Digitizing data in rural applications and making them visible

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Abstract: This paper introduces a comprehensive system chain to address the challenges of smart sensing applications in rural areas. The system comprises both software and embedded hardware components with a primary focus on simplifying the integration of new sensors while prioritizing user-friendliness in small to medium-size applications. Additionally, it provides straightforward data integration of LPWAN solutions and other data sources.

Special focus was set on a lean system setup and easy configuration. Applications in rural areas often comprise a dozen up to a few hundred sensors for one application. The focus of the evaluation was set on community applications such as groundwater monitoring or environmental monitoring.

Additionally, the platform offers a user interface for situated visualization of sensor data, contextualizing the data by projecting it over the location of the sensor using augmented reality. On the hardware side, a modular concept consisting of modular sensor carrier boards and exchangeable CPU platforms allows for easy adaptation to applications and training for schools and industry. The results will be published as Open Hardware and Open Software.

Keywords: Digitalization, Data Integration, Augmented Reality, Rural Sensing, IoT

1 INTRODUCTION

Nowadays it is hard to imagine life without the Internet of Things (IoT). It reshapes the way we perceive and interact with our environments. However, particularly in rural areas, it is a challenge to fully digitize sensing applications and automate measurement tasks due to the potentially limited coverage of communication systems. These challenges in rural areas demand innovative communication solutions. As described by Yuke et al. [1] and Mekki et al. [2], low power wide area networks (LPWANs) have excellent features of low energy consumption, long transmission ranges and high capacity addressing these problems.

Digitalization can not only reduce time and therefore labor costs by avoiding visit of measurement sites for manual readings, but also makes it possible to predict changes in the measurand, which can be of great importance, especially in environmental monitoring and climate change. Augmented Reality (AR) adds support in finding sensors and interpreting data in a local context.

In this paper we present a flexible and extensible architecture and system facilitating the establishment of sensor networks and leveraging collected data effectively in rural areas for profitable use. Such technology is foundational for a sensor-based data economy and is a building block to transform rural areas into smart regions.

2 SYSTEM ARCHITECTURE

A key consideration is to support a variety of communication protocols and ensure an easy way to expand with additional communication protocols. This is achieved by defining multiple roles to allow easy extension and adaptation to changing requirements, as shown in a tree-like system structure in Figure 1.

The developed Dataskop(*DSP)-Backend* includes the server and database with stored data along with configurations for IoT devices. Below are the *DSP-Gateways* that are software programs, which are launched on a device and ensure communication between the server and IoT devices. They are explicitly presented in a distinct column because their logic is separate from that of the server, fostering maintenance, updates, troubleshooting and scalability. However, in a real-world setup, they can also operate on the same machine as the server. *DSP-IoT-Devices* can be custom embedded systems or commercial products with preinstalled software and integrated sensors. They incorporate *DSP-Measurement-definitions* reflecting the individual sensors of the devices. The *Backend-tool* provides a user interface for component configuration. Additionally, data from the server can be fetched via REST for various applications, including an Augmented Reality app for situated visualization of the sensor data.

