the CSIR private 5G testbed used in this study. Section 3 reviews relevant work on smart irrigation systems and communication platforms for agricultural monitoring and control. Section 4 summarizes the contributions of the paper. Section 5 presents the proposed system architecture. Section 6 discusses deployment considerations and practical feasibility aspects of the proposed system. Section 7 reports the private 5G testbed evaluation and the performance of the proposed irrigation system. Section 8 discusses the results. Finally, Section 9 concludes the paper and outlines future work.

2 Overview of the CSIR Testbed

The CSIR testbed used in this study is a flexible private mobile network platform developed to support applied research, prototyping, and experimental validation of 4G/5G use cases in South African conditions, as illustrated in Fig. 1 [14],[31]. The platform is designed to evaluate practical communication architectures for industry- and society-facing applications such as smart agriculture, smart healthcare, education, and other rural and underserved connectivity scenarios.

At the radio access layer, the testbed supports open and software-defined deployments using platforms such as srsRAN and OpenAirInterface, together with software-defined radio and commercial radio equipment depending on the experimental requirements. The architecture is intended to support multiple access technologies and service profiles, including 4G, 5G, and future evolution toward 6G-oriented experimentation. This enables the testbed to accommodate broadband, low-latency, and massive IoT-type use cases within a common research environment.

The core network environment is hosted within the CSIR data centre and supports SA mobile network operation using open-source core network platforms such as Open5GS and other experimental core implementations. The setup provides a controlled environment for configuring user-plane and control-plane functions, application servers, and service integration components required for end-to-end validation. The use of open-source network software also improves flexibility, affordability, and reproducibility of the experiments.

To improve applicability to rural and distributed deployments, the testbed is designed with support for flexible backhaul options, including fixed wireless and IP-based transport. The broader architecture also considers off-grid or energy-constrained operation through solar-powered base station concepts, inverter systems, and lithium battery support. The architecture makes the platform relevant not only for laboratory studies, but also for pilot-oriented investigations in remote and under-connected areas.

In the context of this work, the CSIR testbed provided the private 5G SA environment used to evaluate the proposed automated irrigation system. It enabled controlled integration of the sensing node, the 5G UE acting as a gateway, and the edge application server within a single experimental platform. The testbed therefore served as the communication backbone for evaluating both network-level performance and end-to-end application responsiveness for the smart irrigation use case.

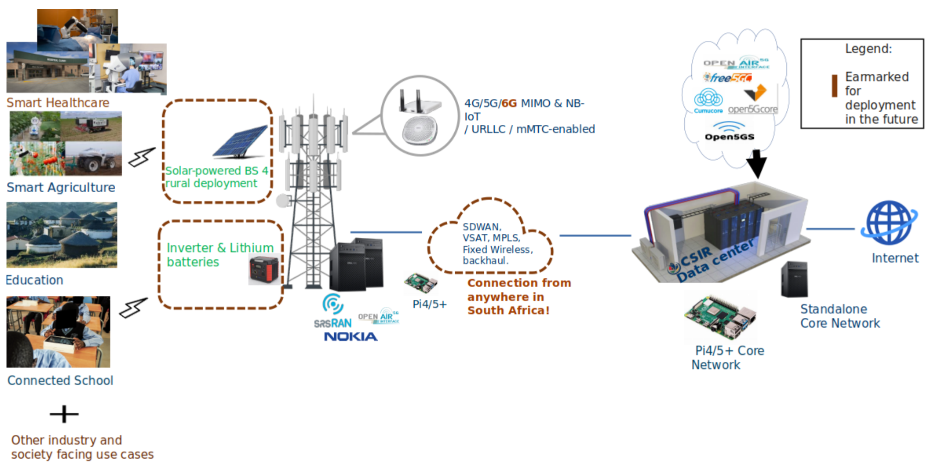

Fig. 1. CSIR 5G Testbed

3 Related Work

Relevant work to this study can be grouped into two areas: (i) sensor-based irrigation systems that use automation and remote monitoring, and (ii) wireless communication platforms used to connect field devices, gateways, and application services.

