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inCASA

Integrated Network for Completely Assisted Senior citizen's Autonomy

D3.1 System and Functional Specifications

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Executive summary

This document aims to analyze the user requirements both from a functional and non-functional point of view and provide the functional and system specifications for the inCASA platform. It is based on the outcome of WP2 and mainly on the D2.2 (“Requirements Consolidation and Prioritisation Iteration 1”) [1]. Moreover, in this document it is presented the inCASA basic architecture which will support the inCASA platform and its building blocks. For every building block, there is an analysis of functional and non-functional specifications.

The output of this document will be used to define the inCASA reference architecture (Task 3.2) that will take its final form after 3 iterations.

The document is for internal use and shall play the role of a mediator between user requirements and technical design and implementation.

1 Introduction

1.1 General Objectives

inCASA will create citizen-centric technologies and a services network to help and protect frail elderly people, prolonging the time they can live well in their own home.

This goal will be achieved by integrating solutions/services for health/environment monitoring to collect and analyze data in order to profile user habits. Furthermore, to this end customized intelligent multilevel alerts/communication services will be implemented.

Data will be made available to care services through a Smart Personal Platform with an embedded Habits Analysis Application which will include [2]:

- access policies to preserve privacy
- planning for day-by-day activities and therapies with multiple alerts
- co-ordination of local public Social and Health Care Services
- help to deploy specialist community based services.

In order to achieve these objectives, collection, exchange and processing of information are of general importance. In the special case of inCASA, the requirements from D2.2 must be taken into account, as they represent the pilots' needs.

1.2 Purpose of this deliverable

The work in D3.1 will be to analyze and evaluate the user requirements specifications from WP2 and unfold design principles for the inCASA infrastructure and software architecture. Additionally architectural requirements in the crossing point of architectural components, from technical and conceptual considerations need to be specified.
This work will lead to a proper architectural design specification (D3.2, D3.3, D3.4), outlining the communication links between the different modules in order to assure interoperability among them. The main objective is to develop a design specification of the system following the significant amount of requirement consolidation conducted by work package 2.

It is planned to have an iterative approach while building the inCASA architecture, which is described in Figure **1**.

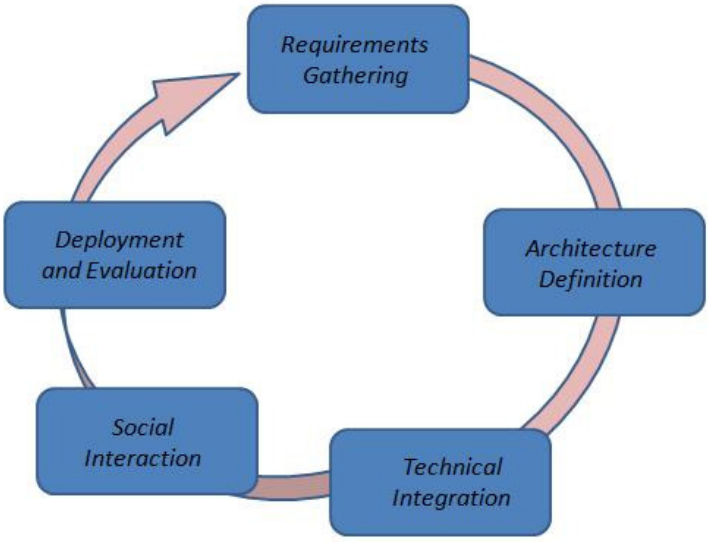


Figure 1: Work Strategy Phases

D2.2, which is the basis of this document, describes the first iteration of the “Requirements consolidation and prioritization”. D2.4 and D2.6 will describe the second and the third iterations of the “Requirements consolidation and prioritization”, which then will serve as basis for D3.2 to D3.4 “Reference Architecture” iteration 1 to 3, respectively.

1.3 Content of this deliverable

Chapter 1 : Introduction and presentation of document's content and scope
Chapter 1 gives an overview of the inCASA project and presents the role of this deliverable.

Chapter 2 : Requirements Analysis
In Chapter 2 we will perform a user requirements analysis from a technical point of view trying to find commonalities on them in order to compile generic functional and system specifications. The analysis will be mainly based on UML use cases and flowchart diagrams.

Chapter 3 : inCASA architecture building blocks
In this chapter, we are going to introduce inCASA platform core components and their relevant functional and non-functional requirements. These building blocks will support the specifications extracted in chapter 2.

Chapter 4 : Design principles
In chapter 4, some significant design approaches will be stated subject to the non-functional requirements of inCASA project.

Chapter 5 : Conclusion
In this final chapter, we will summarize the work conducted in this document and we will refer to the future work in the Architecture Design.

2 User Requirements Analysis

2.1 Platform Overview

The inCASA Platform will integrate pre-existing components to create an enhanced socio-medical platform able to monitor both user *behaviour* and *clinical conditions*. The inCASA primary objectives are to develop a system to support the aging population and facilitate them to stay longer and more healthily in their own home [2]. In more detail, the inCASA platform will:

1. Provide the means to profile the everyday behaviour of elderly people in their own home, through unobtrusive monitoring using motion and contact sensors, as part of a Smart Personal Platform with embedded Behaviour Analysis, to determine unusual behaviour and send alerts via a base station to selected actors
2. Provide elderly people (and patients with special needs) with the means to monitor their health conditions outside traditional healthcare environments, and more specifically while they are at home, by using state of the art personal health systems and integrated telemedicine services
3. Provide doctors and health professionals with more comprehensive monitoring data to understand the social, physical and/or psychological condition of the person and so allow early decision making for personalized care
4. Enable continuity of care through a wider interaction between elderly people or patients and caregivers, especially to include not just health specialists but also relatives or people who have close social relations with the user
5. Integrate home automation into the system to support remote control of electronic devices in the immediate surroundings and provide for the special needs of the elderly to make active ageing a reality.

The inCASA platform is essentially *service oriented*. The inCASA services will functionally address the following two main service domains [2]:

- *Telecare (TC):* A combination of equipment, monitoring and response that can help individuals to remain independent at home. It can include basic community alarm services able to respond in an emergency and provide regular contact by telephone as well as detectors which detect factors such as falls, fire or gas and trigger a warning to a response centre. Telecare can work in a preventative or monitoring mode, for example, through monitoring signs, which can provide early warning of deterioration, prompting a response from family or professionals. Telecare can also provide safety and security by protecting against bogus callers and burglary.
- *Telehealth (TH):* The delivery of health related services and information via telecommunication technologies. Telehealth is an expansion of the functionality of Telemedicine and encompasses prevention, treatment, cure and health promotion aspects. Telehealth is generally used as an umbrella term to describe all the possible variations of health care services using telecommunications.

2.2 Methodology and Initial Requirements

A requirements list was compiled using the input of the inCASA partners responsible for each national pilot, as a primary source of information (methodology section in D2.2 deliverable). The requirements list reflects on the primary objectives of the project and the domain of the services to be offered (TH/TC).

The scope of this section is the mapping of the user requirements that have been consolidated and prioritized (D2.2 deliverable) to system requirements, taking into account available components and software technologies.

The end-users needs were encoded into functional and non-functional requirements as it is dictated from the *Software Requirements Specification* (SRS) methodology [49]. The functional

requirements determine the overall characteristics of the inCASA software components and platform, while the non-functional requirements impose constraints on this mapping (such as performance engineering requirements, quality standards, or design constraints). Regarding the mapping rules:

- Each functional requirement can be *mapped* as one-to-many functionalities made available from the inCASA modules and building components.
- All non-functional requirements are essentially *constraints* that should be enforced while designing / implementing inCASA platform

Functional requirements (type func), consolidated from the respective table of the D2.2 deliverable and *horizontally* categorized in terms of TH/TC domains, are summarized in the following table:

Code	Type	Description	TH	TC
R02	Func	The system could send a reminder (sms or tablet alert) to the user to take measurement	X	
R03	Func	The system should allow professional users to set the usual timing of measurement/assessment (from hh:mm to hh:mm) and the number of measurements/assessments per day	X	X
R04	Func	The system should accept extemporary measurements provided by the user/patient	X	X
R05	Func	The system should allow measurement data visualization and extraction organized per day/per week/per month	X	X
R07	Func	The system should send an alert (On Screen Alert/SMS/e-mail) to the operator (Nurse/Clinician/Case Manager) if there is a consistent variation on the measurements or on the score of assessment, absolute or across time, or if an emergency event is revealed	X	X
R09	Func	The system should allow professional users to set rules: the number of measurements to compare; the range of normality and the limit of the variation (rough limit) to send the alert; the limit of the variation (if more than XX UOM across X continuous measurements/over XX days) to send the alert	X	X
R10	Func	The system could allow professional users to plan for single coded activities (e.g. medication change, appointment)	X	X
R11	Func	The system should be able to send SMS and e-mails. The system should allow professional users to customize the system to send a message to user/relatives/caregiver/neighbor if an event is revealed or an alert is triggered	X	X
R13	Func	The system should allow professional users to set the number of measurements to compare and the formula (e.g. average) to be applied to the selected measurements	X	X
R15	Func	The system should allow the professional users to introduce specific questions or questionnaires to be administered to the patient and assign value to each answer and then calculate scores	X	
R16	Func	The user's house should be provided by battery operated wireless sensors to detect movement of the user inside the house, recording time and duration of detected movement events		X
R17	Func	The system should allow professional users to evaluate changes from a "Normal Habits", by building a "normal habits" profile across 2 weeks of monitoring	X	X
R18	Func	The system should correlate movements to an algorithm made to evaluate NYHA class of everyday activities, by taking into account the movements, the number of people in the home as well as subjective input from the patient.	X	X
R21	Func	Data should be transmitted continuously to the inCASA platform or at least in 30" slots regularly or some times a day. This frequency should be customizable by the operator.	X	X

R24	Func	The user should be provided with a INR monitoring device or provided with a UI to insert manually measurements done with sticks	X	
R25	Func	The user should be provided with Bluetooth actigraphs recording movement at a frequency of one signal per minute	X	X
R27	Func	The system should allow the elderly user or the professional user to start a conference call	X	X
R31	Func	The system should provide a continuous monitoring of the technical emergency sensors, forwarding the emergency signal in seconds after the event is detected		X
R32	Func	Data should be transmitted to the inCASA platform with a customizable frequency.	X	X

Table 1 – Functional requirements categorized as TH or TC

Non-Functional requirements (type tech), consolidated from the respective table of the D2.2 deliverable and *horizontally* categorized in terms of TH/TC domains, are also summarized in the following table:

Code	Type	Description	TH	TC
R01	Tech	The user should be provided with a Bluetooth Weight Scale measuring in Kg	X	
R06	Tech	All data should be stored on the inCASA Repository through a permanent internet connection	X	X
R08	Tech	The user should be provided with a wireless pulse oximeter	X	
R12	Tech	The user should be provided with a Bluetooth blood pressure Monitor measuring in mmHg with pulse metering capabilities	X	
R14	Tech	The user should be provided with a Wireless Tablet connected to the inCASA platform	X	X
R19	Tech	The user's house should be provided by battery operated wireless sensors to detect presence of the user on the bed, recording time and duration of bed permanence events		X
R20	Tech	The user's house should be provided by battery operated wireless sensors to detect presence of the user on a chair, recording time and duration of chair permanence events		X
R22	Tech	Data should be stored on the standard cardiological repository of the KGHNI through integration with the inCASA platform	X	
R23	Tech	The user should be provided with a glucose monitoring device	X	
R26	Tech	The user should be provided with AV Conference platform to get in touch with the professional operators	X	X
R28	Tech	The user's house should be provided with wireless contact sensor to detect opening/closing of the front door		X
R29	Tech	The user's house should be provided with wireless humidity and temperature sensors to detect temp/moisture variations		X
R30	Tech	The user's house should be provided with wireless Gas-Water leak/CO-Smoke Presence sensors to detect emergency events		X
R33	Tech	The user should be provided with a wireless heart rhythm Monitor with at least 3 electrodes measuring rhythm with a basic EKG as output	X	

Table 2 – Non-Functional requirements categorized as TH or TC

Regarding the offered services orientation, the operative word is “tele” which translates into “remote”; therefore it can be argued that the services are organized around the end-user, who in the case of inCASA is the elderly patient situated in his/her home. Raw data is “produced” from the patient’s activity, clinical condition and home environment. The data is then “consumed” by the inCASA platform, possibly initiating interactions with other key actors of the platform.

Therefore, a first attempt at further categorization of functional requirements can focus on *vertical* activities related to the:

- Medical condition of the patient (TH)
- Psychological condition of the patient and self-assessment (TH)
- Patient's habits and activities (TC)
- Home comfort at the patient's house (TC)
- Technical emergencies that may occur in the patient's house (TC)

The vertical decomposition of activities promotes a more distinct categorization of functions and actions to be supported by inCASA services over the telehealth/telecare horizontal domains. This decomposition will facilitate the realization and the integration of *added-value services* at a later stage within the inCASA platform . It also facilitates the *abstraction over activity patterns and user interactions* with the platform, by consolidating common functional requirements per activity. Furthermore, it allows the specific sensor, network and other non-functional requirements to be directly applied on available platform components, hardware and inCASA architecture.

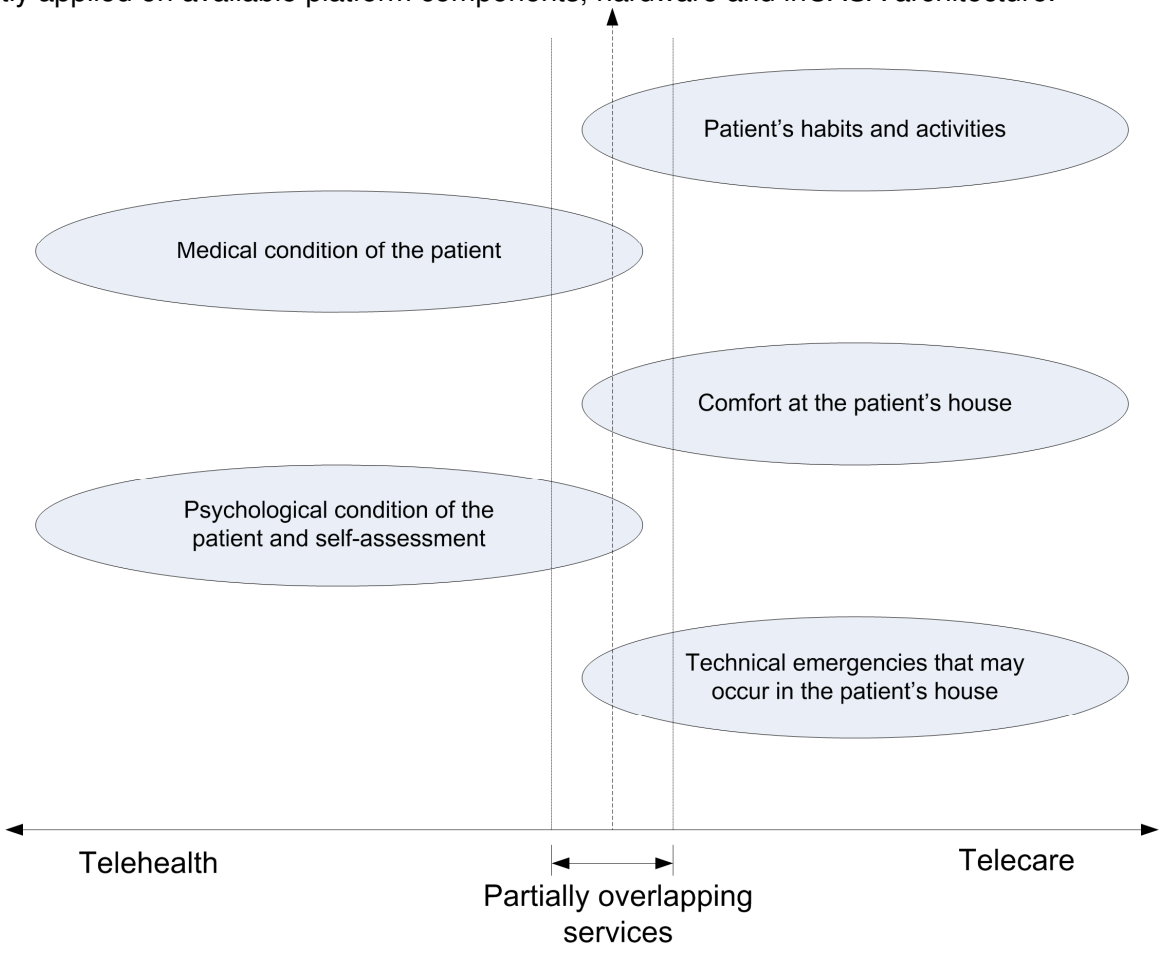


Figure 2: Activities organization per domain (TH/TC) and realized space for the development of added-value inCASA services

The following section will consolidate functional requirements at the described high-level activities and will develop

1. Use case diagrams,
2. Workflows specific to each use case,
3. A compilation of system requirements as a direct result of workflows.

The following analysis will be on the most part pilot agnostic, since one of the primary objectives of the inCASA project is the development of a generalized platform that can be customized to the end-users' needs.

2.3 Telehealth Requirements

Telehealth has already been identified as a domain that encloses telemedicine by encompassing additional key prevention, treatment, cure and health promotion aspects. Towards that end, additional use cases were identified in the functional requirements list that will complement the telemedicine cases. The following use cases will be also addressed while designing and implementing the inCASA platform:

1. *Assessments* as the overall process for identifying and recording the health and social care risks and needs of elderly patients and evaluating their impact on their daily living and quality of life, so that appropriate actions can be planned.
2. *Alerts*, generated if there is a consistent variation, absolute or across time, on the patients measurements or on their assessments, or if an emergency is revealed. Alerts are used to notify the medical personnel in order to decide on appropriate prevention actions or adjust treatment.
3. *Single-coded activities* planning by professional users, such as medication change or setting appointments, while in the same time offering the ability to notify accordingly elderly patients and/or other key persons in close contact to them (i.e. relatives, caregivers).
4. *Reminders* to the elderly patients that didn't take scheduled measurements or didn't timely take their prescribed medicines. They will be rendered in the most appropriate form/presentation to the respective end-users.-

In particular *self-assessment*, apart from the assessment of individual patients' health condition, can be seen as an integral process towards meeting the telehealth objective, since

- it complements the clinical view on individual patients, allowing doctors to draw a picture over their daily living, quality of life under treatment and psychological condition, especially when they face chronic conditions,
- it allows doctors to determine if individual patients are dissatisfied with or face problems regarding their treatment and decide on appropriate adjustments, optionally complemented with the offering of further support by social workers or psychologists.

Regarding the telemedicine requirements to be met by the inCASA services, these specify measurements use cases, which are further consolidated and detailed on the pilot scenarios' level, as described in the D2.1 Preliminary requirements investigation [3]:

- body weight
- blood pressure, oxygen saturation level and glucose
- partial prothrombin time
- heart rate and rhythm (the latter via electrocardiograms)
- actigraphy

These measurements contribute to the building of what can generally be referred to as the *clinical view* on the elderly patients' condition. The *self-assessments* procedure extends clinical measurements and produces valuable data that may be used to complement the individualized clinical view on the patients. The processing of clinical data and self-assessment data may lead to raising *alerts* regarding the condition of elderly patients. From this viewpoint, the clinical measurements data can be further categorized in terms of non-*historical* and *historical substance*, depending on whether each measured value is assessed as a standalone measurement or compared to previously recorded values in the platform. The measurements process is further augmented by *reminders* that may be forwarded to the remotely located patients. Finally, *single-coded activities* facilitates doctors to set appointments or inform patients to change their medication.

The above high level description of consolidated use cases pertinent to the Telehealth orientation of the inCASA services, is summarized and visualized in the UML case diagram in Figure 3: UML use cases overview diagram related to the Telehealth orientation of the inCASA services.

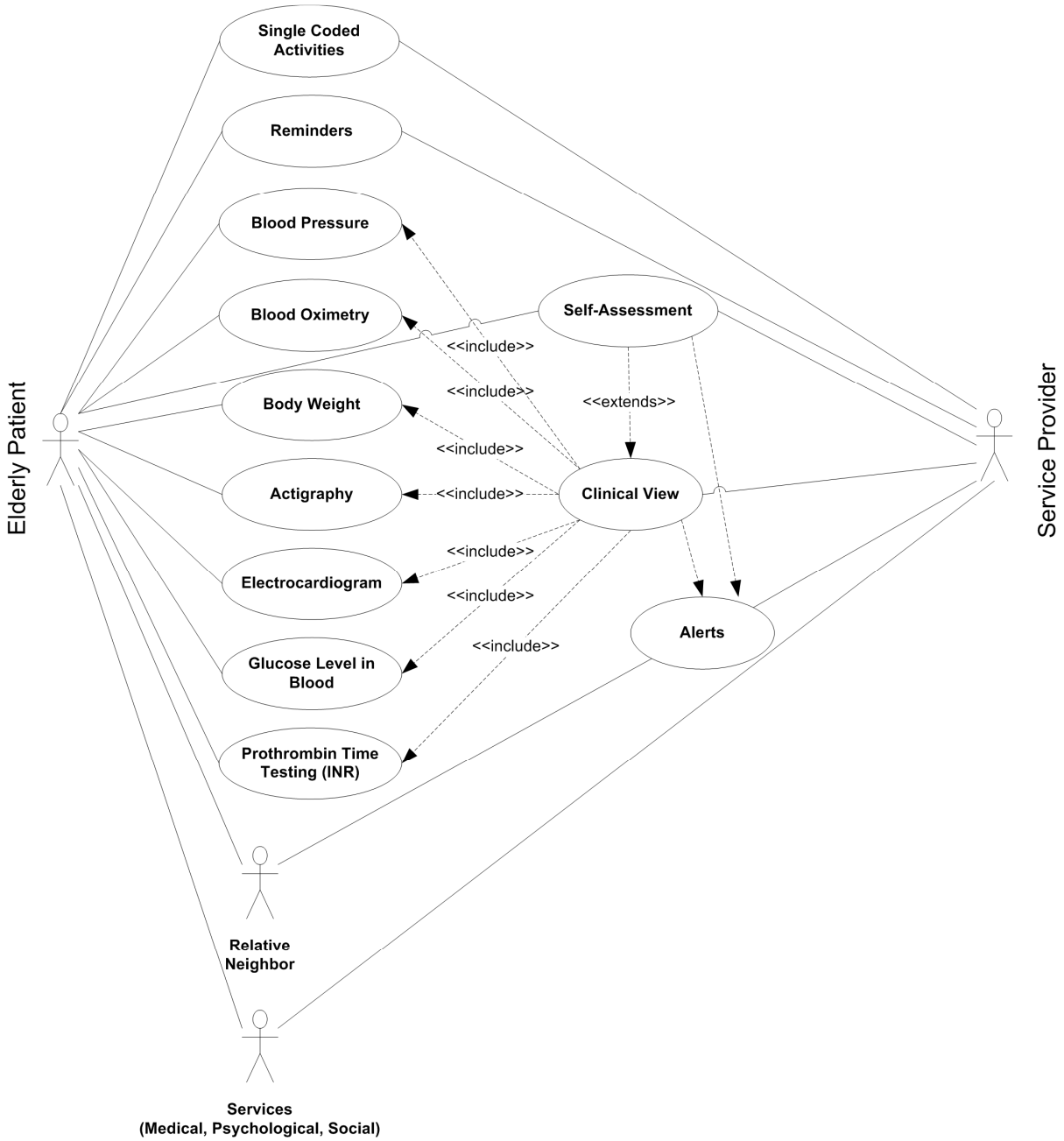


Figure 3: UML use cases overview diagram related to the Telehealth orientation of the inCASA services.

2.3.1 **Medical condition**

The current section breaks down the Medical condition of the patient (TH) activity on the following use cases:

- **UC-TH-1** Clinical Measurement
- **UC-TH-2** Clinical View
- **UC-TH-3** Alerts
- **UC-TH-4** Reminders
- **UC-TH-5** Single-coded Activities

The following synergies will be realized in the inCASA platform: 1) Clinical measurements remotely conducted produce data that updates the patient's clinical view. 2) Internalized to the platform data is used to trigger alerts in accordance to customizable rules, forwarded to the medical personnel. 3) Reminders are sent to patients that didn't timely take measurements or their prescribed medicines. 4) Single-coded activities can be initiated by the doctors as a result of variances in the patients' condition.

The pilot scenarios, overviewed in deliverable D2.1 Preliminary requirements investigation, demand the incorporation of a multitude of clinical measurements. These scenarios are indicative of the versatility that the inCASA platform shall offer in terms of remote monitoring capabilities. From analyzing the requirements derived in deliverable D2.2 Requirements Consolidation and Prioritization Iteration 1, it is clear that a generalized enough methodology for clinical measurements should be devised, that can accommodate for the following factors:

- Whether the measuring device is wearable and able to take measurements automatically.
- Whether it can be interfaced/connected (i.e. wirelessly) to a "measurements hub" or not.
- Whether it can produce reliable measurements in all circumstances or should be checked, against pre-set validity ranges.
- Whether it produces multiple measurements that subsequently need filtering.
- Whether it would be advantageous to offer the option of local storage (largely depends on the selected measurement application).

These aspects of the measurement process will be integrated into the inCASA platform design; the mapping of the pilots' clinical measurements to the respective inCASA provision is summarized in the following table.

Measurement device for	Automated[1]	Connected[1]	Check Validity[2]	Filtering[2]	Local storage[2]
Body weight		X			X
Blood oximetry		X	X		
Blood pressure		X	X	X	
Heart rate		X			
Heart rhythm (via EKG)	X	X			
Glucose level in blood		X			
Prothrombin time testing (INR)			X		
Actigraphy	X	X			

[1] *Related to non-functional requirements;* [2] *Related to functional requirements*

Table 3 – Mapping of the pilots' clinical measurements to the respective inCASA provisions

The clinical measurements procedure developed, is detailed in Table 4 as a series of simple steps. The condition for the initialization of the measurement use case UC-TH-1 is that the scheduler of the platform's respective module signals the initiation of the process. The precondition for conducting the measurements is that the medical device is accessible to the patient and connected to the platform, at the scheduled time of measurement. The result is a successful clinical measurement producing result data registered in the inCASA platform.

The flowchart for the above scenario is depicted in **Figure 4**:

Name	UC-TH-1: Clinical Measurement
Summary	Procedure to conduct clinical measurements and register measurements data with the platform.
Rationale	Clinical measurements are a main source of data tracked by the platform, used to assess the patients' condition and initialize subsequent actions, as a result of further processing (visualization, generation of alarms, etc.)
Users	Elderly Patient
Preconditions	The medical device is accessible to the patient and connected to the platform, at the scheduled time of measurement
Basic Course of Events	1. The scheduler of the platform's measurements module signals the initiation of the measurement process to be conducted by the patient (R3). 2. The patient is audio visually prompted by the platform to access/use the measurements device (R2, R3). The user signals that he is ready to commence with measurement using a specially developed interface for that purpose. 3. Visual cues are provided to the patient to guide him/her through the measurement process: a. Steps for fitting the device. b. Steps for device initialization. c. Steps for taking a single or multiple measurements. 4. Measurement raw data or value is automatically inputted to the platform by means of an established (wireless) data link with the platform (i.e. R1, R8, R33). 5. Measurements are checked for validity in accordance to predefined rules set or using a filtering process for each type of measurement (R13). 6. Measured raw data or value is submitted to the system using a standard clinical format, along with any available/required contextual data (i.e. time or duration of measurement) (R6). 7. Data is stored at the platform repository (R6). 8. Further processing of data (R5, R7).
Alternative Paths	1. In Step 1, if the patient has not taken a previously scheduled measurement or an extemporary measurement is required, the platform periodically forwards him/her reminders - at fixed time intervals (R2, R4). 2. Steps 2 and 3 are optional, if the device is wearable and automated (no cues need to be forwarded by the platform and no special actions taken by the patient) (R33). 3. In Step 4, if the measurements device is not directly connected to the platform, the user is prompted to manually enter the measurement values using a specially developed user interface for that purpose (R24). 4. Step 5 is optional, if not multiple measurements are required/taken. 5. In addition to Step 7, a copy of the measurements is maintained at a local repository, if that is required by the measurement protocol (R6).
Expected result	Scheduled clinical measurement is conducted successfully and result data has been registered with the platform.

