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**Integrated Network for Completely Assisted Senior citizen's
Autonomy**

D3.4 Reference Architecture iteration 3

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Executive summary

The inCASA project started the design of the system architecture in WP3 in view of the fact that there were diverse implementations for each of the pilots. This diversity was the result of the selection of the most efficient approach in order to start up the trials in each country. The second iteration of the architecture is characterized by the attempt to harmonize this diversity. This inCASA reference architecture defines guidelines ensuring coherence throughout the pilots, however, allowing for different implementations. This third iteration of the design of the system architecture refines last issues and consolidates the final architecture. Main input for D3.4 has been the last requirement acquisition document, D2.6. In broad terms, this last iteration has not fundamentally modified the architecture description from the second iteration. There have been some refinements, especially in the SPP and the consumer apps layer.

This document is structured in five main chapters. It is embracing most of the content of the deliverable D3.3 including some refinements, especially in the SPP and Consumer Apps sections, and adding a new chapter, chapter 6, which was requested in the last review. This new section shows, which has been the final solution adopted for each pilot. We considered that it was very important reflecting this information so that everything is well documented and also, to show the versatility of the inCASA solution to be adapted for different situations. From a high level point of view, we can say that most of the pilots use inCASA components. There have been cases when some of them were not needed to satisfy the requirements of that specific pilot-site and that is why that for pragmatic reasons, always the most convenient implementation was chosen.

This document describes how the final inCASA architecture looks like from a functional, data and development point of view. First of all, in chapter 2, we have selected the most relevant requirements that guided this last iteration and the course of the project. The next, chapter explains in detail the different functions and elements of the system, which are split in two main domains: the patient's environment and the platform and how that fits in the inCASA's reference architecture. After that, in chapter 4 describes the data used in the system showing its transformation from the patient's environment to the platform thanks to the function of the LinkSmart middleware (i.e. the old Hydra). In chapter five, the most relevant message flows are provided to understand the most important processes that are dealt by the inCASA system.

Finally, chapter 5 includes the different deployment methods for each of the pilots and documents the final solution, which was chosen for each pilot, and reflects the final combination of the inCASA components. After that, section 6.2 shows the works done to demonstrate how the inCASA platform can be integrated and interoperable with other standard platforms. This was achieved connecting the inCASA platform with the Chorleywood Health Centre (CHC)'s, which is following an independent but standard approach for its pilot. Last but not least, this chapter finalises with a lessons learnt section, which summarizes the pros and cons of the different solution. This document concludes with some reflections in chapter 8.

1 Introduction

1.1 Purpose and Content of this Deliverable

D3.4 describes the third iteration of the inCASA architecture from different points of views, giving detailed information on the format of communication messages. Also, D3.4 explains which changes were needed to achieve one of the most important goals of the inCASA project: showing how Tele-health and Tele-care information can be united and processed in a uniform architecture to provide a more powerful platform for applications to be build-up on top of that.

1.2 Outline of this Deliverable

This document has the following sections:

- Chapter 2 describes the most relevant requirements that have affected to the 3rd iteration architecture and also keeps those which have been more relevant throughout the project.
- Chapter 3 specifies the architecture and describes how the building blocks look like (i.e. chapter 3)
- Chapter 4: shows how data looks like in each link/sub-system of the architecture and how it transforms itself from the patient's environment to the platform to finish in a final consumer app
- Chapter 5 presents the most relevant message flows between the different architecture blocks
- Chapter 6 shows in detail the deployment that has been implemented in each pilot

1.3 Stakeholder Representation

According to [50] a stakeholder is defined as follows:

Stakeholder. *An individual, team, or organization (or classes thereof) with interests in, or concerns relative to, a system.*

This section provides a list of the architecturally relevant stakeholder roles considered in the development of the inCASA architecture described in this document.

For each stakeholder, areas of concern are listed that can be addressed by the information contained in this document:

- **End Users** (elderly people, patients with special needs):
 - need transparent and unobtrusive means to profile habits while they are at home and to monitor their health conditions outside traditional healthcare environments
 - need integrated home automation permitting remote control of electronic devices in the immediate surroundings
- **Operators** (doctors and health professionals):
 - need comprehensive monitoring data for understanding remote End User's social/physical conditions and diagnostics
 - need ways to enable continuity of care through a wider interaction with End Users
- **Caretakers** (End User's relatives or people who has close social relations with him/her):
 - need ways to enable continuity of care through a wider interaction with End Users
 - need integrated home automation permitting remote control of electronic devices in the immediate surroundings
- **Acquirers** (program sponsors, procurement personnel responsible for acquiring the COTS software and hardware to be included in the system):
 - need assurance that the design will address the intended purpose of the system

- need elements of evaluation to build cost/benefit rationales around system and/or sub-system realization
- **Developers** (System and Software Engineers, Database Designers, System Integrators):
 - need to understand the system's structure in order to develop the correct models and piece of software which implements the given system requirements
 - need functional information and details on data structures and information flows to provide product customization and/or realize interfaces and communication channels between modules or between the system and the outside world
- **Maintainers** (Operations Staff, Database Administrators, Systems Administrators):
 - need to understand the system's structure in order to be able to change, remove, or add functions within a maintenance program
 - need to know how data are managed by the system, in order to put in place the proper operational procedures to maintain and protect the data
 - need to have a map of the different interfaces exposed by the system and those set up between system's components, in order to put in place the proper monitoring processes
 - need to know, at a high level, how users of the system interact with it, in order to prepare a support plan

1.4 Viewpoint Definitions

The ANSI/IEEE 1471-2000 Standard [50] prescribes the definition of a set of viewpoints to satisfy the stakeholder community. The 1471-2000 Standard defines views and viewpoints as follows:

View. *A representation of the whole system from the perspective of a related set of concerns.*

Viewpoint. *A specification of the conventions for constructing and using a view. A pattern or template from which to develop individual views by establishing the purposes and audience for a view and the techniques for its creation and analysis.*

Therefore, a viewpoint identifies the set of stakeholder's concerns to be addressed, and identifies the different techniques (such as modelling, consistency checking, etc.), used by any conforming view. A view is a representation of a set of software elements, their properties, and the relationships among them that conform to a defining viewpoint. Together, the chosen set of views show the entire architecture and all of its relevant properties.

The viewpoints selected for inCASA's reference architecture, according to [51], are:

- *Functional Viewpoint:* functional model, system structure, roles and interfaces are in scope of this viewpoint, which views are detailed in Chapter 3.
- *Information Viewpoint:* information content and structure, and system's data management strategies are in scope of this viewpoint, which views are detailed in Chapter 4.
- *Developer Viewpoint:* architectural aspects supporting software development are in scope of this viewpoint, which views are detailed in Chapter 5.

Further viewpoints are available in [51], however, at this early stage of the system's architectural definition, only the Functional, Information e Development Viewpoint makes sense. Such additional viewpoints may be anyway referred in the following given that they will be taken into account in further iterations of the inCASA architectural definition.