Some studies have implemented IoT-enabled irrigation using low-cost sensors, microcontrollers, and threshold-based control logic. These systems typically monitor variables such as soil moisture, temperature, and humidity, and use the measurements to trigger irrigation or support remote supervision [23]. While these approaches show the value of sensor-driven irrigation, they generally focus more on sensing and control than on the communication platform required to support reliable and responsive operation in underserved environments.

To address connectivity constraints, some researchers have considered long-range and low-cost wireless technologies for agricultural monitoring. For example, Gitahi *et al.* implemented a LoRaWAN-based system for monitoring soil moisture and reservoir levels, with irrigation actions triggered remotely through a dashboard interface [7]. Similarly, Bogdanoff and Tayeb proposed a low-cost ISM-band sensor and actuator network for irrigation control across multiple agricultural zones without relying on cellular subscriptions [2]. Although such approaches are attractive from a cost perspective, they are primarily designed for low-data-rate sensing applications and do not examine broadband mobile infrastructures for integrated monitoring, control, and service delivery.

Private 5G networks provide a promising alternative for applications that require more reliable and lower-latency connectivity. However, practical studies in this area remain limited, particularly those based on fully open-source 5G SA implementations. Kurafeeva *et al.* explored agricultural sensor workloads over a private 5G deployment using srsRAN and Open5GS [9]. While relevant, the study gives limited attention to affordability for small-scale farmers and does not discuss end-to-end irrigation control performance in detail. Zhivkov *et al.* reported a private 5G SA farm robotics testbed and presented latency, throughput, and reliability indicators [32]. Although this work demonstrates the suitability of private 5G for agricultural environments, it is not based on an open-source mobile network stack and gives limited attention to affordability and replicability for resource-constrained farming contexts. Shah *et al.* evaluated latency and throughput using srsRAN and Open5GS in a private industrial testbed [25]. That study shows the viability of open-source private 5G for low-latency applications, but it is not focused on smart irrigation use cases and does not investigate sensing, actuation, and remote monitoring in an agricultural setting.

Beyond local agricultural IoT deployments, countries such as the Netherlands, China, Japan, and South Korea have increasingly investigated 5G-enabled smart agriculture for applications including precision irrigation, autonomous farming systems, agricultural robotics, and real-time environmental monitoring [15],[11],[32]. Many of these deployments rely on commercial 5G infrastructure, large-scale farming operations, and advanced automation platforms. In particular, Patra *et al.* investigated private 5G deployment for smart agriculture using edge computing and Citizens Broadband Radio Service (CBRS)-based communication infrastructure, with emphasis on connectivity quality and throughput performance [21]. Similarly, Zhivkov *et al.* evaluated wireless communication capabilities for agricultural robotics in farm environments using 5G technologies [32]. While these studies demonstrate the growing role of 5G in modern agriculture, practical implementations based on fully open-source private 5G SA platforms and low-cost irrigation control for resource-constrained farming environments remain limited.

Overall, the reviewed literature suggests that practical work at the intersection of smart irrigation, open-source private 5G SA networks, and affordable deployment for small-scale farming remains limited. The proposed study addresses that gap by presenting an experimentally validated automated plant watering system implemented over an open-source private 5G SA network using srsRAN and

Open5GS. Unlike narrowband-focused agricultural IoT approaches, the proposed system examines a practical broadband-based architecture for sensing, actuation, monitoring, and remote control.

4 Contributions

This paper makes the following contributions:

1. It presents a practical and affordable smart irrigation architecture that combines low-cost sensing and actuation with a private 5G SA network built entirely on open-source platforms, namely srsRAN and Open5GS. The architecture improves replicability and reduces dependence on proprietary mobile network infrastructure.
2. It demonstrates a hybrid broadband-based agricultural IoT deployment model in which a Wi-Fi-connected sensing and actuation node is integrated with a private 5G SA network through an industry-grade 5G UE. This approach is practical for small-scale farming environments where narrowband agricultural IoT deployments remain constrained or underexplored.
3. It provides an end-to-end experimental validation of automated irrigation over a private 5G SA testbed, including both network-level measurements (latency, throughput, and packet loss) and application-level RTT measurements during real system operation.
4. It shows that private 5G SA can support time-sensitive smart irrigation services while also enabling remote monitoring and manual control through cloud integration, thereby bridging the gap between laboratory 5G experimentation and pilot-ready agriculture deployments.
5. It contributes experimental evidence for the use of open-source 5G SA infrastructure in agriculture, a domain in which practical 5G SA implementations for smart irrigation remain relatively underexplored compared to conceptual studies or narrowband-focused IoT solutions.

