Smarter Suffolk Project

Adult Social Care

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Contents

1 Executive Summary

Suffolk has a higher population of people over 65 years old than average, anticipated to rise (currently 23.8%, projected to rise to 30.6% by 2043). In-home monitoring of vulnerable people living independently in their own home has been found to be a useful support for daily monitoring and remote alerts to enable early intervention, with well-being benefits in health and confidence of the vulnerable independent person and their family, and related economic and resource management benefits. Suffolk County Council's Adult Social Care team offers a range of in-home technological monitoring solutions using a dedicated 4G router to provide WiFi connection and data return. With the deployment of the Suffolk and Norfolk Innovation Network, providing a new long range low power communications network (LoRaWAN) across the county, the Smarter Suffolk project team was asked to assess LoRaWAN connected in-home monitoring devices. This report details the trial of selected devices, and provides recommendations and conclusions for their further development and wider use.

Two suppliers were selected to provide LoRaWAN connected sensors using the Suffolk and Norfolk Innovation Network. Three sensors were selected for trial: an environment sensor that monitors daily living activity in the kitchen by measuring temperature and humidity; a leak detection sensor with alarm suitable for use on a kitchen or bathroom floor; and a bed occupancy / light path sensor to provide light when users get up at night.

The environment and leak detection sensors were battery-powered, small and pre-configured. They could be delivered for easy set-up placed on a shelf or the floor. Anticipated life-time is reported to be in multiple years. The bed occupancy / light path sensor was mains powered and pre-configured, and proved more challenging to set-up, with multiple wires.

The environment sensor provided data to an easy-to-use dashboard, with email alerts on changes of activity status or low temperature. The leak detection sensor and light path sensor did not provide data on dashboard or for project access. The environment sensor did not provide any output to the user, but instead sent output to the user's support network. The leak detection sensor was found to produce a loud alarm when in water. The light path sensor was intended to provide lighting via an LED strip when users got out of bed during the night; this was found to be erratic with lights not turning on or turning on when not needed. The Suffolk Innovation LoRaWAN network, currently in the process of being installed, was found not yet to provide sufficient coverage for many trialled in-home locations. Some users were provided with in-home LoRaWAN gateways, a solution similar to the current provision of a 4G router with in-home monitoring solutions.

User feedback was positive for the environment sensor and its dashboard, and for the leak detection sensor and its alarm. Several users found that the light path sensor was problematic to install and during use. Some users reported interference with home entertainment and WiFi during the trial: laboratory testing of the devices indicated that this may be due to an unnecessary WiFi signal emitted by the light path sensor.

Recommendations are made for device development, including an alert and dashboard integration for the leak detection sensor, and further development of the prototype light path sensor. The Suffolk Innovation Network is not yet sufficiently widespread for adequate residential coverage, though the use of in-home LoRaWAN gateways would support provision of LoRaWAN connected devices. The continuation of support for provision of technological in-home monitoring service for vulnerable independent residents is recommended.

2 Introduction

2.1 Introduction

This report discusses an assessment of in-home sensors for monitoring vulnerable independent persons, run by Suffolk County Council using products supplied by IOT Solutions Group and IOT Stars. It is based on, reports and significantly informed by work undertaken by Suffolk County Council's Smarter Suffolk project team, whose input is acknowledged. This report also uses information supplied by IoT Solutions Group (IoTSG) whose input is also acknowledged.

The first section of this report presents an Executive Summary.

The second section of this report describes Suffolk County Council's view of the potential use of such sensors, the problem field and the requirements for adult social care.

The third section describes the selected commercially available remote sensors that have been trialled in this project. These were selected in conjunction with Suffolk County Council Adult Social Care team, the Suffolk County Council Smarter Suffolk team, and the suppliers. These sensors use Internet of Things (IoT) communication technology to report a range of in-home parameters in near real-time.

The fourth section describes the trial undertaken by SCC, feedback received and tests undertaken during the period of the trial. Sensors were distributed to volunteers (Suffolk County Council employees) across Suffolk. Feedback was gathered from trial volunteers by Suffolk County Council's team. Data has been accessed from the supplier dashboard. Testing has been undertaken on one set of the sensors.

The fifth section presents conclusions and recommendations from this trial.

2.2 In-home monitoring

Suffolk County Council (SCC) are a provider of social care under the Social Care Act 2014. As such, they are interested in in-home monitoring of vulnerable independent people to support adult social care services. There are potential benefits for local authorities and other care providers, and for residents and their families. Such benefits include the possibility of:

- Early intervention based on automated alerts from in-home devices, the trial supplier has claimed that automated alerts have led to paramedic deployment, and potential for life-saving intervention;
- Increased confidence for independent residents and their families;
- Efficient monitoring, with automated monitoring potentially releasing resources in the care system for targeted service delivery, and early intervention potentially reducing further care costs, such as hospital admissions;
- Management of successful post-hospital recuperation.

Following consideration of a range of solutions, SCC Smarter Suffolk project team selected three devices from two specialist suppliers for this trial.

2.3 Suffolk County Council uses of in-home monitoring

Suffolk has a higher than average proportion of people over 65 years old, with 23.8% of the population over 65 in 2020 (Suffolk Observatory, 2021), forecast to rise to 30.6% of the population by 2043 (compared with 22.2% of the population for England as a whole). This

higher and increasing proportion of older residents leads to prioritisation of adult social care to support the needs of the aging population. SCC finds an increasing demand in care services, with adult care and children's services accounting for 75% of its £519 million budget (Hicks, 2020).

Most people wish to remain living in their own home as long as possible (Suffolk County Council, 2021b). SCC provide a range of services to support this, including digital technology services (Suffolk County Council, 2021c). This is supported financially for residents on low incomes for whom these products have been assessed as appropriate. The current digital technology range includes a selection of products including in-home sensors (including door sensors, movement sensors and bed pressure sensors) with an online portal or app, accessible to carers. These connect via Z-wave, Bluetooth and WiFi, for which a 4G router is provided.

SCC have recently launched a new digital care strategy and platform, following work to create a vision of their digital care model (Suffolk County Council, 2021a). This is focused on technology that supports independence, with a focus on gathering data from monitoring to allow preventative and proactive intervention, to minimise incidents. The model works with users' existing care networks of families and personal support, with external response as a backup when needed. Since the system launch in June 2021, 400 users have enrolled, with 500 devices deployed, and similar growth is anticipated over the next few years. Popular devices to-date have been wearable pendants (with accelerometer for fall detection, and GPS to enable geofencing); smart watches (which monitor inactivity, and with GPS for geofencing); and video care phones (enabling easy contact and working as a hub for other technology).

The transition is significantly about culture change, with significant training for assessors to feel confident in how to include the new services in their recommendations. The contract value is anticipated to be in the tens of millions of pounds. Systems and services are designed to be agile and flexible with further developments. Benefits are in user and family outcomes, council services and financial.

SCC experts expect a change over the next five to ten years to developments in software using existing devices such as generic smart watches and in-home smart devices for increased monitoring of vulnerable people.

SCC is interested in exploring resilient and widespread communications networks for connection of digital devices, and is interested in the use of LoRaWAN in this trial.

3 Specific sensors

3.1 Introduction

Suffolk County Council project team explored a range of possibilities for the Adult Social Care aspect of their trial. Initial discussions were focused on the potential benefits of using wearable sensors and the streetlighting management network to support general location knowledge of consenting vulnerable adults, in a manner similar to geofencing. However,

whilst this area continues to be of significant interest, it was not possible to trial it within the timescale of the project.

