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Deliverable 2.8
Update on the Final version of TeNDER Architecture Blueprint, Pilots definition

Work Package 2: Codesign Process

affecTive basEd iNtegrateD carE for betteR Quality of Life: TeNDER Project

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Disclaimer

The TeNDER consortium consists of the following Partners:

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2	MAGGIOLI SPA	MAG	Italy
3	DATAWIZARD SRL	DW	Italy
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[1] **R:** Document, report; **DEM:** Demonstrator, pilot, prototype; **DEC:** Websites, patent fillings, videos, etc.; **OTHER**; ETHICS: Ethics requirement; ORDP: Open Research Data Pilot.

[2] **PU:** Public; **CO:** Confidential, only for members of the consortium (including the Commission Services).

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Acronyms and Abbreviations

Acronym/Abbreviation	**Description**
TeNDER	affecTive basEd iNtegrateD carE for betteR Quality of Life
WPx	Work Package
Tx.x	Task
Mx	Month (where x defines a project month e.g. M8)
EU	European Union
IoT	Internet of Things
IoHT	Internet of Healthcare Things
GP	General practitioner, primary care physician
QoL	Quality of Life
Pwd	Person with Alzheimer's Disease or other form of dementia or mild cognitive impairment
AD	Alzheimer's Disease
PD	Parkinson's Disease
CD	Cardiovascular Disease
LLS	Low-Level Subsystem
HLS	High-Level Subsystem

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Executive Summary

TeNDER is developing an integrated care ecosystem using micro-tools based on affection, communication, monitoring of patients with their care ecosystem (involving their careers and social and healthcare professionals). These micro-tools will be aimed at assisting people with Alzheimer's, Parkinson's and Chronic Cardiovascular Disease. They can be adapted to the needs of each person and based on their health situation and degree of affectation. The services created with this approach will create opportunities to facilitate communication between social and healthcare professionals, extending the autonomy of patients who will live more independently. All this while preserving privacy, monitoring ethical principles, providing data protection and security.

This deliverable is an update of D2.6, which has been incorporated to give continuity to the work carried out during the months of project extension. During the months M34 to M39, collaborative work has been carried out to develop the final version of TeNDER, it's Architecture Plan and the definition of the Pilots.

This document details the definition of the third wave of pilots, the validation phase. It is a co-creation work between technical partners and user partners through the common TeNDER toolbox. This document connects user requirements described in deliverables in WP2, scenarios and system requirements.

It involves the dedicated contribution from end-user entities and medical bodies in TeNDER to analyse the available technologies, as well as to further collect needs and requirements of each specific category of end-users in terms of services solution characteristics, interface and contents as well as current fields of interaction among the involved actors: health professionals, caregivers and associations, local authorities in the pilot countries. State of the art literature will be analysed, compiled, and reported to illustrate and align the needs and constrains for users in the categories defined.

The outcome of this task is a detailed vision of the final system.

1 INTRODUCTION

The development of the TeNDER tool involves a continuous involvement of users and TeNDER partners in service co-creation in order to adapt and develop the tool based on the reality revealed by the user requirements and feedback gathered during testing pilots. To this end, real-world scenarios were developed covering all stages of user activities based on the use cases and user types through which the results of the project will be demonstrated. Based on the specific contribution of end-user entities and TeNDER medical bodies that analysed available technologies as well as gathered further information on the implementation of TeNDER, the system specification is delivered.

Co-creation results in a specification of user needs and requirements, as well as the development of user scenarios that have guided the design of the TeNDER system.

The following deliverable provides system level description according to the results from the co-creation, taking into account the defined pilots description and the user requirements. It includes the specification of the logical structure of the TeNDER architecture, paying special attention to the data storage and processing layer as well as to the communication between the discrete parts/components of the system in order to a) ensure the scalability and extensibility of the TeNDER system and the reliability of the service and b) support the continuous integration and deployment to maintain the service during changes. The objective of this task was to adapt the services proposed to the scope of user requirements, aiming at having a cohesive development of TeNDER tools. Therefore, the WP2 task was dedicated to a) analyse the available technologies, b) collect the needs and requirements of each specific category of end-users in terms of service solution features, interface and content, as well as the current areas of interaction between the actors involved: health professionals, carers and associations, local authorities in the pilot countries (that is reported in Deliverable 2.1, Deliverable 2.4, Deliverable 2.5). The state of the art was analysed, compiled and communicated to illustrate and align user needs and constraints in the defined categories. Real –world scenarios and use cases form Deliverable 2.3 and D2.6 were tested in TeNDER testing piloting phases and resulted in system adaptation for the final validation piloting phase.

The outcome is the definition of the system level description for the design of the overall system architecture, as well as the conduct of a survey and the specification of appropriate indicators for the validation of the user scenarios. Providing a global vision of the system that incorporates the needs of all stakeholders and is supported by medical and social evidence.

1.1 Purpose and scope

The TeNDER tool is based on different technological devices. On one hand, the tracking the daily life management, events and parameter of patients with the aim of improving their autonomy and facilitating the task of carers and professionals in their care and follow-up. On the other hand, it offers a communication tool between all the actors involved, facilitating the intercommunication of patients and carers with social and health professionals, especially in those cases in which professional care and insight in daily activities is required.

All these are proposed by combining easy-to-use technologies that are familiar to the population, such as smartphones and devices such as bracelets, movement sensors and other similar tools through which vital signs are monitored, movements are captured and emotional recognition is carried out, among other types of monitoring.

1.2 Contribution to other deliverables

This deliverable aims to monitor the impacts of TeNDER on the requirements identified in WP1 and WP2, as the ICT solutions are integrated, tested and evaluated. The user requirements explored have contributed to the development of the scenarios and the adaptation of the technology to the users. These developed scenarios will be the basis for system pilot validation phase directly related to WP6 (D6.5-Final Report on large scale Pilots) and WP7 (D7.5-Final Report on QoL Assessment). Furthermore, they will contribute to the work that will be delivered in technical deliverables, as in WP3 (D3.3 Sensorial Subsystems, D3.4 Patient Interface Interaction Analysis and Pathway tracking), WP4 (D4.2-Final version of Multi-Modal Fusion analysis; D4.3-Deep learning Based profile analysis and Recommendation System and D4.4-Personalised interactions and safety perception) and WP5 (D5.5-Final version of TeNDER Services).

1.3 Structure of the document

The objective of this document is to define the final version of the scenarios, based on the requirements and constraints in terms of ethics, privacy, as well as detailing the final navigation of the envisaged components of the TeNDER toolbox. This deliverable is intended to constitute an update of D2.6, by providing a detailed and updated description of the TeNDER architecture, its main components and data flow. It will also include the UML diagram and the description of the pilots.

This deliverable has been organised as follows:

First, the final version of the TeNDER Architecture Blueprint is detailed. This section provides a detailed view of the system, its different levels of development (low level and high level), explaining the modules and a description of each of the services that compose them.

Secondly, it describes the common approach and methodology of TENDER. It includes the strategies carried out to ensure ethical principles in all piloting phases. It also provides the overview of TeNDER from the point of view of user interaction. It describes each of the phases that make up the TeNDER pilots and details the participants involved in each pilot.

Thirdly, it presents all the detailed information about the scenarios being developed in the different pilots. It includes their final definition, providing real examples of scenarios and patients.

Finally, the conclusions of the document are shown.

2 FINAL VERSION OF TENDER ARCHITECTURE

This section provides the details of TeNDER's final architecture, then goes on to detail the modules that compose the entire technological ecosystem, as well as their final services.

2.1 Technical Architecture Overview

As stated in the previous deliverable referring to Service Oriented Architecture (SOA), each element can work individually and interact with other modules as services through interface layers. TeNDER SoA foresees six different structures, where the Low-Level Subsystems (LLS), and the High-Level Subsystems (HLS) are providing the TeNDER.

An overview of the architecture is provided in the image below.

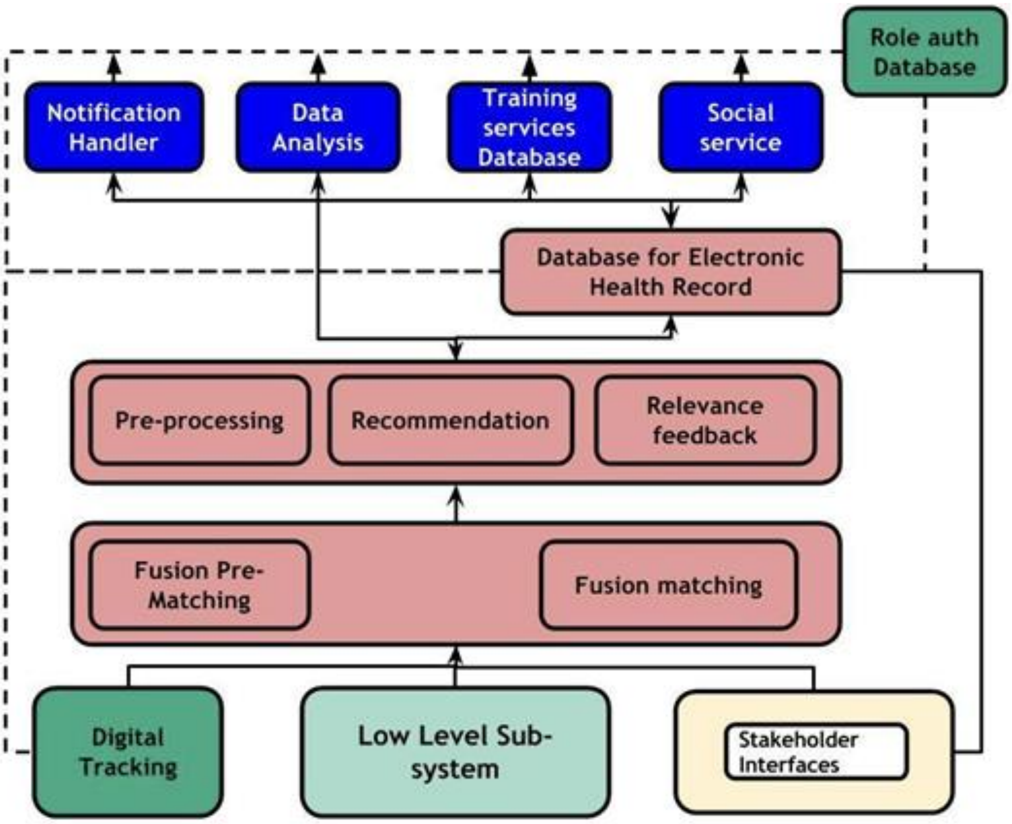

Figure 1.TeNDER System Architecture

Low-level Subsystem is in charge of gathering information from different sources. This subsystem covers the sensor deployment and the communication between different devices, where a backend management module handling data collection, health tracking and abnormal event detection.
On the other hand, both Services and High-level subsystems are located at different servers than the Low-level Subsystems, guaranteeing security and comply with the ethical guidelines of the project.