5 System Architecture

The proposed system architecture consists of three main components: the sensing and actuation subsystem, a private 5G communication infrastructure, and the application layer responsible for monitoring and data processing. Figure 2 presents the proposed automated irrigation system architecture, showing the interaction between the sensing node, the private 5G communication infrastructure, and the application server.

5.1 Sensing and Actuation

A soil moisture sensor connected to an ESP8266 NodeMCU microcontroller periodically monitors soil and environment conditions [5]. The ESP8266 processes the soil sensor readings and compares them with a predefined soil moisture

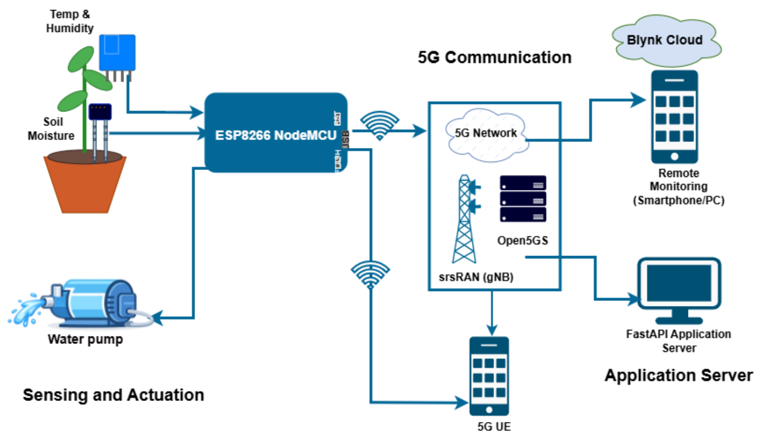

Fig. 2. Automated irrigation system architecture

threshold. When the measured moisture level falls below this threshold, the microcontroller activates an IRLZ44N N-channel MOSFET, which serves as an electronic switching device to drive the water pump and start irrigation. When the soil moisture level reaches the desired value, the pump is automatically deactivated. This mechanism enables closed-loop irrigation control with minimal manual intervention.

5.2 5G Communication

The communication infrastructure is implemented using a private 5G testbed deployed with srsRAN for the radio access network (RAN) and Open5GS for the 5G core network. The RAN is interfaced with a USRP B210 software-defined radio (SDR), which provides the 5G NR air interface [12]. A 5G-capable smartphone with a programmable SIM card serves as the UE, acting as a bridge between the IoT device and the private 5G network.

5.3 Application Server

An edge application server programmed in Python and deployed with the FastAPI framework serves as the endpoint for IoT data transmitted from the ESP8266 via the private 5G network. The server receives sensor readings and system events, logs the data, and sends an acknowledgment response to the device. This request-response mechanism enables RTT computation for end-to-end latency evaluation using timestamps produced at the ESP8266.

6 Practical Feasibility and Deployment Considerations

The deployed testbed used commercially available off-the-shelf hardware components, antennas, general-purpose computing platforms, and 5G UE devices such as smartphones or routers. The software stack was implemented using open-source platforms, namely srsRAN and Open5GS. The use of open-source software reduces dependence on proprietary mobile network solutions and lowers the deployment cost associated with licensing and vendor-specific infrastructure [14].

In rural deployments, the private 5G network may operate as shared infrastructure serving multiple farmers within the same coverage area. Network management could follow a community-based model supported by local users and rural connectivity partners, minimizing the need for specialized operational personnel. Renewable energy solutions such as solar panels with battery backup systems may improve operational reliability in rural environments where grid access is unstable [28].

The irrigation subsystem was designed using low-cost and replaceable electronic components, making it suitable for replication in small agricultural environments. Wi-Fi connectivity between the ESP8266 sensing node and the 5G UE gateway provides a practical bridge between low-cost IoT hardware and the private 5G network. The design supports affordable monitoring and irrigation control while enabling broadband 5G connectivity. A battery supply can power the irrigation system, making it more feasible in farming environments with limited resources.