The following table summarizes the relationships between the areas of concern for the stakeholders intercepted in the previous section and the selected viewpoints. For each area of concern, stakeholders are identified as either primary or secondary, meaning that primary stakeholders are mainly impacted by the concerns with respect to secondary stakeholders.

Area of Concern	Stakeholder	Viewpoint(s) applying
Habits profilation at home and health conditions monitoring	Primary: End Users, Acquirers Secondary: Operators, Caretakers	Functional
Allow remote control of devices	Primary: End Users, Operators, Caretakers Secondary: Acquirers, Maintainers	Functional
Monitoring data for understanding user's conditions	Primary: Operators Secondary: Caretakers	Functional
Continuity of care through a wider interaction	Primary: Operators, Caretakers Secondary: Developers	Functional
Addressing of the intended purpose of the system	Primary: Acquirers Secondary: Developers	Functional
Build cost/benefit rationales	Primary: Acquirers Secondary: Maintainers	Functional
Understand the system's structure	Primary: Developers, Maintainers Secondary: Acquirers	Functional
Understand the data structures and flows	Primary: Developers Secondary: Maintainers	Information
Understand the exposed interfaces	Primary: Developers Secondary: Maintainers	Functional
Understand the user interaction with the system	Primary: Acquirers, Developers Secondary: Maintainers	Functional
Understand the applied security levels and procedures	Primary: Acquirers, Developers Secondary: Maintainers, End Users	Functional Information
System realization	Primary: Developers Secondary: Maintainers	Development
Configuration Management	Primary: Developers Secondary: Maintainers	Development

Table 1. Area of concern for Stakeholders and relevant Viewpoints.

In Chapter 3-5, each viewpoint is adapted in a conforming view, using the following section structure:

- *Introduction*: this section gives a general description of the viewpoint and its rationales
 - *Stakeholder Concerns*: this section lists all of the stakeholder concerns which apply to the viewpoint
 - *Notation and Language*: this section specifies languages and notations used to model or represent views conforming to this viewpoint

2 Third iteration of requirements

The following list shows the results of the analysis, which were derived from the third iteration of requirements coming from D2.6. More details on this work will be given by updating the final consolidated version of D3.1. The main result of this analysis has been a prioritization of the existing requirements and that is why this new round doesn't have much impact in the already consolidated architecture. Adding more sensors in a pilot doesn't really change functional blocks in the basic architecture. In any case, there have been some refinements in the SPP and the Consumer App layer. The following list shows the most relevant requirements that had an especial impact throughout the project:

ID	Rationale	Reporter
1	Platform must show how the combination of Tele-care and Tele-health data can be exploited by consumer applications and add value	Mid-term review
2	Platform must be evolved to meet a standard solution	Mid-term review
3	Provide evidence that consumer applications are built using the inCASA API	Mid-term review
4	Proof that inCASA can be integrated with other standards platform	3 rd review
5	Enhancing self-assessment functions	ALL
6	A lot of look and feel improvements on the final consumer apps	ALL
7	The system must be able to integrate new devices smoothly	ALL

Table 2 - New requirements

In the last iteration of the project, the inCASA platform had to prove its interoperability with other standard platforms. This has been achieved connecting inCASA platform with CHC's system. This work has been described in section 6.2. Moreover, in this last iteration there was a lot of emphasis in the presentation layer, the way in which the Consumer app is presented. A lot of improvements on graphs, self-assessment functions, alerts have been considered in order to satisfy the expectations of the pilots. Thus, most of the effort in this last phase has been put on consolidating the pilots and do refinements over the existing functionalities.

3 Functional Viewpoint

This section shows an overview of the inCASA platform and discusses the different functionalities inside each building block.

3.1 Introduction

The functional viewpoint describes the system's functional components and modules, their roles within the system's architecture and the interfaces they offer. The set and features of the several modules reflect what arises in terms of system specifications, from deliverables [1] and [2].

The *Functional Model View* conforms to the Functional Viewpoint: in this view, all of the functional elements of the inCASA system are detailed, explaining their objectives, roles and interfaces.

3.1.1 Stakeholder Concerns

This viewpoint addresses the concerns of:

- *Acquirers*, which need assurance that the design will address the intended purpose of the system
- *Software Engineers* (among the *Developers*), which have to create models to explicitly show how the functions of the system are implemented within the different modules and components
- *System Integrators* (among the *Developers*), which have to implement interfaces and set up communication channels, either between different inCASA modules or between inCASA system and the outside world
- *Maintainers*, which have to understand the system in order to change, remove, or add functions, and need to locate the modules involved in a given functional area and understand the intentions of the original designers so that modifications fit with the original design.

3.1.2 Notation and Language

Views conforming to the Functional Viewpoint are represented by:

- informal block diagrams, in case of high-level, conceptual descriptions
- UML 2.x diagrams, using subsystems or classes to represent elements and “is part of” or nesting to represent the decomposition relation, in case of low-level logical or physical descriptions.

3.2 inCASA Functional Architecture

The inCASA architecture has been revised keeping into account the benefit of dealing uniformly health and environmental data for a better Tele-health/Tele-care integration, the need of adherence to standard, the experience gained from the first development cycle, and the revised requirements. During the second iteration of the inCASA architecture, a few changes have been agreed by technical partners with regard to the scope, the roles and the responsibilities of some modules. The reference high level architecture view is shown in Figure 1.

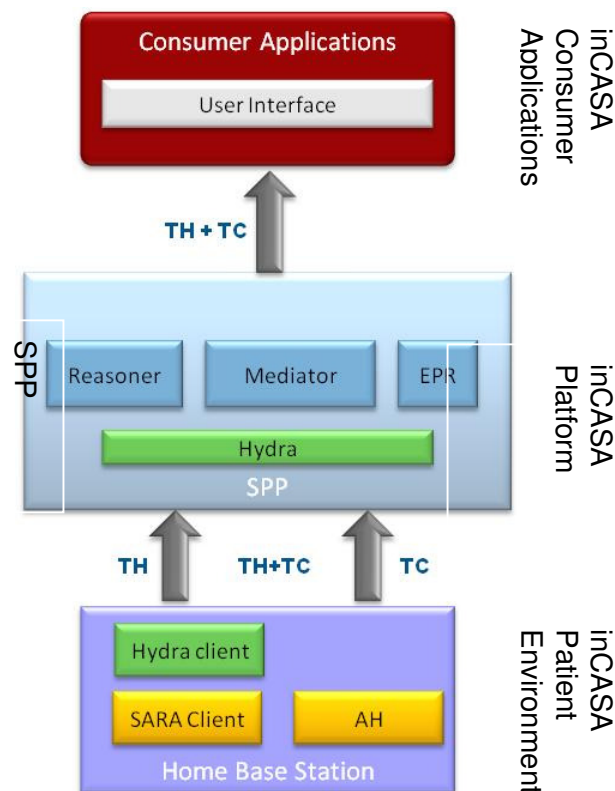


Figure 1 - High level logical view of inCASA architecture second iteration

The inCASA system collects TH and TC information by means of the Home Base Station. This is a processing unit with Windows OS and a user interface (i.e. PC, tablet, etc.) so that the patients can perform some actions (i.e. measures intake, questionnaires fulfilment, etc). TH information is retrieved it by using the SARA system, although any other implementation would be applicable. The same happens with the TC information, which is received by the Activity hub (AH). This AH is a little device connected to the patient's PC/Tables. Both sources of information are forwarded to the Hydra client (i.e. now called LinkSmart) and finally transmitted in a standard way (i.e. HL7, IEEE 11073) to the platform.