The TeNDER architecture foresee a centralized development of the High-level subsystem and services implementation, ensuring scalability of the system allowing the integration of future nodes:

- EHR (Electronic Health Records) is a digital version of a patient's paper chart. EHRs are real-time, patient-centered records that make information available instantly and securely to authorized users. On the basis of existing EHR systems, was implemented the necessary conditions to adapt to the European regulation for data exchanging. It

consists of a database to store the medical profile will extend information available from physical, medical and behavioural activity. The information flow will securely access data from patients, from/to the system and from/to the health professionals.
- Monitoring service. A new monitoring service was deployed which monitors the available resources in the stage and production environments, the secure data storage in system DBs, and also the performance of the services that run on LLS.
- Recommender Engine. It is a component of the HLS that receives data observations from the LLS and extracts relevant patient information from the EHR to generate recommendations or suggestions. It integrates the daily recommender system and the social service matching.

With respect to the data flow, all the data travel between different components of the system in a secure manner by placing in order different security mechanisms to provide a transparent and safe transmission of data that can be considered personal such as health data.
A bird view of data flow is reported in the image below.

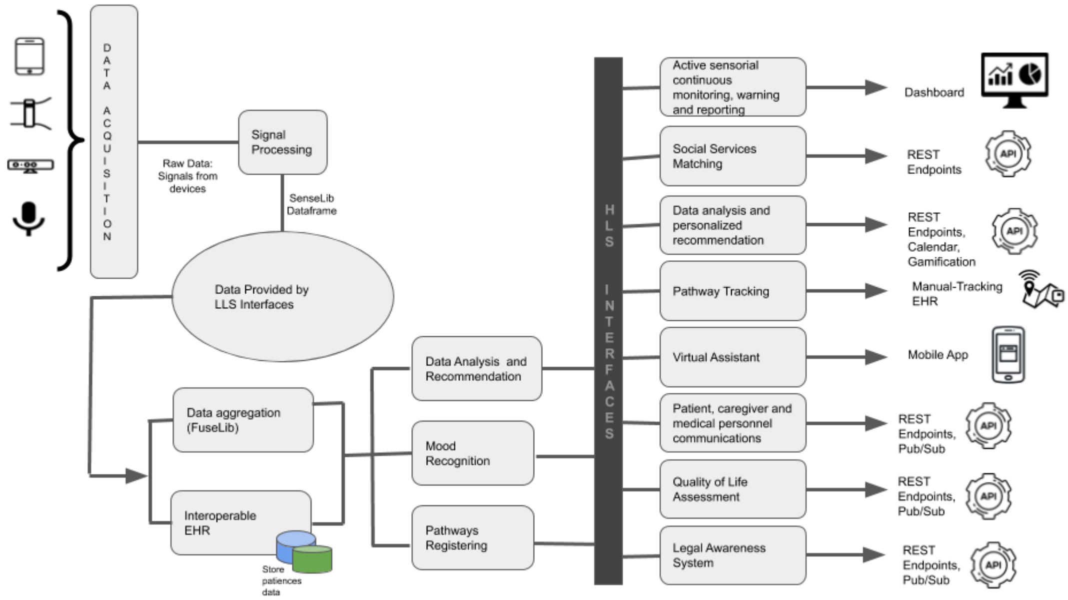

Figure 2. TeNDER Dataflow

2.2 Low-level Subsystem

The low-level subsystem (LLS) is composed by several sensing modules that gather information from the patients. These modules are divided into several categories (all the modules work independently, and the ones desired for the same aim be able to combine their performance to optimize the results, but also to work on their own). The following is short presentation of the HeTra subsystem and its components, as well as of all the independent modules of the LLS.

HeTra subsystem is the core subsystem that enables tracking patient variables and offer to the low- and high-level subsystem's modules the functionality to track specific health characteristics, from direct health situation information to periodical test results and feedback from professionals. This subsystem: 1. Enable users (medical doctors and caregivers) to choose which health characteristics to track and 2. Provide an efficient feedback mechanism that, along with user activity recognition and, through multimodal fusion, will allow for the extraction of valuable conclusions regarding health status.

HeTra will be responsible for the data acquisition from the sensors (Kinect Azure, Intel Realsense, Wristband, Localization Tracker, Sleep Tracker, Voice Tracker, , Binary and Enviromental Sensors). As illustrated in Figure 3, HeTra delivers the acquired data to the Abnormal Behaviour Detector (ABD) subsystem that is part of TeNDER LLS and to the Multimodal Fusion (MMF) subsystem which is part of the HLS.

HeTra will not just deliver raw data as acquired from the sensors but it will also analyse them to extract features that will be useful for subsequent analysis. This analysis will be performed in SENSELib. This library will include sensor data acquisition tools as well as specific algorithms for an initial data processing (tracking, skeleton smoothing, dimensionality reduction etc.).

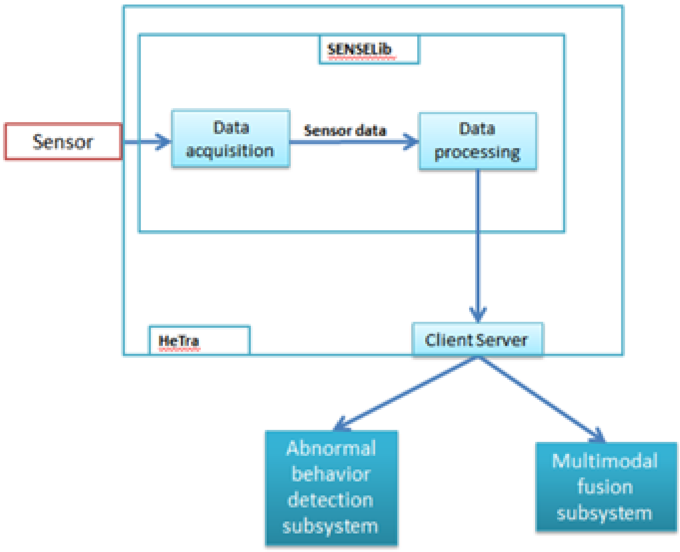

Figure 3. SenseLib schematic description.

A client of HeTra runs on the other subsystems of TeNDER (ABD and MMF subsystems) through which the communication with HeTra will take place.

SENSELib is part of the TeNDER's open API system, and it is used to develop HeTra subsystem. This library provides two types of functionalities, i.e., acquisition and processing ones (Figure 5). HeTra subsystem is able to get and deliver both unprocessed and processed data.

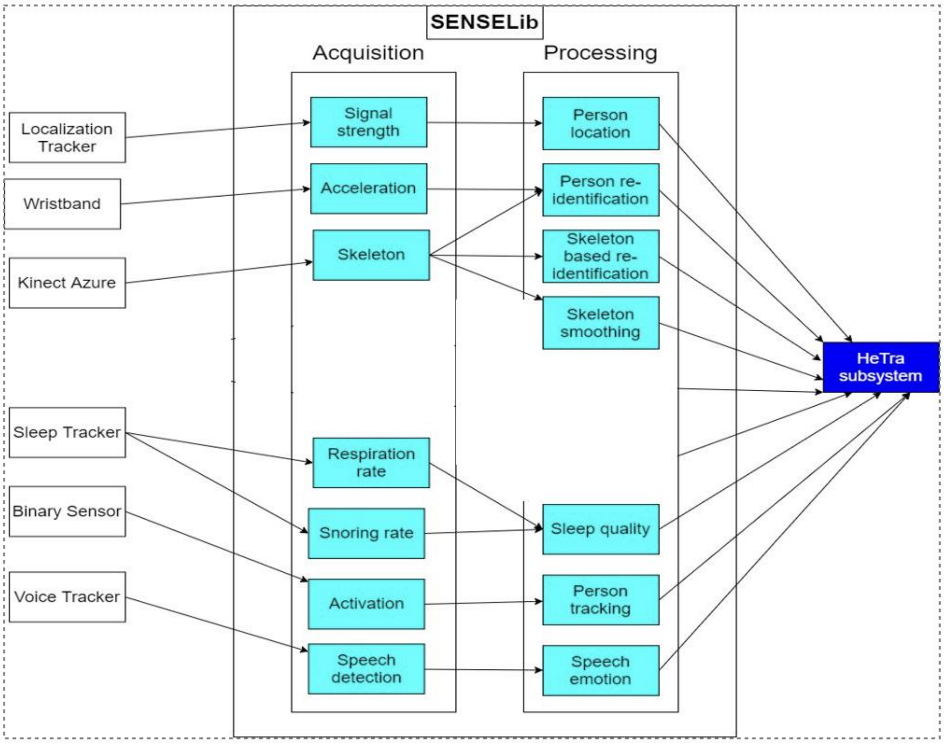

Figure 4. SENSELib Schema workflow

SENSELib modules and their Technical specifications (HW/SW) are presented following.

