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AP NURSE HOME & CARE MONITORING TOOLS

System specification

Version 1
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1. Preface

AP-NURSE is a simple and modular monitoring tool used for patients suffering from Alzheimer's and Parkinson's disease for home and medical applications. 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.

2. System description

The main idea of the proposed tools is to bring a cheap and thus widely affordable solution that can monitor the basics interaction of the patient with the environment during night or job duties and provide fast alert about possible dangers. The tools will not be in direct contact with patients to prevent detachment, damage and their dysfunction. The tools encompass ambient contactless sensors to identify changes in the environment. The setup of sensors will vary according to the target group. Two versions will be available, AP-NURSE HOME and AP-NURSE CARE. Both version are based on the previously performed market research, presented in [1]. In the case of AP-NURSE-HOME, a caregiver will wear a simple rubber watch/bracelet that will identify the incoming signal and warn a caregiver by vibrating. In the case of AP-NURSE-CARE, a caregiver will control the condition of patients from the nurse/control room on a PC or using a mobile device, visualizing the parameters of AP-NURSE-CARE utilizing the simple traffic lights logic. Both configurations will make possible of securely sending anonymized measured data to a dedicated data server for further analysis.

3. Use-case definition

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. The features of AP-NURSE HOME & CARE are shown in **Table 1**.

Table 1: Features of AP-NURSE HOME & CARE [2]

	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	✗	✓

3.1. AP-NURSE HOME

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 their everyday life.

In case of any emergency detected by the monitoring devices, 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). After the caregiver received the notification, he is required to push a button on the device, from which the signal had been sent, to assure that the necessary help was delivered to the patient. If needed, online measured sensor data under and above set thresholds may be sent to dedicated servers for further analysis.

The flowchart of the AP-NURSE-HOME solution is shown in Figure 1.

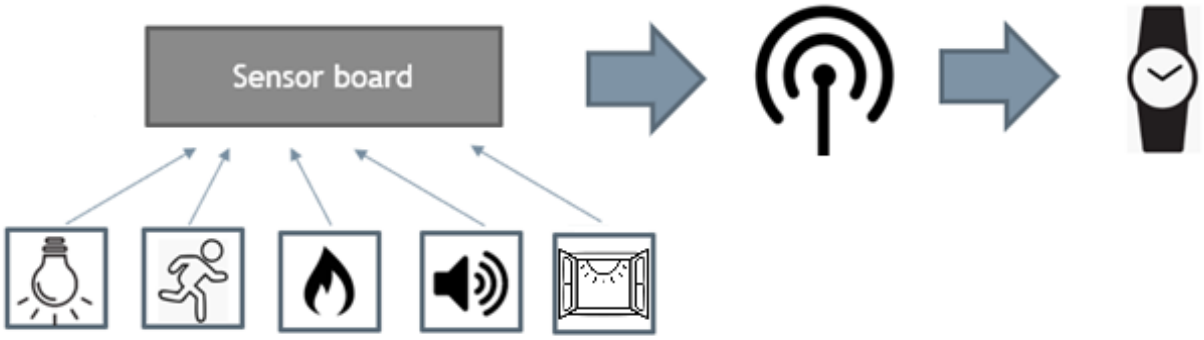


Figure 1: AP-NURSE HOME flowchart

3.1.1. Use-case: Bracelet notification

A simple use-case of the AP-NURSE HOME solution can be seen in **Figure 2** (numbers represents the steps prior to the actuation of AP-NURSE). This use-case represents a routine use of AP-NURSE in the home environment where the patient suffering from Alzheimer's or Parkinson's disease lives with his/her caregiver, who is usually a member of his family.

1. The patient, who had been sleeping, woke up and stepped out from the bed.
2. As part of his/her routine the patients moved towards to kitchen or any room where AP-NURSE is installed.
3. As the patient switched on the light, opened the fridge or turned on the gas stove, AP-NURSE notified the change in the environmental parameters and warned the caregiver who had been sleeping in the next room.
4. The caregiver, who woke up due to the vibrating bracelet, turned off all electronic/gas appliances and put the patient back to bed.

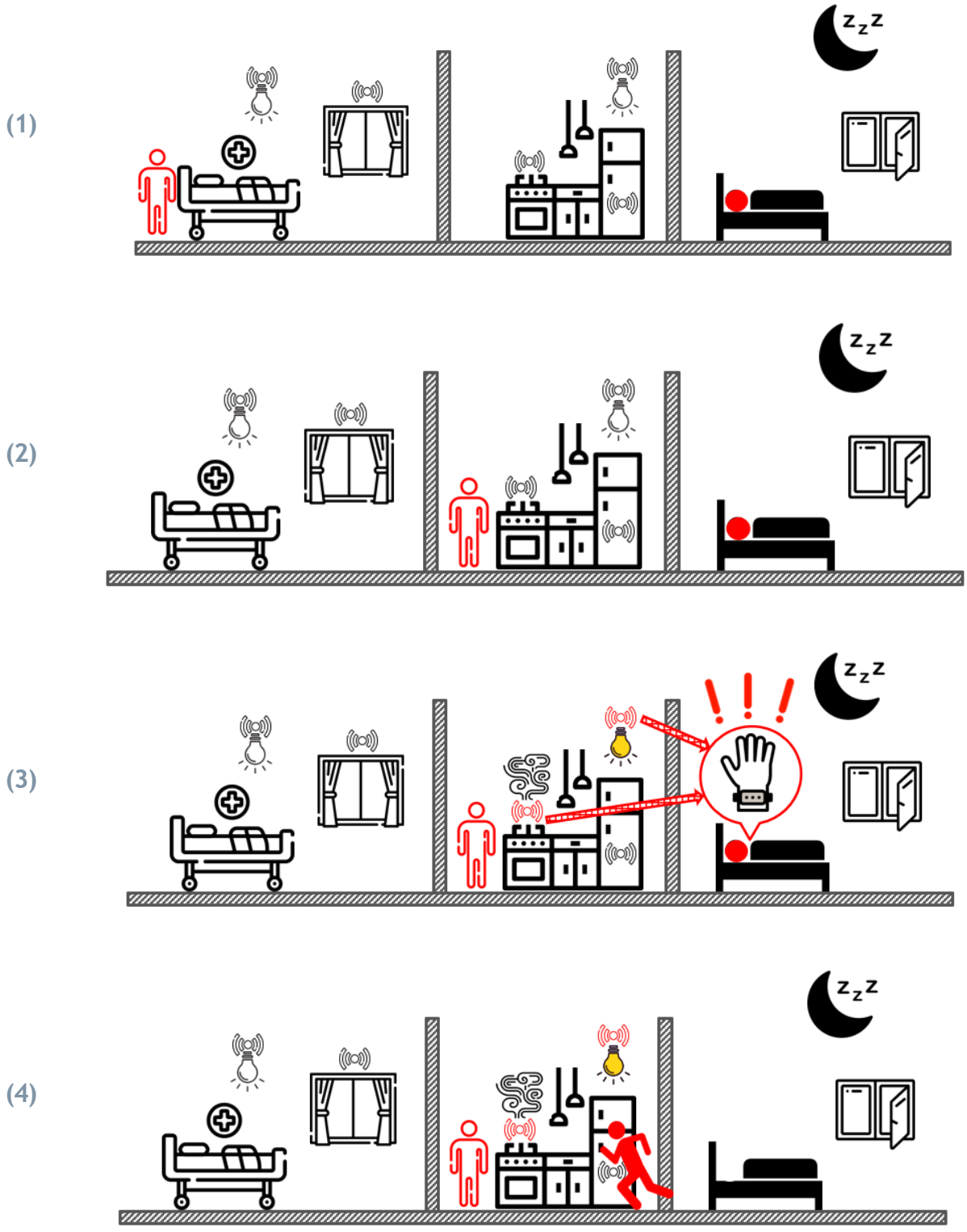


Figure 2: Bracelet notification use-case [1]

3.2. AP-NURSE CARE

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 routine duties of the caregiving personnel. It is assumed that the caregiving personnel controls the condition of patients from the nurse/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.

If required, after a specified monitoring period, artificial intelligence could deliver results of analysis showing the progress and health status of monitored patients. The registration and the setup of the monitor screen would solely be adjustable under an administrator account.

The flowchart of the AP-NURSE-CARE solution is shown in **Figure 3**.