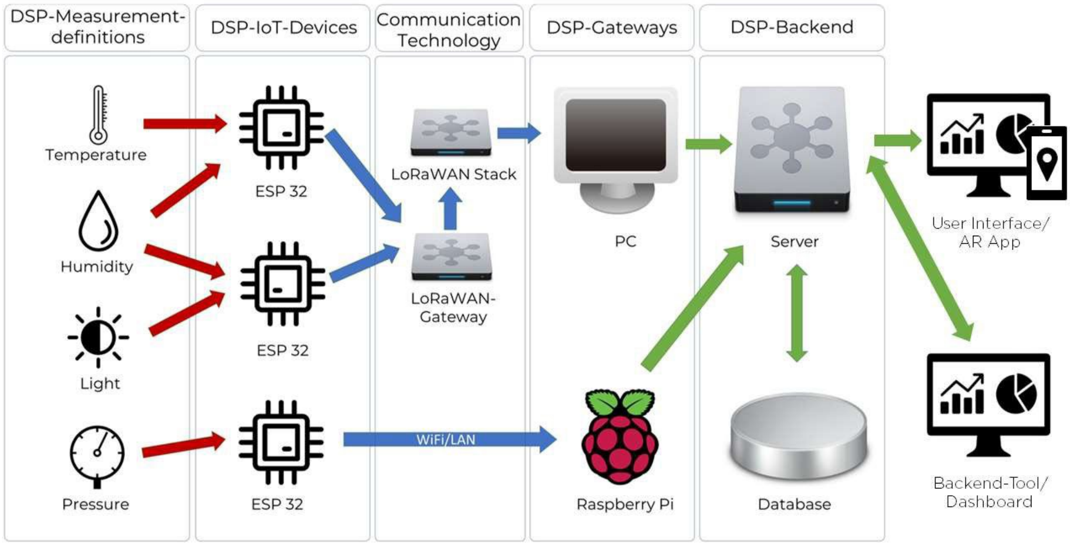

Figure 1: Structure of the system

2.1 DSP-GATEWAY

The software gateway plays a crucial role in facilitating communication between the server and IoT-devices, handling data transmission and configuration exchange. Currently, it supports data exchange via WiFi/LAN (inside buildings) and LoRaWAN [3](outdoor, long range) over commercial but also public networks, demonstrating its remarkable capabilities offering low-energy operations coupled with long-range data transmission[1], effectively overcoming the hurdles of remote installation providing widespread connectivity in rural regions.

Additionally, it is possible to integrate the free environmental data platform *Opensense*, providing access to widely distributed sensors [4]. Upon initialization, the *DSP-Gateway* receives its configuration from the server, adjusting its behavior accordingly. User-initiated changes to the *DSP-Gateway* configuration via the *Backend-tool,* relayed by the server, prompt adjustments in its behavior and the inclusion of newly assigned *DSP-IoT-Devices*. If the firmware of the *DSP-IoT-Device* supports it, the *DSP-Gateway* can selectively dispatch the relevant part of the updated configuration to the *DSP-IoT-Device*, facilitating adjustments like data transmission intervals.

[1] The transmission latency is influenced by both the size of the data and the distance. Since LoRaWAN can operate up to distances of 15km (or more when there is a clear line of sight) data latency may reach a maximum of 2 to 3 seconds (only with large transmission data). For most (monitoring) applications timing is not critical and this latency is typically acceptable. However, the latency (time-on-air) and the spreading factor of LoRa can be easily determined from the radio properties and can subsequently be compensated.

2.2 DSP-IoT DEVICE

The system is designed in way that any IoT-device that implements one of the supported communication protocols can be integrated. Commercial products usually have a fixed payload format for sensor data, which requires user configuration of payload-to-DSP-Measurement-definitions mapping in the Backend-tool. Users define their desired DSP-Measurement-definitions, such as temperature and humidity in the user interface and specify the mapping of bytes from the payload to the corresponding DSP-Measurement-definitions. Upon each sensor message transmission, the gateway routes the message to the server, applying the user-defined mapping. This enables customization of the data from the payload based on user preferences, allowing for segmentation, selective utilization, or pre-storage conversions.

3 GROUNDWATER MONITORING SYSTEM DEMONSTRATOR

The groundwater monitoring system is one of the demonstration setups that were implemented on top of the Dataskop infrastructure [5]. This remote installation illustrates many challenges for IoT applications, incorporating aspects such as battery-powered low-power operation and resilient system connectivity and data processing. To establish a robust wide-range communication with minimal power consumption the LoRaWAN technology was used.

The setup comprises a LiDAR-based distance sensor for measuring water levels, connected to a microprocessor board that handles data collection and communication.

The left-hand side of Figure 2 depicts a visual representation of the system in the field while the right-hand side shows measurements as they are received at the backend server for further processing and visualization by external tools (e.g. Grafana). This practical demonstration proofed the easy installation in the field and already reliably delivered data from a remote site over months.