1. **Multi-Sensorial Capturing module**: Core module to enable tracking patient variables and to offer the service modules the functionality to track specific health characteristics, from direct health situation information to periodical test results and feedback from professionals. Example: Parkinson's patients' daily activities will be correlated to medication they receive and the system should be able to evaluate its impact on their daily routines. Dementia, Alzheimer's, and Parkinson's health plans are analysed and defined during the project to select the homologated scales to use in the tracking the personal status. There are scales for quality of life, dependence, stress, general health level, etc. that will need to be selected together with the clinical and social team in the first stages of the project.
2. **Digital Interaction Module**: With the objective of having a personalized platform that can adapt its behaviour to patient condition and interaction with the TeNDER platform and its services, TeNDER designs and develops an interaction tracking system that analyses patient access to the different interfaces and their behaviour when using the platform in any of the interfaces. This digital behaviour analysis helps the platform to identify recommendations and help the user (patient, caregiver, professional), by analysing her/his knowledgeability on her/his condition and the treatment or processes that need to be followed.
3. **Abnormal Behaviour Detection module**: This module focuses on analysing sensing information to identify behaviour and inform any interested party (professionals, formal/informal caregivers) about the patient's situation. Exploiting intelligent capabilities of an indoors activity recognition methodology, employing ambient and depth sensors, environmental sensors and mobile based sensors, this core subsystem will

provide the TeNDER ecosystem with the capability of assessing on the real deviations from the expected daily conduct of the person (e.g. the senior missed to take a medication dose) and any (previously parameterized) human abnormal behaviour (e.g. for Parkinson's patients need to be controlled if the patient gets blocked or has fallen to help the patient or warn the caregivers)

4. **Affective Computing module:** This module applies advanced deep learning and Computer Vision techniques to extract relevant features (i.e. general, facial, speech or behavioural) that can allow to estimate the expression and mood of patients. This information will be extracted by using the smartphone devices and will be used as input to up-level services that will support the patient.
5. **Localization tracking module**: This module combines the information gathered from different sensing devices deployed across the areas to be monitored (For TeNDER purposes, it will be deployed in all scenarios) through a wireless sensor network. Static binary sensors send information about the interaction with the environment (door open/closed). Wristband devices send health information such as pulse rate and temperature. Moreover, additional information about the position of the participants can be extracted from the wristband by looking at the RSSI (Received Signal Strength Indicator) values, detected by the localization sensors. Main technologies that are employed involve Localization hardware devices. As a result of these techniques a continuous time-real room-level tracking is reached.
6. **Kinect Azure tracking module**: Kinect Azure sensor will be used for person tracking (to monitor the person's movements and body position). Kinect Azure SDK contains a skeleton tracking based on the fusion between RGB information and depth information, there by more accurate in detecting body joints positions and more robust in difficult conditions like change of lights. In addition, it captures and analyses the facial image of the patient and can identify the emotional status of the user.
7. **Kinect Azure sensors will be deployed in all the scenarios**: In home scenario and in Daily centre scenario it will be placed in an elevated position (e.g. above a closet) to amplify the recording area. In the rehabilitation centre the sensor will be placed in front of the subject to better register the change of movement during the exercises.

2.3.1 LLS Modules Description

Table 1. Kinect Tracking module

Kinect Tracking module	Description
Functionalities	Retrieve process and deliver rich sensor data (SENSELib & HeTra low level subsystems). The Kinect tracking module will deliver highly accurate body trajectories, de-noised through a novel filtering procedure. Moreover, tracking will provide re-identification functionalities to correlate trajectories to specific patients. It can also identify the emotional status of the user.
Implemented on	SENSELib

Interfaces Exposed (Outputs)	The HeTra API will enable other subsystems to request and get low level data from sensors. SENSELib will be responsible for the data acquisition from the sensors and their pre-processing to extract features that will be sent through HeTra to Abnormal Behaviour Detection and Multimodal Fusion subsystems.
Interfaces Requested (Inputs)	Wired (USB 3) connection with Kinect as well as the Sensor APIs.
Algorithms employed	Kalman and Kalman/Tobit filtering will be used to filter the acquired skeletons and to decrease the estimation errors.
Instances and Deployment	Depending on each specific use case the hardware deployment will be such, to maximize the possibility to track the patients in their daytime activities.
Programming languages	C#/C++
Libraries	Standard open libraries for video and image processing (e.g., OpenCV)
Issues & Notes	Kinect cameras will operate ~17-19 hours per day. In practice, they will stop working for 5-7 hours every night (in a predefined time interval) in which the patient is sleeping.

Within the TeNDER, it is agreed that Kinect Azure sensors will be used for depth sensing. The specifications for the use of these sensors are the followings:
Each Kinect Azure sensor requires a PC with the following (minimum) specifications:

- Seventh Gen Intel® CoreTM i3 Processor (Dual Core 2.4 GHz with HD620 GPU or faster)
- 4 GB Memory
- Dedicated USB3 port
- Graphics driver support for OpenGL 4.4 or DirectX 11.0
- Windows 8 or 8.1, Windows Embedded 8, or Windows 10

Table 2. Sleep tracking module.

Sleep Tracking module	**Description**
Functionalities	It collects users' sleep data using a Sleep tracking mat which is located under the user's mattress. It monitors and summarizes the quality of sleep (sleep duration, sleep states, respiratory rate, heart rate, snoring, sleep score, sleep apnea).
Implemented on	SENSELib, Python libraries

Interfaces Exposed (Outputs)	API link: https://rr.intectiv.si:10004/sleep-tracker/?SensorID=20801444
Interfaces Requested (Inputs)	Withing's sleep tracker sensor data (json) API link: https://developer.withings.com/oauth2/
Algorithms employed	Processing the detected heart rate, sleep state, sleep state duration, snoring rate, respiration rate data on data frames. Created summarized data is forwarded to Elgoline server from Withing's Cloud.
Instances and Deployment	The sensor is installed under the user's mattress and connected to the local Wi-Fi as described in the sensor installation manual. After that, the user registration on Withing's webplatform is required and the user account must also be linked to Elgoline server in order to allowe the TeNDER application to access and gather the summarized sleep data.
Programming languages	Python
Libraries	Falcon, Json, Requests, Database, Os, other standard libraries for data and file manipulation
Issues & Notes	The Withing's API makes data available after the user wakes up. Only daily summarized data is available, no realtime data.

Table 3. Localisation Tracking module.

Localisation Tracking module	**Description**
Functionalities	It monitors the strength of the signal from the wristbands or other Bluetooth(r) tags worn by the users and determines the room-level position. Identifyposition status and position history of the patient.
Implemented on	SENSELib, Pyton libraries
Interfaces Exposed (Outputs)	API link: /rr.intectiv.si/position-summary?device_mac=[E60E2E36B131]
Interfaces Requested (Inputs)	MQTT protocol with JSON
Algorithms employed	Signal strength of all the localization sensors that are seen by the specific user wristband is compared. The localization sensor with the strongest signal in regard to the user's wristband, represents the room where the user is currently located.

Instances and Deployment	The slocalization sensors are positioned in each room that we want to monitor for user presence(preferably sensors are positioned as far apart as possible to increase detection accuracy and to prevent signal overlap). After plugging the localization sensor to the wall outlet, it must be connected to the local Wi-Fi before it can start sending data.
Programming languages	Python
Libraries	Falcon, Json, Requests, Database, Os, Base64, Sqlite3, paho, other standard libraries for data and file manipulation
Issues & Notes	Daily summarized data is available, real-time data is available internally on low level.

Table 4. Voice tracker Module.

Voice Tracker Module	**Description**
Functionalities	Analyzes audio gathered from the microphone and outputs the corresponding class. The audio can be classified as: - Cry - Laugh - Other Mood detection
Implemented on	TensorFlow is the core part of this module, that is the library in which the neural network runs.
Interfaces Exposed (Outputs)	Json file output
Interfaces Requested (Inputs)	Audio files gathered by the chit-chat module. Audio Flow form microphone device.
Algorithms employed	The module consists of a neural network Yamnet fine-tuned for this specific task, based on Tensorflow2. At the first part of the algorithm there is a silence-recognition algorithm that can recognize if the audio in input is relevant (and then must be analyzed) or not. This module reads the audio (wav) that are saved by the chit-chat module, which is the only module that accesses the microphone and gives them in input to a neural network that outputs the mood recognition. Hence, every time that an audio is considered to be relevant for the mood recognition and saved to the

	corresponding folder, this module will process it and classify the emotion as: laugh, cry, other.
Instances and Deployment	________
Programming languages	Python
Libraries	- Json for the output file containing the prediction - Math for operations on the audio file - Threading because the module is multi-threading - Tensorflow2 for the neural network - NumPy for math operations with the tensors - Yamnet that actually contains the original NN
Issues & Notes	The module is intended to be used for the daily summarization. It is not intended to be real-time.

2.3 High Level Subsystem

High level subsystem, consists of the following submodule:

- **Notification handler** that allows to manage notification and alerts, providing a reliable and battery-efficient connection between TeNDER server and devices that allows to deliver and receive messages and notifications on iOS, Android;
- **Data analytics and Recommendation subsystem** that provides personalized information to the patients, information to the caregivers and patient information to the professionals;
- **Interoperable EHR (EHR)** for proper interoperability and integration in current health systems;
- **Tracking service database**, to obtain meaningful data about our users and target audience and their behaviours, tracking and collating the metrics that matter most to the TeNDER purpose both accurately and securely.
- **Social service**, module devoted to bring the social supply to the patients. The ambition is to integrate medication, medication intake, exercises, nutrition, and non-medical assistance functionalities (daily routines, from cleaning to administration, shopping, occasional travel, or basic finances like paying bills) and related monitoring into connected modules which local caregivers can access and make decisions/provide support services.

2.3.2 SERVICES

TeNDER provides a toolbox of services tackling the main variables (from clinical, social, and quotidian views) that affect patients to improve their QoL and better involve the HealthCare actors:

Services utilize the information generated through the TeNDER ecosystem to generate information to the related stakeholders as depicted in Figure 7. Specifically, TeNDER has created a set of 7 Clusters of Services that, using the core technologies of the system, serving to a plethora of ways in which senior citizens, living on their own, affected by any of several of the Chronic Diseases, are expected to be supported.

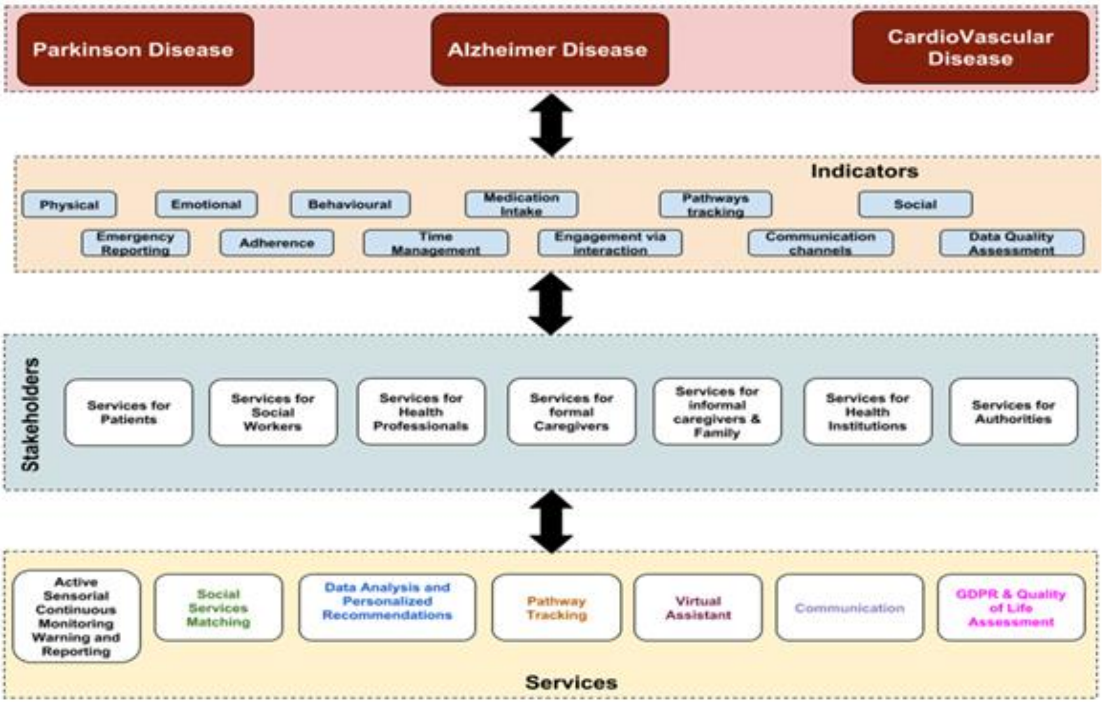

Figure 5. TeNDER Services, Stakeholders, indicators for the Chronic Diseases covered.

