Interreg CENTRAL EUROPE
European Union
European Regional Development Fund

niCE-life

AP NURSE HOME & CARE MONITORING TOOLS

D.T2.2.3 - Construction of Data and Control Nursing Unit and software development

Version 1
09 2020

1. Introduction

AP-NURSE is a simple and modular monitoring tool used for patients suffering from Alzheimer's and Parkinson's disease for home and medical application. It encompasses ambient sensors, which can monitor activity patterns, gas, temperature and sound aspects. Its aim is to simplify the work of home caregivers or nurses by monitoring basic interactions of the patient with their environment during night or job duties and provide fast alert about possible dangers and support independent living of frail elderly. This document aims to collect the most important information regarding the construction of the data and control nursing unit of AP-NURSE and the related software solutions. It consists of 5 thematic pars, starting from the overview of the AP-NURSE system and the requirements influencing the design, following a detailed description of the construction of electronic parts and ending with the definition of the methodology and cases for laboratory testing of AP-NURSE.

2. Overview of the AP-NURSE system

The AP-NURSE digital tool is designed for multiple areas of application, therefor two versions of the system are being developed, the AP-NURSE Home and the AP NURSE Care. AP-NURSE Home is designed for home use and the AP-NURSE Care for centers. AP-NURSE Home is a set of simple and cheap small monitoring devices that monitor several environmental factors of patient surroundings and are placed at home of frail elderly or a patient to ease the everyday life of caregivers, who are usually family members. AP-NURSE Care represents a set of small monitoring devices that monitor several environmental factors of patient surroundings, placed at care center to ease the daily and specifically nightly duties of the caregiving personnel. It is assumed that the caregiving personnel controls the condition of the patients from the nursing/control room on a PC or using a mobile device, visualizing the parameters of AP-NURSE utilizing a simple traffic light logic. The system is configured in a way that online measured sensor data below and above thresholds are sent to dedicated servers for further analysis. The features of AP-NURSE Home & Care are shown in Table 1.

Table 1: Features of AP-NURSE Home & Care

	AP-NURSE Home	AP-NURSE Care
Home use	✓	✗
Use in care centers	✗	✓
Simple design	✓	✗
Low-cost	✓	⚖
PC/mobile based monitoring	✗	✓
Watch/bracelet notifications	✓	✗
Multi-patient platform	✗	✓

The flowcharts of AP-NURSE Home and Care are shown in **Figure 1** and **Figure 2.** In case of any emergency detected by AP-NURSE Home, a caregiver is notified by a simple rubber watch/bracelet. It is assumed that patients live with a caregiver (likely a family member), therefore to ease the life and not to disturb the caregiver's partner (husband, wife) during the night, the bracelet warns a caregiver by vibrating pattern (for communication RF433MHz module with hard encoded addresses is used). In case of the AP-NURSE Care, the caregiving personnel monitoring the conditions of the patients from the nursing room is notified on her computer or mobile app. The conditions of the monitored patients are evaluated using a simple traffic light logic, while green light represents normal condition, orange light abnormal condition and red light critical condition requiring action.

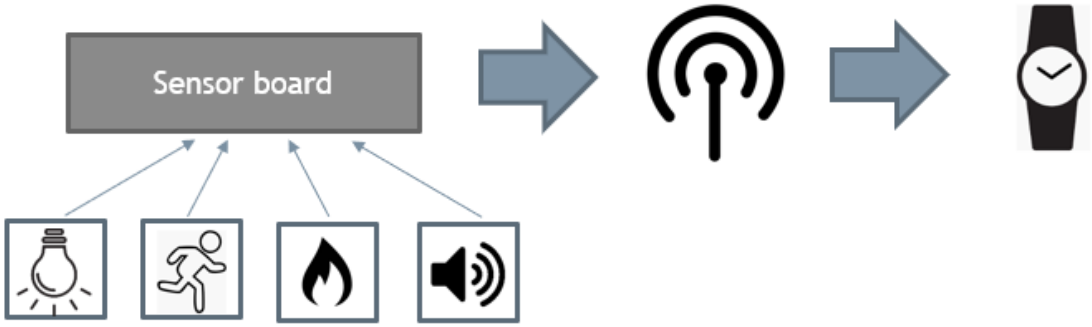


Figure 1: AP-NURSE Home flowchart

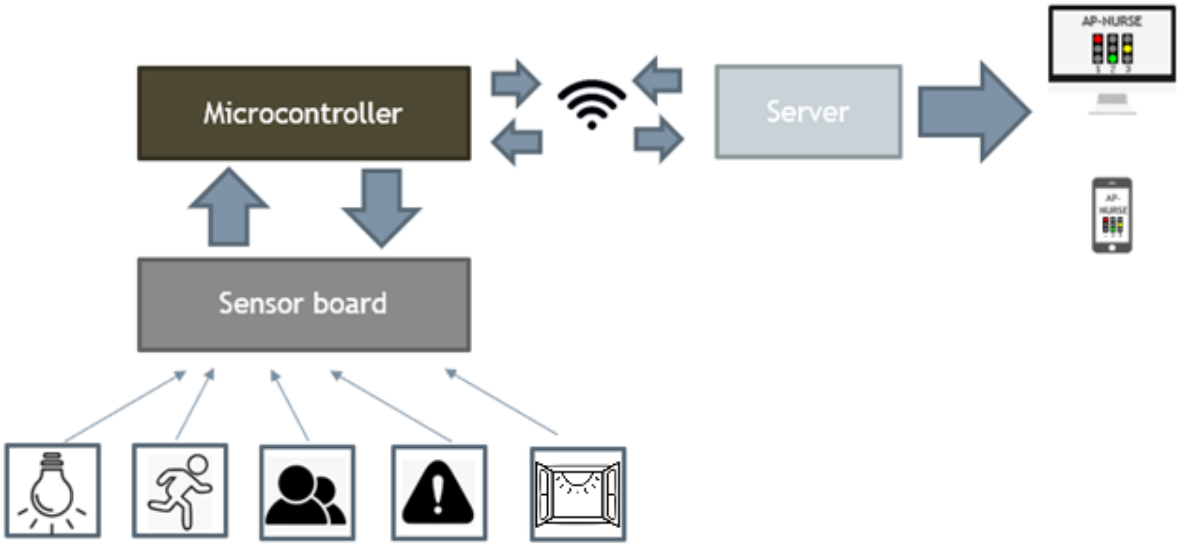


Figure 2: AP-NURSE Care flowchart

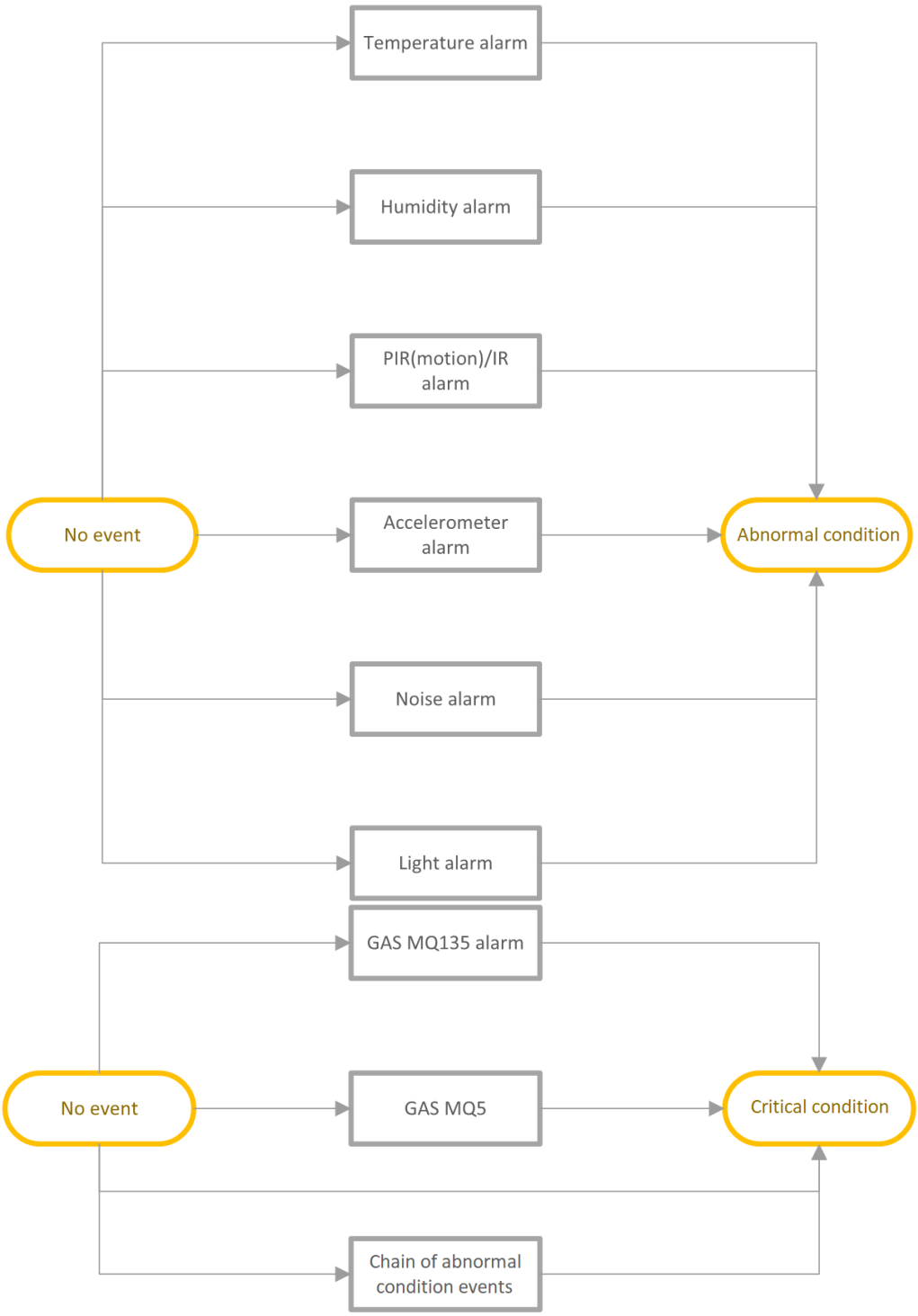


Figure 3: AP-NURSE sensor logic

The AP-NURSE sensor logic is shown in Figure 3. Abnormal and critical conditions shown above means, that every single sensor can trigger such event. The final alert, which is later visible to caretaking personnel is created from those events and other environment variables (for example duration between events). These events also with specific sensors are presented later in this deliverable.

3. Requirements on the system design

3.1. Electronic survey

Both AP-NURSE Home and Care consist of a set of sensors carefully selected to identify the most important events that could occur, when the patients' behavior differs from normal conditions, i.e. the patients stands up, turns on the light, falls down, opens the window etc. The selection of appropriate sensors is based on the experience of project partners operating care centers and social homes in Bratislava, Warsaw and Olomouc. In order to collect information from the potential user of AP-NURSE and project partners involved in the testing of devices an electronic questionnaire using the ***LimeSurvey*** online platform was created. The questioner consists of 65 questions divided into 8 thematic groups. The structure of the survey is as follows:

- Partner identification
- Type of diseases
- IoT solutions
    - Experience with IoT solutions
    - IoT data transfer
    - Application of IoT technologies
- IoT sensors
    - Motion sensors
        - Motion alarms
    - Sound sensors
        - Sound alarm
    - Light sensors
        - Light alarm
    - Gas sensors
        - Gas alarms
    - Sensor of opening /closing a device
        - Alarm of opening / closing a device
    - Temperature sensors
        - Temperature alarm
    - Humidity sensors
        - Humidity alarm
    - Pressure sensors
        - Pressure alarms
- Notifications
    - Sound notification
    - Fire notification
- Data storage
- Even identification
    - On screen
    - On a bracelet
- Other comments

The questionnaire is only accessible through a unique URL address and TOKEN, which serve to identify the partner filling the survey. The URL for the survey is as follows:

- http://147.175.126.100:7122/index.php/553396/lang-en

The illustration of the questions from the survey can be seen in Figure 4 - Figure 11

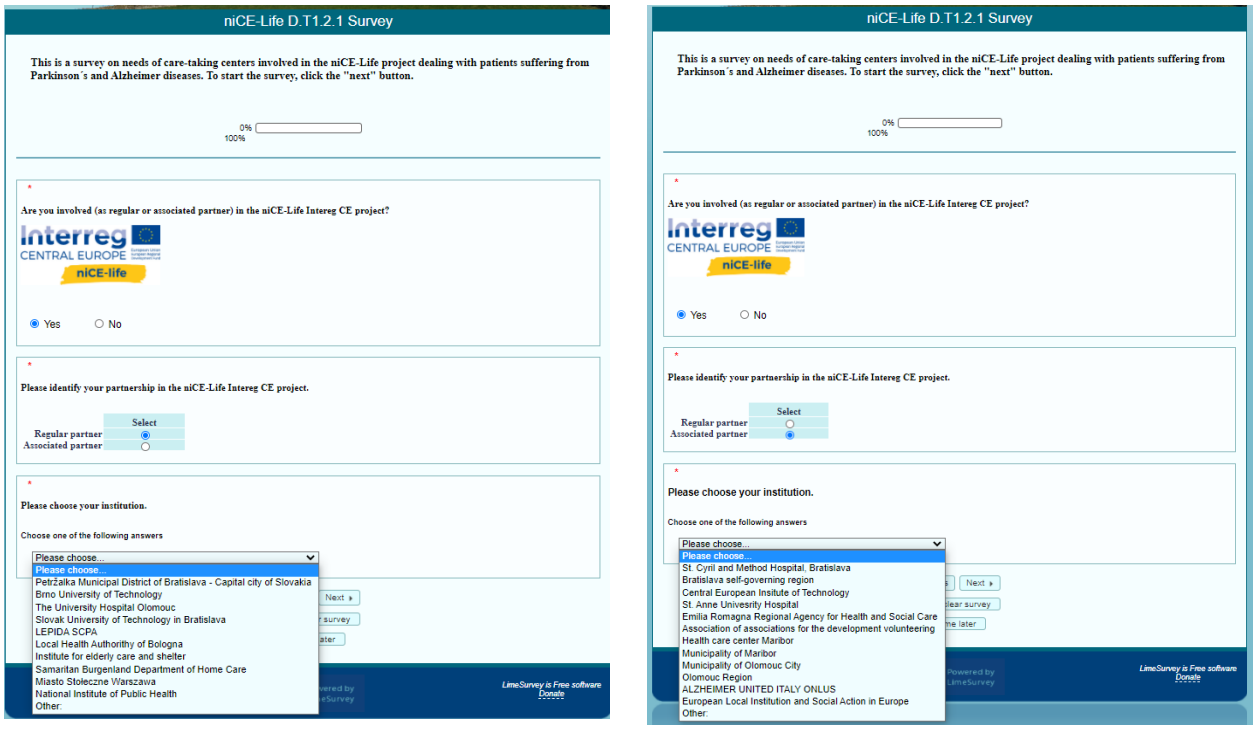


Figure 4: Questions related to partner identifications

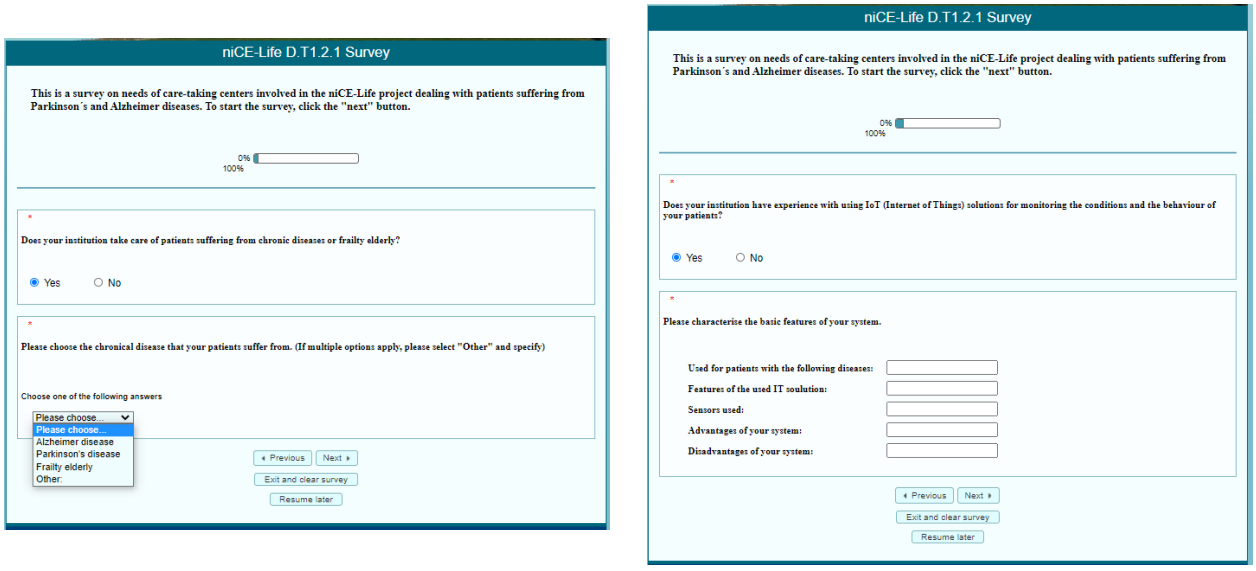


Figure 5: Questions related to experience with IoT technologies

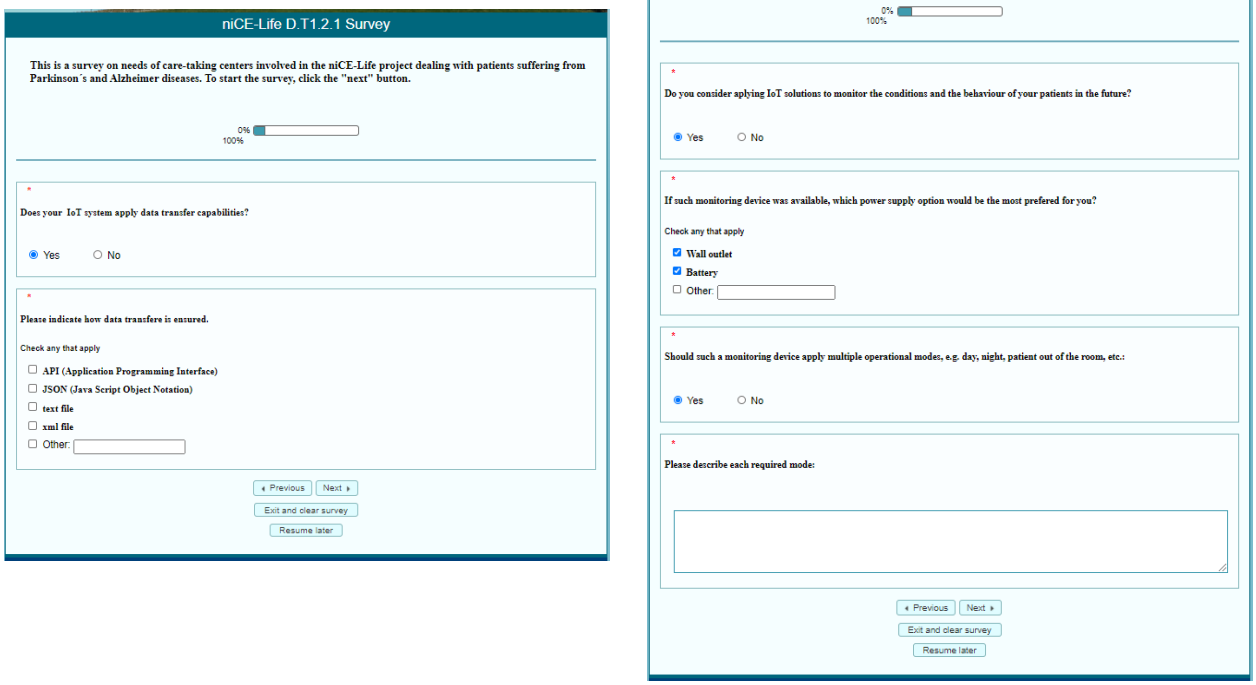


Figure 6: Questions related to the application of IoT technologies

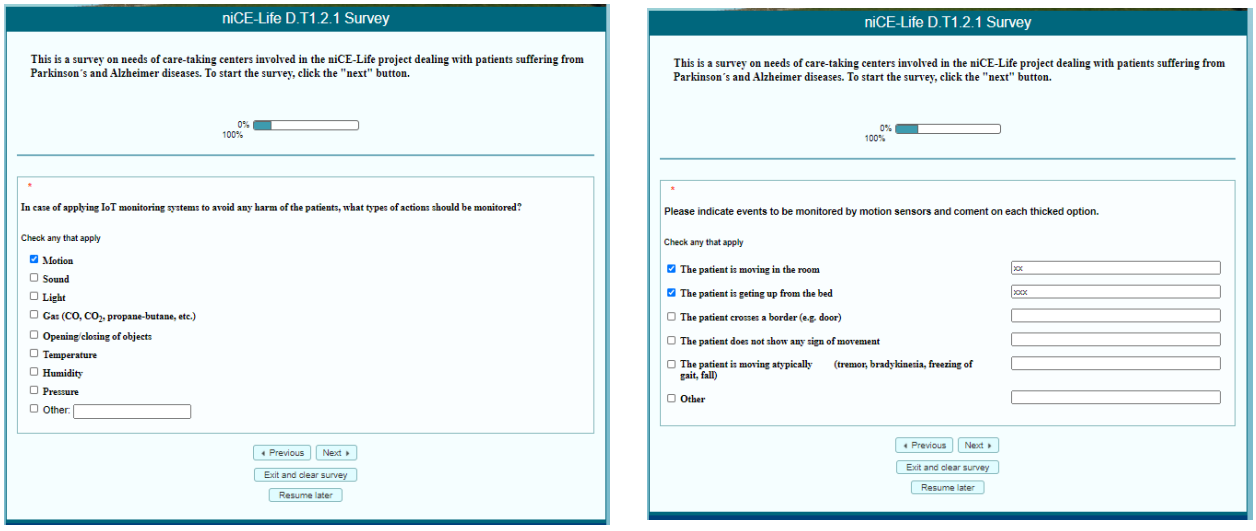


Figure 7: Questions related to IoT sensors (1)

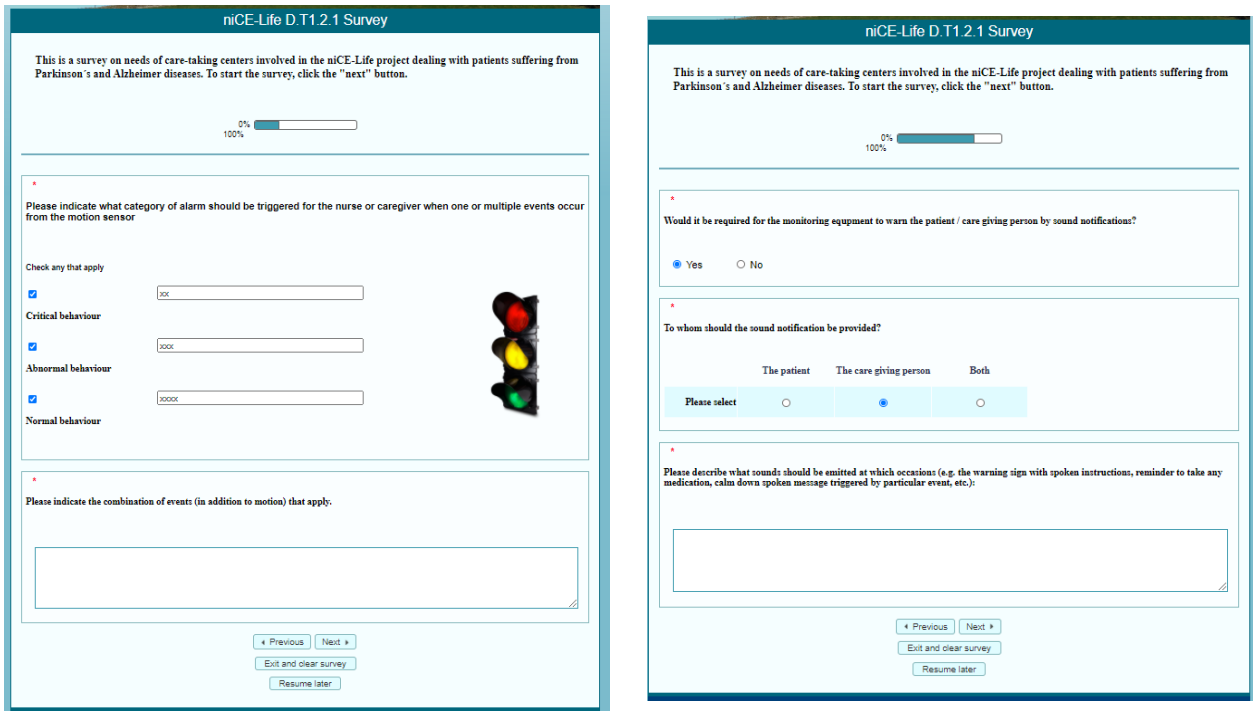


Figure 8: Questions related to IoT sensors (2)

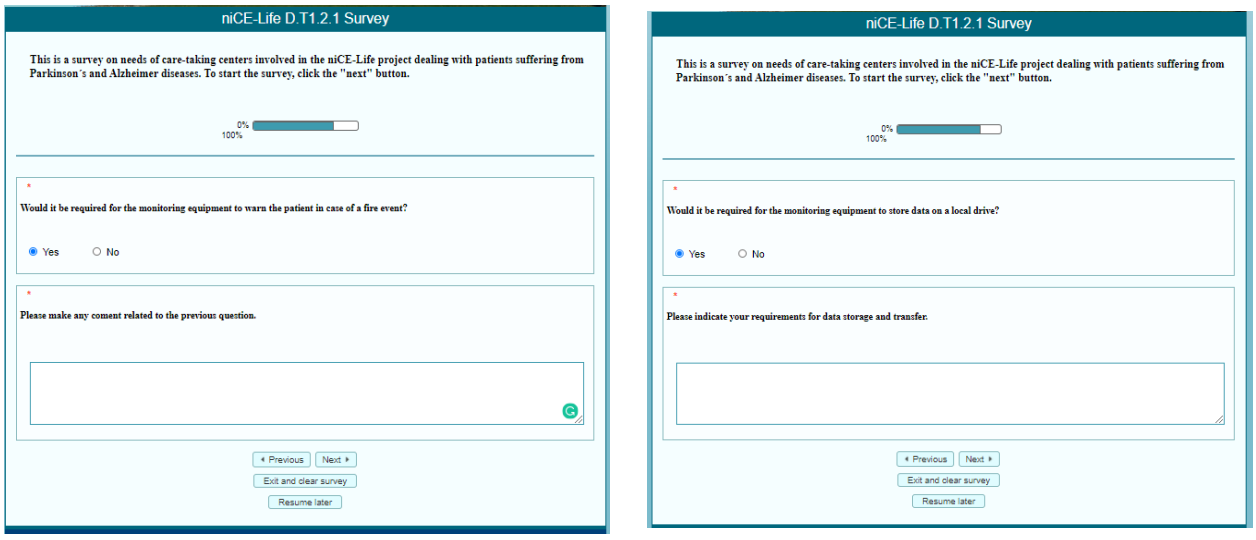


Figure 9: Questions related to the identification of fire events

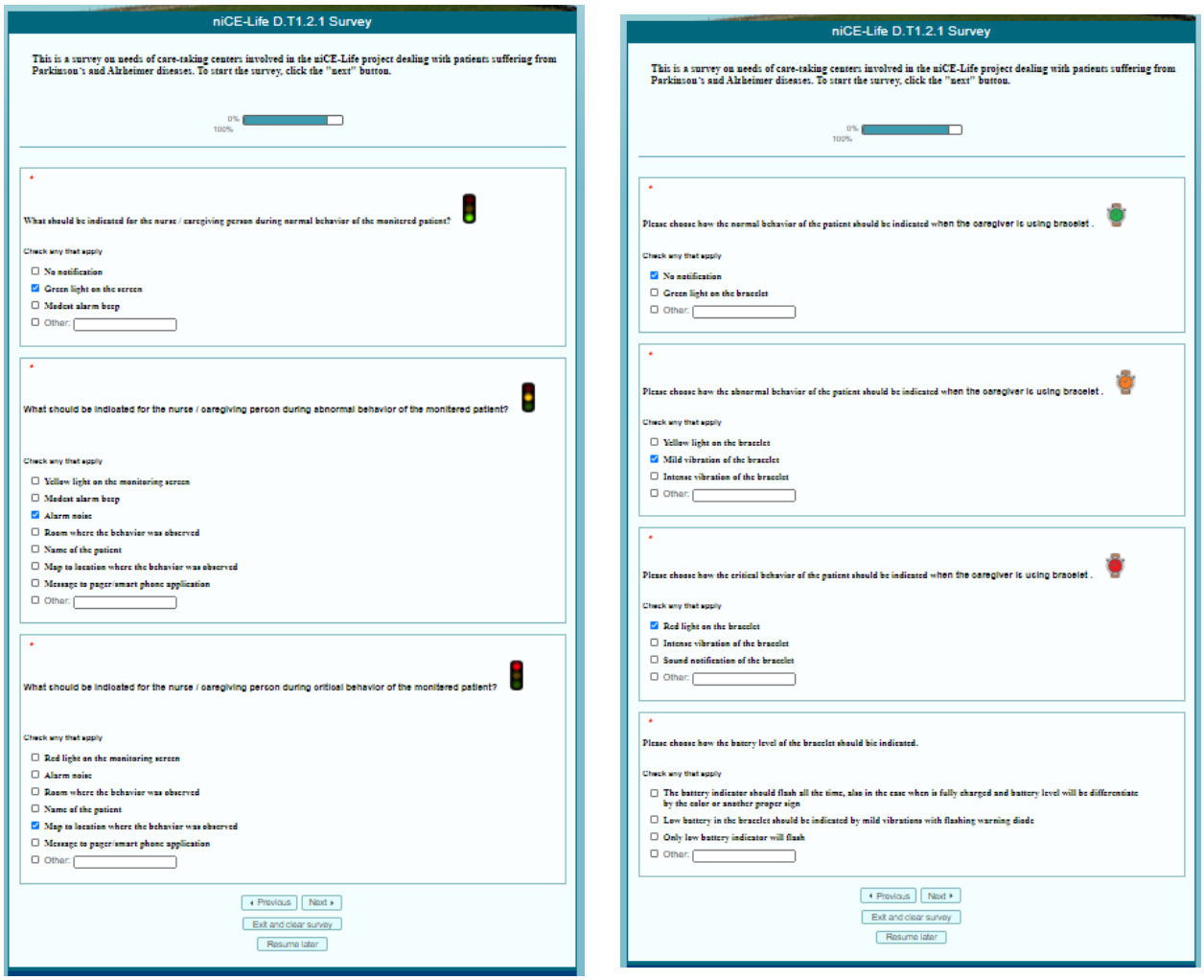


Figure 10: Questions related to event identification

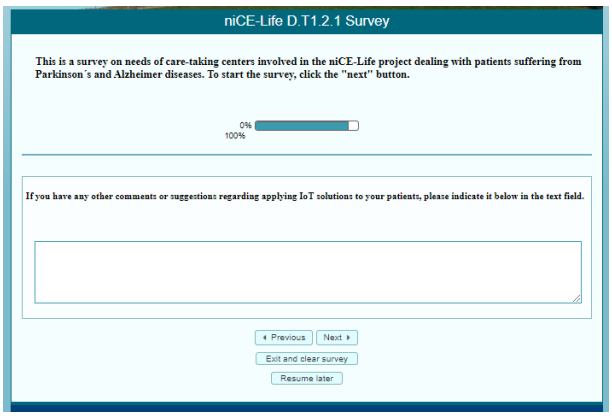


Figure 11: Comments

3.2. Overview of collected data

3.2.1. Partner identification

The results related to partners having the electronic survey completed are shown in Figure 12.