In particular, Hydra middleware, now called LinkSmart, provides a data abstraction received from the Tele-health and Tele-care subsystems, handles uniformly data and can optionally provide a TC-TH data fusion. Hydra sends data to the Mediator through an IHE compliant web service interface. The Mediator is, within the SPP, the module in charge of routing data (to the EPR, to the Reasoner and to external modules such as the CA), managing queues and performing some format transformation towards legacy modules. The Reasoner is the module in charge of analyzing row data, generating derived data and alerts. The consumer apps layer consumes all this processed combined (i.e. TH+TC) information in order to provide added value clinical services. Next subsections will give more detailed information regarding each sub-system.

3.2.1 Patient's environment functional view

One of the most important requirements with regard to the patient's environment concerned an easy-to-use tool, which doesn't make patients feel like in a hospital ([req. 10](#)). For this reason, it has been a fundamental decision to install all local software components in a regular nice portable PC or tablet computer, since it can be integrated in any house as a common device. Apart from that, all inCASA Tele-health sensors are wireless so that they can be hidden once they are commissioned. The inCASA Tele-care sensors are installed in different parts of the house (i.e. door, chair, bed, etc.).

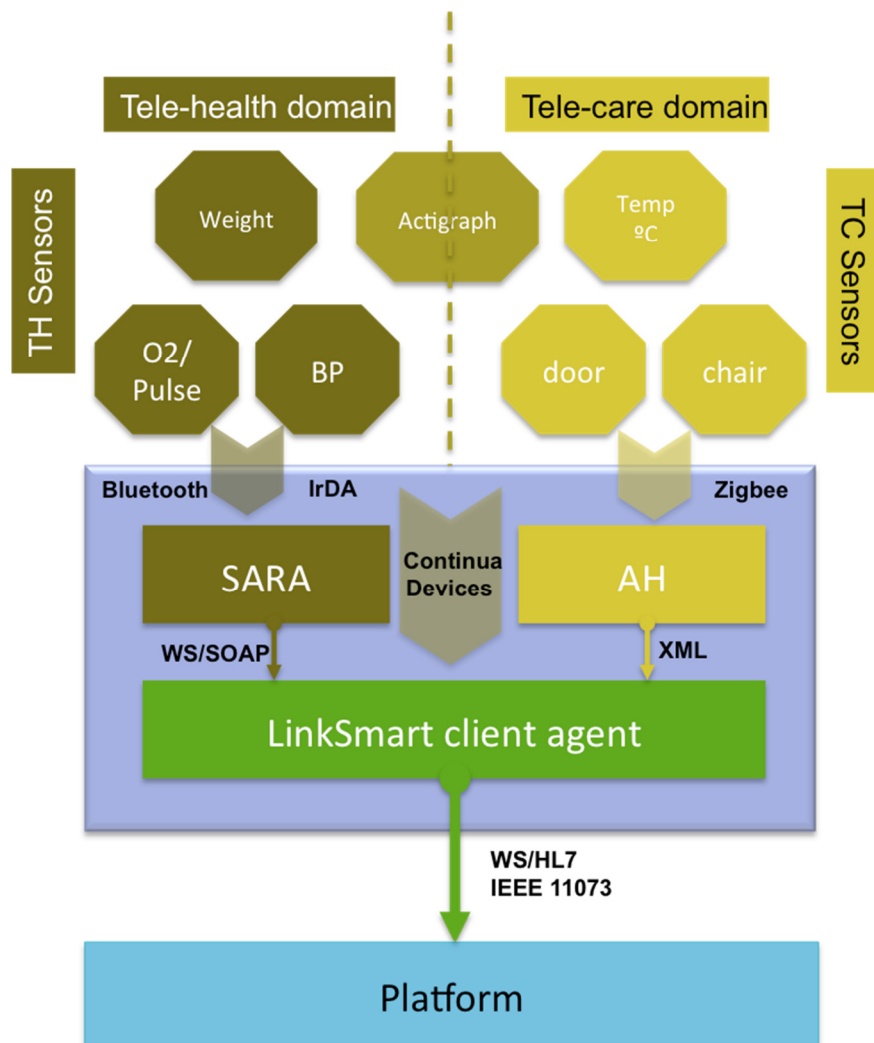


Figure 2 - inCASA patient's environment iteration 2 (LinkSmart is the new name for Hydra)

In Fig. 2, the sensors are organized in two different domains: Tele-health and Tele-care domain. Tele-health information gets into the system via Bluetooth. Alternatively, IrDa is used to integrate the Actigraph ([Req 8](#)). The information is collected by the SARA function and sent to the LinkSmart (i.e. the old Hydra middleware) to be standardized and forwarded to the platform. The Activity Hub (AH) deals with the Tele-care information using ZigBee or EnOcean communication protocol. The AH is a physical device with back-end IP-connectivity to the patient's PC via Ethernet or GPRS. Again, information is forwarded to the LinkSmart client agent, which encapsulates both the Tele-health and the Tele-Care information in a HL7 message following the IEEE 11073 specifications.

3.2.1.1 Tele-health client Domain

The main function of the Tele-health system, SARA, is to capture different kinds of patients' measures including blood pressure, oxygen saturation in blood, blood glucose, weight, etc... After that, the Tele-health system sends the information to the SPP (Smart Personal Platform) both for being stored and for further processing (e.g. alerts, calendar notifications, etc.) via the LinkSmart middleware.

The main role of the Tele-health client system within the inCASA project is the provisioning of all the clinical information to the SPP. For this reason, it will be responsible for:

- Taking patient's measures in a smooth way
- Providing a friendly user interface to patients
- Sending Tele-health information to the platform
- Fulfilling questionnaires in the patient side
- Adding new devices smoothly ([Req 7](#)).

In the Tele-health system, the SARA client consists of the following components:

- *Connectors Layer*: every sensor can use different kinds of communication technologies such as Bluetooth, ZigBee, USB, etc. Therefore, the Tele-health gateway provides a connector for each of these technologies
- *Parser Layer*: here is where the Tele-health gateway collects and decodes the information coming from the sensor
- *Web Services Client*: in this part, the Tele-health Gateway sends the information to the Tele-health platform
- *Patient's UI*: this is a touchable screen that helps patients to insert their measures

Fig. 3 shows a sample view on the user interface for the patient's application.