Table 4 – Breakdown of clinical measurements procedure to simple steps

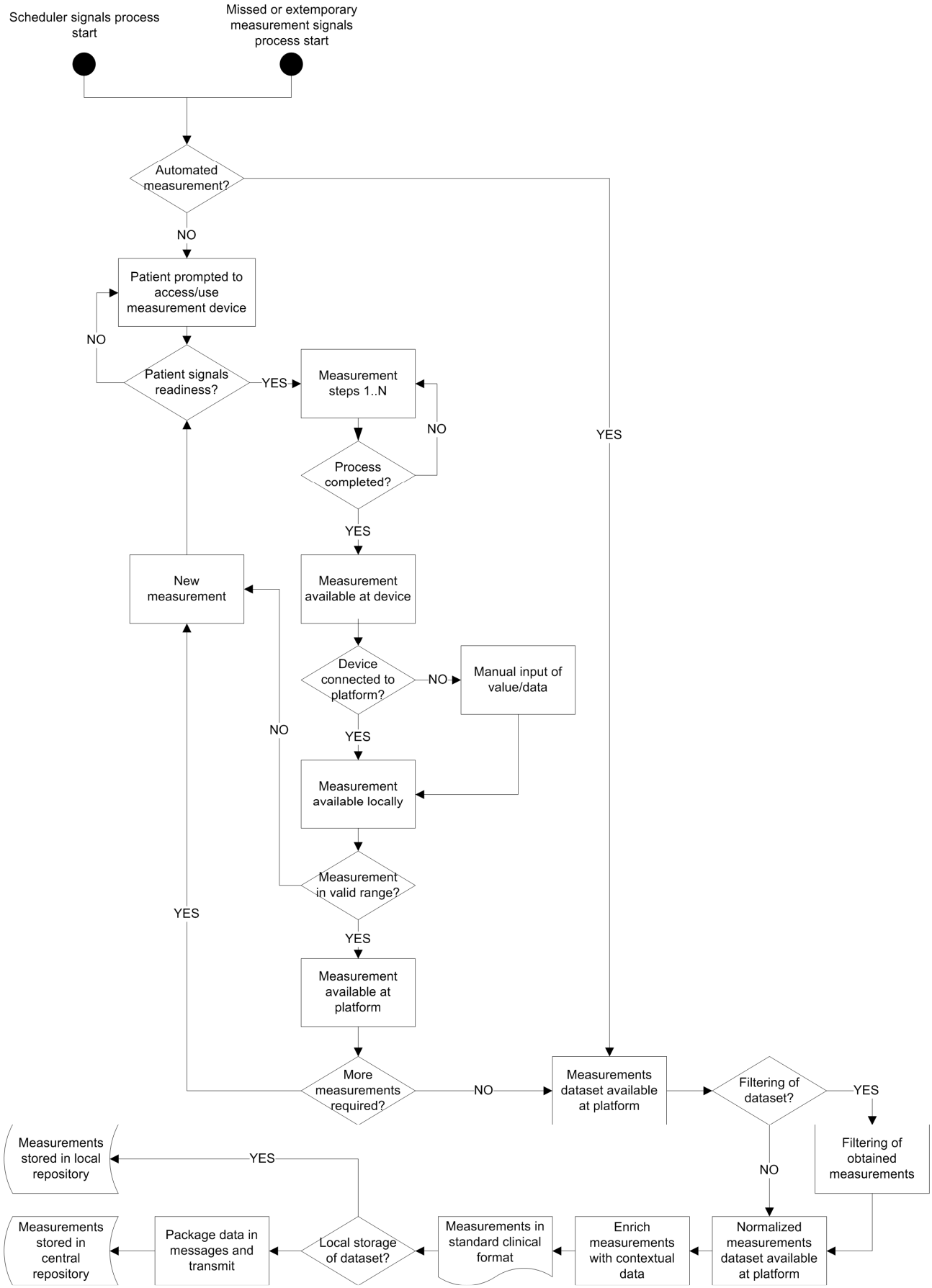


Figure 4: Flowchart of clinical measurements use case (UC-TH-1).

Each clinical variable measured and stored in the platform for the respective patient has predominately the following two valuable properties, in terms of establishing views on the data that is used to assess the clinical condition of the patient:

1. Time point obtained that enables a *snapshot* view in time (i.e. for all monitored variables).
2. Variations between two or more time points that could be used to compose a *trends* view (i.e. for a single variable).

A commanding factor for rendering both views in the appropriate timescale is the pre-set frequency of individual measurements. This piece of information will be used to customize their respective *visualizations* to end-users (i.e. medical personnel). These views will also be complemented by displays of the relevant *alerts*, as described in the following paragraphs.

The inCASA platform will also employ parameterized post-processing algorithms for deriving trends on measured clinical values with *historical substance*. The above aspect of the various measurements' type can be determined from the specific functional requirements pertinent to the array of clinical measurements to be conducted within each pilot, and is summarized in the following table:

Measurement type	Snapshot View[1]	Trends View[2]
Body weight	X	X
Blood oximetry	X	X
Blood pressure	X	
Heart rate	X	
Heart rhythm (via EKG)	X	
Glucose level in blood	X	
Prothrombin time testing (INR)	X	
Actigraphy	X	X

[1] *functional requirements* R3(frequency), R5(visualization); [2] *functional requirements* R5(analysis)

Table 5 – Mapping of clinical measurements' type to snapshot and trends view

After analyzing the measurements' procedure, as described in the deliverable D2.2 Requirements Consolidation and Prioritization Iteration 1, it is easy to break-down the processing for establishing a trend into two distinct phases. That is selecting measurements for subsequent processing from the dataset, by applying an appropriate selection query over the data of a central repository, and processing result data, using the most relevant to the tracked clinical variable algorithms to derive a single or multiple trends.

Regarding the selection of measurements, the following two operators are used:

- *Time/sampling window*: numbers of samples (processing window width), sub-sampling over days or consequent measurements in time are used for the processing.
- *Filtering*: Select measurements taken over subsequent days at approximately the same time or some measurements are outright excluded (i.e. the first measurement in a measurements' dataset).

The generalized modes of processing are also classified as following:

- *Differences over time for select measurements*: evaluated on the tracked levels of change over a given time period.
- *Absolute differences between measurements*: to determine an increasing or decreasing trend of a tracked clinical variable.
- *Averaging of select measurements*: to determine a median trend of measurements.

The procedure for determining the snapshot and trends view on clinical measurements is detailed in the following table as a series of simple steps, while a flowchart for the clinical view update scenario is depicted in **Figure 5.**

Name	**UC-TH-2: Clinical view**
Summary	Methodology of clinical measurements post-processing and visualization, to enable medical practitioners to have a more informed view on the clinical condition of individual elderly patients along with the establishment of trends over the monitoring period for selected clinical measurements.
Rationale	Enabling views and establishing trends over the monitored clinical variables is a considerable assistance to medical practitioners and a core concept in the Telehealth objective specified for the platform.
Users	Medical practitioners (doctors, nurses etc.)
Preconditions	The existence of enough clinical data stored in the central repository, to enable a spherical view over an individual patient's medical condition, and to enable the building of trends over measured data.
Basic Course of Events	1. The measurements module of the platform' signals that new clinical measurement(s) is(are) available for a particular patient (R5). Subsequently the measurement is retrieved from the measurements module to the processing module. 2. The measurement is registered with the platforms' central repository to update the snapshots in time view of the relevant clinical variable, in accordance to type/date/time of measurement (R3, R6). When the update is completed, the processing, visualization and alerts reasoning modules of the platform are signalled (R5, R7). 3. If a trend should be updated for the measured clinical variable (R5), subsequent processing is scheduled to take place when the platform signals that the relevant snapshot view update has been completed. 4. An appropriate selection query to be applied over the snapshot view is built, using pre-defined contextual data regarding the time/sampling window used and optionally any additional filtering of measurements (R3, R5, R6). 5. The central repository is queried and result dataset is retrieved to the measurements module. 6. An appropriate processing algorithm is applied on filtered dataset, selected based on pre-defined contextual data stored in the platform for each clinical measurement type. 7. Result data is used to update the trends view on the clinical variable processed for the particular patient. The centralized platform repository is updated and the visualization and alerts reasoning module is signalled (R5, R6, R7). 8. The visualization module of the platform updates rendering of the snapshot (and optionally trend) view of the respective clinical variable, in a compatible way to the pre-set measurements frequency (R3, R4), while also displaying events (alerts) that may have also been identified by alerts reasoning module (R7).
Alternative Paths	1. Steps 3 to 7 are optional, if no trends should be derived for the measured clinical variable
Expected result	Views on the new clinical measurement are updated along with the respective renderings. The platform's reasoning module is notified accordingly.

Table 6 – Breakdown of clinical view use case to simple steps

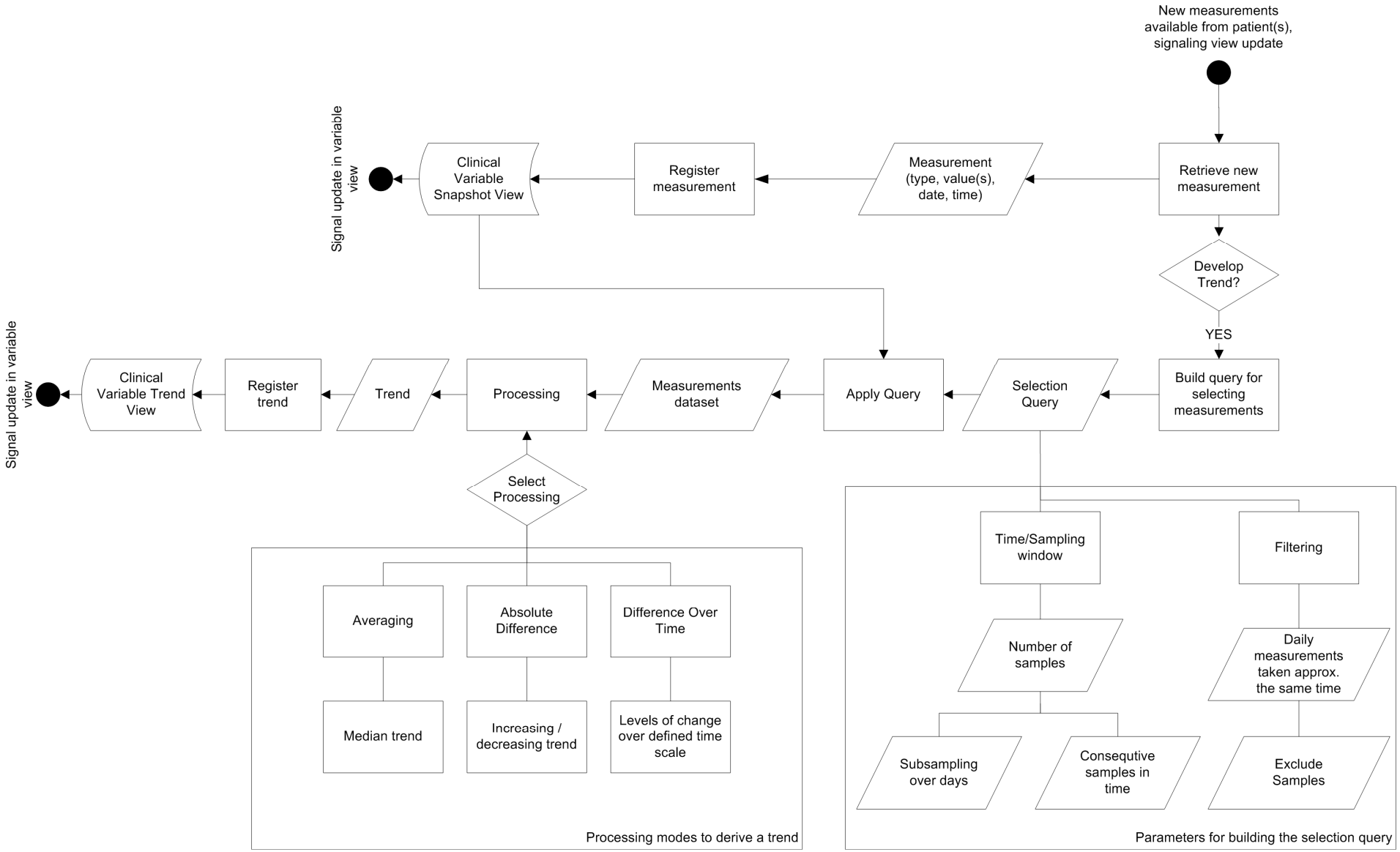


Figure 5: Flowchart of clinical view update procedure (UC-TH-2).

Each clinical variable tracked for the respective patients produces a number of consequent measurements that are stored as snapshots (in time) in a centralized repository and, where applicable, a trend is also established on the previously taken measurements. These measurements' values and their respective trends are used for the evaluation of customized rules to each variable, and if there is indication that the health of a particular patient is worsening, alarms are raised. After analyzing the formulations of these rules, as stated in deliverable D2.2 Requirements Consolidation and Prioritization Iteration 1, it is easy to categorize them in respect to their domain of application (on snapshot values or on trends). Regarding the evaluation of alarms on established trends, two distinct rules are established:

- *Consistent increasing or decreasing*: When a measured clinical variable is increasing or decreasing over a given number of measurements or time period.
- *Unexpected levels of change over defined time scale*: When a measured clinical variable increases or decreases more than a pre-set amount over a given period of time.

For the evaluation of alarms on measurements snapshots, three rules are also applied:

- *Away from optimal or expected values*: When clinical measurements significantly deviate from target values that are considered optimal or from values that were expected as a result of a prescribed treatment.
- *Outside normal limits*: When clinical measurements surpass an upper limit considered as normal or become lower that a given safety value, indicating deteriorating health condition of the patient or that changes should be introduced in his/her treatment.
- *Does not return to normalcy within a set time*: When clinical measurements indicate a health emergency event that does not recede in a pre-defined (short) time.

The alarm rules may be evaluated against *pre-defined or personalized thresholds*, with the latter being a result of pre-existing health conditions of a patient or automatically calculated across a given monitoring period. Some clinical measurements may command, as a result of the above set rules evaluation, *alarms of escalating criticality*, determined on the respective deviation from established target values or value ranges indicating "normalcy". The above analysis is summarized and the respective clinical measurements to be tracked within the inCASA pilots are categorized in Table 7, while Table 8 details the steps taken for raising an alarm. The flowchart for the scenario pertinent to the alarms use case is depicted in **Figure 6**.

Alerts for	Consistent increasing OR decreasing[1]	Unexpected levels of change over defined time scale[1]	Away from optimal OR expected values[2]	Outside normal limits[2]	Does not return to normalcy within a set time[2]	Escalating alarm criticality	Personalized threshold (due to a pre-existing condition OR automatically derived)	Threshold automatically calculated across a given monitoring period
Body weight	X	X	X					
Blood oximetry		X	X					
Blood pressure			X	X				
Heart rate				X				
Heart rhythm					X		X	
Glucose level in blood				X				
Prothrombin time testing (INR)				X		X	X	
Actigraphy	X						X	X

[1] *Related to trends view;* [2] *Related to snapshots view*

Table 7 – Mapping of clinical measurements to alarms conditions

Name	UC-TH-3: Alerts
Summary	Procedure to raise alerts when the medical condition of a patient deteriorates
Rationale	Alerts are automatically generated using a predefined set of multi parameter and customizable rules to enable the timely response of medical personnel to possibly dangerous or deteriorating patients' condition
Users	Medical personnel, Relatives, Neighbours
Preconditions	There is medical data stored in the central repository to enable a spherical view over an individual patients' medical condition and the pertinent trends have been computed.
Basic Course of Events	1. The processing module of the platform signals that new clinical measurement(s) have been registered with the system and that the respective trends have been updated for a particular patient (R5, R6). 2. If an alarm rule should be evaluated against established trends (R7), subsequent processing is scheduled to take place (possibly exploiting data parallelism techniques). 3. Subsequently the latest snapshot value(s) of the measurement is retrieved from the centrally stored snapshots view. 4. The pre-set, personalized or automatically computed (during a "training" or calibration period) thresholds and "normal" limits for the respective clinical value are retrieved from the platform (R7). 5. A set of rules is evaluated for the respective medical variable in order to determine if the measured value is within prescribed limits or deviates significantly from optimal (target) / expected values (R7). 6. The rules evaluation result determines whether the corresponding alarm should be generated or not (R7). 7. If an alarm (or more) is generated, then it is classified depending on its criticality. Alarms with lower critically generate signals to the visualization module to compose them in the respective clinical variable renderings (R5). Alarms with higher criticality signal the messaging module to send (SMS) alerts to doctor or even the patient's relatives/neighbours (R5, R11).
Alternative Paths	1. If rules are to be evaluated against the measured clinical variable established trends, this is done in parallel to steps 3 to 6. 2. Analytically, the pre-set thresholds for the respective trend (determined by its metadata) are retrieved from the platform (R7). 3. A set of rules is evaluated for the respective trend in order to determine if the trend is consistent and/or large changes in the measured values are detected over a pre-set time window (R7). 4. The rules evaluation result determines whether the corresponding alarm should be generated or not (R7). 5. If an alarm (or more) is generated, then it is added to the alarm list already generated by the latest measurement snapshot.
Expected result	Signal to update the composite rendering of alerts on the clinical measurements view. The platform's messaging module has been notified to dispatch alarm messages (SMS or other) to doctors and/or relatives.

Table 8 – Breakdown of alerts use case to simple steps

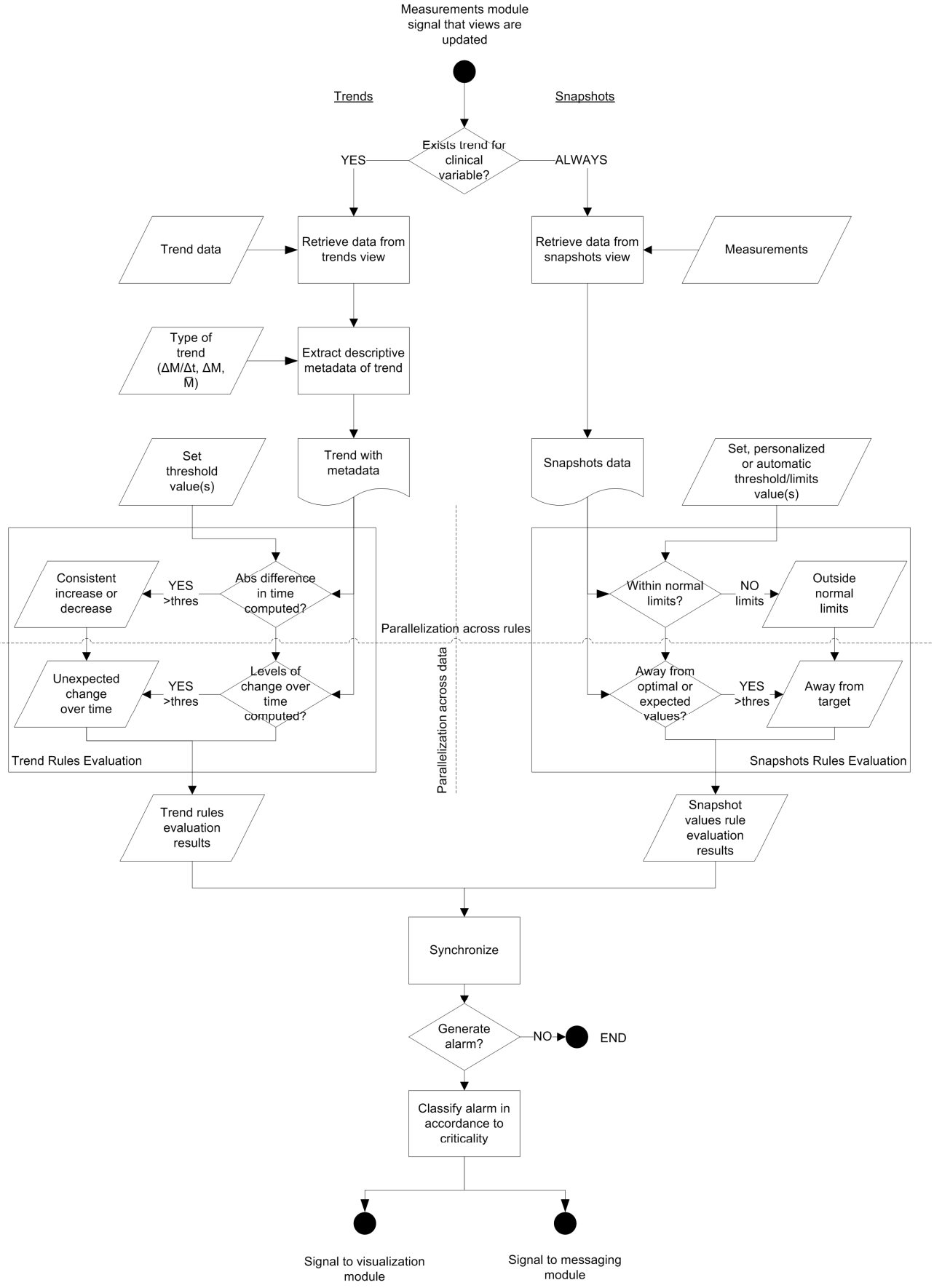


Figure 6: Flowchart of alerts use case procedure (UC-TH-3)

Reminders were previously analyzed as a mechanism to notify the elderly patients that didn't take scheduled measurements or didn't timely take their prescribed medicines. After analyzing the pertinent functional requirements, as stated in the deliverable D2.2 Requirements Consolidation and Prioritization Iteration 1, it is easy to categorize the applicable reminders in the following two broad categories:

- Reminders to the elderly patient, to take a measurement he/her missed.
- Requests to the elderly patient to take an extemporary measurement in a day, as requested by the doctors.

The mapping was based on the specific statements included in the functional requirements R2 and R4. The assignment of specific measurements in the individual pilots is summarized in Table 9.

Reminders for missed or extemporary measurements	Reminder to the user, as a SMS or tablet alert, to take measurement[1]	Request patient to take an extemporary measurement in a day[2]
Body weight	X	X
Blood oximetry		X
Blood pressure	X	X
Heart rate	[3]X	[3]X
Heart rhythm (via EKG)	[4]NA	[4]NA
Glucose level in blood		
Prothrombin time testing (INR)		
Actigraphy	[4]NA	[4]NA

[1] *Related to* (R02); [2] *Related to* (R04)*;* [3] *Same procedure with blood pressure;* [4] *Automatic measurements*

Table 9 – Mapping of clinical measurements to reminders

As it was expected, the functional requirements didn't specify reminders for automatic measurements such as actigraphy or electrocardiograms. In other cases, they were not specified explicitly for all types of clinical measurements to be conducted by the same measuring device (i.e. the case of blood pressure and heart rate measurements).

No reminders were specified for the glucose level in blood measurement and INR testing. Nevertheless, the reminders mechanism is an integral feature of the inCASA platform, and as such it will be implemented in the most generic way possible, allowing the accommodation of any other type of clinical measurement deemed necessary in the future.

The compiled requirements list did not outline any scenarios, specific to the inCASA pilots, under which the patients will be notified to take their prescribed medicine. Nevertheless this is a core functionality to be included in the inCASA implementation, since it aims to offer tools that will enhance the compliance of patients to their prescribed treatment with medicines.

The reminders use case UC-TH-4 is detailed in Table 10 as a series of simple steps. The precondition for the generation of reminders is that a scheduled measurement is detected by the platform measurements module as pending or that a member of the medical personnel (doctor) requires an additional measurement to verify the trend of specific measurements already taken. A second precondition is when the patient didn't follow his/her prescribed treatment with medications, a fact that can be verified by the use of specialized sensors attached to the medicines packages, or inferred by the doctors by observing the trends of the relative health condition indicators. The expected result of the reminders is that the patient will conduct the requested measurement or that the patient will take the medicine respectively. The above scenario is depicted in the flowchart of **Figure 7**.

Name	UC-TH-4: Reminders
Summary	Procedure to send reminders to patients that did not timely take a measurement or when an extra measurement is deemed as necessary by their doctor; also a procedure to remind patients to timely take their prescribed medication.
Rationale	The main benefit of reminders is the expected improvement in compliance of the patients to their medical treatment, both in terms of remotely conducting the necessary clinical measurements and of timely taking their prescribed medication.
Users	Medical personnel, Elderly Patient, Caregiver, Patient Relatives
Preconditions	A precondition is that a scheduled measurement is detected by the platform measurements module as pending or that a member of the medical personnel (doctor) requires an additional measurement to verify an established clinical trend. A second precondition is when the patient did not follow his/her prescribed treatment with medications, a fact that can be verified by the use of specialized sensors attached to the packages of medicines (or inferred by the doctors by observing the trends of the relative health condition indicators).
Basic Course of Events	1. Platform detects that the patient did not take a scheduled measurement or did not receive his/her medication in time (R2). 2. The pending action contextual information is retrieved by the system (R6). 3. Contextual information is used by the system to automatically compile a pending action reminder, including information for additional recipients (i.e. relatives, caregivers) apart from the patient (R2, R3). 4. Compiled reminder for action (measurement or medication) is registered with the system scheduler and is forwarded to the messaging module of the platform (R3). 5. Messaging module decides on the most appropriate form of communicating the reminder to the elderly patient and other recipients (R2). 6. The corresponding alert is forwarded to the patient's device of choice for interfacing to the platform (i.e. tablet), and optionally a SMS message is prepared and send to his/her caregiver or relatives (R2, R14).
Alternative Paths	1. Alternative to Steps 1 to 2, in the case that the doctor requests an extemporary measurement, the following steps are followed (R4). 2. Doctor accesses the management screen of the patient (from the user view screen) (R5). 3. The user management screen is updated by the visualization module of the platform with measurements' schedule information (R3, R5). 4. The doctor selects an available time slot (within the same day) to schedule the extemporary measurement (R3).
Expected result	The expected result of the reminders is that the patient will conduct the requested measurement or that the patient takes the medicine respectively

Table 10 – Breakdown of the reminders use case to simple steps

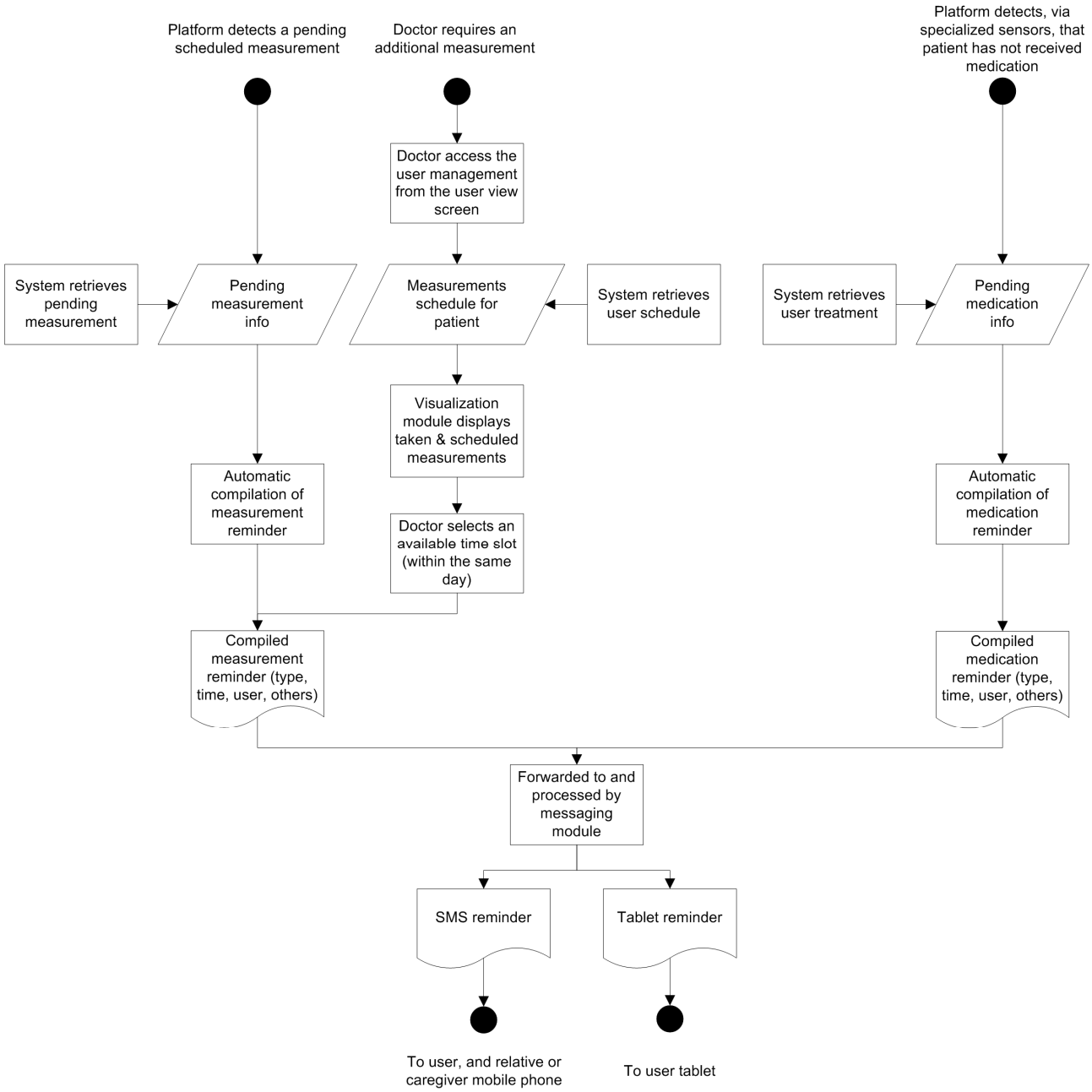


Figure 7: Flowchart of reminders use case (UC-TH-4)

Single-coded activities have been previously defined as an inCASA platform function that facilitates the doctors to plan appointments with or change medication of their patients; appropriate mechanisms will be put in place to notify them and/or other key persons in close contact to them (i.e. relatives, caregivers) about these actions. After analyzing the pertinent functional requirements, as stated in the deliverable D2.2 Requirements Consolidation and Prioritization Iteration 1, the single-coded activities specific functionality can be summarized to:

- Confirmation of changes of medication shown on display and send via SMS to relatives
- Call for visits to the outpatient clinic can be confirmed by SMS to the patient and relatives

This mapping was based on the specific statements of the functional requirement R10, while the SMS facility in place was specified in requirement R11 that is related to the notification of the patient's neighbours, relatives or caregivers in a case of emergency. Although the single-coded activities functionality was described in the deliverable D2.2 only in relation to the blood oximetry monitoring, this facility will be implemented in the inCASA platform in a generic way.

The single-coded activities use case UC-TH-5 is detailed in Table 11 as a series of simple steps. This use case is engaged when a doctor determines, after assessing the condition of a particular patient, that changes in his/her prescribed medication is in order or that he/she should be examined in person. . The expected result of the reminders is that the elderly patient will be provided with the required medication and follow the modified treatment or he/she will visit the doctor at the outpatient clinic in order to be examined. The above scenario is depicted in the flowchart of **Figure 8**.