Answer	Count	Percentage
Petržalka Municipal District of Bratislava - Capital city of Slovakia (A1)	2	33.33%
Brno University of Technology (A2)	0	0.00%
The University Hospital Olomouc (A3)	2	33.33%
Slovak University of Technology in Bratislava (A4)	0	0.00%
LEPIDA SCPA (A5)	0	0.00%
Local Health Authorithy of Bologna (A6)	0	0.00%
Institute for elderly care and shelter (A7)	0	0.00%
Samaritan Burgenland Department of Home Care (A8)	0	0.00%
Miasto Sto?eczne Warszawa (A9)	0	0.00%
National Institute of Public Health (10)	0	0.00%
St. Cyril and Method Hospital, Bratislava (B1)	0	0.00%
Bratislava self-governing region (B2)	0	0.00%
Central European Insitute of Technology (B3)	0	0.00%
St. Anne Univesrity Hospital (B4)	0	0.00%
Emilia Romagna Regional Agency for Health and Social Care (B5)	0	0.00%
Association of associations for the development volunteering (B6)	0	0.00%
Health care center Maribor (B7)	0	0.00%
Municipality of Maribor (B8)	0	0.00%
Municipality of Olomouc City (B9)	2	33.33%
Olomouc Region (B10)	0	0.00%
ALZHEIMER UNITED ITALY ONLUS (B11)	0	0.00%
European Local Institution and Social Action in Europe (B12)	0	0.00%
Other	0	0.00%
No answer	0	0.00%

Figure 12: Involved institutions

3.2.2. Types of deceases

The results related to the types of diseases of patients taken care by the involved partners are shown in Figure 13 and Figure 14. Comments made by the respondents are listed below Figure 14.

Answer	Count	Percentage
Yes (Y)	6	100.00%
No (N)	0	0.00%
No answer	0	0.00%
Not displayed	0	0.00%

Figure 13: Involvement of the partner in care taking

Answer	Count	Percentage
Alzheimer disease (A1)	0	0.00%
Parkinson's disease (A2)	0	0.00%
Frailty elderly (A3)	3	50.00%
Other	3	50.00%
No answer	0	0.00%
Not displayed	0	0.00%

ID	Response
41	All mentioned
29	..
48	all kinds of elderly

Figure 14: Chronical diseases taken care

Description of the patients suffering from Alzheimer's disease:

- The patient lives in his own reality, lost, without contact, or difficult contact with the environment.

Description of the patients suffering from chronic disease:

- Confusion, loss of self-care, need of accompanying, supervision, etc. Counselling for family members.

3.2.3. Experience with IoT solutions

The results related to the experience of involved partners with IoT solutions are shown in Figure 15 - Figure 17.

Answer	Count	Percentage
Regular partner (A1)	4	66.67%
Associated partner (A2)	2	33.33%
No answer	0	0.00%
Not displayed	0	0.00%

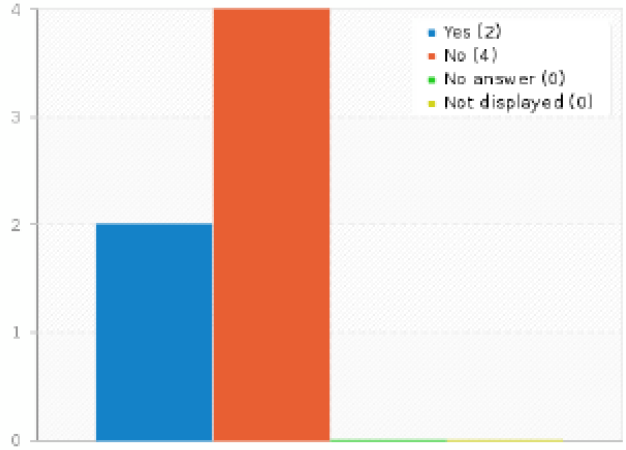


Figure 15: Experience with IoT solutions for monitoring of patients

Answer	Count	Percentage
Answer	2	33.33%
No answer	0	0.00%
Not displayed	4	66.67%

Figure 16: Diseases of patients for which the system was used

Diseases of patients for which the IoT system was used:

- Dementia of elderly.
- Not mentioned.

Answer	Count	Percentage
Answer	2	33.33%
No answer	0	0.00%
Not displayed	4	66.67%

Figure 17: Features of the used IoT system

Features of the IoT system:

- Mechanically controlled from the client's bed.
- Signalization.

Advantages of the used IoT system:

- Information are provided to the care giver without requiring his/her presence in the client's room.

Disadvantages of the used IoT system:

- The system is not capable of identifying the level of danger and the problem of the client.

The results related to data transfer capabilities, considerations of future use, power supply options and the use of multiple operation modes of the IoT solution are shown in Figure 19 to Figure 21 respectively.

Answer	Count	Percentage
Yes (Y)	0	0.00%
No (N)	2	33.33%
No answer	0	0.00%
Not displayed	4	66.67%

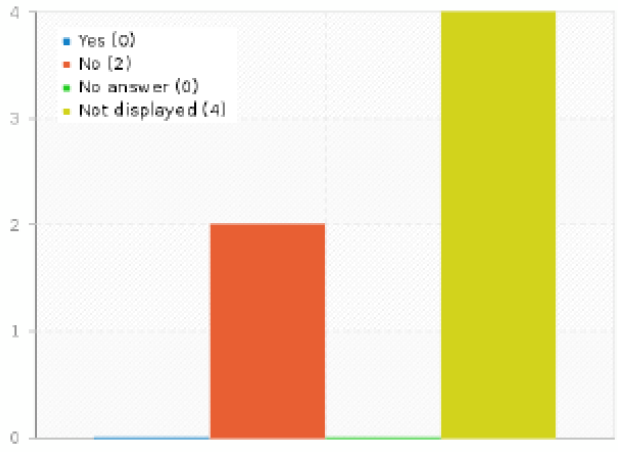


Figure 18: Data transfer capabilities of the IoT system

Indication, how data transfer is ensured:

- No response.

Answer	Count	Percentage
Yes (Y)	5	83.33%
No (N)	1	16.67%
No answer	0	0.00%
Not displayed	0	0.00%

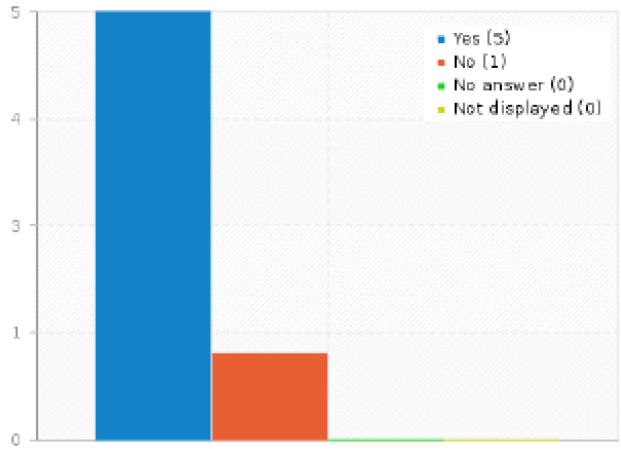


Figure 19: Consideration of using IoT solutions for monitoring the conditions of patients in the future

Answer	Count	Percentage
Wall outlet (SQ001)	2	33.33%
Battery (SQ002)	4	66.67%
Other	0	0.00%
Not displayed	1	16.67%

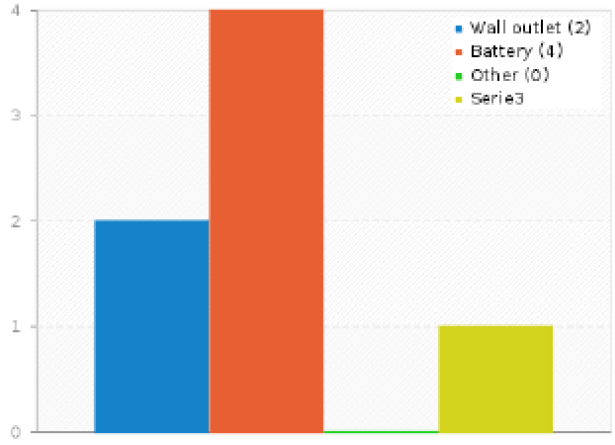


Figure 20: Which power supply option would be preferred for the IoT system

Answer	Count	Percentage
Yes (Y)	3	50.00%
No (N)	2	33.33%
No answer	0	0.00%
Not displayed	1	16.67%

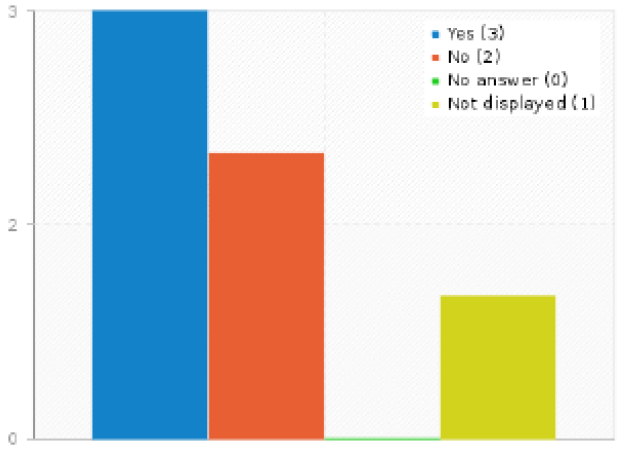


Figure 21: Use of multiple operation modes of the IoT system

Indication of possible operation modes of the IoT system:

- Response 22:
  - Day: monitoring of patient activity, detection of a fall position, monitoring of body temperature, ambient temperature.
  - Night: monitoring of patient activity, detection of a fall position, monitoring of body temperature, ambient temperature, ambient light, patient out of the room.
- Response 31:
  - Day: Movement of the patient in the room, in the premises of the care center and outside the care center. Optionally, monitoring of health conditions.
  - Night: Movement of the patient in the room and in the premises of the care center. Optionally, monitoring of health conditions.
- Response 45:
  - Detection, whether the patient is out of the room.
  - IoT based monitoring of health conditions and environment – COPD, pneumonia, etc.
- Response 51:
  - Maybe cameras which monitor the moves patient in the room.

3.2.4. IoT sensors

The results of question related to the use of IoT solutions are presented in this chapter. The results related to the types of IoT sensors are shown in Figure 22. The results related to the use of individual sensors are shown in Figure 23 to Figure 29.

Answer	Count	Percentage
Motion (SQ001)	5	83.33%
Sound (SQ002)	4	66.67%
Light (SQ003)	2	33.33%
Gas (CO, CO2, propane-butane, etc.) (SQ004)	4	66.67%
Opening/closing of objects (SQ005)	2	33.33%
Temperature (SQ006)	4	66.67%
Humidity (SQ007)	2	33.33%
Pressure (SQ008)	3	50.00%
Other	0	0.00%
Not displayed	1	16.67%

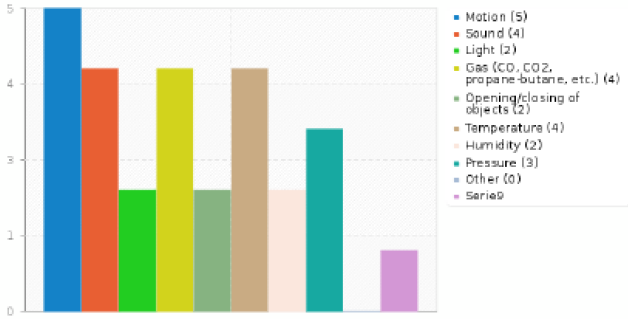


Figure 22: Types of sensors used in case of the IoT solution

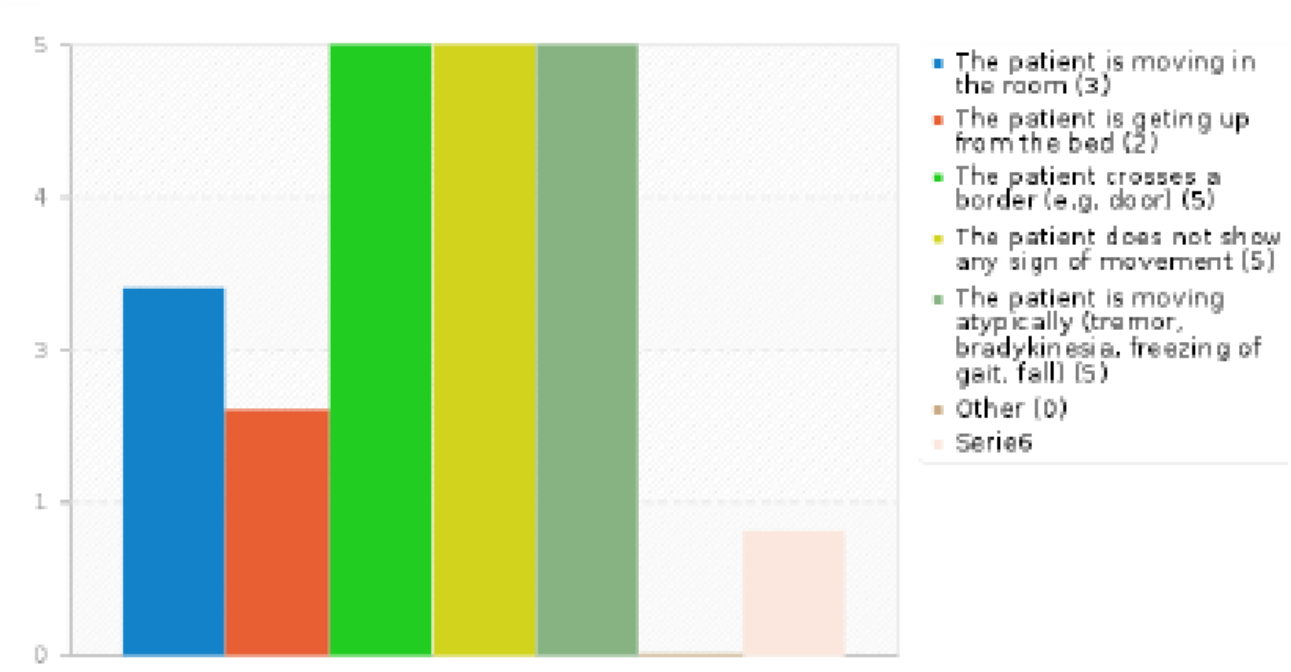


Figure 23: Movement sensor use cases

Combination of events for the movement sensor:

- ID22: temperature, pressure, tipping position.
- ID31:
    - Critical condition: fall, increase of temperature, change of physiological functions, bradykinesia, freeze of walking, etc.
    - Abnormal condition: movement outside the monitored area, change of physiological functions.
- ID45: I do not know which combinations.
- ID51:
    - Critical condition: red light.
    - Abnormal condition: yellow light.

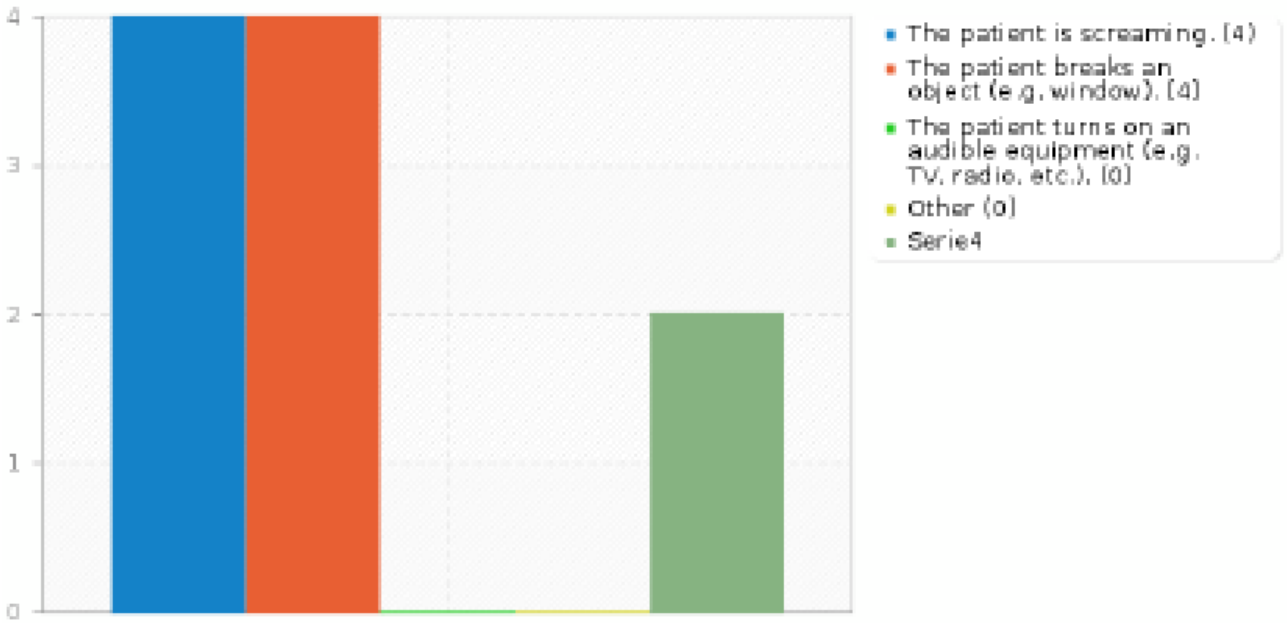


Figure 24: Sound sensor use cases

Combination of events for the sound sensor:

- ID31: Critical condition: The patient is screaming, intensive sudden noise (slamming) not corresponding to the usual behavior and health condition of the patient.
- ID45: I do not know which combinations.
- ID51: Critical condition: red light and sound alarm – aggression / released gas.

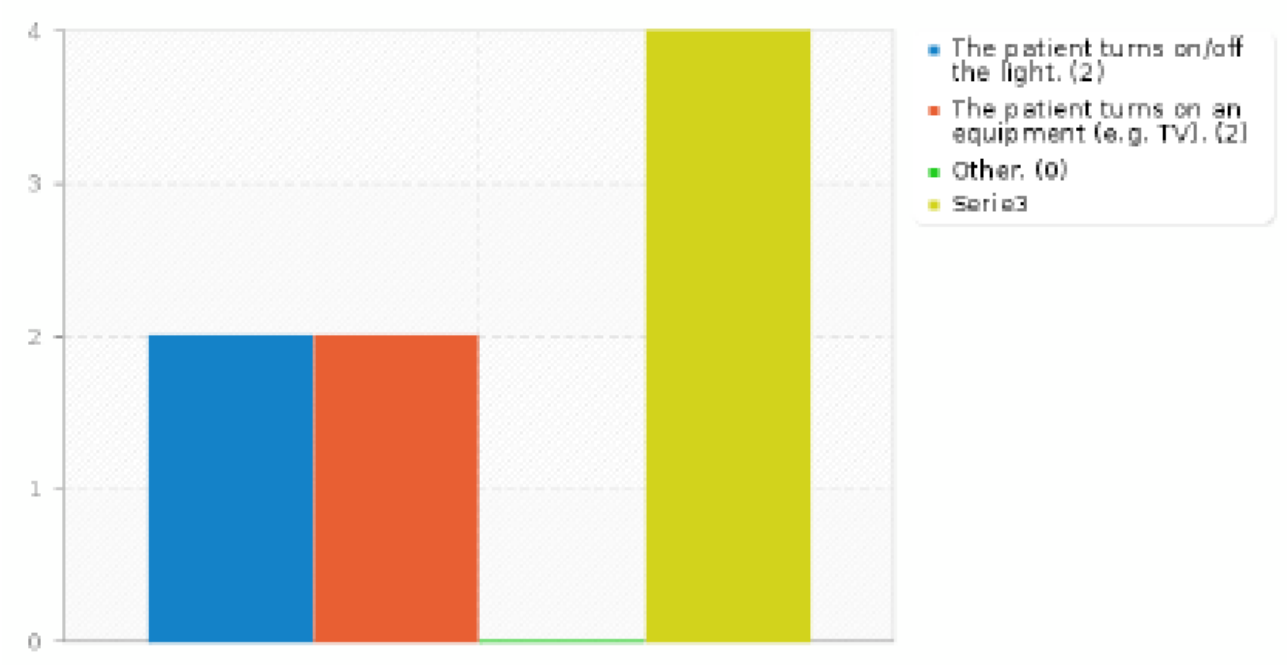


Figure 25: Light sensor use cases

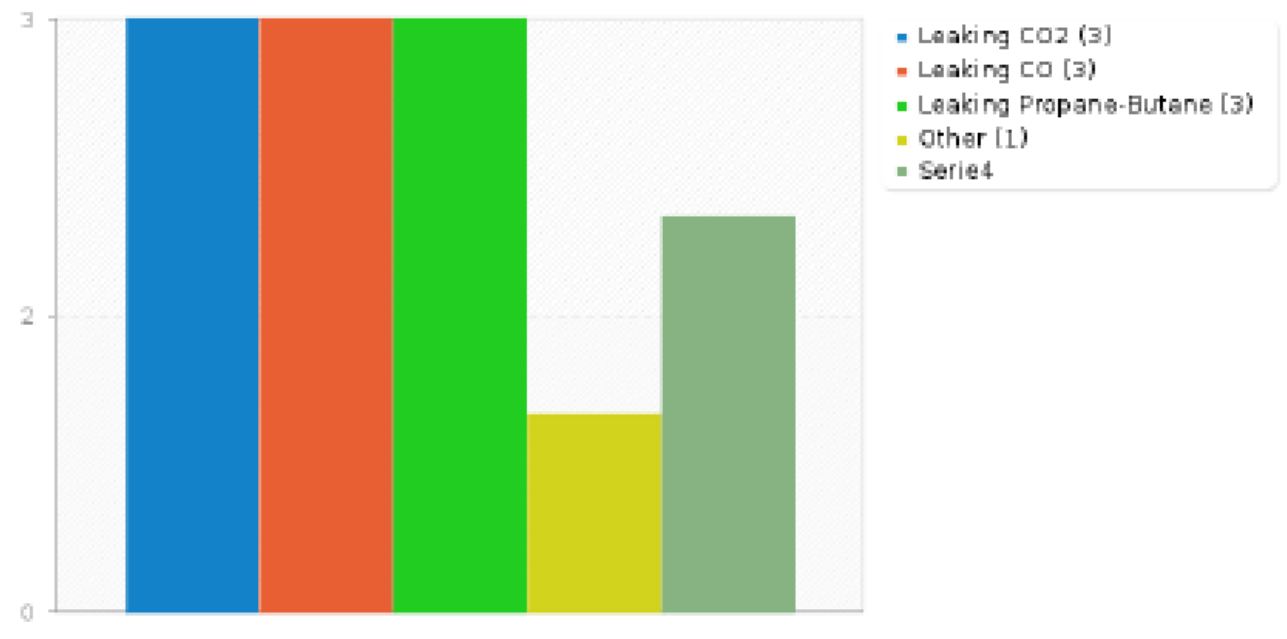


Figure 26: Gas sensor use cases

Answer	Count	Percentage
Yes (Y)	4	66.67%
No (N)	0	0.00%
No answer	0	0.00%
Not displayed	2	33.33%

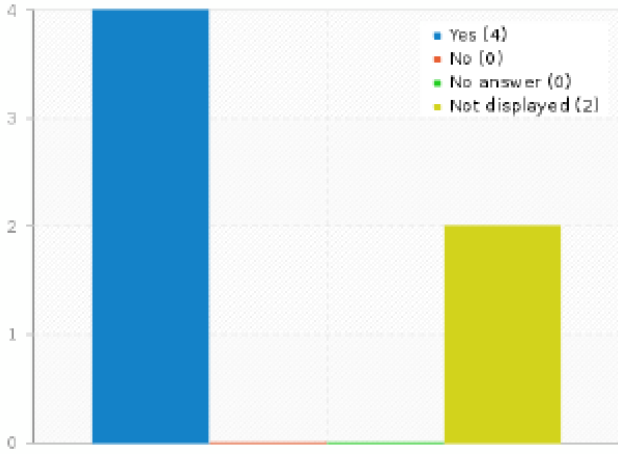


Figure 27: Necessity of warming the patient in case of gas release

Comments related to Figure 27:

- ID31: Fire at the home environment of the patient is a dangerous event, hence it should be signalized too.
- ID43: Maybe should be also the above average electricity power consumption warning.
- ID48: Family member or caregiver should be warned too using sound and light alarm.

