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H2020 REALVALUE

D2.3 BEHAVIOURAL MONITORING HARDWARE

IRELAND & LATVIA

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Document History

Version	Date	Contributor	Comments
0.1	08/06/2016	Ronan O'Malley	Initial draft and document structure.
0.2	30/06/2016	Ronan O'Malley	More detail on background, requirements and hardware.
0.3	21/07/2016	Gerard Finneran	Input on motivation for motion sensing
0.4	21/07/2016	Sarah Darby	Input on user impact and perception
0.5	03/08/2016	Carlos Andrade-Cabrera	Input on requirements of temperature data
0.6	27/10/2016	Ronan O'Malley	Overhaul and refresh of the whole document
0.7	26/11/2016	Ronan O'Malley	Adding sensor data and commentary.
1.0	30/11/2016	Ronan O'Malley	Final edits.

List of Abbreviations & Acronyms

Abbreviation	Definition
BLE	Bluetooth Low Energy
GDI	Glen Dimplex Ireland
INT	Intel R&D Ireland
mA	Milliamps
mW	Milliwatts
SSE	SSE Airtricity
UCD	University College Dublin
UOXF	University of Oxford
UV	Ultra Violet
V	Volts

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1. INTRODUCTION

This deliverable will demonstrate the background, selection and initial data from behavioural monitoring hardware sensors selected to enable task 2.3:

> *"Behavioural monitoring for a defined subsection of dwellings we will provide mechanisms for tracking user behaviour, this will include the integration of off the shelf sensors. An analytics plugin will be developed and deployed on Intel's Enlive platform running on the home gateway which will enable the analysis of user behaviour against defined characteristics. A summary of these results (privacy protected) will be made available to the relevant researchers"*

2. REQUIREMENTS GATHERING

2.1. WORKING GROUP

A working group with members from multiple partners was formed to decide which behavioural sensors would be deployed and what the strategy will be for deploying them. The working group was composed of members from:

- INT – as work package leader, to provide input on technical integration of the sensors into the overall system and with a view to performing analytics on the gateways.
- SSE – as the end-user facing project member, to consult on physical deployment considerations and consumer acceptance and incentivising.
- GDI – as the project coordinator, to ensure alignment with macro level project timeline, to advise on deployment logistics and interaction with the space and water heating SETS.
- UOXF – as the behavioural analysis researchers, to input on data sources for analysis of participant behaviour.
- UCD – as the building modelling researchers, to provide input on data sources that would be beneficial to RealValue building modelling research tasks.

2.2. SENSOR REQUIREMENTS

The output from the initial group workshop was a list of requirements for sensor hardware selection. It was decided the hardware sensors selected for this task should:

- Offer some benefit or incentive to the end consumer to help with acceptance of the sensor and to act as a tool in incentivising project participation. This could be through enhanced comfort, convenience or security.
- Produce data which can enhance the next version of the RealValue user interface [1].
- Provide inputs to develop gateway analytics algorithms which would in turn enhance the user experience or provide additional value to some RealValue stakeholder.
- Provide data that is useful to the behavioural analysis research in Work Package 4.
- Provide data that can be utilised by the building modelling research in Work Package 3.
- Be technically compatible with the radios or interfaces available on the RealValue gateway.
- Be cost-effective so a significant number of sensors can be deployed within the available capital budget.
- Have adequate battery life if battery powered.
- Have a clear purpose that that can be communicated with customers, with data that is still useful after it has been anonymised.
- Can distinguish between humans and pets, ~20% of homes have pets. Alternatively these homes will be avoided.

2.3. SELECTED METRICS

2.3.1. MOTION

The working group selected motion as an important behavioural analysis metric, especially when used to infer occupancy.

With Quantum SETS, each appliance essentially creates its own zone and they can each be programmed with a seven day time and temperature profile. When it comes to home heating efficiency, this is seen as being important, as the home occupant can programme each appliance to match their own requirements, thus making the most efficient use of their heating system. Anecdotal evidence informs us that although the appliances have the ability to be programmed to match the users' requirements, some home occupants set the heating schedule once and do not change it, even if their requirements change. Again anecdotal evidence would suggest that some occupants simply leave the appliances on their default heating schedule even if it is not aligned to their heating requirements. Based on this anecdotal evidence, we believe that there is an opportunity to increase the operating efficiency of the appliances which are linked to motion detection for occupancy inference.