Suffolk County Council selected to work with two companies:

- IoTSG due to their existing products, their support to innovate new products and their ability to work with SCC's LoRaWAN Network. As a specialist IoT monitoring supplier, they offered experience, expertise and existing products that was not available from companies for whom this was not a main line of business. They have a range of low power wide area network (LPWAN) connected sensors for the business-to-business market.
- IOT Stars are a small IoT innovation and prototyping company, who are developing a specific sensor to reduce night-time fall risk.

Suffolk County Council have also supported the ADEPT Live Labs Team in creation of a thematic specific white paper (ADEPT Live Labs, 2021).

3.2 In-home sensors selected

In-home sensors trialled within this project are described in this section. Three sensors were supplied to the project:

- A leak detection sensor, suitable for installation in a kitchen or bathroom, supplied by IoTSG
- An environment sensor, suggested for installation in a kitchen, supplied by IoTSG
- A bed occupancy / light path sensor, for installation in a bed, supplied by IOT Stars

Other in-home sensors, and wearable sensors, are available for support of the target demographic, but were not included in the work covered by this report.

3.3 Network connectivity

These have all been selected to operate on a LoRaWAN network, to take advantage of the potential of the recently-deployed Suffolk and Norfolk Innovation Network (Suffolk County Council & Norfolk County Council, 2021). Further discussion of LoRaWAN and other Internet of Things networks for connected places communication has been presented in Steventon (2021). The accessibility of a communication network is integral to the appropriate selection of sensor hardware. In this project, for some homes, additional in-home LoRaWAN gateways were deployed to enable connection of the equipment. These were pre-configured MultiConnect Conduit, which only required plugging in to ethernet, power and an aerial attachment.

IoTSG also offer deployment using NBIoT where available (90% of their deployed devices), and Sigfox (9% of deployed devices) as well as LoRaWAN (1% of deployed devices), and are planning to use LTE-M. Suffolk does not have NBIoT coverage at present, and limited Sigfox coverage, and does have a strong desire to use SCC's recently deployed LoRaWAN network, which was why this communications technology was chosen for this trial.

Rollout timing of LoRaWAN deployment across Suffolk has meant that existing LoRaWAN gateways have not been sufficient for this in-home trial. Therefore, to support deployment of in-home LoRaWAN devices, indoor LoRa gateways have been deployed per home to supplement SCC gateways. This is not a cost-effective way to provide LoRaWAN coverage, but enabled the trial to proceed.

3.4 Environmental Monitoring Sensor

The Home environmental monitoring (also referred to as Adult Social Care) device was designed by IoTSG in the UK and manufactured in the UK. IoTSG are managing these devices on the IoTSG cloud platform. It measures ambient temperature and another parameter described as 'atmospheric conditions', the specific details of which are commercially confidential. It is recommended to be placed on a surface in the home kitchen. Data from this sensor is used in a personalised manner to identify changes in daily living activities.

It operates on LoRaWAN in this trial and can also operate on other communication networks. The sensor is small (86mm x 86mm x 26mm). It is battery powered with anticipated 3 to 5 year battery life, and also has a micro-USB power connection. Datasheet information is available in the digital archive for this report (IoT Solutions Group, 2021).

*Figure 1: Environmental Monitoring Sensor ((*IoT Solutions Group, 2021)

IoTSG's platform monitors patterns of behaviours from these environmental sensors, develops a baseline of changes in conditions over 48 hours, with measured parameters stated to be affected by daily living activities in the kitchen, such as cooking, boiling the kettle and washing up. Subsequently, alerts (by text or email) are triggered based on behaviour change. A dashboard also displays information.

3.5 Water Leak Detection Sensor

The Water Leak device was both designed and manufactured by a third party supplier. IoTSG are facilitating the trial of this device for SCC by managing these devices on the IoTSG cloud platform. Leak detection is by a connection via metal feet on the base, which triggers a loud alarm as well as a signal to the management platform.

It operates on LoRaWAN in this trial and can also operate on other communication networks. It is small (80mm diameter by 37mm height). It is IP65 rated, so may not be robust in a long-term flood scenario. Datasheet information is available in the digital archive for this report (Siterwell, 2017).

Figure 2: Water Leak Detection Sensor (Siterwell, 2017)

3.6 Bed Occupancy / Light Path Sensor

The Light Path was supplied by a UK development company called 'IoT Stars' run by Michael Setton. The light path sensor is a prototype, on a path towards commercialisation, with further development planned prior to commercial product launch. The innovation and development aspect of the Smarter Suffolk project enabled the project to work with devices in prototype stage. A datasheet was not available for this product; product information from IoT Stars is included in the digital archive for this report (IoT Stars, no date).

The device comprises a pressure sensor strip, to be installed in the bed, and a LED light strip, both connected into a hub box which is mains powered. Installation instructions were provided. Dimensions are:

- Pressure strip: 615mm long, 16mm wide
- LED strip: 1000mm long, 12mm wide
- Hub: 111 x 110 x 65 mm plus aerial

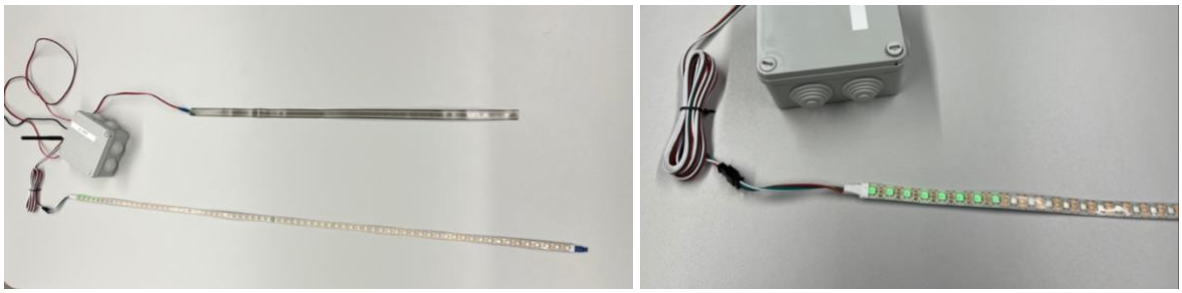


Figure 3: Bed Occupancy / Light Path Sensor (photos: H.Steventon)

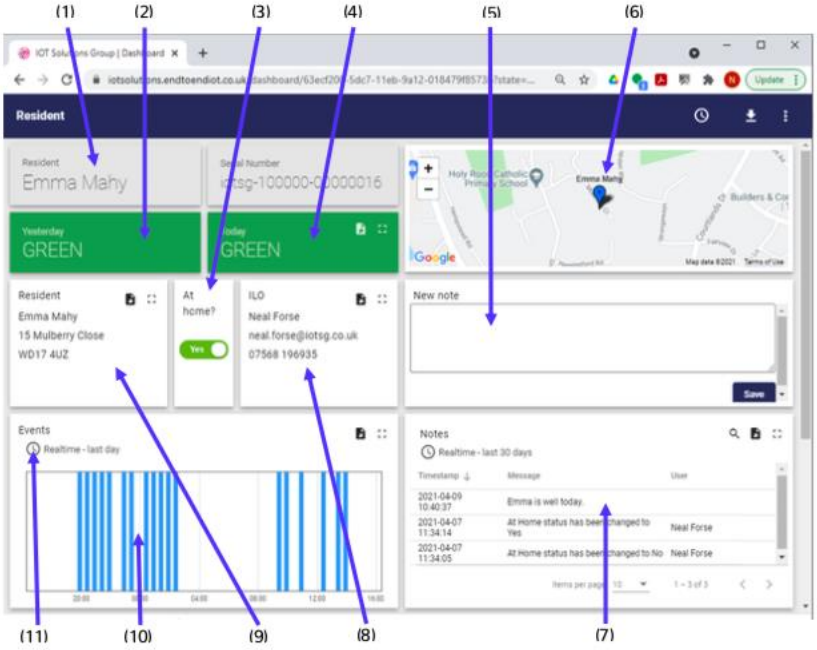
3.7 Dashboard and Alerts: environment sensor

The sensors trialled monitor daily living activities, in order to provide information and raise alerts should atypical behaviour be identified.