Figure 3 - User Interface for taking a weight measure

3.2.1.2 Tele-care client Domain

The inCASA Activity Hub is the central device in the local wireless network. It provides the following features:

- generic bidirectional gateway with tunnelling and data remodelling capabilities,
- extremely low-cost and low-power hardware platform,
- uplink connectivity with lean emBetter TCP/IP stack, allowing HTTP-XML-forwarding,
- direct and indirect access to web2.0-enabled web sites, allowing interactive management over lean channels
- secure communication channels based on TLS
- Ethernet, GPRS and Wi-Fi uplink connectivity
- microSD card and USB-on-the-Go (USB-OTG) for local storage of data and commissioning
- possibility to attach a broad variety of physical interface for short-range wireless networks, including Wireless M-Bus/KNX-RF, IEEE802.15.4/ZigBee, EnOcean Radio Protocol (ERP), Wi-Fi, Bluetooth, Nanotron CSS-based modules, and some more
- Lithium-ion battery for mobile use.

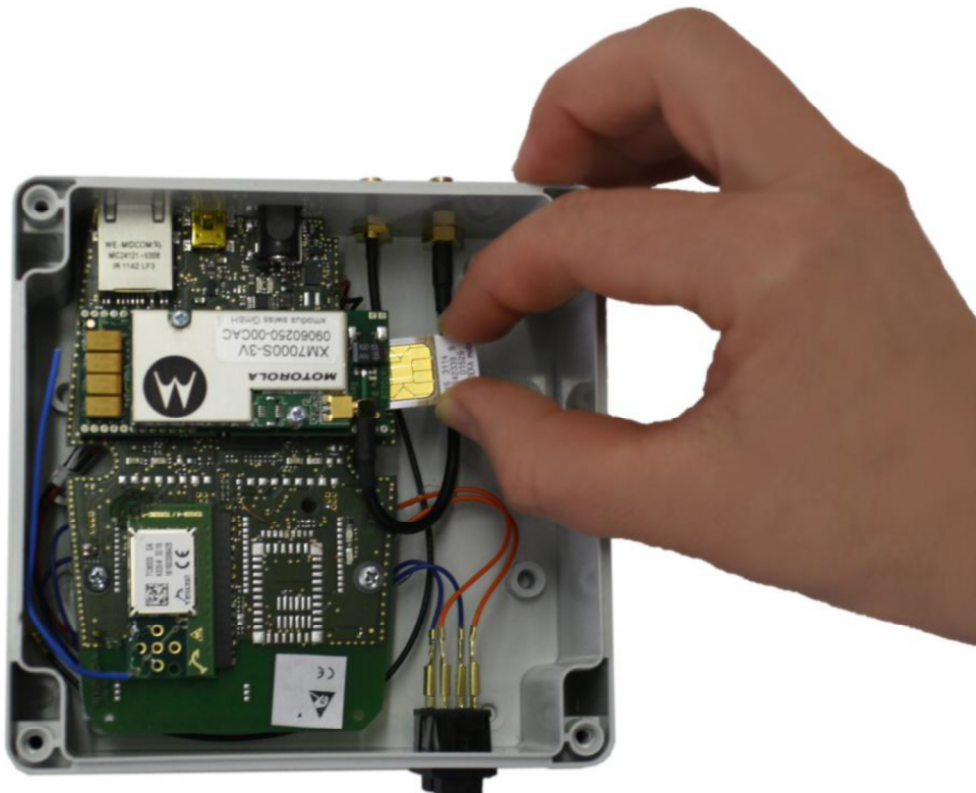


Figure 4 - inCASA Activity Hub, equipped with EnOcean radio and GPRS modules

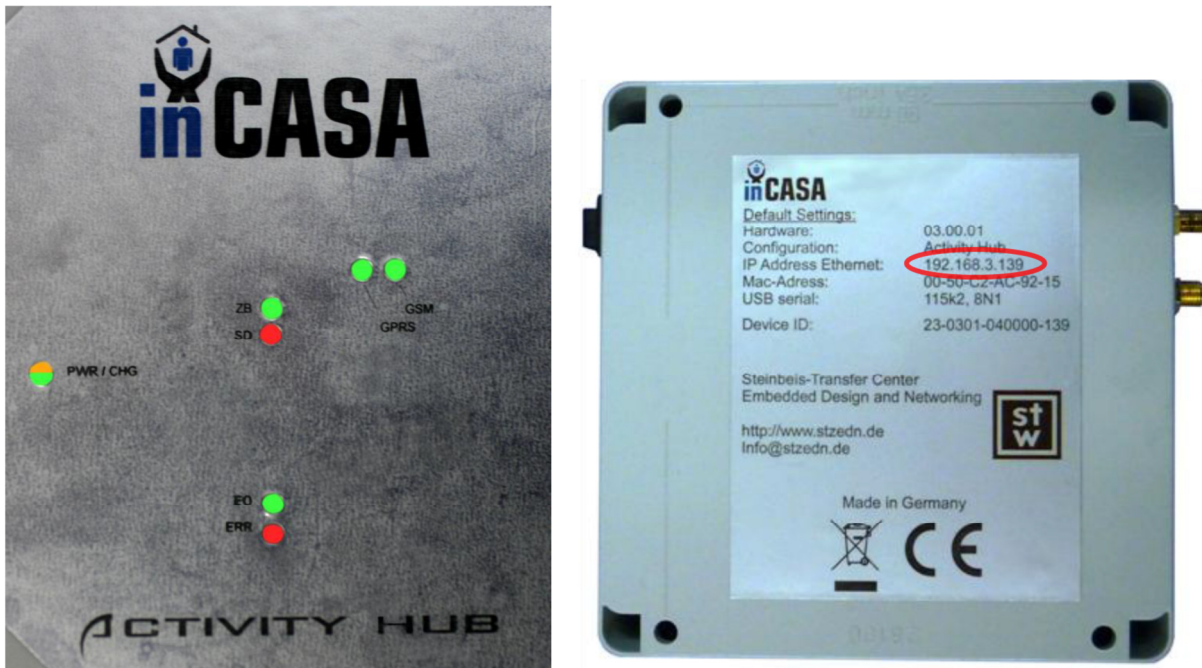


Figure 5 - inCASA Activity Hub, front and back view of ruggedized housing

The inCASA Activity Hub is responsible for the management of the wireless network, the collection of data and of status information from the sensor devices and the forwarding of this data or information to higher level (referred to the ISO/OSI reference model) systems and devices, such as the LinkSmart Middleware and/or to control and monitoring devices.

The Tele-care system specifies the environmental sensor/actuator system. The primary task is to measure, collect, store and forward data and status information of aged and handicapped people in different situations.