Name	UC-TH-5: Single-coded Activities
Summary	Procedure to notify patients and the people close to them of changes in their medication and on scheduled appointments with their doctors.
Rationale	One of the main expected benefits of the inCASA platform is in the domain of prevention and of the reduction of the number of the patient's visits to the hospital. Nevertheless, when it is required the doctor should have the ability to schedule appointments with his/her patients in the out clinic or simply notify them of changes in their medication.
Users	Medical personnel, Relatives, Elderly Patient
Preconditions	The precondition for the registration of single-coded activities by the doctor in the inCASA platform is that after assessing the general condition of a particular patient, he/she determines that changes in the patient's prescribed medication are in order or that the patient should be examined in person.
Basic Course of Events	1. The doctor requests a change to medication or wants to schedule the clinical examination of a patient (R10). 2. Doctor accesses the management screen of the patient (from the user view screen) (R5). 3. The system retrieves the previous patient's appointments and already scheduled appointments OR the patient's medical treatment (prescribed medication) respectively, from the platform's repository (R6). 4. The doctor selects an available timeslot to schedule the appointment OR modifies the prescribed treatment (R10) 5. The doctor may input additional contextual information (i.e. purpose of scheduled appointment). 6. Compiled notice for single-coded activity (appointment or medication change) is registered with the system and is forwarded to the messaging module of the platform (R6, R10). 7. Messaging module decides on the most appropriate form of communicating the notice to the elderly patient and other recipients (R10). 8. The corresponding notice is forwarded to the patient's device of choice for interfacing to the platform (i.e. tablet), and optionally a SMS message is prepared and send to his/her caregiver or relatives (R10, R11, R14).
Alternative Paths	None
Expected result	The expected result of the reminders is that the elderly patient will follow the modified treatment or he/she will visit the doctor at the outpatient clinic in order to be examined.

Table 11 – Breakdown of single-coded activities use case to simple steps

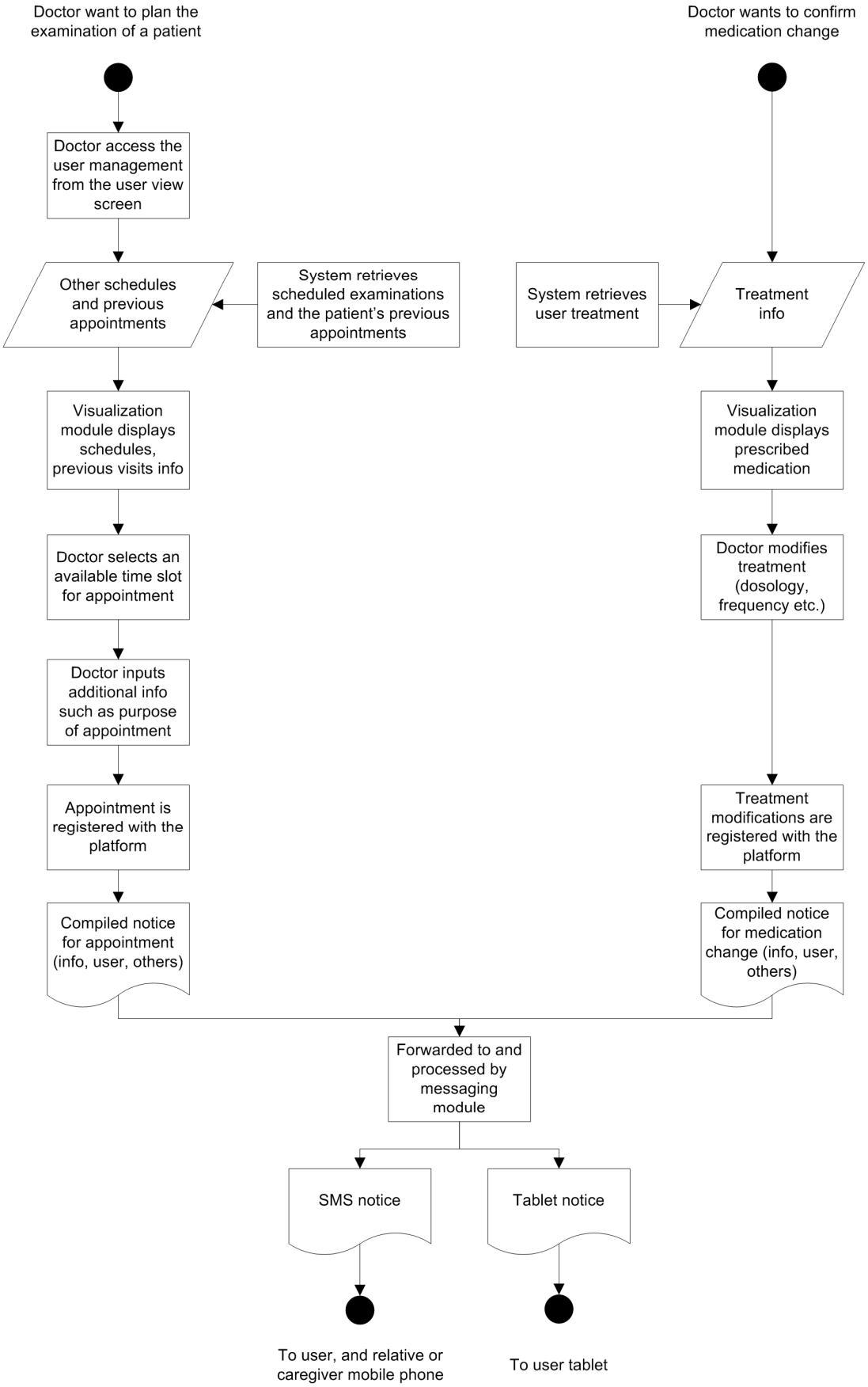


Figure 8: Flowchart of single-coded activities use case (UC-TH-5)

Mapping of clinical measurements to D2.2 functional requirements

Measured Clinical Variable*	Reminders (R02)	Custom freq. of measurements (R3, R4)	Measurements analysis and visualization (R05)	Alerts to medical staff (R07)	Custom alerts threshold (R09)	Plan single coded activities (R10)	Send SMS to patient / relatives (R11)	Custom measurements filtering (R13)
Body weight	X	X	X	X	X			
Blood oximetry		X	X	X	X	X	X	
Blood pressure	X	X	X	X	X			X
Heart rate, rythm (EKG)				X	X			
Glucose level in blood		X		X	X			
INR (prothrombin time)		X		X	X			
Actigraphy		X		X	X			

* (R32) Customization of data transmission frequency is cross-cutting over all clinical measurements

D2.2 Functional requirements specific to clinical measurements' type

Measured Clinical Variable*	EKG data transmission frequency (R21)	Patients provided with specialized User Interface for inputting INR values (R24)	Actigraph recording with a frequency of 1 signal per minute (R25)
EKG (heart rythm)	X		
INR (prothrombin time)		X	
Actigraphy			X

2.3.2 **Self-assessment**

The current section breaks down the psychological condition and self-assessment of the patients (TH) activity on the following two subcases:

- **UC-TH-6a** Self-assessment procedure
- **UC-TH-6b** Self-assessment pre and post-conditioning

The self-assessment procedure use case (UC-TH6a) is detailed in Table 13 as a series of simple steps. The condition for the initialization of the use case is that the scheduler of the platform's respective module signals the initiation of the process (with a predefined frequency – R03, R04). The precondition for conducting the self-assessment procedure is that the tablet is accessible to the patient and connected to the platform, at the scheduled time of measurement. The result is self-assessment scores that are registered with and processed by the platform to derive trends. Another result is the update of the views on assessment results and the respective renderings. The complete flow chart of this use case is depicted in the flowchart of Figure 9.

After analyzing the pertinent functional requirements, as stated in the deliverable D2.2 Requirements Consolidation and Prioritization Iteration 1, the need for customization of the used questionnaires and the respective answers evaluation was consolidated (R15). This requirement complements the need of raising alerts when self-assessment scores are worsening (R07). Our analysis is summarized in Table 12.

Measured Variable*	Reminders (R02)	Custom freq. of measurement (R3, R4)	Measurement analysis and visualization (R05)	Alerts to medical staff (R07)	Custom alerts threshold (R09)	Send SMS to patient / relatives (R11)	Customize questionnaires and answers evaluation (R15)
Self-assessment		X		X	X		X*

* (R15) Specific to self-assessment procedures

Table 12 – Mapping of self-assessment to D2.2 functional requirements

When a constantly decreasing trend is detected over a given number of scores (UC-TH-6a), alarms are raised and forwarded to the doctors and possibly relatives (UC-TH-6b). The above analysis is labelled as the self-assessments post-conditioning and is summarized in Table 14. The aforementioned table also details the series of steps followed by the doctors, when they need to modify the questionnaires along with the scoring rules and the alarms thresholds. This series of steps is labeled as the self-assessments pre-conditioning. The pertinent flowcharts for self-assessment pre and post-conditioning are depicted in Figure 10.

To sum up, this use case realizes the following relations: 1) Patients conduct self-assessments by answering questionnaires regarding their satisfaction with their treatment and quality of life. Compiled data is used to complement the clinical view of individual patients. 2) Answers to the scores are subsequently scored. If there is a significant negative trend in score values, the platform automatically triggers alerts, forwarded to the medical personnel. 3) Doctors are able to modify the questionnaires, the scoring of the predefined answers to questions and the alert thresholds for overall scores.

Name	UC-TH-6a: Self-assessment procedure use case
Summary	Procedure to conduct the self-assessment of the patients and register result scores with the platform.
Rationale	Self-assessment is an integral process towards meeting the telehealth objective: • It complements the clinical view on individual patients. • Allows doctors to determine if individual patients are dissatisfied with or face problems regarding their treatment and quality of life.
Users	Elderly Patient
Preconditions	The tablet is accessible by the patient and connected to the platform, at the scheduled time of self-assessment.
Basic Course of Events	1. The scheduler of the platform's measurements module signals the initiation of the self-assessment process to be conducted by the patient (R3). 2. The patient is audio visually prompted by the platform to access/use the tablet (R14). The user signals that he is ready to answer the questionnaire. 3. The patient is guided through the self-assessment procedure. 4. Answers are automatically inputted to the platform by means of an established (wireless) data link with the platform. 5. Results are submitted to the system using a standard format, along with any available / required contextual data (i.e. time or duration of measurement) (R6). 6. The platform's measurements module signals that a new assessment is available for the patient. Subsequently the patient's answers are retrieved from the measurements module to the processing module. 7. The answers are scored and the final score is registered with the platforms' central repository to update the assessment snapshots view, in accordance to date/time of assessment (R3, R6). 8. When the platform signals that the snapshot view update has been completed, the pre-defined trends calculation is initiated (R5). 9. The central repository is queried and the current and previous assessment scores are retrieved (R3, R5, R6). 10. The difference of the current form the previous score is calculated. 11. The centralized platform repository is updated with the trend view data (R06). The visualization and alerts reasoning modules of the platform are signalled (R5, R7). 12. The visualization module of the platform updates rendering of the snapshot (and optionally trend) view of the assessment, in a compatible way to the pre-set measurements frequency (R3, R4), while also displaying events (alerts) that may have also been identified by alerts reasoning module (R7).
Alternative Paths	In Step 1, if the patient has not taken a previously scheduled measurement or an extemporary measurement is required, the platform periodically forwards him/her reminders - at fixed time intervals (R2, R4).
Expected result	Scheduled self-assessment is conducted successfully; result data has been registered with and processed by the platform to derive trends. Views on new assessment results have been updated along with the respective renderings. The platform's reasoning module is notified accordingly.

Table 13 – Breakdown of self-assessment procedure use case to simple steps

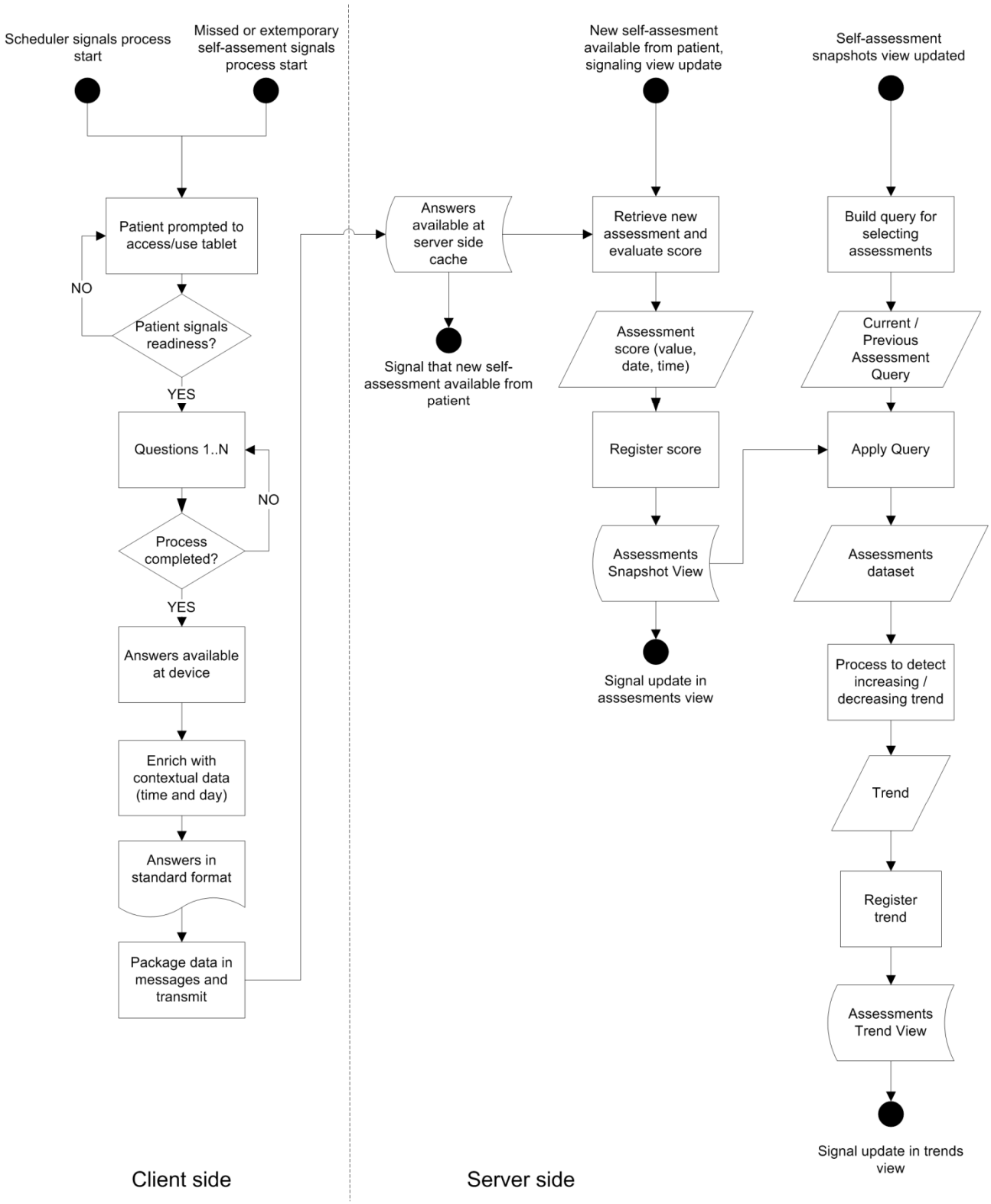


Figure 9: Flowchart of self-assessment use-case procedure (UC-TH-6a)

Name	UC-TH-6b: Self-assessment pre and post-conditioning use case
Summary	Procedure to modify the self-assessment questionnaires (pre-conditioning) and procedure to raise alerts when the self-assessment scores of a patient deteriorates (post-conditioning)
Rationale	Self-assessment procedure should be modifiable by experts. Alerts, which are automatically generated as a result of deteriorating self-assessment scores of individual patients, should reflect the modifications of the self-assessment questionnaires.
Users	Medical personnel (pre and post conditioning), Relatives (post conditioning)
Preconditions	There is medical data stored in the central repository to enable a spherical view over an individual patients' medical condition and the pertinent trends have been computed.
Basic Course of Events	1. (Pre) The doctor requests a change to the self-assessment questionnaire (R15). 2. Doctor accesses the questionnaire configuration screen. 3. The system retrieves and displays the previous questions and scoring rules. 4. The doctor edits/modifies the questions and the pre-defined selection of answers (R15) 5. The doctor may assign new / modify scores for the pre-defined range of answers and the respective questionnaire metadata fields are updated (R15). 6. The doctor may assign new / modified alarm thresholds for constantly increasing/decreasing trends of the overall self-assessment score and the respective questionnaire metadata fields are updated (R9). 7. The modified questionnaire is registered with the measurements module of the platform.
Alternative Paths	1. (Post) The processing module of the platform signals that a new self-assessment score has been registered with the system and that the respective trend has been updated for a particular patient (R5, R6). 2. Analytically, the pre-set thresholds for the trend (determined by the respective questionnaire) are retrieved from the platform (R7). 3. The latest trend value of the assessment is retrieved from the centrally stored trends view. 4. A set of rules is evaluated for the self-assessment trend in order to determine if it is consistently increasing/decreasing (R7). 5. The rules evaluation result determines whether the corresponding alarm should be generated or not (R7). 6. If an alarm is generated, then it is classified depending on its criticality. Alarms with lower critically generate signals to the visualization module to compose them in the respective clinical variable renderings (R5). Alarms with higher criticality signal the messaging module to send (SMS) alerts to doctor or even the patient's relatives (R5, R11).
Expected result	(Pre-conditioning) The measurements and reasoning modules are notified in changes of self-assessment questionnaire. (Post-conditioning) Signal to update the composite rendering of alerts on the self-assessments view. The platform's messaging module is notified to dispatch alarm messages (SMS or other) to doctors and/or relatives.

Table 14 – Breakdown of self-assessment pre and post conditioning use-case to simple steps

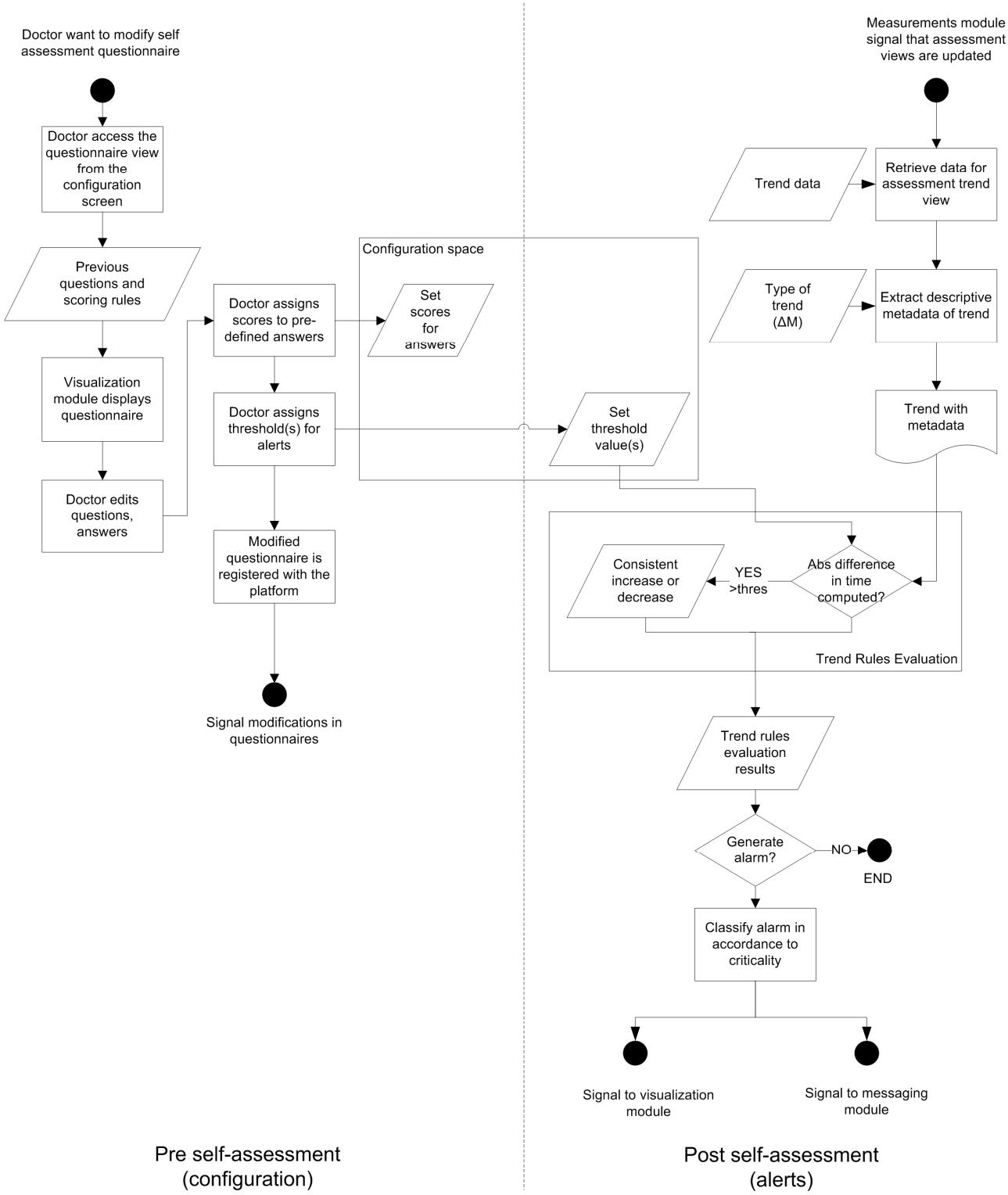


Figure 10: Flowchart of self-assessment pre and post conditioning use-case (UC-TH-6b)

2.4 Telecare Requirements

We define Telecare (TC) as a combination of equipment, monitoring and response that can help individuals to remain independent at home. It can include basic community alarm services able to respond in an emergency and provide regular contact by telephone as well as detectors which detect factors such as falls, fire or gas and trigger a warning to a response centre. Telecare can work in a preventative or monitoring mode, for example, through monitoring signs, which can provide early warning of deterioration, prompting a response from family or professionals. Telecare can also provide safety and security by protecting against bogus callers and burglary.

Devices, such as chair contact sensor, bed contact sensor, passive infrared (PIR) sensor for motion detection, gas leak, smoke detectors, humidity measurer, and so on, allow us to collect data useful for checking and monitoring user condition in their houses.
We disclose in this section a view of different synergic measurements we can provide in order to set up system functional specifications related with Telecare.
The above high level description of Telecare use case services is graphically represented by the UML diagram in Figure 11.

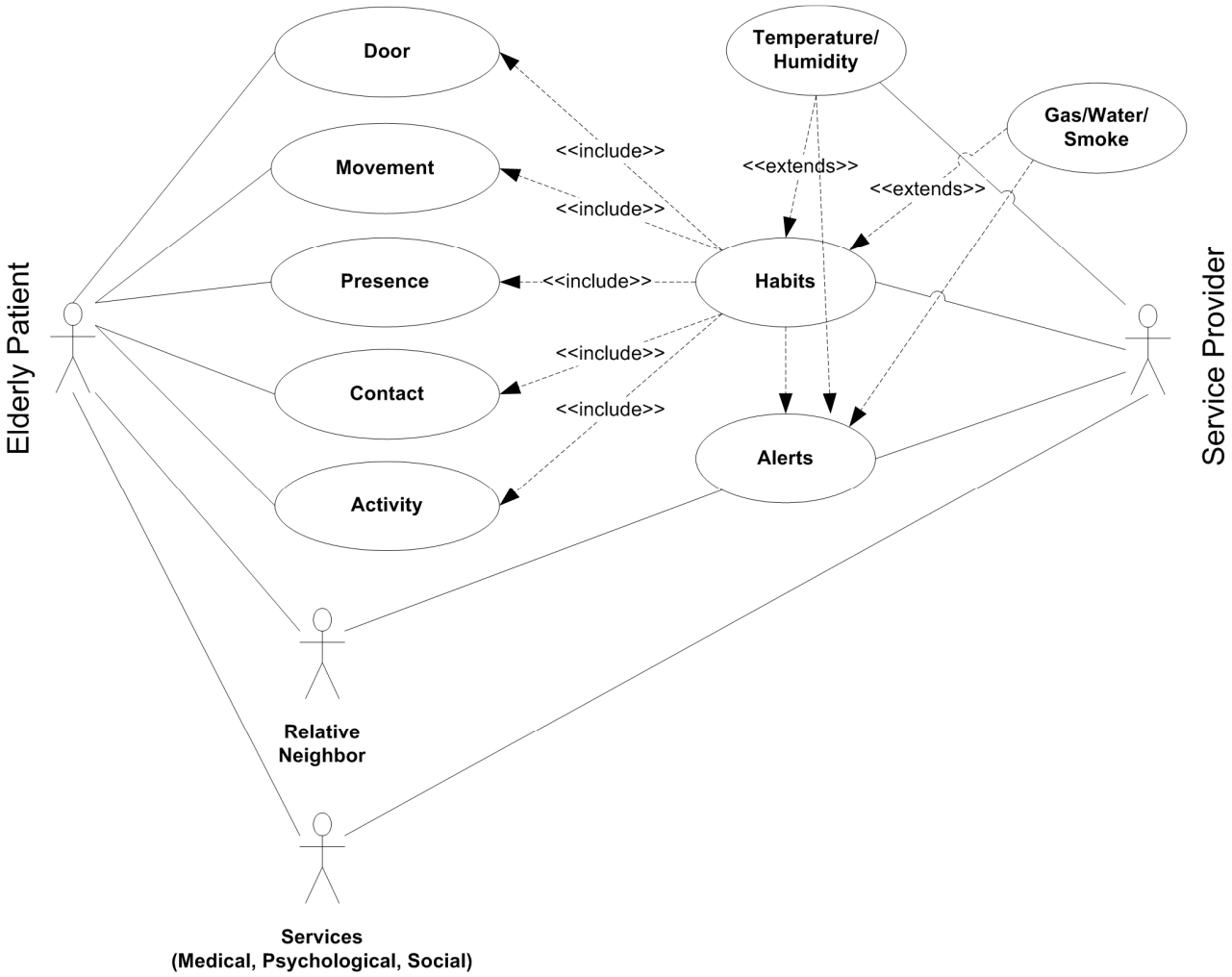


Figure 11: UML use cases overview diagram related to the Telecare orientation of the inCASA services

The Figure 11 drafts main actors, measurements, and activities involved in telecare inCASA services. In order to provide more direct inputs to system specification, in the following section we will analyze main inCASA TC activities.

2.4.1 **Environment Condition**

We identify a set of use cases that describe TC activities, related with user environment conditions. All described activities take into account user home scenarios

- UC-TC-1: Habit Monitoring
- UC-TC-2: Habit-related Alert
- UC-TC-3: Home Comfort and Technical Emergency Alarms

The inCASA solution will collect data unobtrusively and non-invasively on behaviour, using wireless detection of movement. The architecture combines multiple sensors (like Personal Health Systems/Body Sensor Networks - PHS/BSN) and could integrate further data to increase profiling accuracy and achieve the medical target. Depending on local configuration it should be affordable.

Habit monitoring discloses user profile; Home Comfort and Technical Emergency Alarms depict a triggered alert when an emergency situation (gas, water leak, etc.) occurs in the user's premises or when comfort indicators (humidity / temperature measurements) deviate significantly from expected values. Habit-related Alert describes alarming deviations from user habits; particularly, in this class of alerts are considered also specific scenarios occurring whenever a user action causes concern, i.e. he/she goes out without closing the door, and this is independent of his/her habits.

We can classify aforementioned activities in i) Monitoring and ii) Alerting activities. The former disclose user profile, by monitoring his habits in his own house. UC-TC-1 belongs to that class. In turn, UC-TC-2 and UC-TC-3 represent warning activities, as they identify alerts.
Both classes of activities are interlinked, particularly, only after profiling user, by analyzing his habits (UC-TC-1), it is possible to trigger habit related alerts (UC-TC-2), whenever a warning situation happens.
The following table groups TC measurements involved in either Alerting or Habit Monitoring. Particularly, last two measurements obtained by PIR and contact devices are useful for profiling user habits. Contact devices are placed on user door, chair, bed etc.

TC devices for	Alerting	Habit Monitoring
Gas leak	X	
Water leak / flood	X	
CO/Smoke presence	X	
Temperature measurer	X	
Humidity measurer	X	
Movement	X	X
Contact	X	X

Table 15 – Mapping home comfort/ environment measurements to Alerting and habit monitoring events

2.4.1.1 Habit Monitoring

Habit sensors (Activity, motion/presence sensors, door, and contact sensors) will be used to create a behavioral model of the monitored person. Person's activity is automatically measured using environmental sensors.

Preferably, the sensors shall be available out of the shelf, as proven hardware is widely available from home automation or smart metering solutions.

The System should organize data per time/per day/per week, and it should create a profile of actions and pathways defined as "Normal Habits Model". We identify two categories of habit measurements: i) actions with a number of occurrences (how often), ii) ΔT interval between two linked actions.

The following pathways detail possible instances of above categories:

- Occurrence
    a. Pathway "Going to toilet" defines times per day (with time stamps) going to toilet (revealed by motion sensors inside bathroom).
    b. Pathway "Moving inside home" defines number of movements inside the house and time stamp/location of each movement detected by sensors
    c. Pathway "Using TV" defines time stamp of turning on/off TV and hours spent inside TV room while TV is turned On
- Interval
    a. Pathway "Going to bed/Wake up" defines timestamp for going to bed and getting up from bed with ΔT between the time stamps.
    b. Pathway "Going out from home" defines time stamp for going out of home/coming back to home with ΔT between time stamps.