TeNDER services server has exposed an API that allows users to access to the different modules provided. Access will be provided in a secure way via authorized roles.
At the same time, it will expose another secure API where sensors and remote computers will be connected to a central server (TeNDER cloud). All requests will have a valid token previously generated by the login services. A task is in charge of gathering all the services available in the platform. A set of sub-models will be defined to achieve all users' requirements.

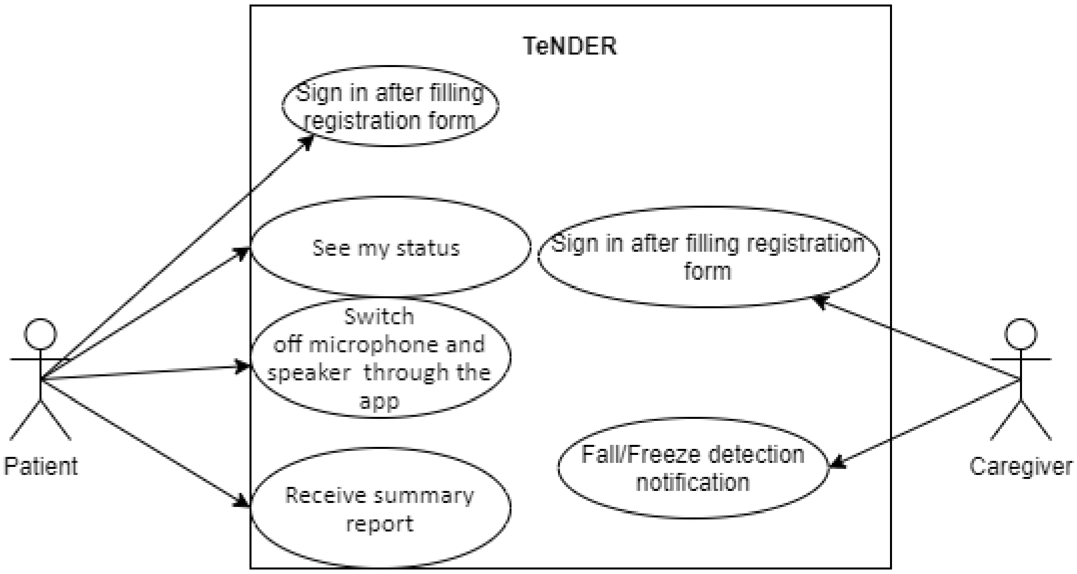

Figure 6. TeNDER UML: HOME SET Parkinson Disease.

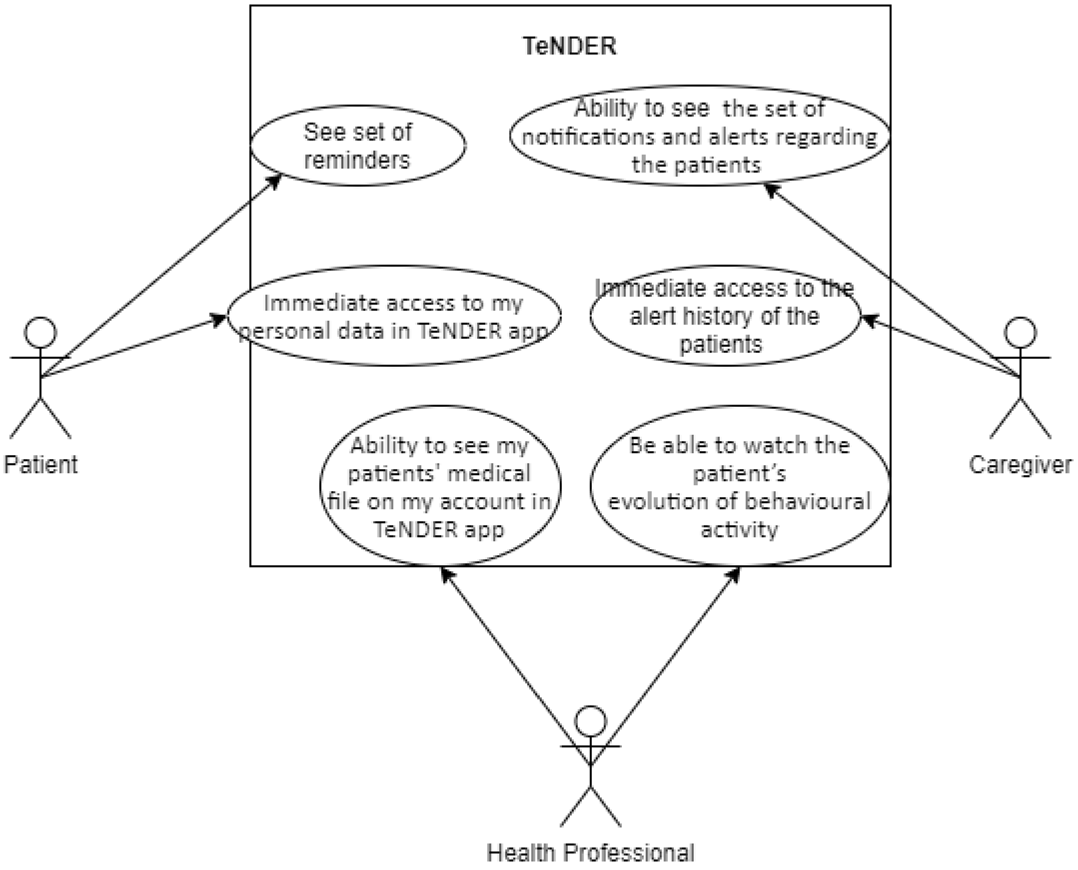

Figure 7. TeNDER UML: Day-Care CENTER Alzheimer or related.

All the services are mostly provided to our users in the form of specific features and sections on our app and platform in general.

2.3.1.1 Service Cluster 1

SC1- Active Sensorial Continuous Monitoring, Warning and Reporting

This system takes advantage of the use of multi-sensorial infrastructure to provide patients with:

- **Health tracking service:** This service will offer patients the monitoring of patient biological, behavioural variables such as blood pressure, weight; reaction to stimulus; Social behaviour (among others). The service will be in charge of capturing relevant data from the patient and his/her environment to detect abnormal situations.
- **Emotional/affective detection service:** this service will be end-user oriented and intends to detect the patient's mood to support their status enabling services that might help him in case of negative feelings (i.e. sadness, depression-like).
- **Warning and reporting service:** this service will be in charge of controlling the patient variables and report any special/abnormal event to the adequate stakeholder (caregiver, informal caregiver, and family) according to the type of event, the relevancy and the action required (i.e. to call emergency services).

Table 5. SC1- Active Sensorial Continuous Monitoring, Warning and Reporting.

SC1- Active Sensorial Continuous Monitoring, Warning and Reporting	Description
Functionalities	Services responsible of providing to patients and caregivers, health professionals with Health Tracking, Emotional/Affective detection of patients and providing reports and input for triggering warning Both on the App and web platform.
Implemented on	TeNDER Services
Interfaces Exposed (Outputs)	Health tracking service Emotional/affective detection service User interfaces both in the in TeNDER APP and Web APP within specify section called safety and wellbeing Warning and reporting service: ▪ Fitbit's Tender app ▪ User interfaces both in TeNDER APP and Web APP providing emergency notification, common notification, alerts.
Interfaces Requested (Inputs)	**Health tracking service** ▪ Input form Recommendation System. ▪ Input form related TeNDER sensors, wristband, position, sleep tracker. **Emotional/affective detection service** ▪ Input form Recommendation System. ▪ Input form related TeNDER sensors, like: microphone, deep camera. **Warning and reporting service:** ▪ Input form Recommendation System. ▪ Input form related available TeNDER sensors, like: microphone.
Algorithms employed	**Health tracking service** • N/A **Emotional/affective detection service** • Sound recognition through a deep learning algorithm using a pre-trained model of predetermined sounds (crying, laughter, falling). **Warning and reporting service:** • Deep Learning algorithms for fall detection • Machine Learning algorithms for freezing detection
Instances and Deployment	**Warning and reporting service:** ▪ Dockerized Abnormal Behaviour Detection (ABD) system
Programming languages	**Health tracking service:** • C# **Warning and reporting service:** ▪ Python (for the ABD general modules)

	▪ Javascript (for the Fitbit's Tender app) ▪ CSS (for the Fitbit's Tender app)
Libraries	**Health tracking service:** • SenseLib: Opun source library for sensors information collection. **Emotional/affective detection service:** ▪ NumPy array with the vectors of the extracted features from the analyzed sound frames **Warning and reporting service:** ▪ NumPy ▪ Keras.Tensorflow ▪ Mqtt
Issues & Notes	▪ No relevant issues

2.3.1.2 Service Cluster 2

SC2-Social Services Matching

This set of services is devoted to bring the social supply to the patients. The ambition is to integrate medication, medication intake, exercises, nutrition, and non-medical assistance functionalities (daily routines, from cleaning to administration, shopping, occasional travel, or basic finances like paying bills) and related monitoring into connected modules which local caregivers can access and make decisions/provide support services.

- Patients can answer the questions (e.i. in regards to companionship, loneliness, financial status, care service support need/instrumental activity) provided through the TeNDER system and select/obtain services and type of assistance from communication channel with the social professionals or through the system recommendation service (a list available locally or have information about the type of assistance provided or available). They can follow their own status and wellbeing, getting suggestions/instructions about wellbeing (daily activity, nutrition or exercise).
- Caregivers can use monitoring data and user requirement information to analyse situation and start/adjust the level of support and select trained staff to provide assistance. They can monitor patients' TeNDER Sections 1-3 Page 12 of 70 adherence to previously agreed activities (from exercises to medication or taking adequate nutrients, vitamins, etc.). They can also obtain information on available social support for carers (like support group, help with grocery etc.).
- Feedback from monitoring or change in available services may lead to modification of level of support.
- Medical information (from other subsystems) may also assist to set the adequate level and combination of support services.
- The services can be used by patients, caregivers (formal or informal), family and social worker (and institutions).