IoTSG provides a dashboard to access ongoing information. It has three tiers of user:

- Resident, being monitored, has no access to the dashboard;
- Independent Living Officer, has access to residents on their case load, but not other residents; for each resident, they access a personal dashboard. ILOs receive daily emails with status updates for the previous and current day, and additional emails if a change in status is detected.
- Borough User, can access each ILO account, and via that each resident's account for residents in their borough.

IoTSG documentation provides the following image of a resident dashboard:



(1) = The name of the Resident
(2) = The Status of the Resident yesterday; either Green, Amber or Red.
(3) = If the resident is away from home for long periods (maybe away on holiday or having overnight stays in hospital for example), then use this switch to prevent alerts being sent in this period.
(4) = The Status of the Resident today; either Green, Amber or Red.
(5) = Write notes here relating the Resident and click Save to store the notes in the Notes window for future reference.
(6) = The location of the Resident on a Map.
(7) = The Note window of a record of all the notes written about the Resident.
(8) = The name, email address and telephone number of the ILO for this Resident
(9) = The name, address, and telephone number of the Resident
(10) = The activity chart for the Resident; each blue line shows there was an activity in the kitchen caused by a human action.
(11) = Click this clock with your mouse pointer to change the time window (12) of the activity chart.

Figure 4: IoTSG user dashboard (Forse, 2021)

Status categories are defined as follows (Forse, 2021):

- *GREEN: the Resident is within their normal activity levels*
- *AMBER: a small reduction in activity has been detected*
- *RED: a significant reduction in activity or no activity at all has been detected*
- *OFFLINE: the device is no longer connected to the network*
- *INSUFFICIENT DATA: there is insufficient data available to determine the status.*
    - *Examples where this is used:*
        - *Within the first 48 hours after Activation.*
        - *After returning from home*
- *AWAY FROM HOME: The resident is away from home as determined by setting the state via.*

Examples from use, and feedback from the Smarter Suffolk project team, are included in Section 4.4.

4 Trial and feedback

4.1 Trial set-up

Suffolk County Council worked with IoTSG to select and trial solutions for in-home monitoring of daily living activities. This trial was planned by the SCC project team, and

recruited twenty non-vulnerable volunteers working from home at locations across Suffolk. Volunteers were recruited from SCC colleagues, by publicising the trial across several departments. They each signed a consent form organised by SCC with IoTSG. During the course of the project, COVID-related risks and restrictions meant that working directly with vulnerable adults on an in-home trial was not appropriate. COVID-related challenges led to delays and difficulties with many aspects of planning and delivering this part of the Smarter Suffolk project.

Each volunteer collected a package containing three sensors:

- Environmental Monitoring (described in Section 3.4)
- Leak Detection (described in Section 3.5)
- Bed Occupancy / Light Path (described in Section 3.6)

When required (found to be in the majority of cases) volunteers were also supplied with a preconfigured in-home LoRaWAN gateway to enable data connection, due to the extent of the roll-out of Suffolk and Norfolk Innovation Network.
Collection was managed in a socially-distanced manner. During collection, the project team demonstrated the process for setting up the light path sensor to each volunteer. The project team, IoTSG, and IOT Stars supported volunteers with troubleshooting and set-up challenges.

One set of sensors was provided to University of Suffolk for assessment in their Smart Living Lab.

Volunteers were given instructions to set up the sensors as follows:

- **Kitchen (environmental monitoring) sensor:** This requires you to pull out a plastic tag (battery isolation tab) and place in your kitchen. User instructions are included in the digital archive associated with this report.
- **Water leak sensor:** This requires you to install two batteries and secure the cover, then place under your dishwasher/washing machine/bath/sink as preferred
- **Bed / Light path sensor** was more complex to install: instructions were provided and further advice available, if required, from the Smarter Suffolk project officer. Manufacturers IoT Stars also provided trouble-shooting support to some participants.

4.2 Connection success

Use of the dashboard supplied by IoTSG on 02/12/2021 indicated that some environment monitors had never connected, some were previously connected, but not connected at the time of review, and some were connected at the time of review:

- 10 users were connected at time of review;
- 4 users had previously connected, but were not at time of review;
- 6 users had never connected.

Users whose environment sensors are not connected are reported as ‘missing’ on the dashboard (Figure 5).

Figure 5: Dashboard indication of a device not connected, reported as 'missing'

It was not possible directly to review success of connection of the other two devices in this trial, as network dashboard access was not available, however, these were included in review with IoTSG on 8/11/2021 (Table 1).

	Environment Monitor	Leak Detection Sensor	Light Path / Bed Occupancy
Good connection	13	8	5
Unreliable connection	3	0	2
Connected once only	0	2	3
Never connected	4	8	9
Total number reviewed	20	18	19

Table 1: Connection status of devices on 8/11/21

It is considered likely that the "never connected" and "unreliable connection" are due to lack of LoRaWAN gateway connectivity. Better connection success was observed for the environment monitor than the leak detection sensor, which is ascribed to more resilient hardware.

4.3 User Feedback

Feedback was collected by Mel Willis, Project Officer, and is included as Appendix A (Willis, 2021). General themes of feedback are summarised here. The Smarter Suffolk project team would like to thank the volunteers for their assistance with this trial.

4.3.1 Environment Sensor

Feedback included the following points:

- **Ease of installation:** '*This sensor was easy to install and have had no issues with this sensor.' 'No issues with this – no real set-up needed, very straightforward'*
- **Location of installation:** *'Placed mine on the kitchen windowsill'. 'Not in direct sunlight.' 'this is placed on top of my kitchen work top' 'It is on a shelf in the kitchen close to the kettle and toaster!'*
- **Data gathered:** uncertainty about what data is gathered; concern about kitchen as unrepresentative *'some … kitchens … may not have any heating, therefore this room will be colder'*; '*Pets in the house could trigger movement sensor'*
- **What happens to the data:** some users wanted more information on who is informed and what steps that person or organisation could take.
- **Lack of reactivity:** *'The kitchen sensor often went unnoticed, and it didn't provide any alerts.' 'Is it meant to do anything?' 'from my perspective it doesn't do anything'* '*Hopefully it is working … as I don't have access to the data.'*

In summary, the sensor was found to be very easy to install, with some variation on location in which it was installed. Some users would have liked more information on what data is

gathered and how it could be used. Some users would have liked an indication that the sensor is operating. Queries were raised whether pet movements could mask reduced movement from the person being monitored.

4.3.2 Water leak sensor

Feedback included the following points:

- **Ease of installation:** *'no problem' 'easy to install'*
- **Location of installation:** *'on the worktop near the sink' 'in the kitchen cupboard below the sink' 'under the washing machine'*
- *'would probably need more than one, as most places now have either utility rooms and/or more than one bathroom or en-suites..' 'would need more than one sensor if placing under washing machine / dishwasher / sink / toilet etc'*
- **Device:** *Small & compact but could be an issue for the elderly to install / replace the batteries*
- **Alarm:** A number of users tested the alarm, both deliberately and due to genuine leaks: '*It was a very loud alarm, which would alert the homeowner within the house of the water leak. (I think my ears are still ringing)' 'I have tested this in water however, it did not go off. … I will give it another try … in deeper water' 'Am going to simulate a flood at some point!'*

In summary, again the sensor was found to be easy to install, though concern was raised over whether an elderly person would be able to change the batteries. Users found the alarm to be very loud, which was helpful though could cause concern if a user is not able to attend to the leak. Users felt that there were many locations within a home that would be suitable for water leak monitoring, and that more than one sensor could be useful.