With further examination of the data it may also be possible to identify zones where the heating schedule overestimates the heating requirement. In these instances it may be possible to compute energy inefficiency as a result of incorrectly programmed appliances, which in turn could be used to influence home occupants to edit their heating schedules to meet their requirements.

In order for this analysis to be reliable, it will be important to include a motion detection device in each zone of the property which is heated using Quantum SETS. The location of the sensors will need to be property dependant and they should be set up to capture all meaningful movement with the zone. Ideally the location of the sensor would be constant throughout the duration of the trial.

The gateway will compare actual room occupancy vs heating schedule and prompt the user with suggested comfort plan modifications via the RealValue user interface.

RealValue researchers can also use the data from motion sensors to validate occupancy profile assumptions, correlate them with end use electricity consumption from appliances and provide a finer estimate of thermal loads inside the domestic dwellings.

It is anticipated that the process of evaluating misalignment of user heating schedule to an occupancy ground truth may assist in adapting user heating schedules to a more tailored set of comfort requirements. This could be conducted in an autonomous, semi-assisted or manual fashion.

2.3.2. TEMPERATURE

Data from supplemental temperature sensors will form an input to Task 3.8. Using this data poses interesting research questions in the modelling and calibration of archetype energy models under uncertain building thermal performance and occupancy. Task 3.2 develops end-use energy models based on archetype information, time of use surveys and occupancy modelling. It is well known that archetype models and time of use surveys are representative of national-level energy consumption, but not entirely representative of individual dwelling performance. The proposed research consists on developing high-resolution archetype models that represent more realistically the actual performance of the urban residential building stock in Ireland. State-of-the-art building calibration techniques will be implemented to identify the baseline model parameters and uncertainty distributions of building models of the same characteristics (configuration, construction period, etc.).

One of the advantages of the current deployment configuration (apartment blocks) consist in that a considerable number of dwellings/SETS devices can be related to a single electricity feeder. Therefore, a scalable assessment of the benefits of retrofit policies (beyond SETS) in the electricity grid can be postulated. Such research has the potential to provide policy makers with evidence on how SETS devices, aggregated at a national level, and enhanced with conventional retrofit techniques (e.g. wall insulation) can help achieve policy targets (e.g. sustainability targets) if implemented at the national level.

The SETS devices include a temperature sensor, which is accurate to +/-0.3 degrees Celsius (rounded to nearest degree) when the device is operational. Therefore, there are considerable time-windows when temperature evolution is not well captured. The proposed research has the potential to calibrate the building models while considering this restriction. For academic rigour, however, validation cases are required. Hence the need to have independent temperature sensors to validate the accuracy of the calibrated models when the SETS devices are not operational.

It is desirable to have at least one temperature reading in the main conditioned area (e.g. largest room). Ideally, the temperature sensor should be located in the middle of the room, which becomes unrealistic for a field trial with commercial customers. A sensible suggestion consists in adding the temperature sensor in the wall opposite to the wall where the heating device is located. It will be assumed that the dwelling temperature corresponds to this sensor for validation purposes.

2.3.3. METERED SMART OUTLET

The motivation behind deploying a controllable smart plugs with metering is three fold.

Firstly, the ability to measure and transmit energy usage of regular pluggable domestic appliances will provide insight to the schedule on which they are used. This in turn will give RealValue researchers an insight into the potential for using these appliances to provide flexibility based demand-side services. Which appliances have most potential for load-shifting? E.g. washing machines, tumble driers, dishwashers.

Secondly, the data on energy consumption will be used to further inform users on domestic energy consumption through the RealValue app [1] and engage them in the project and their energy consumption.

Finally, the ability to centrally control the actuation of the smart plug loads may be explored, bringing new load onto the system for energy services.

3. SENSOR HARDWARE

Appropriate sensors were selected while considering wireless compatibility, price, brand, support, battery and form factor. The RealValue gateway (mark II) has a Zigbee wireless radio and supports many devices using the home automation and smart energy profiles. Zigbee also gives adequate range for indoor home sensing, hence this was selected as the wireless standard for behavioural monitoring sensors.