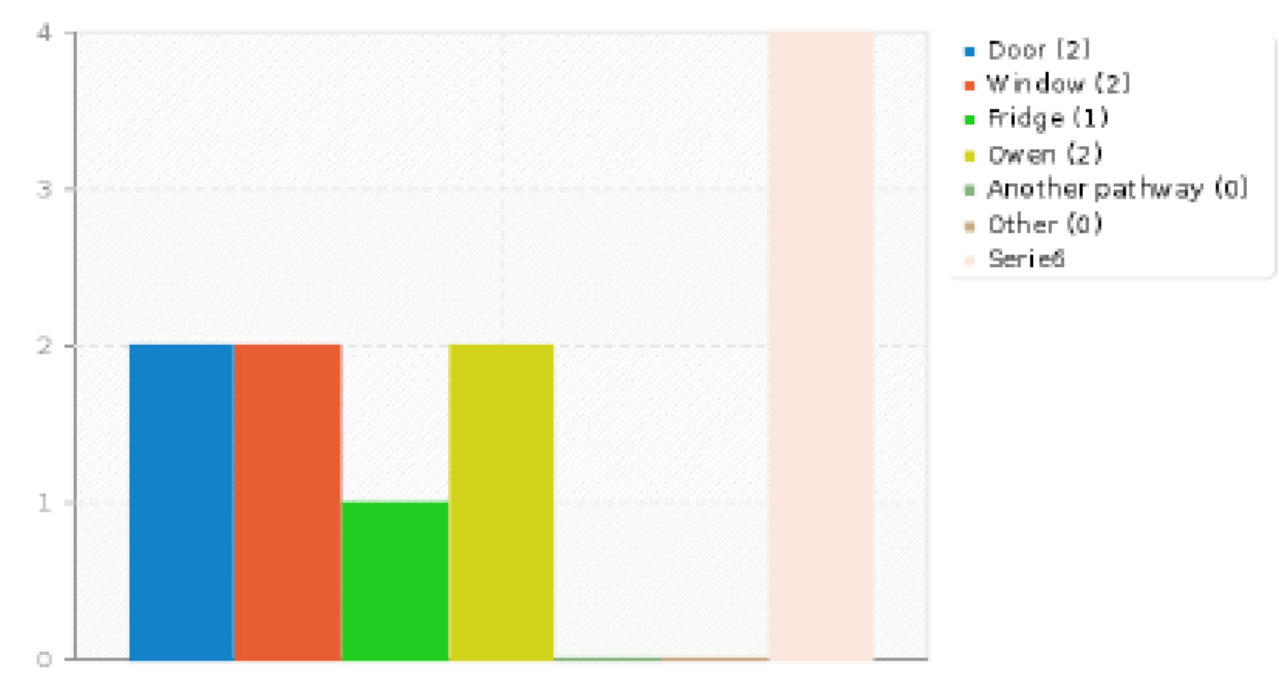


Figure 28: Opening/closing event use case

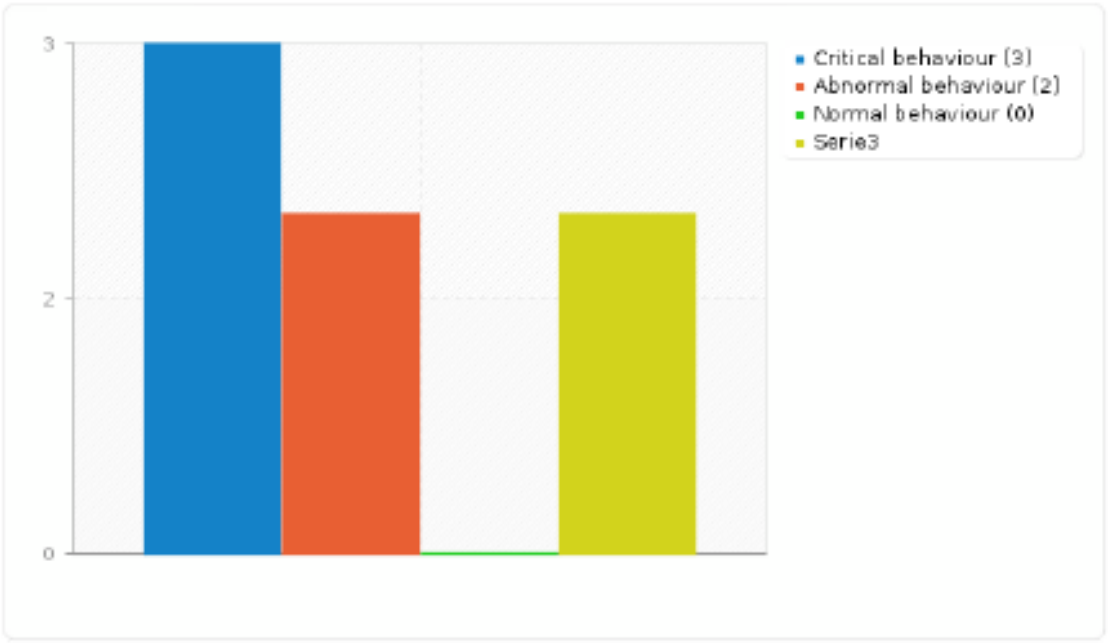


Figure 29: Conditions signalized by temperature sensors

Indication of combination of events for the temperature sensor:

- ID31:
    - Critical condition in case of fire.
    - Abnormal condition in case of significant increase of temperature.
- ID45: In combination with motion - when the patients are lying longer time without movements

Indication of events monitored by humidity sensors:

- ID31: Measurement of air humidity in the center of social care.
- ID45: It can monitor a patient´s home, for example, water leak but depends on who will help them to solve the problem.

Indication of combination of events for the humidity sensors:

- ID31: Measurement of the change of humidity from the reference defined by the Ministry of health
- ID45: Maybe it can show on the monitor, that something has happened but it could not send some alerts directly do to the nurse or maybe it can send info to the family members.

Indication of events monitored by pressure sensors:

- ID45: It can maybe measure gas, but it can be solved by a new cooker which doesn´t need gas but is fully electric.
- ID48: The pressure sensor can be used also for a water leak.

Indication of combination of events for the pressure sensors:

- ID45: combination with humidity.

3.2.5. Notifications

The results related to the notifications provided by the IoT solution are shown in Figure 30 - Figure 32

Answer	Count	Percentage
Yes (Y)	5	83.33%
No (N)	0	0.00%
No answer	0	0.00%
Not displayed	1	16.67%

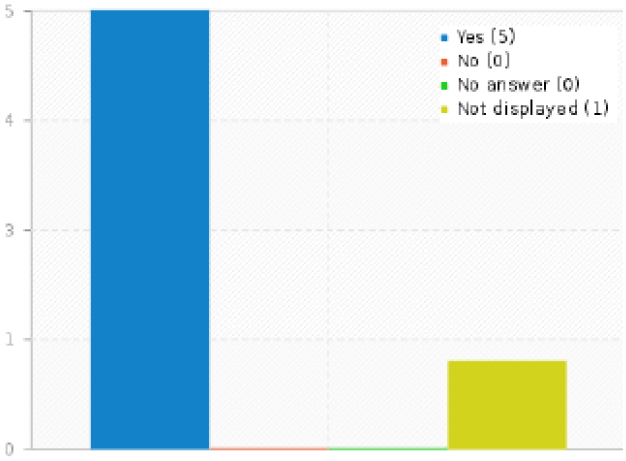


Figure 30: Requirement for warning the patient or the care giving personnel by sound notification

Answer	Count	Percentage
The patient (A1)	0	0.00%
The care giving person (A2)	2	33.33%
Both (A3)	3	50.00%
No answer	0	0.00%
Not displayed	1	16.67%

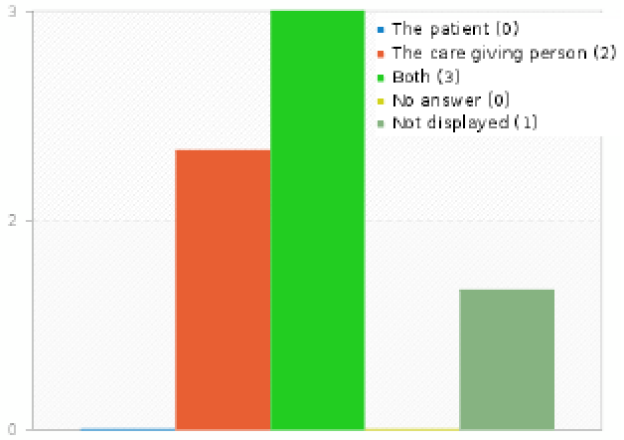


Figure 31: Requirement for warning the patient or the care giving personnel by sound notification

Indication of the type of noise that should be emitted in case of sound notification sensors:

- ID31: The notifications for patients in their home environment should be spoken instructions, such as warnings about taking the medicine or in case of fire.
- ID43: Depend on situation, just to be sure, that the patient is responding.
- ID45: Push notification on the phone - it depends on how critical the situation is.
- ID48: The warning sign with spoken instructions reminder to take any medication individual reminders (to eat, to make a call).

Answer	Count	Percentage
Yes (Y)	4	66.67%
No (N)	1	16.67%
No answer	0	0.00%
Not displayed	1	16.67%

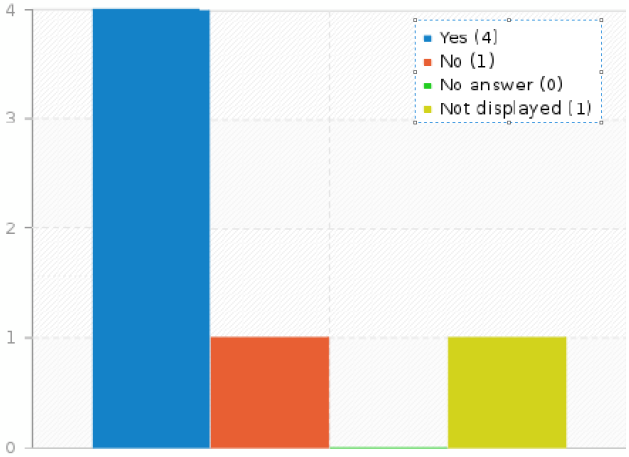


Figure 32: Requirement for warning the patient in case of fire event

Comments related to Figure 32:

- ID31: No comment.
- ID43: Nothing new.
- ID45: It should warm him by the sound and automatically call the family member.

3.2.6. Data storage

The results related to the requirements for data storage are shown in Figure 33.

Answer	Count	Percentage
Yes (Y)	3	50.00%
No (N)	2	33.33%
No answer	0	0.00%
Not displayed	1	16.67%

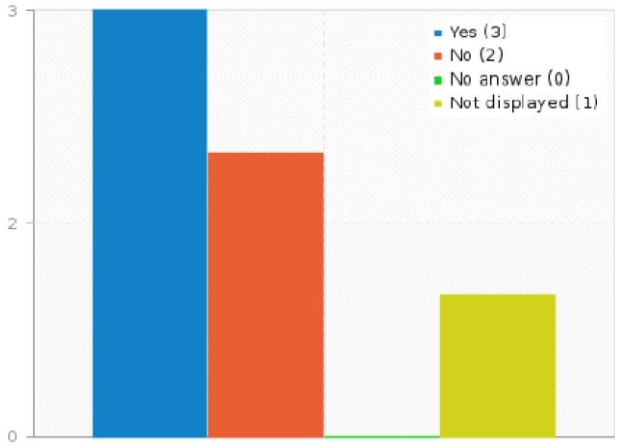


Figure 33: Requirement for data storage

Special requirements for data storage:

- ID31: To delete data after 3 days.
- ID45: To monitor behavioral changes and to use analysis SW to predict it.

3.2.7. Event identification

The results related to event identification, either to the care giving person or on a bracelet, are shown in Figure 34 - Figure 41.

Answer	Count	Percentage
No notification (SQ001)	2	33.33%
Green light on the screen (SQ002)	4	66.67%
Modest alarm beep (SQ003)	0	0.00%
Other	0	0.00%
Not displayed	1	16.67%

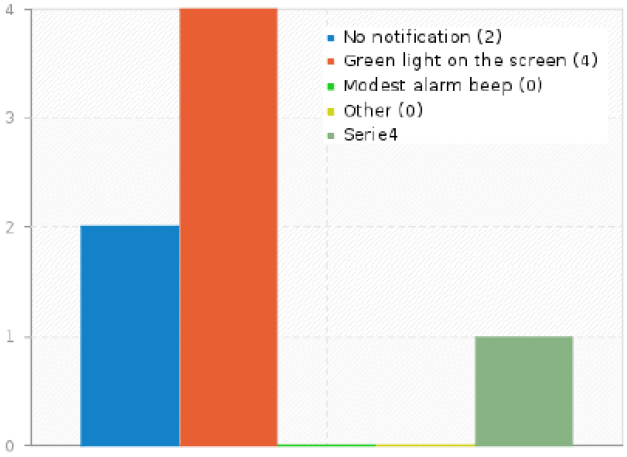


Figure 34: Indication of normal behavior for the nurse / care giver

Answer	Count	Percentage
Yellow light on the monitoring screen (SQ001)	4	66.67%
Modest alarm beep (SQ002)	4	66.67%
Alarm noise (SQ003)	0	0.00%
Room where the behavior was observed (SQ004)	4	66.67%
Name of the patient (SQ005)	2	33.33%
Map to location where the behavior was observed (SQ006)	4	66.67%
Message to pager/smart phone application (SQ007)	4	66.67%
Other	0	0.00%
Not displayed	1	16.67%

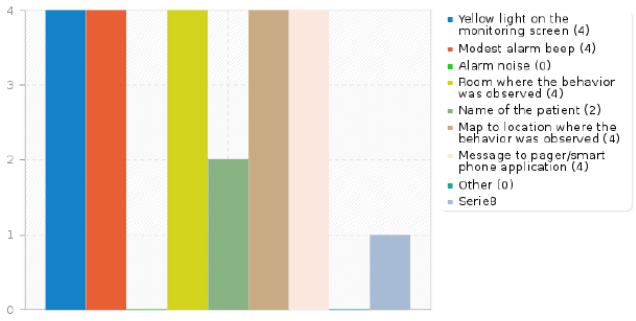


Figure 35: Indication of abnormal condition for the nurse / care giver

Answer	Count	Percentage
Red light on the monitoring screen (SQ001)	5	83.33%
Alarm noise (SQ002)	5	83.33%
Room where the behavior was observed (SQ003)	5	83.33%
Name of the patient (SQ004)	4	66.67%
Map to location where the behavior was observed (SQ005)	4	66.67%
Message to pager/smart phone application (SQ006)	5	83.33%
Other	0	0.00%
Not displayed	1	16.67%

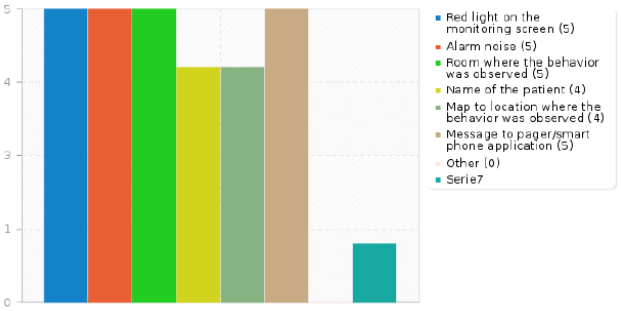


Figure 36: Indication of critical condition for the nurse / care giver

Answer	Count	Percentage
No notification (SQ001)	2	33.33%
Green light on the bracelet (SQ002)	3	50.00%
Other	0	0.00%
Not displayed	1	16.67%

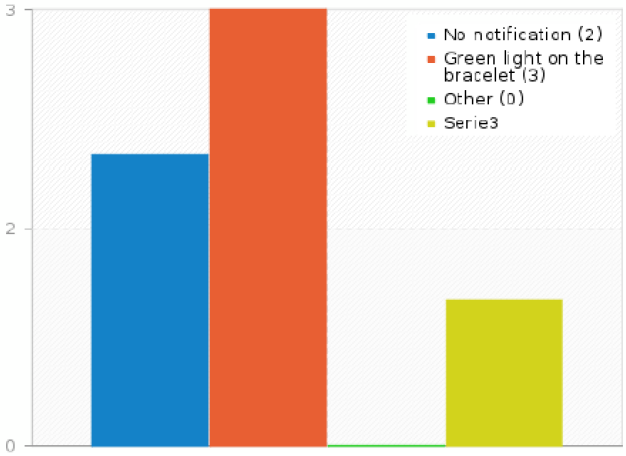


Figure 37: Indication of normal behavior on a bracelet

Answer	Count	Percentage
Yellow light on the bracelet (SQ001)	1	16.67%
Mild vibration of the bracelet (SQ002)	2	33.33%
Intense vibration of the bracelet (SQ003)	0	0.00%
Other	0	0.00%
Not displayed	4	66.67%

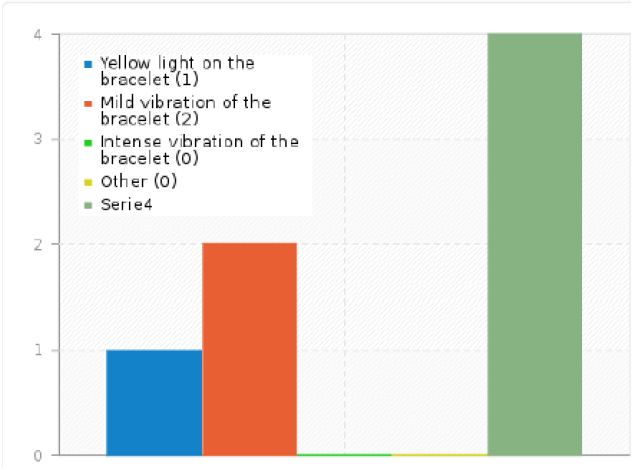


Figure 38: Indication of abnormal condition on a bracelet

Answer	Count	Percentage
Red light on the bracelet (SQ001)	1	16.67%
Intense vibration of the bracelet (SQ002)	2	33.33%
Sound notification of the bracelet (SQ003)	2	33.33%
Other	0	0.00%
Not displayed	4	66.67%

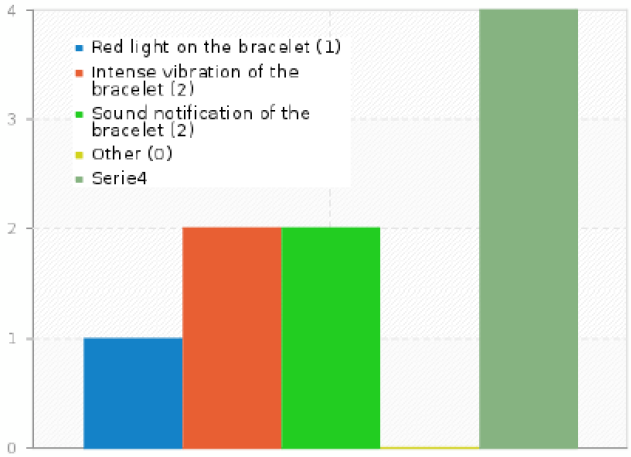


Figure 39: Indication of critical condition on a bracelet

Answer	Count	Percentage
The battery indicator should flash all the time, also in the case when is fully charged and battery level will be differentiate by the color or another proper sign (SQ001)	0	0.00%
Low battery in the bracelet should be indicated by mild vibrations with flashing warning diode (SQ002)	1	16.67%
Only low battery indicator will flash (SQ003)	1	16.67%
Other	0	0.00%
Not displayed	4	66.67%

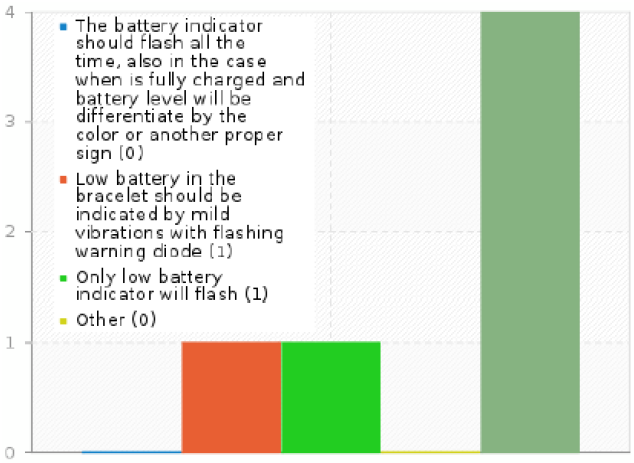


Figure 40: Indication of the battery level of the bracelet

Answer	Count	Percentage
Yes (Y)	2	33.33%
No (N)	0	0.00%
No answer	0	0.00%
Not displayed	4	66.67%

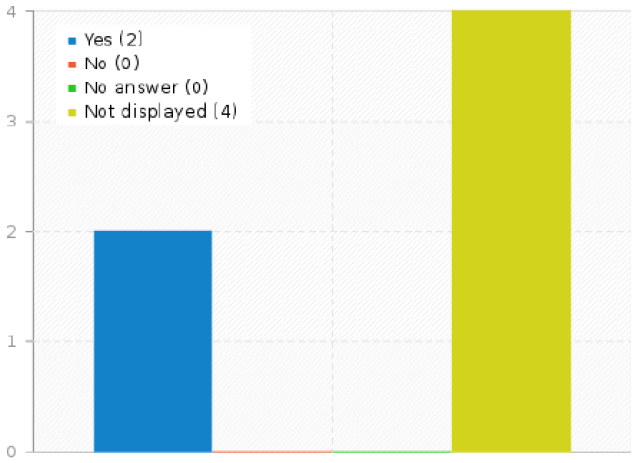


Figure 41: Requirement for the bracelet to be connectable to a smartphone

3.2.8. Other comments

Special comments on the use of IoT solutions are as follows:

- ID31: Setting up signalization options based on the requirements of the user.

3.3. Summary of collected data

The survey has been completed by 6 users representing 3 institutions, the Petržalka Municipal District of Bratislava, The University Hospital Olomouc and the Municipality of Olomouc City. Among them, 3 institutions are involved in the care of patients suffering from frail elderly and 3 have experience with all listed chronical diseases (Alzheimer disease, Parkinson's disease and Frailty elderly).

Regarding the behavior of treated patients, the partners responded that their patients live in their own reality, lost, without or in limited contact with their environment. They also suffer from confusion, loss of self-care, need of an accompanying person and separation.

Two out of six respondent claimed that they already have experience with IoT solutions for monitoring the conditions of their patients. The system is mainly used for patients suffering from dementia. It is a simple system controlling the client´s bed and serving for signalization of behavioral changes. Its advantage is that information are provided to the care giver without requiring his/her presence in the client's room. However, the system is not capable of identifying the level of danger and the problem of the client. In addition, the system does not have data storage capability.

Five out of six respondent claimed that they would use IoT solutions for monitoring the conditions of their patients / clients in the future. 66.67 % of the respondent claimed that the most suitable option for power supply would be from battery, while 33.33 % selected wall outlet and 16.16 % prefer both options. 50 % of the respondents would also prefer multiple operation modes of the IoT system making possible different regimes for day and night or distinguishing between immobile and mobile patients. Regarding the sensors, the most important once are the motion (5 counts), sound (4), gas (4), temperature (4), pressure (3) light (2), humidity (2) and the opening/closing event (2) sensor. The respondent found important for the movement sensors to be combined with temperature and noise sensors. 66.67 % of respondents also claimed that in case of gas release or fire event, it would be important to notice not only the care giver or the family member, but also the patient himself. In case of humidity sensors, it is important to measure the difference of the level of humidity from the one defined by the Ministry of health.

Five out of six respondent found the IoT solution important to provide sound notifications both to the patient and the care giver. Only 33 % of respondents think that it is appropriate to notify only the care giver. They claimed that notifications of patients in their home environment should be in a form of spoken instructions and also push notification should be available on the smartphones of family members. The majority of respondent claimed that in case of a fire event, the IoT solution should notify the patient and call his/her family members.

In case of system that provides notification on a smartphone or PC/laptop, normal behavior of the patient should be signalized by green light on the screen. Abnormal condition of the patient should be signalized by yellow light on the screen, with modest alarm beep and by message on mobile phone. In some cases, it would be also preferable to provide a map to the location where the behavior was observed. The critical condition should be signalized by red light, strong alarm and by message to pager/smart phone. It would be also important to provide information on the patient, i.e. name, room number, map.

When bracelet is used for notifications, the respondent claimed the normal behavior should either be not signalized or signalized by green light on the bracelet. Abnormal condition should be indicated by yellow light and mild vibration of the bracelet. Critical condition should be signalized by strong vibration, red light and loud sound on the bracelet. The users indicated, that low battery level of the bracelet should be also indicated by flashing light or vibration. 33 % of respondent claim the bracelet to be connectable to a smartphone.

4. Construction of AP-NURSE units

The construction of the AP-NURSE units is divided into two branches based on the proposed systems (Home and Care). The AP-NURSE Home porotype was developed based on the former deliverable D.T2.2.2 **[1]**, where the brief description and schematics for the development were shown. The whole system was designed from the scratch, including the definition of the PCB boards and all other assembly processes. In the case of AP-NURSE Care, the porotype was based on the M5STACK platform that achieves high modularity and provides high level of inter-connectivity. In the following sub-sections, the possible modifications and versions of AP-NURSE Home & Care are explained including hardware, software, server and casing descriptions.

4.1. AP-NURSE Home

One of the goals of AP-NURSE Home is to become an affordable monitoring system for patients suffering from Alzheimer's and Parkinson's disease treated at their home environments. Therefore, the components for the construction of devices were chosen cost-efficiently aiming to decrease the total price of the whole monitoring system. Regarding the first idea, purpose of the system would be to monitor multiple premises at the patient's home and possible monitoring layout grid is shown in Figure 42. The purpose of each node is different, and an example of the monitoring sensor compositions is shown Figure 43. The AP-NURSE Home porotype was developed in a maximal configuration manner, i.e. if required, all sensors should be connected to one node. The signalization of possible events is provided on the bracelet worn by the caregiver via radio transmission, where the flashing yellow light represent abnormal and the red light critical condition of the patient. The event is also indicated by vibration of the bracelet. Further information about the event signalization can be found in the deliverable [1]. If required, AP-NURSE Home might be further extended to be applicable in care centers, where bracelet signalization is not effective. Therefore, the AP-NURSE Home may support data collection on server and remote alert notification using HTTPS requests. The prototype features also day/night mode, where the mode can be switched manually or can be triggered automatically, if the internet network is available. The automatic day/night mode switch is required for application in care centers, where many nodes are in operation simultaneously. The possible versions of AP-NURSE Home are presented in the next sub-section.