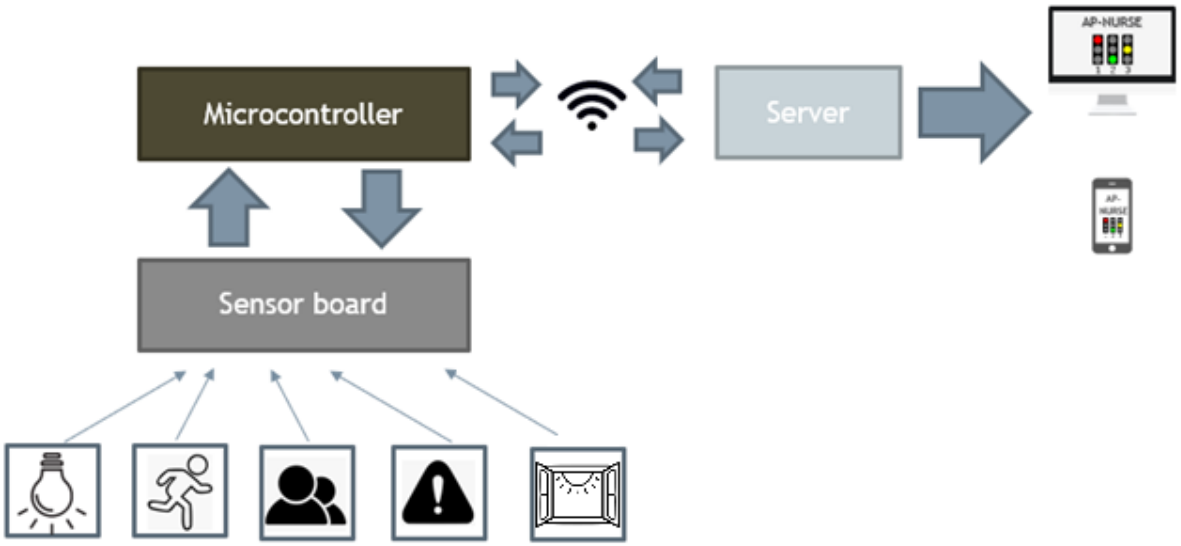


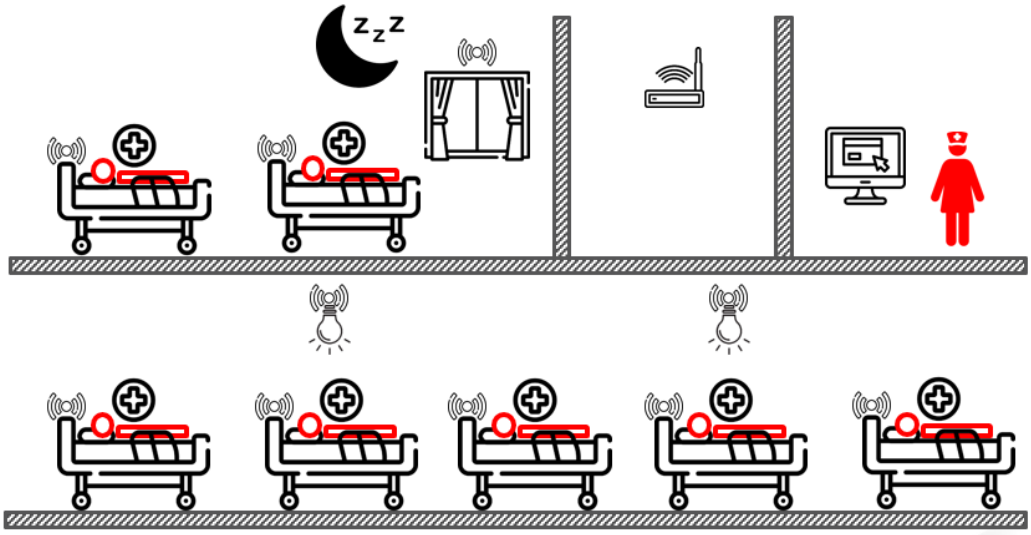
Figure 3: AP-NURSE CARE flowchart

3.2.1. Use-case: Nursing room

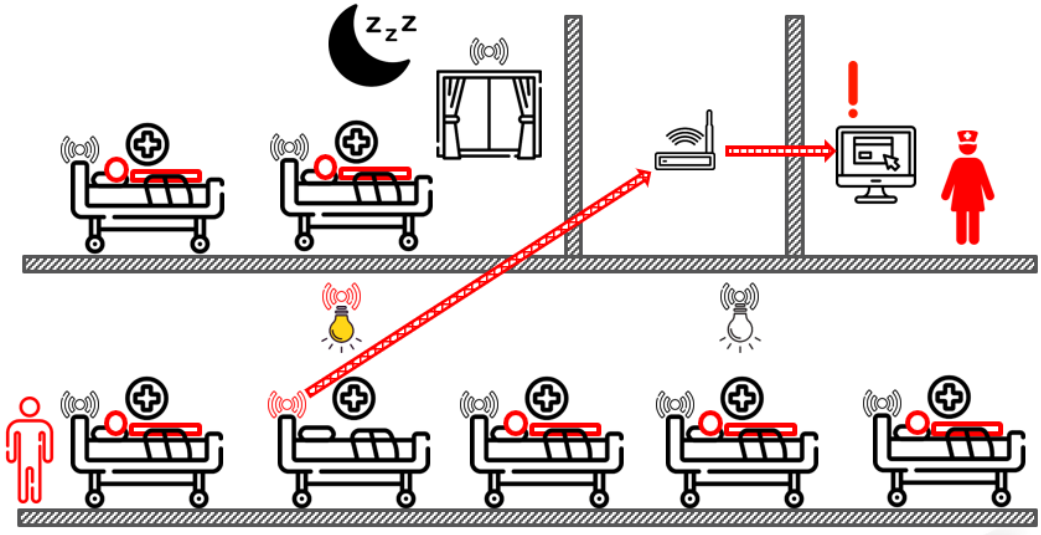
A simple use-case of the AP-NURSE CARE solution can be seen in **Figure 4**. (numbers represent the steps prior to the actuation of AP-NURSE). This use-case represents the use of AP-NURSE in the care center where multiple patients from Alzheimer's or Parkinson's disease are accommodated in rooms while their conditions are monitored by the professional personnel from the nursing room.

1. One of the patients, who had been sleeping, woke up and stepped out from the bed.
2. As the patient started to move in the room equipped by multiple AP-NURSE sensors, the PC or the APP installed on the mobile of the caregiving personnel provided the first notification, classified as warning.
3. By switching the lights on the patient actuated multiple sensors and the PC or mobile provided the next notification and required the personnel to intervene.
4. The caregiver, notified by PC or his/her mobile, put the patient back to bed, made sure the remaining patients were safe and reset the PC/APP notifications.

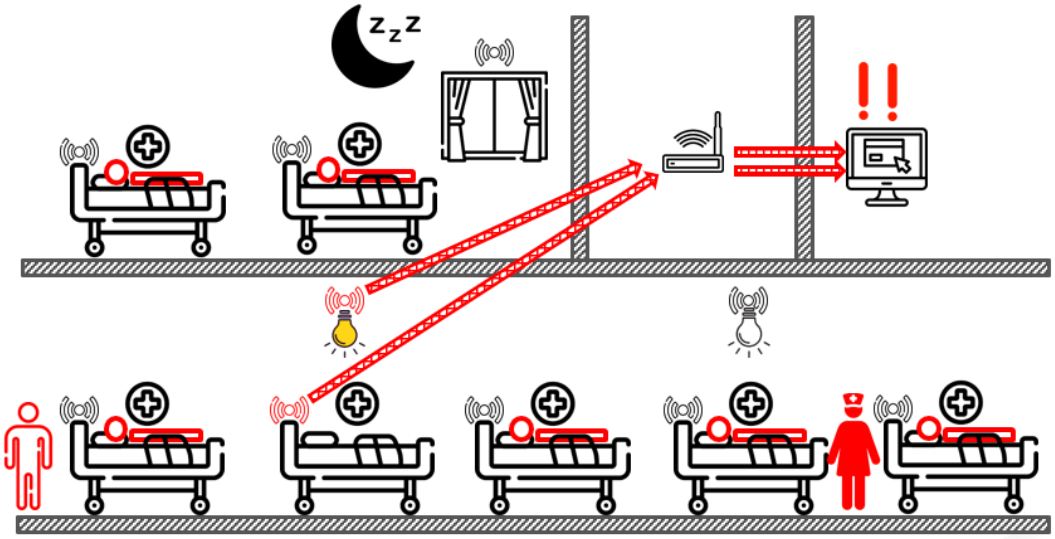
(1)



(2)



(3)



(4)

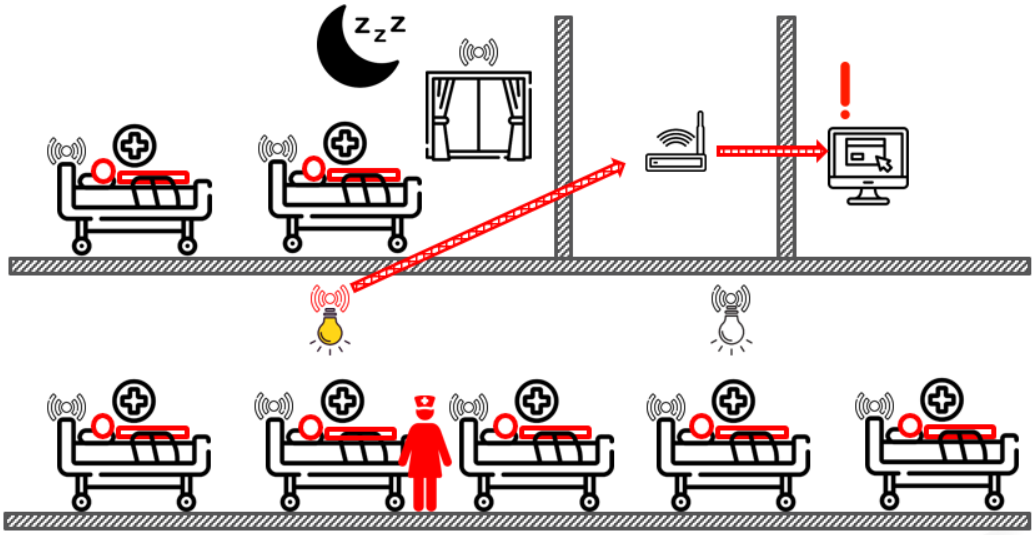


Figure 4: nursing room use-case [1]

4. System design

The AP-NURSE system encompasses two specific solutions and three hardware platforms. AP-NURSE HOME is designed as a simple, cheap and fail-safe peer-to-peer communication gate between sensors and the receiver, i.e. the vibrational rubber bracelet worn by the caregiver. The APP-NURSE CARE is a more sophisticated tool, encompassing multiple sensors, traffic light event logic, multiple communication platforms (PC, mobile App) and front-end – back-end interaction. The back-end part of the system serves for data storage, data processing, data analysis, result review, communication with the frontend part, etc. The back-end solution could be ensured by a dedicated global server or local servers at the level of application facilities.

4.1. AP-NURSE HOME

4.1.1. Data acquisition

In the case of the AP-NURSE HOME solution, no special data gathering is foreseen. Based on the measurement of environmental parameters, AP-NURSE HOME notifies the caregiving personnel wearing a vibrating and alarmed rubber bracelet. The bracelet provides two levels of notification (warning, danger). The most important data obtained are thus the frequency and the type of notification for a given patient over a specified monitored period. If required, the obtained notification data can be stored on a dedicated server and further analyzed to evaluate the progress of the patient over time. The microcontroller with a sensor board may have multiple operation modes (day and nighttime) to avoid generating false signals for example during the daytime when the motion of the patient is not limited.

4.1.2. Data processing and analysis

Data processing is directly performed by the NodeMcu ESP8266 microcontroller, to which the sensors are connected. The software of ESP8266 supports simple statement logic for triggering and transmitting an appropriate notification. Based on the triggered event, the microcontroller generates the warning or

the danger signal and sends it via radio transmission to the caregiver's bracelet. Since the caregiver does not have any additional information about the event, he is required to check the patient's status.

The microcontroller has also multiple operation modes and based on these modes, the statement logic categorizes all events into proper signal groups. Some examples are listed below and through the testing of the prototype the list of events will be expanded or modified:

- **Warning: ORANGE**
  - **Trigger of the motion sensor in the hallway during the daytime.**
  - **Temperature change in the patients' room during the daytime.**
- **Danger: RED**
  - **Trigger of the gas sensor in the kitchen during all operation modes.**
  - **Trigger of the motion sensor in the hallway during the nighttime.**
  - **Trigger of the noise sensor in the patients' room during the nighttime.**
- **Status OK: no indication on the bracelet**
  - **Trigger of a noise sensor in the patients' room during the daytime.**
  - **Trigger of a lighting sensor in the patients' room during the daytime.**
  - **Trigger of a motion sensor in the patients' room during the daytime.**

During testing and in special cases, the monitored data can be stored, serving the data analysts, the technicians maintaining the monitoring system or the neurologists, psychologists, general practitioners, specialists and experts engaged in the treatment of Parkinson's and Alzheimer's diseases. If required, the monitored data may be stored and processed on an external dedicated server or on a local server. The NodeMcu ESP8266 can communicate with the external data server through the internet via WiFi connection.