TC devices for	Occurrence (times per day)	Interval (ΔT between time stamp)
Movement detection	X	X
Detecting usage (i.e. door, bed, chair Contact sensors)		X

Table 16 –Mapping Habit measurements to Occurrence or Interval views

Name	TC-UC-1: Habit Monitoring
Summary	Procedure to map user habits, where they are defined as the repeating of a single or complex actions (like sitting on a chair or going out of home,..) or a pathway (a sequence of actions like going out of bedroom to toilet every day after getting up from bed) for several times at about the same time during a week.
Rationale	Monitoring user habits is crucial in order to automatically identify anomalous situations and send alerts to the user, carers and to the Service Provider. So, Healthcare and Social Care professional users will be able to take the right decision and to plan interventions.
Users	Elderly Patient
Preconditions	Environment/habit sensors are correctly installed in the user house, connected with home gateway by wireless, which in turn is connected to the monitoring server.
Basic Course of Events	1. The monitoring server signals the initiation of the habit monitoring process to be conducted for one week (the time frame should be configurable) (R3). 2. The system retrieves the set of personalized actions and associated parameters to be monitored (R3, R18). 3. The system registers any single action coming from the User's house, including the time stamp of the events occurring before the expiration of the tuning time frame (R5, R16, R19, R20, R28). 4. The system creates a profile of actions and pathways defined as "Normal Habits Model", by measuring and profiling actions/pathways (R6, R32).
Alternative Paths	Step 2-4 are iterated for two weeks: the system should check the variations of the Normal Habits Model for 2 weeks after the first profiling to allow a first iterative "tuning" of the model (R17).
Expected result	The expected result of the habit monitoring is getting user profiles, useful for automatically identifying habit-related anomalous situations

Table 17 – Breakdown of Habit Monitoring Use case to simple steps

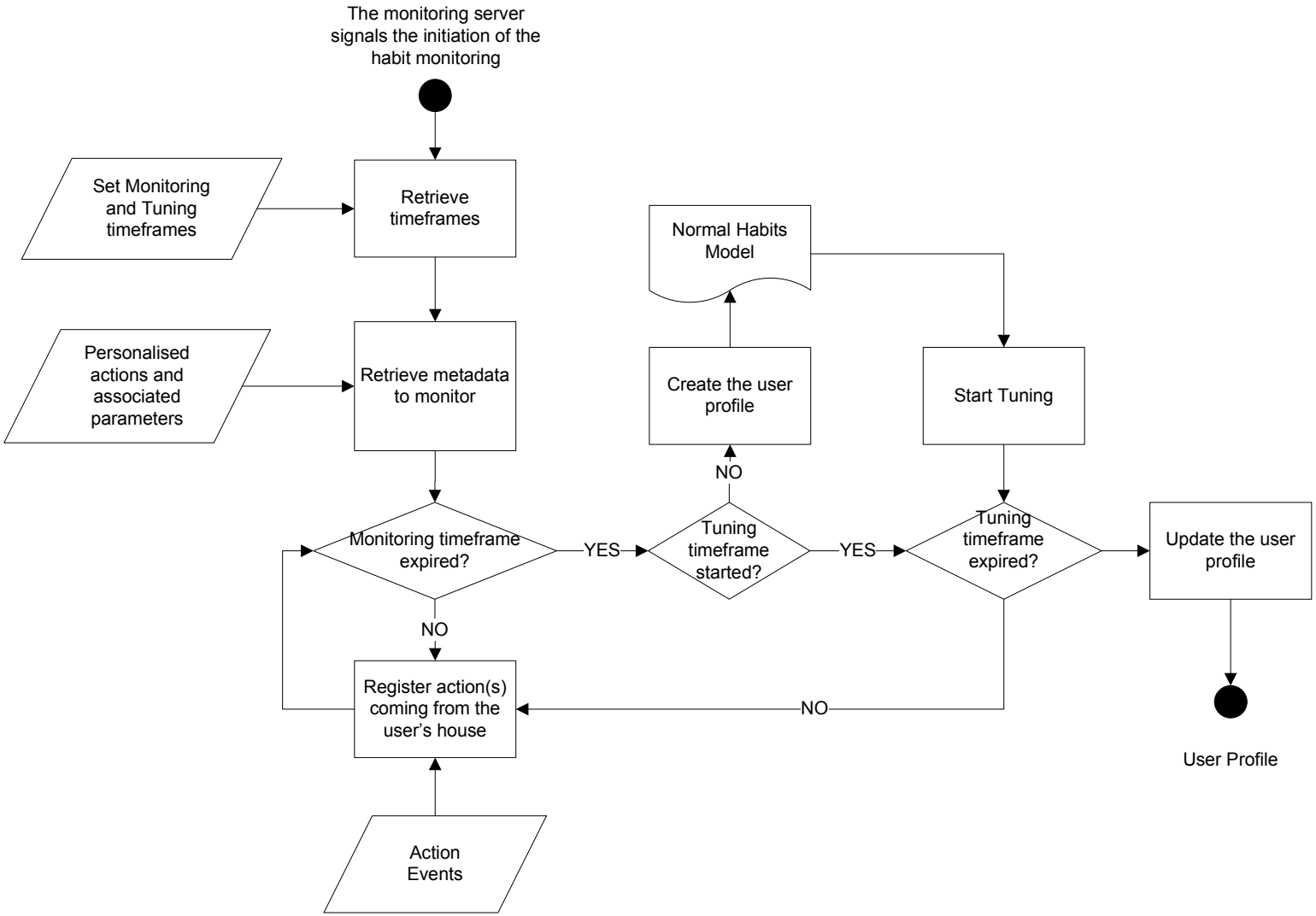


Figure 12: Flowchart of Habit Monitoring use-case (UC-TC-1)

2.4.1.2 Habit-related Alerts

Regarding the evaluation of habit-related alarms on established user profile, the following rule is applied:

- *Unexpected levels of change over defined time scale*: When a consistent variation across time of a normal habit (according to user profile) is detected in the duration of the monitoring period.

An example scenario that triggers the above rule is when PIR motion devices and contact bed sensor register that the user is moving inside his home abnormally:

User is moving during night (while he normally sleeps during night) → after a number of movement events detection (means no occasional wake up) → alert message to Operator → next day user phone call (it depends on single case) → if success → alert stop → if not success → send an operator to verify user conditions.

Additionally, for the evaluation of alarms on absolute unexpected actions, the following rule is applied:

- *Absolute warning:* When a user action deviates from absolutely considered "normal" behavior (not related with his profiled user habit)

The absolute warning rule is applicable to particular situations where a user behavior is considered absolutely abnormal, aside from his habit profile. An example can clarify the scenario:
A user forgets to close door, after going out.
If he goes out without closing the door→ after 1-30 mins → SMS to relative/neighbor → if he closes door → alert stop → if he doesn't close door → after 1-30 mins → alert message to Operator → user phone call + relative/neighbor call → if success → alert stop → if not success → send an operator/technician to close the door and verify user conditions
Specifically, such sequence of actions will always result in the automatic generation of an alert by the inCASA platform, irrespectively of the monitored user habits and past actions.

The alarm rules may be evaluated against *pre-defined or personalized thresholds*, with the latter being a result of monitored user habits across a given period. Some user habits measurements may trigger, as a result of the above set rules evaluation, *alarms of escalating criticality*, determined on the respective deviation from values indicating "normalcy". The parameters of the alert and their classification in terms of their criticality will be fine-tuned during the pre-pilot tests. The result mapping of TC monitoring devices to types of warning raised when a particular user behavior/habit is detected by the inCASA platform is presented in Table 18.

TC devices for	Unexpected levels of change over defined time scale	Absolute warning	Personalized threshold (due to defined habit user profile)	Escalating alarm criticality
Movement				
PIR Motion sensor	X		X	X
Contact				
Bed sensor	X		X	X
Chair sensor	X		X	X
Door sensor	X	X	X	X
Appliance sensor	X		X	

Table 18 – Mapping environment measurements to Habit-related Alerts

Table 19 details the steps taken for raising a habit–related alarm in this use case. The flowchart for the scenario pertinent to the alarms use case is depicted in Figure 13.

Name	**TC-UC-2: Habit-related Alert**
Summary	Procedure to generate an alert when a user action anomalously deviates from his habits.
Rationale	Generating habit-related alerts allows healthcare and social care professional users to take the right decision and to plan interventions to prevent risks for the user.
Users	Elderly Patient, Relative, healthcare and social care professional.
Preconditions	Environment/habit sensors are correctly installed in the user house and (wirelessly) connected to a home gateway; in turn the gateway is connected to a monitoring server. Also a habit user profile is already built based on data collected during a previous training period.
Basic Course of Events	1. The monitoring server signals that a new habit-related event has been registered within the system (R03, R21). 2. If the habit monitoring rule should be evaluated against previous habit events, they are retrieved from the system. 3. The profiled normal user habits are retrieved from the system. 4. A set of rules is evaluated for the respective habit-related event, in order to determine if the measured value is within prescribed limits or deviates significantly from usual habits (R07, R09). 5. The system describes the warning event by the variables: identification – name – description – priority – severity. 6. The rules evaluation result determines whether the corresponding alarm should be generated or not (R07, R13) 7. If an alert is triggered, and priority class is determined, then a corresponding type of alerting action is triggered: alarms with lower criticality generate signals to the visualization module (R5). Alarms with higher criticality activate the messaging module to send (SMS) alerts to operators or even the patient's relatives/neighbors (R5, R11). If crucial emergency is identified, intervention of experts is required. 8. The system enables a method on the GUI to mark the alert as "forwarded to (select role)" or "solved".
Alternative Paths	1. From step1, if the new registered event is labeled absolutely (not related with user profile) warning, then an alert is directly triggered. (Go to step 7) 2. From step 5 an evaluation of event severity is provided. Afterwards the system defines priority classes: non urgent – mild urgent – urgent – very urgent – emergency. These priority classes are attributed based on available personalized user habits or in some cases irrespective to past user actions. 3. From step 8, the system shows a list of the users and related alert ordered per priority/per severity/per time 4. From step 8, the system permits the opening of an user dedicated page on which single alert is described
Expected result	Signal to update the composite rendering of alerts on the habit monitoring view. The platform's messaging module has been notified to dispatch alarm messages (SMS or other) to operators and/or relatives

Table 19 – Breakdown of Habit-related Alerts Use case to simple steps

Figure 13: Flowchart of Habit-related Alert use-case (UC-TC-2)

2.4.1.3 Home Comfort and Technical Emergency Alarms

Towards meeting the Telecare objective of the inCASA platform, the level of comfort at the user's premises is also determined by conducting a series of temperature and humidity measurements, using specialized sensors installed therein. Additionally, technical emergencies, like gas/water leaks or even fires that may occur, are automatically detected by the respective sensors installed in the user's home; these possibly dangerous events are registered with the platform and the operators are immediately notified of such events. For that purpose, the following classes of alarms are defined, in accordance to their prioritization:

- *Emergency alarm* (gas/water leaks, fire), requiring the immediate intervention of the platform's operators (high priority).
- *Home comfort direct alarm* evaluated over environmental measurements (medium priority).
- *Home comfort alarm* evaluated over environmental variables trends (low priority).

The environment conditions, monitored for the determination of the comfort at home levels, tend to change slowly over time; consequently it is assumed that the evaluation of the alerts over the current measurements always precedes the evaluation over the respective established trends.

Regarding the evaluation of alarms on established trends of home comfort indicators, the following rule is applied:

- *Unexpected levels of change over defined time scale*: When a measured home comfort variable increases or decreases more than a pre-set amount over a given period of time.

For the evaluation of direct alarms and emergency alarms, the following rules are applied:

- *Outside normal limits*: It occurs when environment or home comfort measurements exceed an upper or lower limits considered as normal (home comfort direct alarm) and/or safe (emergency alarm).
- *Does not return to normalcy within a set time*: When home comfort measurements indicate an event that does not recede within a pre-defined period of time.

The direct alarm rules may be evaluated against pre-defined or personalized thresholds, with the latter being a result of pre-existing home conditions of a patient or automatically calculated across a given monitoring period. Some home comfort measurements may trigger, as a result of the above set rules evaluation, alarms of escalating criticality, determined on the respective deviation from established target values or value ranges indicating "normalcy". The above analysis is summarized and the respective measurements to be tracked within the inCASA pilots are categorized in Table 20, while Table 21 details the steps taken for raising an alarm. The flowchart for the scenario pertinent to the alarms use case is depicted in Figure 14.

TC devices for	Unexpected levels of change over defined time scale or period	Outside normal limits	Does not return to normalcy within a set time	Escalating alarm criticality	Personalized threshold (automatically derived)
Gas leak		X			
Water leak		X			
CO/Smoke presence		X			
Temperature measurer	X	X	X	X	X
Humidity measurer	X	X	X	X	X

Table 20 – Categorization of Home Comfort and Technical Emergency Measurements

Name	UC-TC-3: Home Comfort and Technical Emergency Alarms
Summary	Procedure to generate an alert when environment conditions critically change.
Rationale	Alerts are automatically generated, by checking home comfort and/or emergency parameters. The alarming scenario allows timely response of expert operators, relatives, neighbours, and thus prevents dangerous situations for the patients.
Users	Elderly Patient, Relative, Neighbours, healthcare and social care professionals.
Preconditions	Environment sensors are correctly installed in the user house, and they are connected with home gateway by wireless. Professional users set rules about the limits of the variations for home comfort parameters.
Basic Course of Events	1. The processing module of the platform notifies that new home comfort measurement(s) or environment emergency signal(s) have been registered with the system and that the respective trends have been updated for a particular patient (R05, R06, R29, R30, R31). 2. If an alarm rule should be evaluated across time (R07), subsequent processing is scheduled to take place (possibly exploiting data parallelism techniques). 3. The pre-set, personalized or automatically computed (during the tuning time frame) thresholds and “normal” limits for the respective home comfort or environment emergency values are retrieved from the platform (R7). 4. A set of rules is evaluated for the respective environmental variable in order to determine if the measured value is within prescribed limits or deviates significantly from expected values (R7). 5. The rules evaluation result determines whether the corresponding alarm should be generated or not (R7). 6. If an alarm (or more) is generated, then it is classified depending on its criticality. Alarms with lower critically generate signals to the visualization module to compose them in the respective renderings (R5). Alarms with higher criticality signal the messaging module to send (SMS) alerts to operator or even the patient’s relatives/neighbours (R5, R11).
Alternative Paths	1. From step 2, if rules are to be evaluated against the home comfort variable established trends, the latest snapshot value(s) of the measurement is retrieved from the centrally stored snapshots view. 2. Analytically, the pre-set thresholds for the respective trend (determined by its metadata) are retrieved from the platform (R7). 3. A set of rules is evaluated for the respective trend in order to determine if large changes/deviations in the measured values are detected over a pre-set time window or period (R7). 4. The rules evaluation result determines whether the corresponding alarm should be generated or not (R7). 5. If an alarm (or more) is generated, then it is added to the alarm list already generated by the latest measurement snapshot
Expected result	Signal to update the composite rendering of alerts on environment measurements view. The platform’s messaging module has been notified to dispatch alarm messages (SMS or other) to operators, relatives, neighbours.

Table 21 – Breakdown of Home Comfort and Technical Emergency Alerts Use case to simple steps

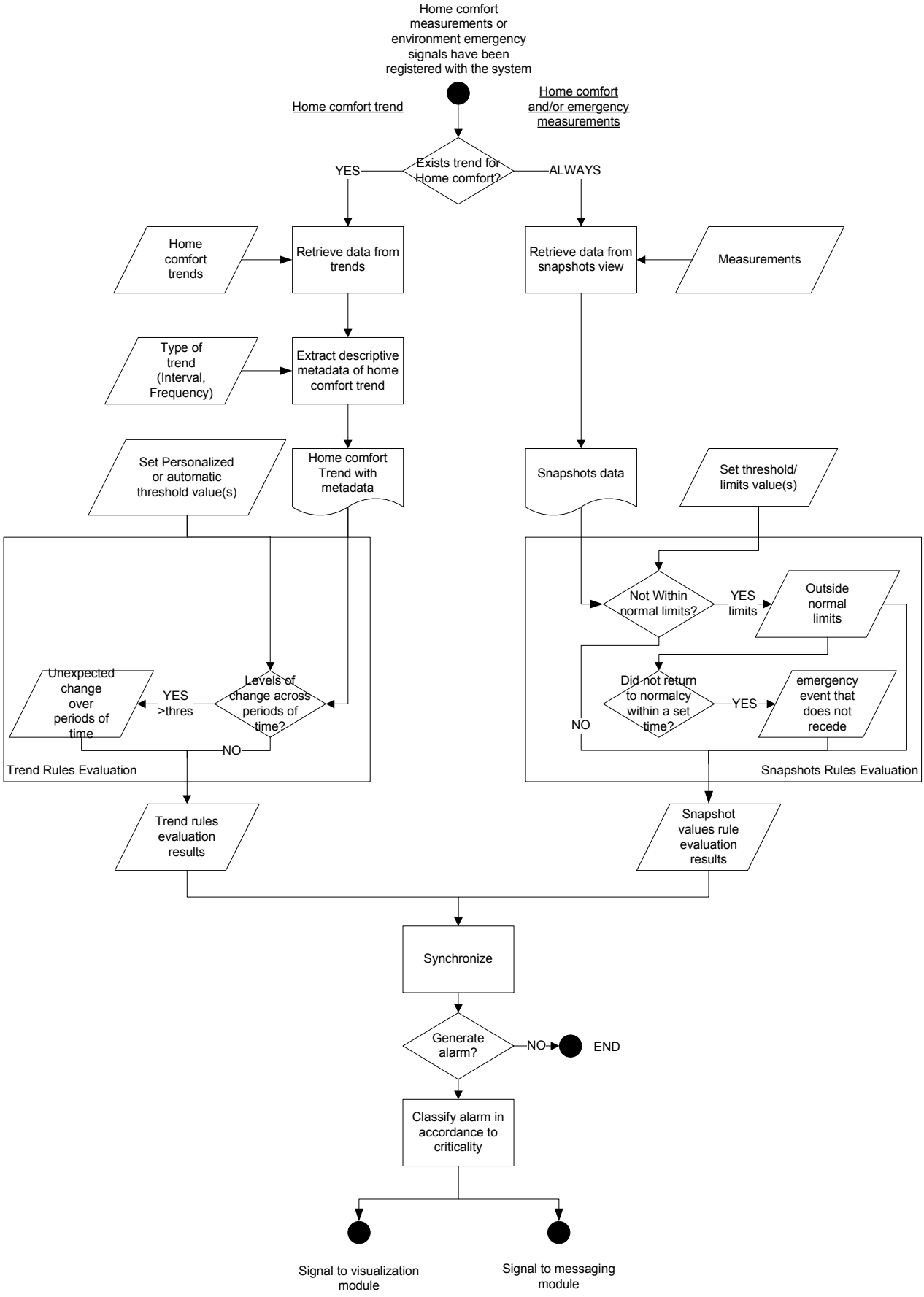


Figure 14: Flowchart of Home Comfort and Technical Emergency Alarmsuse-case (UC-TC-3)

2.5 Monitoring Requirements and Specifications

The monitoring requirements that can be derived from Tables 1 and 2 together with the specifications set by these, will all assist in implementing the main goal of inCASA (i.e. to help and protect frail elderly in their homes). This goal will be achieved by integrating solutions and services for health and environmental monitoring to collect and analyse data. In turn, this data also need to fulfil the monitoring requirements in order to profile user behaviour so that an implementation of customized intelligent multilevel alerts/communication services can be done for inCASA.

As such, the monitoring requirements on tables 1, 2 are here coupled together so that the inCASA platform will be able to handle both Telehealth and Telecare orientations. This means that functional and non-functional requirements are aggregated into one common denominator (i.e. the actual monitoring requirement) which is then valid as a specification. The specification will take the form of an information/data flow model describing the staged requirements.

In inCASA, users at home will have their lifestyle and medical condition monitored by a Home Sensor Network and by wearable and portable Human Monitoring Sensors. The monitoring requirements at stake here will ensure the continuing quality and effectiveness of the services that are to be provided in inCASA to meet an individual's needs and identifying whether and how the individual's needs have changed.

These individual changes will not only be of value for the individual her/himself but also for the social services department where this will be undertaken as processes when an individual's care needs are assessed and appropriate services are provided. Assessing their needs will make it possible to develop a care plan and a care package to meet their needs. Meeting the monitoring requirements will therefore provide a combination of equipment, monitoring and response factors that can help individuals to remain independent at home. Both Telehealth and Telecare can work in a preventative or monitoring mode providing safety and security but also health monitoring and illness prevention services.

To steer the data flow direction of the model all of the requirements are categorized into type of service and level of implementation. As it involves remote monitoring a client-server approach is necessary to take in order to realise a distributed data flow. The types and levels are the following:

Type Name	Category	Description
ServiceType 1:	Devices	Includes both medical and environment sensors and devices.
ServiceType 2:	Remote Client	System/Services that occur on client side.
ServiceType 3:	Remote Server	System/Services that occur on server side.
ServiceType 4:	Feedback Patient	Relevant feedback to the patient.
ServiceType 5:	Feedback Professionals	Relevant feedback to the professional, doctor or family.
ServiceType 6:	Configuration Patient Side	Enables configuration on client side or on patient's Home Based System.
ServiceType 7:	Configuration Professional Side	Enables configuration on server side or on professional's Remote Service Provider.

Table 22 – Monitoring types and levels

Mapping the requirements in table 1 and 2 then leads us to a new representation of each single categorized requirement where they each are being related to a service type. Reoccurrences are high-lighted in recognisable colours indicating some common interface or feature in the inCASA platform.

Type Name	Requirements Code
ServiceType 1:	R01, R08, R12, R14, R16, R19, R20, R23, R24, R25, R28, R29, R30, R31, R33.
ServiceType 2:	R06, R14, R18, R21, R26.
ServiceType 3:	R06, R22.
ServiceType 4:	R02, R05, R14, R26, R31.
ServiceType 5:	R05, R07, R17, R26, R31.
ServiceType 6:	R04, R14, R27, R32.
ServiceType 7:	R03, R09, R10, R11, R13, R15, R17, R22.

Table 23 – Requirements mapping to monitoring types

Transferred into building blocks where type name is associated with categories we now see the following which is of use when modelling a monitoring requirements specification model:

Having this allows us to extract the relationship between each requirement and directly map these out on a specifications model. For example, the blue R14 is occurring in ServiceType 1, 2, 4 and 6 indicating that its relationship spans over devices, the remote client and directly returns as a feedback to the patient. This model would typically have a remote monitoring structure built something according to the figure below where module connectors are common denominators:

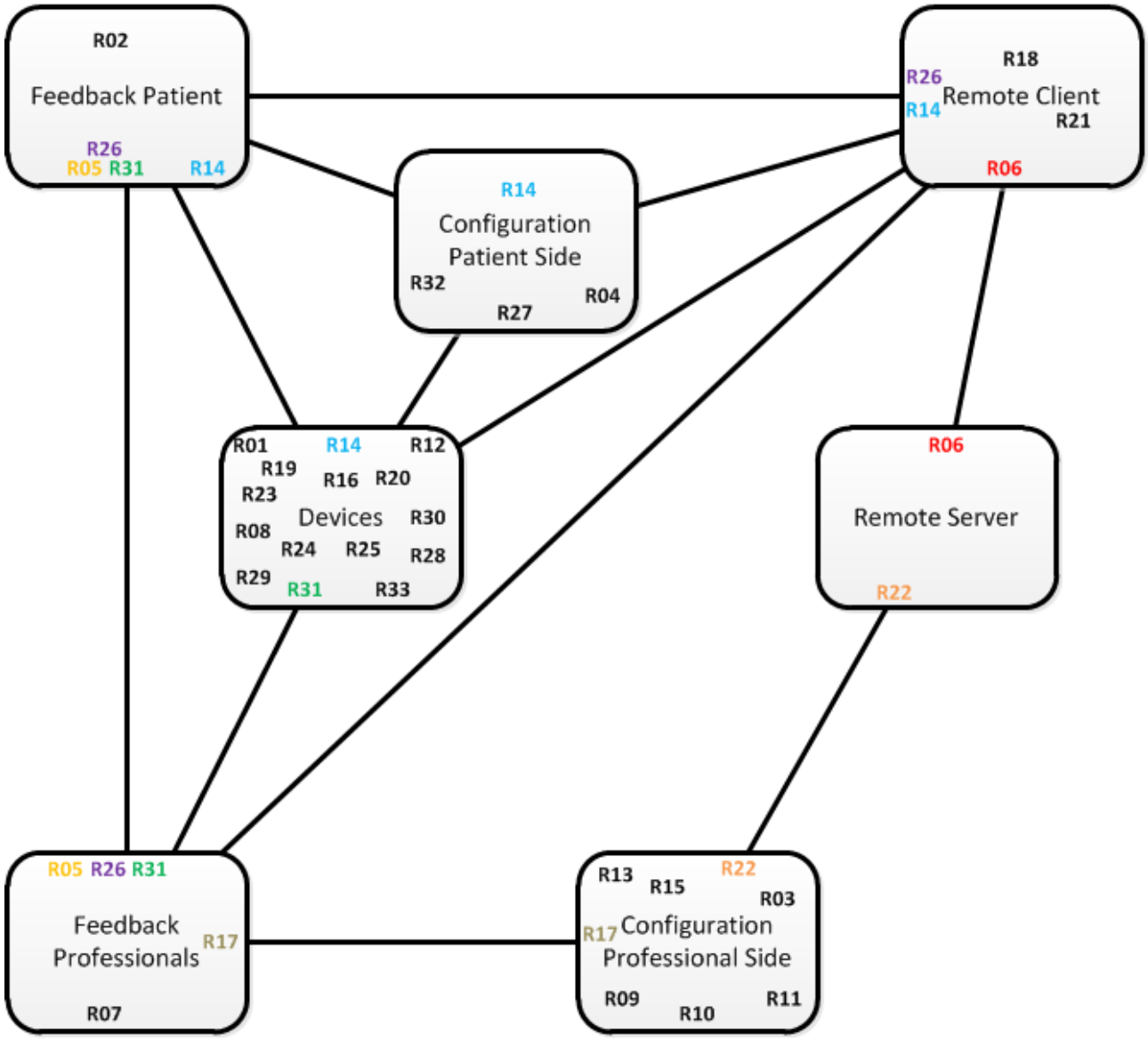


Figure 15: Monitoring specifications model

Using this model to predict a remote monitoring specification that may be used for inCASA platform structure enables easy logical distribution of physical entities.

Devices are by vendors' logical entities to place externally from the inCASA platform. As these are spatially closest to the user the Remote Client, these need to be located within that environment, e.g. the elderly person's apartment. Configuration of the services provided by the Remote Client should preferably be situated near to the client itself as it eases usability and enhances the physical performance of configuration. The feedback of the configuration as well as the patient feedback can either be web based or provided directly on a screen within the proximity of the Remote Client. Whether this is done on the same apparatus or on other is a design issue and not discussed here. Remote monitoring is conceptualized at the Remote Server side and the same allocation of requirement functions may occur in a similar way as the Remote Client side. Still, if also the professional feedback would be offered as a web based application considerations on sharing portal with patients should be taken in order to enforce common remote monitoring structure by an equivalent disposition of implemented requirement functions.

With this knowledge we can objectify the functions and requirements into a coherent specification model that specifies the localisation of each one of these according to a real physical world. The

next figure shows an example of a possible remote monitoring hardware distribution with software functionalities for the inCASA platform. This can be used as monitoring specification in D3.2.