4.3.3 Light path sensor

Users provided more feedback on the light path / bed occupancy sensor than the other devices, due to challenges with installation and during use. This feedback included the following points:

- **Ease of installation:** installation was found to be challenging, with issues relating to location of power sockets, positioning the pressure sensor in bed, positioning the light strip, and presence of cables. Selected comments include: *'Would need to be installed and set up far more easily for the elderly.' 'A pain. Lots of cables, it wasn't the easiest to set up and seemed to be very inconsistent.' 'I did originally follow instructions and stuck it on the skirting board, but it kept falling off.' 'This sensor was tricker to set up and harder to install due to the weight of my mattress also, I am unable to install the light near the door due to the position of my bed and size of my room.'* '*We played with the location of the sensor strip to try and get it to work as intended. This was quite difficult as it seemed to need more weight to work. We then used the frame of the bed where it seemed to work, but it has been random.'*
- **Presence of cables:** Several users were concerned about the wires and cables associated with this product. *'I am assuming that a commercial product would be wireless (between the LED light & sensor box) otherwise the trailing wires will be introducing a trip hazard (safety conscious me thought of that and put a mat over the wires – then tripped on the mat!).' 'the set up / wiring and cabling for the bed sensor as all very untidy and potentially a trip hazard'*
- **Data gathered**: the SCC project team reports that some volunteers expressed concern about the type of data that might be gathered by an in-bed pressure sensor especially

with respect to privacy. Data was not acquired from this sensor during this trial, but further trials of the equipment should be clear to users the level of data gathered and privacy of that data.

- **LED light strip illumination:** Some users found the LED illumination useful: *'Very useful,' 'it definitely has been useful when getting up in the middle of night'* Other users found it disruptive, and applied solutions that included moving and covering the light strip: *'Light strip seemed too bright and too long, I just left it coiled up and still gave sufficient light in a dark room.' 'I ended up putting the light in a drawer.' 'The light strip does now live coiled up in a cardboard box so I'm less aware when it's on when perhaps it shouldn't but even in the box at night there is a glow under my bed at times.' 'This light was originally positioned running down the side of my bed however, after 2/3 nights of being woken by the light I then moved it to behind the headboard.'* One user suggested a longer light strip could be useful: *'LED strip could possibly be slightly longer or at least have the option of different lengths'* One user felt that the light strip may not be adequate for the purpose: *'In terms of the light, I'm not sure how much it would help in an older person situation as I still think they'd need to turn the light on…if it were linked to turning a dimmer switch on, that would probably work better.'* Some users removed the light strip as it was attacked by pets: '*Weren't able to set-up due to our cat's interest'* Alternatives were postulated: '*I wonder if just a simple night-light would be a better and simpler option, just giving a low but continual light through the night?'*
- **LED light strip illumination with movement:** Some users found that the light strip became illuminated when they moved in bed, rather than left the bed. *'when* [my partner and I] *are both in the bed the light goes off with the lightest of movements. Such as lifting an arm, rolling over or even pulling the duvet. This is very annoying given the brightness of light.'*
- **With partners sharing a bed:** Some users found the impact of the light strip disruptive when their partner got out of bed: '*I had to remove the lighting strip quite quickly as my partner works night shifts and it became annoying.'*
- **LED light strip illumination was found to be erratic:** Initially, the light strip was configured for an incorrect time zone, resulting in illumination during the day but not at night. Many users found the light strip was illuminated at unexpected times. Few participants found the light strip to operate as anticipated. *'Mine is illuminated all-day which is a pain, however it was going off approx. 6.30pm (5.30pm now clocks have changed).'* (clocks were originally out of sync due to length of pre-storage; this was adjusted remotely by IOT Stars adjusting the clocks of the devices) *'the LEDs were very temperamental with movement, often causing the room to glow at all times of the night. Recently, the light seems to stay on for longer.' 'the light … has spent many days on all day unless I have put a large box on the bed over the sensor, a couple nights its flicked on and off so often that the plug got ripped out of the socket, the light is quite bright which is great for the intended task but not if it switches on when it shouldn't.'* '*Whenever I got out of bed the lights would stay on permanently until I returned, which wasn't ideal during the daytime!' 'It is a bit random.'*

Whilst the benefits of the product were recognised, concerns regarding the current hardware and operational reliability suggested that further development is required. One user commented *'has NEVER worked properly.'* The sensor and associated light strip was found to be challenging to install, the illumination erratic and for many users too bright or triggered when not desired.

Having separate solutions to night-time light and to bed occupancy monitoring, or a wireless connection linking them, may be preferable. One user wondered *'[is] this … better than the plug in PIR night lights that have been about for many years'?* Project team feedback compared it with another solution as voice-activated WiFi-connected lights.

One user commented *'In principle great idea, but the execution is a bit off the mark!'* which sums up the experience with this sensor and light strip.

The author of this report comments that the light strip functionality was the primary experience for our users, who did not comment on the potential benefits of bed occupancy sensing for vulnerable independent people.

4.3.4 General comments for use in an older (vulnerable independent) person's home

Where appropriate, specific comments have been incorporated into the preceding sections for relevant sensors.

In general, the environment and leak detection sensors were found to be easy to install and described as *'unobtrusive'*. The bed occupancy / light path sensor was found to be challenging, and considered likely to be off-putting for self-installation by the target user group. '*Should these sensors be used in an older person's home, these would need to be set up appropriately, securely (light path sensor) and the cables (light path sensor) safe on behalf of the homeowner.' 'I think the light-path sensor may be a little 'tech-heavy' and daunting for OAPs, not least due to the size of the box and number of wires involved.'*

In feedback, one user reported interference with their home entertainment systems: *'Ever since the sensors have been in place, two TVs in the house have switched on during the day/night, and I can only assume (I hope) that this is due to the sensor frequencies. My Alexa also started to glow as if it was being interacted with during the night. Since, I have been switching the Alexa and both TVs off at the wall. Although last night, I forgot, and the TV switched on again.'* Anecdotally, concerns were also raised by other trial users about interference with in-home Sky Boxes and WiFi system. These reports of interference with home entertainment and communications systems were addressed with testing, reported in Section 4.5.

As discussed in Section 3.1, some users were also provided with an additional LoRaWAN gateway (referred to as a 'booster'). When LoRaWAN is available from the Suffolk and Norfolk Innovation Network or other external supply, these sensors can be easy to connect to their data network. One user with a booster found *'the need to have a booster is an inconvenience – my router is next to my front door for instance, meaning I have a lot of clutter which isn't easily hidden.'*

Overall feedback was positive in terms of potential to support vulnerable independent people in their home settings. *'I think the sensors overall work really well and I can see them being great for older people, especially the light sensor.' 'I think in their current form, the kitchen and water leak sensors are well suited to living in an older person's home.'*

4.4 Project Manager Feedback

Within the Smarter Suffolk trial, the ILO role was undertaken by Project Development and Delivery Manager, Brig Sodano-Carter.

4.4.1 Dashboard, Alerts and Emails: Environment Sensor

An example dashboard from the project shows the ease of access of the status data (Figure 6).