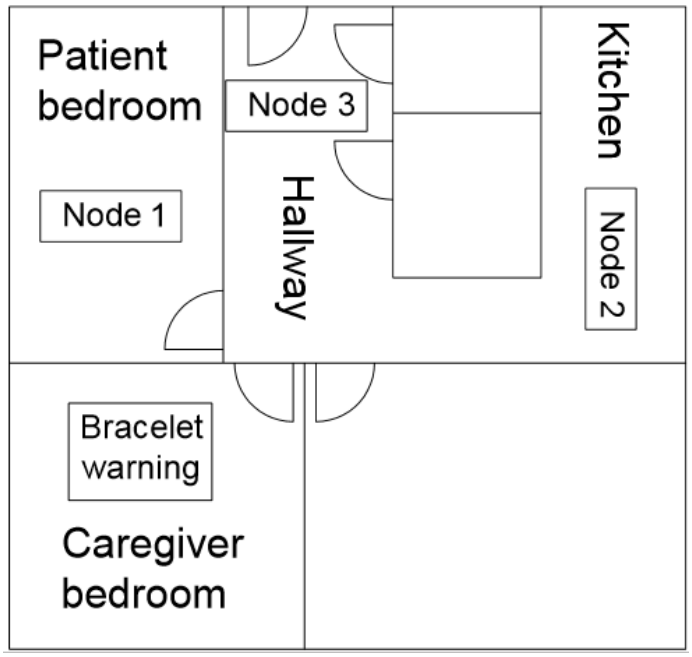


Figure 42: AP-NURSE Home monitoring layout grid

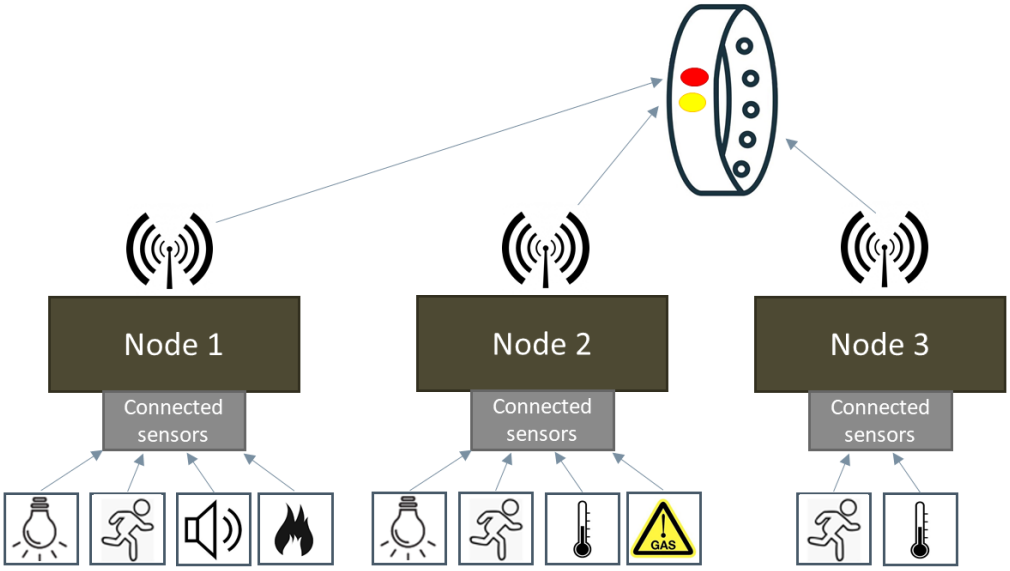


Figure 43: AP-NURSE Home node designs example

4.1.1. Versions

The versions of AP-NURSE Home have been selected based on specific needs of potential users, especially the Home for elderly at the Mlynarovičova street, operated by the Petržalka Municipal District of Bratislava. Insights and remarks obtained from the representatives of the Home for elderly, played an important part in the design of AP-NURSE Home. The current version of AP-NURSE Home consists of two self-developed motherboards (PCB circuit boards), one design for the main sensor device and one design for the bracelet. The main sensor device is by default capable of mounting all sensors that were proposed for AP-NURSE Home:

- PIR – movement
- force / pressure
- noise
- gyroscope
- gas, smoke
- BME - temperature, humidity
- light

A series of tests of sensors and their settings were prepared and they are described later in Chapter 5 in more detail. Alerts, which are results of occurred events are based on the logic defined in previous chapter. The alerts are not only sensor-based, but rather event-based, as it is defined in Table 2. The table includes all versions, which are expected to be tested at the Home for elderly and also at the STU testing environment. Since the final settings of devices depends on testing, here on the basic functionality and sensor outputs are described. All scenarios are tested and experimental sensor are to be evaluated (gyroscope, noise).

Table 2: Versions of AP NURSE Home

AP NURSE HOME version	Type of patient	Device mode	Event	Sensors						Trigger alert
				Mov.	Force	Noise	Light	Gas	Temp.	
AP1 - under the bed (mobile)	mobile	day	patient got up from the bed	1	1>0					✗
		night	patient got up from the bed	1	1>0		0			⚠
		night	fall from the bed	1	0=0		0			❗
		day	walking in the room	1	0					✗
		night	walking in the room	1	0		1			⚠
		night	walking in the room	1	0		0			❗
		day / night	smoking					1		❗
AP2 - doors to toilets in patient's room		night	loud noise			1				❗
		day / night	temperature drop						1	⚠
		day / night	entering the bathroom	1						⚠
		day / night	stuck in the bathroom	0=0						❗
		day / night	leaving the bathroom	1						✗
AP3 - under the bed (imobile)	imobile	day / night	patient got up from the bed	1	1>0					❗
		day / night	walking in the room	1	1					⚠
		day / night	smoking					1		⚠
		night	loud noise			1				⚠
		day / night	temperature drop						1	❗
AP4 - common rooms, stairs, forbidden zones for patients	mobile / imobile	night	movement	1						✗
		night	loud noise			1				⚠
		day	movement	1						✗
		day	loud noise			1				✗
AP5 - doors to common toilet or bathroom doors		night	entering the common bathroom	1						⚠
		night	stuck in the common bathroom	0=0						❗
		night	leaving the common bathroom	1						✗
AP6 - kitchen		day / night	gas leakage / smoke detection					1		❗
		night	movement	1						❗
		night	loud noise			1				❗
		night	light				1			⚠

Brief description of AP-NURSE Home versions:

- AP1 version is meant to be placed under the mobile patient's bed, to monitor basic movement around the room, noise and patient's movement in the bed.
- AP2 is designated for mobile patient's bathroom door. Opening the door will trigger the sensor and based on the time delay and optional noise sensor will trigger the alert.
- AP3 is similar to AP1 version, but it is for immobile patients.
- AP4 should be placed in common places like stairways or hallways to monitor mostly movement in the night.
- AP5 is similar to AP2 but with different alerts setting.
- AP6 is designed to be used in a kitchen like environment, aimed mostly on gases and smoke.

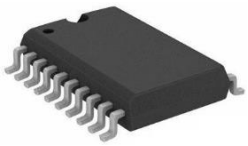
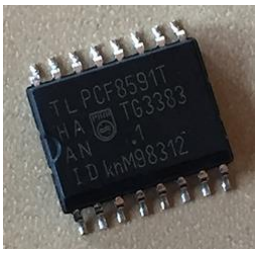
As can be seen, there are six main proposed versions of AP-NURSE Home, which are divided based on the mode, possible event in near their proximity and patient's mobility. The selected sensors are: movement, force, noise, light gas and temperature sensor. Alert in each device is estimated based on the sensors response, in table marked "1" as triggered and "0" as not triggered. Symbol ">" represents transition from one state to another, while "=" stands for keeping the state of the sensor for a certain (not defined yet) time.

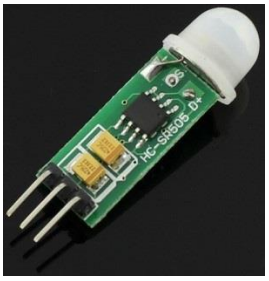
4.1.2. Hardware

AP-NURSE Home is based on the NodeMcu ESP8266 microcontroller that monitors the environment via multiple sensors attached. The hardware components and connectivity schemes of the sensors to ESP microcontroller were briefly described in [1]. The list of components with their technical description are summarized in Table 3.

Table 3: List of AP-NURSE Home components

USB adapter ER-RPA10055A 	The USB adapter supplies the voltage to the AP-NURSE Home sensor board through micro USB port. The output voltage and current is 5V / 3A DC.
Power bank – 4400 mAh 	The power bank can be installed to the sensor board for the power supply. The power bank contains pass-through feature that enables continuous charging from the power-outlet. If the loss of power supply in power outlet occurred, the power bank restarts itself and starts to power supply the sensor board. The output voltage and current is 5V / 1A DC.
NodeMcu ESP8266	The NodeMcu unit integrates the chip ESP8266 as its main unit. It contains the Xtensa LX106 32-bit processor with 80 MHz clock frequency. The 1 MB compiled code can be stored in this

	microcontroller for the operation and analysis of different events signalized by the connected sensors. In total 11 GPIO pins are placed on ESP8266. The operational voltage range is between the 3.3 - 5 V and the current is 12 mA.
RF 433 MHz transmitter and receiver 	The communication between the sensor board and the bracelet is provided via RF 433 MHz radio. The operation voltage of the transmitter is 3 – 12 V, the current 9 – 40 mA, the transmission power 25 mW, the maximal frequency error +150 kHz and the transmission range is 90 m in open spaces. The operating voltage of the receiver is 5 V and maximal current is 5.5 mA [2].
HT12E and HT12D (20 SOP-A version)  	The encoder and the decoder provide correct communication between RF 433 transmitter and receiver. To ensure a proper communication, both oscillation circuits has to be correctly setup. Currently the encoder oscillator utilizes 1 MΩ resistor and the decoder uses 68 kΩ resistor. More information about the oscillator setup can be found in [1]. The encoder working voltage is 2.4 – 12 V, standby current 0.1 µA (at 5 V) and the output high voltage is on the level 3 V [3]. The decoder working voltage is 2.4 – 12 V, maximal operation current 1 µA, maximal standby current 400 µA and the output high voltage is in the range of 3.5 – 5 V [4]. Using these components, 7 devices can be operated in parallel. Each transmitting device can send 4 different signals through the AD8-AD11 switches.
PCF8591 analog extender 	PCF8591 is used as analog extender for the NodeMcu ESP8266. NodeMcu ESP8266 contains only one analog input and therefore, the extender will provide additional analog connections for multiple analog sensors, if required, through I^2C protocol. The operation voltage is 2.5 – 6 V and the input voltage from the analog sensor is 1 V [5].
Buzzer	The function of the buzzer is to produce acoustic alarm during critical and abnormal conditions. The working voltage is 3.5 – 5.5 V and the maximal operation current 25 mA [6].

	
BME 280 Atmospheric Sensor 	BME280 Atmospheric Sensor is a combined digital humidity (from 0 to 100 % relative humidity with ±3 % accuracy), pressure (from 300 to 1100 hPa) and temperature sensor (range from -40 to 85 °C with ±1 °C accuracy). This sensor achieves high performance in all applications requiring the measurement of above-mentioned variables. If necessary, BME280 can operate in sleep, normal and forced mode (performing one measurement and returning to the sleep mode). The working voltage of the sensor varies is from 3.3 V to 5, the working current 400 mA, standby current 200 µA [7].
HC-SR505 PIR Sensor 	HC-SR505 Mini PIR Motion Sensor is photosensitive sensor that can monitor the person's presence in the sensing area (approximately conic angle 100 degrees to the distance 7 m). The operational temperature is in the range from 20 to 80 °C, therefore the indoor application is considered in case of the AP-NURSE Home version. It supports operating voltage range between 4.5 - 20 V with current lower than 50 µA [8].
MQ Gas Sensors 	Two types of gas sensors are considered for AP-NURSE Home. The first one is the MQ-5 gas sensor that can detect LPG, LNG, natural gas, iso-butane, propane with high sensitivity (e.g. the resistivity of the sensors lowers 4.5 times when the concentration of LPG increases from 200 to 10000 ppm) [9]. Its application in AP-NURSE Home is in kitchen, where the patient may accidently turn on the gas stove. The second gas sensor is the MQ-135, which is suitable for detecting smoke and other gases such as NH_3, NO_X, alcohol, benzene, CO, CO_2, etc. [10]. The operation voltage of both sensors is 5V with the consumption lower than 800 mW. The standard detection conditions are at 20 °C and 65 % relative humidity for both sensors.
MPU6050 accelerometer	MPU6050 sensor is a 6-axis motion tracking device that combines 3-axis gyroscope and 3-

	axis accelerometer. The power supply working voltage is in the range from 2.375 to 3.46 V, working current 500 μA. The application of the MPU6050 is to monitor movement of the patient. The possible location of this sensor can be in areas where the patient has to cross some kind of boundary (e.g. door or window) or can be placed in the bed under the mattress to monitor the sleep behavior of the patient [11].
KY-038 Noise Sensor 	Sensor KY-038 is used for the detection of noise in the area. The working voltage of the sensor is 5.0 V. The detection range is approximately 30 – 130 dB. The sensor supports the setup of the threshold when the signal is generated, therefore it can be easily optimized for appropriate environment [12].
GL5528 photoresistor 	GL5528 photo-resistor is used for the detection of light. The principle is simple, the lighting of the sensor will change the resistivity of the photo-resistor and the change of the voltage is registered by the NodeMcu ESP8266. The maximum input voltage of the photo-resistor is 150 V. The resistivity value in the dark is 1 MΩ and in the light between 8-20 kΩ. The lightning is measured between 10 and 100 lux [13].
FSR 402 Force Sensor 	FSR402 force sensor is used for the measurement of the applied force on any kind of surface or object. The operation voltage is 3.3 V. This sensor can be used for the monitoring of barrier that should not be crossed by the patient. For example, during night, the patient should not leave the apartment, so this sensor can be placed under the door-mat in the hallway. This sensor can measure the mass in the range from 100 g to 10 kg [14].

After the testing all of the chosen components, the circuit schematics were designed for both the sensor board (Figure 44) and for the bracelet (Figure 45). Based on these schemes, prototype PCB circuit boards were designed for manufacturing. The PCB porotypes of the sensor board and the bracelet board are shown in Figure 46 from top and bottom view. The graphical design of the whole sensor board prototype with all components, except the sensors is shown in Figure 47. The sensors will be connected to the appropriate headers directly or by extending cables to ensure effective and portable casing design of whole device. In this design two buttons will be embedded in the casing, one restart button and one programmable event button. Day/night switch is also embedded in the casing. Inside of the casing there is an address switcher, which is used to change the signal addresses of the encoder for the parallel communication of multiple nodes. The power supply of the sensor board may be direct from the wall outlet or from battery.

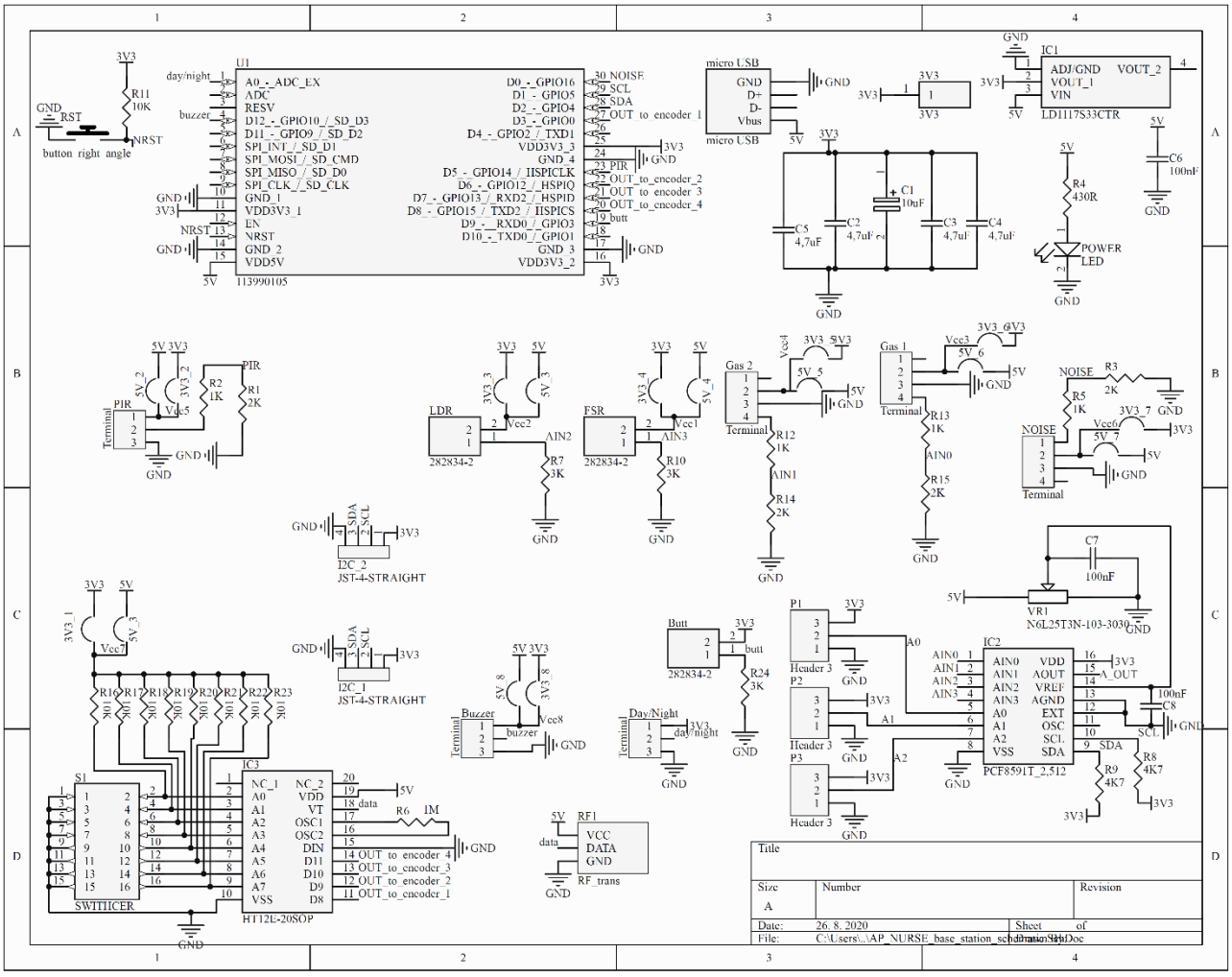


Figure 44: AP-NURSE Home sensor board schematics

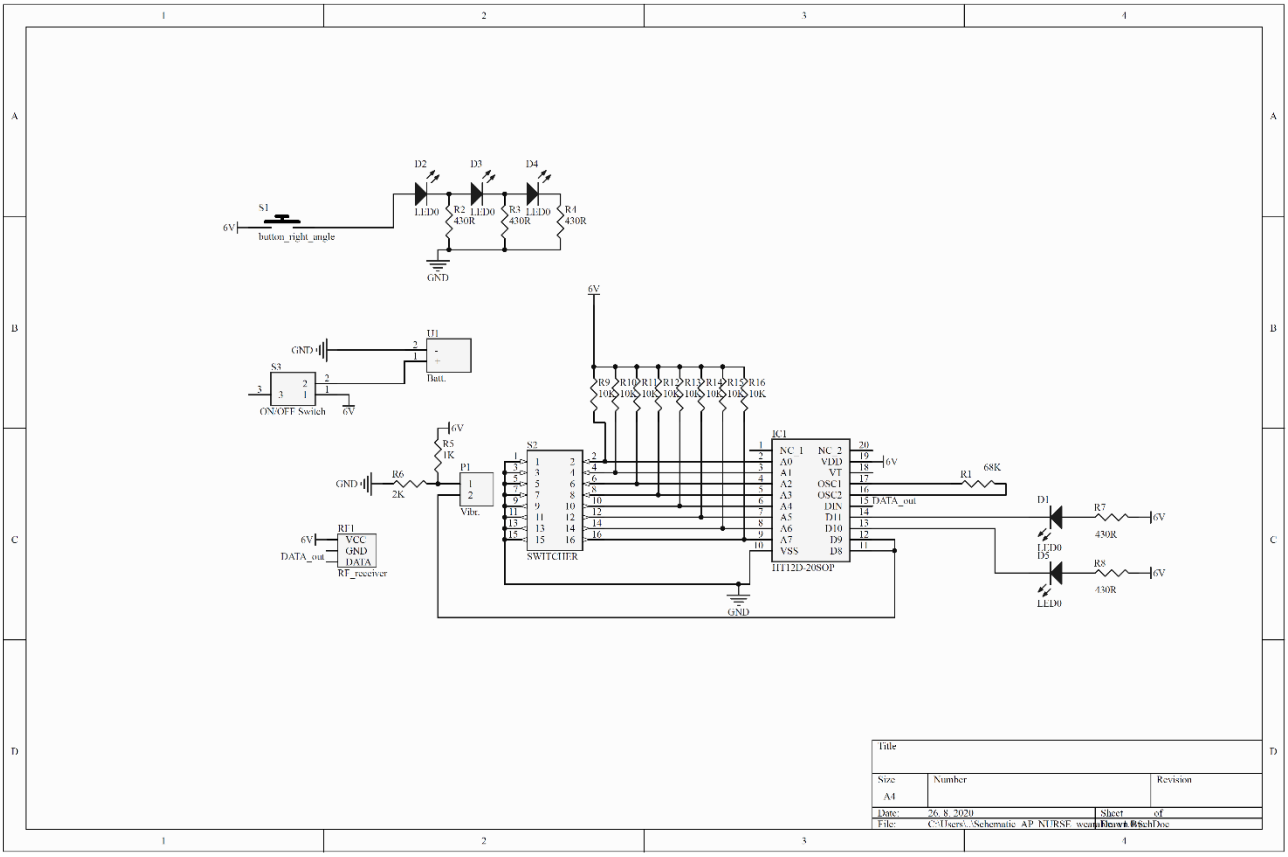
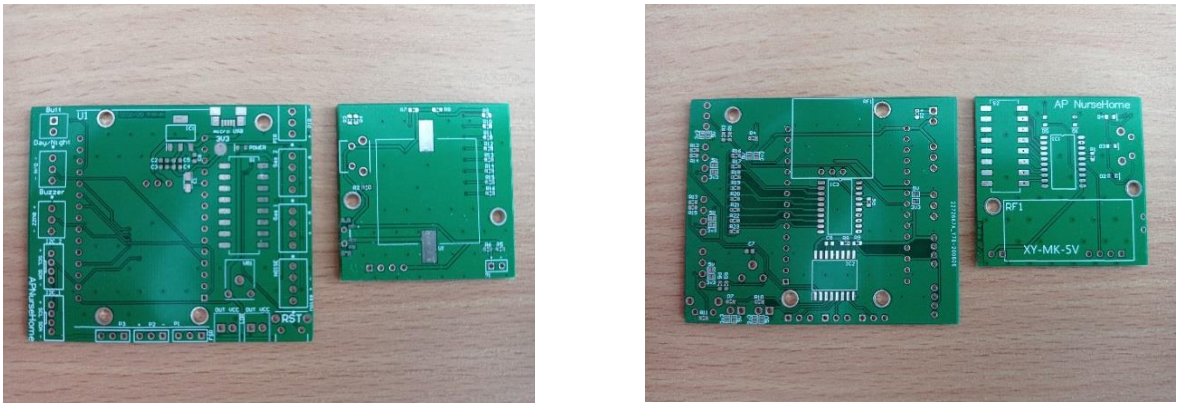
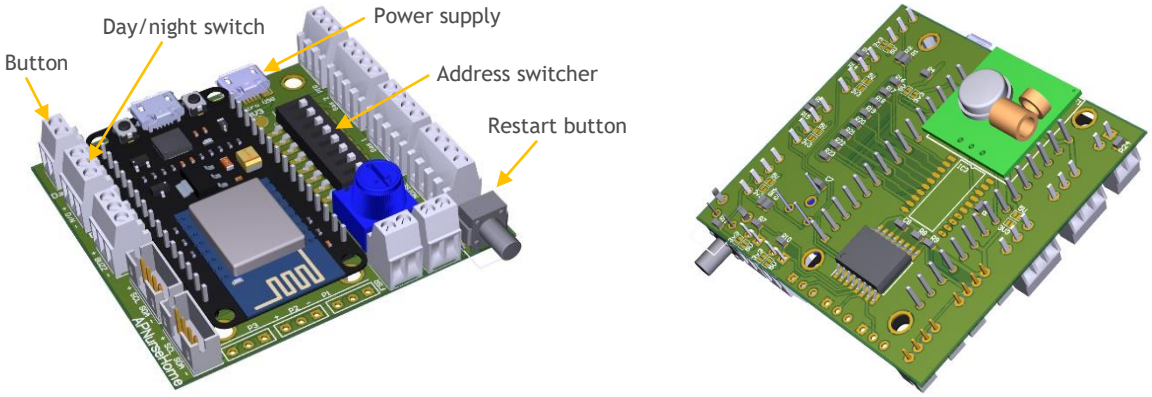


Figure 45: AP-NURSE Home bracelet schematics



a) Top view *b) Bottom view*

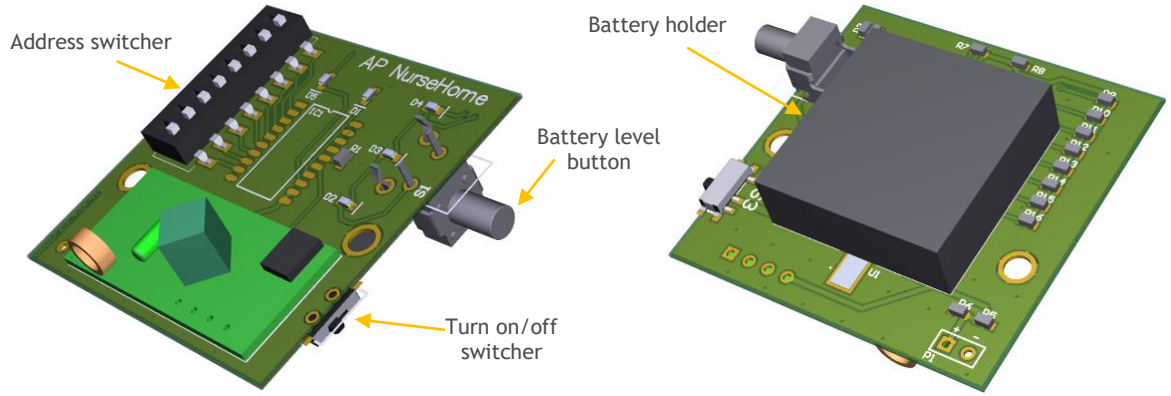
Figure 46: AP-NURSE Home PCBs



a) Top view *b) Bottom view*

Figure 47: AP-NURSE Home Design of PCB sensor board

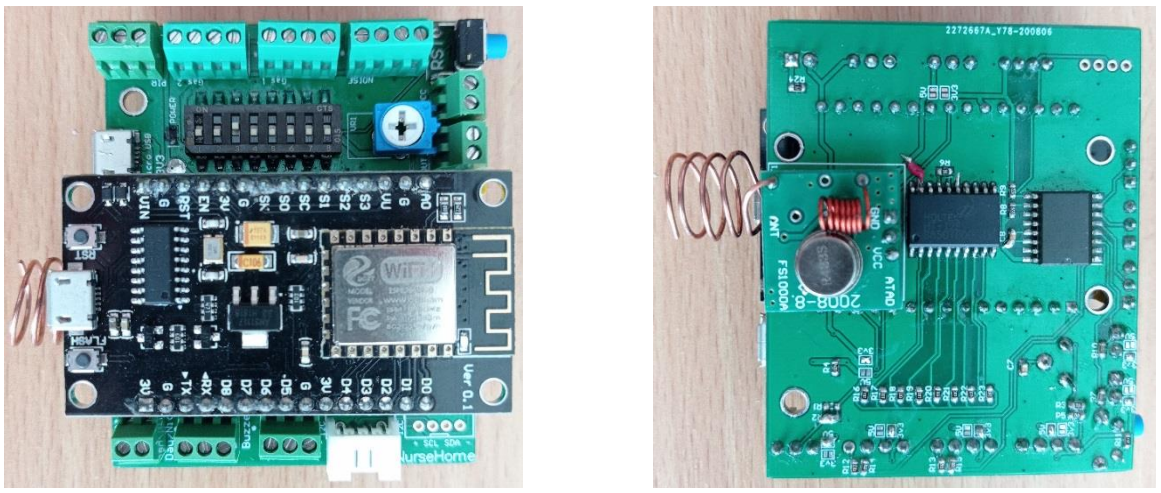
The graphical design of the board of the bracelet prototype, with all components except the vibration module, is shown in Figure 48. The vibration module will be connected next to the CR2330 battery holder. Like the sensor board, the bracelet module also includes address switcher enabling changing the address of the decoder for parallel communication of multiple nodes. One switcher is embedded into the casing and its function is to turn on the device. The function of the button embedded in the casing is to monitor the battery level of the bracelet. The R2, R3 and R4 resistors (from schematics in Figure 45) are used for proper monitoring of the battery level.



a) Top view *b) Bottom view*

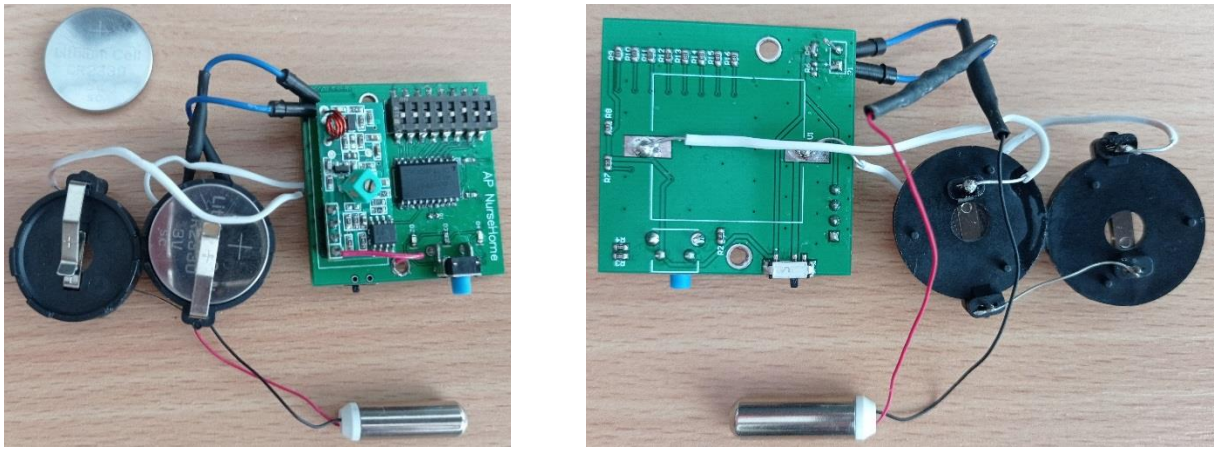
Figure 48: AP-NURSE Home Design of PCB bracelet board

The functional porotype was created and the sensor board porotype is shown in Figure 49. Additional antenna was attached to increase the distance of the radio transmission communication and, based on the frequency (433 MHz) the antenna should have length approximately 16 cm. The bracelet prototype is shown in Figure 50. Two separate battery holders were used for the testing of different voltage inputs and in the future, compact casing will be embedded to the prototype.



a) Top view *b) Bottom view*

Figure 49: AP-NURSE Home sensor board prototype



a) Top view *b) Bottom view*

Figure 50: AP-NURSE Home bracelet prototype

4.1.3. Software

The AP-Nurse Home unit is fitted with a custom built firmware based on the ESP8266 Arduino core. It is capable of handling data acquisition with the use of a variety of supported sensors. Its firmware supports configurable multi-level alert warnings triggered by external or internal events such as:

1. Motion
2. Light
3. Noise
4. Smoke
5. Gas
6. Pressure
7. Ambient temperature and humidity
8. Wi-Fi connection loss

In case of user demand, the firmware also supports data collection and remote alert notification using HTTPS requests. A more detailed description of the firmware is shown in **Figure 51**.