3.1. WIRELESS MOTION AND TEMPERATURE SENSOR

The first sensor selected was the Centralite 3328 Micro-Motion sensor [2]. This is a battery powered Zigbee wireless sensor that measures motion within a 4.5m detection range. It also has a built-in temperature sensor with accuracy of ±0.4°C (max). It requires a single CR-2450 3V battery which can last up to two years. The sensor is displayed in Figure 1.

Figure 1 Battery powered Zigbee motion and temperature sensor selected for deployment

3.2. SMART ENERGY METERING OUTLET

The second sensor selected was Centralite 3200-Ggb Smart Outlet [3]. This is a mains powered Zigbee wireless sensor that measures power, current and voltage for a connected appliance with a UK/Ireland plug. It also has a switch which is user operational via the side buttons and can be read and written from the Zigbee hub. The sensor is displayed in Figure 2 and Figure 3.

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Figure 2 Smart energy metering outlet selected for RealValue

Figure 3 Rear view of smart energy metering outlet

4. PRELIMINARY DATA

One of each sensor type was installed in a friendly location for capturing preliminary data. The sensors were paired with a RealValue gateway (mark II), and any sensor events captured were transmitted into the RealValue platform's historical data store.

The motion/temperature sensor was installed in a living room area in the vicinity of an electric storage heater (non-smart), but not directly above it. The motion sensors field of view was directed towards a main living area and thoroughfare to the kitchen. Initial data from the first four days is displayed in Figure 4. This shows a cumulative count of motion events in the space. The sensor was configured to reset between motion events after thirty seconds. This interval will be reduced for deployments in the field to extend battery life.

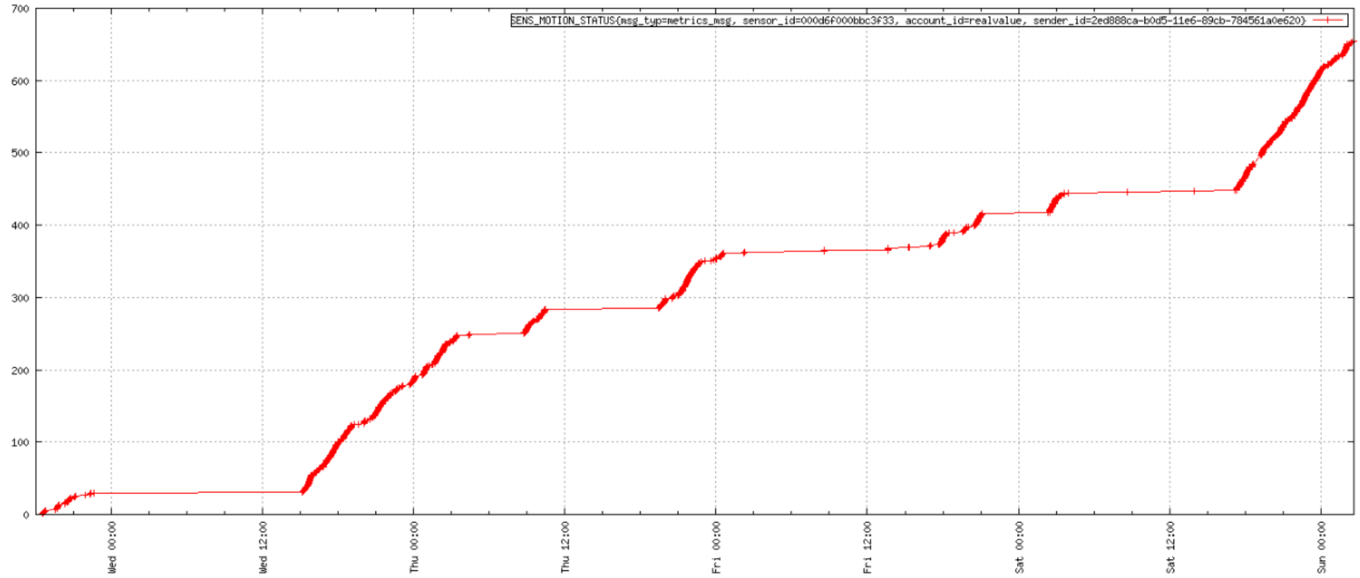

Figure 4 Cumulative total motion events captured over four days in an apartment living room

The temperature data from the initial test of the micro-motion sensor is displayed in Figure 5 (units of degrees Celsius x 100). The initial spike in temperature can be attributed to body heat from handling the sensor during installation. After this stabilises the room temperature fluctuates between sixteen and twenty degrees.