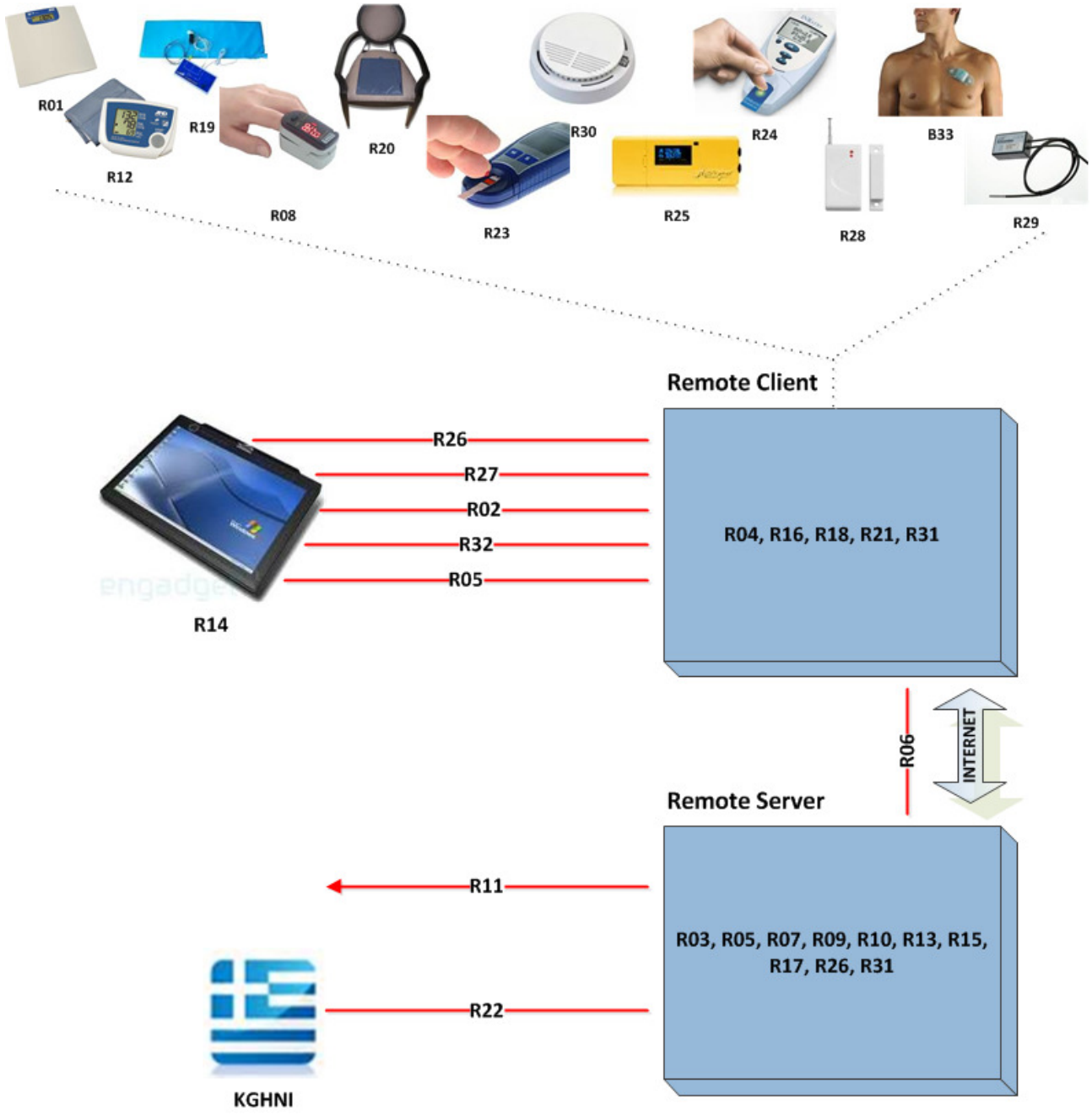


Figure 16: Possible inCASA remote monitoring hardware distribution

Looking at the specifications model above it is easy to distinguish what is needed in order to fulfil a Telehealth or Telecare operating solution. The Remote Client need to comply with relevant communication protocols and stacks offered by the different sensor device vendors. It also needs to carry the data flow while keeping its original appearance as much as possible (e.g. eliminate loss of data). The Remote Client is the most stressed specification object and it is therefore recommended to provide an advanced, high performing and interoperable solution for inCASA.

The monitoring responds to different terminating data manipulations performed both at client as server side. The Remote Client therefore needs to be robust offering varying both local and global

services without failure. The relationship between the Remote Client and the Remote Server need to be stable and therefore requires a permanent Internet connection.

The Remote Client and the patient tablet (R14) could reside within the same hardware if appropriate by the strains the Remote Client is being tried out for.

3 inCASA Building Blocks

3.1 Introduction

The purpose of this section is to present the specifications of the inCASA building blocks that will support the user requirements as analyzed in chapter 2. The inCASA building blocks are either pre-existing or developed during the project life-cycle technologies but even in the first case they should be modified or configured accordingly to cover project needs.
From a monitoring point of view, this chapter will highlight all needed elements that will give real sense to the abstract inCASA monitoring model produced in chapter 2.5

3.2 Overview of the network architecture

The proposed network architecture follows the structured network approach, which is commonly used in distributed networks. A very detailed description derived from the requirements of multi-utility metering can be found in [5]. This description encompasses:

- *primary communication* between a local sensor or actuator and a data collector/gateway,
- *secondary communication*, which allows the local monitoring of data and events at the customer premises,
- *tertiary communication* between the data collector/gateway and the provider of the functionality (utility),
- *quaternary communication* between the utility and other market players.

All four levels are relevant for the inCASA architecture. Figure 17 shows the different communication levels in the inCASA architecture.

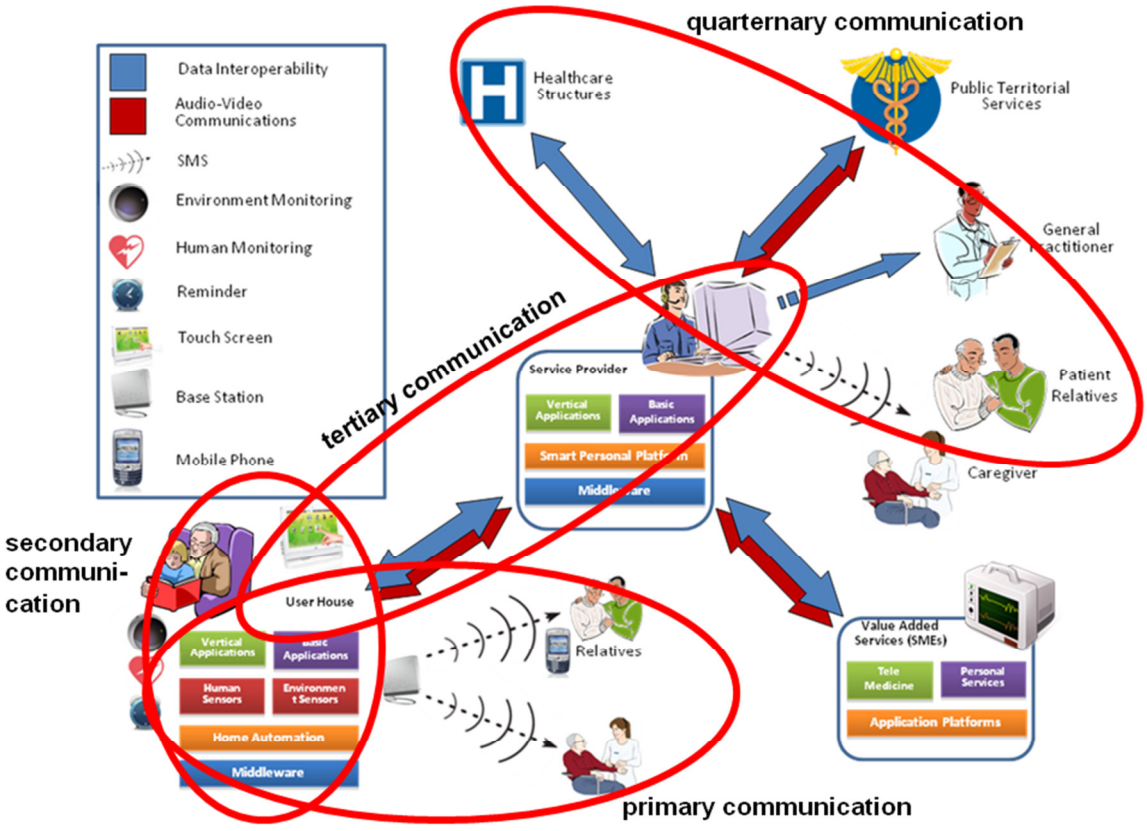


Figure 17: Communication Levels in inCASA architecture

3.3 Overview of the inCASA architecture

inCASA platform is mainly divided into two entities:

1. End User's premises where both clinical and environmental data are collected.
2. Service provider's infrastructure where data are collected, analyzed, stored and made available to Consumer Applications.

The two entities are communicating with each other through Web Service calls over a P2P network provided by the Hydra Middleware, more described in chapter 3.5.2.
In order to support its end-to-end operation, the inCASA overall architecture is presented in Figure **18**. In the subsequent paragraphs, each component's functional and non-functional specifications are listed with respect to the inCASA platform goals.

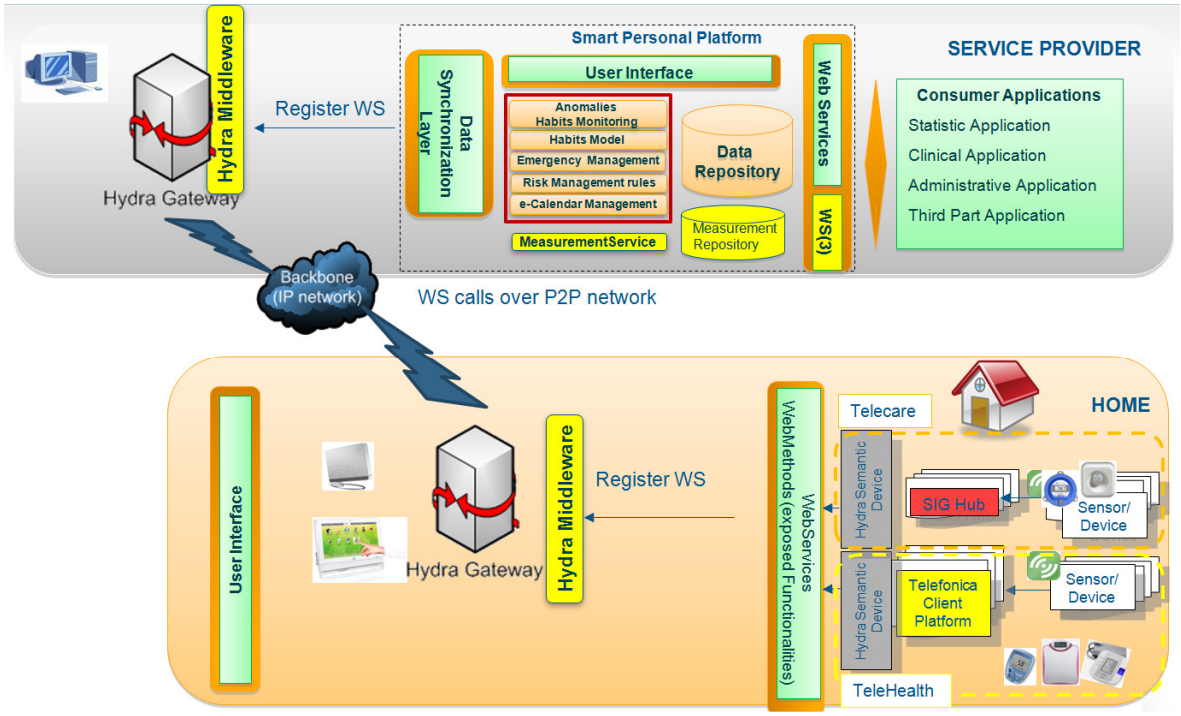


Figure 18: inCASA Architecture

3.4 Home Infrastructure

The inCASA system integrates into the monitored persons' home to record the persons' activity and their health status. This requires some infrastructure to access the relevant data and to forward them to the evaluating server. Besides the vital sign monitoring devices described in 3.4.1.2, home monitoring sensors are included. Example sensors are depicted in the figure below. The activity hub shown in this picture acts as a gateway between the Personal Area Network (PAN) and the Wide Area Network (WAN) based on Internet protocols. The activity hub is described in 3.4.2.1.

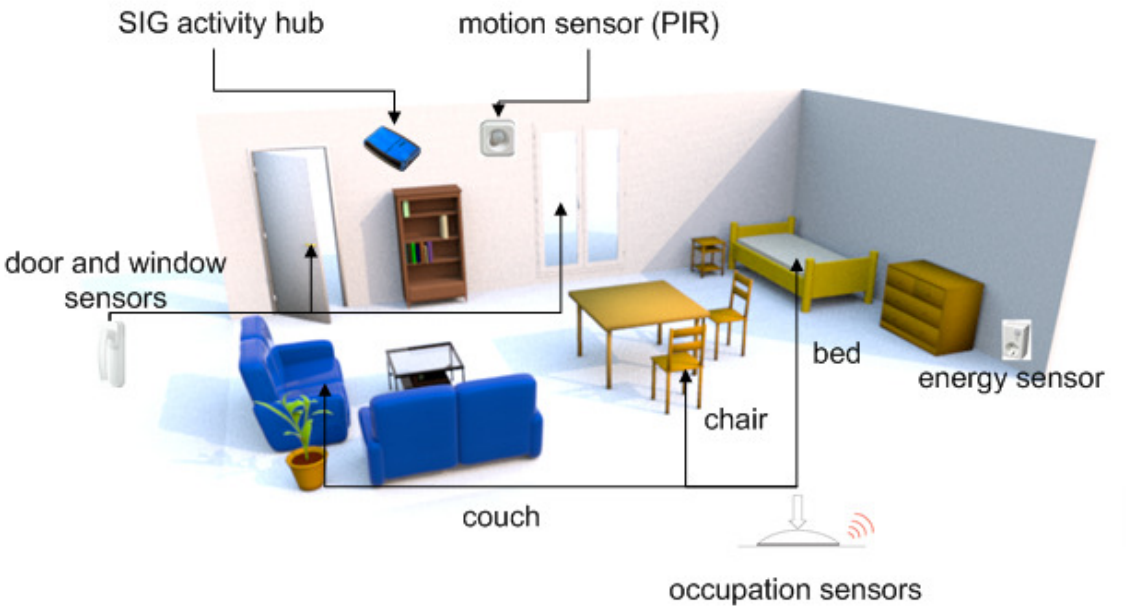


Figure 19: inCASA home Infrastructure

3.4.1 Monitoring Devices

3.4.1.1 Environment Monitoring Devices

The clinical and environmental data is collected by many different types of activity sensors and actuators. The requirements for these devices cannot be globally defined, as the sensors and actuators have very different purpose and therefore also different performance parameters. But it is possible to index them in three categories.

1. **Action-based activity sensor**
   Action-based sensors only transmit information if an action occurred or a status changed.
2. **Cyclic-based activity sensor**
   Cyclic-based sensors measure parameters and transmit data periodically.
3. **Actuators as an extension**
   Actuators are used to perform an action (not periodically). They will be included as a later extension to the initial inCASA system.

The common basic **functional requirements** of all activity sensors are:

1. To measure the given parameter *as precisely as possible*.
2. To perform measurements with *as little energy as possible* to ensure a long operation time powered by batteries.
3. To always be *available* to measure parameters, transmit and receive data.
4. To offer the possibility of configuration change for personalized adaption.

Activity measurement and person identification shall be performed without requiring people to wear a radio device (tag). If such a tag is indispensable for the functionality, additional value shall be generated from the tag, e.g. panic button functionality.
The common **non-functional requirements** are basically:

1. The inCASA project does not follow the objective to design new hardware devices, which leads to the requirement that the sensors should be *commercially available, preferably with second source*.

2. During the first months of the project, the pilots created a list of parameters, which should be monitored in the inCASA project. The major purpose of the domotic network is *to cover all of these parameters for optimized patient monitoring*. The collection of these parameters resulted in the sensor table shown in chapter 3.4.1.1.2A.
3. This collection of the parameters can be performed using different communication protocols. Most of them have *wireless connectivity* in common. This eases network installation, not only in the retrofit cases, but also under the conditions of different country-specific rules.
4. Easy installation and maintenance of the devices (park and play) is required to ensure that no technical know-how is needed. This should be valid also for easy maintenance tasks, e.g. changing batteries.
5. The activity sensors should be as small as possible and if possible hidden to the customer.
6. The devices should have the CE certification. The use of devices that that are still in prototype status during the course of the inCASA project is not encouraged by the technical partners of the consortium. In this case, the responsibility of the well-functioning of the device is also up to the single pilot that will proceed in such decision.
7. Personal data shall not be accessible.

3.4.1.1.1 *Sensor Selection Criteria*

Habit sensors, motion or presence sensors, and contact sensors will be used to create a behavioural model of the monitored person. Preferably, the sensors shall be Off The Shelf (OTS), as proven hardware is widely available from home automation and smart metering solutions. Amongst these, only standard products shall be regarded providing long-term availability of compatible hardware. To ease the sensors' installation, it is anticipated that they communicate wirelessly.

The sensors shall require as little intrusion as possible into the existing hardware, e.g. using adaptor plugs, leading to inexpensive and flexible pilot installations. Monitoring of water, heat, or gas consumption usually requires intrusive sensors. In this case, the pilot's property management needs to guide the selection process.

The remainder of this chapter is organized as follows. First, the variables to monitor are described to cover the complete domotic environment of the regarded persons. For these variables, commercial solutions are presented based on the different radio standards. If monitoring is insufficient using commercial sensors, solutions for tracking people and customizing sensor modules are presented. Appendix A contains further information about commercially available sensors products.

The variables to monitor have to be selected in accordance with the pilots. Preferably, the human movements are not to be monitored directly using distance calculation to anchor points, but indirectly, the person's activity is measured using environmental sensors. Based on this approach, the model can remain functional even if the monitored person forgets to wear the radio tag. This approach comes with the drawback that identification is not possible, and if there are multiple persons in a household, differentiation and behavioural model creation is a very difficult task. In these cases, sensors that are directly worn, like the actigraph, may permit the differentiation of different persons in the same environment.

3.4.1.1.2 *Classification of sensors and actuators*

Additionally to the sensors, actuators can be integrated into the network to ease the persons' life or raise the safety. Those sensors and actuators can be classified according to different parameters. First, direct activity, like opening a window or a water tap is measured. If the sensor's position is exactly known, and as the monitored person's position must be in the direct neighbourhood of the sensor, the person can be localized quite precisely. The second group concerns sensors informing about the person's activity without any localization. The actigraph is one example for this kind of sensors. The information becomes still less reliable if additionally, the identification is not possible.

This scenario is given if there is only a Passive InfraRed (PIR) motion detector. This type of sensor only informs about the presence of some person in a room. The identification or precise localization is not possible. The last group of sensors provides information that is only valuable in combination with further information. For example, a light sensor's information of a bright room has a different meaning during night and day. Data fusion of multiple sensors or the combination of the information with further knowledge is crucial for drawing a valuable conclusion from these sensors. Such kind of functionality could be included in the Reasoner module of the platform in the server side.

A. Sensors for the variables to monitor

The following table lists different sensors for the domotic network. It has to be highlighted that for most of them, there are multiple sources providing OTS devices for the different variables and wireless technologies. For the final device selection, the availability of the single devices in the pilot countries is to check.

	Radio technology					Application covered
	ZigBee	EnOcean	KNX RF	Wireless M-Bus	Z-Wave	
Brightness		Sensor S4.2.7				√
Light switch	Sensor S1.2.5	Sensor S4.2.1	Sensor S2.2.1		S5.2.2, S5.2.1	√
Temperature /humidity sensor	Sensor S1.2.4	Sensor S4.2.5				√
Electricity meter (per device)	Sensor S1.2.2				Sensor S5.1.1	√
Electricity meter (per apartment)	Sensor S1.1.3		Sensor S3.1.2	Sensor S3.1.2		√
Water meter (per apartment)				Sensor S3.1.3		√
Gas meter (per apartment)	Sensor S1.1.1			Sensor S3.1.4		√
Heat meter (per apartment)				Sensor S3.1.1		√
Door/window contact	Sensor S1.2.1	Sensor S4.2.8	Sensor S2.2.3		Sensor S5.2.5	√
Occupancy sensor	Sensor S1.2.3	Sensor S4.2.6			Sensor S5.2.4	√
Door handle switch		Sensor S4.2.3				√
Door lock	Sensor S1.2.6				Sensor S5.2.3	√
Position switch		Sensor S4.2.4				√
Contact sensor (chair)		Sensor S4.2.9				√
Contact sensor (bed)		Sensor S4.2.10				√
Shade control			Sensor S2.2.2		Sensor S5.2.6	√
Generic radio modules	Sensor S1.2.	Sensor S4.2.11	Sensor S2.2.4	Sensor S3.1.	Sensor S5.2.7	√

Table 24 – Radio sensor cross reference

The table shows that for all variables to monitor, commercial products are at hand, which reduces the time to market and the financial risk for the inCASA project.

B. Actuator units

Apart from the sensing units, also actuator units can be installed locally. These actuators may switch devices, or give an alarm. Actuators are only foreseen in future extensions of the basic setup, but the primitives to include actuators need to be implemented early. Security issues are of major interest for systems like inCASA, and this holds especially true for actuators. In case of compromised sensors, a faulty measurement message might be received. The plausibility checks will then lead to the sensor to be seen as undependable and cause an alarm. But a compromised actuator might directly affect a person's comfort or even safety, which would not be tolerable. Therefore, a good choice of the actuator products and of the wireless technology used to connect them is crucial.

3.4.1.1.3 *Example telecare sensor set used in the pre-pilot phase*

In chapter 2.4, the relevant parameters were listed for the telecare scenario. For those parameters, a sub-set is chosen for the basic sensor set, while additional sensors are added for the extended sensor set. Those sensors include the following devices:

Parameter	Basic sensor set	Extension	Preferred technology	Source	Reference
Door / Window contact	X		ZigBee	IPSA	S1.2.1
Movement	X		ZigBee	IPSA	S1.2.3
Presence	X		ZigBee	IPSA	S1.2.3
Chair contact	X		EnOcean	Funkstuhl	S4.2.9
Bed contact	X		EnOcean	Funkstuhl	S4.2.10
Activity	X		Wireless M-Bus	Farnell	S3.1.5
Temperature		X	ZigBee	IPSA	S1.2.4
Humidity		X	ZigBee	IPSA	S1.2.4
Gas		X	ZigBee	IPSA	S1.1.1
Flood		X	ZigBee	Netvox	S1.1.4
Smoke		X	ZigBee	IPSA	S1.2.7

Table 25 – Telecare sensor selection

3.4.1.2 Vital Sign Monitoring Devices

3.4.1.2.1 *Chronic disease overview*

A disease is considered to be chronic[1] when it persists for a long time, at least over a year. But in many cases it lasts for life.
But, why are chronic diseases so important to monitor?

- 80% of people over 65 have at least one chronic health condition (USA)
- Chronic conditions drive 75% of health care costs (USA)
- Population is ageing:
  In Europe
  - 80+ population doubles until 2050
  - 60+ population will grow from 20% in 1995 to 25% in 2020

[1] http://en.wikipedia.org/wiki/Chronic_(medicine)

In 2020 in USA:
- 48% of population will at least one chronic disease.
- 25% of population will at least two chronic diseases.

- Chronic conditions will drive 80% of health care costs.

There are many types of chronic diseases:

- AIDS
- Autoimmune diseases: Lupus erythematosus
- Benign prostatic hyperplasia
- Cancer
- Cardiovascular diseases: Arterial Hypertension, Hypercholesterolemia, Cardiac arrhythmia, Atherosclerosis, Ischemic Heart Disease, Congestive Heart Failure.
- Chronic fatigue syndrome
- Chronic hepatitis
- Chronic osteoarticular diseases
- Chronic renal failure
- Chronic respiratory diseases: Asthma, Chronic obstructive pulmonary disease (COPD)
- Diabetes mellitus
- Hearing impairment
- Mental disorders: Anxiety disorder, Major depression, Schizophrenia
- Neurological disorders: Dementia, Parkinson disease, Stroke
- Obesity
- Osteoporosis
- Psoriasis

The main chronic diseases, which drive the vast majority of health care costs, are the following:

— Asthma
— Chronic Obstructive Pulmonary Disease (COPD)
— Congestive Heart Failure (CHF)
— Coronary Artery Disease (CAD)
— Diabetes Mellitus
— Major Depression
— Stroke

The following chart shows the biometric parameters used to monitor adequately each disease.

	Blood Cholestherol (LDL - HDL)	Blood Glucose Level	Blood Oxygen Saturation (SpO2)	Blood Pressure (SYS-DIA)	Body Weight	Glycosylated Hemoglobin (HbA1c)	Heart Electrical Activity (ECG)	Heart Rate	Physical Activity	Pulmonary Capacity (PEV-FEVI)	Respiratory Rate	Temperature
Asthma			N	N			N	N	N	N	O	
Chronic Obstructive Pulmonary Disease (COPD)			N	N		O	N	N	N	N	O	
Congestive heart failure (CHF)	N		N	N	N		N	N	O	O	O	
Coronary artery disease	N	O	O	N		N	N	N			O	
Diabetes mellitus		N		N	N		N	N			O	
Major depression				N			N	N			O	
Stroke				N	N		N	N			O	

N Necessary parameter to be monitored (> 90% of cases)
O Optional parameter to be monitored (< 90% of cases), depending on diagnostic.

3.4.1.2.2 *Personal Monitoring Devices in inCASA*

Device refers to electronic device that is used to gather information from its surroundings and transmit it where needed.

Each device may be composed of one or more sensors, which are the components that capture the information.

The sensors can be grouped into:

- Personal sensors: used to measure all kinds of parameters (physiological, biochemical, physical activity or location) of the person that it is using it.
- Ambient sensors: used to gather information from the environment and to interact with it.

Focused on Personal Sensors (physiological, biochemical and physical activity), the devices that measure parameters that inCASA project is interested in can be classified as:

- ✓ Cholesterol Meter : Blood Cholestherol (LDL + HDL)
- ✓ PT/INR Meter : Blood Coagulation (INR)
- ✓ Pulse Oximeter: Blood Oxygen Saturation (SpO2)
- ✓ Heart Rate: Blood Pressure Monitor, Blood Pressure (SYS-DIA)
- ✓ Glucometer: Blood Sugar Level
- ✓ Scale: Body Weight
- ✓ HbA1c Meter: Glycosylated Hemoglobin
- ✓ ECG Meter: Heart Electrical Activity (ECG)
- ✓ Heart Rate Meter: Heart Rate
- ✓ Activity Monitor : Physical Activity
- ✓ Thermometer: Temperature
- ✓ Spirometer: Pulmonary Capacity (PEV-FEVI)
- ✓ EEG Meter: Brain Electrical Activity (EEG)
- ✓ EMG Meter: Muscle Electrical Activity (EMG)
- ✓ GSR Meter: Electrical Resistance of the Skin (Used to measure stress levels etc)

The devices can be categorized following different criteria:

- According to reactive process used to obtain the measurement:
  1. Physical: work measuring physical properties like temperature, colour, noise, shape, etc.
  2. Chemical: work through plain chemical reactions.
  3. Biochemical: work through the interaction between organic components introduced in the samples.

- According to the communication media used:
  1. Cable: RS232, USB, proprietary
  2. Wireless Mobile Communication: GSM, 3G, CDMA, etc.
  3. Wireless Short Range Communication: Wi-Fi, IrDA, Bluetooth, Zigbee, etc.

- According to the number of monitored parameters:
  1. Mono-parameter device: it measures only one parameter.
  2. Multi-parameter device: it measures more than one parameter.

- According to how it is used:
  1. Invasive: it requires a perforation into the body.
  2. Wearable: it needs to be worn on the body.
  3. Portable/Mobile: it is hold by one hand when it is used.
  4. Fix: it is set on a fix location.

- According to API Availability:
  1. Private API
  2. Public API: public and no standard
  3. Standard API: public and standard

- According to relationship with the Continua Alliance:
  1. Certified: company is Pro. Member of C.A. and the device is certified.
  2. Promoter Member: full right member company.
  3. Contributor Member: non-voting member company.
  4. No member: company is not member of C.A.

	Cholestherol Meter	Pulse Oximeter	Blood Pressure Mon	Glucometer	Scale	HbA1c Meter	ECG Meter	Heart Rate Meter	Activity Monitor	Thermometer	Spirometer
Asthma		N	N				O	N	O		N
Chronic Obstructive Pulmonary Disease (COPD)		N	N				O	N	O		N
Congestive heart Failure (CHF)	N	N	N		N		N	O	N	O	O
Coronary Artery Disease (CAD)	N	O	N	O			N	N	N	O	
Diabetes Mellitus			N	N	N	N		N	N	O	
Major Depression			N					N	N	O	
Stroke			N		N			N	N	O	

N Necessary parameter to be monitored (> 90% of cases)
O Optional parameter to be monitored (< 90% of cases), depending on diagnostic.

In order to select among the commercially available personal monitoring devices, some basic functional and non-functional specifications should be satisfied:

Functional specifications:

- Must be suitable for home use.
- Preferred wearable than portable or invasive.
- Measure the clinical parameter *as precisely as possible with as little energy as possible*

Non-Functional specifications:

- Preferred short-range wireless than long-range or wired communications.
- Consider devices that apparently are not exclusively commercialized as a part of a closed provider solution pack.

With respect to the above-mentioned specifications a detailed list of available personal monitoring devices may be found in Appendix B

3.4.2 Home Gateway

3.4.2.1 Telecare Gateway: Activity Hub

3.4.2.1.1 *Functional Requirements*

The activity hub acts as a generic low-cost bidirectional gateway between HTTP-XML-traffic and low-level short-range wireless connectivity [6]. Therefore, one or more radio interfaces are required for the dedicated WPAN protocol to link the environmental monitoring devices to the inCASA network. The following functional requirements are given:

1. The SIG Activity Hub may act as a gateway for telecare.
2. Data from the environmental monitoring devices shall be encapsulated into IP-based traffic.
3. End-to-end reliability shall be provided
4. Logging data from the environmental monitoring sensors shall be supported even if there is no connectivity to the Hydra station
5. Support for model creation and maintenance

3.4.2.1.2 *Non Functional Requirements*

1. Security
    a. Avoiding physical unauthorized data access.

       Physical access to the data stored in the activity hub is not very difficult to perform if the data are located in an external memory like a USB drive or a storage card. Even a storage device located on the printed circuit board is relatively easy to read out as their datasheets are publicly available. Therefore, the data located on memory devices should be encrypted.

    b. Avoiding logical unauthorized data access (Environmental monitoring devices).

       Well-established wireless sensor communication protocols are designed to use very little energy and hardware resources. Therefore not all communication protocols support security features. Every wireless communication protocol which is used in the home infrastructure should use an encryption mechanism for the data.

    c. Avoiding logical unauthorized data access (Internet connectivity).