Table 6. SC2-Social Services Matching.

SC2-Social Services Matching	Description
Functionalities	This cluster of services is in charge of bringing social supply to the patients and provide resources to use and adapt the support services available.
Implemented on	TeNDER Services
Interfaces Exposed (Outputs)	TeNDER services Rest Endpoint ▪ User interfaces within for TeNDER APP with specific section called questionnaire Recommender engine
Interfaces Requested (Inputs)	Questionnaire on the patient and carers status and need for social support, Recommendation System, Monitoring, Medical Information from other subsystems
Algorithms employed	• t-SNE • k-Means
Issues & Notes	No relevant issues

2.3.1.3 Service Cluster 3

SC3-Data Analysis and Personalized Recommendations

Professional oriented service to offer value on the patient data gathered through different services and through the analysis of the interaction amongst all the involved parties. The objective will be to generate knowledge by a continuous data analysis focus on all patients' information identifying patterns and models of best practices in coordination, treatment, recommendations offered, gamification integration, interaction design, etc. Knowledge will be offered to medical and social professionals while using platform services with information on alternatives used by other professionals of the platform in the actions they are taking.

- Follow-up protocols: Chronic conditions need follow up protocols to understand their evolution and patient's specific needs at all stages. This service will automatically recommend forms and questionnaires to identify patient situation, while recommendations will also be targeted to caregivers that take care of patients on a daily basis. The service will include different protocols depending on the disease of the patient and will be open to new protocols when future targets are incorporated into the platform.

Table 7. SC3-Data Analysis and Personalized Recommendations

SC3-Data Analysis and Personalized Recommendations	**Description**
Functionalities	Knowledge generation and sharing with medical and social professionals
Implemented on	TeNDER Services
Interfaces Exposed (Outputs)	TeNDER Services: Rest Endpoint, Calendar User interfaces both in TeNDER APP and Web APP within section called “recommendations/ suggestions”
Interfaces Requested (Inputs)	TeNDER Services: Questionnaires TeNDER EHR: Patient information
Algorithms employed	▪ API calls ▪ Deep Learning techniques ▪ Clustering techniques ▪ Classification algorithms
Instances and Deployment	▪ Dockerized container: Recommendation module
Programming languages	▪ Python ▪ HTML
Libraries	• Tensorflow • Numpy • Sklearn • NLTK
Issues & Notes	No relevant issues

2.3.1.4 Service Cluster 4

SC4-Pathway Tracking

This service employs all data flow across the System and will analyse the patient non-clinical activity, providing all stakeholders with relevant information to optimize time management in the patient healthcare chain.

- Clerical Pathway: using all information available, this service will register the entire repository of events associated to healthcare attention to the patient. This service has been implemented by the TeNDER EHR server which supports interoperability using the HL7 communication protocol for easier connection with external systems. In this server, all the patients' activities and data are stored. TeNDER ecosystem provides also its own user interfaces (web and mobile applications) that offer all the necessary information to users (patients, doctors, caregivers, etc).

- Quality of data provided: This service enables TeNDER to improve continuously in the manner that information is retrieved and presented to health professionals. This service continuously monitors the quality of the offering information (i.e. recommendations, graphs, evolutions, sensor readings, etc), and the optimal efficiency of the system.

This service is based on two different approaches, in the first one, we collect feedback directly from the users of the system. Secondly, we have developed a separate monitoring framework that observes the operation of the TeNDER ecosystem and in case of an abnormal detection informs the administrator of each health organization. As abnormal events, we consider issues like the unexpected shut down of a user's PC, the failure of the data storage in the cloud due to a network disconnection, sensor disconnection, etc. In every case, an email alert notification is generated with all the necessary information and sent to the appropriate person in order to evaluate and solve the issue.

Table 8. SC4-Pathway Tracking.

SC4-Pathway Tracking	Description
Functionalities	Employ all data flow across the System, analyse the patient non-clinical activity and provide stakeholders with information relevant with optimising time management in the patient healthcare chain. Check that all patients' data are stored properly to the TeNDER EHR.
Implemented on	TeNDER Services
Interfaces Exposed (Outputs)	▪ TeNDER Services: Manual-Tracking ▪ TeNDER EHR ▪ TeNDER Monitoring service ▪ TeNDER Web and Mobile application
Interfaces Requested (Inputs)	▪ TeNDER Services: Rest Endpoint (HTTPS) ▪ Publish/Subscribe (AMQPs) Input form related TeNDER sensors, like: microphone, kinect
Algorithms employed	N/A
Instances and Deployment	Web Application developed (React), Mobile Application developed (Android, iOS), Message broker (RabbitMQ), TeNDER EHR (Tomcat), Databases (PostgreSQL, MongoDB), TeNDER Remote DB (Django).
Programming languages	Java, SQL, Python, Spring.
Libraries	>= Java 1.7, Spring Core, Spring MVC, Spring Data, Python, Django, RabbitMQ, prometheus-client, fhirclient, python-keycloak.

Issues & Notes	No relevant issues

2.3.1.5 Service Cluster 5

SC5-Virtual Assistant

Patient-oriented, this service is intended to be of help in everyday life for users who are not hospitalized and spend most of their time within the home.
For this service, specific devices provide or acquire data to two submodules that make up the "Virtual Assistant" service, namely the "reminder module" and "chit chat module."
Reminder module" plays aloud the text of a reminder from the Tender app using its speaker.

The technical specifications are given in the table below.

Table 9. SC5-Virtual Assistant: Reminder module

SC5-Virtual Assistant *Reminder module*	**Description**
Functionalities	Retrieve reminders from the Android TeNDER App calendar and play them at the established time on the client speakers using Microsoft Text-To-Speech Engine
Implemented on	• HTTPS API for data retrieval • Microsoft Text-To-Speech Engine for Text-To-Speech operations • Celery for tasks scheduling
Interfaces Exposed (Outputs)	The module will enable audio playing through system default speakers
Interfaces Requested (Inputs)	HTTPS API will retrieve TeNDER Android app reminders in a JSON format
Algorithms employed	Basic date and time arithmetic operations
Instances and Deployment	Depending on each specific use case, the corresponding language packs are needed in order to perform a correct Text-To-Speech
Programming languages	Python
Libraries	• Celery for tasks scheduling, • Pyttsx3 for Text-To-Speech operations • Pydub for audio playing • Datetime for date and time arithmetic operations
Issues & Notes	If the set language is not installed in the system, the Text-To-Speech engine will use the current active Windows

	language and the audio may be played using a wrong language voice, accent and tone

This sub-module consists in a set of regularly executed tasks which communicate with the TeNDER App via HAPI-FHIR API Interface. The reminder module checks for new or edited calendar reminders and copies them in a local SQLite Database.
If a non-scheduled reminder is found, the module will then schedule the corresponding "speak" task. If the user has set a vocal notice for the event on the TeNDER app (i.e. 1 day before the actual event), there will also be a notice "speak" task.
Each "speak" task will use the default host audio speakers and will read what the user has written in the "Info" field of the TeNDER reminder via Microsoft Text-To-Speech engine.
The module also keeps the local SQLite Database clean by regularly detecting and removing expired or deleted reminders.
Below is an image showing the data flow.

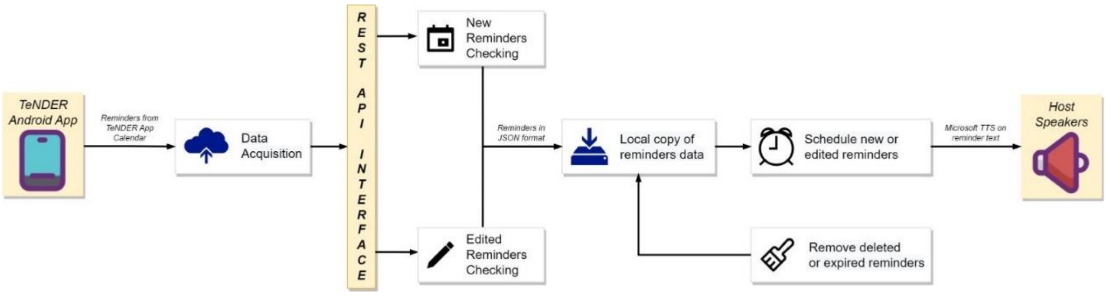

Figure 8. Reminder module data flow.

Chit chat module provides for a voice interaction between patient and chit chat because of a microphone that acquires requests from the patient and triggers certain events and vicversa the module interacts with the
patient upon the occurrence of certain events (as example: recorded elevated heartbeat).

The technical specifications are given in the table below.

Table 10. SC5-Virtual Assistant: Chit Chat Module.

SC5-Virtual Assistant *Chit Chat Module*	**Description**
Functionalities	• Sends a notification to the caregiver if the patient asks it • Sends a notification if the patient is not feeling well, or an irregular heartbeat is received from the HAPI FHIR API • Talks to the patient to check if everything is ok • Listens to the patient and answers simple questions • Remember to the patient the scheduled events

Implemented on	• HAPI FHIR API for data retrieval • Easygui for the system integrator interface • SpeechRecognition library with Google's API • Microsoft's voice language pack with Pyttsx3 library
Interfaces Exposed (Outputs)	Audio playing through selected speakers Sends notification
Interfaces Requested (Inputs)	Audio flow coming through selected microphone Health information obtained from HAPI FHIR API
Algorithms employed	The module is based on a multi-threading event-based application. In order to manage the skills that can be triggered, there is a semaphore-based algorithm that guarantees mutual exclusion. Then, if two or more events are gathered (for instance an irregular heartbeat rate and a request by the patient at the same time), the semaphore will act as a scheduler in order to avoid overlapping between the two routines.
Instances and Deployment	________
Programming languages	Python
Libraries	• Pyttsx3 for the Text-to-Speech • SpeechRecognition for the speech recognition • Pydub for audio handling • Requests to communicate with HAPI FHIR API • Datetime for days and hours handling • Easygui for the system integrator interface
Issues & Notes	If the set language is not installed in the system, the Text-To-Speech engine will use the current active Windows language and the audio may be played using a wrong language voice, accent and tone

This module consists of a set of skills that can be triggered either by voice (Speech Analysis) or by an event detected by a sensor (API information). activation of the module can be either just a vocal skill that answers to the patient's question or a networking skill that sends notifications to the caregiver. The module checks regularly the HAPI-FHIR API, when a new event is detected (irregular heartbeat rate, too low number of steps per day...), it will ask if everything is fine to the patient and/or sends a notification to the caregiver.
Below is an image showing the data flow.