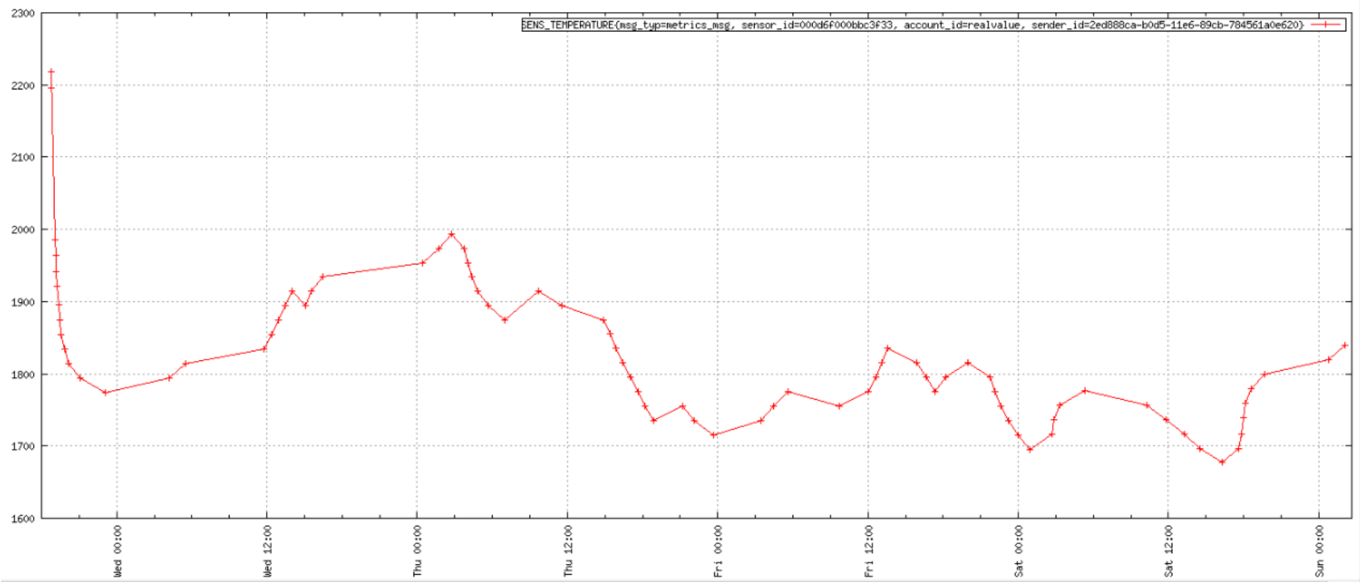

Figure 5 Temperature data over four days from an apartment living room in Ireland in November heated by a single (non-smart) electric storage heater (units degrees Celsius x 100)

The smart metering outlet was installed on a 2015 model 43" smart LED TV manufactured by a well-known brand. The data captured on power (mW), current (mA) and voltage (V) are displayed is Figure 6, Figure 7 and Figure 8 respectively. The "on" and "standby" states can clearly be observed in power and current data, which would enable analysis on appliance flexibility.