7 5G SA Baseline Performance Profiling

The performance of the private 5G testbed was evaluated using throughput, latency, and packet loss measurements between the 5G UE and a server within the local data network. In the deployed setup, the Next Generation (NG) interface was successfully established between the gNB and the Open5GS core network. After successful attachment and Packet Data Unit (PDU) session establishment, the UE was assigned an IP address and was able to exchange user-plane traffic with the application environment.

The performance of the private 5G SA testbed was evaluated at two levels. First, the underlying network was evaluated by measuring latency, throughput, and packet loss. Second, the complete automated irrigation system was evaluated using application-level RTT measurements during real system operation. This two-level evaluation provides insight into both the communication capability of the testbed and the practical responsiveness of the implemented irrigation service.

7.1 Evaluation Results

The private 5G testbed was successfully configured with an operational Next Generation (NG) interface between the srsRAN gNB and the Open5GS core network. The UE attached to the network following Radio Resource Control (RRC) reconfiguration, after which a Packet Data Unit (PDU) session was established and an IP address was assigned to the UE. Based on this operational setup, latency, throughput, and packet loss measurements were performed to evaluate the communication performance of the deployed 5G network before connecting the smart irrigation system.

Latency, Throughput, and Packet Loss Latency measurements were obtained using ICMP ping tests between the 5G UE and a server located within the local data network. The packets traversed the full 5G communication path, including the RAN, the 5G core network, and the user plane function (UPF). Throughput measurements were conducted using *iperf3* executed on the UE to generate controlled TCP traffic between the UE and the same server in the local data network.

Figure 3 summarizes the measured network performance of the private 5G testbed obtained from repeated measurement trials using 100 packet transmissions. The RTT results indicate an average latency of 37.708 ms, with observed values ranging from 19.557 ms to 159.896 ms and a measured standard deviation (mdev) of 30.106 ms. The throughput results show 16.4 Mbps in the uplink and 50.9 Mbps in the downlink. No packet loss was observed during the latency measurements.

These results indicate that the deployed open-source private 5G SA testbed provided stable connectivity and sufficient communication performance for the targeted IoT-based irrigation application. The measured latency remained low enough to support responsive communication, while the achieved throughput was more than adequate for the low-bandwidth sensing and control traffic generated by the system.