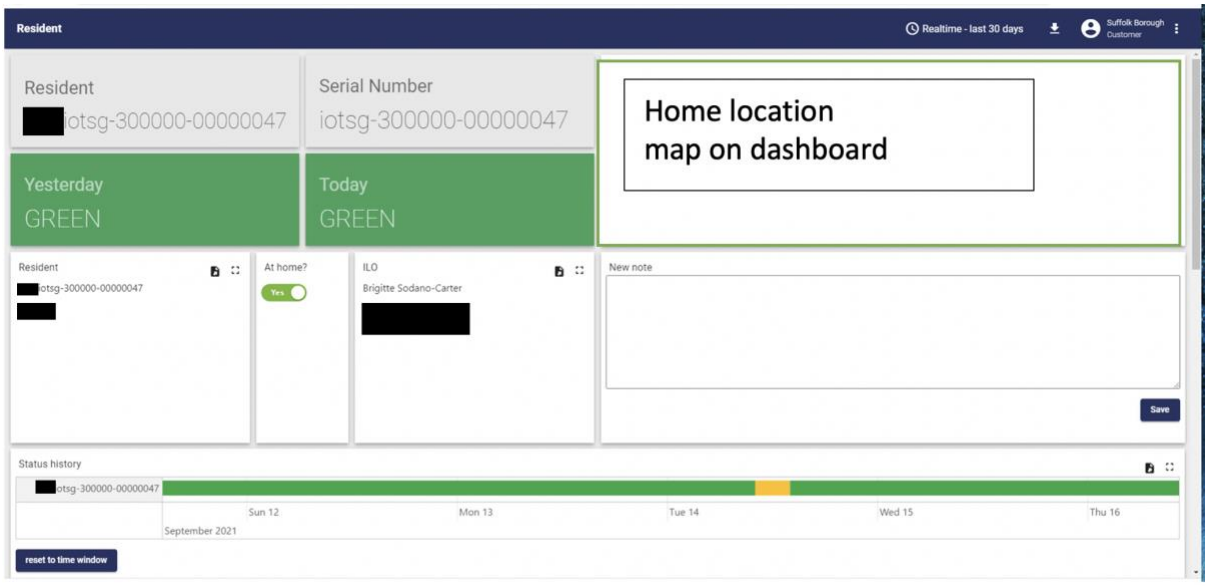


Figure 6: An example resident's dashboard

Mobile device application was also described as being easy to use.

The Smarter Suffolk ILO remarked about the email "fuel poverty" alerts (at inside temperature below 15°C): "*I am getting "covid poverty fuel alerts" from the IOT Solutions dashboard when temperature inside volunteer homes is at 15 degrees. This is because they have dogs and leave their backdoors open but may be so useful for vulnerable people who may feel they cannot put heating on especially given the harsh news of late!"* and "*Just love the extra daily alerts I get from IOT to tell of covid poverty fuel issues if a volunteers house fall to 15c!"*

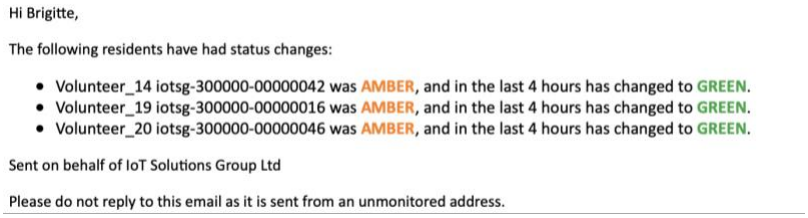
These emails were popular with the Smarter Suffolk ILO, who felt that they would assist with remaining aware of changes in status of residents assigned to them. Examples of fuel poverty and status change emails are included below (Figure 7 and Figure 8).

iotsg-300000-00000022 fuel poverty alert - temperature is 15.95°C

Sent on behalf of IoT Solutions Group Ltd

Figure 7: An example of a fuel poverty alert

Smarter Suffolk followed up some "fuel poverty" low temperature alerts, and report that in many cases low kitchen temperature was associated with open external doors to enable pets to access the garden.


Hi Brigitte,

The following residents have had status changes:

- Volunteer_14 iotsg-300000-00000042 was AMBER, and in the last 4 hours has changed to GREEN.
- Volunteer_19 iotsg-300000-00000016 was AMBER, and in the last 4 hours has changed to GREEN.
- Volunteer_20 iotsg-300000-00000046 was AMBER, and in the last 4 hours has changed to GREEN.

Sent on behalf of IoT Solutions Group Ltd

Please do not reply to this email as it is sent from an unmonitored address.

Figure 8: An example of a status-change email

The SCC project team found that they received multiple status change emails on many days, reporting on some days multiple status changes for the same individual between green, red and amber. On discussion with volunteers, the reason for some status changes could be identified, but it was not apparent what the cause for all observed status changes. The project team report that the implications of status change were not easy to understand, and further training in this for users would be desirable.

Temperature data is displayed on and downloadable from the residents' dashboard, but humidity data does not appear to be presented or available directly. Interpreted 'event' data is presented with time of event.

4.4.2 Dashboard, Alerts and Emails: Leak Detection Sensor

Suffolk County Council has not been provided with access to reported information from water leak sensors.

4.4.3 Dashboard, Alerts and Emails: Bed Occupancy / Light Path Sensor

Suffolk County Council has not been provided with access to reported information from the light path sensor. Data storage has been created for the Light Path sensor on Suffolk's LoRaWAN server, and raw data is available to the product developers for decoding.

4.5 Radio Frequency Emissions Testing

One concern that had been reported by some volunteers is their experience with the provided devices interfering with their home entertainment systems, as described in Section 4.3.4.

To explore this, the radio frequency emissions from the three devices have been analysed. Analysis was undertaken in the range of 800MHz to 3GHz, using an RF spectrum analyser in a sealed radio-frequency anechoic chamber (Figure 9). This was not formal calibrated testing, and results should be confirmed in further tests.

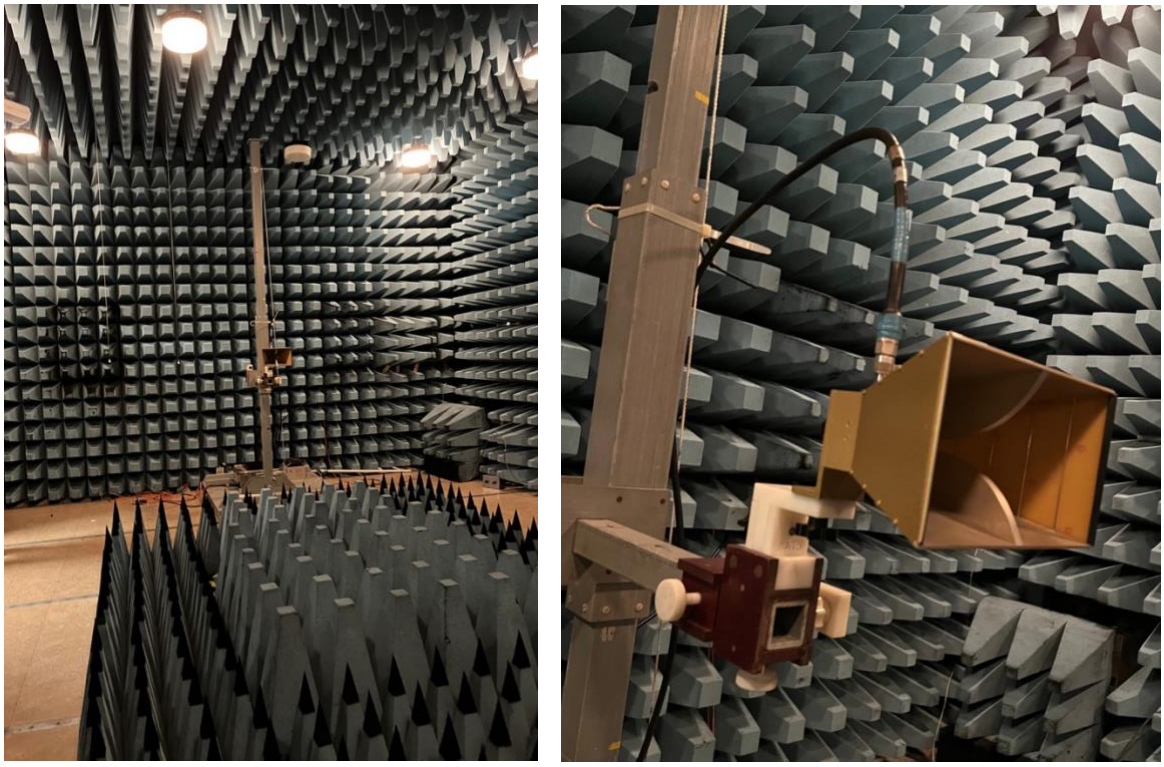


Figure 9: Radio Frequency testing in RF-anechoic chamber

This test was carried out separately on:

- Environmental sensor
- Leak detection sensor
- Light path sensor
- Empty anechoic chamber (to identify any background emissions)

No radio frequency emissions were identified from the environmental and leak sensors, nor from the empty chamber.