4.2. AP-NURSE CARE

4.2.1. Data acquisition

In the case of the AP-NURSE-CARE, two methods of data gathering are possible. The first method is similar to the one in the case of AP-NURSE-HOME. It represents the collection of notifications on a computer located in the nurse room or on a mobile app. The second method comprises the collection of environmental data on a dedicated server. The environmental data include changes in the ambient temperature, airflow, light intensity, gas concentrations, movement, crossing a barrier or opening-closing a specific device (fridge, window door, oven, etc.) These data together with the frequency and type of notifications may serve to evaluate the progress of the diseases of monitored patients and help in decision making regarding the treatment of the patient.

Regarding the frequency of data acquisition, two options are available:

- periodical data gathering - from milliseconds to minutes;
- change follow monitoring – if some parameter changed or exceeded the threshold, notification would be provided.

4.2.2. Data processing and analysis

The users of the stored data could be neurologists, psychologists, general practitioners, specialists and experts in the treatment of Parkinson's and Alzheimer's diseases as well as data analysts, IT specialists and experts in machine learning and artificial intelligence. Due to this broad user base of gathered data, various data processing options are possible.

- **Processing of raw data** – The processing of these data involves inspection of the data content (checking the correct receipt of packages, data size and format control, etc.), battery status and communication. Correctly obtained data are stored as evaluated data in the database either at the dedicated server or at the local servers. If multiple communication or data transfer errors are encountered, these events are evaluated as communication errors. In such a case, intervention is required by the personal. The same applies in case of low battery or loss of power supply.
- **Processing of basic data related to the frequency of notification**. This data processing involves the adjustment of evaluated data and creating a logical database of notifications, as sets of notification time vs. notification type function pairs. Three levels of notifications are possible, Green notification as a regular status check, Orange notification as a warning and Red notification as danger requiring intervention. The database of these function pairs would be as follows:
  - NODE1: 21/05/2020 03:11:06 - **GREEN**(STATUS CHECK: OK, BATERY: 87%)
  - NODE1: 20/05/2020 19:34:54 - **ORANGE**(SINGLE EVENT: PIR1: EVENT)
  - NODE3: 26/05/2020 12:00:16 - **RED**(MULTIPLE EVENTS MOVE1: EVENT, GAS1: EVENT)
- **Processing of filtered environmental data relevant for medical and IT purposes**. The processing of environmental data is performed using the created debase of notification. In order to analyze the severity of notification and their relation with the monitored patients, these data are extended by the exact location of sensors, by parameters related to the nature of the diseases and by previously obtained notification data. This processing may also involve the use of predictive behavioral models and the application of machine learning and AI principles. Since this processing option relies on the size and type of gathered generic data, the filtering procedure is yet unknown. It will be selected based on rough analyses of the testing data, likely after the project closure.

5. AP-NURSE HOME - system implementation

5.1. Back-end hardware solution

AP-NURSE HOME is designed as a simple and easy to use communication gate between sensors (placed in the patient's environment) and vibrational rubber bracelet worn by the caregiver, therefore its safe operation does not necessarily require back-end hardware solutions. However, if required the gathered data may be stored and analyzed at the dedicated STU server or local servers. More information regarding the dedicated STU server can be found in the system implementation chapter of the AP-NURSE CARE solution.

The local server solutions will be based on the available Open Source Automation Platforms (OpenHab, Home Assistant, Domoticz, HealthyPi) where the monitoring visualization of the received data will be adjusted to the target group needs and platform abilities. The chosen software will be installed on Raspberry Pi, due to the low electricity consumption allowing the 24/7 operation mode. Though there are many Single Board Computers, Raspberry Pi is still the choice for many developers because of the support and the associated price. In case of necessity, the automation platform will be connected to the available free services allowing to push notifications or warnings to the user android phone.

5.2. Front-end hardware solution

AP-NURSE HOME is based on the NodeMcu ESP8266 microcontroller [3] paired with the rubber bracelet via radio communication. The monitoring device includes the NodeMcu ESP8266 core unit with peripheral sensors and RF433 MHz transmitter [4] encapsulated in an appropriate casing, maintaining damage and vibration resistance. The bracelet includes warning signal lights, battery indicator, vibration module and the RF433 MHz receiver [4].

5.2.1. Operation scheme

The general scheme of AP-NURSE HOME **Figure 5**. It is considered that AP-NURSE HOME can be used to monitor multiple premises. For instance, if the patient's bedroom is monitored, the monitoring system has multiple modes of operation based on the daytime. Motion, light, noise and smoke are monitored by Node 1. If required, it is possible to monitor events, such as opening the window, increase of the ambient temperature, change of the humidity, increase of the atmospheric pressure, etc. If some of these events occur during the night, Node 1 generates the signal, which is emitted to the caregivers' bracelet through the RF433 MHz transmitter. Subsequently, the bracelet vibrates upon the actuation and flashlight notification is provided, according to the event logic. During the daytime, motion, light, and noise signals can be omitted to avoid triggering false events to the bracelet. Node 2, placed in the kitchen, can monitor dangerous gases such as propane-butane. The last Node 3 is optional and is placed in the hallway. Its function is to monitor the possible leave of the patient from the home during nighttime (it can also monitor other parameters such as smoke, temperature, etc.). The operation scheme of AP-NURSE HOME with three nodes is shown in **Figure 6**. During the testing phase of AP-NURSE or on special occasions, the monitored data could be gathered for further analysis. For such a purpose the NodeMcu ESP8266 may send the data by WiFi connection to the dedicated server or to the local server.

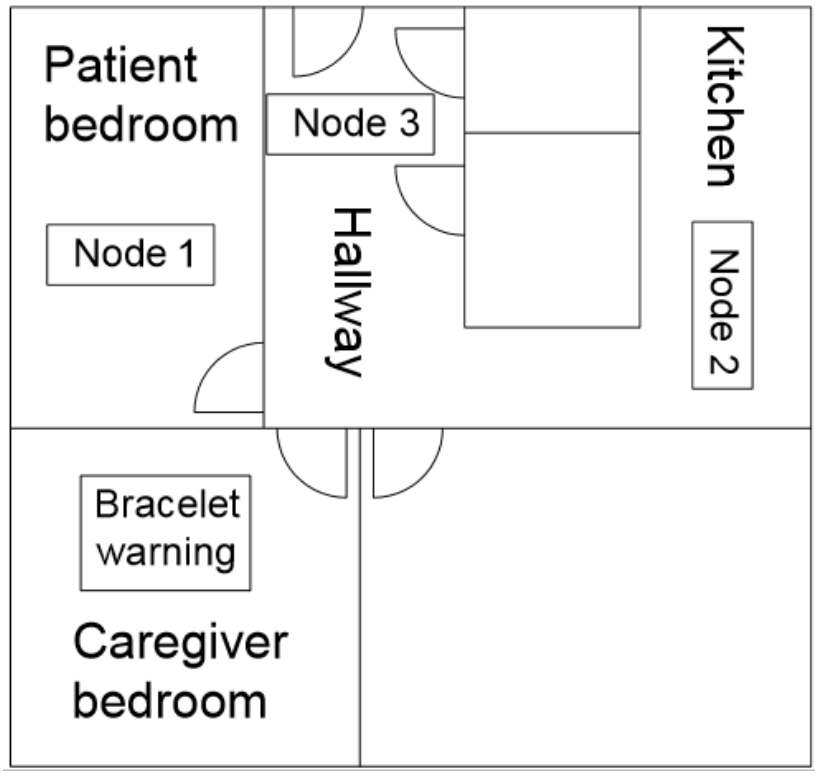


Figure 5: AP-NURSE HOME general scheme

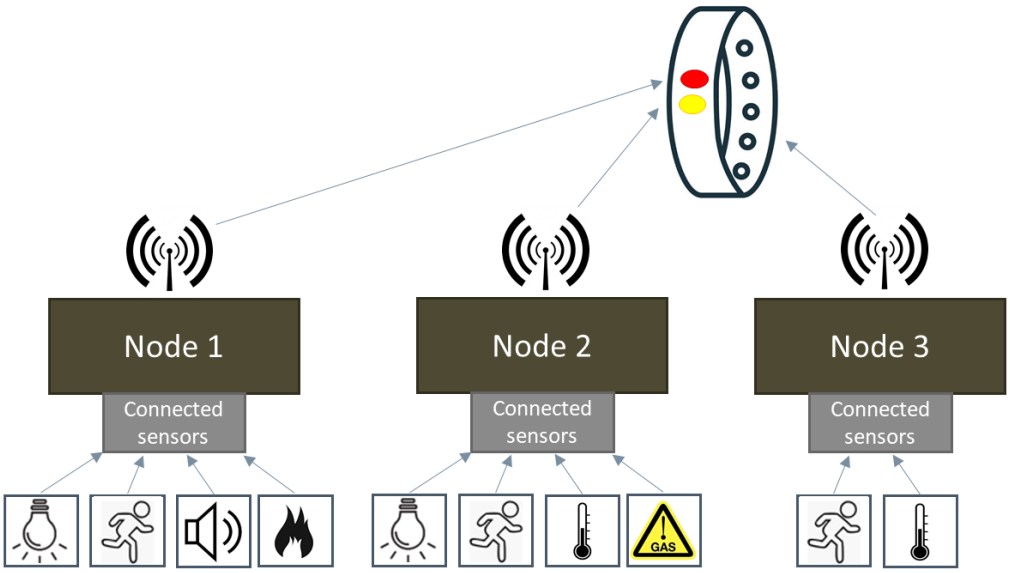
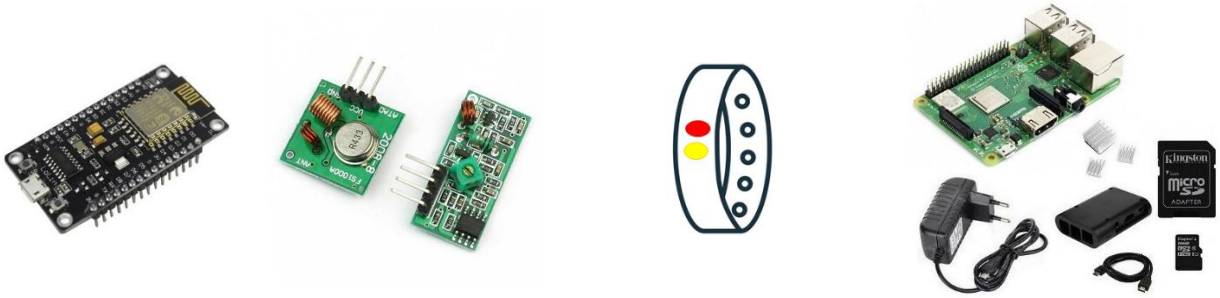


Figure 6: AP-NURSE HOME operation scheme

5.2.2. Core units

The core units of AP-NURSE HOME are shown in **Figure 7**. **The NodeMcu unit**, integrating the chip ESP8266 (**Figure 7**-a) is the main unit. It contains the Xtensa LX106 32bit processor with 80 MHz clock frequency. The 1 MB compilated 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 and current are 3.3 V and 12 mA respectively.



a; NodeMcu ESP8266 [3]