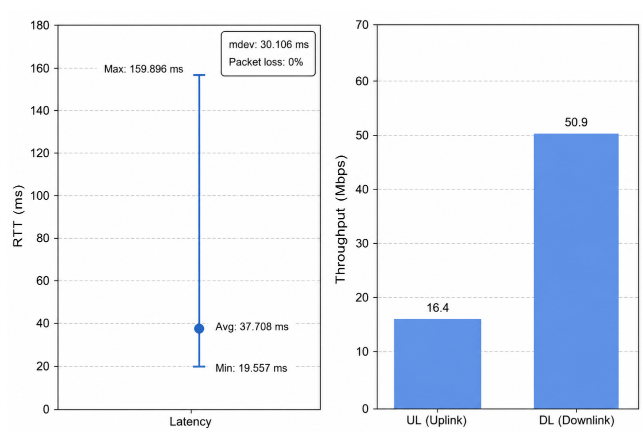

Fig. 3. Performance summary of the private 5G SA testbed

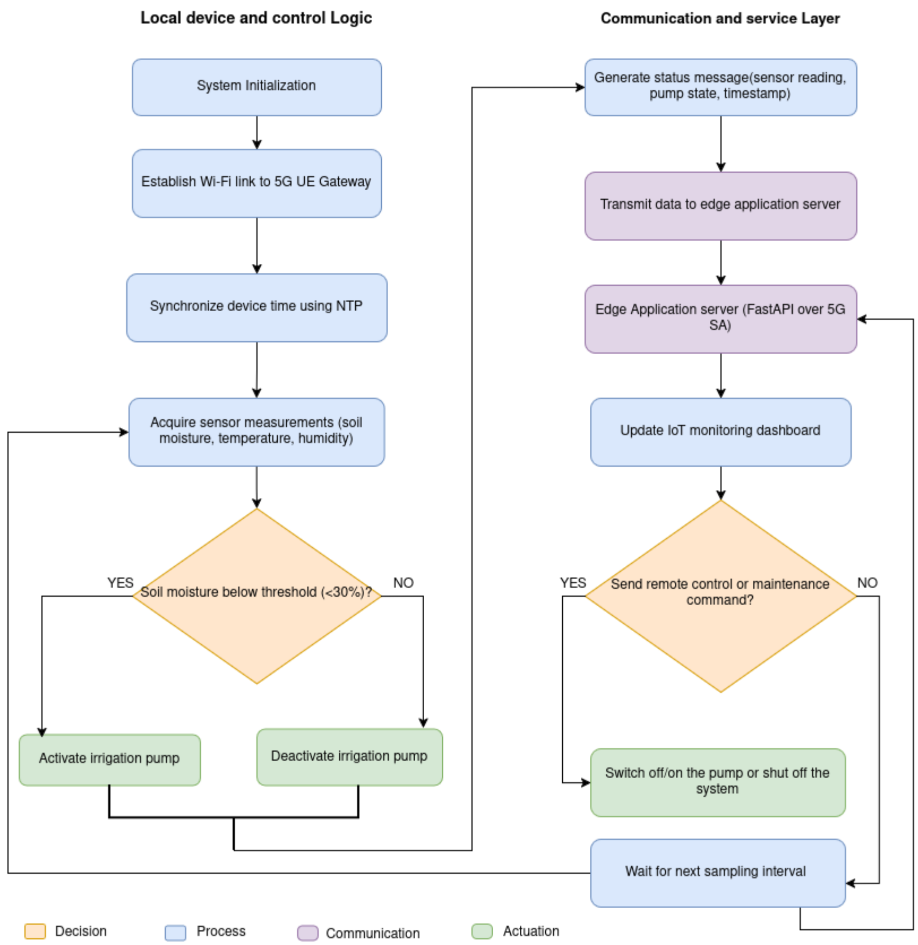

Fig. 4. Operational workflow of the proposed automated irrigation system.

7.2 Overall System Operation Workflow

Figure 4 illustrates the operational workflow of the proposed irrigation system, including environmental sensing, threshold-based irrigation control, and communication with the application server through the private 5G network. The system operates by connecting a soil moisture sensor and a temperature–humidity sensor to an ESP8266 microcontroller, which periodically collects environmental measurements. For the experiment, the soil moisture threshold was configured to 30%, and the irrigation pump was activated for a duration of 5 seconds when the threshold condition was met. In practical agricultural deployments, the moisture threshold and irrigation duration can be calibrated depending on crop type and soil conditions.

Soil conditions were considered dry when the measured moisture value fell below 30% and wet when the value exceeded this threshold. When the soil moisture level dropped below the configured threshold, the microcontroller activated the water pump to initiate irrigation. Once the soil moisture value exceeded the threshold, the pump was automatically deactivated.

Initially, sensor readings and pump status were transmitted directly between the sensing device and a local monitoring interface within the 5G testbed, without external cloud integration. The Blynk IoT cloud platform [1], was subsequently incorporated to enable remote monitoring, data visualization, and manual control of the irrigation system. The platform provides real-time visualization of soil moisture, temperature, humidity, and pump status, allowing users to manually activate or deactivate the irrigation pump when required.

The hardware implementation supporting the system operation workflow is illustrated in Fig. 5, which shows the connections between the sensing devices, the ESP8266 microcontroller, and the pump driver circuit. A 1N4007 diode is connected across the water pump in reverse bias to provide flyback protection. Since the pump behaves as an inductive load, switching transients can generate high-voltage spikes that may damage the MOSFET. The diode safely dissipates these transients, thereby improving system reliability. Resistors are included for signal conditioning and protection. A 470 Ω gate resistor limits inrush current to the MOSFET gate, while a 10 kΩ pull-down resistor ensures stable logic levels during startup and prevents unintended pump activation.