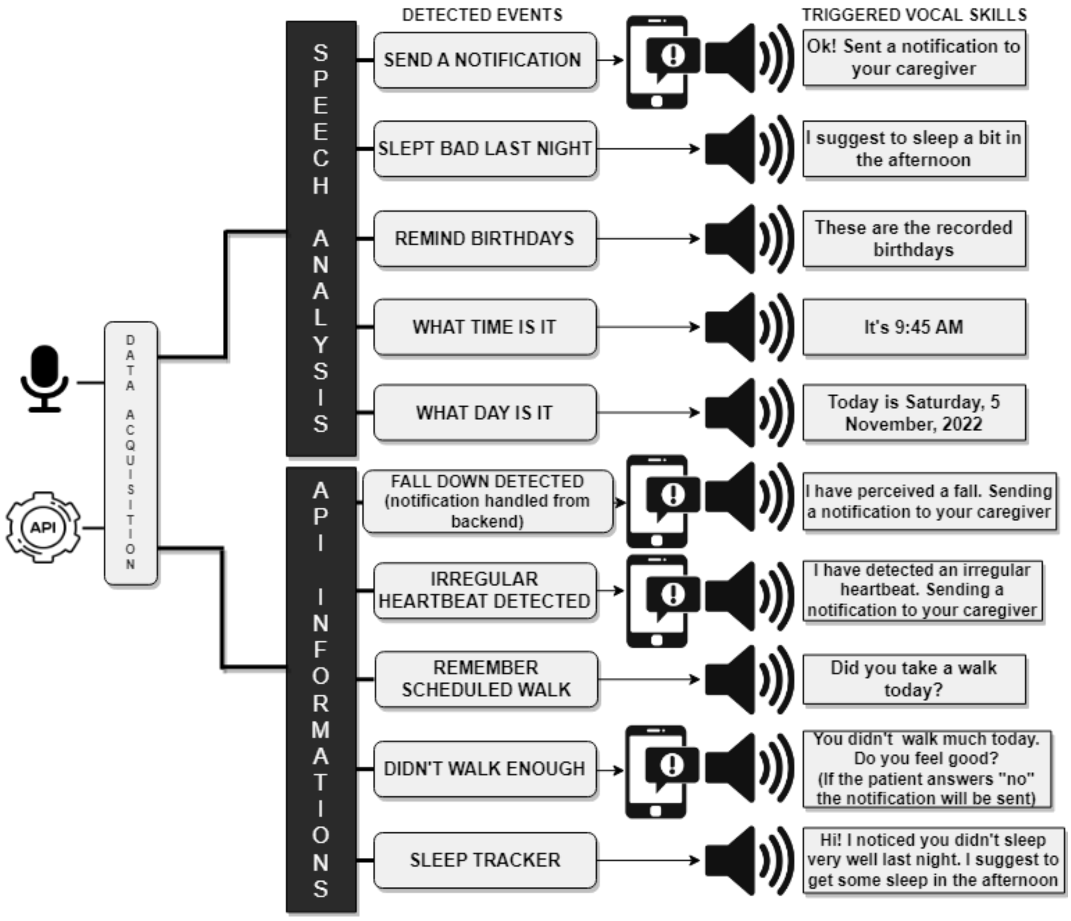

Figure 9. Chit chat module Data flow.

2.3.1.6 Service Cluster 6

SC6- Patient, Caregiver and Medical personnel Communications

This is a communication tool basted on a rapid open-source framework for web applications where users need to log in and share information.
Therefore, users will be able to access this service from TeNDER App or web app for health professionals: the final aims of this service is to offer social communication among users of the Platform at different privacy levels and with different following objectivesos:

- Family Support: Communication among family members, caregivers, and patients to reduce patient loneliness and to offer personal services for the patient.
- Social Interaction: Among patients with similar situations to motivate patients with socialization.
- Care Support: Communication between professionals and caregivers or patients.
- Coordination: Foster coordination among medical and social professionals.
- Share Knowledge: Communication among professionals to share treatment knowledge and best practices.

Table 11. SC6- Patient, Caregiver and Medical personnel Communications.

SC6- Patient, Caregiver and Medical personnel Communications	Description
Functionalities	Offers social communication among platform users at various privacy levels and with different objectives The service consists of an external platform that can be accessed via mobile or web app
Implemented on	TeNDER Services TeNDER Front End Layer
Interfaces Exposed (Outputs)	Translations Server: 195.251.117.117:8080 Users Server: https://social-prod-tender.maggiolicloud.it
Interfaces Requested (Inputs)	N/A
Algorithms employed	N/A
Instances and Deployment	Open-source rapid development framework for web applications where users need to login and share information. Standalone version for translations, dockerized version for users.
Programming languages	PHP, MySQL
Libraries	Apache 2.4 PHP 7.4.25 MariaDB (formerly MySQL)
Issues & Notes	Elgg 3.3. does not support PHP8, although any PHP7 version will do. The current installed version of Apache is Apache 2.4.52. Be sure to perform an update as soon as it comes out for security reasons. Dockerized version is configured to work with the TeNDER Keycloak Authentication service.

2.3.1.7 Service Cluster 7

SC7-Quality of Life Assessment

This service will allow users to measure and know the impact of their interactions with the different functionalities of the TeNDER system. Additionally, this service will allow to match questionnaires related to QoL (i.e. SF-36, SF-12, OP-QoL, PDQ8, PDQ39 or QoL-AD) in an interactive manner by using interface dynamic tools

Table 12. SC7-Quality of Life Assessment.

SC7-Quality of Life Assessment	Description
Functionalities	This service entails the administration of questionnaires to assess users' quality of life.
Implemented on	TeNDER Services
Interfaces Exposed (Outputs)	TeNDER Services: Rest Endpoint, Pub/Sub, Notification via Pub/sub. User interfaces within specify section called questionnaire. Ckan interface to visualise monthly reports for each organization registered in the HAPI FHIR server. Each report, generated as an excel file, contains several sheets with data that corresponds to patients, caregivers, practitioners and several metrics regarding their disease and devices.
Interfaces Requested (Inputs)	TeNDER Services: TeNDER EHR, Questionnaire
Algorithms employed	N/A
Instances and Deployment	Web Application developed with NodeJS with RabbitMQ deployed into TeNDER and acceded with Load Balancer for Rest API and Pub/Sub for RabbitMQ. Neo4j Graph database
Programming languages	Node JS, JavaScript, CypherQL, Python
Libraries	>= Node JS 4.4.4, Rabbit MQ 3.6.2, Neo4j Community 3.0.1
Issues & Notes	No relevant issues

3 TeNDER COMMON APPROACH AND METHODOLOGY

To define the final version of TeNDER applied to the pilots, preliminary development work has been carried out on the adoption of the requirements and constraints in terms of ethics and privacy. In parallel, the definition of the scenarios in the final design approach of TeNDER has been carried out.

3.1 Ethical and legal management

Legal and ethical aspects have been continuously addressed in TeNDER, starting with D1.1 Fundamental Rights, Ethical and Legal Implications and Assessment, which defined the framework and principles applicable to technical works. Further details were reported on in the first impact assessment (delivered in M22), namely data protection, privacy, ethics and safety aspects of the development process. In order to avoid replication of already submitted work, we will here summarise the most pertinent points. Further two impact assessments follow up on the second and third wave of pilots, and will be released in the D1.5 (due M42).

The main legal and ethical challenges of the project have concerned the inclusion of patients in the pilots, the processing of personal data and the wider ethical and societal implications of technologies used in a remote integrated care model.

The processing of personal data falls under the regime of the General Data Protection Regulation (GDPR). In order to develop the system and run pilots, the personal data of patients and caregivers are processed. They are defined in Art. 4(1) and (2) respectively as: **'personal data'** means any information relating to an identified or identifiable natural person **('data subject')**. **'Processing'** means any operation or set of operations which is performed on personal data or on sets of personal data, whether or not by automated means, such as collection, recording, organisation, structuring, storage, adaptation or alteration, retrieval, consultation, use, disclosure by transmission, dissemination or otherwise making available, alignment or combination, restriction, erasure or destruction.

Since TeNDER is concerned with health and aging technology, the data that will be processed falls under the regime of special categories of data (art. 9 of the GDPR). This article specifies that health data can only be processed if specific criteria are met, such as processing with the explicit consent of the patient. '**Health data'** under the GDPR mean personal data related to the physical or mental health of a natural person, including the provision of health care services, which reveal information about their health status.

Health data can only be processed if strict conditions are met: in TeNDER, we have relied on patients' explicit consent, which was collected prior to pilots by each end user from their respective patients. While the GDPR provides for a specific regime for children's consent, there is no equivalent restriction for patients experiencing cognitive decline. The consortium has thus decided to go *beyond the minimum legal regime*, and established additional safeguard procedures in order to ensure the patients' consent is truly informed. These procedures are described in D10.3 and D10.4.

Moreover, data processing agreements have been concluded between end users, acting as data controllers, and their processors – the technical partners. **'Controller'** means the natural or legal person, public authority, agency or other body which, alone or jointly with others, determines the purposes and means of the processing of personal data; **'processor'** is defined as a natural or legal person, public authority, agency or other body which processes personal data on behalf of the controller.

Legal and ethical concerns have been documented in serial impact assessments, through the collaboration of the legal, user and technical teams collaborate. This contributes to the accountability principle (art. 5(2) of the GDPR), and in-built privacy processes lead to the privacy by design approach (art. 25 of the GDPR); both of which are crucial in ensuring that patients' data protection rights are centred.

The consortium has taken specific steps to respect applicable legal and ethical frameworks, and several measures regarding the treatment of personal data have been adopted by the consortium partners. More specifically, our approach rests on ex ante and ex post legal analyses:

1. **Definition of applicable framework in D1.1 Fundamental Rights, Ethical and Legal Implications and Assessment** (First Version): applicable legal and ethical frameworks, such as the GDPR, elemental principles of biomedical ethics, and regulation of medical devices. Based on our analysis, we defined the fundamental obligations of pilot partners vis-à-vis patients on protection of personal data, involvement of participants in pilots, ethical and social aspects, and safety requirements of medical devices deployed. Further ethics compliance was demonstrated by our work in WP10. *Delivered in the first year of the project.*
2. **Impact assessment and continuous legal and ethical monitoring:** in the impact assessment, we take into account the nature, scope, context and purposes of the processing in the development process in order to ascertain risks to the fundamental rights and freedoms of patients involved. Our initial findings were be reported in the *D1.4 First legal/ethical monitoring report, delivered in M22*, and will be revisited in *D1.5 Final legal/ethical monitoring report (due M42).*
3. **Final legal evaluation of the technical development and project research:** D1.6 Final version of Fundamental rights, ethical and legal implications and assessment *(due M42)*. This deliverable will provide an assessment of the project with a view to inform similar future projects about their legal and ethical impact.