       As the protocols are standardized, many tools are available to monitor the traffic or to conquer weak security algorithms. There are two approaches providing sufficient security to Internet connections. On the one hand, a secure IP tunnel can be established to a known communication partner resulting in a virtual private network (VPN), on the other hand, Transport Layer Security (TLS) can be used for a secure socket interface. Both technologies are state-of-the-art, and one of those approaches should be applied for the inCASA project.
2. Flexibility
    a. Backend connectivity

       Different physical interfaces are possible: from an Ethernet connection over Wi-Fi, GPRS to Public Switched Telephone Network (PSTN) modems.

    b. Home infrastructure

       The SIG Activity Hub supports different communication entities for the home infrastructure. Therefore different communication protocols can be used.

    c. Future extensions

       Because the SIG Activity Hub acts as gateway possible future physical interfaces can be installed.
3. Mobility

The SIG Activity Hub can either be powered by a mains-powered supply or by batteries.

4. Encapsulation

   Besides the gateway function the SIG Activity Hub shall be able to encapsulate the received data from the home infrastructure in a standardized communication protocol like the Continua IEEE11073 standard. Thus the data is delivered in a well-known from regardless of which home infrastructure protocol is used to communicate with an environmental monitoring device. This aspect will be discussed in chapter 3.4.2.1.3.

3.4.2.1.3 *IEEE11073 conformance of the Activity Hub*

Most of the functional and non-functional requirements for the inCASA Activity Hub can be derived from [4]. The IEEE standard specifies the variables to monitor and their range completely, and thus, this specification can be used in many cases. But as it clearly concentrates on event-based communication, the models and limits to cause and event must be defined a-priori. In the inCASA system, the basic idea is to evolve the models during the project, which requires the Activity Hub to also support the transmission of raw sensor data to permit the model creation. This approach causes additional communication and workload for the Activity hub, and in a final version, the feature should be turned off. This leads to the following additional requirements:

1. Functional requirements:
   a. The Activity Hub must transmit events reported from the sensors to the Hydra middleware.
   b. The Activity Hub shall provide raw sensor data.
   c. The raw data interface shall be (dis-)engageable .
   d. The limits for the event notification shall be modifiable.
2. Non Functional Requirements:
   a. The different sensors' device concepts shall be derived from those described in chapter 5 of [4].
   b. The communication model shall be derived from chapter 8 of [4]

3.4.2.2 Telehealth Gateway: SARA client

3.4.2.2.1 *Functional Requirements*

Telehealth Gateway will be based on a pre-existing solution of Telefonica (SARA client) that will be modified accordingly to adapt to inCASA needs. The Telehealth Gateway has to allow patients and doctors sharing information and real time measurements. All these have to be done in a safe way while always keeping patients' sensitive data protected. As far as inCASA platform is concerned, the Telehealth Gateway should meet the following functional requirements:

1. The Telehealth Gateway must provide a mean to measure vital signs.
   a. Telehealth Gateway should collect data from medical devices/sensors that will be part of the inCASA platform (see Appendix B).
   b. Health information must be encapsulated by the Telehealth Gateway.
   c. Information must be sent regardless of the type of the available underlying network technology.
   d. Telehealth gateway should establish communication with Hydra middleware located in the home infrastructure. Hydra will be the entity to interconnect the two parts of the inCASA architecture (Home infrastructure and Service Provider side).
2. A Graphic User Interface (GUI) with a Touchable Screen should be used in order to make inCASA a user-friendly platform.
   a. A flat screen must be provided within patients' house.
3. User must be able to select between different vital signs to be measured.

   a. Heart Rate.
   b. Blood Oxygen Saturation.
   c. Blood Pressure Monitor.
   d. Body Weight.
   e. Blood Glucose Level.
   f. Blood Coagulation/INR.
4. User must be able to send health information to the doctor through the Telehealth Gateway
   a. Different web services will control all the actions users can do.
   b. Information will be encapsulated in a SOAP body.
5. As derived from the user requirements (R04, R24), the Telehealth Gateway should support the manual insertion of measured data
   a. For example, if there is no availability of an INR device connected to the platform, user should be able to insert the data as measured with the use of sticks.
6. Telehealth Gateway should be combined with a tablet in which patient can complete questionnaires provided by the medical personnel
   a. Questionnaires will be related to patient's self-assessment.
   b. The system should be able to send the assessment results to the service provider side meaning that apart from the transmission of vital signs measurements, the interface between Telehealth Gateway and Hydra middleware should be extended to support self-assessment results.

3.4.2.2.2 *Non Functional Requirements*

Apart from its functional requirements, telehealth gateway is subject to non-functional requirements too with emphasis put on its security issues. Such requirements and specifications are listed below:

1. Security
   a. Vital signs information will be protected at a physical level by means of the hardware provided for every sensor. Moreover, SSL protocol will be used to guarantee end-to-end secure communication.
   b. At patient's house, in case of using a WIFI network for sending the information, the network will have to be protected by using WEP ciphering and WPA-PSK passwords. Moreover, only the patient's MAC Address equipment will be allowed to use the network.
2. Encapsulation
   a. All communications will be encapsulated using HTTP protocol. This request-answer protocol will allow us to capture patient's measures
3. Compliance with the vital sign monitoring devices
   a. Messaging in the TeleHealth gateway will use XML to pass information from client devices to the inCASA platform. The Data format will follow the directives of Personal Health Data standards, ISO/IEEE 11073
   b. Telehealth gateway should support both Continua and not-Continua compliant vital sign monitoring devices

3.4.2.2.3 *SARA Client overview*

SARA client will be the part of the inCASA architecture responsible of collecting the data from the medical devices and transmit them to the Hydra middleware. It should be modified accordingly in order to adapt to the aforementioned specifications.

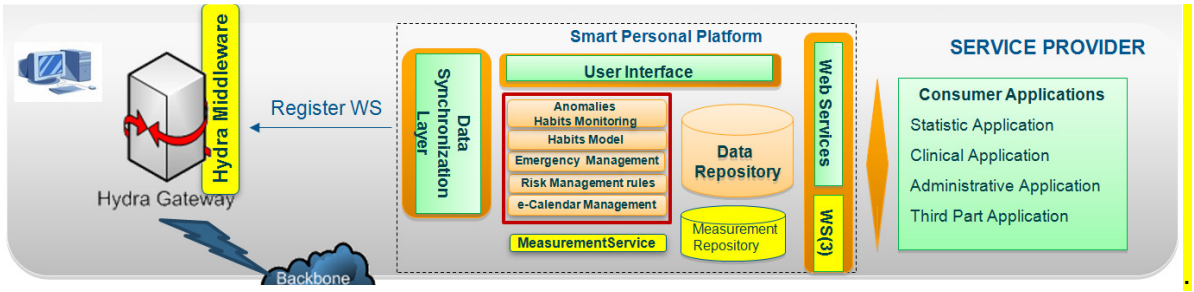
SARA client already supports a subset of the above requirements as shown in the following:

1. Patient can select the variable to be measured

2. Patient can insert manually data into the system

3. Platform supports Calendar view for the patient

3.5 Remote Service Provider Infrastructure



3.5.1 Smart Personal Platform

3.5.1.1 Personal Data

The right to privacy is a human right and is protected by legislation. The European Convention for the protection of Human Rights and Fundamental Freedoms (ECHR) of 1950 which formed the European Court of Human Rights provides a very high protection of the individual The ECHR provides the legal background for the development of specific legislation to protect the interest of the citizen when ICT is used in healthcare. Legal reference to EU directives and recommendations are widely treated on D2.2 and D2.3 documents.
Personal Data treated within the inCASA project are divided in two areas:

- **Non sensitive data:** for example administrative data pertaining to vital statistics (Name, Surname, date and city of birth, etc.) and related legal entities (like Hospital names and locations, companies, etc.). It can be an expression of an opinion about the individual or an indication of the intentions of any person towards that individual. The data can be biographical even when a combination of different data sources is needed to identify the individual e.g. where individuals are identified only by numbers in a database but a list of to whom the numbers correspond is maintained elsewhere;

- **Sensitive data:** Some personal data is classed as sensitive personal data. This type of data is subject to further regulations under local Data Protection Acts and can only be processed under certain circumstances.

Personal data becomes sensitive if it includes any of the following types of information about an identifiable, living individual:

- racial or ethnic origin;
- political opinions;
- religious beliefs;
- trade union membership;
- physical or mental health;
- sexual life;
- commission of offences or alleged offences.

Personal Data managed by inCASA project Service Providers follow the subsequent requirements:

a) sensitive and non-sensitive data must be stored on different repositories;
b) structured documents must be digitally signed and stored encrypt;

c) signed documents eventually produced for project safety purposes (like internal emergency status declarations start/stop) are not displayed to users and should be stored in a separate area of the system;
d) sensitive data for social and clinical purposes must be anonymous and kept in a separate place from other single use related personal data;
e) anonymous data should be "un-anonymized" for social and clinical purposes by matching the authorization level of the user requesting the access to such data;
f) anonymous data should be kept anonymous for administrative purposes;
g) anonymous data should be kept anonymous for epidemiologic purposes;
h) sensitive and non-sensitive data and documents produced should be stored locally: the Service Provider is responsible of the data and only anonymous data can be sent across national borders;
i) Personal data must be accessible from any user (restricted to his personal identity) at any time by request;
j) Personal data must be erasable at any time by request from the user;

Treatment of sensitive data requires a signed informed consent.

All the entities involved in personal data collection and management must be directly authorized by the user to act with his personal data.

A specific informative on personal data management should be produced and made available for downloading anytime by any citizen directly or non-directly involved.

More information about specific local laws will be analyzed with pilot sites representatives to customize the management of data depending on local rules.

In the next paragraph, the way personal data have to be treated within inCASA Service Provider infrastructure is presented.

3.5.1.2 Habits Model

The Smart Personal Platform (SPP) will receive (and store in a repository) data coming from the integrated Home Base Stations and will include a reasoning module able to perform continuous monitoring and analysis of activities of users and to take or suggest decisions in response to specific situations.

A habit model will be defined to capture user normal behaviour, which will be used as a reference to detect anomalous behaviours in a specific condition, as well as to detect indicators of degradation of well-being.
To describe user habits and develop an appropriate habits model, the system needs to know a large number of parameters.

Those parameters should be organized in data structures containing the parameter name, the parameter value and the information about the context where and when the values was collected.

The habits model is a complex entity; moreover it should be deduced from indirect factors like the use of doors, the time spent in bed or in the chair and so on. To achieve this result, sensors will be placed in the user environment to collect the data mentioned above. Data coming from sensor will be analysed considering where they are located in the house.

During installation, the installer should register data regarding sensor position in the map of the house: those data will be stored by the SPP in the database to be used to locate sensors (e.g. door sensor should be linked to the physical position of the door, presence sensor to the room where it is positioned etc).

The use cases that the system will implement were described in D2.1 [1] and in chapter 2 of this document.

To create the habit model based in D2.1 user requirements and D2.2 use cases, the following parameters should be monitored:

- Movement at home
- Contact
  - Door
  - Bed
  - Chair
- Wrist movement (Actigraphy)

For each parameter, values should be stored in the database

Some data can be pre-processed to obtain more useful information.

Chair sensor:
Timestamps collected by the chair sensor (sent when user sits and stands up) can be merged in a value indicating the sit down time.

Bed sensor:
Timestamps collected by the bed sensor (sent when user is lying and stands up) can be merged in a value indicating the lying time.

Door sensor:
Timestamps collected by the door sensor (sent when user opens and closes the door) can be merged in a value indicating the in-room time.

The SPP Reasoner manages an ontological knowledge base that represents the objects in the scenario, and on such knowledge base it applies reasoning rules and decides the actions to perform on the basis of the recognized context.

The ontological model is managed using the following W3C Semantic Web standards, which are being applied in an increasingly large spectrum of applications in which domain knowledge is conceptualized and formalized:

- *RDF (Resource Description Framework)*
- *OWL (Web Ontology Language)*
- *SPARQL (SPARQL Protocol and RDF Query Language)*

All the entities used by the context aware reasoning module must be represented in the ontology.

It is important to highlight that there must necessarily be a correspondence the between ontological model used by the reasoner and the logical models used for communication through Web Services. We define Logical Model as the model representing an entity in the system, so all entities in the scenario must be represented through logical models, used for the communication within the system. Logical Models are written using XML language and to be sure the logical model is well formatted, an XML Schema is used to validate it.

Each logical model has a correspondent ontological model that is used within the context aware reasoning module. Each class represented in an ontological model describes a category of objects in the scenario (e.g. movement sensor, bed, door). An instance of a class in the knowledge base represents a specific individual in the scenario (e.g. the door of the bed room).

User is an entity and must have an ontological model instantiated in the knowledge base.

User activities and habits will be modelled as pieces of context information.

Context Awareness module must provide user profiles, associated to the user ontological model, in order to define the preferences and habits of the user.

Habits can be modelled as attributes of the user profile. For each attribute an average value (e.g. sleeping time) and/or a threshold (e.g. min and max bathroom usage) should be added.
For each attribute with average value or threshold a delta value to be used to evaluate if there is a change in the habit or there is an anomaly can be defined.
For a single user model should be possible to associate multiple users' profiles.

Following an example of user model with 2 user profiles and related attributes:

User Model
- UserProfile01
  - SleepingTimeAverage
  - SleepingTimeAverageDelta
  - TypicalGoToBedTime
  - TypicalGoToBedTimeDelta
  - TypicalWakeupTime
  - TypicalWakeupTimeDelta
  - .....
- UserProfile02
  - OutOfRoomTimeAverage
  - OutOfRoomTimeAverageDelta

The system will support a seamless mode of recognition of the user model so the user will not have to explicitly log in.

3.5.1.3 Habits monitoring

A "User Habit" is defined as the repeating of a single or complex action (like sitting on a chair or going out of home) or a pathway (a sequence of actions like going out of bedroom to toilet every day after getting up from bed) for several times at about the same time during a week. The SPP will build a "normal habits" profile by considering actions during a certain timeframe, e.g. across 2 weeks of monitoring.

Anomalies habits are represented as a parameter (or group of parameters) in the user profile that exceeds a threshold plus an additional delta. All sensors data should be collected during the pre-pilot phase.

Based on the amount of difference between the expected and the actual value the system can:
1. Decide if it is a regular change in habit and suggest adaptation of thresholds to consider changed habits.
2. Decide if it is an anomaly and then trigger an alarm.

There are other parameters that are not user dependent but can influence habits.
Those parameters (e.g. temperature, humidity) will be taken into account when creating the context information.

3.5.1.4 Risk Management Rules

During the activity, the system will update the knowledge base according to changes detected by the sensors (updating properties of existing entities) and analyze the context data to identify the possible actions needed or risks to be handled.

Risks can be defined as a value or threshold reached by a parameter or set of monitored parameter, which can refer to a point in time or to repeated occurrences of situations in a certain timeframe.
To calculate risks, for example, the state of the following sensors should be monitored and available to the context reasoning:

- Door Sensor
- Bed Sensor
- Chair Sensor
- Movement Sensor

The changes in the above parameters will lead to a change in a single value or may require a step of data processing or aggregated data update.

The risk event can be also triggered by the system after observing suspicious situation which could indicate a degradation of user conditions (e.g. habit monitoring can discover an anomaly and trigger a risk alert).
The context information used to detect the risk can be managed by different levels of abstraction:

- Context data directly acquired from the devices and received through the Web Services module (e.g. data from sensors).
- Context derived: context information derived from basic context data.
- Context composed: aggregated by the rules using direct context data, specific information of a service (e.g. thresholds) and derived contexts. It is functional for decision-making.

For example, the position of people or devices may be an element of Context data directly acquired, while the number of people in a certain area, calculated from the observation of the positions of individuals, may be Context derived information. A further degree of aggregation and abstraction is composed using the Context derived and Context data, e.g. "Too high temperature inside the apartment for the normal user activity."

The reasoning process consists of 2 phases to be able to execute the sequence of the rules execution:
Context recognition: for every service the set of rules (ContextRules) exists. Their goal is to identify the service actual context. At the end of this process the ontology will be updated using the property *RecognizesContext* of desired services.
Action request; on the basis of recognized context using set of specific rules (ActionRules), will be decided an action (e.g. trigger an alarm or send the warning message to the Service provider/Consumer application) and property *DecidesAction* will be updated.

The context awareness component should indicate the recognized contexts and all necessary information to understand the decision motivation; in this way information could be visualized to the user (Professional application) and could be traced to internal log files.

The most important subcomponents will be ContextManager and OntologyManager. RulesEngine will execute the necessary rules while the QueryEngine will be used to extract the information related to the context or/and to services of context awareness and ontology.

The alarm or warning messages will be sent to the Service Provider (Consumer Application) through WebServices.

3.5.1.5 Socio-Medical Calendar

Socio-medical calendar is a component of the system which will directly help users of the inCASA system.

Socio-medical Calendar will be an easy-to-use scheduler for inCASA operators which will support operators to plan for activities within inCASA services, to set reminders for the elderly users and on which take notes on actions and on which record all the remarkable.

This module will be a scheduling rules package for a single operator as well as for a team. It will help to create an organized schedule for the whole staff and to plan for reminders to be sent to the users or surrounding people (relative/neighbour/nurse) through e-mail, sms or phone call.

Each operator will create a profile to run his personal schedule allowing the viewing of multiple profiles at a time, to view the schedules of several or even all operators of the team simultaneously.

It will allow jumping to the required date, editing appointments, managing patient data, planning for a reminder to be sent to single user's home gateway (where an interactive module is deployed) and record actions and related notes.

All information will be accessed through a GUI by a single user sign-on and linked to the "calendar entry" just for the session. Personal data will be stored in Service Provider's infrastructure repository, secured with an encryption algorithm and "single access key" protected preventing from unauthorized access.

The secured archive will be auto backup function enabled.

The archive will allow user to extract data and export to a variety of formats, including MS Outlook, XML, HTML, XLS, TXT, CSV.

3.5.1.6 Emergency Management

Emergency management is the business logic defining workflow to tackle an anomalous issue and drives headquarters operators interacting with elderly persons or performing correct acts to resolve the situation.

Within the normal routine of the system, an event flagged as an emergency could happen. The system will receive the information as an emergency and will immediately trigger an alert and request a specific action.

Emergency can be defined as a trigger event detected by a sensor or an outcome of a determined workflow.

Data related to Emergency events should have a dedicated table in the Database so every module can access to this information.

To trigger an emergency, state of the following sensors should be monitored and available to the context reasoning:

- Water Leak Sensor
- Gas Leak Sensor

- Smoke Sensor
- CO Sensor

Any change in the above parameters from the "=0" value will lead to an immediate alert on the operator's workstation.
All data, included those related to emergency scenario, will be stored in the Database.
Reasoner should have a dedicated rule running on emergency related data.
Also, data related to emergency scenarios, should be received by Professional (Consumer) Application and an action should be taken when an emergency occurs.

The context information used to trigger an emergency will be managed by "context data", directly acquired from the devices and received through the Web Services module (e.g. data from sensors).

As a binary trigger event, the context will be composed only by an O/I message. A set of rules might handle logic (if needed) to react to the emergency or to escalate it.

Where applicable (actuators installed), through the WebServices an activation request could be sent to elements of the system in the form of logical models with updated properties (e.g. new state for an actuator). This could allow handling (in the future platform extensions) actions such as, e.g. close the main gas or water tap.

3.5.1.7 Consumer Applications

The Consumer Applications (CAs) are a *set of high level views* available to the personnel of the hospital (i.e. doctors, nurses, social workers). In terms of provided functionality, CAs differentiate from the Repository GUI for doctors/nurses use, that will only be accessible by specialized personnel (doctors and database/system administrators) and will offer direct access to the central repository, for configuring the platform or enabling other support actions. As far as the inCASA project is concerned, CAs will be accessed by key personnel that are responsible for tracking the elderly persons' condition but *without being able to directly modify data in the central repository or the platform's configuration*.

After analyzing the requirements specified by the end-users, and within the context of the already defined use cases, we purpose a *layered approach* to CAs services:

- *Personalized data and alerts view* (for individual patients):
  - Multiple views on the clinical condition of the elderly patient and on the contextual data regarding his/her habits. The corresponding alerts will also be rendered on these views.
  - Multiple views on the comfort at the patient's home indicator. The technical emergency alerts will also be rendered on these views.
  - Alerts will be rendered in different colors to indicate their criticality along with their primary intended recipients (i.e. doctor, nurse, social worker).
  - Composite views that enable the end-users to display multiple variables or indicators on the same diagram (i.e. weight and glucose monitored data or level of movement and bed permanence sensor data).
  - The snapshots dataset will be used to render each view on every monitored data. The user will be able to switch to the trends view, if such view is applicable to the corresponding monitored data.
- *Executive view* (overview of all patients' condition):
  - This view will render a (priority) list of patients along with summary information on their condition.
  - Color priorities from green to red will be assigned and displayed for each patient, in accordance to their health status evaluation and last occurred medical/technical emergency, which may command a low response time.

- This view is also complemented with the last alert raised about each individual patient.
- The end-user will be able to select a patient to view the respective tracked data and alerts history.
- The end-user (doctor) will be able to select a patient to schedule a single-coded activity (set an appointment for examination, medication change).
- Optionally, the end user will be able to select a patient to set up a teleconference with.

Additional cross-cutting concerns to be addressed in the CAs implementation are:

- Reminders or other pieces of information, that do not explicitly require the intervention of professional users, will not be rendered/handled by the CAs.
- Individual views may be customized to each end-user role (i.e. different views for nurses and doctors). Application of security permissions assigned to each role will be enforced to ensure that no liabilities will arise regarding the access to private data.
- Administrative tasks will be separately handled by the Admin UI. For example, if the doctor wants to change a target value for a measured clinical variable, he/she will have to invoke the Admin UI from the CAs applications.

Mapping the requirements in Table 1 and 2 then leads us to a new representation of each single categorized requirement where they each are being related to a view type as shown in the following table.

Type Name	Requirements Code
Personalized data and alerts view	(functional) R05, R17, R18, R31, (non-functional) R06
Executive view (overview of all patients' condition)	(functional) R10, R18, R27, R31, (non-functional) R06. R26

Table 26 – Requirements mapping to CAs views

Towards meeting the above specification, CAs views compilations will be based on the following back-end (server-side) modules:

- *Anomalies Habits Monitoring*: Based on the habitual/mobility data of patients tracked by the inCASA platform and in correlation to their medical history, a comprehensive set of alarms is set-up to notify medical health personnel, when there is a significant variation in their behavior patterns that may indicate ill-response to prescribed treatments or possible indicate a deterioration in their health condition.
- *Risk/Emergency Management*: A set of indicators are implemented in this module that allows the automatic provision of notifications to the medical personnel, when patients are facing possibly dangerous or abnormal conditions. The indicators' definition will be partially based on the specific chronic health condition tracked by the inCASA platform and evaluated against available data.
- *e-Calendar Management*: This module provides an overview on the patients' health status to doctors and allows them to make informed decisions on when to schedule their next appointment to conduct further medical examinations, possibly based on automatically assigned by the system priorities.

These modules will physically be deployed on the inCASA server, and implemented as business/core-logic modules of a co-deployed application server.

Type Name	Category	Description
Anomalies Habits Monitoring Module	Application Server	Builds upon fused habitual/mobility data of patients tracked by the inCASA platform, using environment sensors or devices. Correlates behaviour model to the medical view of individual patients and to their respective chronic condition.

Risk/Emergency Management Module	Application Server	A set of indicators are implemented in this module that summarize patients' condition; summaries are complemented with most recent alerts/notifications; the summaries list items are prioritized in accordance to the assigned criticality of indicators and alerts.
e-Calendar Management Module	Application Server	Provides an overview on the patients' status to doctors and allowing them to make informed decisions on when to schedule their next appointment to conduct further examinations.

Table 27 – CAs business/core-logic modules residing on the application server.

Essentially CAs structuring is based on the following core components/layers of the inCASA platform:

- *Communication layer* as an abstraction over the application programming interface to the EPR repository of the Smart Personal Platform (SPP).
- *A rules engine* that compiles a set of rules defined over the pertinent medical protocols; patient's data available from the EPR repository will fire these rules to a different extend, allowing events to be initialized and reported through the CAs user interface.
- *Aplication server* for the compilation of the respective views of the Consumer Applications, to be dynamically updated as new events are reported. Each view will be rendered as a web page based on the different viewpoints and roles of the end-users (medical practitioner, social worker etc.).

Implementation-wise the prescribed CAs components/layers are built upon the services offered by the SPP. These platform services are exposed high level functionality as web-services. Within this line of thinking two different scenarios are compiled:

- *Scenario 1*: The CAs core logic is implemented as an SPP module. The functionality of the CAs is exposed as web services that can be consumed by an application server responsible for rendering the respective views. This scenario virtually eliminates the need for the specification of a specialized communication layer to access core SPP services (access to EPR database, built-in rule engine).

Scenario 2: The CAs are built as an external to the SPP module, but use exclusively high level interfaces to SPP core functions (i.e. using web services). This scenario entails the use of an application server that will render the respective views, along with an extensive communication layer that will allow access to core SPP services (EPR database, built-in rule engine). The prevailing advantage of this approach is the loose-coupling of the CAs with the SPP using higher level interfaces, allowing their independent development.

3.5.2 Backbone Gateway: Hydra Middleware

Mobility in the healthcare and social care is a more and more important topic and challenges in the mobile domain are mobile applications and services, middleware for mobile communications, security mechanisms, network architectures, technologies, and protocols for wireless and mobile communications which clearly cannot be solved in short term. Therefore it is important to address aspects of long term evolution and security aspects in the design and specification by establishing a high flexibility with respect to used methods and algorithms. Providing a flexible but robust middleware solution can therefore be seen as the cornerstone of the inCASA platform implementation.

3.5.2.1 Functional Requirements

On the technology side, the inCASA solution aim to reduce duplication of information collection and assessment activity such as when patients move from one part of the service to another. Moreover, reducing the proliferation of record systems and unnecessary duplication of information would also assist professionals across the services to be familiar with the system and enable easier retrieval of information, but foremost to ensure information for an individual. This objective

can be achieved thanks to an unique platform as described above and by unifying process workflow and by enabling relevant information to be shared between the health and social care records systems, subject to the individual's consent. Building and assembling the inCASA platform from different resources is then dependent on the requirements met for its interfacing technology where the Hydra Middleware is presupposed to play a central role. The functional requirements here describe the eligibility of the Hydra Middleware for this purpose.

3.5.2.1.1 *The Hydra Middleware Architecture as basis*

The contribution by the Hydra middleware for the initial prerequisites described above is that it can provide for: a discovery mechanism hiding differences in lower level protocols, web service enabled access to all devices, security and trust policies which directly can be used by the developer of inCASA applications, and an IDE for the inCASA application developers. The embedded and mobile Service-oriented Architecture (SoA) in Hydra provides interoperable access to data, information and knowledge across heterogeneous platforms, including web services. For this, a main functional requirement of the Hydra encounter modules is to provide interfaces in order to enable this access. As such, the Hydra Middleware in inCASA will be able to support a true ambient intelligence for ubiquitous networked devices.

The Hydra middleware incorporates support for self-discovery of devices. When a Hydra enabled device is introduced to the BAN or PAN, the middleware is able to discover and configure the device automatically. In Figure **20** we see an example of a Hydra device network. Hydra distinguishes between two different devices. More powerful devices are capable of running the Hydra middleware natively and smaller devices that are too constrained or closed to run the middleware. Proxies are used for the latter devices where the proxies are embedded in the BAN or the PAN node. These proxies presumably have more computing power than the device itself has and once proxies are in place, all communication is optimised by being based on the IP protocol.

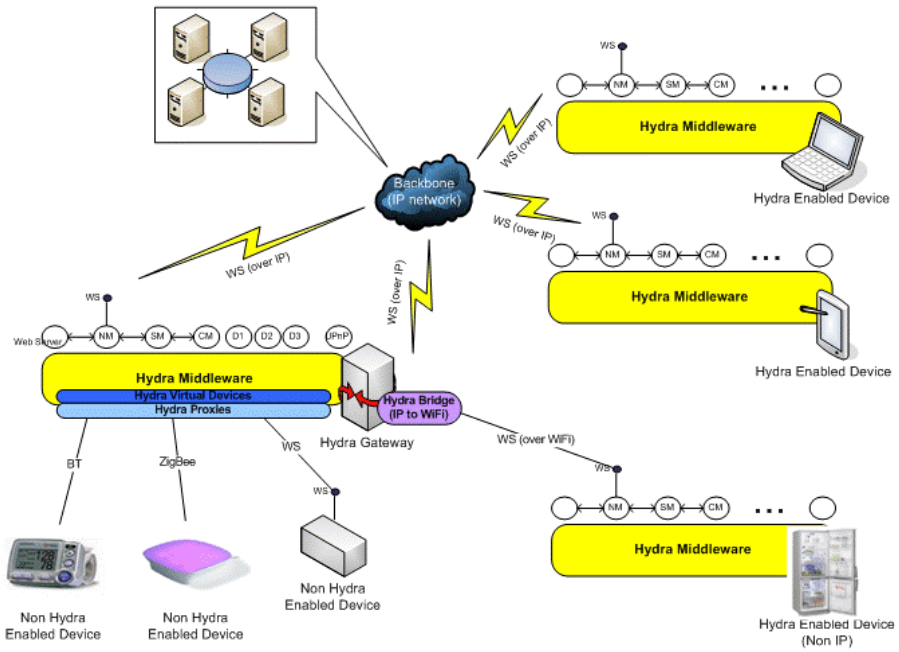


Figure 20: Incorporation of devices using the Hydra middleware.