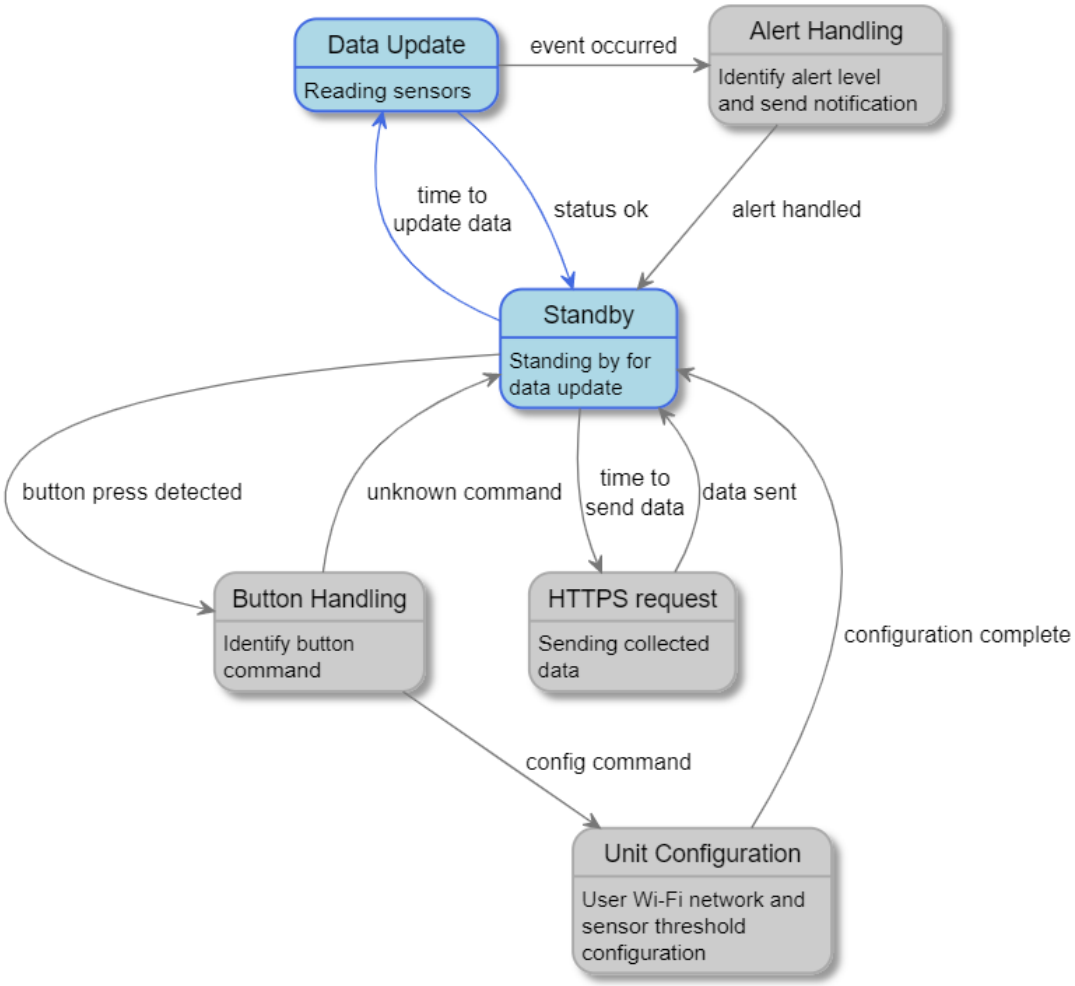
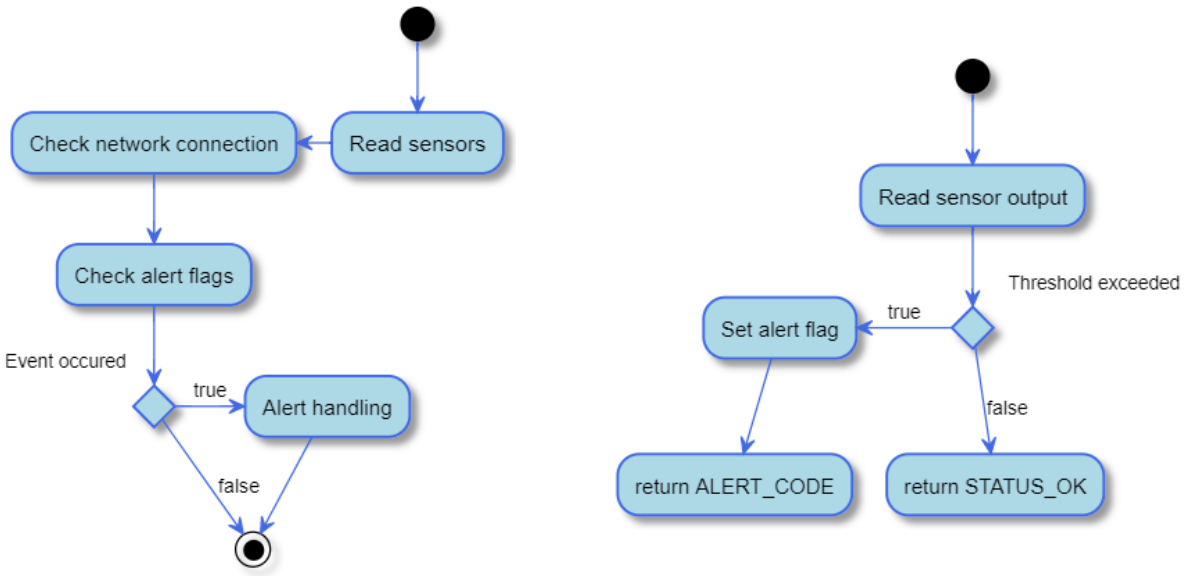


Figure 51: AP-NURSE Home firmware state diagram

On device boot, the esp8266 initialises its peripherals and the AP-Nurse Home control module. After the unit is booted, the Wi-Fi network connection is in order. On successful network connection the firmware enters its main program loop. The main loop consists of two alternating states: unit standby and data update. During the standby state, the unit stands by either for a data update, button command interrupt or collected data dispatch HTTPS request. Once data update has been initiated, the firmware reads all connected sensor outputs and evaluates them. The process of data update is shown in Figure 52.



a) Data update *b) Sensor reading*

Figure 52: AP-NURSE Home data processing diagram

During the data update phase, the firmware also verifies the network connection. In case of a sensor value overrun or network connection loss, an alert flag is set. The alert flags are subsequently evaluated and alert handling is triggered as it is shown in Figure 53.

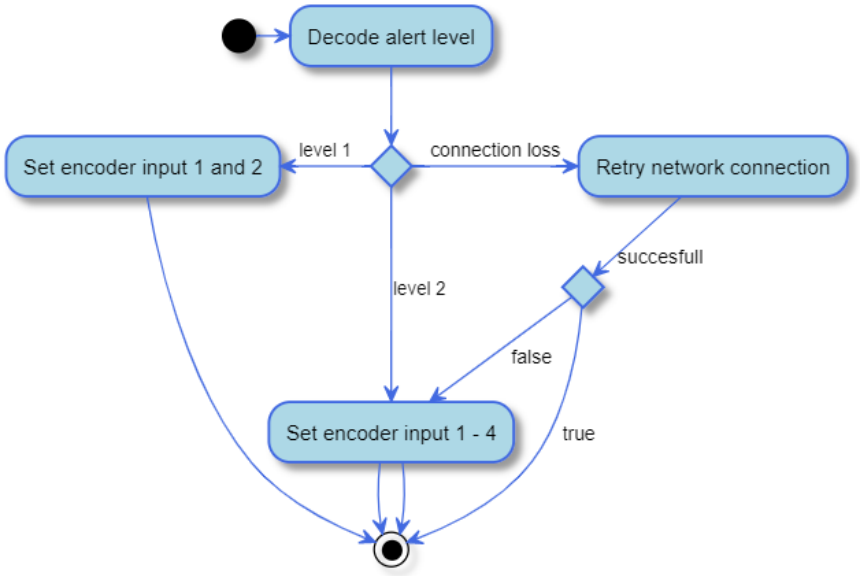


Figure 53: AP-NURSE Home alert handling diagram

Alert notification is provided by controlling four data inputs of the HT12E RF communication encoder that subsequently transmits the given notification. The AP-NURSE Home firmware also features a button handler able to distinguishing between multiple button commands consisting of a short and long button press. The present version of the firmware is however configured only to respond to a long button press. Alternative button commands and their function will be the subject of future testing. The long button press command triggers the unit configuration mode. The unit configuration uses a local server accessible through a Wi-Fi access point generated by the unit (Figure 54). Once connected, the unit can be configured using any standard internet browser.

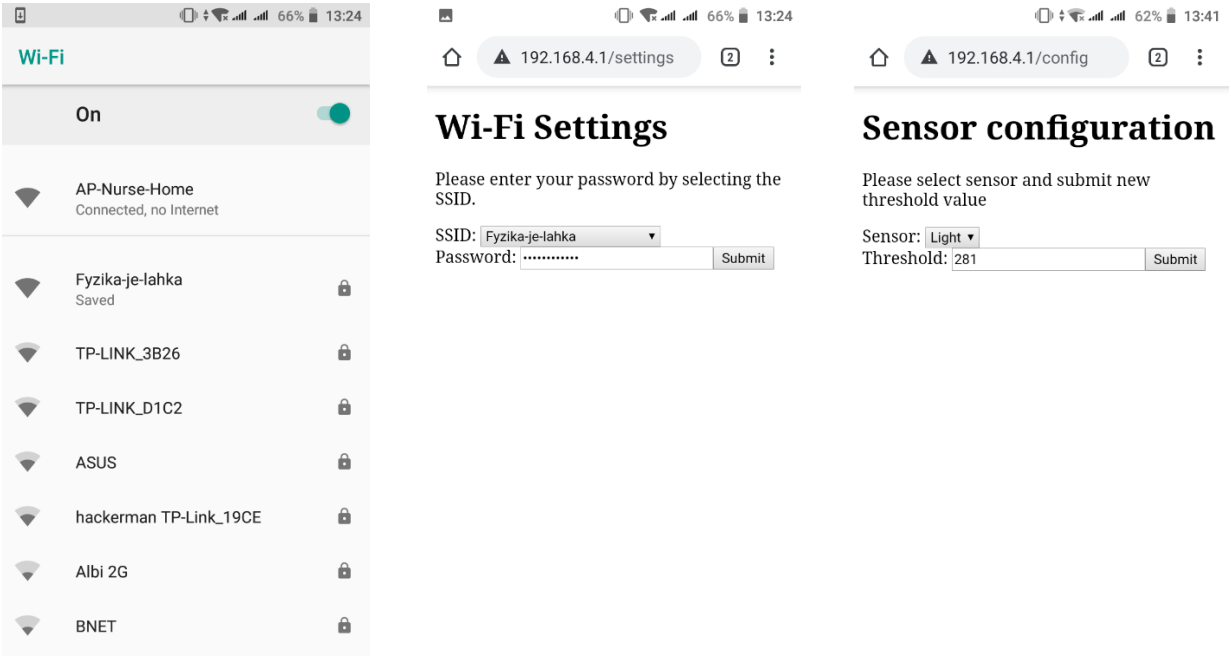


Figure 54: AP-NURSE Home unit configuration

4.1.4. Casing

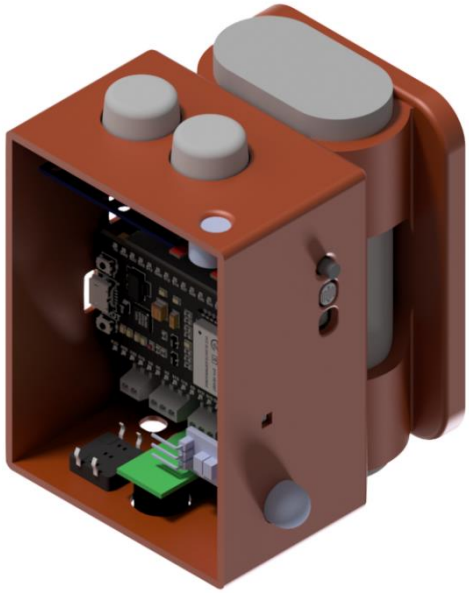
The AP-NURSE Home casing is designed to cover and secure the hardware. The following requirements have been established and applied in the design:

- Simple construction: The casing is designed to be printed on the 3D printer. The supports are not required. The model is possible to print with most of the 3D printers' types.
- Easy access: All controllers are easily accessible from the top side. The top cover is possible to open fast and easy with no requirements for screwing. The additional demounting of the parts is not necessary. All frequently used controllers are possible accessible from the exterior of the casing box.
- Easy mounting/demounting: Except the control board, the parts are mounted/demounted with no additional mounting/demounting requirements for other parts.
- Wiring elimination: The positioning of the peripheries is designed to eliminate the wiring length. The position of the peripheries is therefore as close as possible to the connectors on the control board.
- Stable parts fixation: The control board is fixed by the screw. Other parts are fixed by the pressure of the casing box tops and by the soft glue.
- Box fixation: There are holes from the bottom side of the box to provide the screw-based fixation on the wall.

The AP-NURSE Home consist of AP-NURSE Home base and AP-NURSE Home wearables.

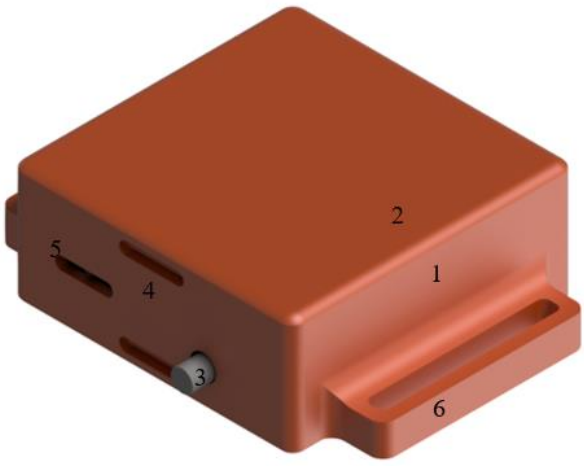
AP-NURSE Home base casing consist of three parts – battery holder, box base part and box cover part (Figure 55). Battery holder is designed to be fixed on the wall by the screws or just situated on the table or another flat area. The parts are fixed together with a screw-free fixation system, just by pressing them together. The battery may be inserted or removed also when the whole system is mounted together. The dimensions of the mounted system are 8.6 cm x 5.4 cm x 7.6 cm.

a; Mounted casing box for the AP-NURSE-HOME base. 1. Box cover part, 2. Box base part, 3. Temperature+humidity+pressure sensor, 4. Reset button, light sensor, connector for deformation sensor, PIR sensor, 6. Gas sensor, 7. Voice sensor, 8. Battery, 9. Battery and module holder

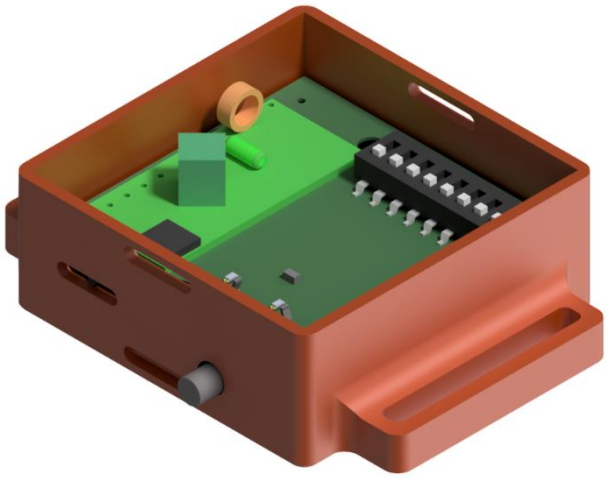


b; Removed box cover part from the AP-NURSE-HOME base. After removing the cover part, additional controllers are accessible on the PCB

Figure 55: AP-NURSE Home base casing



a; Mounted casing box for the AP-NURSE-HOME wearables. 1. Box base part, 2. Box top cover part, 3. Reset button, 4. Fixation slot, 5. Button slot 6. Strap slot



b; Removed box cover part from the AP-NURSE-HOME wearables. After removing the cover part, additional controllers are accessible on the PCB

Figure 56: AP-NURSE Home wearables

AP-NURSE Home wearables (see Figure 56) casing consist of three parts – box base part, box bottom cover part and box top cover part. Battery is accessible by opening the box bottom cover part. The reset button is accessible from the outside the box, the other buttons located on the PCB are accessible after removal of the top cover part. The parts are fixed together with a screw-free fixation system, just by pressing them together. The dimensions of the mounted system are 4.4 cm x 6.0 cm x 1.9 cm.

4.2. AP-NURSE Care – M5STACK

Since the AP-NURSE Care system aims to be used in social homes and care centers, where patients suffering from Alzheimer's and Parkinson's diseases are treated, it encompasses multiple modules able to monitor several environmental indicators at the same time. The client solution consists of one or multiple sensor units (SU), a central unit (CU), and a communication gateway. A sensor unit is a small handy device that is placed in a dedicated position in the patient's environment (bedroom, stairs, kitchen, etc. – see Figure 57). It is responsible for the measurement of various parameters, such as temperature, light intensity, noise, etc. In addition to monitoring environmental parameters, the sensor units communicate with the central unit using a wireless interface. This unit is placed in the nursing room and collects parameters from individual sensor units. The processed data and all respective warnings and notifications can then be displayed on a PC or using a mobile APP. Figure 42 shows the diagram of possible locations of individual devices. It enables the display of collected data, which it then transfers to a dedicated server, where the measured data is processed.

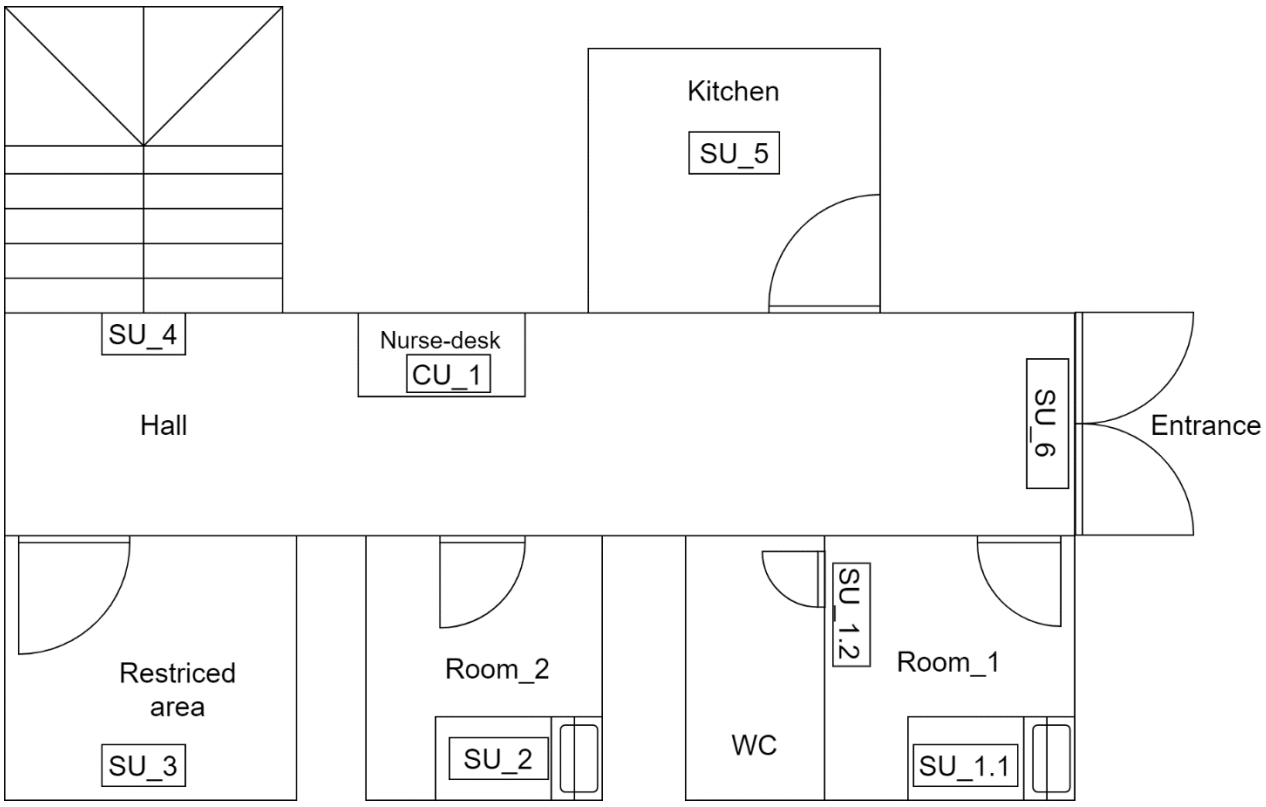


Figure 57: AP-NURSE Care monitoring layout grid

4.2.1. Versions

In order to fulfil the widest possible spectrum of use cases in care centers, AP-NURSE Care has to be adapted into a set of sensor unit and central unit configurations. These configurations are based on the AP-NURSE Home versions described in Table 2. The sensor unit configurations are shown in Figure 58 - Figure 60. These configurations cover four cases defined in the chapter describing AP-NURSE Home. AP1, AP2, AP4 and AP6. The AP3 and AP5 versions are not considered for AP-NURSE Care.

1. AP1 - under the bed

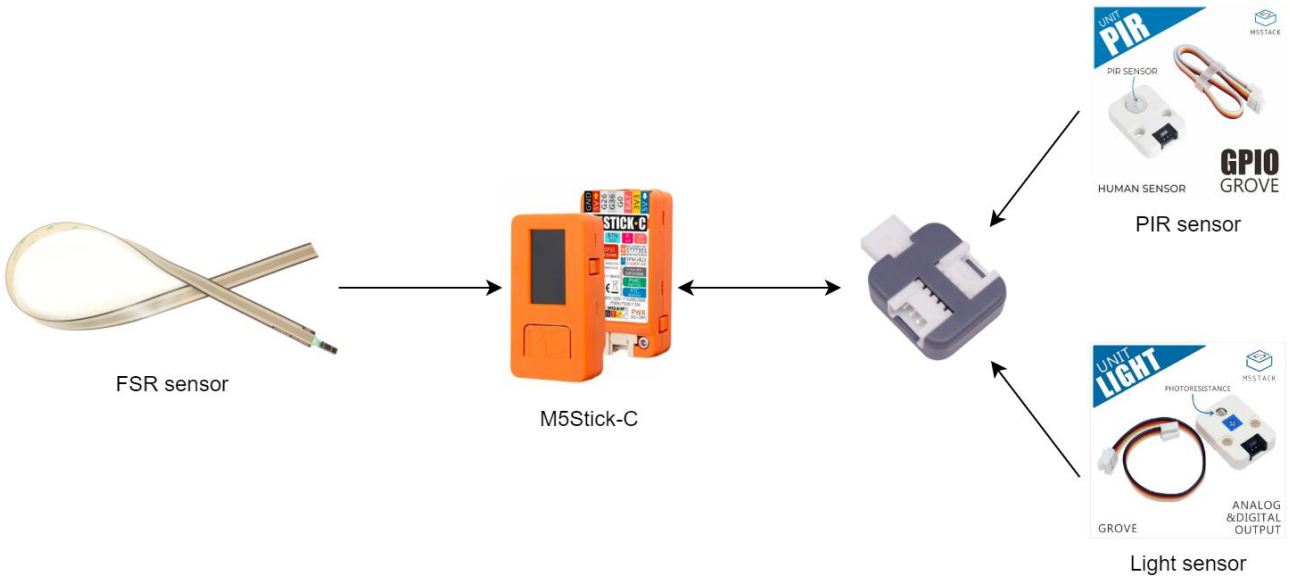


Figure 58: AP-NURSE Care sensor unit – AP1 version

The combination of PIR motion sensor, light sensor and a force sensitive resistor for monitoring of a person location and a bedroom bed occupation. This allows identification of undesirable states, such as when a person falls from his/her bed.

2. AP2 – doors to toilets in patient´s room

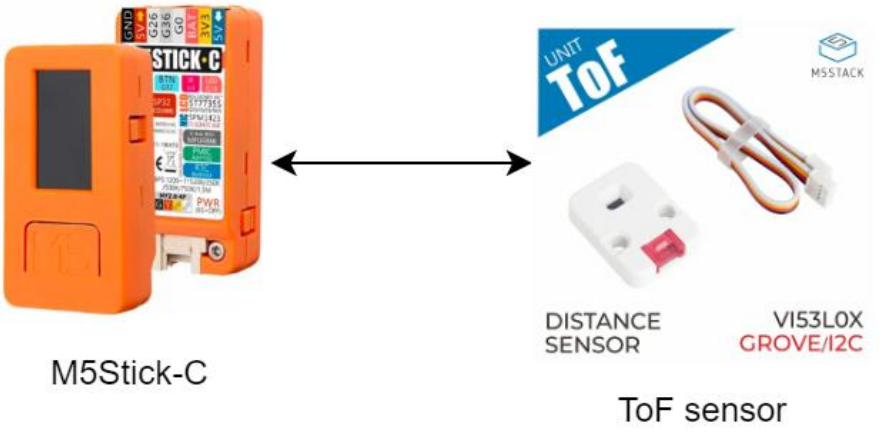


Figure 59: AP-NURSE Care sensor unit – AP2 version

The AP2 version of the sensor unit is designed to monitor and react to a door threshold passage using a time of flight sensor.

3. AP4 – common rooms, stairs, forbidden zones for patients

Figure 60: AP-NURSE Care sensor unit – AP4 version

The AP4 version of the sensor unit features motion detection using a PIR motion sensor.