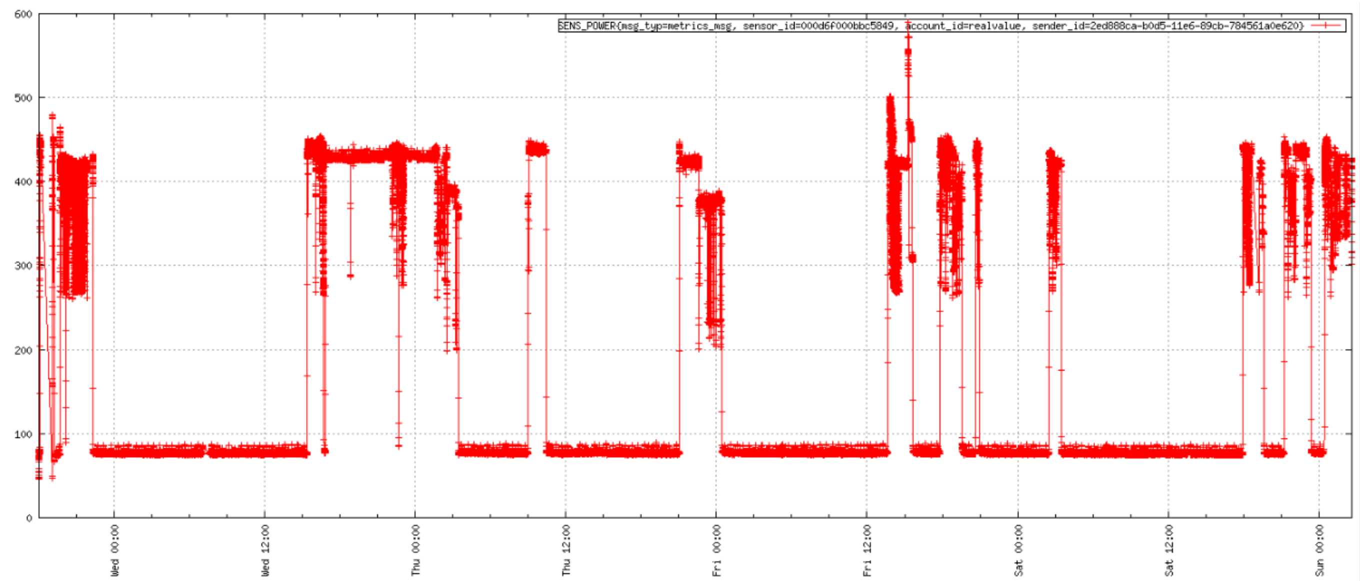

Figure 6 LED TV power consumption data from a smart metering outlet over a four day period

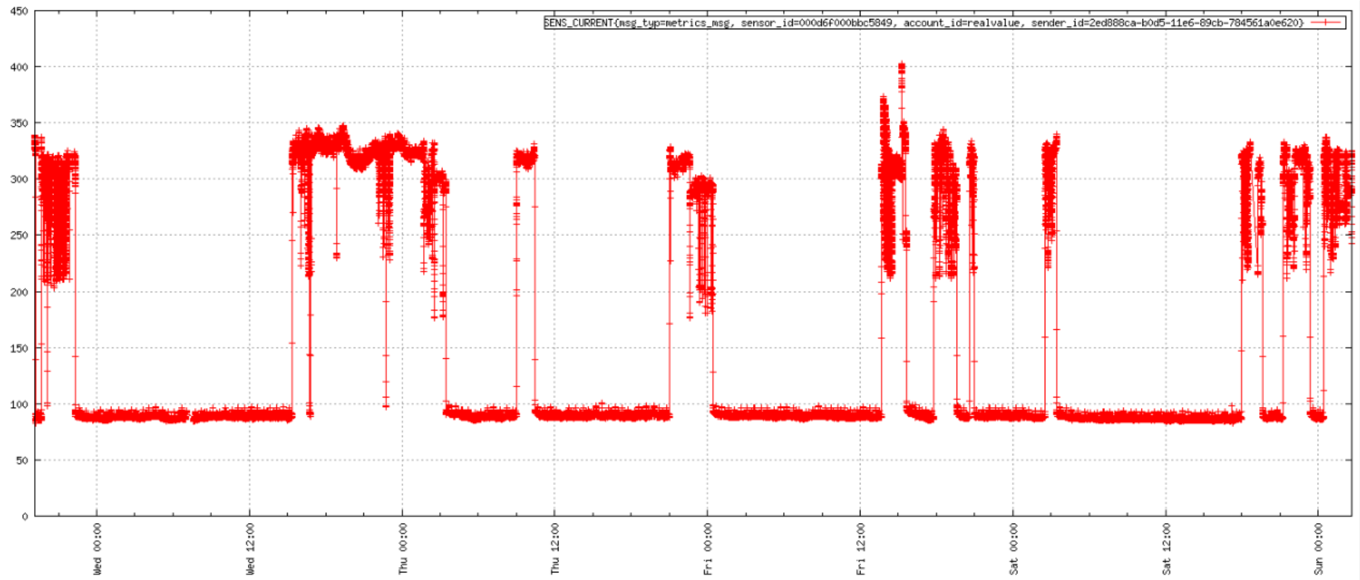

Figure 7 LED TV electric current data from a smart metering outlet over a four day period