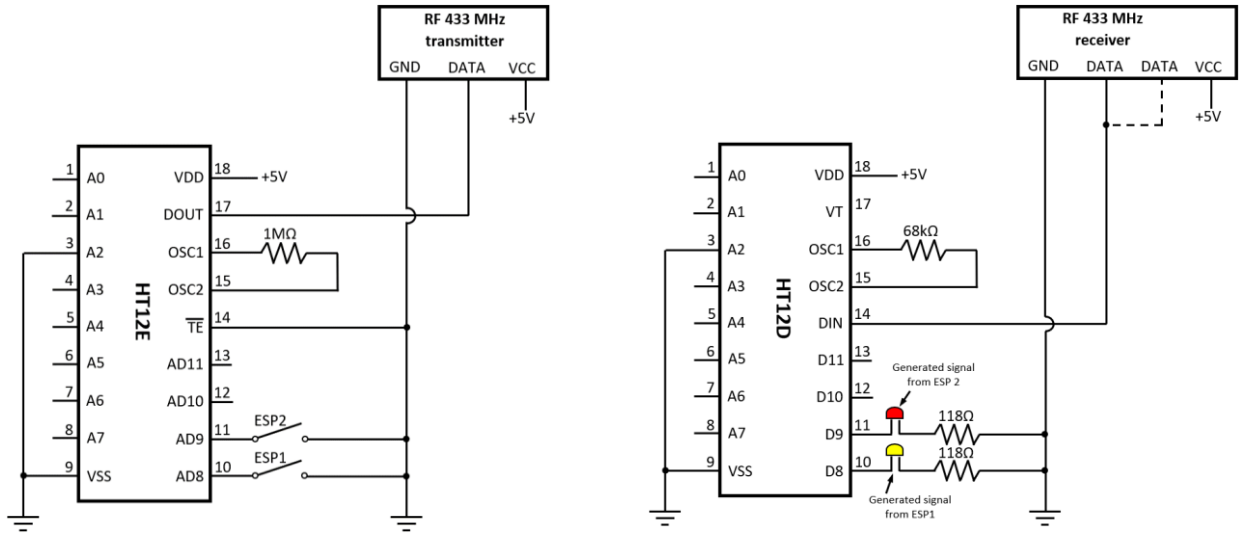
b; RF 433 MHz unit [4]

c; Monitoring bracelet

d; RaspBerry Pi server (optional) [5]

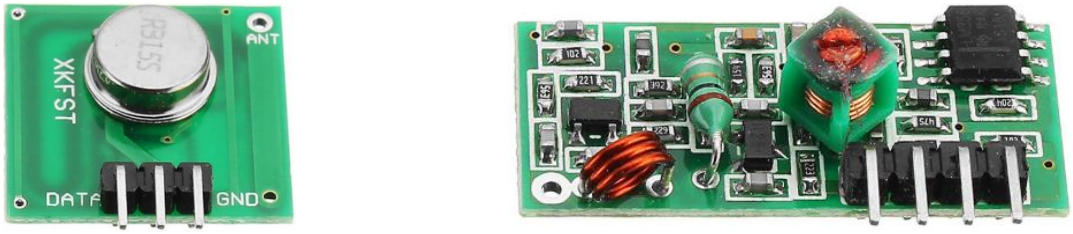
Figure 7: AP-NURSE HOME core units

The second core unit is the **RF433 MHz** receiver-transmitter unit (**Figure 7**-b). To ensure correct function of the whole transmission, the HT12D (**Figure 9**-a) decoder and the HT12E (**Figure 9**-b) encoder are required. The operation schemes of the transmitter and receiver circuits are shown in **Figure 8**. In the transmitter circuit the *ESP1* and *ESP2* switches can be controlled by the NodeMcu ESP8266 microcontroller to generate input signal in case of alarm event. Using these core units 7 devices can be operated in parallel. Each transmitting device can send 4 signals through the AD8-AD11 switches. It is also possible to set oscillation frequency utilizing the resistivity between the *OSC1* and *OSC2* pins. The HT12E and HT12D diagrams of oscillation frequencies are shown in **Figure 10**.



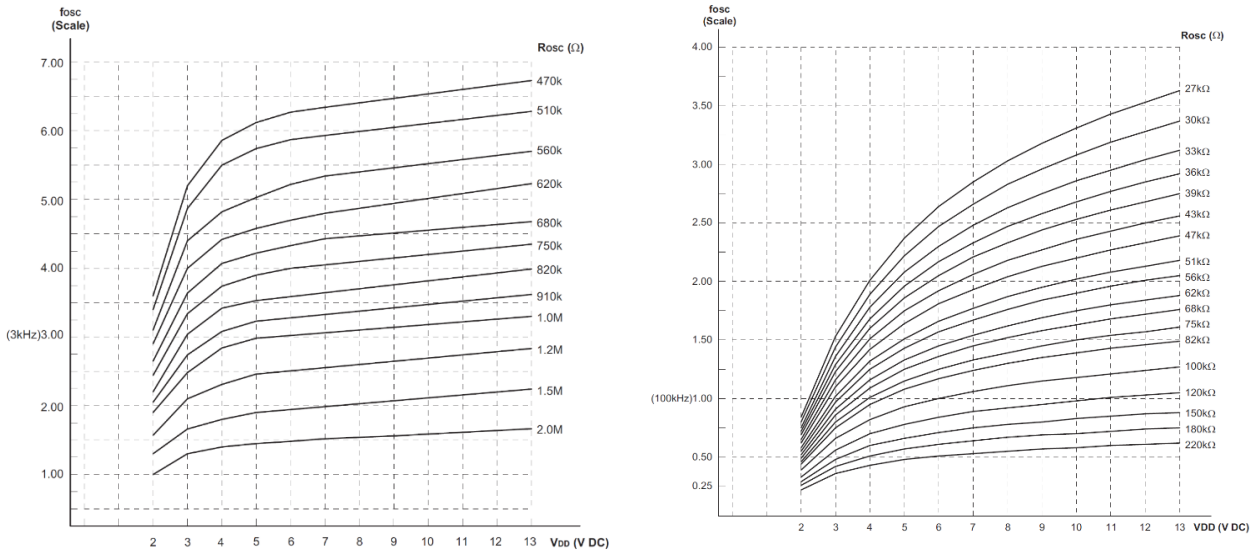
a; transmitter b; receiver

Figure 8: AP-NURSE HOME transmitter and receiver scheme [6], [7]



a; transmitter **b; receiver**

Figure 9: RF 433 MHz transmitter and receiver [4]



a; HT12E [6] b; HT12D [7]

Figure 10: oscillation frequency setup

The third core unit is the **bracelet.** The final design of the bracelet will be constructed during the finalization of the electronic part; therefore, the operation scheme of the bracelet is yet unknown. The bracelet itself should include the parts presented in the scheme of the receiver (**Figure 8**). In addition to the receiver and the decoder, the bracelet would consist of the signalizing diodes, vibration module, battery, battery indicator and optional rechargeable micro-USB port. The radio communication scheme of the AP-NURSE HOME prototype is shown in **Figure 11.**

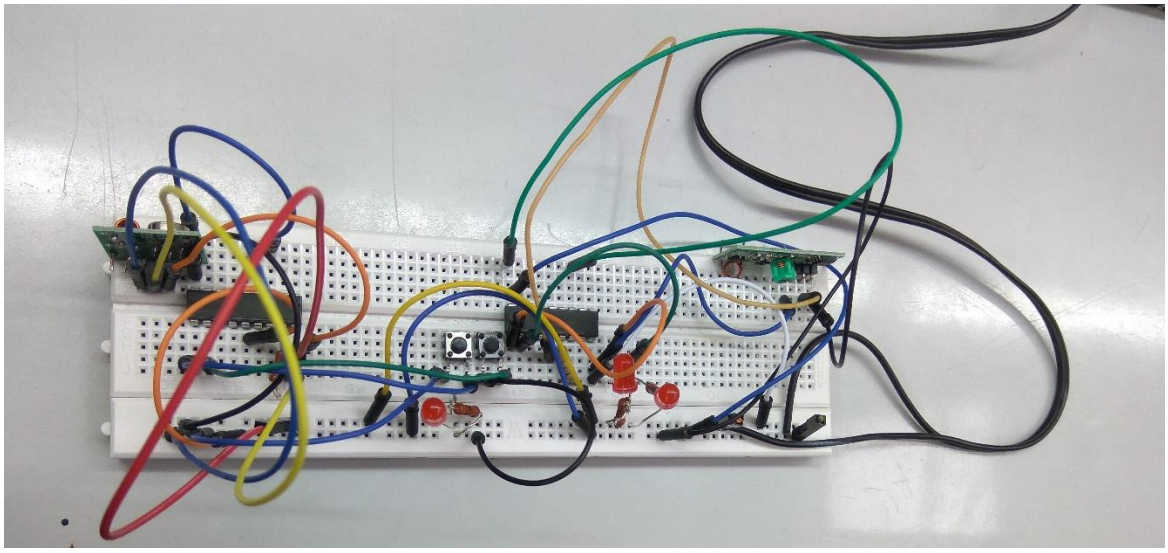
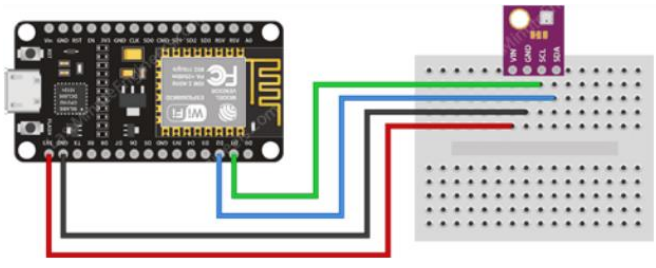


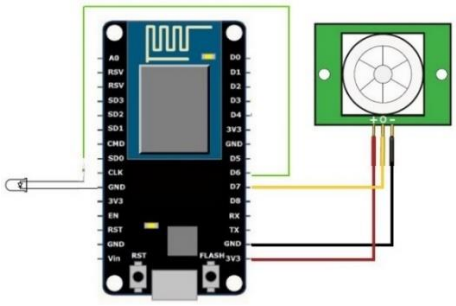
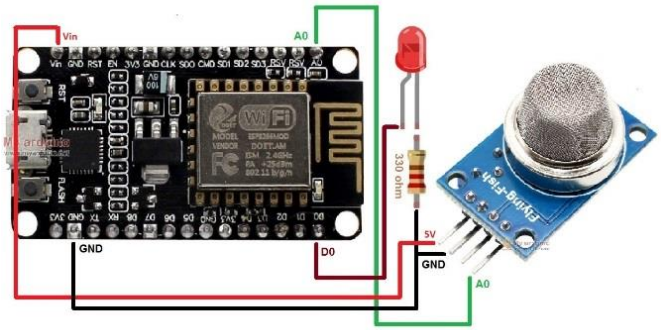
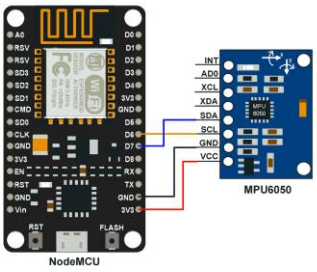
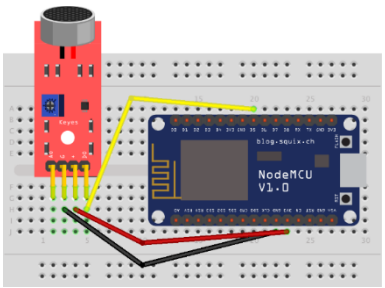
Figure 11: AP-NURSE HOME prototype