4. AP6 - kitchen

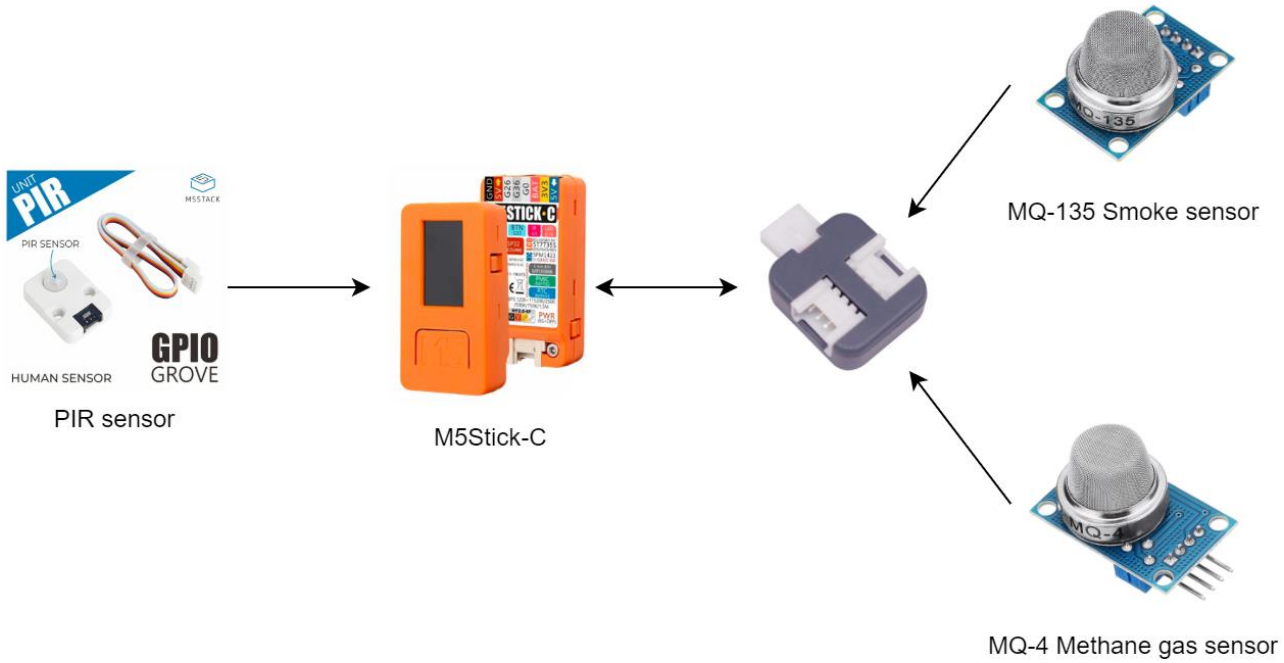


Figure 61: AP-NURSE Care sensor unit - AP6 version

The AP6 version of the sensor unit allows quick detection of fire and dangerous gas using the MQ-4 methane gas and a MQ-135 air quality sensor. This also features motion detection using a PIR motion sensor.

The AP-NURSE Care central unit has been adapted into three separate versions, Standalone, Lite and Utility. They are shown in Figure 62- Figure 64:

1. Standalone

M5Go Lite

Figure 62: AP-NURSE Care central unit – Standalone version

The standalone version of the central unit consists of a singular M5Go Lite node.

2. Lite

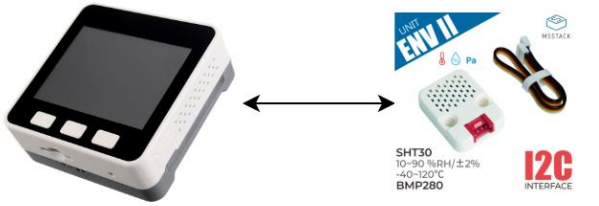


Figure 63: AP-Nurse Care central unit – Lite version

The Lite version of the AP-NURSE Care central unit features the SHT30 sensor for ambient temperature and humidity measurement.

3. Utility

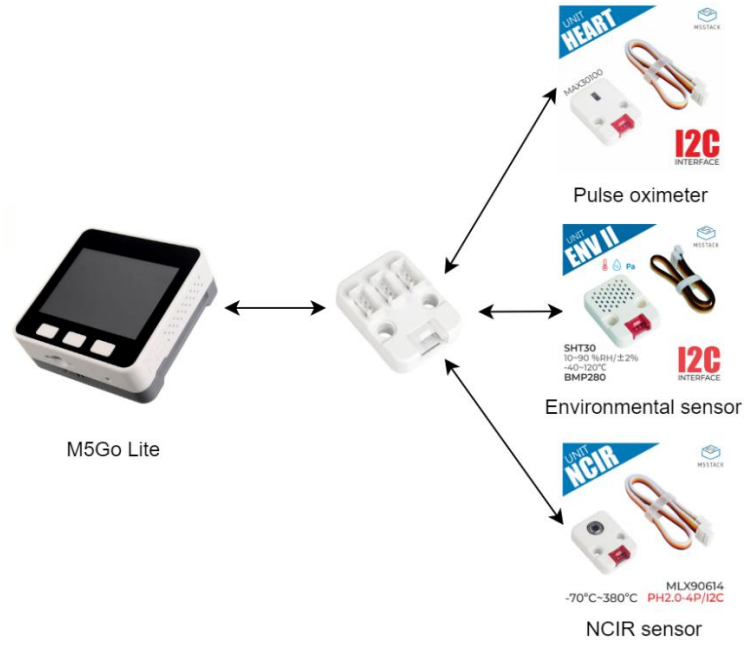


Figure 64: AP-Nurse Care central unit- Utility version

The Utility version of the central unit features, besides the SHT30 ENVII, MAX30100 pulse oximeter and a NCIR sensor for utility heartrate and body temperature measurements.

4.2.2. Hardware

M5Stack is a modular stackable product development toolkits based on ESP32 (The world's most popular Wi-Fi SoC, upgrade of ESP8266). The M5 ecosystem consists of the main controller "core", stackable modules and bases, grove compatible sensors "units" and different applications for industry IoT. M5Stack is committed to provide easy-to-develop and cost-effective IoT devices

4.2.2.1. Operation scheme

Since the AP-NURSE Care system aims to be used in social homes and care centres, where patients suffering from Alzheimer's and Parkinson's diseases are treated, it encompasses multiple modules, able to monitor several environmental indicators at the same time. The operation scheme of AP-NURSE Care based on the M5STACK platform is shown in Figure 65. The solution consists of one or more sensor units, a central unit and a communication gateway for connection to the network. The sensor part consists of a power supply element, a control unit (m5stick) and sensors connected via a HUB. These devices are connected to the central unit via wireless network. The wireless communication between the central and sensor units can be handled using either Wi-Fi or BLE (Bluetooth low energy). The effectiveness of said wireless interfaces is a subject of future testing.

The central unit also periodically sends the information obtained from the sensor units to the server and at the same time displays any notifications. The information sent to the server is evaluated and plotted in a graph that can be displayed on a PC or mobile phone.

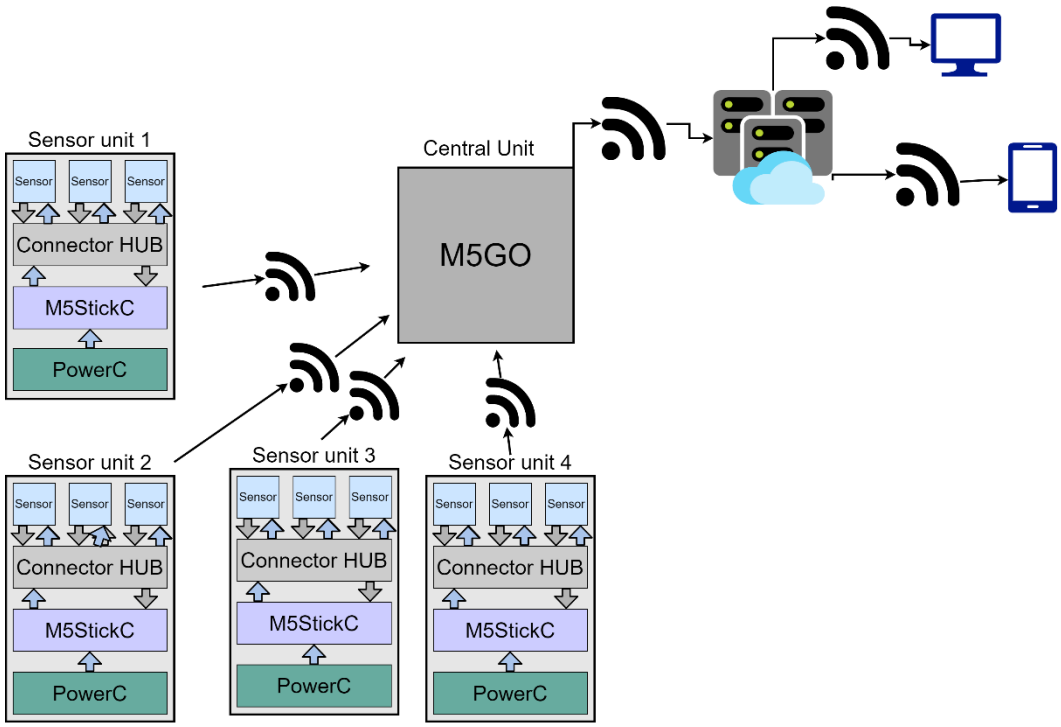


Figure 65: AP-Nurse Care implementation using the M5Stack platform and an online evaluation system

In addition to this implementation the AP-NURSE Care can be configured for a standalone service. In this mode, the Care system is able to operate without the usage of the online evaluation system.

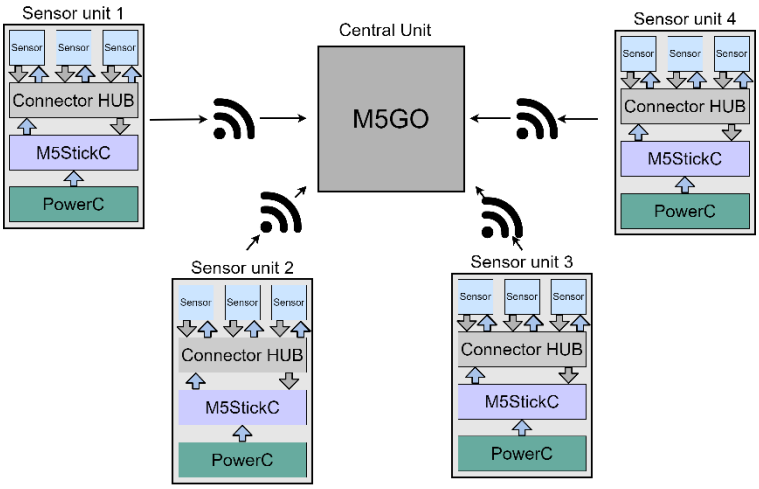


Figure 66: AP-Nurse Care standalone implementation using the M5Stack platform

4.2.2.2. Core units

The main core units of the AP-NURSE Care solution are the M5StickC and M5GO. M5StickC is a mini M5STACK core unit, powered by ESP32 microcontroller, which is a single 2.4 GHz Wi-Fi and Bluetooth combo chip and integrates a 4-MB SPI flash. It is a portable, easy-to-use, open-source, IoT development board. M5stickC is one of the core devices in the M5Stack product series. The Hat ENV unit is the core unit used to detect the temperature, humidity, air pressure and magnetic field. This product relates via I2C protocol that allows the user to obtain 4 types of environmental data thru just 2 pins, together with the tiny body, which makes it a powerful application for environmental data collection. It is built in a continually growing hardware and software ecosystem. It has a lot of compatible modules and units, as well as the open-source code. The M5Stick-C core unit is shown Table 4.

Table 4: M5Stick-C core unit

M5Stick-C 	M5 Mini-CORE based on ESP32 chip, including WiFi and Bluetooth. • Power input 5V @ 500mA • Ports USB Type-C, GROVE(I2C+I/0+UART) • ESP32 • 4 MB Flash • 6-Axis IMU SH200Q • Red LED • IR transmitter • Microphone • Buzzer • 2 Buttons, 1 Reset • Display (0.96-inch color, TFT LED) • 2.4G Antenna • 95 mAh @3.7V (Lipo Battery) • Extendable Socket Wearable & Wall mounted

M5GO is a full-feathered, highly integrated, upgraded development board that provides plenty of hardware resources, such as LCD screen, speaker, Led bar, 16M flash, microphone, and more. This M5STACK development board can be programmed by using Arduino IDE, WebIDE UIFlow, Micropython, and Blockly. It greatly simplifies the development process for those projects, which require a joint hardware and software solution. The M5GO unit is shown in Table 5.

Table 5: M5GO unit

M5GO 	M5GO controller itself is already a full-feathered, highly integrated, upgraded development board which provides plenty of hardware resources. • ESP32 240 MHz dual core, Wi-Fi, Bluetooth • Power input 5V @ 500mA • Ports: USB Type-C, GROVE(I2C+I/0+UART) • Display (2-inch color, TFT LED) • 16 MB Flash • Microphone • 3 Custom Buttons • TF card slot (16G Maximum size) • 2.4G Antenna • 500 mAh @3.7V (Lipo Battery) • Extendable Pins & Holes • Wearable & Wall mounted

4.2.2.3. Sensors

In order to meet the requirements of using AP-NURSE Care in care centers, the core units will be equipped with several simple but robust M5STACK sensors. The number of sensors per one module is limited to 5 pieces. The configuration of sensors will depend on the specific application. The list and the description of M5STACK sensors can be found in Table 6.

Table 6: M5STACK sensors

NCIR Temperature Sensor Unit 	• Operating voltage: 4.5 to 5.5V • Measuring object temperature range: -70°C ~ 380°C • Measuring ambient temperature range: -40 to 125 °C • Measurement accuracy at room temperature: ±0.5°C • Field of view: 90°
Time-of-Flight Ranging Unit 	• Measure absolute distances up to 2m • The wavelength of laser: 940nm

PIR Motion Sensor 	• Detects the distance: 500cm • latency time: 2s • Sensing range: < 100° • Quiescent current: < 60uA • Operating temperature: -20 - 80 °C
Mini Heart Rate Unit 	• Programmable Sample Rate and LED Current for Power Savings • Ultra-Low Shutdown Current (0.7μA, typ) • Advanced Functionality Improves Measurement Performance • High Sample Rate Capability • Fast Data Output Capability
Light Unit with Photo-resistance 	• 10K adjustable resistor • larger and accurate range of light intensity
3-Axis Digital Accelerometer 	• Ultralow power • 3-axis accelerometer • resolution (13-bit) • measurement at up to ±16G • I2C digital interface • Single tap/double tap detection • Activity/inactivity monitoring • Free-fall detection
90° / 180° IR Reflective Unit 	• Vertical Layout • IR limit switch • Fast response time • High sensitivity
Mini GPS/BDS Unit	• Support single system positioning of BDS/GPS/GLONASS satellite navigation systems, or multi-system joint positioning in any combination • Support D-GNSS differential positioning

	
M5STICKV K210 AI camera 	• Dual-Core 64-bit RISC-V RV64IMAFDC (RV64GC) CPU / 400Mhz (Normal) • Dual Independent Double Precision FPU • Neural Network Processor (KPU) / 0.8Tops • Field-Programmable IO Array (FPIOA) • Dual hardware 512-point 16bit Complex FFT • SPI, I2C, UART, I2S, RTC, PWM, Timer Support • AES, SHA256 Accelerator • Direct Memory Access Controller (DMAC) • Micropython Support • Firmware encryption support
Mini Dual Button Unit 	• 2 buttons

4.2.2.4. Connection and power expanders

Grove-T is a T-shaped hub used to connect multiple sensors to the M5StickC core unit. It is also used for GROVE port expansion. Grove-T is just a hardware expander. The communication of multiple sensors is maintained through a software solution. 1 to 3 HUB expansion Unit is used for GROVE port expansion. HUB is just a hardware expander same as Grove-T just with 3 HUB ports. The Grove-T and the HUB expansion unit are shown in Table 7.

Table 7: Grove-T and HUB expansion unit.

Grove-T 	**Grove-T** is a T-shaped hub
HUB expansion Unit 	1 to 3 HUB Expansion Unit

18650 C HAT is a rechargeable battery base, designed for M5stickc with built-in 18650 large capacity rechargeable lithium battery. It can provide long-term endurance for the equipment. The base is designed with the plug-in structure of the HAT series, which can be used to maintain reliable connection with the M5StickC. The bottom is equipped with a USB type C charging interface, which is convenient and can quickly charge the battery. The USB port of the battery base is only used as a charging interface, and does not have UART function. There are many types of mounting holes on the back of the base, which can be easily installed by the user into all types of planes.

Power C HAT is a charging module specially designed for m5stickc, with built-in IP3005 high-precision lithium battery protection IC and IP5209 power management IC. It uses the I2C communication protocol to carry out data transmission with m5stickc of the host computer and can check the voltage, current, and other information. The back battery seat of the module can be installed with two batteries, which can be charged by the charging module and can also be used as a charging treasure to provide external power through the battery. The module is equipped with an independent switch, which can be opened once and closed twice. The 18650 C HAT and the Power C HAT are shown in Table 8.

Table 8: 18650 HAT and Power C HAT

18650 HAT 	• Port USB Type-C • Chargeable • Battery replaceable • 2200mAh rechargeable battery
Power C HAT 	• Port USB Type-C • Battery testing • Mobile power bank • Battery charger • IIC Address 0x75 • independent switch

4.2.3. Software

The AP-NURSE Care sensor unit and central unit are fitted with a modified version of the M5STACK UIFlow firmware based on the MicroPython 1.11 operating system supporting OTAP (over the air programming) for convenient unit software upgrades. The AP-NURSE Care sensor unit is capable of handling data acquisition with the use of a variety of supported sensors. Its firmware supports configurable multi-level alert warnings triggered by external or internal events. A more detailed description of the firmware is shown in Figure 67.

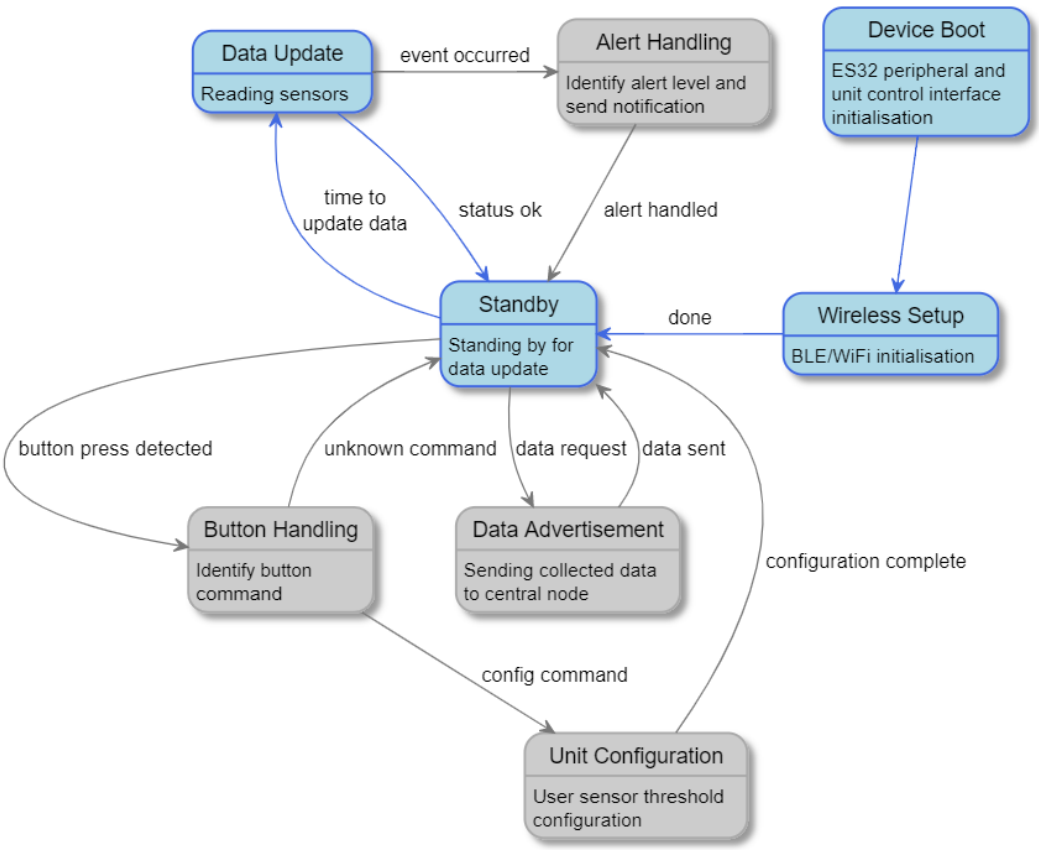


Figure 67: AP-NURSE Care sensor node firmware state diagram

The AP-NURSE Care central unit firmware reads data collected by a sensor unit in set intervals. Moreover it reacts to alert notifications issued by the sensor node and handles them accordingly to the alert level as shown in Figure 68. The AP-Nurse central unit firmware also handles periodical ambient temperature and humidity readings and utility heartrate and body temperature readings.

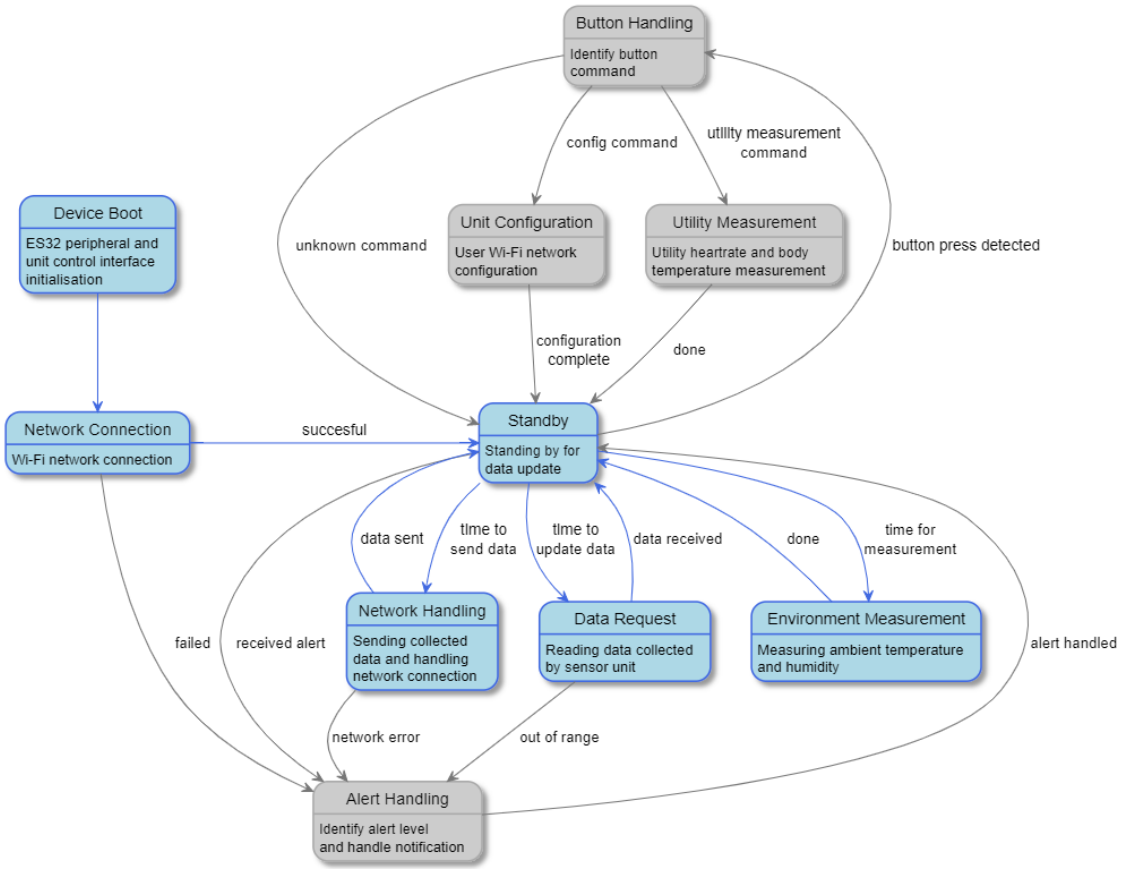
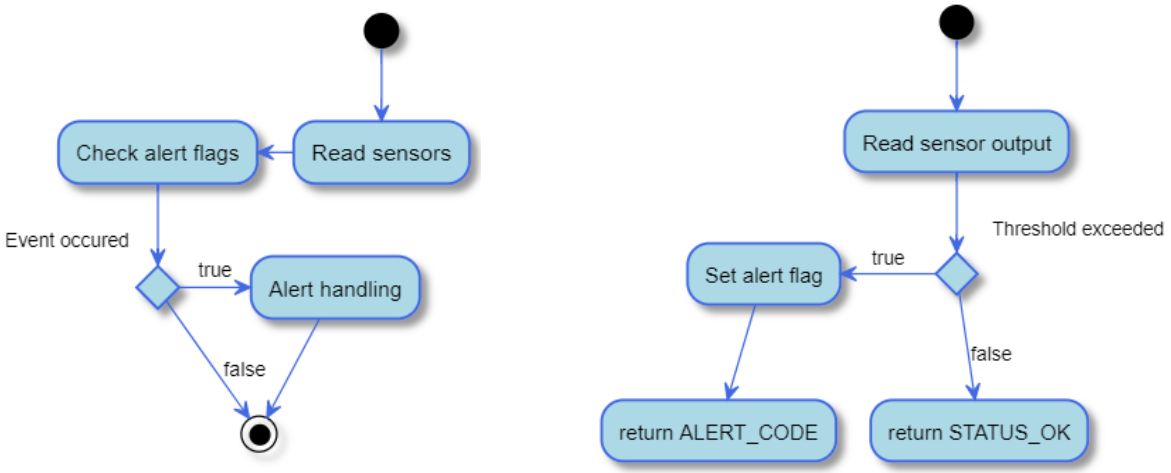


Figure 68: AP-NURSE Care central unit firmware state diagram

Data update and sensor reading by the sensor unit is handled analogously to the AP-Nurse Home unit, as shown in Figure 69.



a; Data update b; Sensor reading

Figure 69: AP-NURSE Care data update and sensor reading diagrams

Alert handling is enabled by an alert code unique for different types of events. Details of the alert handling process are shown in Figure 70. Example of alert notification is shown in Figure 71.

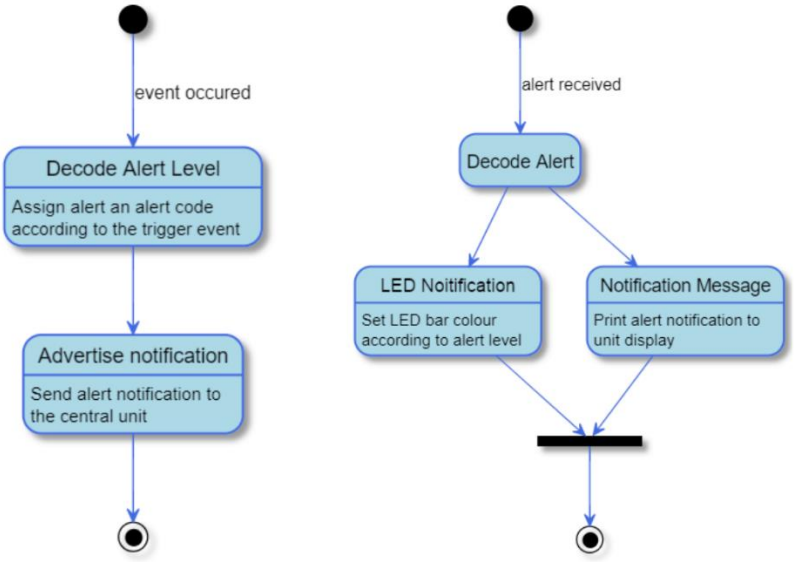


Figure 70: AP-NURSE Care sensor and central unit alert handling process

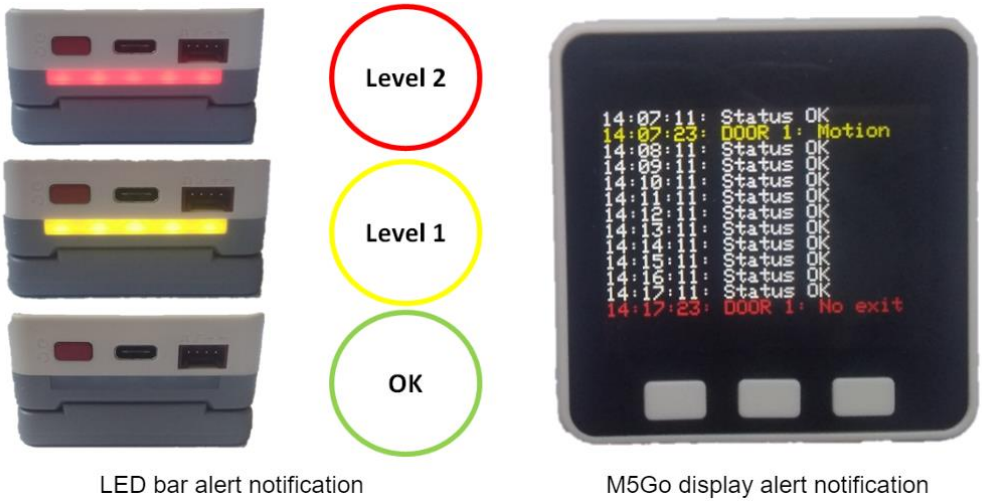


Figure 71: AP-NURSE Care Alert notification

The configuration of both the sensor unit and central unit is triggered by a long button press. As seen in the case of AP-NURSE Home unit, configuration uses a local server accessible through a Wi-Fi access point generated by the unit. Once connected the unit can be configured using any standard internet browser. Example of the AP-NURSE Care unit configuration can be seen in Figure 72.