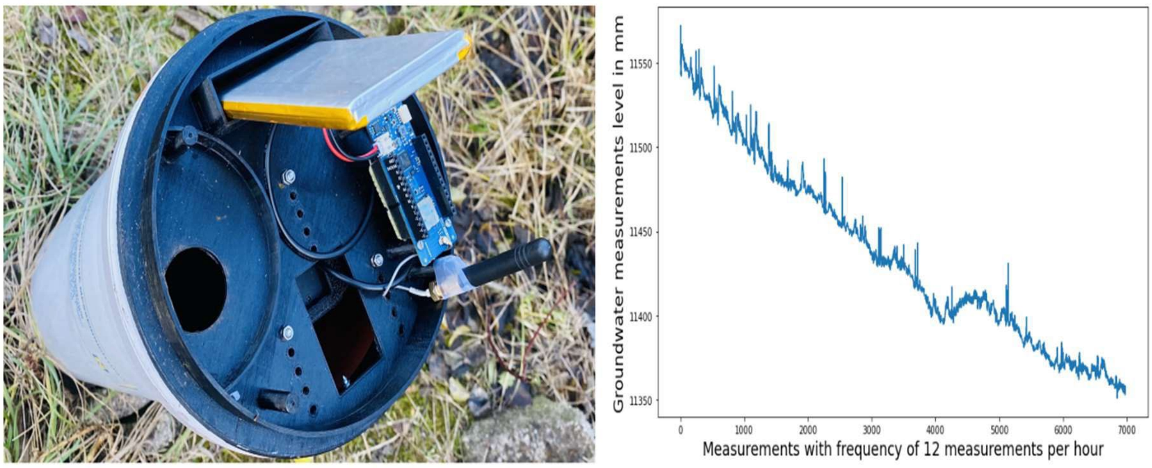

Figure 2: System setup along with sensor- derived groundwater level measurement data.

4 SITUATED DATA VISUALIZATION WITH AUGMENTED REALITY DEMONSTRATOR

To demonstrate the full benefits of location-aware data, we deployed level sensors into disinfectant dispensers. This deployment showcased how sensors can be localized in the environment, with data displayed in spatial context. This use case emerged from the necessity to manage over 70 dispensers at the University campus facilities during the COVID-19 pandemic.

Battery and liquid levels were continuously measured for each dispenser. A Hall effect sensor was mounted outside of the dispenser housing to measure the liquid level, utilizing a floating magnet in the liquid container. Additionally, a split adapter was connected to the battery to power the additional embedded system and to measure and monitor the battery voltage.

On the client side, we emphasized location-based and situated data visualizations [6] to aid navigation and comprehension of data concerning where the sensors are deployed. Facility managers could then navigate the data using conventional dashboards, including list and map views indicating the location and status of devices. Furthermore, sensor data could be visualized with Augmented Reality, displaying the measurement values as points, bubbles, and bars directly over the dispensers (see Figure 3).

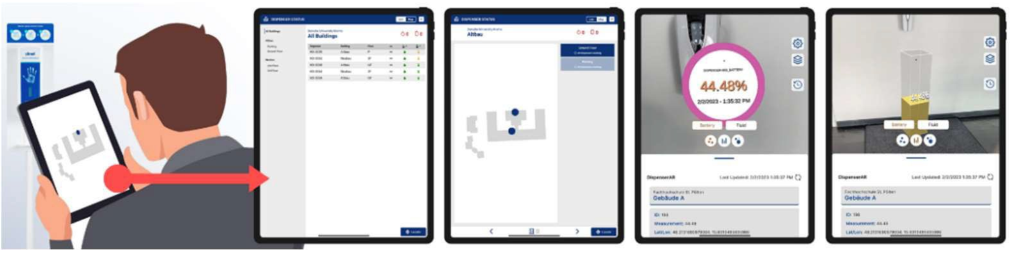

Figure 3: Visualization of location-based sensor data from disinfectant dispensers.

5 CONCLUSION

The study highlights the importance of the utilization of LoRaWAN technology, coupled with a flexible and extensible design, for addressing the dynamic demands of digitalization of applications in rural settings. By prioritizing adaptability and effortless integration of diverse communication protocols, the approach aims to establish a robust foundation for widespread, easy and profitable IoT solutions, addressing the challenges posed by rural environments and their diverse as well as evolving needs. Results will be published as open hard and software to be available for SMEs to setup their applications.

6 ACKNOWLEDGMENT

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