Another feature of the inCASA Activity Hub is to store the data and information of the sensor devices for specific periods of time, e.g. if the inCASA Activity Hub is mobile and is used by a person to collect data from different locations in a hospital or a nursing home. In this case the stored data can be downloaded from the inCASA Activity Hub later, when it is connected to the Internet. Before storing the data on accessible media, the data are encrypted.

From a physical point of view, different wireless protocols can be provided by the inCASA Activity Hub. However, from application point of view it is not important which WPAN protocols is used – be it ZigBee, Bluetooth, EnOcean Radio Protokocol, IEEE802.11 (Wi-Fi) or other protocols.

The information from the wireless devices and the associated protocol will be:

- either forwarded to the LinkSmart middleware platform in case it supports the respective protocol
- or translated to the generic exchange protocol, if LinkSmart does not provide support to the respective protocol.

Consequently, it is possible to select a wireless technology under pure technical criteria such as energy consumption, available off-the-shelf devices, supported features or security level.

The Activity Hub can integrate a variety of sensors, for example:

- **Motion sensor**
A motion sensor device primary detects if one or more person/s is/are present in the nearby area. The sensor will be triggered by movements, such as walking. But it is not able to distinguish activators. So the information which is obtained by the motion sensor is: either there is a person or a moving object in the room, or not.
- **Door and window sensors**
These sensors are able to detect if the door or the window is opened or closed. This information can be helpful, e.g. to open respectively close doors and windows automatically to support people who are not able to do this on their own.
- **Occupation sensors**
Occupation sensor devices can detect what people are doing. In this case the sensor devices are used to monitor the behaviour of people. E.g. with the help of the bed occupation sensor it is possible to detect if a person gets up or not. If a person doesn't get up in the morning could possibly send a nurse to look after him or her in time.
- **Energy sensors**
These sensor devices collect information about the current consumption. They can be used for ordinary power sockets. If a person forgets to shut down an electrical device it is possible to notice this.

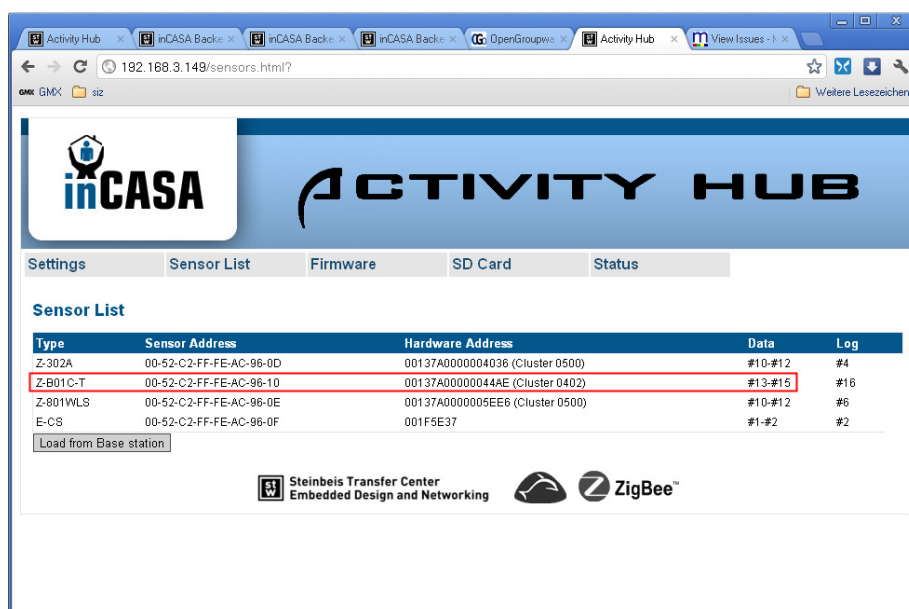


Figure 6 – Management of an inCASA motion / temperature sensor from web-based management interface of the inCASA Activity Hub

The sensor devices forward their data to the inCASA Activity Hub. The physical and application layer interface supports different health care and home automation protocols. The central elements include i.e.:

- ZigBee with its derivatives for different application profiles, i.e. Home Automation (HA) and ZigBee Health Care (ZHC) profiles,
- EnOcean Radio Protocol (ERP) for the interconnectivity with energy-autarkic sensor nodes,
- Wireless M-Bus for energy monitoring applications.

The Activity Hub combines and communicates with several radio modules and radio protocols. The internal communication uses a generic serial communication protocol.

3.2.2 inCASA Platform

3.2.2.1 Overview

The inCASA platform takes on the advantages of existing partner systems and integrates them in order to support an enhanced socio-medical platform that will be able to monitor both user behaviour and clinical conditions. Based on this, the SPP will be able to create a user behaviour model upon which alerts can be specified and generated in case of anomalous situations. The consumer applications will consume these services transparently whether its origin is from the Tele-health or Tele-care, what we may call, “domain”.

To realize these services the inCASA platform is composed of a home infrastructure where a Home Base Station encompasses both domains by the use of the LinkSmart client-side middleware. On the backend side of the inCASA platform a remote service provider infrastructure with the lead of the SPP is collecting pan-domain user monitored data. Comprising both Tele-care and Tele-health where the Activity Hub represents first and where the SARA client represents the second justifies the need for the inCASA platform to be open for extensions and scalable. The SPP should be able to cover the complexity of the various monitoring systems/domains, collect and exchange data in a uniform easy to understand way.

Between 12th and 13th January 2012, there was a technical meeting held in Barcelona where it was discussed how and what the most suitable approach for delivering a solid platform solution that would fit all possible pilots at stake in the project. Figure 1 shows the agreed architecture that the next coming development efforts should focus on.

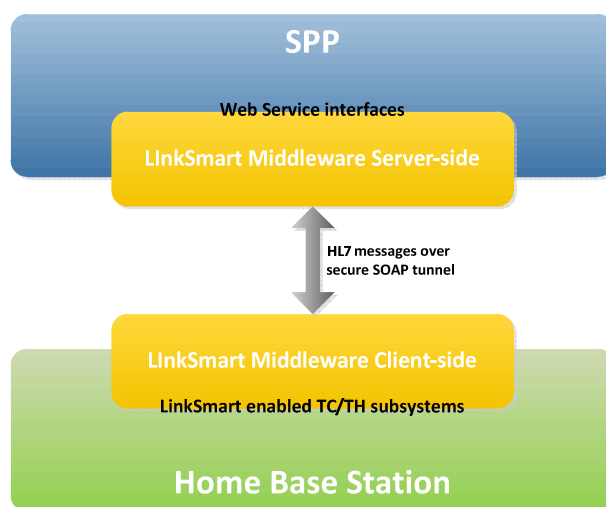


Figure 6 - LinkSmart P2P network communication

Figure 1 illustrates how the inCASA platform deals with widespread use of Tele-health and Tele-care systems and manages as a single uniform resource for the consumer applications. A bottom-up approach describes how the Home Base Station (HBS) placed in the elderly's home both supports the SARA Client and the Activity Hub. HBS is based upon the LinkSmart middleware technology and provides transparent measurement access throughout the specific instance of the inCASA network. Both the LinkSmart client and server actually look the same from a software point of view but in a full inCASA platform deployment only the client side will have the Object-Oriented software handling Tele-care and Tele-health distinctions. In settings, where a pilot only would use the server side part of the inCASA platform (e.g. GPRS communication), the server side will support both side technologies (i.e. domain specific device connectivity and interfaces to the SPP).