3.2 TeNDER approach

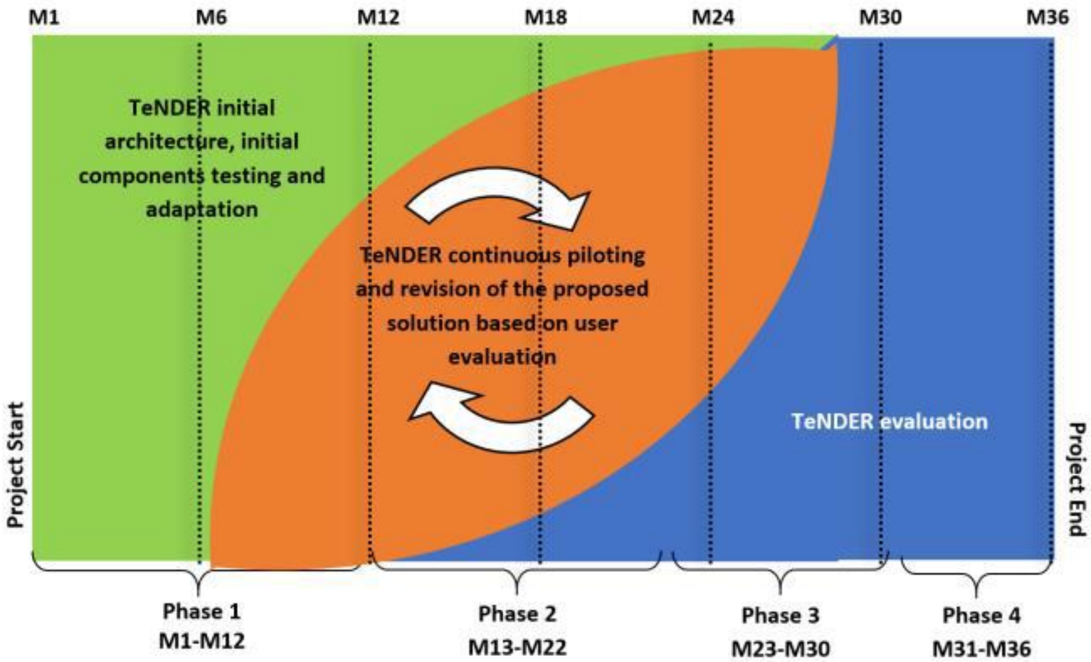

Figure 10. TeNDER phased approach.

TeNDER is developed in 2 parts. The first part corresponds to Phase 1. This phase is the initial part of the project. The second part corresponds to the co-design process (Phase 2, 3 and 4). Details of the phases are given below:

1. Phase 1 (M1-M11) was devoted to study the flow of provisions (Deliverable 2.1), the proposed scenarios (Deliverable 2.3) and relevant evidence from the literature (Deliverable 2.4), but also the actual experiences of potential participants through an observational study using surveys and interviews. Throughout this phase, basic developments of independent components were carried out by the technical partners.
2. During Phase 2 (M12-M22), a working prototype was ready, and 5 pilots were initiated to demonstrate the system in real environments: homes, rehabilitation rooms, and hospitals. The second part of the co-design process (Phase 2, 3 and 4) has been carried out throughout the Mock-Up testing and also throughout the piloting phase in the 5 TeNDER pilot centres. This is a large-scale intervention phase lead within WP6 that has been carried out in a total of 5 institutions in different countries. During this pilot phase, feedback from users has been continuously received through interviews and observations. Each user is invited to reflect and comment on their own opinions about the tool in order to incorporate the modifications and improvements detected. This continues the collaborative work with the beneficiaries of the tool.
3. Within Phase 3 (M23-M30) different potential end-users of TeNDER (patients, carers and professionals) were involved in the co-design process through the feedback collected during the first pilot phase and the second testing phase of TeNDER. User requirements, usability and acceptance of the technology were investigated and Persona cards (Personas, models) were created (Deliverable 2.4), evaluation was provided in 2 internal reports WP1, Reports Evaluation Strategy and Protocols. In this way, we were able to visualise the needs of TeNDER users, define and confirm the requirements of several differently abled patients, the people around them and, in addition, the different types of professionals included in the patients' care pathway. This helped to develop a technological tool adapted to their preferences and needs for the following pilots.
4. Phase 4 (M24-M42) includes the final development of the last version of the TeNDER tool, that is passed to the last piloting phase with the purpuse of the validation and the QoL analysis. The QoL methodologies will allow to establish the impact of TeNDER solutions on the patient's life. As the diseases are neurodegenerative, the methodology will consider the evolution of the patients in terms of maintenance of QoL by studying the evolution and impact of the technology.

The following tables list the actors involved in the collection of user requirements in each of the pilots. It can be seen that in each of the phases the actors directly involved in TeNDER have collaborated, offering their opinions, needs and experiences of use through different data collection tools, combining qualitative and quantitative methodology. This feedback has made the co-creation of the TeNDER tool possible.

Table 13. Actors involved in Pilot 1.

ACTORS INVOLVED IN PILOT 1 (SERMAS) M1-M35				
		PATIENTS	CAREGIVERS	PROFESIONALS

		AD	PD	CVD		HP	SW	Other
Phase 1	Survey requeriments	2	8	10	21	13	-	2
	Interview requeriments	1	-	1	2	1	1	-
Phase 2	FIRST WAVE	-	-	33	10	31	-	8
	Testing Lab 1	-	-	14	10	13	-	-
	SECOND WAVE	5	2	62	11	26	-	6
Additional user requirements		2	1	-	3	-	2	-
TOTAL		**10**	**11**	**120**	**57**	**84**	**3**	**16**

Table 14. Actors involved in Pilot 2.

ACTORS INVOLVED IN PILOT 2 (APM) M1-M35								
		PATIENTS			CAREGIVERS	PROFESIONALS		
		AD	PD	CVD		HP	SW	Other
Phase 1	Survey requeriments	-	20	-	20	9	1	-

	Interview requeriments	-	3	-	3	3	-	-
Phase 2	FIRST WAVE	-	31	-	16	8	-	-
	Testing Lab 1	-	11	-	-	4	-	-
	SECOND WAVE	-	38 (+21 controls)	-	29	8	1	1
Additional user requirements		-	-	-	-	-	1	-
TOTAL			103(+21)		68	32	3	1

Table 15. Actors involved in Pilot 3.

ACTORS INVOLVED IN PILOT 3 (UNITOV) M1-M35								
		PATIENTS			CAREGIVERS	PROFESIONALS		
		AD	PD	CVD		HP	SW	Other
Phase 1	Survey requirements	2	2	-	2	2	1	-
	Interview requirements	1	-	-	2	1	1	-

Phase 2	FIRST WAVE	9	11	-	19	8	-	-
	Testing Lab 1	-	1	-	-	1	-	-
	SECOND WAVE	9	11	-	22	8	-	-
Additional user requirements		-	-	-	-	-	-	-
Total		**21**	**24**		**45**	**20**	**2**	

Table 16. Actors involved in Pilot 4.

ACTORS INVOLVED IN PILOT 4 (SKBA) M1-M35								
		PATIENTS			CAREGIVERS	PROFESIONALS		
		AD	PD	CVD		Health	Social	others
Phase 1	Survey requirements	-	-		-	4	-	-
	Interview requirements	5	-	5	5	4	-	-
Phase 2	FIRST WAVE	13	1	8	13	7	-	-
	Testing Lab 1	-	1	1	-	7	-	-

	SECOND WAVE	17	-	23	16	6	-	1
Additional user requirements		-	-	-	-		-	-
TOTAL		35	2	37	34	32	-	1

Table 17. Actors involved in Pilot 5.

ACTORS INVOLVED IN PILOT 5 (SPO) M1-M35								
		PATIENTS			CAREGIVERS	PROFESIONALS		
		AD	PD	CVD				
Phase 1	Survey requirements	20	-	-	20	10	1	2
	Interview requirements	3	-	-	3	1	2	1
Phase 2	FIRST WAVE	25	-	-	15	2	2	2
	Testing Lab 1	-	-	-	-	-	-	-
	SECOND WAVE	44 (+ 25 controls)	-	-	26	4	2	2

Additional user requirements	2	-	-	8	7	3	3
TOTAL	94(+25)	-	-	72	24	10	10

The final design of the TeNDER tool is the result of the study of user needs and requirements, which have been collected through different tools detailed in WP2 Deliverables and the outcome of which has served to provide feedback and evaluation to guide the design of the TeNDER system requirements.

4 PILOTS DEFINITION

The result of this section is a complete overview of the scenarios in which the TeNDER system is implemented. These are real scenarios for each of the participating user institutions: home set, hospital, day-care and rehabilitation room. The outcome of the scenarios is based on the needs of all the actors involved in the co-creation process. During this co-creation process, feedback from users has been collected continuously through Surveys and Interview requirements and through testing-lab and Additional user requirements.

4.1 Phase 1: approach to the requirements, usability, and acceptance

During Phase 1 of the pilots, user requirements are established to define the final architecture of TeNDER. Through the creation of laboratory prototypes and testing, possible limitations and drawbacks have been identified. This phase was carried out during M1-M12 and throughout the project feedback on requirements, usability and acceptance has been collected. The results of this part are detailed in D2.5 and D2.7.

4.2 Phase 2,3 and 4: Pilots' Implementation.

Final version of scenarios and use cases

This sub-section provides the final version of the scenarios based on each of the diseases included in the project: AD CVD and PD. For this differentiation, each of the particular requirements and health needs of each disease have been studied. Thus, the result is a specific scenario for each disease. The following tables describe the scenarios and the characteristics of: people involved, functionalities, devices, modules, services and Outcomes System Requirement.

A. HOME SET Scenario

The home set scenario is proposed for 4 of the 5 institutions involved and includes all three diseases: AD, CVD and PD. It should be noted that the CVD scenario does not include functionalities aimed at more dependent or more severely affected patients, such as AD and PD.

Table 18. HOME SET Scenario.