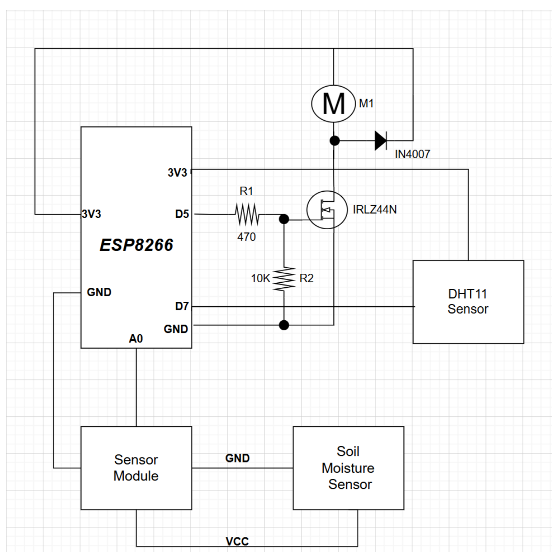

Fig. 5. Hardware implementation of the automated irrigation system.

7.3 System Performance Results Through 5G Network

The performance of the automated plant watering system over the private 5G network was evaluated by measuring the time taken for data packets to be transmitted from the ESP8266 microcontroller to the application server and for the response to return to the device. Latency measurements were performed under two configurations: (i) operation without IoT cloud platform integration, where communication occurred entirely within the local 5G testbed, and (ii) operation with IoT cloud platform integration, where the IoT platform enabled remote monitoring and manual control of the irrigation pump.

Prior to latency measurements, Network Time Protocol (NTP) synchronization was configured to ensure that the ESP8266 device and the application server used a common time reference. This ensured that timestamps generated during data transmission and reception could be used to compute valid RTT measurements.

System Monitoring Interface Figure 6 shows the IoT cloud platform dashboard used for remote monitoring and manual interaction with the irrigation system. The dashboard displays soil moisture level, temperature, humidity, and pump status in real time. It also provides controls for activating maintenance mode and manually switching the irrigation pump. The interface was implemented using widgets available in the Blynk IoT platform, including gauge widgets for sensor visualization, switch widgets for pump and maintenance control, and value display widgets for monitoring packet sequence numbers and communication timing.

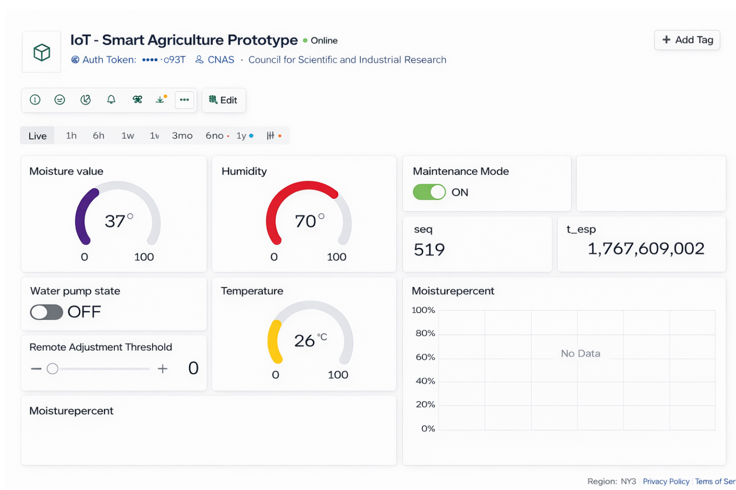

Fig. 6. IoT platform dashboard used for remote monitoring and manual control of the irrigation system.

End-to-End Application Latency The end-to-end application latency represents the time required for a data packet to be transmitted from the ESP8266 microcontroller to the server and for the response to return to the device. The RTT latency was calculated as shown in equation (1).

$$RTT = t_{receive} - t_{sent} \tag{1}$$

Where t_{sent} is the timestamp when the ESP8266 transmits the data packet and $t_{receive}$ is the timestamp when the response is received from the server.

Figure 7 presents the RTT values plotted against the packet sequence number when the irrigation system operated within the local 5G testbed without the monitoring dashboard integration. A packet sequence number is a number attached to each transmitted data packet to maintain packet order, detect packet loss, and enable latency measurements such as RTT. In this configuration, communication occurred directly between the ESP8266 device and the application server. The experiments were repeated using 50 sensor data packet transmissions to improve reliability. The recorded RTT values ranged from approximately 60 ms to 170 ms.