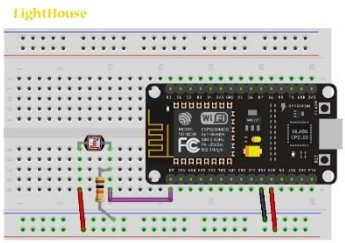
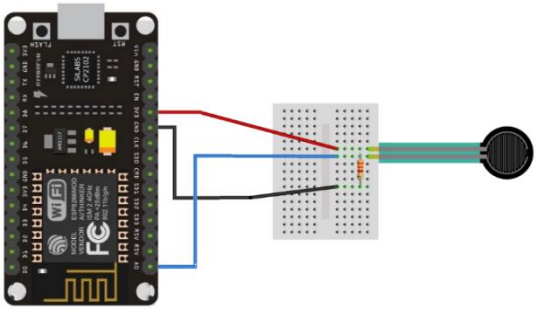
5.2.3. Sensors

In order to meet the requirements of using AP-NURSE HOME in patients' homes, the core units will be equipped with several simple sensors. The configuration of sensors will depend on the specific application, but the most important sensors considered for the testing of AP-NURSE HOME are shown in **Table 2**. Each sensor is presented with its NodeMcu ESP8266 connection scheme.

Table 2: AP-NURSE HOME sensors

BME 280 Atmospheric Sensor [8] 	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 operating voltage of the sensor varies is from 3.3 V to 5V.

HC-SR505 PIR Sensor [9] 	HC-SR505 Mini PIR (or other alternative) Motion Sensor is photosensitive sensor that can monitor the person's presence in the sensing area (approximately angle 120 degrees to the distance 7 m). The operational temperature is in the range from 15 to 70 °C, therefore the indoor application is considered in case of the AP-NURSE HOME version. It supports operating voltage up to 20 V with power consumption lower than 50 µA.
MQ Gas Sensors [10] 	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. Its application in AP-NURSE-HOME version 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. The operating voltage is 5 V and the operation temperature range is approximately from -10 to 45 °C for both sensors.
MPU6050 accelerometer [11] 	MPU6050 sensor is a 6-axis motion tracking device that combines 3-axis gyroscope and 3-axis accelerometer. The power supply voltage is in the range from 2.375 to 3.46 V. 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.
KY-038 Noise Sensor [12] 	Sensor KY-038 is used for the detection of noise in the area. The input voltage of the sensor is 3.3 V. The sensor supports the setup of the threshold when the signal is generated, therefore it can be easily optimized for appropriate environment
GL5528 photoresistor [13]	GL5528 photoresistor is used for the detection of the light. The principle is simple, the lighting of the sensor will change the resistivity of the photoresistor and the change

	of the voltage is registered by the NodeMcu ESP8266. The maximum input voltage of photoresistor is 150 V. The resistivity value in the dark is 1 MΩ and in the light between 8-20 kΩ.
FSR 402 Force Sensor [14] 	FSR402 force sensor is used for the measurement of the applied force on any kind of surface or object. This sensor can be used for the monitoring of barrier that should not be crossed by the patient. For example, during the 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.
3709 WAVESHARE analog extender [15] 	3709 WAVESHARE can be 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.

Another important component is the power source with emergency power supply. In the case of power outage, the battery would maintain the operation of the microcontroller for some limited time and microcontroller will trigger the warning signal to the caregiver. This system also allows to monitor the battery level by the voltage divider and this information is monitored directly by the microcontroller. The scheme of the rechargeable module is shown in **Figure 12** [16].

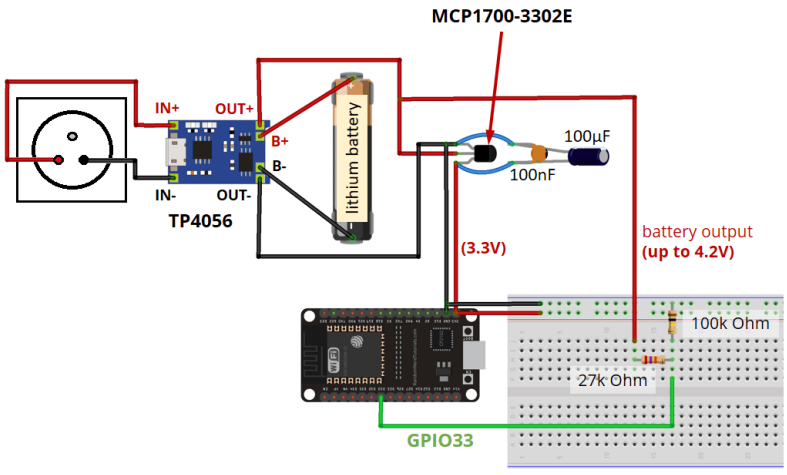


Figure 12: Scheme of the AP-NURSE HOME rechargeable module [16]

5.3. Software solutions

In the case of all AP-NURSE HOME monitoring devices, the standard ESP-EASY software will be used. This software is planned to be directly flashed on the NodeMcu ESP8266 microcontroller. ESP-EASY supports WiFi communication, monitoring of digital and analog inputs, simple statement logic for the triggering of the warning signals and also sending of relevant monitored data to the remote data server. For the local RaspBerry Pi servers, the standard implementation of Linux referred to as Raspbian, will be used as the operating system. Considering that this type of data-sharing is foreseen for special cases only, the standard open-source automation system Domoticz can be utilized for the data collection and processing of the monitored data. Also, simple processing scripts can be developed for the interpretation of monitored data.

5.4. Security

No severe data security issues are expected in the case of the final AP-NURSE HOME device, since, except for special cases, no internet connection will be set up. The whole communication will be based on the radio transmission between the monitoring device and the bracelet and the signals will just trigger the warning sign on the bracelet (no specific data will be sent through the radio transmission). The security issues may occur due to the interference with other devices using the same radio frequency transmission (433 MHz) used by the neighbors. To avoid these types of scenarios, the switcher will be included to change the address on the decoder (HT12D) and the encoder (HT12E). In case of special events requiring setting up communication with the dedicated server, the same security measures will take place as in the case of the AP-NURSE CARE solution.

6. AP-NURSE-CARE - system implementation

6.1. Back-end hardware solution

In the case of the AP-NURSE-CARE system primarily the STU dedicated server will be used. The multiplatform application in the back-end solution was designed in .NET Core 2.2. It is an open-source development platform. The application server manages client requests and forms a communication channel between IoT devices and the client application. The basis of the created system is modularity and flexible design, which allows extending the application with new functionality.

The modern Angular framework was chosen as a platform for creating a web application. It is an open-source framework, based on the Typescript programming language, created by Google and further developed with the help of a community of individuals. The application was developed in version Angular 9. Due to the need to create a responsive page, the look was created in the Material Design approach.

The system can integrate new types of IoT devices. Currently, the system is divided into four modules:

- **User administration module,**
- **Device module,**
- **Configuration device module,**
- **Data acquisition module.**

6.1.1. User administration module

To ensure access to device data only for authorized users, 3 types of powers have been created:

- **Observer -** has the right to see information and detail of the device, display measured data in graphs,
- **Editor** - has the same rights as the observer, but can also change the details of the device (such as its name) and modify its configuration,
- **Owner** - this is the user who registered the device, so he has full authority (as an editor), but can also share the device for other users and assign them a role (editor or observer)

6.1.2. Device module

The device module is used to manage and register devices. Allows the users to create groups of devices with the same properties, such as the Living Room / Room group, which includes all devices located in the living room (**Figure 13**). The created device group can be shared with other users (for example, family members / staff), who, in the case of group membership, can monitor or modify (according to the assigned authority) devices that do not belong to them.

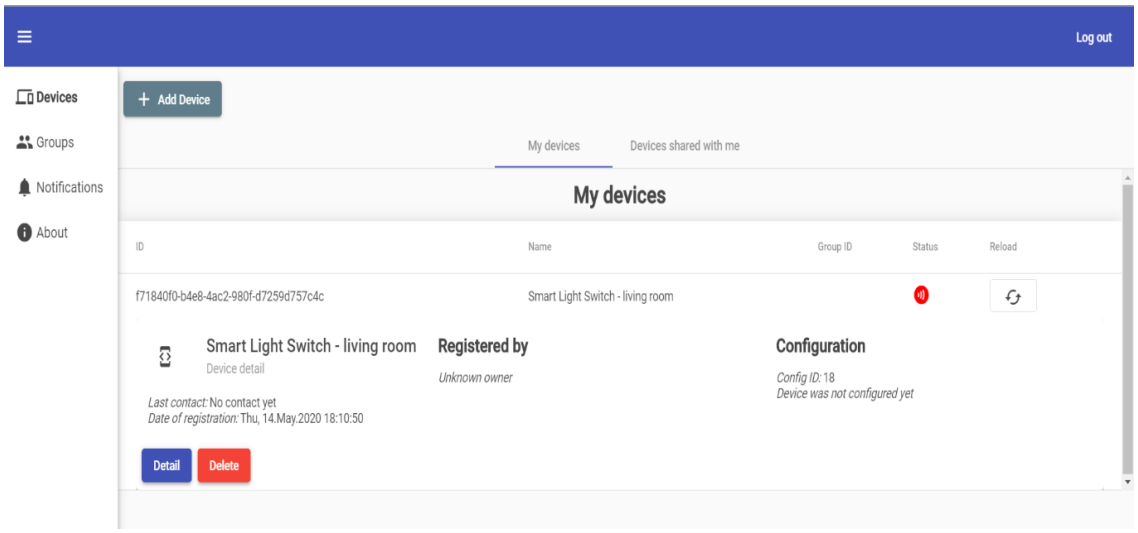


Figure 13: Device module

Sorting devices into groups allows clear management of devices for a larger number of users for whom the devices are relevant. One device can be in multiple groups of devices at the same time, and one user can be the owner or member of multiple groups. The owner of the group - the user who created it - can change the permissions of other users in the group, add new ones, or remove them.

