

# Demo: SPES-2 – A Sensing Platform for Maintenance-Free Residential Monitoring

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## Abstract

SPES-2 is a sensing board for room-level monitoring in a home environment. It constitutes a vital modality of the SPHERE architecture: a multi-modal sensing platform for healthcare in a residential environment. SPES-2 uses an optimised implementation of the IEEE 802.15.4-2015 TSCH (Time-Slotted Channel Hopping) standard to operate efficiently and reliably in unknown environments for more than one year without battery replacement, providing continuous information about the ambient characteristics of the room (such as temperature, humidity and light levels), as well as presence information captured through a motion sensor.

## 1 Background

Residential monitoring using low-power sensing technology will play a key role in the future of healthcare provision, as national health systems face serious economic challenges due to the ageing of the population and the rise of incurable chronic illness. In this context, the vision of SPHERE (Sensor Platform for HEalthcare in Residential Environment) is to develop a multipurpose, multi-modal platform of home sensors, that would facilitate residential healthcare through learning the routines of the residents, identify suspicious abnormalities, and facilitate timely interventions [8]. The SPHERE platform is based on three sensing technologies: a Body Sensor Network made up of ultra low-power wearable sensors [5]; a Video Sensor Network focusing on recognition of activities through video analysis [6]; and an Environ-



**Figure 1. The SPHERE Environmental Sensor (SPES-2) deployed in a terrace-house in the city of Bristol, UK.**

mental Sensor Network of sensing platforms that capture the home ambiance with a room-level granularity.

Within 2017, the SPHERE platform will be deployed in 100 households of volunteers in the city of Bristol, UK, for a period of 6 to 12 months. To achieve this goal, the SPHERE platform must be deployable within few hours and operate robustly for up to 12 months. Indeed, maintenance visits must be kept to the absolute minimum - not just because of the associated costs, but also because the slightest participant's inconvenience holds the risk of them opting out of the study. In addition, the deployed sensing technology must be safe and aesthetically acceptable to the volunteers.

To this end, we have designed and developed the SPES-2 (SPHERE Environmental Sensor, ver. 2). SPES-2 (shown in Figure 1) is a wireless embedded system that constitutes the core component of the Environmental Sensor Network of the SPHERE platform. SPES-2 is user-centred designed around the aforementioned challenges, with particular focus on the requirement for reliable operation in unknown and hard-to-visit environments for a period of more than 12 months.

## 2 Hardware and Software Design

SPES-2 is a battery-powered sensor board that builds on the functionality of the TI SensorTag [7]. It is based on the Texas Instruments CC2650 System-on-Chip (SoC) for processing and wireless communication. The CC2650 is a multi-standard 2.4 GHz wireless system; it supports Bluetooth Low Energy (BLE) and IEEE 802.15.4. For processing, the CC2650 incorporates an ARM Cortex-M3 microcontroller unit (MCU). Wireless connectivity is achieved via a printed meandered 2.4 GHz monopole antenna. The physical dimensions of the board are  $75 \times 75 \times 1.6$  mm, enclosed in an off-the-shelf casing (dimensions  $85 \times 85 \times 25$  mm).

SPES-2 incorporates a series of sensors for monitoring the residential environment. These include: a temperature and humidity sensor (HDC1000); a light sensor (OPT3001); a barometer (BMP280); a passive infrared (PIR) motion sensor (EKMB1101); and a microphone (SPH0641LU4H-1) used for noise level sensing. Moreover, SPES-2 exposes an interface for connecting external sensors. In addition, the board offers 64 MB of non-volatile storage. The board is powered by a 3.6V AA battery (typical capacity of 2.7 Ah). All the peripheral components are carefully selected because of their low-power profile. Indeed, with the PIR sensor operating continuously, the idle current of SPES-2 is approximately  $3 \mu\text{A}$ . This idle consumption is sufficiently low to support 12 months of operation on a single battery cell.

In terms of software, SPES-2 is based on the IEEE 802.15.4-2015 TSCH (Time-Slotted Channel Hopping) standard [1]. The TSCH standard uses channel hopping against interference and frequency-selective fading. As a result, it is characterised by high reliability in terms of packet delivery rates, and increased predictability in terms of energy consumption, as compared to commonly used low-power CSMA (Carrier Sense Multiple Access) MAC (Medium Access Control) protocols. Such properties make TSCH a fit-for-purpose solution for interference-prone deployments, such as the SPHERE deployment in Bristol.

Our TSCH implementation for SPES-2 builds upon the open-source ContikiOS port of the protocol [2]. As part of the development of the firmware of SPES-2, we have developed and contributed to the ContikiOS with the first open-source port of TSCH for the CC2650 radio. In addition, we have proposed a methodology that allows CC2650-based TSCH networks to operate at microsecond-level synchronisation accuracy [3]; a feature that enables significant energy savings through the optimisation of the guard time. Lastly, aiming at further improving the reliability of TSCH in residential environments with high and unpredictable interference, we have investigated and proposed a set of algorithms for adaptive channel selection [4].

## 3 Demonstration and Concluding Remarks

SPES-2 implements one of the three primary modalities of the SPHERE sensing platform for healthcare in a residential environment, monitoring the ambient characteristics of a room (including temperature, humidity, air pressure and light levels), and capturing presence information through a continuously-running motion sensor. A subset of the sensor data, as produced by SPES-2, is shown in Figure 2.

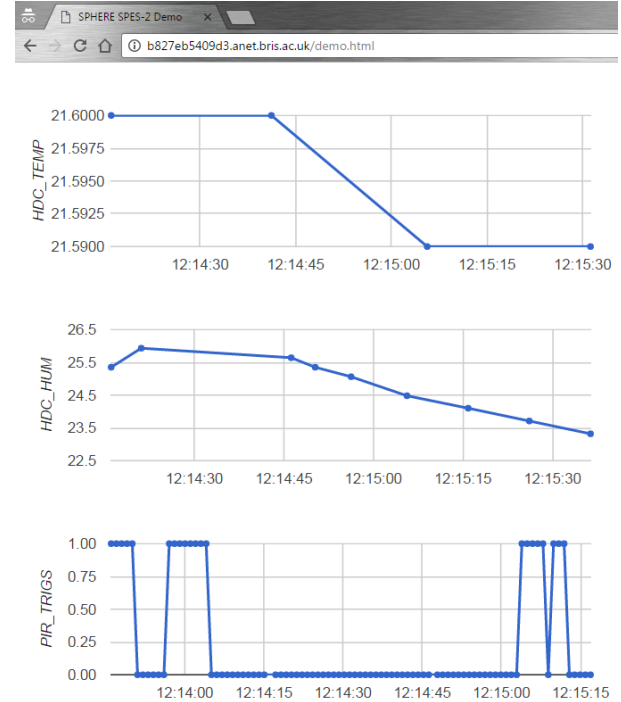


Figure 2. Live demonstration of SPHERE's SPES-2.

In 2017, more than 500 SPES-2 sensing platforms will be deployed in the city of Bristol, UK, as part of the SPHERE deployment in the households of 100 participants.

## 4 Acknowledgment

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