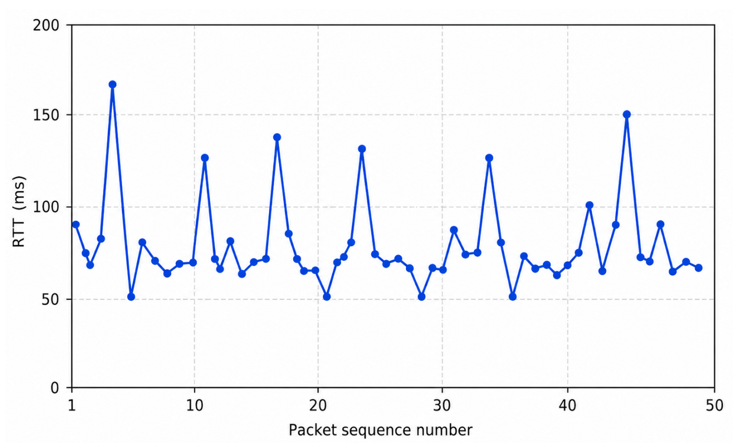

Fig. 7. RTT latency versus packet sequence number without IoT platform integration.

Figure 8 shows the RTT values obtained when the IoT monitoring platform was integrated into the system. In this configuration, sensor data and control messages were transmitted through the IoT monitoring cloud server for remote monitoring and manual system control. The RTT values were plotted against the packet sequence number recorded during system operation. The recorded RTT values ranged from 40 ms to 390 ms during the transmission of 50 data packets.

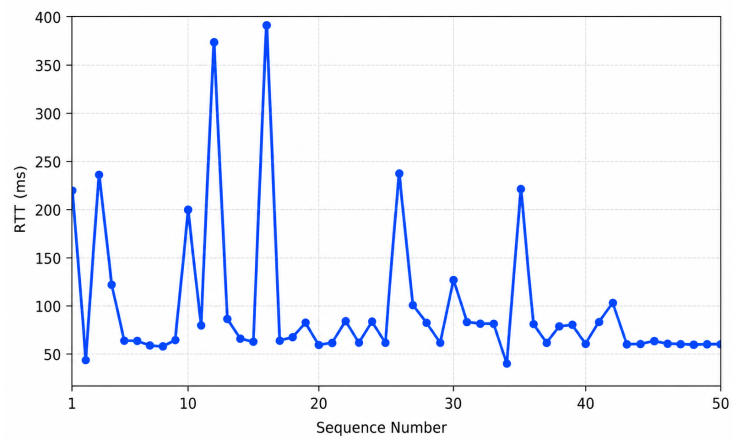

Fig. 8. RTT latency versus packet sequence number with IoT cloud integration.

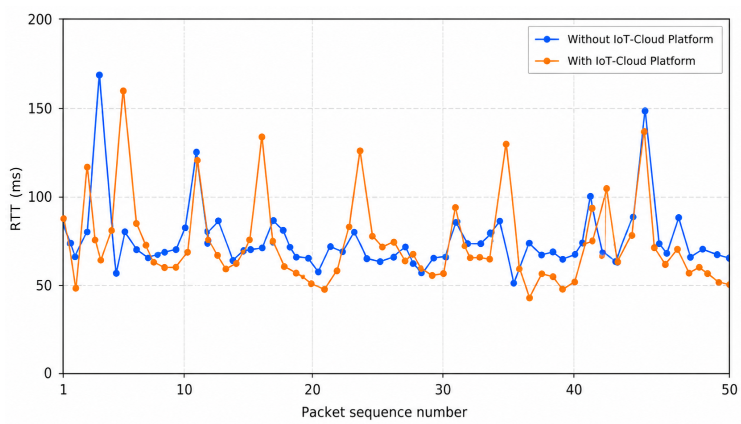

Fig. 9. RTT latency comparison between system operation with IoT monitoring platform integration and without it.

8 Discussion of Results

The results obtained from the private 5G testbed demonstrate the communication performance achieved during both network evaluation and system-level operation of the automated irrigation system.