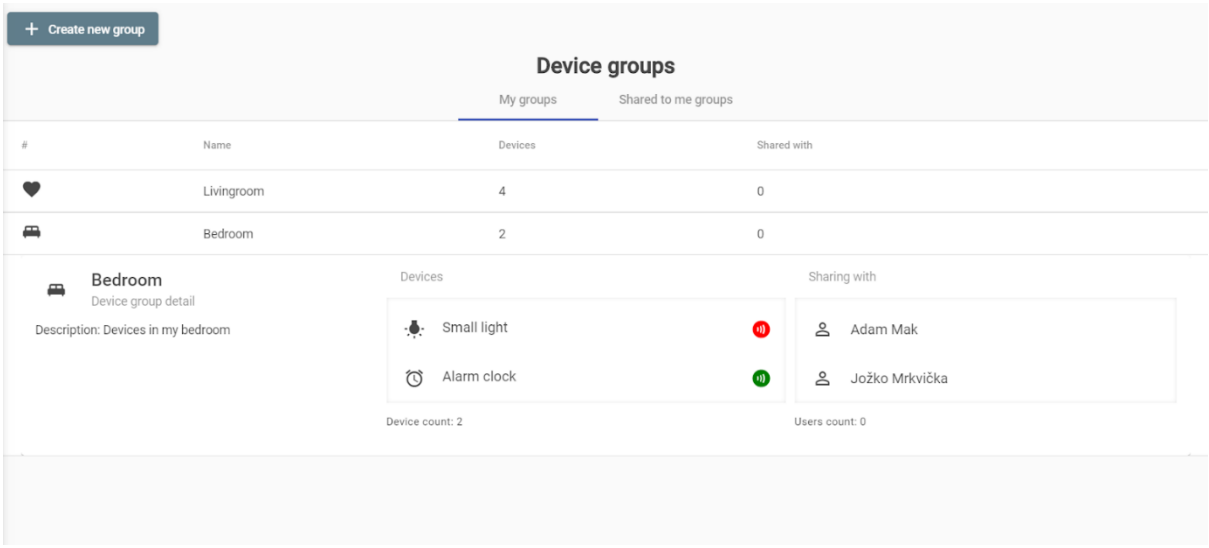


Figure 14: Management of device groups

6.1.3. Configuration module

This module takes care of device configurations, whether setting the correct basic configuration for a new device or changing the configuration received from the client application. The device configuration allows you to set the range and frequency of data acquisition over time and defines system settings that clearly determine the behavior of the device. The configuration module is shown in **Figure 15**.

Versions of configurations are used to ensure that the configuration on the device is current. When receiving a request from the device, the module checks the version of the configuration used and, in the case of a newer version from the client application, sends the new version to the device. The module does not allow to modify the configuration of the same device if the modified version does not match the version used on the device (when the server is waiting for a new version to be sent to the device, and at the same time receives another version from the client).

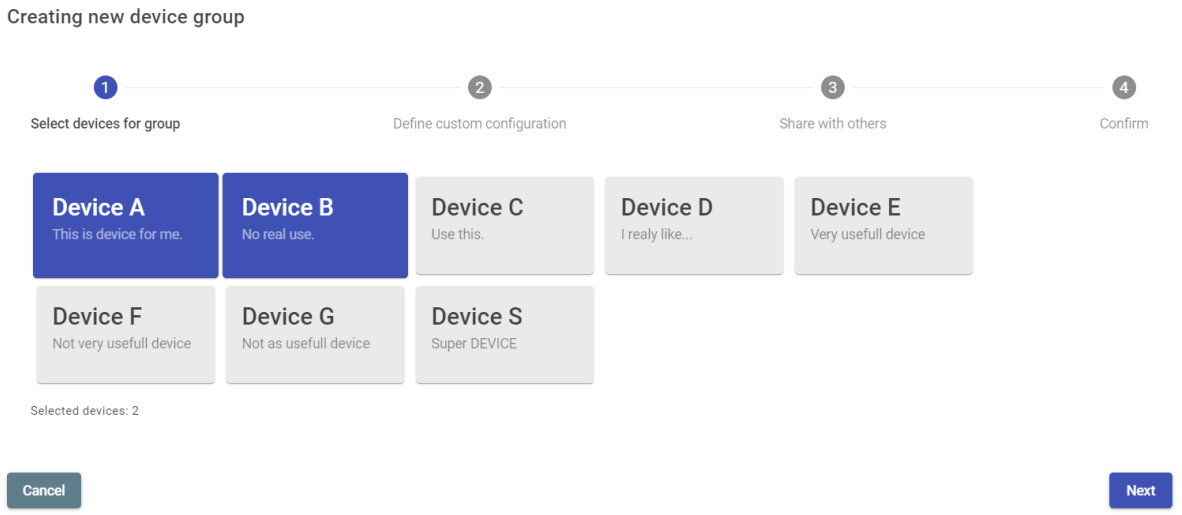


Figure 15: Configuration module

6.1.4. Data acquisition module

The data module ensures the acquisition of data from individual IoT devices, their processing and sending to the client application for display. Data collection is ensured by loggers, which define each sensor connected to the device, and take care of sending data at defined intervals, or on request. The module also provides statistical data processing, analysis and evaluation, based on various parameters.

To ensure the transparency of the measured data, the module provides the possibility of using data filtering. As a filter, it is possible to set the date range, as well as the time range, or their combination (for example, display of measured data for the last week, but only from 12:00 to 13:00). It is also possible to filter the data according to the measured quantity, or to select only the minimum / maximum / average value. The filtering results can be displayed in the client application or exported to .csv format. Example of the time charts is shown in **Figure 16**.

Figure 16: Charts of the data acquisition module

6.2. Front-end hardware solution – Waspmote platform

The Waspmote hardware architecture has been specially designed for work with extremely low power consumption. Digital switches allow to turn on and off any of the sensor interfaces as well as the radio modules. There are more than 120 sensors available to connect to Waspmote: CO, CO2, soil moisture, wind, IR presence, humidity, temperature, pH, liquid, luminosity, etc. Built-in encryption libraries ensure the authentication, confidentiality (privacy), and integrity of the information gathered by the sensors. 15 different wireless interfaces are available including long-range (4G / NB-IoT / Cat-M / LoRaWAN / LoRa / Sigfox / 868 MHz / 900 MHz), medium-range (ZigBee / 802.15.4 / DigiMesh / WiFi) and short-range (RFID-NFC / Bluetooth 2.1 / Bluetooth Low Energy) which gives to Waspmote flexibility to be applicable in any situation and environment. [17]

6.2.1. Operation scheme

The main goal of AP-NURSE-CARE is to increase the quality of the caregiving services by utilizing smart assistance. The priority is to minimize the harmful events and optimize the work of caregiving personnel. The client solution consists of monitoring units, communication gateway and evaluation unit. The operation scheme of AP-NURSE CARE based on the Waspmote platform is shown in **Figure 17**. The monitored rooms are equipped by the unit which is responsible for measurements of several parameters such as temperature, light intensity, noise, quality of air, position on bed or presence in a room, and communication with the evaluation unit via the gateway. Connection and communication of the units, PC and server is provided via local WiFi access point (communication gateway) and LAN connection. AP-NURSE CARE evaluates the patient's behavior in a room for the whole day. The raw data are stored and processed on a local PC or on the data server. Smart notification is carried out by a visualization of the key parameters through simple traffic light logic on a display of a PC or a mobile device. History of the monitored parameters is also available for caregiving personnel to evaluate the evolution or periodicity of the client's habits in different time ranges.

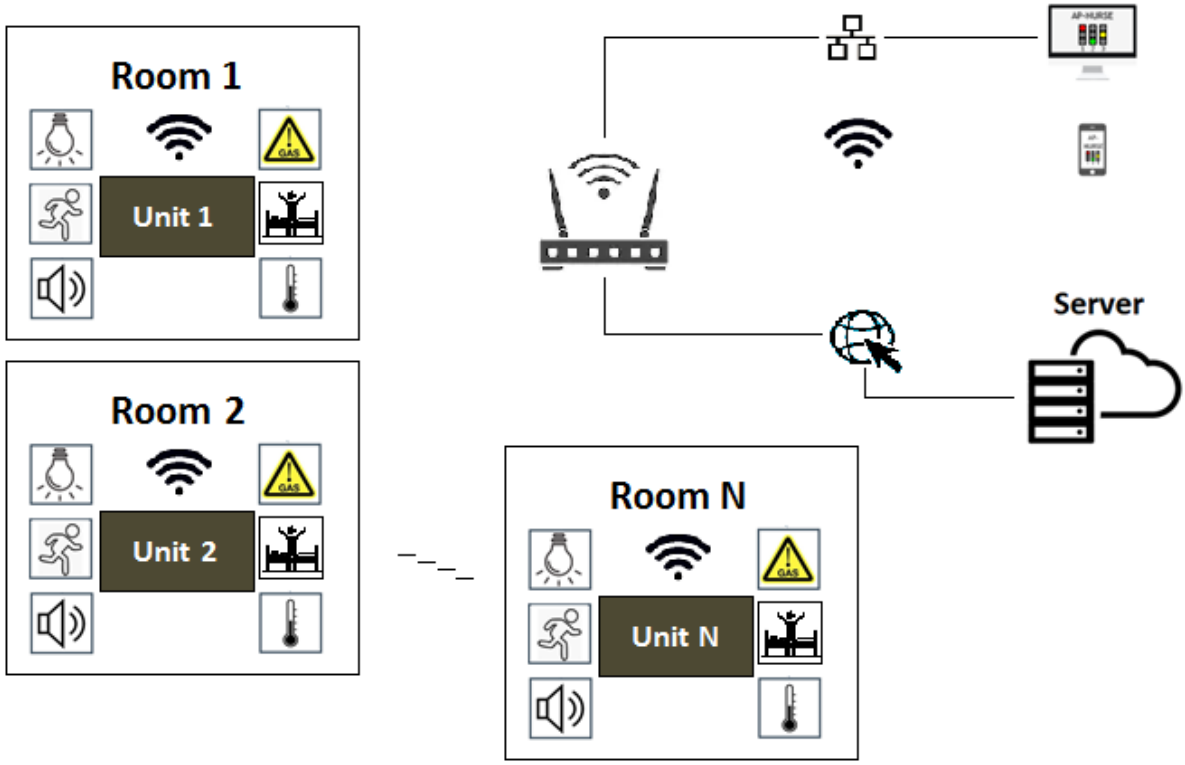


Figure 17: Waspmote operation scheme

6.2.2. Core units

The main core units of the Waspmote solution are the Waspmote motherboard, the expansion modules and the wireless module. The core units are shown in **Figure 18**.

a; Motherboard b; Expansion Modules c; Wireless Module

Figure 18: Waspmote core units [18]

The Waspmote motherboard design is prepared for the integration of both inputs (sensors) and outputs (actuators), which allow growing the wide range of existing sensor boards. The new sensors can be connected to the Waspmote's 2x12 and 1x12 pin connectors, which permit to use 16 input and output signals, 7 of which can be used as analog inputs and 1 as a PWM (Pulse Width Modulation) output signal. Besides, there is a line to ground, 3.3 V and 5 V power feeds, 2 selectable connections to the serial communication (UART) inputs and outputs, connection to the two lines of the (I2C) SCL and SDA Inter-Integrated Circuit bus, and connection to inputs for high level and low-level interrupt. [18]

The Expansion modules serve for the integration of sets of sensors based on application requirements. This integration requires some type of electronic adaptation or signal processing prior to reading by the microcontroller. Combination of the variety of sensors and expansion modules, a wide range of applications can be achieved, such as city pollution or forest fires monitoring, air quality or greenhouse management, security, emergency monitoring, and water quality control. [18]

The Wireless module is based on the WiFi PRO module which supports the SSL3/TLS1 protocol for secure sockets. On the WLAN interface, it supports WEP, WPA and WPA2 WiFi encryption. The WiFi PRO module may connect to any standard router which is configured as Access Point (AP) and then send data to other devices in the same network such as laptops and smartphones. Besides, they can send data directly to a web server located on the Internet. [18]

6.2.3. Sensors

In order to meet the requirements of using AP-NURSE CARE in care centers the core unit will be equipped with several sensors. The configuration of sensors will depend on the specific application. The list and description of the sensors can be found in **Table 3**.