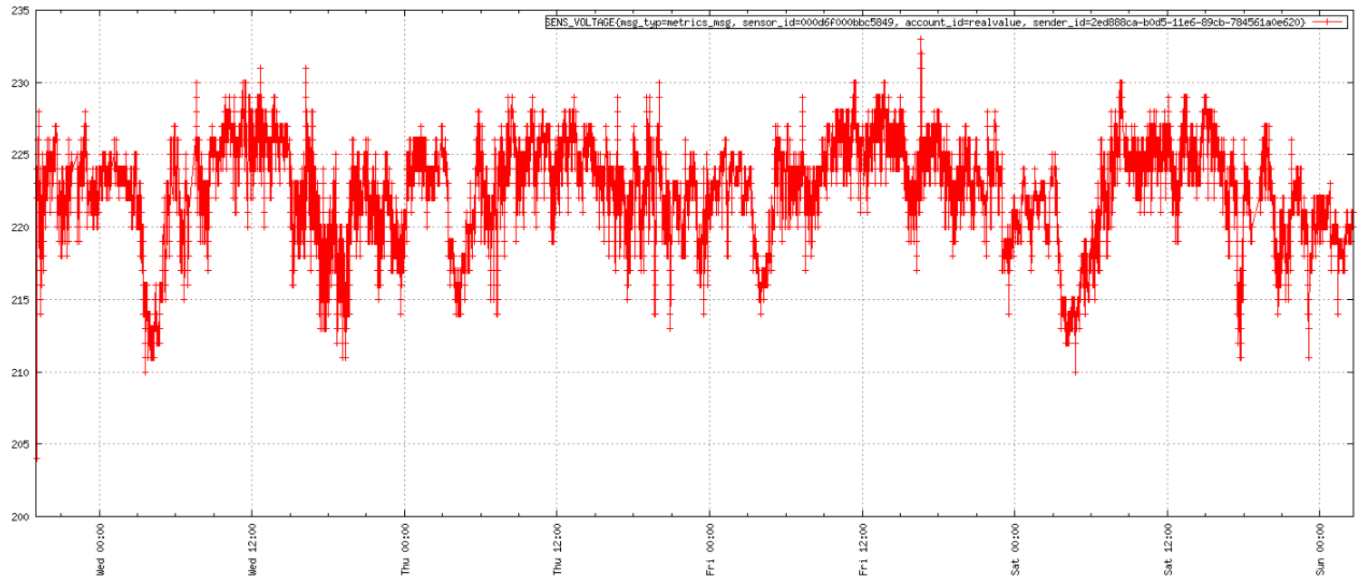

Figure 8 LED TV voltage data from a smart metering outlet over a four day period

5. CONCLUSION

A cross-functional working group has selected two behavioural monitoring hardware sensors for deployment in the Real Value trial. The motivations behind their selection and the intended applications of their data have been demonstrated in this deliverable. This hardware will be deployed in Ireland throughout 2017. Some integration steps still remain, including sensible down-sampling of smart outlet data and configuration of battery powered sensors to achieve a trade-off between data resolution, battery life and storage capacity.

6. REFERENCES

[1] R. O'Malley and D. Noronha, “RealValue Deliverable 2.4 User Interface,” February 2016.

[2] Centralite Systems, Inc., “Product Data Sheet 3-Series Micro Motion Sensor,” [Online]. Available: https://www.centralite.com/downloads/DataSheet-3SeriesMicroMotionSensor.pdf. [Accessed November 2017].

[3] Centralite Systems, Inc., “Product Data Sheet 3-Series Smart Outlet (Type G),” [Online]. Available: https://www.centralite.com/downloads/DataSheet-3SeriesSmartOutletTypeG.pdf. [Accessed November 2017].