If we look again on the figure above (Figure 20) that illustrates the two cases, we will see on the right the terminal that directly can incorporate Hydra middleware and is able to establish communication with services on the inCASA platform. In the situation on the left, the devices cannot operate the Hydra middleware (because they are too resource constrained or have proprietary interfaces). In this case, proxies are created on the BAN or PAN node (in this case a mobile phone) that virtualises the device vis-à-vis the inCASA platform. Any service will think it is communicating with the device, where in fact it is communicating with the proxy.

In sum for this section we can state that the first sets of functional requirements by the involvement of the Hydra Middleware in inCASA are:

- To support different standardized wireless and wired sensor devices communication technologies (e.g. ZigBee, Bluetooth, EnOcean).
- The need of interface descriptions of the modules involved in the data exchange with the inCASA Hydra middleware.
- To bi-directionally support data transmission between inCASA modules without the risk of lower QoS.
- To create proxies for all devices, both medical as non-medical (e.g. environment sensors) found relevant for use by the inCASA platform.
- To process basic semantic annotation and interpretation of monitored variables and their values.
- To allow some caching abilities to ensure that failed data transmission can be recovered on higher conceptual level.

3.5.2.1.2 *The use of Web Services*

Traditional WS architectures are based on client-server architectures, where the server is an always-on end system with a well-known endpoint address, which should be known by clients beforehand (using either service descriptors or UDDI registries). The SOAP tunnelling approach proposes a way to replace this client-server architecture for a distributed one, using the Network Manager P2P platform. In this architecture, all the peers will act as clients and servers at the same time. Figure **21** shows an example of a client-server based architecture and the distributed approach. Furthermore, actual Web Service (WS) communications require direct connection between the client and the server, being impossible to consume services across networks.

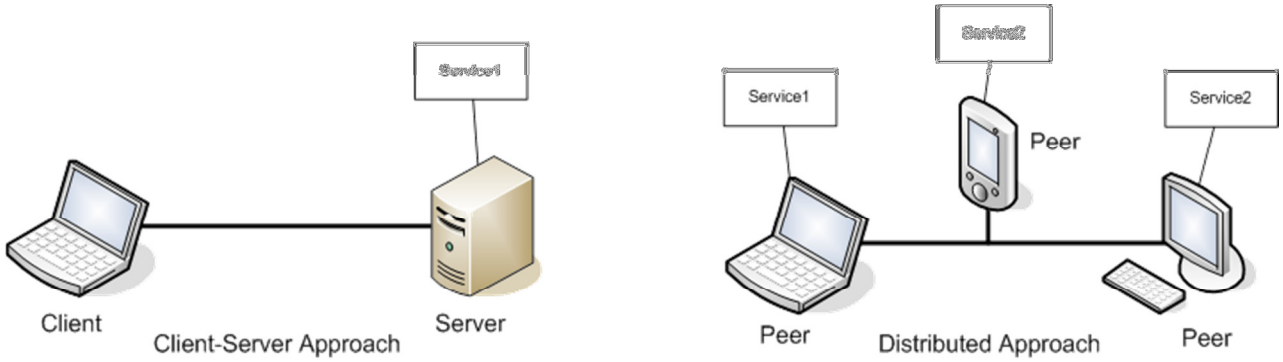


Figure 21: Client-server vs. Distributed approaches

As the Hydra architecture is service-oriented and WS is the technology used to implement it, the communication between applications running in different inCASA Hydra-enabled devices is most suitable to be based on SOAP messages that run in a distributed network approach.

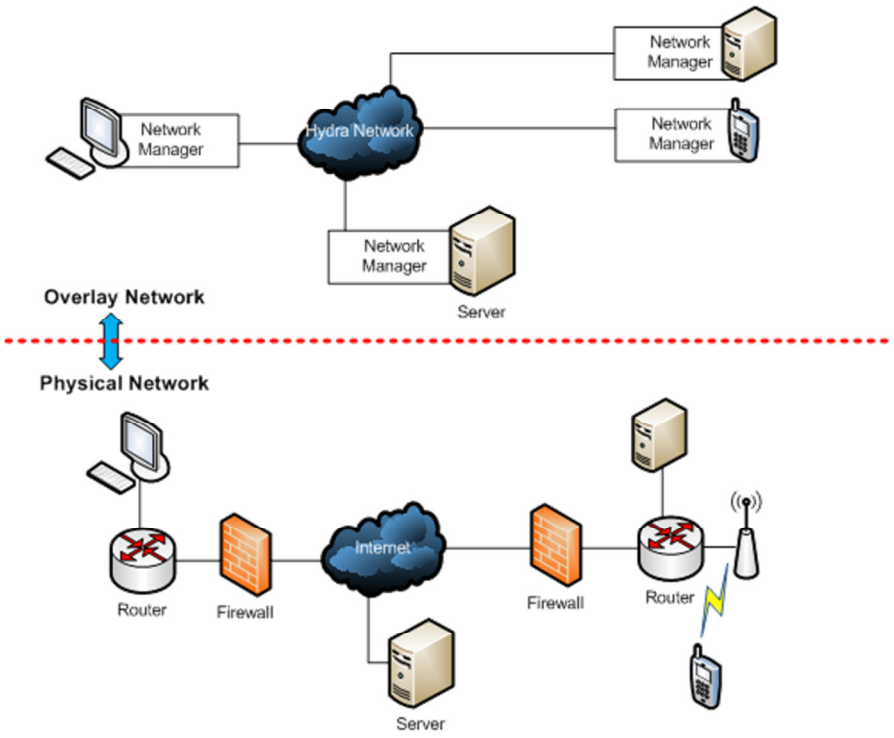


Figure 22: Overlay network for Hydra in inCASA.

From the middleware point of view, a Hydra Identifier (HID) based addressing method has been defined for Hydra, instead of the usual IP based one. The responsible of managing these HIDs is the HID Manager. Its main functionality is providing a unique context dependent identifier for every device (physical or virtual), resource or service, called HID. It is also responsible of maintaining the idTable, a data structure dedicated to store the matching between logical and physical identifiers. However, this addressing is useless if there is not a way to propagate this information to other HEDs involved in the inCASA Network. The Backbone Manager can then be responsible of spreading this information between the different HEDs in the network. Thus, every HID Manager belonging to the inCASA Network keeps inside the Hydra idTable an updated list of every HID in the network. This process is known as Network Manager Discovery and can easily be deployed over the inCASA platform solution. This means that the inCASA Network (Hydra Network as seen in Figure **22**) communicates the left hand side Network Manager (e.g. deployed in patient's home) with the different Network Managers at right hand side (e.g. ATC or a physician's clinic) and back.

In sum for this section we can state that the last sets of functional requirements by the involvement of the Hydra Middleware in inCASA are that:

- The inCASA Hydra Middleware needs to be able to communicate with its adjacent gateways (i.e. inCASA platform modules) in order to receive telecare and telehealth data respectively. For this Web Services form the communication basis but where formats may be of variable kind (e.g. XML, IEEE11073).
- The inCASA Hydra Network Manager will benefit when deployed on adjacent upper layer module (i.e. server side) for data management etc.
- The inCASA Hydra Middleware preferably should be based on Web Services as the communication for inCASA.

3.5.2.2 Non Functional Requirements

The most non-functional requirements regarding Hydra are practically absent or covered by the Hydra functionalities. For example, security goals such as confidentiality, authenticity and non-repudiation are through Hydra addressed by a particularly trust-worthy design and implementation of web-service based mechanisms. These are enriched by ontologies. The inCASA platform can

use the concepts behind the Hydra security meta-model where semantic resolution of security focus on moving security from identity-based into a semantic and credential-based solution. In sum for this section we can state that the set of non-functional requirements by the involvement of the Hydra Middleware in inCASA are:

- To ensure that the inCASA communication supports the necessary security and reliability set in WP2 through the use of the semantic Hydra functionalities.
- To ensure that authenticity and privileges are transparent throughout the inCASA platform.

3.5.2.3 Example 1 - Basic Hydra Middleware Implementation

In Hydra, devices are presented as UPnP devices by the Device Manager. UPnP discovery information is though usually restricted to Local Area Networks. But using the SOAP tunnelling the Device Manager is able to exchange the UPnP information between different Discovery Managers in the inCASA Network. Thus other Device Managers will be able to control UPnP devices located in remote networks using the SOAP technique presented in this section. This allows for communication and access between devices that are in two different networks, for instance between the social caretaker's office and the patient's home (Figure 23).

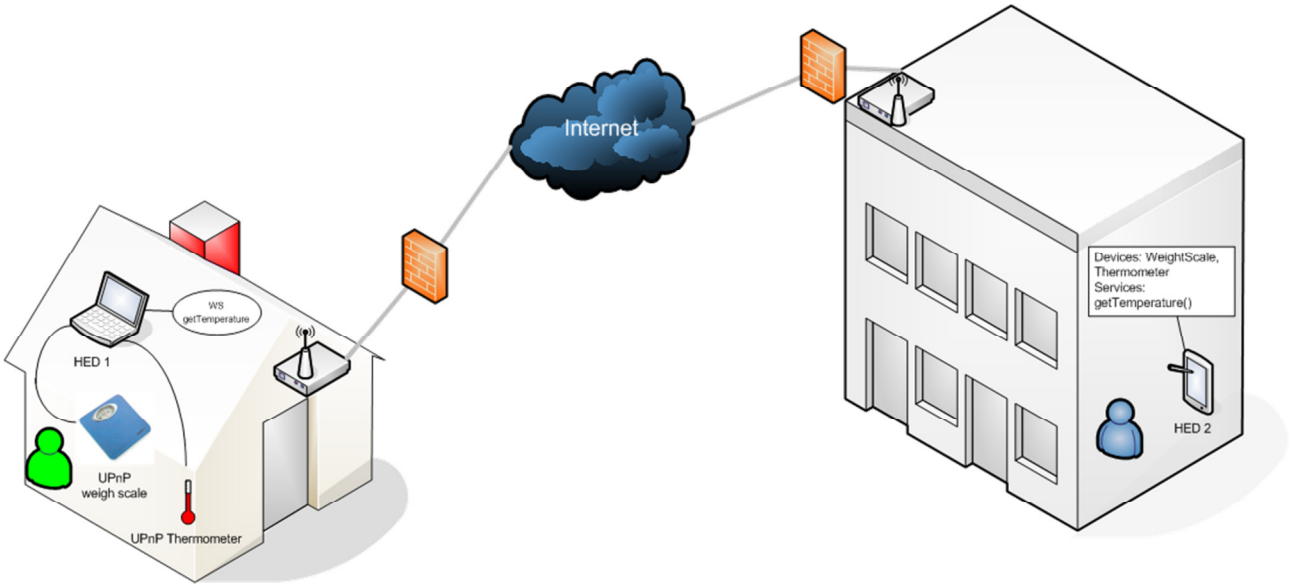


Figure 23 - SOAP tunnelling applications example in inCASA.

This example therefore assumes that a patient (i.e. elderly) is at home and now and then takes measures according to ordination. Environmental sensors build up a behavioural model by which alarms eventually can detect abnormalities. If the left house in the figure is the patient's home and the right house is for example the ATC centre in Torino, the Hydra Middleware can enable the inCASA platform to pick up the sensor values that are collected by the different modules at patient's home and transport the data via Internet (that is via disjointed inCASA Network Managers) to the ATC centre where the data can be monitored and evaluated by the social or health care. The functional requirement of SOAP tunnelling can thereby ensure a secure communication between patient and caretaker and by semantic messaging of data also fulfil a non-functional requirement such as reliability.

3.5.2.4 Example 2 - Hydra as Continua Compliant

Even though Hydra is a middleware and the MDA is a part of that middleware, the inCASA platform can benefit from Hydra tests within two different application domains: home automation and eHealth. Recent developments in home automation has resulted in new types of home appliances that are DLNA-compatible (a further development of UPnP), mainly various media management devices. These devices should be able to coexist in a inCASA network, with other types of sensors and actuators based on various wireless technologies like ZigBee, Bluetooth and RF, which are

supported by Hydra. In the area of health, Hydra is supporting the use of various monitoring and sensor devices, for vital signs monitoring and environment sensors.

The Continua Health Alliance (Continua Health Alliance 2010) was formed to establish an ecosystem of interoperable personal health systems that empower people and organizations to better manage their health and wellness. This goal was to be accomplished by ensuring interoperability between components, systems, and subsystems incorporated within these health systems. To achieve this aim, Continua established a Technical Working Group (TWG) to select the standards and specifications and define Design Guidelines to further clarify the standards and specifications to ensure interoperability might be achieved.

The Continua Health Alliance's Design Guidelines[2] contains references to the standards and specifications that Continua selected for ensuring interoperability of devices. It also contains additional Design Guidelines for interoperability that further clarify these standards and specifications by reducing options in the underlying standard or specification or by adding a feature missing in the underlying standard or specification. These Continua Alliance guidelines focus on the following interfaces: PAN-IF - A common Interface to Personal Area Network health devices, xHRN-IF - An interface between Disease Management Services (DMS) WAN devices (i.e. xHR Senders) and Electronic Health Record (EHR) devices (i.e. xHR Receivers). These guidelines were specifically written for device manufacturers that intend to go through the Continua Certification process with their devices, companies that integrate Continua devices in systems and subsystems, and test labs that certify compliance to Continua specifications.

The Continua Architecture is in part similar to the inCASA platform, and is designed to accomplish similar goals. The architecture depicted in figure below corresponds to the patient's sphere, and includes the wireless and wired sensor connections of the Continua Sensor-LAN interface, that conveys sensor data to the Application Hosting Device (AHD), see Figure **24**. The AHD acts, in effect as a gateway and forwards the data to the WAN device in the healthcare enterprise over the Continua WAN interface, see Figure **25**. This corresponds to the internal parts of the data management layer of the inCASA platform and could by ease be implemented according to this.

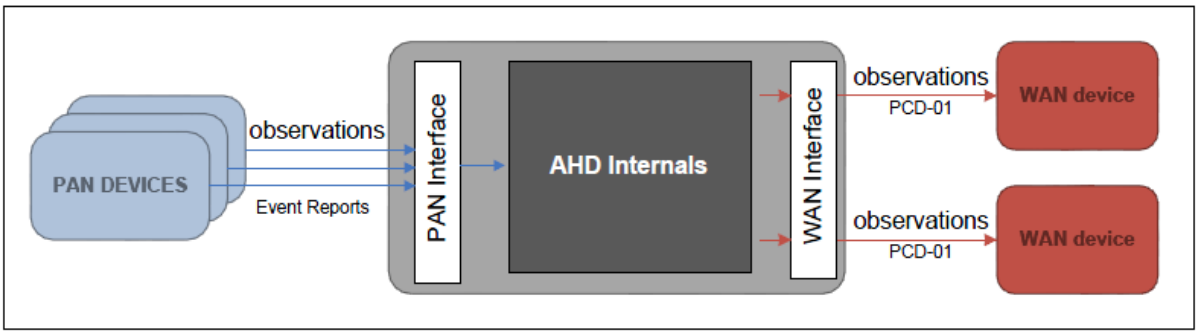


Figure 24: Model showing how AHD may collect observations from multiple PAN devices at any given point in time and a single PAN device may deliver data to multiple persistent sessions. Likewise, an AHD may deliver these observations to zero or more WAN devices.

Within the inCASA project, the UK national pilot will reuse pre-existing technology solutions and devices compatible with the Continua Architecture. In this respect, the pilot will help identify interoperability aspects of the inCASA platform with recently ratified standards, forecasted to have a growing long-term impact on the personal health systems industry. The expected result is that added-value will be brought to the inCASA platform, by introducing concerns related to the deployment of diverse services and devices early on in the architecture design and implementation.

[2] http://www.continuaalliance.org/products/design-guidelines.html

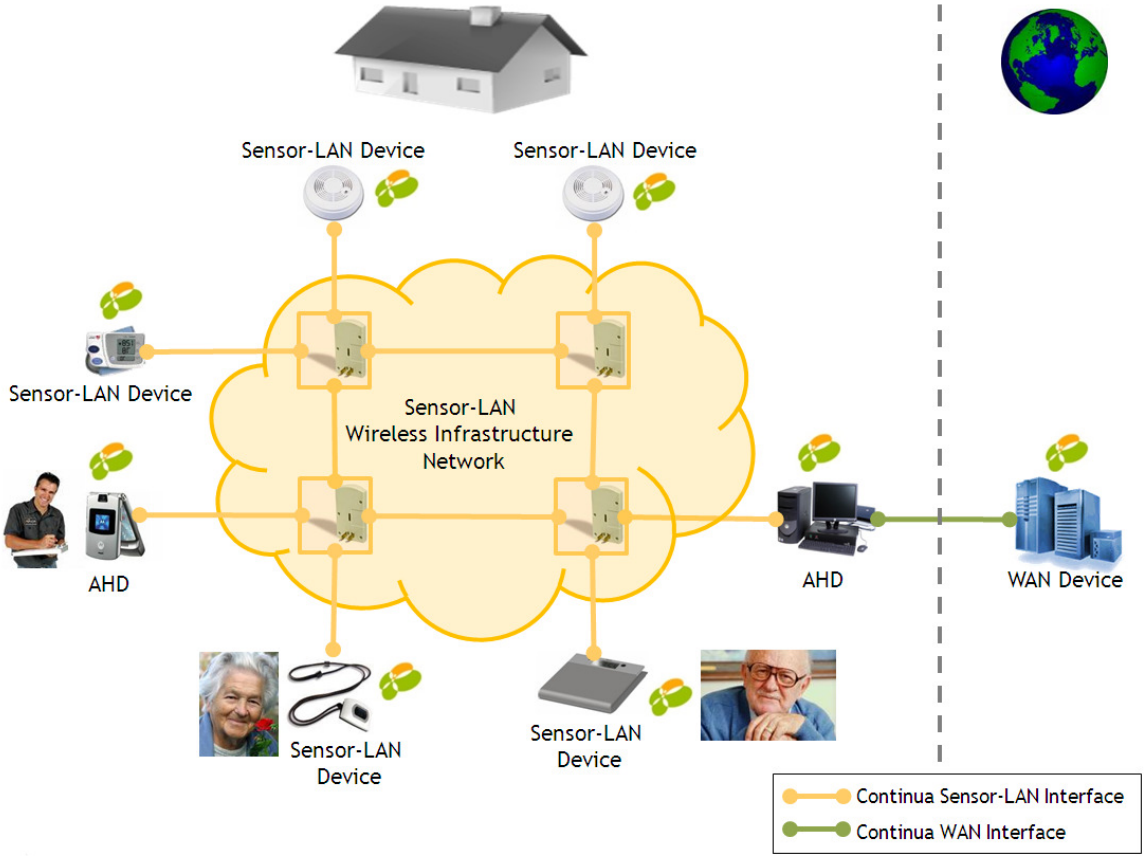


Figure 25: Sensor-LAN Conceptual Setup (from Continua Sensor LAN Interface Design Guidelines).

The standards used as the basis of Continua compliance are recently ratified, and thus commercially available devices are increasingly being announced. Some of the major manufacturers that were involved in the development of the IEEE standards and the specialisations have devices available.

In Appendix C, there is a list of the monitoring devices selected for the UK pilot which all are Continua compliant.

Finally, the example here could be a patient that uses a Continua compliant medical device to send physiological values to his or her doctor. The inCASA platform may then rely on the currently implemented Continua interface that exist in the Hydra Middleware and bypass other modules for this cause. The Hydra Network Manager could pick up this request and process the data according to the internal Hydra AHD structure whereas so called WAN Device (i.e. physician's office computer) receives the data in form of the IHE-PCD01 format. All provided by the Hydra Middleware itself but still overhauled by the inCASA platform.

In sum, the starting point of inCASA is the reuse of pre-existing technology solutions that come from different sources. The final goal is to build a strong synergy between investment made by the public and the private sector, in order to build an integrated solution that can be delivered according to a pay per use model. The choice of technologies available for integration within these systems is large and alternative technologies are considered by the Continua Health Alliance that has been mentioned here but also by others. The simplest way to see Hydra as Continua compliant in inCASA is to address its functionalities and services in the Continua AHD model and centre Continua topology where it serves incoming and outgoing data according the Continua guidelines.

4 Design Principles for inCASA

4.1 Functional and Technical principles

To build inCASA system, we set a number of functional and technical principles that will ensure the implementation of a comprehensive yet flexible platform. The goal is to create a commercial product that can evolve and incorporate new scenarios for remote healthcare monitoring.

inCASA spreads over a large number of biometric and home automation devices that again can spread over large spatial areas. For those highly distributed systems some basic design principals have to be considered. This chapter enumerates and describes an array of general design considerations that form the character and affect the appearance of the inCASA architecture, considerations that have already been taken account in Hydra design. Note that while some of these considerations may seem obvious in retrospect, the contribution of this section lies not only in identifying them, but also in illustrating how the design of the architecture addresses these issues. These issues influence the software development process of all the aforementioned inCASA components.

I. **Distributed vs. Centralized Approach**

Devices for collecting biometric parameters and home automation sensors combine several hardware and software components such as content, applications, displays, etc. required for the delivery of multi-purpose services. Users of such devices will share their content with other users either over a network or through other storage media. The inCASA project aims at an automatic sharing of content and information between several devices of a single user, but also among users. In addition, inCASA focuses on applications and services that will be deployed in environments, in which parts of the application need to be distributed. The distribution occurs on two different levels: on a conceptual level where information is distributed and on an implementation level where system components are distributed. A management of distributed components occurs in a centralized or decentralized manner.

A centralized approach bases upon a centralized component or server for several types of information and services, which provide requested information to the applications running on several devices. This approach decouples the acquisition of information (content, user-related information, context, device properties, etc.) from the processing of this information. These applications can actively request the desired information from the server or passively be notified about changes. The server collects all information from accordant acquisition components and provides it to interested applications. A centralized approach suffers from a restricted scalability, in consequence of a maximum of applications that can be served by the server. In addition, the problem of privacy rises, since all user-related information is bundled and stored in one place. Instead of maintaining all information and services in one centralized place, a distributed approach holds the information at several places to avoid a potential bottleneck. Small devices maintain the information required by the application themselves and process it directly. This approach requires the device to have the capability to store and process all of the necessary data, which may not be efficiently achieved for a simple device with restrictions concerning space, weight, or energy consumption. The decentralized approach avoids the lacking scalability of the centralized approach and allows the user to control the way how their personal information is published and thus, their privacy is guaranteed. On the other hand, the sharing of information while preserving privacy is an issue.

The **inCASA system aims for a centralized approach**, in which all data that are collected in the field are forwarded to the Hydra platform. The sensor networks use a star topology, which is the only common topology for all supported network standards. The Activity Hub or the Sara Client platform act as a concentrator forwarding the communication flow to their logically connected

Hydra platform, while multiple Activity Hubs may be connected to the same Hydra platform. This platform is connected over a secure tunnel to another Hydra implementation on the server. During the project, this centralized approach with all data in one single place eases the model creation and dissemination, which is one of the most crucial parts of the project.

II. Application Robustness

The inCASA project is not meant to invent guarantee of service for distributed networks. It is assumed that the communication channels do not significantly change during the system use, and that all devices in the environment of the inCASA components work within the limits of the European Norms. In that case, standard algorithms, e.g. Frequency Agility, are used to overcome the interference. This requires that during the installation process, the link quality over the complete data path is checked. During the lifecycle, the inCASA system may face the following communication errors:

a. **Missing contact to a single sensor**. In case of a crucial sensor, an alarm is generated in the backend, otherwise, the service personnel are informed.
b. **Missing contact to the Sara Client or the Activity Hub**. It will be distinguished between an intentional shutdown, e.g. as the monitored person decided to stop the service, and a system failure. When stopping the service intentionally, a message is sent to the Hydra platform, and the shutdown is only performed if this is acknowledged.
   On an unintentional shutdown, the backend will raise an alarm, which results in contacting the service provider or the person. Such an alarm will also be raised in case of an intentional shutdown if the connection is not re-established within the predefined time.
   If the Activity Hub or the Sara Client becomes aware of their connection loss, they try to contact their alternative Hydra Platform, which can be reached using a pre-defined IP address. This measure counteracts the cascading tree approach described above, but it provides the opportunity to shut down a single Hydra Platform without disturbing the system functionality. If the field devices are not able to contact any Hydra Platform, they go on with the model they had received on their last contact with the Hydra Platform. This reduced functionality is shown to the user.
c. **Missing contact of the Hydra Platform to the server**. The Hydra Platform on the client side regularly updates the models to apply from the server. In case of a communication failure, it goes on with the latest models available, but configuration changes are not permitted during this phase. At the server side, an alarm leads the information of service personnel.

III. **Modularity**.

The system must avoid a design oriented to a particular scenario. Therefore, the system can be easily expanded in different ways:

a. For CHF patients for example, blood pressure, weight and cardiac rhythm are monitored. However the platform supports flexible monitoring of vital signs by addition of new sensor devices in order to increase the biometric monitoring capabilities (pulse oximetry, blood glucose, ECG etc.).
b. Flexible deployment of questionnaires on symptoms and patient overall status.
c. Updated details on treatment and medication provided to the patient
d. Addition of educational content (videos, advices, etc).
e. The communication protocols and the different sensor models are selected to support the abstraction of the underlying technology.
f. Service-Oriented Architecture, devices, sensors and application should be loosely coupled and available through service interfaces
g. Support for both non-Continua and Continua devices. It is important that both legacy devices/sensors already available on the market can be integrated with inCASA platform as well as Continua devices

h. Use of IEEE11073 data models for device virtualisation. We will use the IEEE11073 data models for the internal representation of devices, even if the device is a non-Continua device.

IV. **Patient-centred care and customization**. Patients have different restrictions depending on different factors: severity of the pathology, age, sex, co-existence with other pathologies. Therefore the platform has to allow the customization of chronic care plans according to the particular patient's condition. Customization implies the selection of the most convenient vital sign monitors (including associated alarms), questionnaires, medication, plus educational content.

V. **Easy-of-use**. That is a mandatory principle specially, when addressing a population that has little experience with computers. Therefore, usable and accessible interfaces should be provided. Easy-of-use is also a key aspect towards ensuring the engagement of the patient which ultimately relies on the adherence to treatment. The easy-of-use has also a positive impact on patient's motivation.

VI. **Alarm Generation**. The system has to provide mechanisms for the early detection of alarm signs that may impact on patient's safety. For example, the platform shall detect if patient reports a worsening of symptoms related to his/her disease, vital signs are out of expected ranges or medication intake is skipped.

VII. **Security and Privacy**. **No personal data is sent out of the hospital domain, and no personal data are stored in field devices**. The sensor data that are stored before being forwarded to the Hydra platform shall be encrypted if access to these data might be possible. The communication protocols shall use encryption according to nowadays standards.

VIII. **Complementarity with existing clinical processes**. This means that the system is ready to be integrated with Hospital Information Systems (Personal Health Records applications, among others).

4.2 Information Provisioning

It is of key importance that information can also be observed locally. There are two possibilities to provide information to the local user. One alternative is the direct communication to the gateway or middleware and the other alternative is the provisioning of the data from the backend system. In both cases, a graphical user interface (GUI) is required. For both cases of connectivity, the GUIs can be implemented as well as a rich client or as a rich internet application (RIA). This second approach comes with an enormous number of advantages in the world of embedded communication. The advantages of RIA are freedom of installation and a so-called single source of software. The software has to be provided only at the server, not at each individual client. Above all, this software provisioning is independent of the distance of the client, i.e. it may be a local client or a remote client, which is connected over a network. Consequently, this approach may even allow the provisioning of GUI independent of the discussion of local or backend data provisioning. The largest disadvantage is the fact the run-time environment of a web-browser (http-client) is used. Hence, the implementation is dependent on the browser type and version. As a consequence, it is recommended that only an interoperable subset of GUI functionality is used.

5 Conclusion

This deliverable provides a systematic transcription of the inCASA platform specifications and design principles. A critical factor towards meeting aspects of the individual inCASA pilots, as described in Deliverable 2.1 “Preliminary requirements investigation”, and the consolidated requirements, as listed in Deliverable 2.2 “Requirements consolidation and prioritization iteration 1”, was the provision of an abstraction over the inCASA platform use cases. The developed use cases were also mapped to the components and the software modules made available by each individual technical partner of the inCASA project.

From the functional point of view, the inCASA platform core services are categorized over the Telehealth and Telecare domains in Chapter 2. This division greatly simplified the analysis process. It also enabled the identification of cross-cutting concerns, to be addressed by the deployment of layered added-value services and user applications. Towards this end, the output of the analysis process was provided in the form of use case diagrams, accompanied by clearly defined series of steps for the implementation of the respective workflows.

In the following Chapter 3, a high-level reference architecture is proposed, based on the user requirements analysis and on the partners’ pre-existing technologies and know-how. In this respect, both functional and non-functional specifications are clearly defined and mapped to every building block of the high-level architecture. Additionally, a comprehensive list of available monitoring devices is compiled, in order to support the requested parameters measurements. This list will be used by the WP6 procurement part for the final selection of sensors and devices.

Finally in Chapter 4, design principles are set, subject mainly to security, privacy and performance goals. Telecare and Telehealth requirements were treated in a homogeneous way, with respect to the inCASA main objective of integrating both in a single platform.