Table 3: List of Waspmote sensors

Temperature, humidity and pressure sensor	The atmospheric sensor is characterized by low-power, high accuracy and wide-range. It is laboratory calibrated sensor. Operational range for temperature is -40 to +85 ºC, for humidity is 0 to 100% HR and for atmospheric pressure is 30 to 110 kPa. [19]
Hall-Effect Sensor (doors and windows)	This is a magnetic sensor is based on the Hall effect. The sensor's switch remains

	closed in the presence of a magnetic field, opening in its absence. [20]
LDR Sensor	A photocell changes (also called a photodetector, CdS, or photoconductive cell) resistance depending on the amount of light it is exposed to. These little sensors make great ambient light triggers (when the light in the room turns on, do something). [21]
PIR Sensor OEM	PIR is a simple to use motion sensor. After the power up, the sensor gets a snapshot of the still room, which takes approximately 1-2 sec. If anything moves after that period, the 'alarm' pin will go low. It is a highly integrated module popularly used for entry detection, it complies with a microcontroller or DC loads. [22]
Sound Detection Sensor Module	The sound sensor can identify the presence of (according to the principle of vibration), intensity, or a particular frequency of the sound. [23]
Carbon Dioxide Gas Sensor	It is a Carbon Dioxide Gas Detector with Analog Signal Output. The detector features a high sensitivity and good selectivity to carbon dioxide. Operation voltage is 6V DC and analog output woks in a range 0-2 V. [24]
Air Quality sensor	MICS-6814 is air quality detector and gas It is a Carbon Dioxide Gas Detector with Analog Signal Output. The detector features high sensitivity and good selectivity to carbon dioxide. The operation voltage is 6V DC and analog output works in a range 0-2 V. [25]
Thin Film Pressure Sensor	It is a resistor type flexible sensor that is flexible, ultra-thin, and has an extreme response. The sensor is manufactured from the highly sensitive flexible nanometer materials which provide highly sensitive detection of the pressure. Pressure signals can be converted into a corresponding electrical signal output using a simple circuit. [26]

6.3. Front-end hardware solution – M5STACK platform

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

6.3.1. Operation scheme

Since AP-NURSE CARE is aimed to be used in social homes and 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 operation scheme of AP-NURSE CARE based on the M5Stick platform is shown in **Figure 19**. The client solution consists of modules, the display and evaluation units, and the communication gateway. A module is a small handy device that is placed in a dedicated position in the patient's environment. This device is responsible for the measurement of various parameters, such as temperature, light intensity, noise, etc. It consists of the core units (M5StickC, Groove-T and PowerC) and multiple sensors. In addition to monitoring environmental parameters, the modules communicate with the display and the evaluation unit. This unit is placed in the nursing room and collects parameters from individual modules. M5Go Lite is the core unit of the display and evaluation unit. Although it makes it possible of displaying individual measured data, this unit transfers the raw data to the dedicated software, where the measured data are processed. The processed data in a form of warnings and danger indications are displayed on a PC in the nursing room or using a mobile APP.

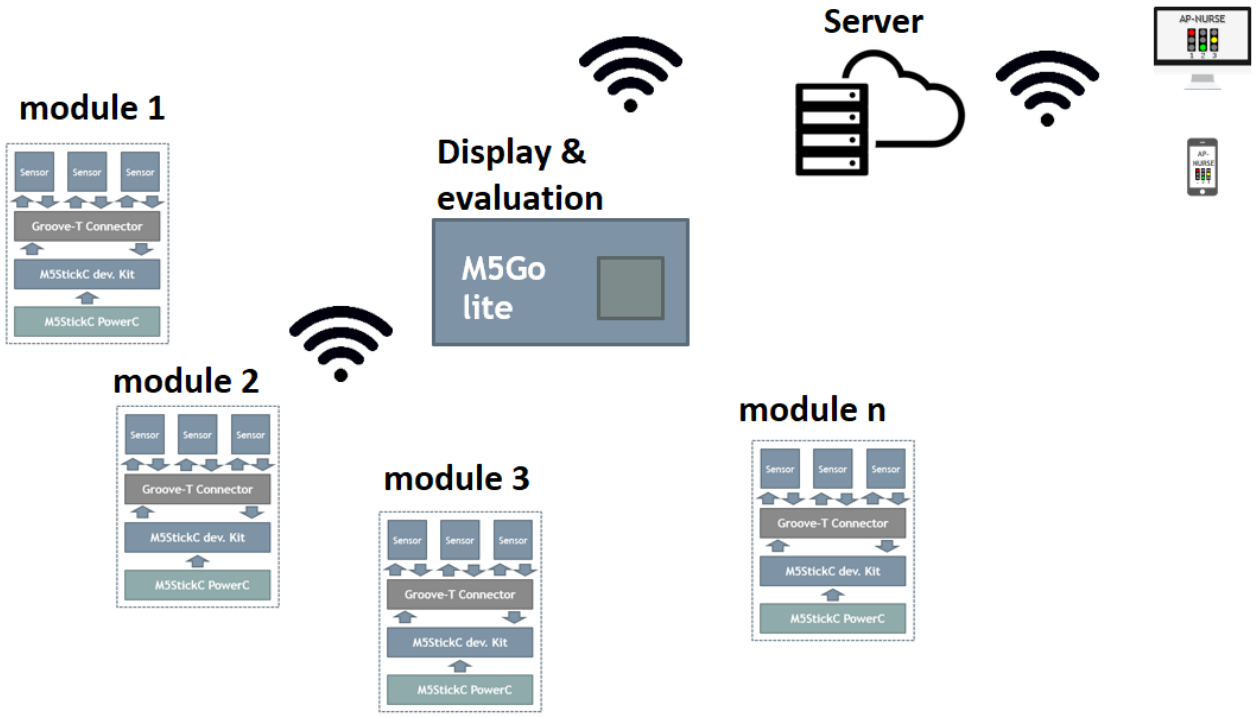


Figure 19: M5STACK operation scheme

6.3.2. Core units

The main core units of the AP-NURSE CARE M5STACk solution are the M5StickC, M5GO Lite, Groove-T and PowerC. The core sensors are shown in **Figure 20**.

a; M5StickC b; M5Go lite c; Grove-T d; PowerC

Figure 20: M5STACK core units [27]

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. Hat ENV unit It 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.

M5GO Lite is a light pack of M5GO kit, instead of having 6 M5units, M5GO-Lite provides 1 ENV + accessories and the same M5 controller as M5GO. M5GO-Lite is also designed for STEM education. M5GO controller itself is already 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.

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.

PowerC 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.

6.3.3. 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 4.**

Table 4: List of M5stack sensors [28]

NCIR Temperature Sensor Unit 	NCIR can be used to measure the surface temperature of a human body or other objects. This sensor measures infrared light bouncing off remote objects so it can sense temperature without touching them physically. Because it doesn't have to touch the measured, it can sense a wider range of temperatures than most digital sensors. It takes the measurement over a 90-degree field of view so it can be handy for determining the average temperature of an area. It is factory calibrated in wide temperature ranges: -40 to 125 ˚C for the ambient temperature and -70 to 380 ˚C for the object temperature.
Time-of-Flight Ranging Unit 	This sensor employs time-of-flight techniques to resolve distance between the emitting point and the reach point of a subject, measuring the round-trip time of an artificial light signal provided by a laser. This unit integrated provides accurate distance measurement whatever the target reflectance, unlike conventional technologies. It can measure absolute distances up to 2m in less than 30ms.
PIR Motion Sensor 	PIR is used to measure infrared (IR) light radiating from objects in its field of view. PIR sensors are commonly called simply "PIR", or sometimes "PID", for "passive infrared detector". The term passive refers to the fact that PIR devices do not radiate energy for detection purposes. They work entirely by detecting infrared radiation emitted by or reflected from objects.
Mini Heart Rate Unit 	It is a complete pulse oximetry and heartrate sensor system solution designed for the demanding requirements of wearable devices. It provides a very small total solution size without sacrificing optical or electrical performance. Minimal external hardware components are needed for integration into a wearable device. The subjects simply puts his finger on the detection area.
Earth Moisture 	It is a Soil Moisture Sensor for measuring the moisture in the soil and similar materials. The two large exposed pads function as probes for the sensor, together acting as a variable resistor. The higher moisture that is in the soil means the better the conductivity between the two so that the sensor will result in lower resistance, and a higher SIG out. The user can read the moisture in the soil by ADC.

Light Unit with Photo-resistance 	It is a light intensity sensor unit with an adjustable photoresistor. A photoresistor is a light-controlled variable resistor. The resistance of a photoresistor decreases with increasing incident light intensity, and vice versa. It exhibits photoconductivity which makes it possible to detect the varies based on Voltage, and use an AD to convert the digital data. It incorporates a Dual Differential Comparators LM393 that compares the differential voltage between the photoresistor and the varistor. It offers a larger and accurate range of light intensity.
3-Axis Digital Accelerometer 	The accelerometer is an electromechanical device that will measure acceleration forces. These forces may be static, like the constant force of gravity, or they could be dynamic - caused by moving or vibrating the accelerometer. By measuring the amount of static acceleration due to gravity, the user can find out the angle the device is tilted at with respect to the earth. By sensing the amount of dynamic acceleration, the user can analyze the way the device is moving. This sensor is able to obtain 3- axis of Acceleration. It is a 3-axis accelerometer with high resolution (13-bit) measurement at up to ±16 g. Digital output data is formatted as 16-bit digital pairs.
90° / 180° IR Reflective Unit 	These are two limit switches with different orientation placement. They are used for controlling machinery as part of a control system, as a safety interlock, or to count objects passing a point. A limit switch is an electromechanical device that consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection. The actuator of this Unit consists of a pair of IR part, emitter side and receiver side (silicon phototransistor. The IR is directly emitted from one side to another, so if there's no object in between, the receiver gets the IR signal.
Mini GPS/BDS Unit 	It is the M5Unit version of GPS with the Zhongke Weibeidou navigation and amplification chip. It supports many types of satellite navigation systems, it is able to receive satellite signals on 56 channels GNSS signal from 6 satellite navigation systems, joint location, navigation, timing, and more. The module is able to obtain accurate global location information, quick and accurate positioning for anywhere in the city, in the canyon, under the overhead, and inside the car.
M5STICKV K210 AI camera 	M5StickV AI Camera possesses machine vision capabilities, equips OmniVision OV7740 image sensor, adopts OmniPixel®3-HS technology, provides optimum low light sensitivity, supports various vision identification capabilities. In addition, M5StickV features more hardware resources such as a speaker with built-in I2S Class-D DAC, IPS screen, 6-axis IMU, 200mAh Li-po battery, and more. It is able to perform convolutional neural network calculations at low power consumption, so M5StickV will be a good zero-threshold machine vision embedded solution. It is in support of MicroPython, which eases the programming.