When assessing the light bath / bed occupancy sensor, radio frequency emissions were observed during the start-up phase of the equipment in the emission detection trace at three distinct frequencies, emitted at frequency and duration over the period of analysis:

- With a single large peak at 868 MHz, associated with LoRa protocol;
- With a single smaller peak at 1.7 GHz, considered likely to be associated with the first harmonic of the 868 MHz signal;
- Across the range 2.41 to 2.48 MHz, associated with WiFi protocol signals, with multiple large overlapping peaks associated with multiple WiFi channels.

These are shown in Figure 10 below.

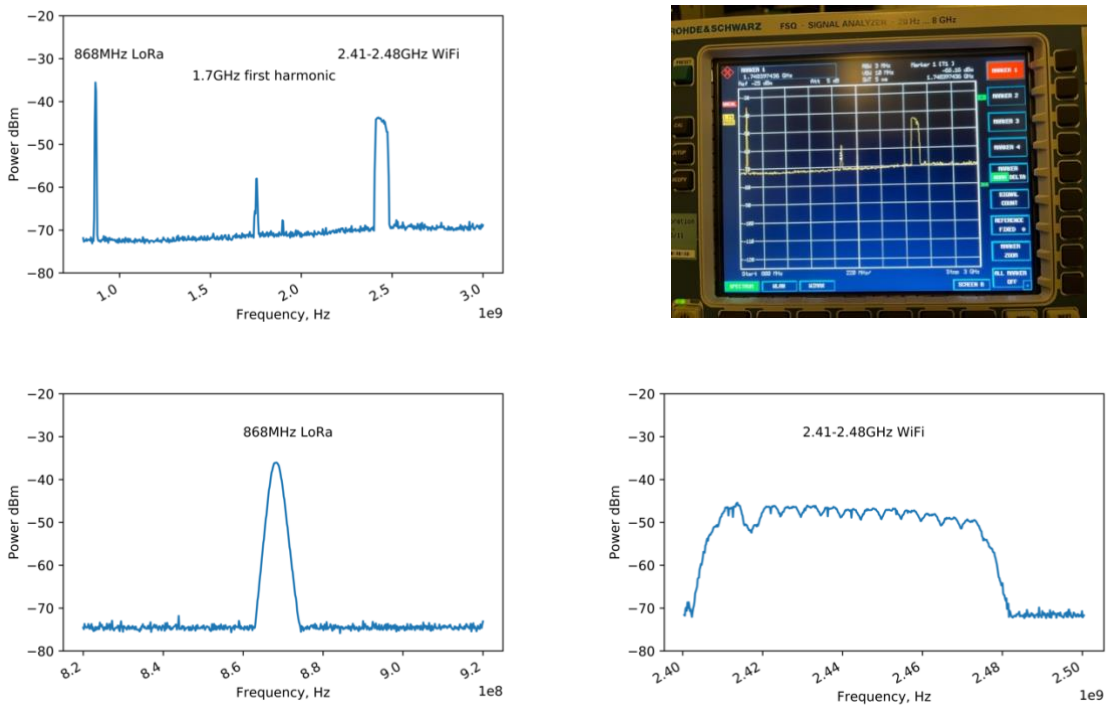


Figure 10: Radio frequency measurements of emissions from bed occupancy / light path sensors showing: emissions across the spectrum 800MHz to 3GHz; photograph of the signal analyser screen; emissions in the Wi-Fi band across the spectrum 2.4-2.5GHz; emissions in the LoRa band across the spectrum 8.2 to 9.2 MHz.

The bed occupancy / light path sensor is intended to use LoRa protocol communication with a LoRaWAN gateway, so a signal at this frequency is not unexpected. However, the LoRa signal is expected to be periodic during regular use. The high proportion of LoRa signal emission observed represents the start-up phase of the device as it seeks connection to a LoRaWAN gateway. If there is continued operation in this phase, it may contravene the LoRaWAN protocol duty cycle and ISM regulations during this phase.

The device was not provided as WiFi-connectable, and no WiFi signal was expected from this device. The developers, IOT Stars, explain that WiFi has been left enabled to enable additional configuration if that were required. A development board within the prototype device (Raspberry Pi ZeroW) is causing these emissions, which possibly should be switched off in board configuration if not required.

It is considered possible that this is the cause of interference with home entertainment and communication systems encountered by trial participants, described in Section 4.3.4. Recommendations are made to remove WiFi emissions from this device if not required, to manage repetition of the start-up phase in case of unreliable LoRa connection, and to undertake radio frequency testing of the bed occupancy / light path sensor, prior to further in-home testing. It is also considered likely that the high level of LoRa emissions may have interfered with the LoRa signal from the other devices under trial, reducing their connection efficiency.

5 Conclusions and Recommendations

Provision of in-home sensors has potential for significant benefits for support and confidence of independent living for vulnerable people. Suffolk has a significant and growing need to support independent living for an increasing older population.

This report has discussed the trial of LoRaWAN-connected in-home sensors for adult social care monitoring. Three sensors have been trialled, and conclusions drawn separately for each of them, along with general recommendations.

5.1 Environmental Monitoring

The environmental monitoring sensor was well received by volunteers. Ease of supply, installation and set up of the sensor were commended. Not requiring the user to connect to communication services is considered a benefit of the system, though it requires the presence of an appropriate LPWAN service, which vary by geographical location.

The following recommendations are made:

- This trial has not been able to assess the basis of the behavioural monitoring in terms of using environment monitoring to track changes in residents' behaviour.
- The dashboard and alerts were considered to be easy to use and useful.
- The sensor was unobtrusive, easy to deliver and easy to set up. Removal of the battery isolation tag can be done prior to delivery if required.
- Volunteers suggested that awareness from the device that it is operational would be useful.
- The sensor only monitors environmental changes in the room it is set up in, suggested to be the kitchen. This is the room considered likely to have the most frequent environmental changes triggered by daily living activities.

5.2 Leak Detection

The leak detection sensor was well received by volunteers. As for the environment sensor, ease of supply, installation and set up of the sensor were commended. Not requiring the user to connect to communication services is considered a benefit of the system, though it requires the presence of an appropriate LPWAN service, which vary by geographical location.

The following recommendations are made:

- Integration of data from the leak detection sensor to alerts and dashboards for support is recommended, to enable the sensor to be of use to independent living support services or families.
- The data returned from the leak detection sensor was not available for analysis during this trial, so the reliability of the information could not be assessed.
- The sensor is unobtrusive, easy to deliver, and easy to set up. Some users may require assistance with installing the batteries.
- The leak detection audible alarm is loud and has been triggered deliberately and accidentally by several trial participants.