Further analysis will be conducted in the following Deliverable 3.2 “Reference Architecture iteration 1”, where specified workflows/use cases, non-functional requirements as architecture/performance constraints and available platform components/proposed monitoring equipment detailed in this document will be mapped to the inCASA architecture and interfaces specification

6 Glossary

AMP	Alternate MAC/PHY
APSME	Application Support Layer Management Entity
ASE	Application Service Element
BR	Basic Rate
CBC	Cipher Block Chaining
DES	Data Encryption Standard
DI	Device ID
DIM	Domain Information Model
EDR	Enhanced Data Rate
EEP	EnOcean Equipment Profile
ERP	EnOcean Radio Protocol
ERTM	Enhanced Re-Transmission Mode
FCS	Frame Check Sequence
GUI	Graphical User Interface
HA	Home Automation
HDP	Health Device Profile
LE	Low Energy
MCAP	Multi-Channel Adaptation Protocol
OTG	On The Go
P2P	Point-to-Point, Peer-to-Peer
PAN	Personal Area Network
PKI	Public Key Infrastructure
RIA	Rich Internet Application
SKKE	Symmetric-Key Key Establishment
SSL	Secure Socket Layer
SSP	Secure Simple Pairing
TCP	Transmission Control Protocol
TLS	Transport Layer Security
VPN	Virtual Private Network
WAN	Wide Area Network
WPAN	Wireless Personal Area Network

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Appendix A. Commercial Activity Sensors

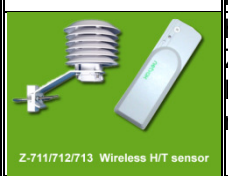
A.1 ZigBee Devices

A.1.1 ZigBee Smart Energy Devices

	Sensor	Illustration	Source	Remark
S1.1.1	Gas meter		http://www.itron.com/	
S1.1.2	Water meter		http://www.zigbee.org/DesktopModules/ZigBeeVariousProducts/ProductDetails.aspx?ProductRevisionID=322	
S1.1.3	Electricity meter		http://www.lsis.biz/	
S1.1.4	Flood sensor		http://www.netvox.com.cn/download/Netvox%20Catalog(English%20Version)V2.9.9.pdf	

Table 28 – ZigBee/6LoWPAN Smart Energy Devices

A.1.2 ZigBee Home Automation Devices

	Sensor	Illustration	Source	Remark
S1.2.1	Position Sensor Door / Window		http://www.netvox.com.cn/Z-301A.asp	One example of multiple devices
S1.2.2	Energy sensor (per device) plus switchable outlet		http://www.netvox.com.cn/Z-800.asp	
S1.2.3	Occupancy sensor / PIR Motion Sensor		http://www.netvox.com.cn/Z-B01%20ZigBee%20Motion%20Detector.asp	One example of multiple devices
S1.2.4	Temperature/ humidity sensor		http://www.netvox.com.cn/Z-B01%20ZigBee%20Motion%20Detector.asp	
S1.2.5	Light switch / dimmer		http://www.netvox.com.cn/Z-B02.asp	One example of multiple devices

S1.2.6	Door lock		http://www.bdhhi.com/accesscontrol/	
S1.2.7	Smoke detector		http://www.netvox.com.cn/Z-A01A%20Z-A02E.asp	
S1.2.8	Gas detector		http://www.netvox.com.cn/Z-A01BCD.asp	
S1.2.9	Generic radio module		http://www.netvox.com.cn/Z-100.asp	One example of multiple devices

Table 29 – ZigBee/6LoWPAN Home Automation Devices

A.2 KNX RF Sensors

A.2.1 KNX RF Smart Energy Devices

	Sensor	Illustration	Source	Remark
S2.1.1	Electricity meter		https://eb.automation.siemens.com/goos/catalog/Pages/ProductData.aspx?region=DE&language=en&tree=CatalogTree&nodeID=10032292&regionUrl=%2f&activetab=order#activetab=order&	One example of multiple devices

Table 30 – KNX RF Smart Energy Devices

A.2.2 KNX RF Home Automation Devices

	Sensor	Illustration	Source	Remark
S2.2.1	Light switch		https://eb.automation.siemens.com/goos/catalog/Pages/ProductData.aspx?catalogRegion=WW&language=en&nodeid=10032300&tree=CatalogTree&regionUrl=%2f#activetab=order&	One example of multiple devices

S2.2.2	Shade control		https://eb.automation.siemens.com/goos/catalog/Pages/ProductData.aspx?catalogRegion=WW&language=en&nodeid=10032308&tree=CatalogTree&regionUrl=%2f#activetab=order&	
S2.2.3	Door/window contact		https://eb.automation.siemens.com/goos/catalog/Pages/ProductData.aspx?catalogRegion=WW&language=en&nodeid=10032306&tree=CatalogTree&regionUrl=%2f#activetab=order&	One example of multiple devices
S2.2.4	Generic radio module		http://www.pedeu.panasonic.de/index.cfm?UUID=20D65392D3924DFDAFDBAB3651BF30F5&and_uuid=83EFD98252104F74B01DFCDD23162396&obj_ID=164	Identical to Wireless M-Bus

Table 31 – KNX RF Home Automation Devices

A.3 Wireless M-Bus Sensors

A.3.1 Wireless M-Bus Smart Energy Devices

There are many devices available from energy providers. But as the market is very regulated in this field, cooperation with energy providers is vital.

	Sensor	Illustration	Source	Remark
S3.1.1	Heat meter		http://kamstrup.com/14934/multical-402-btu-meter	One example of multiple devices
S3.1.2	Electricity meter		http://kamstrup.com/7728/Kamstrup-162BCDE	One example of multiple devices
S3.1.3	Water meter		http://kamstrup.com/12246/MULTICAL-61	One example of multiple devices
S3.1.4	Generic Wireless M-Bus sensor connector		http://www.hydrometer.de/index.php?id=2055&L=1	
S3.1.5	Mobile Data Collector / Activity logger		http://it.farnell.com/texas-instruments/ez430-chronos-868/kit-dev-ez430-chronos-wless-watch/dp/1779157	

S3.1.6	Generic radio module		http://www.pedeu.panasonic.de/index.cfm?UUID=20D65392D3924DFDAFDBAB3651BF30F5&and_uuid=83EFD98252104F74B01DFCDD23162396&obj_ID=164	Identical to KNX RF

Table 32 – Wireless M-Bus Smart Energy Devices

A.4 EnOcean Sensors

A.4.1 EnOcean Smart Energy Devices

EnOcean does not provide Smart Energy technology.

A.4.2 EnOcean Home Automation Devices

	Sensor	Illustration	Source	Remark
S4.2.1	Light switch		http://www.adhocelectronics.com/Products/Wireless-Lighting-Control	One example of multiple switches
S4.2.2	Pull-wire switch		http://www.steute.com/index.php?id=222&L=0	One example of multiple switches
S4.2.3	Door Handle Switch		http://www.steute.com/en/domains/control-technology/products/industrial-switchgear-with-radio-technology/radio-door-handle-switch-tgfm.html	e.g. solar powered device
S4.2.4	Position Sensor Door / Window		http://www.distech-controls.com/	One example of multiple devices
S4.2.5	Temperature/ CO2/humidity		http://www.thermokon.de/EN/thermokon-sensortechnik-14/start.html	
S4.2.6	Occupancy sensor		http://www.echoflexsolutions.com/node/217	One example of multiple devices

S4.2.7	Light sensor		http://www.opus-schalter.de/en/index.htm	One example of multiple devices
S4.2.8	Window sensor		http://www.opus-schalter.de/en/index.htm	
S4.2.9	Occupancy sensor: chair		http://www.funkstuhl.de/en/solutions/funkstuhl/	
S4.2.10	Occupancy sensor: bed		http://www.funkstuhl.de/en/solutions/matcontrol/	
S4.2.11	Generic radio module		http://it.farnell.com/enocean/rcm110/modulo-ricevitore/dp/1518020	

Table 33 – EnOcean Home Automation Devices

A.5 Z-Wave Sensors

A.5.1 Z-Wave Smart Energy Devices

	Sensor	Illustration	Source	Remark
S5.1.1	Electricity meter		http://www.horstmann.co.uk/utilities.php#telemeters	Not very common

Table 34 – Z-Wave Smart Energy Devices

A.5.2 Z-Wave Home Automation Devices

	Sensor	Illustration	Source	Remark
S5.2.1	Light switch		http://www.cooperwiringdevices.com/	One example of multiple switches
S5.2.2	Lamp dimming control		http://www.cooperlighting.com/	One example of multiple dimmers

S5.2.3	Door lock		http://link.schlage.com/Solutions/Pages/RemoteAccessControl.aspx	
S5.2.4	Motion sensor		http://www.act-remote.com/HPW/Specs/ZIR010_spec.pdf	
S5.2.5	Door/window contact		http://www.everspring.com/Products/Home_Automation_Detail.asp?parentUID=83&UID=355&CateUIDList=0,83	
S5.2.6	Shade control		http://store.homeseer.com/store/DBMZ---Z-Wave-DC-ShadeBlind-Motor-Controller-ESI-P853C192.aspx	
S5.2.7	Generic radio module		http://www.zen-sys.com/modules/Products&Techonology/?id=5&chk=d1a9e91460927f93c86518b2e040c7f9	

Table 35 – Z-Wave Home Automation Devices

Appendix B. Personal Monitoring Devices

A. Blood Cholesterol Meter:

a. PTS CardioCheck / CardioCheck PA

b. STEPS Biometer Dual Monitoring

B. PT/INR Meter:

a. HemoSense INRatio PT/INR Meter

Manufacturer: Hemosense
Model: INRatio PT/INR Meter

- **Type:** Portable
- **Use**: Invasive
- **Communications**: None
- **Power**: 4xAA
- **Autonomy**: 200 uses
- **Data Storage:** 60 measurements.
- **Param./Range/Error**:
  - INR / 0,8-8,0 / 0,1-1,0
- **Application**: ?
- **Continua Alliance:** No member
- **API**: private
- **Availability**: available
- **Price:** ?
- **Contact:** Grifols International
- **Web**: www.hemosense.com
- **Phone/Email:** 93.571.08.22/ jordi.puig@grifols.com /

b. Roche CoaguChek XS Plus

Manufacturer: Roche
Model: CoaguChek XS

- **Type:** Portable
- **Use**: Invasive
- **Communications**: IrDA
- **Power**: 4xAAA
- **Autonomy**: ?
- **Data Storage:** 100 measurements.
- **Param./Range/Error**:
  - INR / 0,8-8,0 / 0,1-1,0
- **Application**: web
- **Continua Alliance:** Promo. Member
- **API**: standard (POCT1-A2)
- **Availability**: available
- **Price:** $360
- **Contact:** Roche Diagnostics
- **Web**: www.coaguchek.com
- **Email/Phone:** 900 210 341

C. Pulse Oximeter:

a. Cardguard PMP4 SelfCheck Oxy Pro

Manufacturer: Cardguard

Model: PMP4 SelfCheck Oxy Pro

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: Bluetooth
- **Power**: 2xAAA.
- **Autonomy**: ?
- **Data Storage:** ?
- **Param./Range/Precission**:
  - SpO2 / 0–100% / 2 digits
  - Pulse rate / 18-300 / 3 digits
- **Application**: PDA/Web
- **Continua Alliance:** Contrib. Member
- **API**: private
- **Availability**: ?
- **Price:** ?
- **Contact:** Card Guard
- **Web**: www.cardguard.com
- **Email/Phone:** sales@cardguard.com

b. Nonin Avant 4100

Manufacturer: Nonin

Model: Avant 4100

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: Bluetooth Class 1
- **Power**: 2xAA.
- **Autonomy**: 120 hours.
- **Data Storage:** 33 hours.
- **Param./Range/Error**:
  - SpO2 / 0–100% / 0,1%
  - Pulse rate / 18-300 / 3%
- **Application**: PC
- **Continua Alliance:** Promo. Member
- **API**: public
- **Availability**: Available
- **Price:** $495 (SDK incl.)
- **Contact:** Nonin Medical
- **Web**: www.nonin.com
- **Email/Phone:** oem@nonin.com

c. Nonin Onyx II 9560

Manufacturer: Nonin

Model: Onyx II 9560

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: Bluetooth Class 2
- **Power**: 2xAA.
- **Autonomy**: 600 uses.
- **Data Storage:** 20 measurements.
- **Param./Range/Precission**:
  - SpO2 / 0–100% / 2 digits
  - Pulse rate / 18-321 / 3 digits
- **Application**: PC
- **Continua Alliance:** Cert. in process
- **API**: public
- **Availability**: Available
- **Price:** $350 (SDK incl.)
- **Contact:** Nonin Medical
- **Web**: www.nonin.com
- **Email/Phone:** oem@nonin.com

D. Blood Pressure Monitor:

a. A&D UA-767PBT

Manufacturer: A&D

Model: UA-767PBT

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: Bluetooth Class 1
- **Power**: 4xAA.
- **Autonomy**: ?
- **Data Storage:** 40 measurements.
- **Param./Range/Precission**:
  - SYS / 20-280mmHg / 3mmHg
  - DIA / 20-280 mmHg / 3mmHg
  - Pulse rate / 40-200 / 5%
- **Application**: PC
- **Continua Alliance:** Promo. Member
- **API**: public
- **Availability**: Available (TID)
- **Price: 150 $**
- **Contact:** A&D Medical
- **Web**: www.aandd-eu.net
- **Email/Phone:** deutschland@aandd-eu.net

b. Cardguard PMP4 BP Pro

Manufacturer: Cardguard

Model: PMP4 BP Pro

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: Bluetooth
- **Power**: 2xAA.
- **Autonomy**: ?
- **Data Storage:** 99 measurements.
- **Param./Range/Precission**:
  - SYS / 70-260mmHg / 3mmHg
  - DIA / 40-185 mmHg / 3mmHg
  - Pulse rate / 40-240
- **Application**: PDA/Web
- **Continua Alliance:** Contrib. Member
- **API**: private
- **Availability**: ?
- **Price:** ?
- **Contact:** Card Guard
- **Web**: www.cardguard.com
- **Email/Phone:** sales@cardguard.com

c. Corscience 705IT BT

Manufacturer: Corscience

Model: 705IT BT

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: Bluetooth
- **Power**: 4xAA/Power supply
- **Autonomy**: ?
- **Data Storage:** ?
- **Param./Range/Precission**:
  - SYS / 0-299mmHg / 3mmHg
  - DIA / 0-299 mmHg / 3mmHg
  - Pulse rate / 40-180 / 5%
- **Application**: Web
- **Continua Alliance:** No Member
- **API**: private
- **Availability**: Available
- **Price:** 249€
- **Contact:** Card Guard
- **Web**: www.corscience.es
- **Email/Phone**: info@corscience.es/ 932 531 867

d. Telcomed Wrist Clinic BT

Manufacturer: Telcomed (Medic4all)

Model: Wrist Clinic Bluetooth

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: Bluetooth Class II
- **Power**: ?
- **Autonomy**: ?
- **Data Storage**: ?
- **Param./Range/Precission**:
  - SYS-DIA / 0-299mmHg / 3mmHg
  - Pulse rate & Pulse rate regularity
  - 1 lead ECG
  - SpO2 / 0–100% / 2 digits
  - Temperature
  - Respiratory rate
- **Application**: web
- **Continua Alliance:** No Member
- **API**: private
- **Availability**: available
- **Price:** ?
- **Contact:** Medic4all
- **Web**: www.telcomed.ie
- **Email/Phone:** jllanes@grupogss.com

E. Glucometer:

a. LifeScan OneTouch Ultra 2

Manufacturer: LifeScan

Model: One Touch Ultra 2 + t+ cradle

- **Type:** Portable
- **Use**: Invasive
- **Communications**: Bluetooth
- **Power**: Lithium cell
- **Autonomy**: 1000 measur. / 1 year.
- **Data Storage:** 150 measurements.
- **Param./Range/Precission**:
  - Glucose / 10-600 mg/dl
- **Application**: PDA/PC
- **Continua Alliance:** Contrib. Member
- **API**: private
- **Availability**: Available
- **Price:** £ 12 + £ 70
- **Contact:** Lifescan John. & John.
- **Web**: www.onetouchdiabetes.com
- **Email/Phone:** info@LifeScan.es / 900.100.228

b. Roche Accu-Chek Compact Plus

Manufacturer: Roche Diagnostics

Model: Accu-Chek Compact Plus

- **Type:** Portable
- **Use**: Invasive
- **Communications**: IrDA
- **Power**: 2xAAA/2xAAA NiMh
- **Autonomy**: 1000 measur. / 1 year.
- **Data Storage:** 500 measurements.
- **Param./Range/Precission**:
  - Glucose / 10-600 mg/dl
- **Application**: PDA/PC
- **Continua Alliance:** Promo. Member
- **API**: private
- **Availability**: Available
- **Price:** 24€
- **Contact:** Roche Diagnostics
- **Web**: www.accu-chek.es
- **Email/Phone:** 900 210 341

F. Scale:

a. A&D UC-321PB

Manufacturer: A&D

Model: UC-321PB

- **Type:** Fixed
- **Use**: Non invasive
- **Communications**: Bluetooth Class 1
- **Power**: 4xAA
- **Autonomy**: 1000 measurements.
- **Data Storage:** 40 measurements.
- **Param./Range/Error**:
  - Weight/ 1-200kg/100g
- **Application**: None
- **Continua Alliance:** Promo. Member
- **API**: Public
- **Availability**: available (TI+D)
- **Price:** ?
- **Contact:** A&D Medical
- **Web**: www.aandd-eu.net
- **Email/Phone:** deutschland@aandd-eu.net

b. Cardguard PMP4 SelfCheck W. Scale

Manufacturer: Cardguard

Model: PMP4 SelfCheck W. Scale

- **Type:** Fixed
- **Use**: Non invasive
- **Communications**: Bluetooth Class 1
- **Power**: 1x9V
- **Autonomy**: 1000 measurements.
- **Data Storage:** 20 measurements.
- **Param./Range/Error**:
  - Weight/ 5-150kg/0,3-0,6Kg
- **Application**: PDA/web
- **Continua Alliance:** Contrib. Member
- **API**: private
- **Availability**: ?
- **Price:** ?
- **Contact:** Card Guard
- **Web**: www.cardguard.com
- **Email/Phone:** sales@cardguard.com

G. HbA1c Meter

a. Bayer Healthcare A1CNow+

Manufacturer: Bayer Healthcare

Model: A1CNow+

- **Type:** Portable
- **Use**: Invasive
- **Communications**: None
- **Power**: Cells
- **Autonomy**: ?
- **Data Storage:** ?
- **Param./Range/Error**:
  - HbA1c / / 1%
- **Application**: PC/PDA/Mobile/web
- **Continua Alliance:** Promo. Member
- **API**: N/A
- **Availability**: Available (USA)
- **Price:** ?
- **Contact:** Bayer (USA)
- **Web**: www.a1cnow.com
- **Email/Phone:** +1 408-524-2255 stacey.roseblade.b@bayer.com

H. Electrocardiograph:

a. Aerotel Heart View P1218 + BT

Manufacturer: Aerotel

Model: Heart View P12/8 BT

- **Type:** Portable
- **Use**: Non invasive
- **Communications**: Bluetooth
- **Power**: Cells
- **Autonomy**: ?
- **Data Storage:** ?
- **Param./Range/Error**:
  - ECG 12-8 chan
- **Application**: Web
- **Continua Alliance:** No Member
- **API**: private
- **Availability**: Available
- **Price:** ?
- **Contact:** Aerotel Medical Systems
- **Web:** www.aerotel.com
- **Email/Phone:** +972 3 559 3222

b. Alive Heart Monitor

Manufacturer: Alive Technologies

Model: Heart Monitor

- **Type:** Wearable
- **Use**: Non Invasive
- **Communications**: Bluetooth Class 1
- **Power**: Li-ion Rechargeable Battery
- **Autonomy**: 2-4 days
- **Data Storage:** 5 days (SD 256 MB).
- **Param./Range/Error**:
  - ECG 1 chan / 300 sps – 5.3mVpp
  - 3 Axis accel / 75 sps – 2,7g
- **Application**: PC/PDA/Mobile/Web
- **Continua Alliance:** No Member
- **API**: private
- **Availability**: for testing (TI+D)
- **Price:** 1.200€ (Sensor+SDK)
- **Contact:** Alive Tech. (Australia)
- **Web:** www.alivetec.com
- **Email/Phone:** david.peeler@alivetec.com

c. Corscience CorBELT

Manufacturer: Corscience

Model: CoreBELT

- **Type:** Wearable
- **Use**: Non Invasive
- **Communications**: Bluetooth
- **Power**: 1xRechargeable AA
- **Autonomy**: 24 hours
- **Data Storage:** ?
- **Param./Range/Error**:
  - ECG 1 chan
  - Physical activity
- **Application**: ?
- **Continua Alliance:** No Member
- **API**: private
- **Availability**: available
- **Price:** ?
- **Contact:** Corscience
- **Web:** www.corscience.es
- **Email/Phone:** info@corscience.es

d. VPMS V-Patch System

Manufacturer: VPMS

Model: V-Patch + V-Pod + V-Cell

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: GPRS
- **Power**: Cells
- **Autonomy**: 7 days
- **Data Storage:** 48 hours
- **Param./Range/Error**:
  - ECG 3 chn
- **Application**: Web
- **Continua Alliance:** No Member
- **API**: private
- **Availability**: Available
- **Price:** 674€ (4xPatch+V-Pod+V-Cell)
- **Contact:** VPMS Europe
- **Web:** www.vpatchmedical.com
- **Phone/Email:** stene@vpatchmedical.com / +44 (0)207 183 5136

I. Pulse Rate Meter:

a. Aerotel MDKeeper

Manufacturer: Aerotel

Model: MD Keeper

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: GPRS
- **Power**: Rechargeable Batteries
- **Autonomy**: ?
- **Data Storage:** ?
- **Param./Range/Error**:
  - Heart rate
  - 1 lead ECG
  - SpO2

- **Application**: web
- **Continua Alliance:** No Member
- **API**: private
- **Availability**: under development
- **Price:** ?
- **Contact:** Aerotel Medical Systems
- **Web:** www.aerotel.com
- **Email/Phone:** +972 3 559 3222

b. Polar RS800 CX

Manufacturer: Polar

Model: RS800 CX

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: IrDA
- **Power**: Lithium Cell
- **Autonomy**: 1 year (1h/day)
- **Data Storage:** ?
- **Param./Range/Error**:
  - Heart rate /15-240 bpm/1-2bpm

- **Application**: PC/web
- **Continua Alliance:** Promo. Member
- **API**: private
- **Availability**: Available
- **Price:** 389€
- **Contact:** Polar Electro Iberica
- **Web**: www.polaribérica.es
- **Email/Phone:** info@polaribérica.es / 902159951

c. Suunto T4c
d. Telcomed Watch me

Manufacturer: Telcomed (Medic4all)

Model: Watch me

- **Type:** Wearable
- **Use**: Non invasive
- **Communications**: Bluetooth Class II
- **Power**: Rechargeable battery
- **Autonomy**: ?
- **Data Storage:** ?
- **Param./Range/Error**:
  - Heart rate
  - Heart rate regularity
  - 1 lead ECG

- **Application**: web
- **Continua Alliance:** No Member
- **API**: Private
- **Availability**: Available
- **Price:** ?
- **Contact:** Medic4all
- **Web**: www.telcomed.ie
- **Email/Phone:** jllanes@grupogss.com

J. Activity Monitor:

a. Exmocare Empath
b. Sener BioSEN
c. Sparkfun Witilt

K. Thermometer:

a. Digital Wireless Monitor Temperature Device
b. Bodymedia Sensewear

L. Spirometer:

a. Cardguard PMP4 SpiroPro

Manufacturer: Cardguard

Model: PMP4 SpiroPro

- **Type:** Portable
- **Use**: Non invasive
- **Communications**: Bluetooth
- **Power**: AAA
- **Autonomy**: ?
- **Data Storage:** ?
- **Param./Range/Error**:
  - Air flow rate/ 0-14 lps / 10%
  - Air volume / 0 -8 l / 10%
- **Application**: PDA/web
- **Continua Alliance:** Contrib. Member
- **API**: Private
- **Availability**: Available
- **Price:** ?
- **Contact:** Card Guard
- **Web**: www.cardguard.com
- **Email/Phone:** sales@cardguard.com

b. Corscience Asthma Monitor AMI+BT

Manufacturer: Corscience

Model: Spirometer AMI + BT

- **Type:** Portable
- **Use**: Non invasive
- **Communications**: Bluetooth
- **Power**: AAA
- **Autonomy**: ?
- **Data Storage:** ?
- **Param./Range/Error**:
  - PEF / 60-840 lpm/ 4%
  - FEV / 0,5-8 lpm / 3%
  - Air volume / 0 -8 l / 4%
- **Application**: PDA/web
- **Continua Alliance:** Contrib. Member
- **API**: private
- **Availability**: Available
- **Price:** 600€
- **Contact:** Corscience
- **Web:** www.corscience.es
- **Email/Phone:** info@corscience.es

Device Type	Brand	Device Name	Blood Cholestherol (LDL, HDL)	Blood coagulation (INR)	Blood glucose level	Blood oxygen saturation (SpO2)	Blood pressure (SYS-DIA)	Body weight	Brain electrical activity (EEG)	Electrical resistance of the skin	Glycosylated hemoglobin (HbA1c)	Heart electrical activity (ECG)	Heart rate	Muscle electrical activity (EMG)	Physical activity	Pulmonary Capacity (PEV-FEVI)	Respiratory Rate	Temperature
Blood Cholestherol	Polymer TS	CardioCheck PA	X		X													
	Q. STEPS	Biometer Dual Mon.	X		X													
Pulse Oximeter	Cardguard	PMP4 SelfCheck Oxy Pro				X							X					
	Nonin	Avant 4100				X							X					
	Nonin	Onyx II 9560				X							X					
Blood Pressure Monitor	A&D	UA-767PBT					X						X					
	Cardguard	PMP4 BP Pro					X						X					
	Cardguard	PMP4 SelfCheck BP					X						X					
	Corscience	705IT BT					X						X					
	Telcomed	Wrist Clinic BT				X	X					X	X				X	X
Glucometer	LifeScan	OneTouch Ultra 2			X													
	Roche	Accu-Chek Compact Plus			X													
Scale	A&D	UC-321PB						X										
	Cardguard	PMP4 SelfCheck W.						X										
HbA1c Meter	Bayer	A1CNow+								X								
Electro-cardiograph	Aerotel	Heart View P1218 + BT									X							
	Alive	Heart Monitor									X			X				
	Corscience	BlueECG BT12 y BT3/6									X			X				
	VPMS	V-Patch, V-Cell, V-Pod									X							
Heart Rate Meter	Aerotel	MDKeeper				X					X		X					
	Polar	RS800 CX											X					
	Suunto	T4c											X					
	Telcomed	Watch me				X					X		X					
Activity Monitor	Exmocare	BT2							X		X		X					X
	Sener	BioSEN									X			X			X	X
	Sparkfun	Witilt									X			X			X	X
Spirometer	Cardguard	PMP4 SpiroPro														X	X	
	Corscience	Asthma Monitor AMI+BT														X	X	

Table 36 – Medical devices, brand and parameters mapping

Device Type	Brand	Device Name	Communications	API	Availability	Continua Alliance
Blood Cholestherol	Polymer TS	CardioCheck PA	-	-	X	-
	Q. STEPS	Biometer Dual Mon.	-	-	X	-
Pulse Oximeter	Cardguard	PMP4 SelfCheck Oxy Pro	BT	Private	X	X
	Nonin	Avant 4100	BT	Public	X	X
	Nonin	Onyx II 9560	BT	Public	X	Cert. in Progress
Blood Pressure Monitor	A&D	UA-767PBT	BT	Public	X	X
	Cardguard	PMP4 BP Pro	BT	Private	?	X
	Cardguard	PMP4 SelfCheck BP	BT	Private	?	X
	Corscience	705IT BT	BT	Private	X	-
	Telcomed	Wrist Clinic BT	BT	Private	X	-
Glucometer	LifeScan	OneTouch Ultra 2	BT	Private	X	X
	Roche	Accu-Chek Compact Plus	IrDA	Private	X	X
Scale	A&D	UC-321PB	BT	Public	X	X
	Cardguard	PMP4 SelfCheck W.	BT	Private	?	X
HbA1c Meter	Bayer	A1CNow+	-	-	X	X
Electro-cardiograph	Aerotel	Heart View P1218 + BT	BT	Private	X	-
	Alive	Heart Monitor	BT	Private	X	-
	Corscience	BlueECG BT12 y BT3/6	BT	Private	X	-
	VPMS	V-Patch, V-Cell, V-Pod	GPRS	Private	X	-
Heart Rate Meter	Aerotel	MDKeeper	BT	Private	-	-
	Polar	RS800 CX	IrDA	Private	X	X
	Suunto	T4c	RF	Private	X	-
	Telcomed	Watch me	BT	Private	X	-
Activity Monitor	Exmocare	BT2	GPRS / ZB	Private	Prototype	-
	Sener	BioSEN	BT	Private	Prototype	-
	Sparkfun	Witilt	BT	Private	Prototype	-
Spirometer	Cardguard	PMP4 SpiroPro	BT	Private	X	X
	Corscience	Asthma Monitor AMI+BT	BT	Private	X	X

Table 37 – Medical devices specifications

Appendix C. Continua compliant monitoring devices already selected for the UK pilot

Device	Manufacturer	IEEE 11073	Wireless Communication Protocol
BP	A&D	Yes	Zigbee
Weight	A&D	Yes	Zigbee
SpO_2	Nonin	Yes	Zigbee
Blood Glucose	LifeScan One Touch Ultra 2	Yes	Zigbee
Medication Monitor	Pivotell	Yes	Zigbee
Chair Sensor	Tynetec	Yes	Zigbee
Bed Sensor	Tynetec	Yes	Zigbee
PIR	Optex	Yes	Zigbee
Fall/PERS	Tynetec	Yes	Zigbee

Table 38 – Continua compliant devices for the UK pilot