Figure 8 describes in a simple way how LinkSmart enabled Tele-care and Tele-health subsystems (i.e. Activity Hub and SARA Client) and their measurement collective features are securely communicated over the inCASA network as HL7 messages even though none of the subsystems use Continua compliant devices.

The LinkSmart enabling of Tele-care and Tele-health subsystems provides common support for creating HL7 based ORU-R01 messages. This is a feature given by the HL7Parser method that is able to aggregate both domain data into a single message (read more about this in chapter 5.2) or as separate messages depending of backend interpretation support.

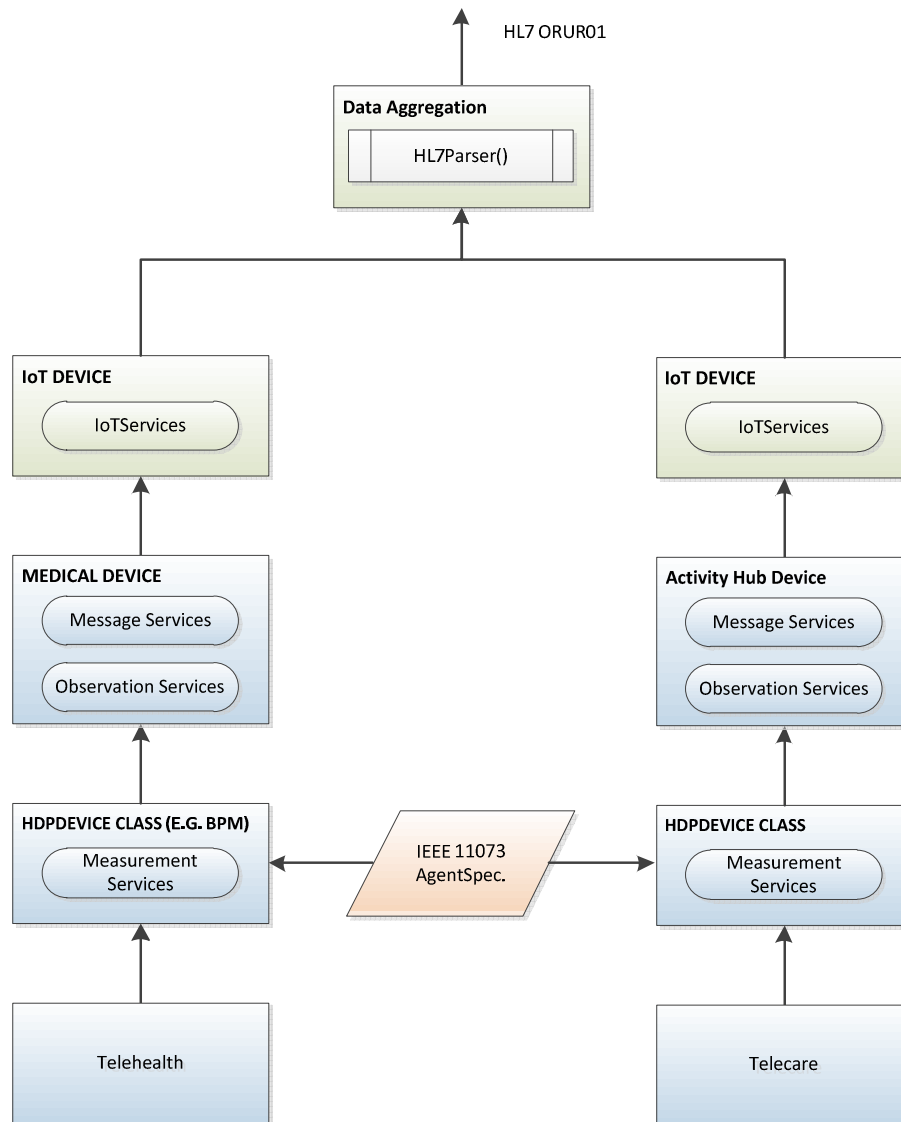


Figure 8 - Object-Oriented hierarchy of Tele-care and Tele-health devices that responds to the superclass IoT Device enabling common services for SPP and end-user.

The mapping of well-known sensors and devices across the domains to existing IEEE 11073 Agent Specializations are made by a specific HDP-Device class created for that sensor or device. Going upwards in Figure shows how domain specific device services are generated and exposed together with the IoT Services common to all types of sensors and devices in use in the inCASA network. Each SARA Client device instantiates a Medical Device class while the Activity Hub sensors become part of the Activity Hub Device class. The HL7 message is available as Web Service for the backend SPP Mediator. Some examples of this communication can be seen in section 5.2.

3.2.2.2 SPP functional description

The SPP is made of different modules:

- a Data Repository, called EPR (Electronic Patient Record), which allows storage and retrieval of End User-related data from both Tele-care and Tele-health domains
- a Reasoning module, called Reasoner to analyse data and either to take decisions in response to anomalous situations and alert conditions or to show divergence from habits model to an expert user (e.g. medical operator)
- an integration layer, called Mediator, which allows the interfacing of the SPP with external applications and which lets internal SPP modules communicate with each other.

With respect to the functional description in D3.2 [65] there is no need for interaction with a specific Tele-health server, as functionalities are carried on by the same components as for Tele-care.

3.2.2.2.1 Reasoning module

The reasoning module includes a Semantic Reasoner, which manages an ontological view of the system and performs rule based reasoning that implements a monitoring logic. In addition it can rely on plugins to perform specific tasks such as habit profiling or to perform aggregations on historical data that can be extracted from the data repository.

The reasoning module is responsible for:

- Building a customized End User's habit profile based on observations from environmental sensor
- Using the customized habit profiles to automatically recognize abnormal activity (e.g. the person remains in bed longer than usual, which might indicate a deterioration of his psychological or physical health conditions)
- Using the personalized threshold levels for triggering Tele-health alerts when a medical emergency emerges.
- Recognizing anomalous Tele-care situations (e.g. door left open for more than one hour)
- Recognizing anomalous Tele-health situations (e.g. a sudden weight increase which might indicate a severe water retention)
- Generating alerts with appropriate priority and severity, and manage alerts (escalation or termination) based on the evolved situation

To perform the functionalities listed above, the reasoning module shall collect, select and structure the context data, in order to create and maintain the knowledge base needed for context recognition and decision making.

