Low-Cost WASN for Real-Time Soundmap Generation

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Abstract

Recent advances in technology have enabled the development of affordable **low-cost acoustic monitoring systems**, as a response of several fields of application that require a close acoustic analysis in real-time: road traffic noise in crowded cities, biodiversity conservation in natural parks, behavioural tracking in the elderly living alone and even surveillance in public places for safety reasons.

This paper presents a low-cost wireless acoustic sensor network developed to gather acoustic data to build a **24/7 real-time soundmap**. Each node of the network comprises an omnidirectional microphone and a computation unit, which processes acoustic information in-situ to obtain non-sensitive data (i.e., equivalent continuous loudness levels or acoustic event labels), which are later sent to a cloud server. Moreover, it has also been studied the placement of the acoustics sensors in a real scenario, following acoustics criteria.

The ultimate goal of the deployed system is to enable the following functions:

- To measure the L_{eq} in real-time using a predefined time window.
- To identify changing patterns in the previous measurements so that irregular situations can be detected.
- To prevent and attend potential anomalous situations.

The proposed network aims to encourage the use of **real-time non-invasive methods** to obtain behavioural and environmental information to take decisions in real-time.

Requirements

According to the ISO 1996-2, sensors should be placed following the next directives:

1. On outdoor environments:
   - Microphones should be located at a height of 4.0±0.5 meters from the floor in high building areas.
   - Microphones should be located at a height of 1.2±0.1 meters in residential areas.
   - The distance between the microphones and reflecting surfaces should be from 0.5 to 2 m.
2. On indoor environments:
   - Microphones should be placed 0.5 meters apart from walls and 1 meter apart from significant sound-transmission elements.
   - Distance between nodes should be greater than 0.7 meters.

Furthermore, sensors should be calibrated to get comparable measured levels between nodes. All sensors should measure 94 dB level at 1 kHz at 1 m distance in a controlled environment (i.e., on an anechoic chamber and using a calibrator).

Hardware design

All units of the WASN are identical to simplify the scalability in number of nodes. Concretely, each node contains a **Raspberry Pi 3B+** as its computational unit. Since the system has been designed to be steadily active, the node may reach high temperatures. To avoid heating problems, a **heat sink** has been placed to cool it down.

As a low-cost alternative of an acoustic sensor, a **plug-and-play USB Microphone** with an external ADC integrated in the serial bus has been chosen. The sensor has an omnidirectional acoustic pattern that allows to capture all possible sound sources from any direction at a maximum sampling rate of 48 kHz at 16 bits.

The electret condenser microphone is USB powered. Thus, to ensure a correct full functionality, the node requires a **5V 3A power supply**.

Components of the system

Component	Model	Main features	Price
Microphone	LYM00002	Lavelier USB 48kHz 16 bits/sample	11 €
Computational unit	Raspberry Pi Model 3B+	SDRAM 1 GB 64 bits CPU at 1.4 GHz WiFi connection	37 €
Power supply	UGREEN CD122	18W/5V/3A	12 €
USB wire	USB to microUSB		3 €
Total			**63 €**

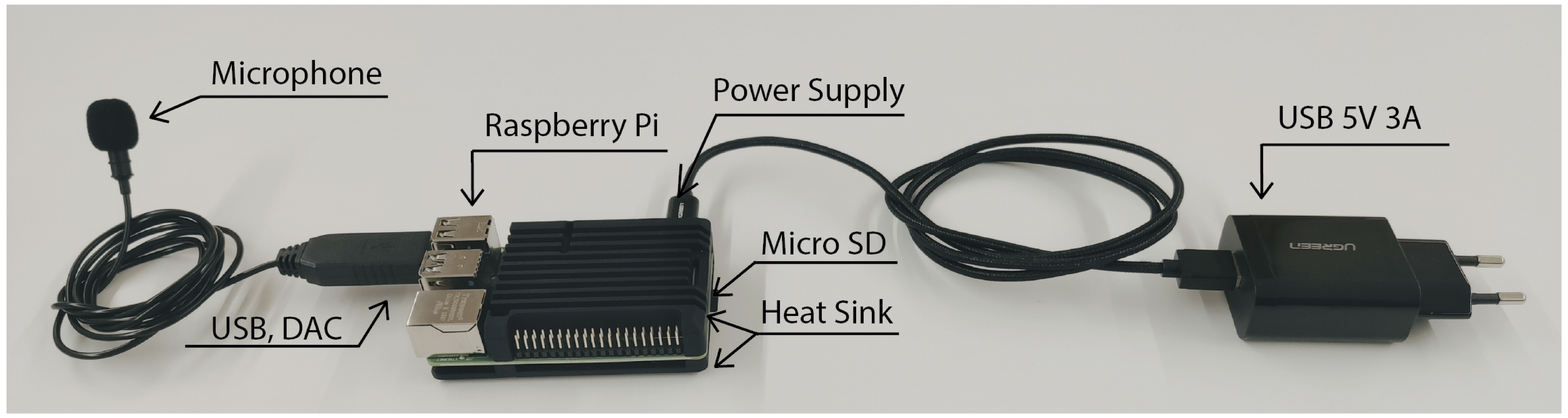

Figure 1: Hardware of each node of the network.

Design Process and Evaluation

To test the capabilities of the sensors, each node has been programmed to process an audio stream sampled at **22.05 KHz, with a bit depth of 16 bits**. Specifically, the nodes run OS Raspian Lite, and conducted tests have shown that the system uses the **100 % of CPU and 20 % of RAM** when running a software that is continuously (1) acquiring 4-second windows of raw audio data, (2) processing the audio streams to obtain acoustic descriptors such as the equivalent level, and (3) storing the data descriptors in the node's memory and sending them to a cloud server together with a time-stamp.

To synchronize the nodes of the network, the Network Time Protocol has been chosen. This results on a **maximum delay of 1 ms among nodes**.

Conclusion

Conducted tests ensure the synchronisation between the nodes, thus avoiding the need of a hub. The decentralised design together with the use of non-sensitive features, allow us to envisage the application of the proposed WASN in surveillance of active elderly in their own homes or in the street for noise monitoring solutions. Moreover, the proposal has taken into account scalability, so a more complex signal processing algorithm could be deployed in the nodes in the future. The authors set as future lines the detection of acoustic events of interest, which could be implemented in the nodes, and predefined alarms could be triggered accordingly.

Acknowledgements

Authors would like to thank La Salle Campus BCN - URL for partially funding the research.

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