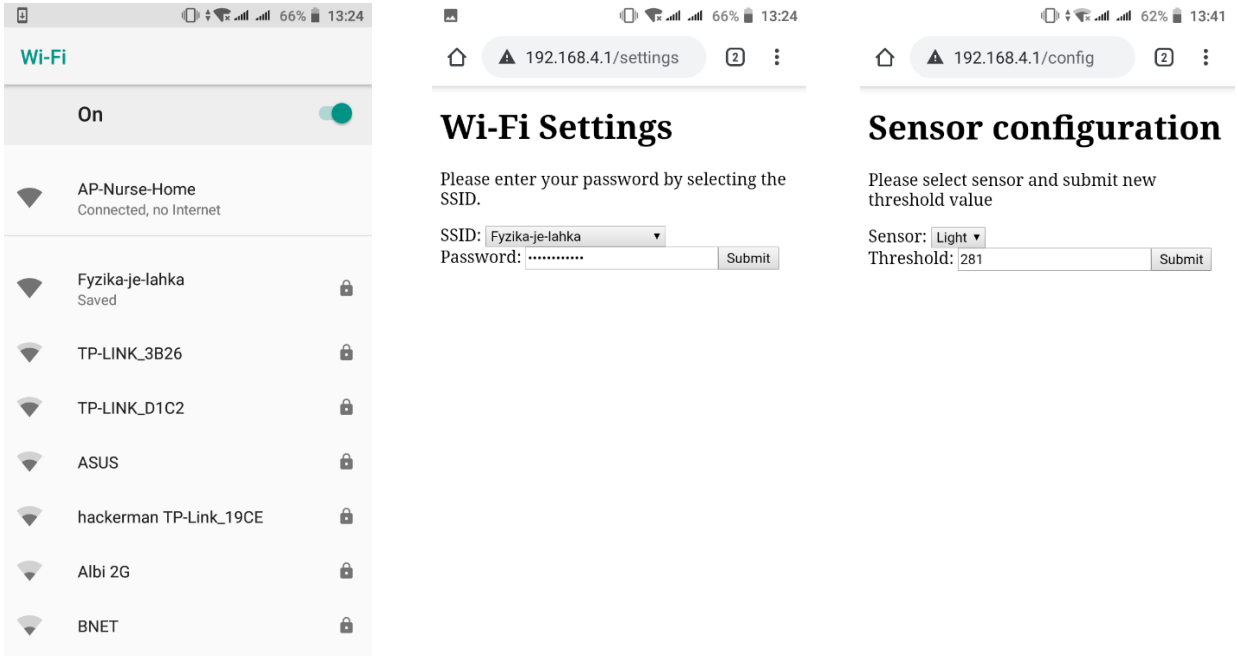


Figure 72: AP-NURSE Care unit configuration

4.2.4. Server

We designed a solution for the management and analysis of IoT devices divided into three communicating parts. The client part, which allows the client to easily and intuitively manipulate the devices via a web browser. The server part, which processes requests from the client, collects the necessary data from the IoT devices or modifies their devices, and supplies the client part with the required device information. The IoT device interface represents the IoT devices themselves and their system settings.

The server is designed in the programming API, which allows the client web application to communicate with the server based on requests and responses.

For the simplicity of the transfer of the entire IS environment and further implementation of the entire server system, it was designed as a virtual server of the VMware (https://www.vmware.com) service with HW requirements (see below). The requirements for running the IS Server software based on "Docker" (https://www.docker.com) is a platform for developers and system admins to build, run, and share applications with containers. The use of containers to deploy applications is called containerization. Containers are not new, but their use for easily deploying applications is. Containerization is increasingly popular because containers are: flexible, lightweight, portable, loosely coupled an ease scalable. We can increase and automatically distribute container replicas across a data centre. Main requirement for our IS was secure solutions. Docker Containers apply aggressive constraints and isolations to processes without any configuration required on the part of the user.

As database was used a MariaDB Server (and its predecessor MySQL) has been used around the world for over 20 years, there are huge amounts of learning resources and documentation available. MariaDB Platform is the complete enterprise open source database solution, with the versatility to handle transactional, analytical or hybrid transactional/analytical workloads as well as relational or document data, and the ability to scale from standalone databases and columnar data warehouses to fully distributed SQL databases executing millions of transactions per second and performing interactive, ad hoc analytics on billions of rows (https://mariadb.com).

Optimal HW parameter for server:

- 2xCPU (CPU Intel Xeon E5420 2.5GHz)

- 3GB RAM

- 50GB disk

Software installation:

- VMware version 5.5

- CentOS Linux release 7.8.2003 (Core)

- min. version Docker 19.03.12

- database Maria DB 10.1.45-MariaDB

The IS serves for the visualisation of data gathered by a custom configured AP-Nurse Care system. It allows for adding an arbitrary number of data loggers (sensor units) communicating with the IS through a registered device (central unit). Example of the IS data visualisation interface is shown in Figure 73.

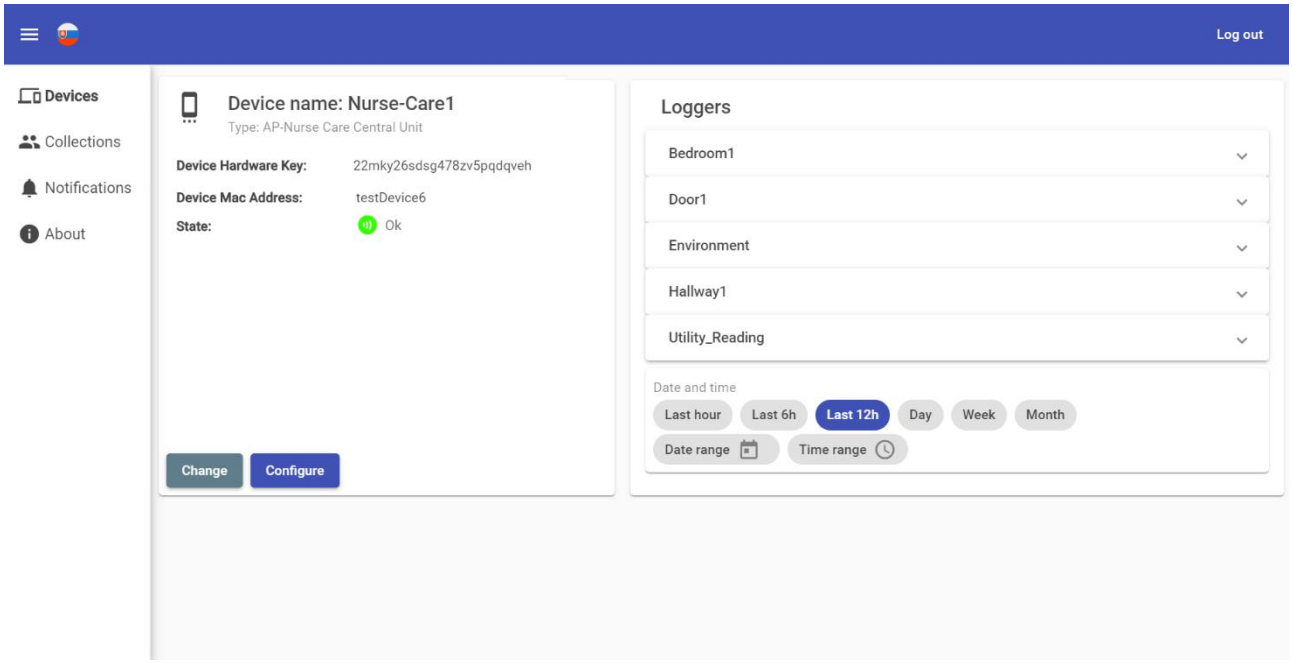


Figure 73: IS data visualization interface

Here a user can see the registered device details such as its type and more importantly the system status shown under the "*State*" label. Moreover, monitoring of the entire system is accessible through charts of the gathered measured data as shown in Figure 74.

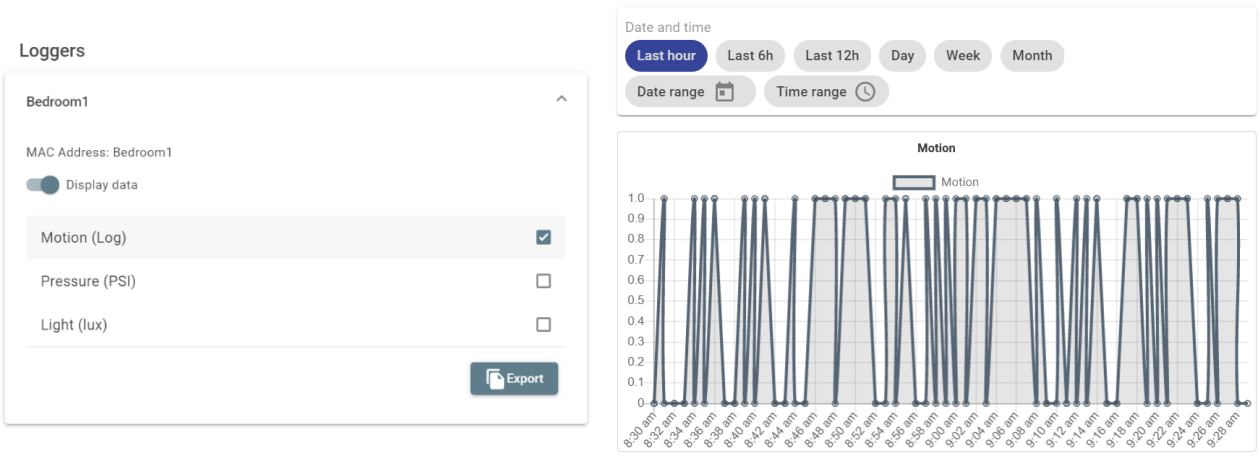


Figure 74: IS data preview

As shown in Figure 75, there exist 3 levels of notification. System status indicates normal condition, when no alert notification occurred. In case of a sensor unit generated alert notification the system status shows normal or critical condition alert with further alert details (**Figure 76** and **Figure 77**).

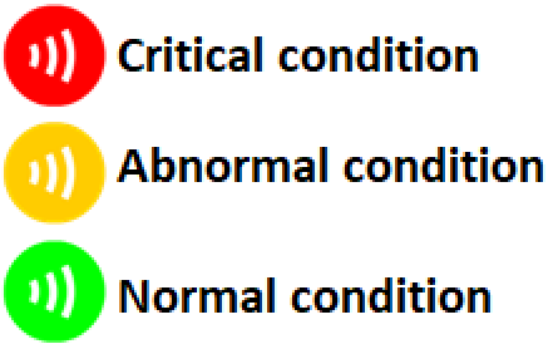


Figure 75: System status indication

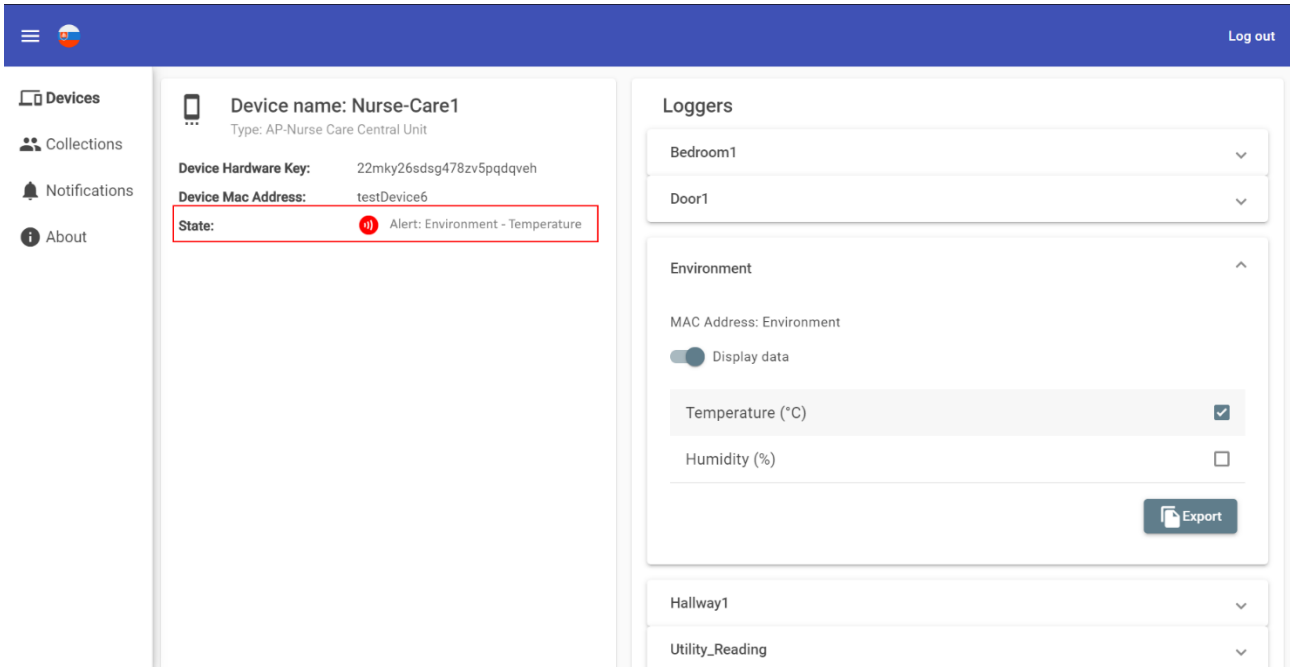


Figure 76: Critical condition notification

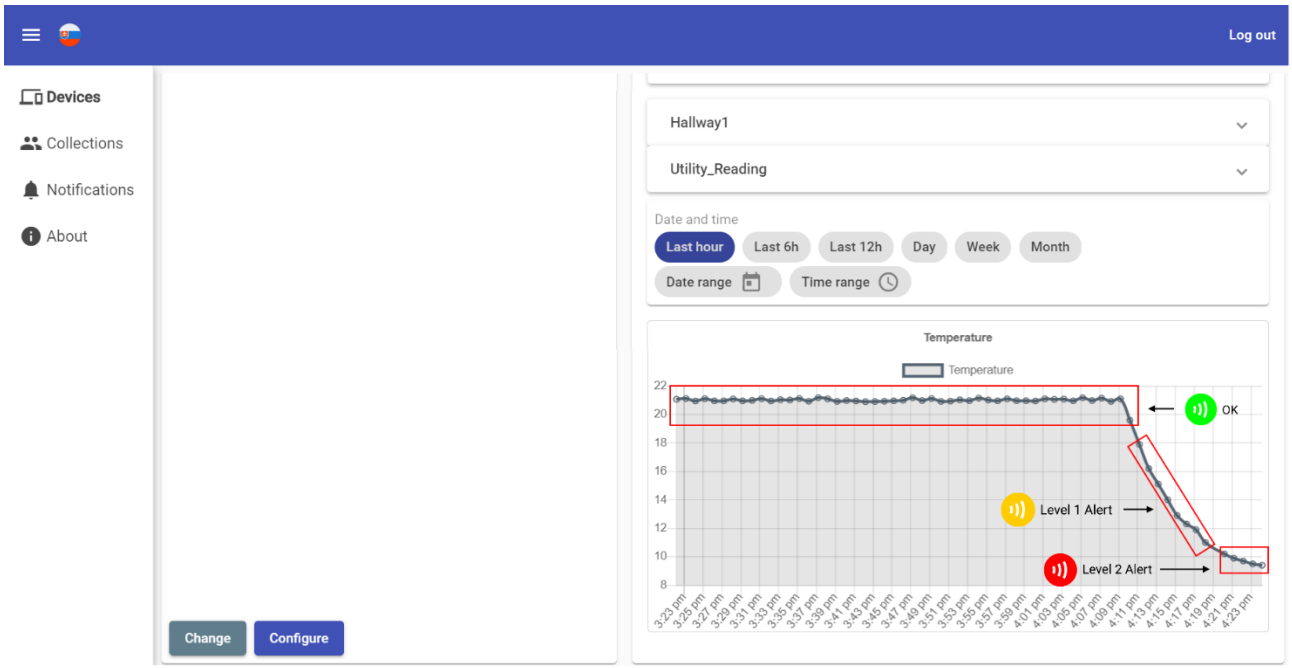


Figure 77: Alert trigger example

4.3. AP-NURSE care - Waspmote

Due to not finalized public procurement of major components of the Waspmote solution in Petržalka and Warsaw, all related activities were postponed and will be describe in the subsequent deliverables.

5. Testing

5.1. Testing environment

Both systems, AP-NURSE Home and Care, are designed to be deployed in an interior and mainly in rooms where patients spend the most of their time. To test all sensors, micro-controllers, communication modules, their workability in real environment and also not to bother the clients and the staff of care centres, special testing room was designed and prepared at STU. In a phase of testing, it is very important to gain practical experience with all prototypes and to validate the prepared scenarios or test cases. Therefore, the testing has to go through all initialization events, event chains, predictable or non-predictable sequences of the events, proposed caregivers' responses, and should validate the thresholds and also the ability of the whole system to operate in case of multiple events. Thus the testing environment has to be as similar as it is possible to the real testing site. According to the project schedule, the first testing will be carried out locally at STU. If cases occur, when the local testing is inefficient, the testing will continue at the selected care centre in uninhabited rooms. The main features and equipment of the testing room are as follows:

- Adjustable bed (can be used as a sofa)
- Open and lockable cabinets
- Armchair and office chairs (spatial barriers, wheelchair)
- Tables (caregiver monitoring desk)
- Washbasin
- Shelves (with good or worse access)
- Basic household appliances (available in Care centres – coffeemaker, radio, TV)
- Power sockets (limited number and access)
- Openable Window
- Sunblind (to simulate day/night cases)

The primary arrangement of the testing room is shown in **Figure 78**- **Figure 81**.

Figure 78: Testing room - bed, armchair, open cabinet, small table

Figure 79: Testing room - tables, chairs, shelves, coffeemaker, phone

Figure 80: Testing room - washbasin, exit doors, chairs, coat hanger

Figure 81: Testing room - lockable cabinet, washbasin

5.2. Testing procedure

The testing procedure developed for the AP-NURSE Home and Care devices consist of the following two phases:

1. Function tests
2. Test cases

5.2.1. Function tests

5.2.1.1. AP-NURSE Home function tests

Functional test must be performed on every AP-NURSE Home device. The listed tests verify the basic functionality and performance of the developed device. These tests are based on the events according to schemes presented in Figure 82 - Figure 85. There are four basis event flow tests from which function test are derived and specified in Table 9. All function test must be performed at least 10 times and the results must be evaluated in the test protocols. The results of the function test performed for each device, are also recorded in a test protocol. In the event flow charts, the following marking are used:

- Grail infill box – sensor board functionality
- White infill box – bracelet board functionality (AP-NURSE Home wearable)

Event flow test 1 - EFT-H-1

Event flow test 1 verifies:

- turning on/off whole device
- paring functionality
- putting device into stand by regime

EFT-H-1 tests are specified in Table 9.

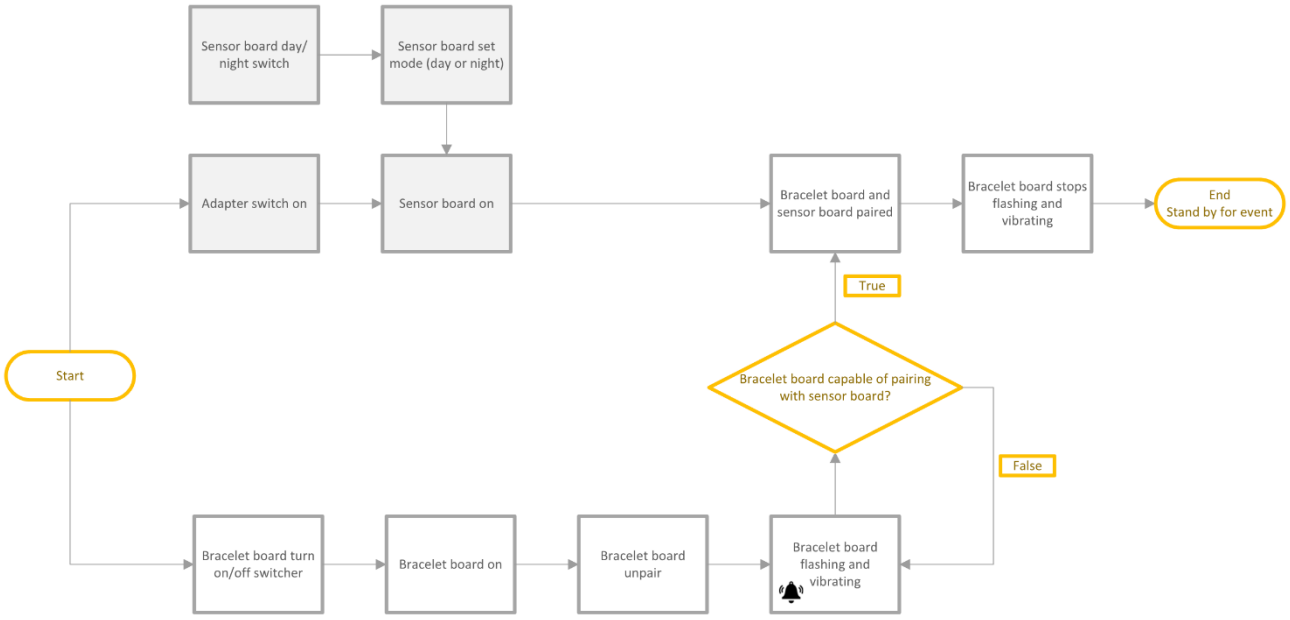


Figure 82: AP-NURSE Home event flow 1

Event flow test 2 - EFT-H-2

Event flow test 2 verifies:

- unpairing due to the loss of signal
  - sensor board turned off
  - sensor board reset
  - bracelet board turn off
- unpairing due to the increase of distance between receiver and transmitter

EFT-H-2 tests are specified in Table 9.

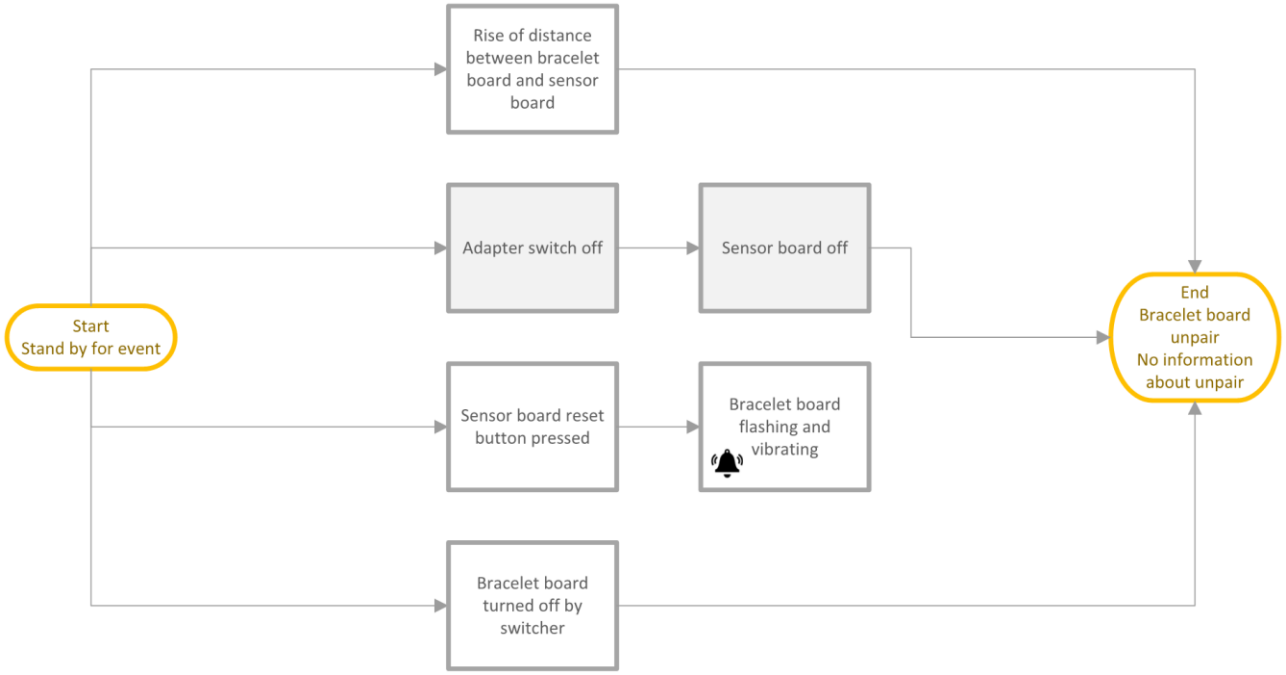


Figure 83: AP-NURSE Home event flow 2

Event flow test 3 - EFT-H-3

Event flow test 3 verifies watch functionality of displaying battery level. Specific tests are specified in Table 9.

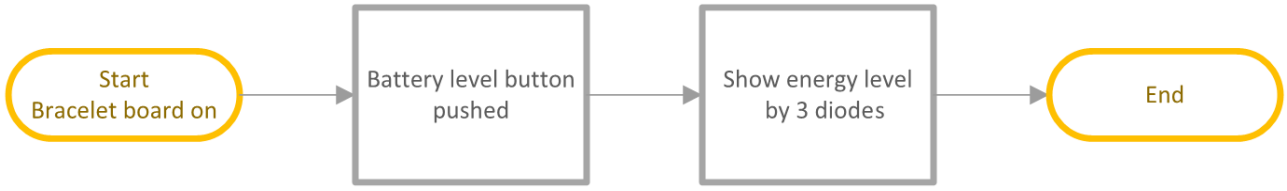


Figure 84: AP-NURSE Home event flow 3

Event flow test 4 - EFT-H-4

Event flow test 4 verifies:

- filtering abnormal condition and critical condition
- day/night event filtering
- abnormal condition/ critical condition alarm trigger
- alarm signalization / alarm muting
- time delay to device to back into stand by regime

Specific tests are specified in Table 9.

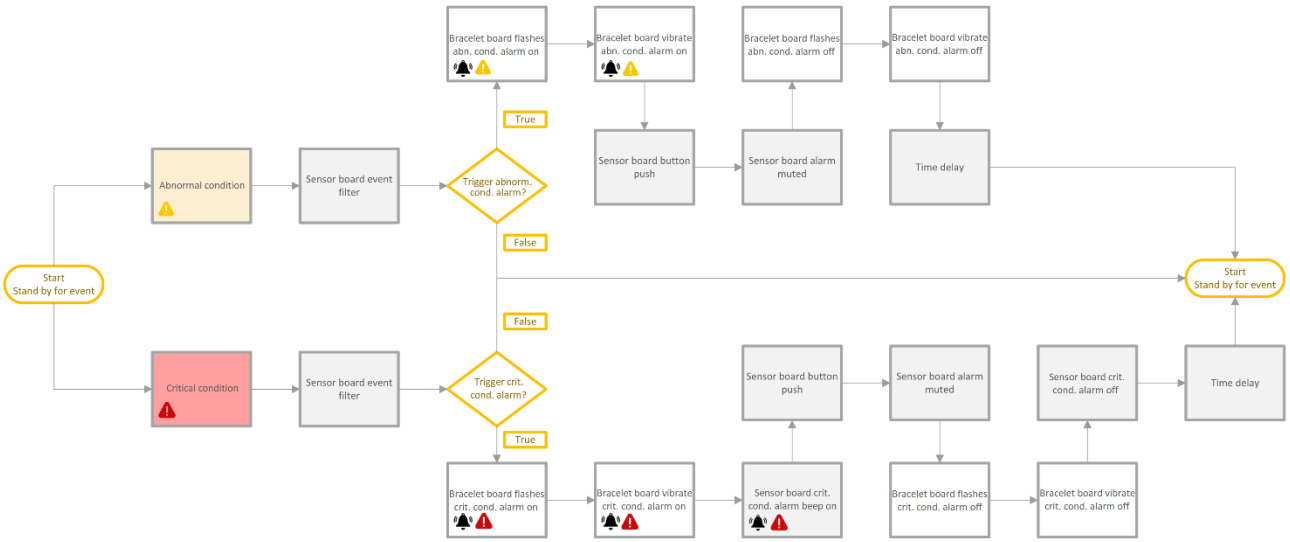


Figure 85: AP-NURSE Home event flow 4

Specialized tests and sensor tests - ST-H

Specialized tests that cannot be categorized in any of above categories:

- unpairing distance in case of clear distance between bracelet board and sensor board.
- unpairing distance in case of distance with barriers between bracelet board and sensor board.
- testing of PIR movement sensor with collimator. Collimator provides tighter angle in which movement sensor triggers alarm. This can be applied as a barrier crossing the detection area.
- functionality of each sensor, triggering an abnormal condition and a critical condition.