The Semantic Reasoner uses W3C Semantic Web standard languages for modelling data. The semantic representation used by the Reasoner is an OWL-DL ontology that provides a representation of context awareness services in charge of monitoring specific situations and their relation with devices, apartments, and monitored users.

The knowledge base is structured in a base ontology with high level classes and different ontology (sub-) models for specific device/service classes. This way it can be dynamically managed and easily extended by adding models for the new entities. In particular there can be a separate OWL model for each type of entity, namely for each device, for each type of context awareness service, for each conceptual entity used by the Reasoner (e.g. user habits, alerts).

The update of the knowledge base is event-driven: it is updated according to events communicated by the Mediator where a publish/subscribe mechanism is used. For instance, the Reasoner subscribes to changes related to the thermometer entities, and it is notified of each temperature measure. Once the ontology is updated, the rules based reasoning is executed. Two sets of rules

can be run for evaluating the context and for managing proper reaction (e.g. generating or managing alerts). When a significant change occurs in the context (a new alert condition is met, overtaking of the alarm level or of the threshold of significant reference) the Reasoner must be able to deliver to the Mediator an event that notifies the change. The system must be able to detect and process the context data changes, make reasoning, take decisions and actions in short time.

3.2.2.2.2 Mediator

The integration layer is represented by a Mediator component, which main purpose is to decouple SPP sub-systems by offering standard, SOAP/XML-based interfaces in order to gain interoperability. Tasks accomplished by this component must be:

- *to interconnect modules with each other*: they must not be interconnected directly, since such integration pattern leads to point-to-point interfaces, difficult to manage and maintain; wrapping in services the resources exposed by the modules is a SOA best practice which allows scalability without too much impact on existing systems
- *to adapt module interfaces*: in case of heterogeneous technologies and/or data formats, transformation is an issue which must not be a concern for merely functional modules; a single module must not change its interfaces on the behalf of a foreign system, because that means creating a dependency which tightens systems together and does not allow them to grow independently
- *to allow notification of specific events*: the events generated by the different modules must be notified to the external applications, either to a configurable endpoint or through a publish & subscribe mechanism, as needed; even if such feature could be directly provided by a single event-emitting module, it is a best practice to provide a single entry point for the applications, abstracting from the specific module arising events.

To allow querying the EPR: the Mediator must allow retrieving from the EPR data such as measures, derived data, alerts, information about patients, etc., according to IHE PCD-02, as defined in Section 4.4.1.

The Mediator provides a publish/subscribe interface towards the Reasoner to notify events, such as measures received from the home base station.

Handling of alerts is addressed in the Mediator routing them from the source to the destination, taking care of providing them to the EPR for storage and notifying them to the Consumer Application. An alert update service is also provided to allow an Operator logged on a Consumer Application to add notes and details about an alert once it is being managed. Sources of alerts should be Hydra, which could generate or propagate simple alerts generated based on simple conditions at the house level (e.g. gas presence), and the Reasoner, which could generate alerts due to environmental conditions or anomalous conditions concerning the End User and deserving attention.

The primary functionality of the Mediator is both to integrate the different subsystems of the SPP and to integrate the SPP itself with other inCASA modules and the external systems. Measure and alert messages constitute two different data flows which are sent by Hydra to the SPP on different channels. All of the messages must be directed to the Data Repository in order to be stored.

3.2.2.2.3 Data Repository

As described in D3.2 [65], the data repository is managed by an EPR application, customized for the inCASA project.

The EPR handles and stores health and environmental information, giving access to data by means of suitable interfaces, exposed as services and accessed by the Mediator.

No End User's or Operator's GUI should be directly provided by the module except for a simple administrative interface for conveniently dealing with master data in charge to the EPR (patients' demographic information).

Raw data incoming from Home Base Stations must be collected and persistently retained within the Data Repository. The Data Repository gives persistence also to derived data (e.g. average health measures, total number of certain events per day...) and habit profiles and allows modification and querying from the outside. Service interfaces are compliant to the IHE integration profiles and are defined in D4.3.

3.2.3 Consumer applications

Consumer Applications (CA) provide a single point of access (Web UI) for the inCASA operators to access measurements and alarms generated by the inCASA platform, over both the Tele-care and the Tele-health domains; visualizations and specially constructed views enable the inCASA operators to make informed decisions on the care of elderly people monitored by the platform. Interfaces to the CA for intercepting the measurement and alert messages are specified in accordance to the bottom-up architectural approach (Figure 9). Specifically, all updates made available from or forwarded (specific to alerts handling) to the SPP mediator are encoded using HL7 messages (Section 4.4) and served using web services adhering to standardized IHE integration profiles (Section 0).

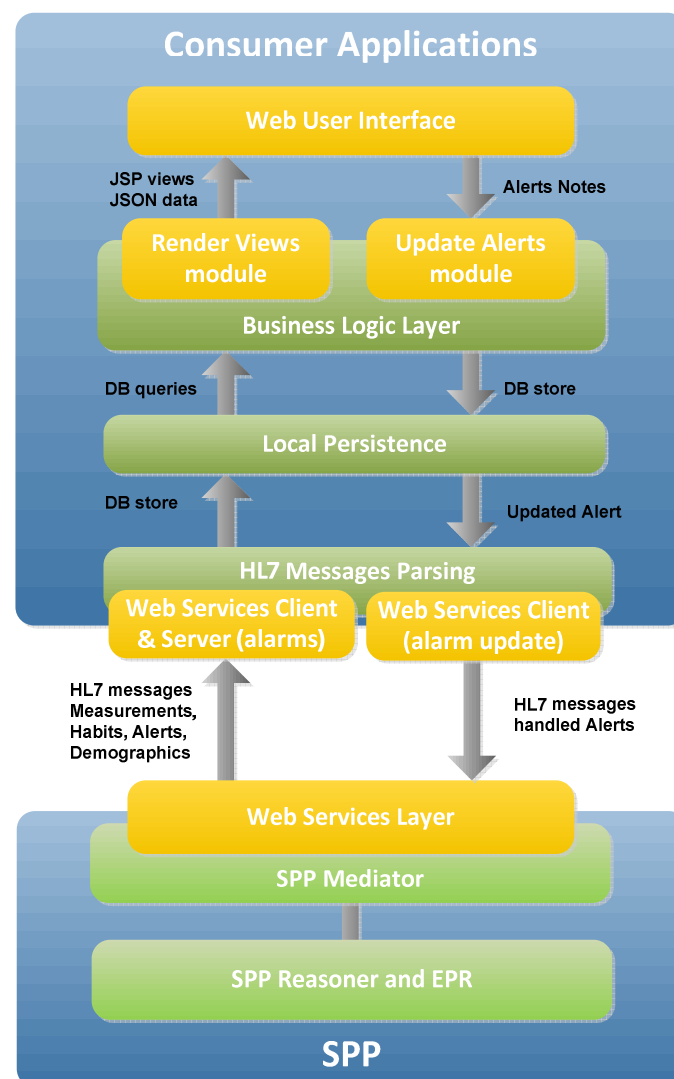


Figure 9 - Interfacing Consumer Applications with the SPP

The above figure illustrates how the Consumer Applications interface to the SPP mediator that exposes both Tele-health and Tele-care data stored in the inCASA platform. CA includes a web service module to receive HL7 messages containing patient data, including patient info and demographics, measurements, habits and alerts, from the SPP. Another web service client is implemented in order to expose updated alert events to the SPP, containing notes on the subsequent actions initiated by the platform operators.