5.3 Bed Occupancy / Light Path Sensor

The light path sensor presented a number of problems to volunteers. It had been supplied to volunteers for self-installation, though it is recommended by the developer that a trained professional installation with personalisation would be available for the target demographic.
The following recommendations are made:

- Currently, the data returned from the bed occupancy / light path sensor is not being applied to dashboards or alerts. Without the use of the data to provide alerts, the sensor is not of use to independent living support services or families.

- The data returned from the bed occupancy / light path sensor was not available for analysis during this trial, so the reliability of the information could not be assessed. Provision of data alerts or dashboard would fit with the intended use of the product for bed occupancy monitoring, and potential night-time falls identification.
- The sensor has proved to be complex to set up, with wires proving trip concerns and challenges to installation, and requiring a conveniently located power socket. As above, in typical deployments, installation would be anticipated to be undertaken by a trained professional.
- The LED light strip was found to be erratic and not consistently behaving as expected. Pressure calibration can be adjusted during installation and remotely, although this was not undertaken during this project.
- The LED light strip was triggered by movement within the bed, and to one partner getting up whilst the other remained in bed. Anticipated use is for people living alone.
- Further research is recommended on ideal provision of light at night to prevent falls in the target demographic, such as location, brightness and colour of lights. The device developers state that the device lighting is personalisable to user preference.
- Some users reported interference with home entertainment systems. It is considered likely that the bed occupancy / light path sensor may be the source of some interference. It is recommended that WiFi is disabled during configuration of the development board if not required.
- Radio frequency testing also revealed a high duration of LoRa emissions during the start-up phase. It is recommended that configuration is checked so that LoRa emissions are within the duty cycle requirements of the protocol, and that management of the start-up phase in case of lack of connection is considered.
- Continued development of the product should include removal of unwanted radio-frequency (WiFi) emissions for installations where WiFi is not required, with radio spectrum testing if possible, prior to further in-home testing, and work towards CE certification.

5.4 General recommendations

In general, the following recommendations are made:

- It was not possible during the course of this project to trial sensors with the vulnerable population who would be the intended users. It is recommended to further trial them with anticipated user groups. As discussed above, the light path / bed occupancy sensor requires additional development and testing prior to further in-home trials, and prior to provision to vulnerable users.
- The leak detection and light path sensors did not provide access to alerts, data or information. This is required prior to additional testing, and integration of live information with an online dashboard or app would be required prior to commercial deployment.
- Exploratory work by the Smarter Suffolk project team and the potential user groups indicated a significant level of confusion by users and families about the different monitoring and alarm options available to them. Additional education and information is recommended to support users and families to understand the range of options available and their potential benefits and limitations.
- The SCC project team remain interested in the potential for diffuse networks such as county-wide LoRaWAN or the street lighting asset and network to provide a geographically widespread adult social care support and monitoring solution that

extends beyond the home. Further exploration and development of such a solution is recommended.

5.5 Conclusions

The Suffolk and Norfolk Innovation Network of LoRaWAN gateways was found not to provide sufficient coverage to support this trial of in-home sensors. The provision of internal LoRaWAN gateways per residence is considered unlikely to be cost effective for individual residences, although it is comparable to the current monitoring solution offered by SCC, which supplies each residence with a 4G connected router to provide dedicated WiFi and enable pre-delivery configuration. Installation of LoRaWAN gateways for the ASC use case may be appropriate for an area of multiple occupancy, such as a sheltered housing complex, where multiple residences could be covered by one gateway.

The environment sensor was felt to be providing easy to use data relating to changes in daily living activities in dashboard and alert functions. It was not part of this trial to confirm the accuracy of data and status changes. Changes in status are associated with changes in activity patterns in a single room.

The leak detection sensor has not yet been configured to provide useable data to independent living supporters or families. The sensor itself had a loud alarm, and volunteers considered that it would be useful in multiple locations within the home.

The light path / bed occupancy sensor has not yet been configured to provide useable data to independent living supporters or families. It requires significant additional development work to move from early prototype to mature product. Recommendations for some of the next steps are made in this report. The developers are undertaking further development of this product.

The Smarter Suffolk project was pleased to be able to trial sensor technology as part of the trial funding that could potentially support other areas of SCC's work. In-home monitoring for vulnerable people will be important to support independent living for an aging population. Devices such as the environment and leak detection sensors which are easy to supply and install, and can potentially connect to LPWAN without user action, when linked to a useful dashboard and alert mechanism, will continue to be a key part of this solution. Benefits including early intervention and increased confidence can have a significant positive impact on well-being of these residents and direct and indirect use of health, care and emergency resource.

6 Discussions

With thanks to the following people for valuable discussions:

Sam Bassett, Digital Care and Innovation Lead, Suffolk County Council
Richard Webster, Project Director Suffolk LiveLabs, Suffolk County Council
Brig Sodano-Carter, Project Development & Delivery Manager for Suffolk LiveLabs, Suffolk County Council
Melanie Willis, Project Officer for Suffolk LiveLabs, Suffolk County Council
Trevor Morsman, Research Manager**,** Applied Research, Openreach Research, BT
Paul Putland, Health and Social Care Lead, Applied Research, BT
Neal Forse, Founder and CTO, IoT Solutions Group

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Willis, M. (2021) *IOT Volunteers feedback after 1 month*.

8 Document History

Date	Version	Author	Notes
12/2021	Draft 1.0	H Steventon	Reviewed with Prof N Caldwell
12/2021	Issue 1.1	H Steventon	Issued to Suffolk County Council

9 Appendix A: User Feedback

User Feedback gathered by Mel Willis during the trial (Willis, 2021).

Date of feedback early November 2021 (after one month of use)

Feedback from volunteer No.6:

What are your thoughts on the kitchen sensor? Where did you place it?
Not fully understanding what data this is collecting apart from possible movement. This information could be mis-leading if there is a pet in the house for instance, which is quite often with elderly people. Mine placed on the kitchen windowsill.

What are your thoughts on the water leak sensor? Where did you place it?
Useful for what they are designed for, however, would probably need more than one, as most places now have either utility rooms and/or more than one bathroom or en-suites. Mine is in the kitchen cupboard below the sink.

What are your thoughts on the light-path sensor? Have you found it useful or a pain?
Very useful, LED strip could possibly be slightly longer or at least have the option of different lengths. Mine is illuminated all-day which is a pain, however it was going off approx. 6.30pm (5.30pm now clocks have changed).

Do you have anything to share about their potential for use in an older person's home?
Improvement of the technology especially the set up / wiring and cabling for the bed sensor as all very untidy and potentially a trip hazard, elderly people could see this as off putting if they were to consider having this installed, I think.

Feedback from Volunteer No.8:

Kitchen sensor - no problem I placed it on the worktop near the sink.

Water leak sensor - no problem. I placed it under the sink cupboard on the floor.

My bed light-path sensor has NEVER worked properly.

Feedback from Volunteer No.9:

What are your thoughts on the kitchen sensor?
It is a nice small unit but if it was sensing room temperature then what are the parameters, for example in some elderly peoples' kitchens they may not actually have any heating, therefore this room will always be much colder than the lounge. If the sensor is triggered, then who is advised of this? I placed mine on the Kitchen windowsill but not in direct sunlight.

What are your thoughts on the water leak sensor?

Small & compact but could be an issue for the elderly to install / replace the batteries, also would need more than one sensor if placing under washing machine / dishwasher / sink / toilet etc. I placed mine under the washing machine.

What are your thoughts on the light-path sensor?
Would need to be installed and set up far more easily for the elderly. Light strip seemed too bright and too long, I just left it coiled up and still gave sufficient light in a dark room. If this sensor is purely for emitting light when getting out of bed for the elderly, then it could be useful as long as they are not bed bound.