HOME SET Scenario			
Disease	AD	CVD	PD
EPIC	**Primary:** User (Patient) **Secondary:** Caregivers (Family) Health Professionals, Social workers and other professionals	**Primary:** User (Patient) **Secondary:** Caregivers (Family) Health Professionals and other professionals	**Primary:** User (Patient) **Secondary:** Caregivers (Family) Health Professionals and other professionals
Required functionalities	Physical activity (steps and heart rate) Fall detection Sleep quality Humidity and temperature detection Confusion and disorientation Room localization	Physical activity (steps and heart rate) Fall detection Sleep quality	Physical activity (steps and heart rate) Fall detection Sleep quality Humidity and temperature detection Confusion and disorientation
Modules:	Activity /Acceleration Tracking module, Sleep Tracking module	Activity /Acceleration Tracking module, Sleep Tracking module	Activity /Acceleration Tracking module, Sleep Tracking module
Devices:	▪ Fitbit Versa 2 ▪ Smartphone ▪ Withings Sleep Sensor ▪ Binary sensor (implemented in June 2022) ▪ Temperature and Humidity sensor (implemented in June 2022) ▪ Localization sensor	▪ Fitbit Versa 2 ▪ Smartphone ▪ Withings Sleep Sensor	▪ Fitbit Versa 2 ▪ Smartphone ▪ Withings Sleep Sensor ▪ Binary sensor (implemented in June 2022) ▪ Temperature and Humidity sensor (implemented in June 2022) ▪ Localization sensor
Services (Main out of 7 Service Clusters:):	**SC1**: Active Sensorial Continuous Monitoring, Warning and Reporting. **SC2:** Social Services Matching **SC3**: Data analysis & Personalised Recommendations. **SC4**: Pathway Tracking	**SC1**: Active Sensorial Continuous Monitoring, Warning and Reporting. **SC2:** Social Services Matching **SC3**: Data analysis & Personalised Recommendations. **SC4**: Pathway Tracking.	**SC1**: Active Sensorial Continuous Monitoring, Warning and Reporting. **SC2:** Social Services Matching **SC3**: Data analysis & Personalised Recommendations. **SC4**: Pathway Tracking.

	SC5: Virtual Assistant. **SC6**: Communication. **SC7**: Quality of Life Assessment	**SC5**: Virtual Assistant. **SC6**: Communication. **SC7**: Quality of Life Assessment	**SC5**: Virtual Assistant. **SC6**: Communication. **SC7**: Quality of Life Assessment
Outcomes System Requirement:	Primary & secondary: Activity during day and night; quality of sleep, safety and wellbeing; vital signs; fall detection	Primary & secondary: Activity during day and night; quality of sleep and wellbeing; vital signs; fall detection	Primary & secondary: Activity during day and night; quality of sleep and wellbeing; vital signs; fall detection

B. HOSPITAL Scenario

The hospital scenario is proposed for 3 of the 5 institutions involved and includes 2 of the three diseases: AD and CVD. It should be noted that as it is a more restricted place of activity for the patient, the required functionalities are more limited and specific than in the home scenario.

Table 19. HOSPITAL Scenario.

HOSPITAL Scenario		
Disease	AD	CVD
EPIC	**Primary:** User (Patient) **Secondary:** Caregivers (Family) Health Professionals, Others (Social Workers)	**Primary:** User (Patient) **Secondary:** Caregivers (Family) Health Professionals Others (Social Worker)
Required functionalities	Tracking the activity and wellbeing during day and night; information goes from user to caregiver, health professional and others.	Tracking the activity and wellbeing during day and night; information goes from user to caregiver, health professional and others.
Modules:	Activity /Acceleration Tracking module, Sleep Tracking module, Kinect Tracking module	Activity /Acceleration Tracking module, Sleep Tracking module, Kinect Tracking module
Devices:	▪ Withings Sleep sensor, ▪ Fitbit versa 2 smartband ▪ (Kinect Azure) ▪ Smartphone /Tablet	▪ Withings Sleep sensor, ▪ Fitbit versa 2 smartband ▪ (Kinect Azure) ▪ Smartphone /Tablet
Services (Main out of 7 Service Clusters: **):**	**SC1**: Active Sensorial Continuous Monitoring, Warning and Reporting. **SC2:** Social Services Matching **SC3**: Data analysis & Personalised Recommendations. **SC4**: Pathway Tracking **SC5**: Virtual Assistant.	**SC1**: Active Sensorial Continuous Monitoring, Warning and Reporting. **SC2:** Social Services Matching **SC3**: Data analysis & Personalised Recommendations. **SC4**: Pathway Tracking. **SC5**: Virtual Assistant.

	SC6: Communication. **SC7**: Quality of Life Assessment	**SC6**: Communication. **SC7**: Quality of Life Assessment
Outcomes System Requirement:	Primary & secondary: Activity during day and night; vital signs; quality of sleep and well beeing; fall detection	Primary & secondary: Activity during day and night; vital signs; quality of sleep and well beeing; fall detection

C. DAY CARE CENTRE Scenario

The day care scenario is proposed for 2 of the 5 institutions involved and includes 2 of the three diseases: AD and PD. In the day care centre, patient activity is similar to that of the home set, but taking into account that the patient's situation is more limited in terms of autonomy and activity due to more advanced degrees of the disease compared to some patients who are at home 24 hours a day. Moreover, some functionalities are not applicable in day-care centre due to the service provided already or due to the working hours (for example sleep monitoring, temperature tracking...).

Table 20. DAY CARE CENTRE Scenario.

DAY CARE CENTRE Scenario			
Disease	AD	CVD	PD
EPIC	**Primary:** User (Patient) **Secondary:** Caregivers (Family) Health Professionals, social worker, other professionals	**Primary:** User (Patient) **Secondary:** Caregivers (Family) Health Professionals, social worker, other professionals	**Primary:** User (Patient) **Secondary:** Caregivers (Family) Health Professionals, social worker, other professionals
Required functionalities	Tracking the activity at the centre, location within the centre and possible function if a person leaves the area; fall detection	Tracking the activity at the centre, Physical activity (steps and heart rate), location within the centre and possible function if a person leaves the area; fall detection	Tracking the activity at the centre, Physical activity (steps and heart rate), location within the centre and possible function if a person leaves the area; fall detection
Modules:	▪ Activity ▪ Localization module ▪ Door opened/closed module ▪ Notifications	▪ Activity ▪ Localization module ▪ Recommender ▪ Notifications	▪ Activity ▪ Localization module ▪ Recommender ▪ Notifications
Devices:	▪ Wristband ▪ Localization sensors ▪ Binary sensor for the door ▪ Smartphone/tablet	▪ Fitbit versa 2 smartband ▪ Wristband ▪ Localization sensors ▪ Real Sense ▪ Smartphones	▪ Fitbit versa 2 smartband ▪ Wristband ▪ Localization sensors ▪ Real Sense ▪ Smartphones

Services (Main out of 7 Service Clusters: **):**	**SC1**: Active Sensorial Continuous Monitoring, Warning and Reporting. **SC2:** Social Services Matching **SC3**: Data analysis & Personalised Recommendations. **SC4**: Pathway Tracking **SC5**: Virtual Assistant. **SC6**: Communication. **SC7**: Quality of Life Assessment	**SC1**: Active Sensorial Continuous Monitoring, Warning and Reporting. **SC2:** Social Services Matching **SC3**: Data analysis & Personalised Recommendations. **SC4**: Pathway Tracking. **SC5**: Virtual Assistant. **SC6**: Communication. **SC7**: Quality of Life Assessment	**SC1**: Active Sensorial Continuous Monitoring, Warning and Reporting. **SC2:** Social Services Matching **SC3**: Data analysis & Personalised Recommendations. **SC4**: Pathway Tracking. **SC5**: Virtual Assistant. **SC6**: Communication. **SC7**: Quality of Life Assessment
Outcomes System Requirement:	Monitoring of activities, safety and wellbeing	Activity Fall detection Vital signs	Activity Fall detection Vital signs

D. REHABILITATION ROOM Scenario

The rehabilitation room is proposed for 1 of the 5 institutions involved and includes PD. This scenario is the most specific as it incorporates functionalities aimed at detection during the rehabilitation session.

Table 21. REHABILITATION ROOM Scenario.

	REHABILITATION ROOM Scenario
Disease	PD
EPIC	**Primary:** User (Patient) **Secondary:** Caregivers (Family) Health Professionals, Social workers, Other professionals
Required functionalities	Physical activity (steps and heart rate) Fall detection Rehabilitation tool
Modules:	▪ Activity ▪ Rehabilitation ▪ Recommender ▪ Notifications
Devices:	▪ Fitbit versa 2 smartband ▪ Kinect 2 ▪ Smartphones ▪ Speaker
Services (Main out of 7 Service Clusters: **):**	**SC1**: Active Sensorial Continuous Monitoring, Warning and Reporting. **SC2:** Social Services Matching **SC3**: Data analysis & Personalised Recommendations.

	SC4: Pathway Tracking **SC5**: Virtual Assistant. **SC6**: Communication. **SC7**: Quality of Life Assessment
Outcomes System Requirement:	Activity Fall detection Vital signs Feedback for rhb

5 KPIs STATUS

Table 22. KPI Status

KPIs	**STATUS**
Co-design TeNDER content, producing more than 10 intervention programs.	**ACHIEVED**
Include over 3 different types of stakeholders and service users across the various co-design phases	**ACHIEVED**
Involve at least 20 end-users (elders, carers, doctors) during the TeNDER co-design process	**ACHIEVED**
100% coverage of end-user requirements through functional validation during TeNDER's test phases	**ACHIEVED**
Recommendations for information sharing, communication among different entities involved, based on the organisational and collaboration model selected for the pilots (>10).	ONGOING
Number of real-life experiments (at least 4)	**ACHIEVED**
Stakeholders from different backgrounds (doctors, caregivers, policy makers) will be involved through targeted events.	**ONGOING**[3]

The targeted events have been reported in D8.5 and D8.8 for M1-M18. M18-M42 will be reported in detail in D8.10 and D8.13, which will be submitted M42 given the granted extension.

6 CONCLUSIONS

This deliverable reflects the work done during the months of extension of the project. In which we have worked hard and in a coordinated way to reach the final results of the TeNDER architecture.

On the more technical side of the deliverable, this document shows the development of the final version of TeNDER. It shows the final service-oriented architecture (SOA), in which each element can work individually and interact with other modules such as services through interface layers. On the other hand, the development of the low-level subsystem and the high-level subsystem achieve the correct functioning of the TeNDER architecture.

As for the development of the scenarios, it can be seen how co-creation has given rise to concrete scenarios of everyday life in which each of the functionalities offered by the TeNDER system is adapted both to the scenario itself and to the needs of the patient and caregivers, taking into account the disease with which they live.

This deliverable also shows how progress has been made in the achievement of the KPIs.

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