The network performance measurements indicate that the deployed private 5G infrastructure provided stable connectivity and sufficient communication performance for IoT-based operation. The observed latency, throughput, and packet loss results demonstrate that the testbed can support responsive sensing, monitoring, and irrigation control services.

When the automated plant watering system was integrated with the network, end-to-end application latency was evaluated using RTT measurements obtained directly from the ESP8266 device. During local operation without IoT cloud integration, communication remained within the private 5G testbed between the microcontroller and the application server, resulting in relatively stable RTT behaviour.

When the IoT platform was integrated, the RTT latency increased to a range of 40 ms to 390 ms. This increase is attributed to the extended communication path involving the public internet and the IoT monitoring cloud server before the response returned to the ESP8266 device.

Figure 9 compares the RTT behavior observed during local system operation and during operation with IoT cloud platform integration. The results show that cloud integration introduced additional communication delay due to the extended communication path through external network infrastructure. The difference in latency between the two configurations can be explained by the communication paths followed by the system. Without IoT platform integration, communication remained within the local 5G testbed:

ESP8266 → Wi-Fi → 5G UE → gNB (srsRAN) → 5G Core (Open5GS) → Application Server → 5G Core → gNB → 5G UE → Wi-Fi → ESP8266.

When the IoT monitoring platform was integrated, the communication path extended to external cloud services:

ESP8266 → Wi-Fi → 5G UE → gNB (srsRAN) → 5G Core (Open5GS) → Public Internet → IoT monitoring Cloud Server → Public Internet → 5G Core → gNB → 5G UE → Wi-Fi → ESP8266.

The additional network segments increased the overall communication distance, contributing to the higher RTT values observed during system operation.

A major latency increase occurred at several packet sequence numbers, when the RTT exceeded 300 ms during cloud-integrated operation. The observed RTT increases are attributed to remote monitoring operations performed through the IoT monitoring platform, including maintenance mode activities, as shown in Fig. 6. During this occurrence, a manual control command was issued from the cloud platform and transmitted through the extended communication path before reaching the ESP8266 device.

Despite the additional latency introduced by cloud integration, the system maintained continuous environmental monitoring and reliable pump control. Sensor readings for soil moisture, temperature, and humidity were successfully transmitted to the monitoring interface, and irrigation was triggered when the soil moisture threshold condition was reached. The IoT monitoring dashboard enabled visualization of sensor data and allowed manual activation or deactivation of the irrigation pump when required.

Compared with related smart agriculture and private 5G studies reported in [21] and [32], the proposed implementation demonstrated comparable low-latency communication while utilizing a fully open-source SA 5G architecture. Unlike several large-scale smart agriculture deployments that depend on commercial 5G infrastructure and advanced automation platforms, the proposed system focused on a low-cost and irrigation use case suitable for small-scale farmers. The achieved RTT performance and stable communication behavior demonstrate the feasibility of integrating broadband private 5G connectivity with affordable IoT-based irrigation control.

Overall, the results indicate that the private 5G network can support IoT-based smart agriculture applications while enabling remote monitoring and control through cloud integration.

9 Conclusion and Future work

This paper presented an automated plant watering system implemented over an open-source private 5G SA network using srsRAN and Open5GS. The study targeted a practical smart irrigation use case relevant to small-scale farming environments, where water scarcity, limited digital infrastructure, and rising irrigation costs continue to constrain the adoption of precision agriculture technologies.

The experimental results indicate that the deployed infrastructure can support responsive sensing, monitoring, and threshold-based irrigation control.

The study makes three main contributions. First, it demonstrates the feasibility of using open-source private 5G SA infrastructure for a practical smart irrigation application. Second, it presents a broadband-based hybrid architecture in which a low-cost sensing node connects locally via Wi-Fi, while network connectivity is provided by an industry-grade 5G UE. Third, it provides experimental evidence of both network and application-level performance, providing a more deployment-oriented assessment than purely conceptual studies.

Future work will extend the system to multi-node deployments, larger outdoor test scenarios, and broader evaluation under field conditions. Additional work will also investigate scalability, robustness, and more advanced irrigation strategies based on data-driven decision support and intelligent control.

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