Mini Dual Button Unit 	It is a device that has two buttons with different colors. The button status can be detected by the input pin status, simply capturing the high/low electrical level.

6.4. Software solutions

Programming of the Waspomote units is carried out through the Integrated Development Environment for Waspmote (Waspmote IDE). This IDE is used for writing the code, compiling, and uploading it to Waspmote unit. It is also used to monitor serial output and for debugging. The IDE contains also the Waspmote API (the API is the set of all libraries needed for compiling programs). The encryption libraries for Waspmote ensure the authentication, confidentiality (privacy), and integrity of the information gathered by the sensors. To do so, different cryptography algorithms including AES 256, RSA 1024, and MD5 have been implemented. The software is normally uploaded using the USB connection but in the multi-unit application, the Over the Air Programming (OTAP) enables software upgrades of the nodes without the need for physical access. Software upgrades can be made in minutes and it is possible to choose between updating single nodes (unicast) or an entire network (broadcast). [29]

6.5. Security

Since AP-NURSE is designed to gather data reflecting the conditions of monitored patients, special attention should be paid to secure the transfer, access and storage of data. Data collected for analysis will be stored on the dedicated server of the Slovak University of Technology in Bratislava or locally at the monitoring site and no data will be provided to third parties. They used the dedicated server of the Slovak University of Technology in Bratislava implements a high standard of inherent safety and cybersecurity. The local servers will ensure communication only through local networks without internet connection thus minimizing the risk of cyber threats. Although no personal data will be collected, all measures taking place in data management will be strictly in line with the EU's The General Data Protection Regulation 2016/679. Principles of collection, transfer, access, and storage of data will be thoroughly defined in the data management plan. Specific issues related to the data management policy and security will be addressed in deliverable D.M.3.7 – Data protection manual.

7. Procurement of key components

The AP-NURSE systems are based on three hardware platforms, as it is described in previous chapters, which requires three sets of sensors and auxiliary components. Based on the proposed design and specific construction needs, more than a thousand electronics items were identified for purchase. Market research identified potential suppliers and help to group identified items into packages. Criteria for the selection of suppliers were unit or package price, availability, delivery time, and cost of freight. These criteria helped to select twelve companies that would be able to supply all key components for the construction of all three systems. The procurement process followed the University Directive 10/2016-SR [30], which is in an

agreement with the public procurement law and Implementation manual version 4 [31] (Slovak version - Pravidlá oprávnenosti výdavkov pre slovenských projektových partnerov verzia 4). The procurement process began early in March of 2020. All suppliers were asked for the quote and based on provided data, selected suppliers were provided by the orders. The special approach was applied to the supplier of the components for the Waspmote platform, where the identified company is the exclusive importer of Libelium components to Slovakia. This exclusivity was supported by the certificate, which finally simplified the procurement process in this case. Due to the COVID-19 pandemic, the procurement process (collecting of the quotations, processing and issuing of the orders) was prolonged to the rest of Period 2 and the first half of Period 3. Sequentially, as individual orders were sent, the delivery of some components was also affected by delays.

8. References

[1] STU team, „Deliverable D.T1.3.1 - Identification of most suitable care solutions for model of thealth and care services for frail elderly - Internal Review of technical solutions," 2020.

[2] STU team, „Deliverable D.T2.2.1 - Coordination Meeting," 2020.

[3] Editor's office, „root.cz," 20 November 2017. [Online]. Available: https://www.root.cz/clanky/nodemcu-a-jeho-verzie-doska-s-wi-fi-cipom-esp8266/. [Cit. 31 May 2020].

[4] instructables.com, „Using an ESP8266 to Control Mains Sockets Using 433mhz Transmitter and Receiver," [Online]. Available: https://www.instructables.com/id/Using-an-ESP8266-to-Control-Mains-Sockets-Using-43/. [Cit. 31 May 2020].

[5] rlx.sk, „rlx.sk," [Online]. Available: https://rlx.sk/sk/raspberry-pi-kit-pack-bundle/6503-rlx2-kit-rpi3plus-16gb-raspberry-pi-3-starter-kit2-16gb-noobs-sd-cardcasehdmi-cable-3xchladicezdroj-5v2a.html. [Cit. 31 May 2020].

[6] Holtek Inc., „HT12A/HT12E - 212 Series of Encoders," Holtek Inc., 2009.

[7] Holtek Inc., „HT12D/HT12F - 212 Series of Decoders," Holtek Inc., 2009.

[8] lastminuteengineers.com, „lastminuteengineers.com," [Online]. Available: https://lastminuteengineers.com/bme280-esp8266-weather-station/. [Cit. 31 May 2020].

[9] CodeChamp, „instructables.com," [Online]. Available: https://www.instructables.com/id/Interface-PIR-Sensor-With-NodeMCU/. [Cit. 31 May 2020].

[10] myarduino.net, „myarduino.net," [Online]. Available: https://www.myarduino.net/article/197/%E0%B8%AA%E0%B8%AD%E0%B8%99%E0%B9%83%E0%B8%8A%E0%B9%89%E0%B8%87%E0%B8%B2%E0%B8%99-nodemcu-esp8266-%E0%B9%80%E0%B8%8B%E0%B9%87%E0%B8%99%E0%B9%80%E0%B8%8B%E0%B8%AD%E0%B8%A3%E0%B9%8C%E0%B8%95%E0%B8%A3%E0%B8%A7%E0%B8%88%E. [Cit. 31 May 2020].

[11] electronicwings.com, „electronicwings.com," [Online]. Available: https://www.electronicwings.com/nodemcu/mpu6050-interfacing-with-nodemcu. [Cit. 31 May 2020].

[12] T. Maekelbergh, „thibmaek.com," 13 June 2019. [Online]. Available: https://thibmaek.com/post/detecting-sound-level-using-esp8266-and-esphome. [Cit. 31 May 2020].

[13] CodeChamp, „instructables.com,“ [Online]. Available: https://www.instructables.com/id/NodeMCU-With-LDR/. [Cit. 31 May 2020].

[14] esp8266learning.com, „esp8266learning.com,“ [Online]. Available: http://www.esp8266learning.com/esp8266-force-sensitive-resistor-example.php. [Cit. 31 May 2020].

[15] tme.eu, „tme.eu,“ [Online]. Available: https://www.tme.eu/sk/details/wsh-3709/konvertory/waveshare/3709/. [Cit. 31 May 2020].

[16] randomnerdtutorials.com, „randomnerdtutorials.com,“ [Online]. Available: https://randomnerdtutorials.com/power-esp32-esp8266-solar-panels-battery-level-monitoring/. [Cit. 31 May 2020].

[17] Libelium, „Libelium,“ Libelium Comunicaciones Distribuidas S.L, [Online]. Available: http://www.libelium.com/products/waspmote/overview/. [Cit. 20 05 2020].

[18] Libelium, „Waspmote technical quide,“ Libelium Comunicaciones Distribuidas S.L., 2017.

[19] Libelium, „Cooking-hacks,“ Libelium Comunicaciones Distribuidas S.L., [Online]. Available: https://www.cooking-hacks.com/temperature-humidity-and-pressure-sensor.html. [Cit. 20 05 2020].

[20] Libelium, „Cooking-hacks,“ [Online]. Available: https://www.cooking-hacks.com/hall-effect-sensor-doors-and-windows.html. [Cit. 20 05 2020].

[21] Libelium, „Cooking-hacks,“ Libelium Comunicaciones Distribuidas S.L., [Online]. Available: https://www.cooking-hacks.com/ldr-sensor.html. [Cit. 20 05 2020].

[22] Libelium, „Cooking-hacks,“ Libelium Comunicaciones Distribuidas S.L., [Online]. Available: https://www.cooking-hacks.com/pir-sensor-4935.html. [Cit. 20 05 2020].

[23] A. group, „aliexpress,“ AliExpress.com, [Online]. Available: https://www.aliexpress.com/item/32573302472.html?spm=a2g0o.productlist.0.0.3b84450fSGdr4v&algo_pvid=8b3d2948-ee89-452d-862c-853046ab3553&algo_expid=8b3d2948-ee89-452d-862c-853046ab3553-0&btsid=0ab6d5951585256292445838e1799&ws_ab_test=searchweb0_0,searchw. [Cit. 20 05 2020].

[24] A. group, „Aliexpress,“ Aliexpress.com, [Online]. Available: https://www.aliexpress.com/item/32974027647.html?spm=a2g0o.detail.1000014.3.54452e29adxDoE&gps-id=pcDetailBottomMoreOtherSeller&scm=1007.13338.146400.0&scm_id=1007.13338.146400.0&scm-url=1007.13338.146400.0&pvid=7cfcd944-5b29-401f-a3ae-7e767c38d4b5. [Cit. 20 05 2020].

[25] A. group, „Aliexpress,“ Aliexpress.com, [Online]. Available: https://www.aliexpress.com/item/4000215089588.html?spm=a2g0o.productlist.0.0.721bffa9Jgfiqw&algo_pvid=3fb9dbd3-7d64-42c9-9285-0da2dd3d0c32&algo_expid=3fb9dbd3-7d64-42c9-9285-0da2dd3d0c32-51&btsid=0ab6d7051585259664448314 7e0c69&ws_ab_test=searchweb0_0,sear. [Cit. 20 05 2020].

[26] „Interlink Electronics FSR® Force Sensing Resistors,“ Interling Electronics, 2020.

[27] M5stack, „M5stack core,“ [Online]. Available: https://m5stack.com/collections/m5-core. [Cit. 01 06 2020].

[28] M5stack, „M5stack units,“ [Online]. Available: https://m5stack.com/collections/m5-unit. [Cit. 01 06 2020].

[29] Libelium, „Waspmote Quickstart Guide,“ Libelium Comunicaciones Distribuidas S.L., 2014.

[30] Slovenská technická univerzita v Bratislava, „Verejné obstarávanie v podmienkach Slovenskej technickej univerzity vBratislave,“ Slovenská technická univerzita v Bratslave, Bratislava, 2017.

[31] M. Blaško, „Pravidlá oprávnenosti výdavkov pre slovenských projektových partnerov verzia 4,“ Úrad vlády Slovenskej Republiky , Bratislava, 2020.