European Partnership on Metrology
Call 2024 –Digital Transformation, Green Deal, Normative and Research Potential

Selected Research Topic number: **SRT-v23**
Version: 1.0

Title: Metrology for performance characterisation of low-cost sensor networks

Abstract

There is an increasing need to provide traceable in-situ calibration of Low-Cost Sensors (LCS) in sensor networks for applications such as pollution monitoring. The quality of the data provided by the existing LCS networks is very limited due to a lack of metrological calibration and traceability. Therefore, proposals should concentrate on portable reference instrumentations for measuring noise, air, and water pollutants and greenhouse gases to achieve traceable measurements. Moreover, digital calibration certificates (DCC) and machine learning approaches should be applied to improve the performance of the data provided by the networks.

Keywords

Low-cost sensor, calibration, traceability, Low-cost sensor networks, digital calibration certificates, sensor network performance, machine learning, portable reference instrumentation, field test protocols, pollution monitoring, atmospheric observation

Background to the Metrological Challenges

Sensor networks based on low-cost sensors (LCS) are generally regarded as an emerging tool to monitor essential environmental parameters aiming to manage and mitigate risks with potentially high impact on society. For example, LCS networks could allow air pollution monitoring at a lower cost and with a higher spatial density compared to higher cost measurement networks. However, the use of LCS for monitoring air quality is limited by the low or unknown measurement accuracy that they can achieve. There is a strong push to use these data for decision-making by local authorities and others, requiring that the measurements are traceable and underpinned by standardisation. The proposed research focuses on addressing these issues by means of portable or integrated reference instrumentation. For instance, portable reference instruments based on the new concept of optical gas standards (OGS) have become available for calibration services listed in the CIPM Key Comparison Database (KCDB). This availability is a significant step in the metrology community as it can now be used to improve sensor networks. Recent progress in optical integration (e.g. microLED architectures, structured light sources, hybrid electro-photonic Systems-on-a-Chip) point to the possibility of further miniaturising these systems not only to facilitate their mobility but also to make them scalable and more cost-effective, without compromising their metrological relevance. LCS are expected to provide spatial information anchored by 'high quality' reference sensors either on site or operated at specific intervals, enabling routine mobile round-robin field comparisons to continuously improve the quality of data provided by LCS networks. To address the complexity of the data acquired in e.g. large LCS networks, an efficient use of digital technologies is required. Such digital technologies include the provision and use of digital calibration certificates (DDC) and a machine-readable digital representation of units. In this regard, a close collaboration is expected in the future between metrological communities, LCS suppliers and network operators. Furthermore, the European Metrology Network (EMN) for Climate and Ocean Observation Strategic Research Agenda has highlighted the importance of sensor networks and their required improvement for monitoring purposes for end users [1].

EMN POLMO identified that the development of methodologies to evaluate the performances of LCS to allow their further utilisation for indicative value provision in future directives is of high priority by 2027, and it also highlighted standardisation efforts for WG42, TS for gases (CEN/TS 17660-1: 2021) and for PM (TS 17660-2).

However, there is still a lack of engagement with the standardisation committee for guidelines on LCS characterisation/validation, which must be addressed. The proposal aims to define general protocols to improve the quality of data acquired in LCS sensor networks through traceable calibration.

This proposal aims to perform field testing in smaller-scale demonstrator networks. In addition, to develop practical guidelines that support the development of measurement and calibration protocols. Based on those guidelines, the individual metrological communities (e.g. air quality, water quality, noise mapping) are invited to research technological solutions suitable for their areas. The methods and technologies will also be tested in smaller-scale demonstrator networks in the proposal. The research will concern the efficient distribution of calibrators, e.g. as an integral part of the LCS platform or as a separate device, the achievable quality in a real-world scenario, and the influence of environmental factors on the networks. Therefore, as part of this proposal, advanced data-processing methods are investigated. The proposed research will contribute to providing evidence that can be adopted as CEN or ISO standards, which will be widely applicable in Europe. The result of this research will be used by e.g. CEN TC264/WG42 to develop standards on the performance requirements of LCS in networks.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on the traceable measurement and characterisation of LCS networks.

The specific objectives are

1. To produce good practice guides for the calibration of LCS networks. The guides will include i) determination of calibration intervals, ii) spatial distribution of calibrated sensors in LCS network, and iii) the required quality and durability of calibrations and iv) input from LCS manufacturers and network operators.
2. To develop portable reference instrumentation for pollution monitoring of air-borne particles (e.g. PM10, PM2.5), gases (e.g. HCHO, CO, CO_2, CH_4, NO, NO_2, SO_2, NH_3, BTEX, O_3), noise (e.g. audible and inaudible), and water-borne elements (e.g. dissolved oxygen, chlorine) with a targeted uncertainty lower than 10 %. The portable reference instruments to be developed, optimised and miniaturised will include for example laser spectrometers operated as optical gas standards (OGS), and acoustic reference sensors and calibrators. To define LCS pollution types for specific applications and to develop calibration and test protocols using the good practice guides from objective 1 for portable reference instrumentation in LCS networks describing traceable drift test, long-term reproducibility of results and uncertainty estimation procedures.
3. To develop field test protocols for in-situ calibration of sensor networks, including the application of digital calibration certificates (DCC). To test the protocols and instruments developed in Objective 2 in the laboratory and field measurements for existing sensor networks. To set the target uncertainties of the field work with stakeholders to meet Data Quality Objectives (DQO) requirements for sensor networks. To develop i) communication protocols, ii) application of DCC, and iii) evaluation of the comparability of the results across the network. To draft a New Work Item Proposal (NWIP) using the protocols and results to provide input to for example the Technical Specification CEN/TS 17660-1:2022 for trace gas measurements using LCS.
4. To improve sensor network performance using machine learning approaches. To investigate and improve the performance of LCS for issues such as environmental changes and ageing using machine learning techniques (e.g. artificial neural networks). To develop demonstrators monitoring the network to predict sensor failures, detect anomalies, and plan calibration intervals.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (e.g. accredited laboratories, instrumentation manufacturers), standards developing organisations (CEN, ISO), and end users (e.g. air quality networks, atmospheric observation infrastructures like ACTRIS-ERIC, WMO-GAW, AIRPARIF).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. Proposers shall give priority to work that meets documented needs, in particular those supporting the European Green Deal. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMPIR project 17IND02 SmartCom and Metrology Partnership project 22DIT02 FunSNM and how their proposal will build on those.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.8 M€ and has defined an upper limit of 2.8 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the pollution monitoring sector, LCS manufacturers and network operators.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.

Additional information

[1] *EMN for Climate and Ocean Observation Strategic Research Agenda* https://www.euramet.org/research-innovation/metrology-partnership/strategic-research-and-innovation-agendas