

Revisiting Environmental Sensing Nodes: Lessons Learned and Way Forward

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Summary:

Setting up sensors for the purpose of environmental monitoring should be a matter of days, but often drags over weeks or even months, preventing scientists from doing real research. Additionally, the newly developed hardware and software solutions are often reinventing existing wheels. In this short paper, we revisit the design of our environmental sensing node that has been monitoring industrial areas over a span of two years. We share our findings and lessons learned. Based on this, we outline how a new generation of sensing node(s) can look like.

Keywords: sensing node, sensor network, environmental monitoring, low-cost, LoRaWAN

Motivation

Scientists need data to gain new knowledge. Thanks to open-source code and maker communities, and modern embedded hardware technology, a near infinity of solutions to environmental monitoring exist. However, no inexpensive ready-to-go system has been established, which leaves individual scientists with developing a custom system nearly from scratch, taking away valuable research time to tedious development time.

To facilitate this process for future scientists, we share our experience with the development and instrumentation of our low-cost sensing nodes. We propose our current ideas that might be helpful for scientists designing environmental sensing platforms.

Lessons Learned

Literature shows that there are a lot of developments for low-cost sensing nodes [1]. It is beyond the scope of this paper, to give a detailed overview on these. Instead, we highlight lessons that we learned from own previous projects [2, 3].

In [2], we proposed a stationary sensing node with active ventilation fan for air quality monitoring. These nodes have been working in outdoor and indoor scenarios for multiple years since then.

When outdoor scenarios are addressed and power supply is limited, we emphasize that the whole system must be designed for low-power consumption holistically. Care should be taken

during the selection of electronics and the design of the software architecture, as low power is only achievable to a certain degree by tuning subsystems individually from each other. Similarly, external power supply, such as batteries, need to be dimensioned adequately.

We also advise checking the orientation of sensors thoroughly. Some sensors may have mounting orientations that are better than other, e.g., dust may clutter horizontally oriented optical lenses. Similarly, a mitigation procedure for sensor drift should be thought of. Especially for low-cost (dust) sensors, it may be more sensible to replace whole sensors, instead of cleaning them in the field. As low-cost sensors are prone for unreliable readings or outages, we advise to keep a sensor replacement strategy in mind. When multiple sensing nodes are deployed in a sensor network, the network might be used to absorb outages of individual sensors [4].

Lastly, we want to highlight the accessibility of data. This is of course dependent on the scenario, but occasions may arise in which also non-experts may need easy access to the sensor data. Concretely, travel restrictions due to the global COVID-19 pandemics forced us to rely on external non-experts for data retrieval.

Design Ideas for a Revised System

To reflect the learning from our previous system, we outline, how a new environmental sensing node can look like. To ensure a high reusability and flexibility of the sensor platform, we propose a modular sensing node, that can

be quickly equipped with different sensor modules. The key idea is that each sensing node consists of a single main module, which receives data in a standardized format from the different sensor modules. By this, sensor modules must be developed and programmed only once and can then be reused in different scenarios and constellations.

To ensure seamless wireless connectivity, we will use both WLAN and LoRaWAN. LoRaWAN stands for Long Range Wide Area Network and is a network protocol that enables long-range wireless communication between devices. With LoRaWAN, distances up to 15 km over ground can be covered, while consuming low power [5]. Thus, a single LoRa gateway can ensure the coverage of various nodes in outdoor scenarios. Adding WLAN functionality helps to easily address indoor or office scenarios, where WLAN most probably already exists, and no designated gateway needs to be installed. Fig. 1 shows exemplary coverage areas for both communication protocols. We envision a unified cloud to which all gateways are connected, as shown in Fig. 2. By this, the end user may retrieve the data easily through a single access point, ideally being able to flexibly query the desired information.

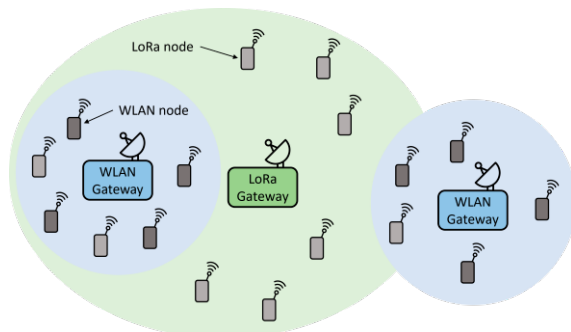


Fig. 1: Sensing nodes are transmitting their data to local gateways. These can be WLAN or LoRa gateways.

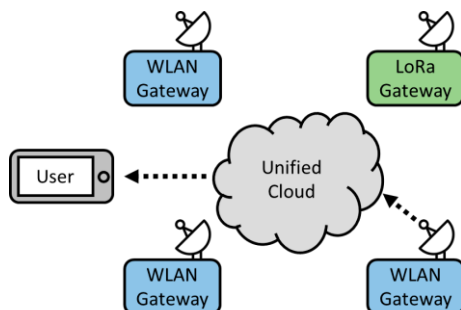


Fig. 2: All gateways transmit their data to a unified server with database. End users gather their data from this database.

Lastly, we propose to mostly use commercial off-the-shelf components for the casing of the

electronics and sensors to keep hardware costs as low as possible. Two different design concepts of different price points are displayed in Fig. 3. The left concept is based on a custom-manufactured tower unit, into which different sensor modules can be embedded. While this design is more flexible regarding sensor size, manufacturing custom components is costly. In contrast, the right concept utilizes a commercially available ABS thermoplastic box for the main module, under which different sensor modules are attached, making the system more cost efficient.



Fig. 3: Different concepts for a modular sensing node. The left picture shows a system where two different modules are attached to the core 'tower unit'. On the right, four sensor modules are attached underneath a main module.

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