Do you have anything to share about their potential for use in an older person's home?
As mentioned in my first answer, some elderly people may not have heating in the kitchen which could be an issue for this type of sensor. The water leak sensor could cause a problem if the elderly person is bed bound and live on their own as this could cause them to panic if the alarm was to go off due to a leak.

Feedback from Volunteer No.10:

What are your thoughts on the kitchen sensor? Where did you place it?
Is it meant to do anything? The kitchen sensor often went unnoticed, and it didn't provide any alerts. I placed it on my worktop.

What are your thoughts on the water leak sensor? Where did you place it?
The water leak sensor was put on the floor, underneath the sink, close to the washing machine. To help with the trial, I did put it in some water. It was a very loud alarm, which would alert the homeowner within the house of the water leak. (I think my ears are still ringing)

What are your thoughts on the light-path sensor? Have you found it useful or a pain?
A pain. Lots of cables, it wasn't the easiest to set up and seemed to be very inconsistent. I ended up putting the light in a drawer as the LEDs were very temperamental with movement, often causing the room to glow at all times of the night. Recently, the light seems to stay on for longer.

Do you have anything to share about their potential for use in an older person's home?
Should these sensors be used in an older person's home, these would need to be set up appropriately, securely (light path sensor) and the cables (light path sensor) safe on behalf of the homeowner.

Main observation – Ever since the sensors have been in place, two TVs in the house have switched on during the day/night, and I can only assume (I hope) that this is due to the sensor frequencies. My Alexa also started to glow as if it was being interacted with during the night. Since, I have been switching the Alexa and both TVs off at the wall. Although last night, I forgot, and the TV switched on again.

Feedback from Volunteer No.12:

What are your thoughts on the kitchen sensor? Where did you place it?
It's on a shelf at the end of wall mounted cupboards, nearish to the sink. Do I have any thoughts on it – no not really as from my perspective it doesn't do anything – if it has an alarm type feature in it so as far as I'm aware it's not been triggered.

What are your thoughts on the water leak sensor? Where did you place it?
I put in on the floor just under the bathroom sink. Again no thoughts as it's never been triggered – a visitor did think it was some weird air freshener!

What are your thoughts on the light-path sensor? Have you found it useful or a pain?
In principle great idea, but the execution is a bit off the mark! I did originally follow instructions and stuck it on the skirting board, but it kept falling off (but consequence is its been great at picking up dust & cat hair so not all bad!), but the real killer was the light – it has spent many days on all day unless I have put a large box on the bed over the sensor, a couple nights its flicked on and off so often that the plug got ripped out of the socket, the light is quite bright which is great for the intended task but not if it switches on when it shouldn't. The light strip does now live coiled up in a cardboard box so I'm less aware when its on when perhaps it shouldn't but even in the box at night there is a glow under my bed at times. I am assuming that a commercial product would be wireless (between the LED light & sensor box otherwise the trailing wires will be introducing a trip hazard (safety conscious me thought of that and put a mat over the wires – then tripped on the mat!)

Do you have anything to share about their potential for use in an older person's home?
In terms of the night light thing yes in principle but it does make me how this is better than the plug in PIR night lights that have been about for many years (admittedly if you have a dog that could set it off I guess).

Feedback from Volunteer No.13:

Kitchen sensor - this is placed on top of my kitchen work top. This sensor was easy to install and have had no issues with this sensor.
Water leak sensor – this sensor is placed under my sink in the kitchen, again, easy to install. I have tested this in water however, it did not go off. Gemma has since suggested it needed to be in deeper water so I will give it another try.
Light path sensor – this sensor was tricker to set up and harder to install due to the weight of my mattress also, I am unable to install the light near the door due to the position of my bed and size of my room. This light was originally positioned running down the side of my bed however, after 2/3 nights of being woken by the light I then moved it to behind the headboard. I think the idea of the light works well however, the light only goes on/off when myself and my partner are in the bed – not sure if this is due to my mattress being so thick or if it just cannot sense my weight on my own. However, when we are both in the bed the light goes off with the lightest of movements. Such as lifting an arm, rolling over or even pulling the duvet. This is very annoying given the brightness of light; however, it defiantly has been useful when getting up in the middle of night.

I think the sensors overall work really well and I can see them being great for older people, especially the light sensor.

Feedback from Volunteer No.14:

What are your thoughts on the kitchen sensor? Where did you place it?
No thoughts of note – the sensor was positioned on my kitchen windowsill.

What are your thoughts on the water leak sensor? Where did you place it?
No thoughts of note – the sensor was positioned on the floor next to my bath for a time, then under my sink.

What are your thoughts on the light-path sensor? Have you found it useful or a pain?
The light path sensor worked well, although I had to remove the lighting strip quite quickly as my partner works night shifts and it became annoying. Also, for some reason, whenever I got out of bed the lights would stay on permanently until I returned, which wasn't ideal during the daytime! I appreciate this may be due to user error however…

Do you have anything to share about their potential for use in an older person's home?
I think in their current form, the kitchen and water leak sensors are well suited to living in an older person's home. That being said, I think the light-path sensor may be a little 'tech-heavy' and daunting for OAPs, not least due to the size of the box and number of wires involved. Additionally, the need to have a booster is an inconvenience – my router is next to my front door for instance, meaning I have a lot of clutter which isn't easily hidden.

Feedback from Volunteer No.18:

What are your thoughts on the kitchen sensor? Where did you place it?
Hopefully it is working which is probably the place to start for all the sensors as I don't have access to the data. It is on a shelf in the kitchen close to the kettle and toaster!

What are your thoughts on the water leak sensor? Where did you place it?
As above, under a sink in our utility room. Am going to simulate a flood at some point!

What are your thoughts on the light-path sensor? Have you found it useful or a pain?
As above regarding it working. It is a bit random. We played with the location of the sensor strip to try and get it to work as intended. This was quite difficult as it seemed to need more weight to work. We then used the frame of the bed where it seemed to work, but it has been random. In terms of the light, I'm not sure how much it would help in an older person situation as I still think they'd need to turn the light on…if it were linked to turning a dimmer switch on, that would probably work better.

Do you have anything to share about their potential for use in an older person's home?
As above for light path and depending on whether others are working, they are unobtrusive so think they could work fine.

Feedback from Volunteer No.16:

1) What are your thoughts on the kitchen sensor? Where did you place it? Placed it on main kitchen shelf – halfway between back door and interior door. No issues with this – no real set-up needed, very straightforward

2) What are your thoughts on the water leak sensor? Where did you place it? Placed near the stopcock, which is an area where the door is normally closed – didn't test the alarm (thankfully) but wondered if it would be loud enough to be heard through an interior door? No issues, though removing the batteries (done to check the serial number) wasn't easy, with extremely tight fitting – certainly could be an issue if an older person has to change the batteries.

3) What are your thoughts on the light-path sensor? Have you found it useful or a pain? Weren't able to set-up due to our cat's interest…I wonder if just a simple night-light would be a better and simpler option, just giving a low but continual light through the night?

4) Do you have anything to share about their potential for use in an older person's home? I think clear instructions on suitable locations for sensors would be needed for older people. Support might be needed for any hub internet connection issues.

ENDS

10 Appendix B: Connection status review

Connection status was reviewed from the IoTSG dashboard. Users whose environment sensors were not connected were reported as 'missing'.

User	Connection status
1	Connected
2	Previously connected, 'missing' since 28/11/21
3	Connected
4	Previously connected 'missing' since 27/11/21
5	Connected
6	Previously connected 'missing' since 19/11/21
7	Never connected
8	Never connected
9	Connected
10	Never connected
11	Connected
12	Connected
13	Never connected
14	Connected
15	Never connected
16	Previously connected, 'missing' since 02/12/21
17	Never connected
18	Connected
19	Connected
20	Connected