5.2.1.2. AP-NURSE Care function tests

Functional test must be performed on every AP-NURSE Care device. The listed tests verify the basic functionality and the performance of the developed device. These tests are based on the events presented in schemes in **Figure 86** - **Figure 90**. There are five basis event flow tests from which function test are derived and specified in Table 10. All function test must be performed at least 10 times and the result must be evaluated in test protocol. The results of the function test performed for each device are also recorded in a test protocol. In the event flow charts the following marking are used:

- Grail infill box – sensor unit functionality
- White infill box – central unit functionality

- Blue infill box – other communication device such as PC or smartphone

Event flow test 1 - EFT-M-1

Event flow test 1 verifies:

- turning on/off sensor unit

EFT-M-1 tests are specified in Table 10.

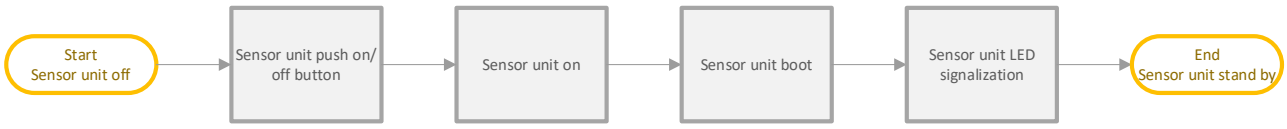


Figure 86: AP-NURSE Care event flow 1

Event flow test 2 - EFT-M-2

Event flow test 2 verifies:

- turning on central unit
- pairing central unit with sensor unit

EFT-M-2 tests are specified in Table 10.

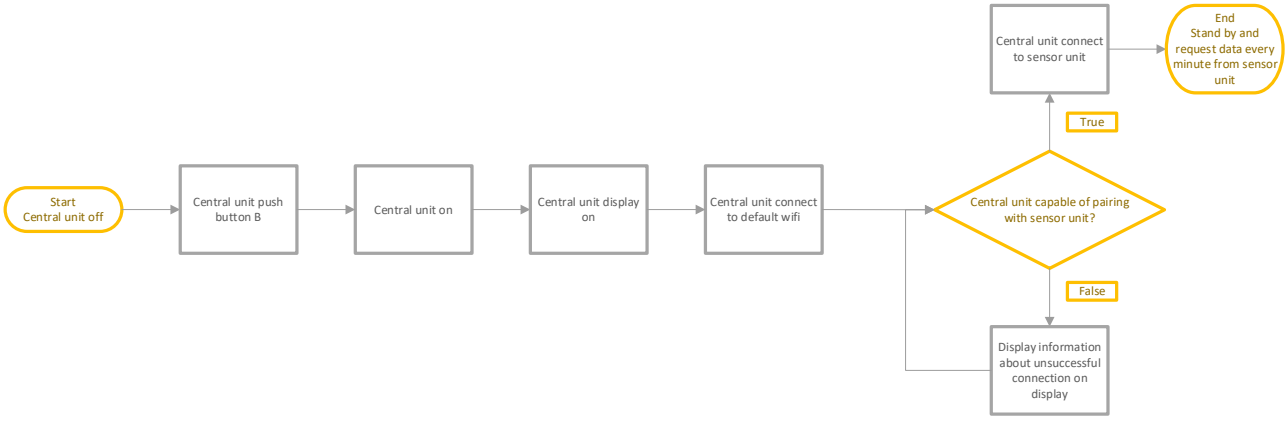


Figure 87: AP-NURSE Care event flow 2

Event flow test 3 - EFT-M-3

Event flow test 3 verifies:

- turning off central unit
- unpairing due to the increase of distance between sensor unit and central unit
- turning sensor unit off
- resetting sensor unit

EFT-M-3 tests are specified in Table 10.

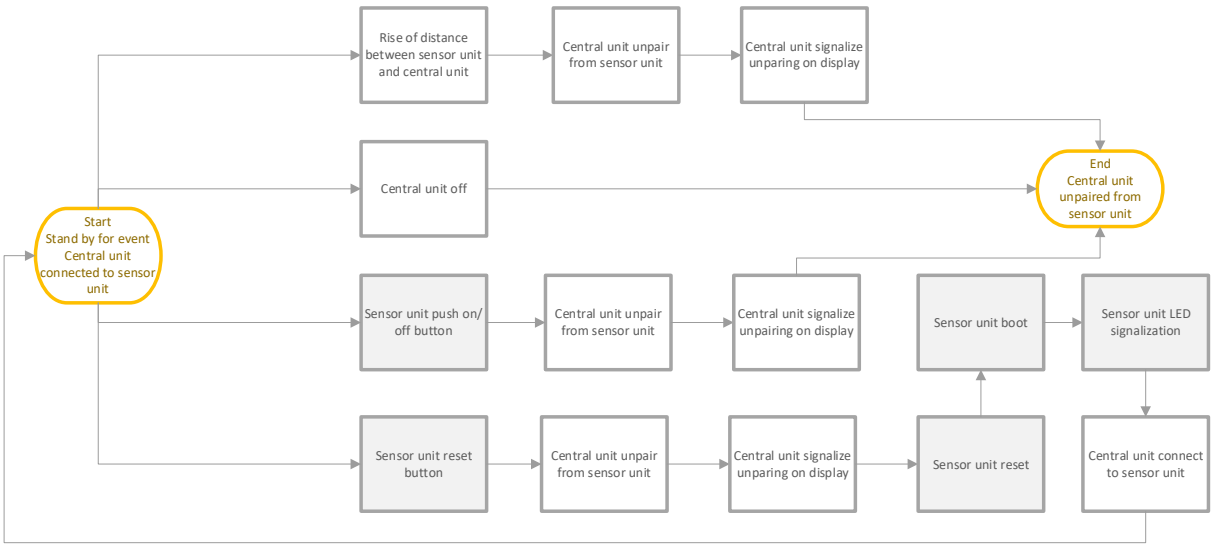


Figure 88: AP-NURSE Care event flow 3

Event flow test 4 - EFT-M-4

Event flow test 4 verifies:

- manual wi-fi access point creation

EFT-M-4 tests are specified in Table 10.

Figure 89: AP-NURSE Care event flow 4

Event flow test 5 - EFT-M-5

Event flow test 5 verifies:

- filtering abnormal condition and critical condition
- day/night event filtering
- abnormal / critical condition alarm trigger
- alarm signalization / alarm muting

EFT-M-5 tests are specified in Table 10.

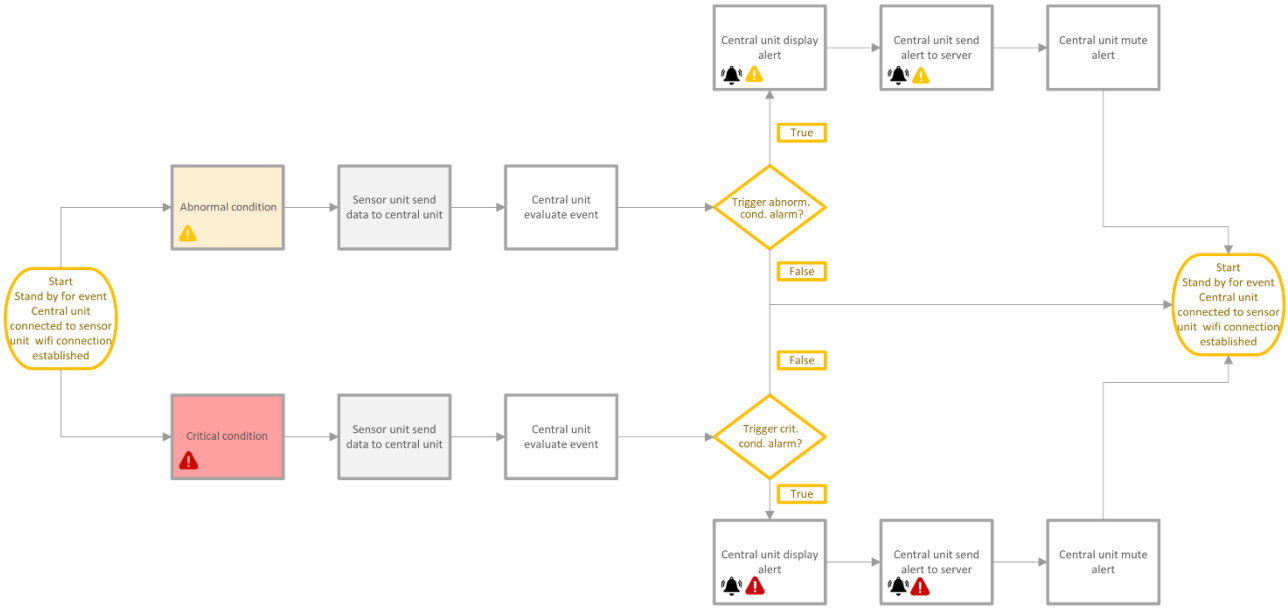


Figure 90: AP-NURSE Care event flow 5

Specialized tests and sensor tests - ST-M

Special tests that cannot be categorized in any of above categories:

- unpairing distance in case of clear distance between central unit and sensor unit
- unpairing distance in case of distance with barriers between central unit and sensor unit
- functionality of each sensor, triggering an abnormal condition and critical condition

5.2.1.3. List of function tests for all AP-NURSE devices

Table 9: Overview and description of function tests of for AP-NURSE Home devices

Test	Initial state	Events					End state
EFT-H-1	bracelet board off - sensor board box off	sensor board adapter switch on	bracelet board on	bracelet board pair	signalize pairing		stand by
EFT-H-2	stand by	sensor board boxadapter off no baterry in sensor board	bracelet board unpair	sensor board adapter on	bracelet board pair	signalize pairing	stand by
EFT-H-3	stand by	sensor board reset	bracelet board unpair	bracelet board pair	signalize pairing		stand by
EFT-H-4	stand by	bracelet board off	bracelet board on	bracelet board pair	signalize pairing		stand by
EFT-H-5	stand by	rise in distance between redexer and transmitter	bracelet board unpair	fall in distance between redexer and transmitter	bracelet board pair		stand by
EFT-H-6	stand by	sensor board adapter off	sensor board powered from baterry, nothing happends	sensor board adapter on	bracelet board vibrate		stand by
EFT-H-7	bracelet board on	click baterry button					show baterry level
EFT-H-8	bracelet board on	click baterry button	verify LED signalization of baterry level with actual baterry level by voltage measurement for different baterry states				show baterry level
EFT-H-9	stand by	trigger abnormal condition	fiber event				stand by
EFT-H-10	stand by	trigger critical condition	don't fiber event	signalize critical condition alarm	mute critical condition alarm		stand by
EFT-H-11	stand by	trigger abnormal condition	don't fiber event	signalize abnormal condition alarm	mute abnormal condition alarm		stand by
EFT-H-12	stand by	trigger abnormal condition	don't fiber event	signalize abnormal condition alarm	mute abnormal condition alarm	time delay	find out best practical time delay
ST-H-1	stand by	trigger temperature sensor board					catch abnormal condition
ST-H-2	stand by	trigger humidity sensor board					catch abnormal condition
ST-H-3	stand by	trigger movement sensor board					catch abnormal condition
ST-H-4	stand by	trigger accelerometer sensor board					catch abnormal condition
ST-H-5	stand by	trigger noise sensor board					catch abnormal condition
ST-H-6	stand by	trigger light sensor board					catch abnormal condition
ST-H-7	stand by	trigger gas #Q135 sensor board					catch critical condition
ST-H-8	stand by	trigger gas #Q5 sensor board					catch critical condition
ST-H-9	bracelet board off - sensor board off	20m distance between redexer and transmitter, no barriers	sensor board adapter switch on	bracelet board on	lower the distance between redexer and transmitter	bracelet board pair	find out maximum distance for bracelet board to pair with sensor board in case of no barriers between them
ST-H-10	bracelet board off - sensor board off	20m distance between redexer and transmitter, with barriers	sensor board adapter switch on	bracelet board on	lower the distance between redexer and transmitter	bracelet board pair	find out maximum distance for bracelet board to pair with sensor board in case of single or several walls between them
ST-H-11	stand by	motion sensor board is mounted in collimator	trigger movement sensor board with different distance and angle of triggering object from movement sensor board				evaluate usage of movement sensor board with collimator for barier detection cases
ST-H-12	stand by	fall of sensor board	trigger gyroscope event				evaluate posibility to recognise movement of sensor board

Table 10: Overview and description of function tests of for AP-NURSE Care - MSTACK devices

Test	Initial state	Event					End state
EFT-#-1	sensor unit off, central unit off	sensor unit push on/off button	sensor unit on	sensor unit boot	sensor unit LED signalization		sensor unit stand by
EFT-#-2	sensor unit off, central unit off	central unit push button B	central unit on	central unit display on	central unit create access point		display information about unsuccessful connection with sensor board on display
EFT-#-3	sensor unit on, central unit off	central unit push button B	central unit on	central unit display on	central unit create access point	central unit connect to sensor unit	stand by and request data every minute from sensor unit
EFT-#-4	stand by for event central unit connected to sensor unit	rise of distance between sensor unit and central unit	central unit unpair from sensor unit	central unit signalize unparing on display			central unit unpaired from sensor unit
EFT-#-5	stand by for event central unit connected to sensor unit	central unit off					central unit unpaired from sensor unit
EFT-#-6	stand by for event central unit connected to sensor unit	sensor unit push on/off button	central unit unpair from sensor unit	central unit signalize unpairing on display			central unit unpaired from sensor unit
EFT-#-7	stand by for event central unit connected to sensor unit	sensor unit reset button	central unit signalize unpairing on display	sensor unit reset, Sensor unit boot	sensor unit LED signalization	central unit connect to sensor unit	stand by for event Central unit connected to sensor unit
EFT-#-8	stand by for event central unit connected to sensor unit no wifi connection	central unit push button A	central unit creates access point to wifi with local server	connection to access point with any device on address 192.168.4.1	insert name and password into log in form in browser	show connection logs in browser	successful wifi connection
EFT-#-9	stand by for event central unit connected to sensor unit	trigger abnormal condition	fiber event				stand by for event Central unit connected to sensor unit
EFT-#-10	stand by for event central unit connected to sensor unit	trigger critical condition	don't fiber event	signalize critical condition alarm on central unit display	central unit send alert to server	display alert in web browser, mute alert	stand by for event Central unit connected to sensor unit
EFT-#-11	stand by for event central unit connected to sensor unit	trigger abnormal condition	don't fiber event	signalize abnormal condition alarm on central unit display	central unit send alert to server	display alert in web browser, mute alert	stand by for event Central unit connected to sensor unit
ST-#-1	stand by for event central unit connected to sensor unit	trigger temperature sensor unit					catch abnormal condition
ST-#-2	stand by for event central unit connected to sensor unit	trigger humidity sensor unit					catch abnormal condition
ST-#-3	stand by for event central unit connected to sensor unit	trigger movement sensor unit					catch abnormal condition
ST-#-4	stand by for event central unit connected to sensor unit	trigger accelerometer sensor unit					catch abnormal condition
ST-#-5	stand by for event central unit connected to sensor unit	trigger noise sensor unit					catch abnormal condition
ST-#-6	stand by for event central unit connected to sensor unit	trigger light sensor unit					catch abnormal condition
ST-#-7	stand by for event central unit connected to sensor unit	trigger gas sensor unit					catch critical condition
ST-#-8	stand by for event central unit connected to sensor unit	trigger gas IR sensor unit					catch critical condition
ST-#-9	sensor unit off, central unit off	20m distance between redirect and transmitter, no barriers	EFT-#-1	EFT-#-3	lower the distance between sensor unit and central unit	central unit pair	find out maximum distance for central unit to pair with sensor unit in case of no barriers between them
ST-#-10	sensor unit off, central unit off	20m distance between redirect and transmitter, with barriers	EFT-#-1	EFT-#-3	lower the distance between sensor unit and central unit	central unit pair	find out maximum distance for central unit to pair with sensor unit in case of single or several walls between them

5.2.2. Test cases

To simulate the behaviour of AP-NURSE devices a series of test cases were created. These test cases serve as a tool to find out specific threshold values for sensors and to test overall practical usage of the AP-NURSE devices. The selection of tests cases was driven by three criteria, the location in which the AP-NURSE devices are to be deployed, the type of the patient (mobile/immobile) and by the monitoring regime (day/night). For all tests cases 3 locations were defined:

- Room
    - AP1 – under the bed (mobile patients)
    - AP2 – doors to toilet in patient´s room
    - AP3 – under the bed (immobile patients)
- Common areas
    - AP5 – doors to common toilet or bathroom doors
    - AP6 - kichen
- Forbidden areas
    - AP4 – common rooms, stairs, forbidden zones for patients

According to the specific application, individual alerts can be muted. For example: walking in the room during the daylight. However, in general, the system must detect all events and it's up to logic layer of device to choose whether to trigger an alert. The list of selected test cases for both AP-NURSE Home and Care are shown in Table 11.

Table 11: Test cases

Test case	Device	Position of AP-NURSE device	Regime of device	Type of patient	Initial state	event	Sensor detect an change of state										Trigger alert	note
							Laser	Motion	Pressure	Noise	Light	Gyroscope	Gas	temperature	Humidity	Time		
1	Home / Care	under the bed	day	mobile	patient lling in the bed	patient got up from the bed		✓	✓								✗	
2	Home / Care	under the bed	night	mobile	patient lling in the bed	patient got up from the bed		✓	✓								⚠	
3	Home / Care	under the bed	any	mobile/imobile	patient lling in the bed	fall from the bed		✓	✓	✓							❗	
4	Home / Care	under the bed	night	mobile/imobile	patient lling in the bed	fall from the bed		✓	✓	✓	✗					✓	❗	specific noise
5	Home / Care	under the bed	day	mobile	patient got up from the bed	walking in the room		✓								✓	✗	
6	Home / Care	under the bed	night	mobile	patient got up from the bed	walking in the room in the dark		✓			✗					✓	⚠	
7	Home / Care	under the bed	day / night	mobile/imobile	patient in the bedroom	smoking							✓			✓	❗	
8	Home / Care	attached to the mattress	day / night	mobile/imobile	patient lling in the bed	movement in the bed		~	~			✓					✗	
9	Home / Care	under the bed / in the room	day / night	mobile/imobile	patient in the bedroom	Loud noise (TV or screaming)				✓						✓	⚠	
10	Home / Care	under the bed / in the room	night	mobile/imobile	patient in the bedroom	loud TV in the night				✓	~					✓	⚠	
11	Home / Care	under the bed / in the room	day / night	mobile/imobile	not important	long open window								✓		✓	⚠	Drop in temperature
12	Home / Care	in the room / kitchen	day / night	mobile/imobile	preparint hot water	led from kettle is left over so it does not automaticly turn off								~	✓	✓	❗	Sudden rise in humidity
13	Home / Care	in the room	day / night	mobile/imobile	not important	fire							✓	✓			❗	drop in temperature
14	Home / Care	in the room	day / night	mobile/imobile	not important	slow rise of Co2 (unventilated room)							✓				⚠	slow rise of Co2
15	Home / Care	in the room	day / night	mobile/imobile	not important	fall of furniture		✓		✓						✓	⚠	specific noise
16	Home / Care	kitchen/ bathroom	day / night	mobile	not important	Open water tap				✓					✓	✓	⚠	detection over long time
17	Home / Care	kitchen	day / night	mobile	not important	leaking natural gas							✓			✓	❗	
18	Home / Care	bathroom door	day / night	mobile	not important	entering bathroom		✓									✗	
19	Home / Care	bathroom door	day / night	mobile	entering bathroom	stuck/fall in bathroom		✗		~						✓	⚠	undetected exit from the bathroom for for a long time
20	Home / Care	attached to the mattress	day / night	mobile	entering bathroom	another person sittin on the bed			✓			✓					✗	
20	Home / Care	bathroom	day / night	mobile	entering toilet	detection of toilet use				✓	✓					✓	✗	specific noise
21	Care	any	day / night	mobile	entering room	detection bariere crossing	✓										⚠	specific noise

explanatory notes:

- check mark – sensor detects change of state ✓
- cross – detection of state change was expected but did not occur in a specific time ✗
- tilde – optional detection that can help recognize the event with more probability ~
- abnormal condition ⚠
- critical condition ❗

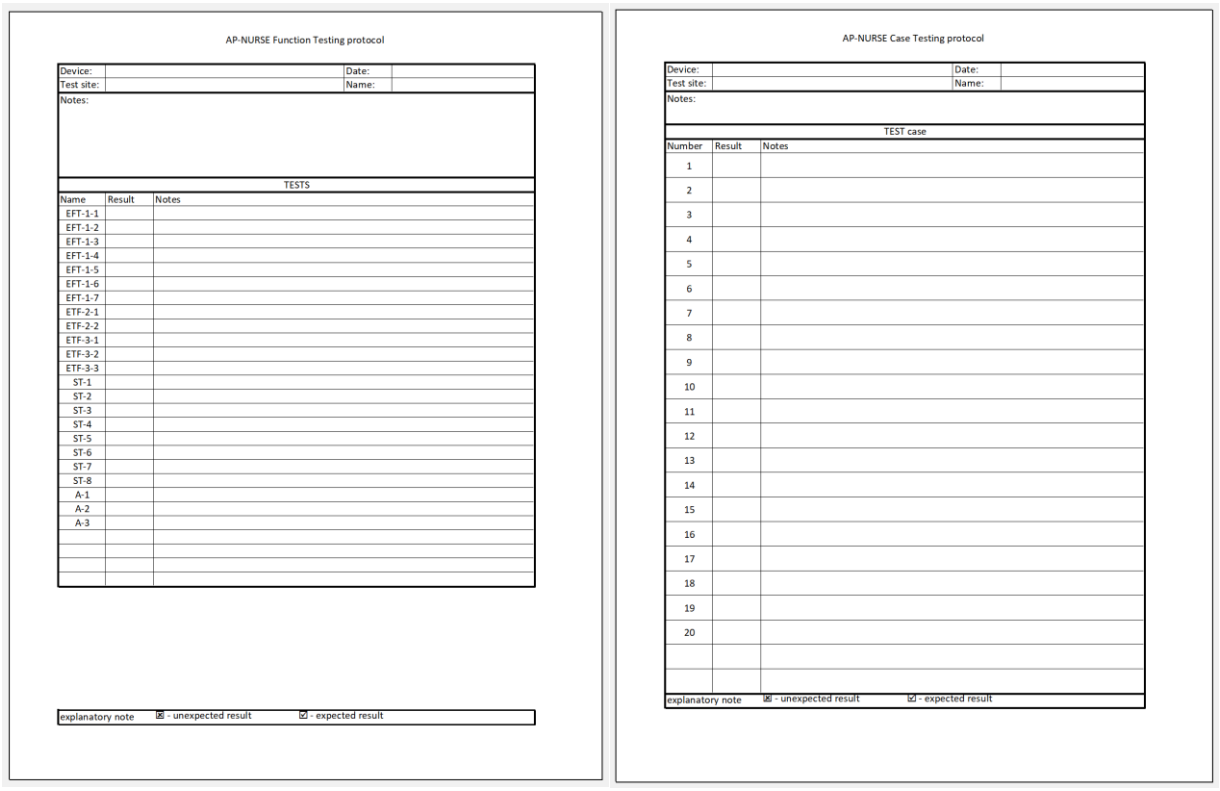
Test Case examples:

1. Test case 4 – fall from the bed during night
    - Patients is lying in the bed and suddenly fall down from the bed. Movement sensor detects movement in the room, pressure sensor under the patient matrices detect downfall of pressure. Noise sensor might detect short specific sound. Patient did not turn on the lights in the room. Critical condition alert is triggered.
2. Test case 10 – Loud TV in the night
    - Noise sensor in patient room with television detent high signal values. Combination with sensors capable of measuring light might be also helpful. Abnormal condition alert is triggered.

5.2.3. Testing methodology

Overall testing consists of the following steps:

1) Function tests for every AP-NURSE device
    - processing of the device test report protocol
    - evaluation of the correct functioning of the device
    - correction of possible production defects of the equipment -> new function testing
2) Performing Test case testing for selected AP-NURSE devices
    - processing of the device test report protocol
    - evaluation of sensor triggering values
    - processing of conclusions and proposals for corrections and repairs
3) Output control of the device
    - Automated testing of devices



AP-NURSE Function Testing protocol

Device:		Date:	
Test site:		Name:	

Notes:

TESTS

Name	Result	Notes
EFT-1-1		
EFT-1-2		
EFT-1-3		
EFT-1-4		
EFT-1-5		
EFT-1-6		
EFT-1-7		
ETF-2-1		
ETF-2-2		
ETF-3-1		
ETF-3-2		
ETF-3-3		
ST-1		
ST-2		
ST-3		
ST-4		
ST-5		
ST-6		
ST-7		
ST-8		
A-1		
A-2		
A-3		

explanatory note ☒ - unexpected result ☑ - expected result

AP-NURSE Case Testing protocol

Device:		Date:	
Test site:		Name:	

Notes:

TEST case

Number	Result	Notes
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

explanatory note ☒ - unexpected result ☑ - expected result

Figure 91: AP-NURSE function testing protocol (left) and test case (right) protocol

6. Conclusion

This document summarizes the construction of data and control nursing unit as well as the software of the AP-NURSE Home and Care devices. It consists of five chapters, i.e. introduction, overview of the AP-NURSE platform, requirement on the system design, construction of the AP-NURSE device and testing. The requirements on the system design were created based on the results of an electronic survey, created using the LimeSurvey open platform, consisting of 65 questions in 8 thematic groups. The survey was completed by 6 respondents from the Petržalka Municipal District of Bratislava, The University Hospital Olomouc and the Municipality of Olomouc City. Among them, 3 institutions are involved in the care of patients suffering from frail elderly and 3 have experience with all listed chronical diseases (Alzheimer disease, Parkinson's disease and Frailty elderly). The construction of AP-NURSE units is divided into two branches based on the proposed systems (Home and Care). To express the needs of caregivers, 6 version of AP-NURSE Home were created, among which 4 are also available in case of AP-NURSE Care. The versions of AP-NURSE represent six use cases, for which the system can be utilized. The signalization of events, in case of both Home and Care solutions is based on a simple traffic light logic, where green light represents normal, yellow light abnormal and red light critical condition. For both AP-NURSE Home and Care, issues related to the used hardware, the software development, the casing and the server are comprehensively described. The last chapter of the document is dealing with the testing of AP-NURSE devices in laboratory conditions, for which special testing room was designed and prepared at STU. The testing procedure consists of function tests, to verify whether the hardware was assembled in a proper way and the software implements the required functionality, and test cases, simulating real conditions of patients a verifying the functionality of the whole solution. The test cases are defined in accordance with the AP-NURSE versions (AP1-6) reflecting various testing locations, types of patients and daily regimes. Although, according to the goals of the project, the AP-NURSE Care solutions should be follow two directions of development, only the M5STACK platform is described in the document. Due to not finalized public procurement of major components of the Waspmote solution in Petržalka and Warsaw, all related activities were postponed and will be describe in the subsequent deliverables.

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