HL7 messages are analysed and filtered during parsing, and all useful data is extracted and stored in the local data repository. The business logic layer serves as an intermediate (controller) responsible for requesting, using structured queries (model) to the repository, data required for rendering the web front-end interface (views). The views presented to the inCASA operators are hence constructed using standard template technologies (JSP) and enriched with measurements plots, dynamically updated using Web 2.0 technologies (asynchronous JavaScript calls for requesting data in the JSON format). Also, there are special provisions for intercepting and presenting alerts in a near real-time fashion (Atmosphere framework). Thus, the structuring and presentation of available data depends on the respective domain (Tele-health/Tele-care) and its class (measurements/alerts).

Of course, the end users can interact with the CA through the graphical user interface (GUI) that enables them to request new views and also note actions taken in response to emergencies indicated by the alerts. The latter is realized through a specialized updated alerts module that forwards the operator notes to the messaging layer. Subsequently a new HL7 message is constructed with the updates and forwarded to SPP through the web service layer.

4 Information view

In this section, data transformation from the patient's environment to the consumer applications is presented. LinkSmart middleware has a key role to homogenize information coming from the Tele-health and the Tele-care domains into HL7 messages.

4.1 Introduction

This viewpoint describes the information content and structure and how the system stores and manipulates the data passed through the information flows. Data models are depicted, with respect to the available level of detail. The objective of this viewpoint is also to provide indications about other possible critical aspects such as ownership and security.

The *Data View* conforms to the Information Viewpoint and it is focused on main data structures, semantics and scheme, according to the level of detail available for a corresponding functional block.

4.1.1 Stakeholder Concerns

This viewpoint addresses the concerns of:

- *Database Designers* (among the *Developers*), which have the task of modelling system's data repositories
- *Database Administrators* (among the *Maintainers*), which must have the knowledge of the general aspects of the data flows they will manage
- *System Engineers* (among the *Developers*), which is responsible for developing and integrating the various database components of the system.

4.1.2 Notation and Language

Views conforming to the Information Viewpoint are represented either by UML 2.x class diagrams or plain text tables listing an entity's attributes or XML schema/DTD definition.

4.2 Patient's environment

Main role of the patient's environment is to collect data and send it to the platform. In the next sections main data messages that will have to be dealt by LinkSmart are described giving details about each of the fields.

4.2.1 SARA Client

The SARA client collects information from a big range of sensors that use different proprietary data formats. SARA is flexible enough to integrate new devices with different schemes and create its own data message that will be forward it to the LinkSmart client agent. For any kind of sensor, there is a data message that is always the same is shown and this is how it looks like:

```
<soapenv:Envelope
xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/">
  <soapenv:Header/>
  <soapenv:Body>
    <storeMeasure>
      <ak>
        <idKit>1</idKit>
        <passWS>kitP_pwd</passWS>
        <userWS>kitP</userWS>
      </ak>
      <id></id>
      <idDevice>1</idDevice>
      <name>systolic-pressure</name>
      <dateReception>1302533492752</dateReception>
      <dateTransmission>1302533492752</dateTransmission>
      <dateMeasure>1302533492752</dateMeasure>
      <unit>mmhg</unit>
      <!--1 or more repetitions:-->
      <measureValue>114</measureValue>
    </storeMeasure>
  </soapenv:Body>
</soapenv:Envelope>
```

Most important fields determine the name of the measure, the date when the data was collected and send it, the unit of the measure and of course, the value of the measure. Information is encapsulated using SOAP and send to the LinkSmart by Web Services.

The next table describes a little bit more each of the fields of the message:

4.3 Data Message (storeMeasure)
AK (Application Kit): Identifies the TH Kit for the patient <ul style="list-style-type: none"> • Id Kit: Identificator for the patient/Kit • passWS: Credentials for the Kit • userWS: Credentials for the Kit
idDevice: Identifies the TH device
Name: Describes the name of the measure
DateReception: date when the measure was received by SARA
DateTransmission: date when the measure was transmitted by SARA to the platform
DateMeasure: date when the measure was taken by the TH sensor
Unit: describes the unit used by the measure
MeasureValue: shows the value of the measure

Table 3 - Data Message SARA client

4.2.2 Activity Hub

The Activity Hub collects information from all the domotic sensors in the house and sends them to the LinkSmart in XML/HTTP protocol. The next message shows a datagram sent to the middleware client agent:

```
<?xml version="1.0"?>
<incasa>
  <type>10</type>
  <id>8</id>
  <seq>163</seq>
  <flag>00</flag>

  <service>
    <sid>1</sid>
    <format>1</format>
    <exponent>0</exponent>
    <unit>01</unit>
    <data>00</data>
  </service>
  <service>
    <sid>2</sid>
    <format>2</format>
    <exponent>1</exponent>
    <unit>°C</unit>
    <data>0123</data>
  </service>
</incasa>
```

Unlike Tele-health messages, here services are defined to concatenate measures from different sensors. Because domotic sensors transmit at the same time, it is important to be able to compact all this information in a single message.

Table 4 explains the meaning of each field in detail:

Data Message (storeMeasure)
Type: Number that might help to identify different kinds of kits installations
Id: Number that identifies patient's kit
Seq: Number that helps the server to reconstruct messages
Flag: Number that might be used for identifying specific situations (i.e. alerts)
Service: Service related to a specific sensor <ul style="list-style-type: none"> • Sid: Sensor id • Format: Number that might help to establish different kinds of formats to send information • Exponent: Number that represents the exponent of numeric data • Unit: Shows measure's unit • Data: Represents the value of the data message

Table 4 - Data message Activity Hub

4.3 inCASA Platform

In combination with the decision to adopt and follow the Continua Guidelines where possible and the notion that the inCASA project reuses pre-existing solutions/services for human/environment monitoring, that are integrated in order to collect and analyse data to profile user habits and implement customized intelligent multilevel alerts/communication services, some slight customizations have taken place. This involves two steps. The first step is to integrate these pre-existing systems and adopt parts of the Continua Guidelines where suitable. At this time, the main adoption of it is beyond device communication and the use of HL7 message formats within the inCASA platform. The second step is already supported by the LinkSmart middleware but requires that existing systems modify their device communication to align with the IEEE 11073-20601 Optimized Exchange Protocol. The flexibility and support offered for the different contributing project subsystems are illustrated in Figure 10..

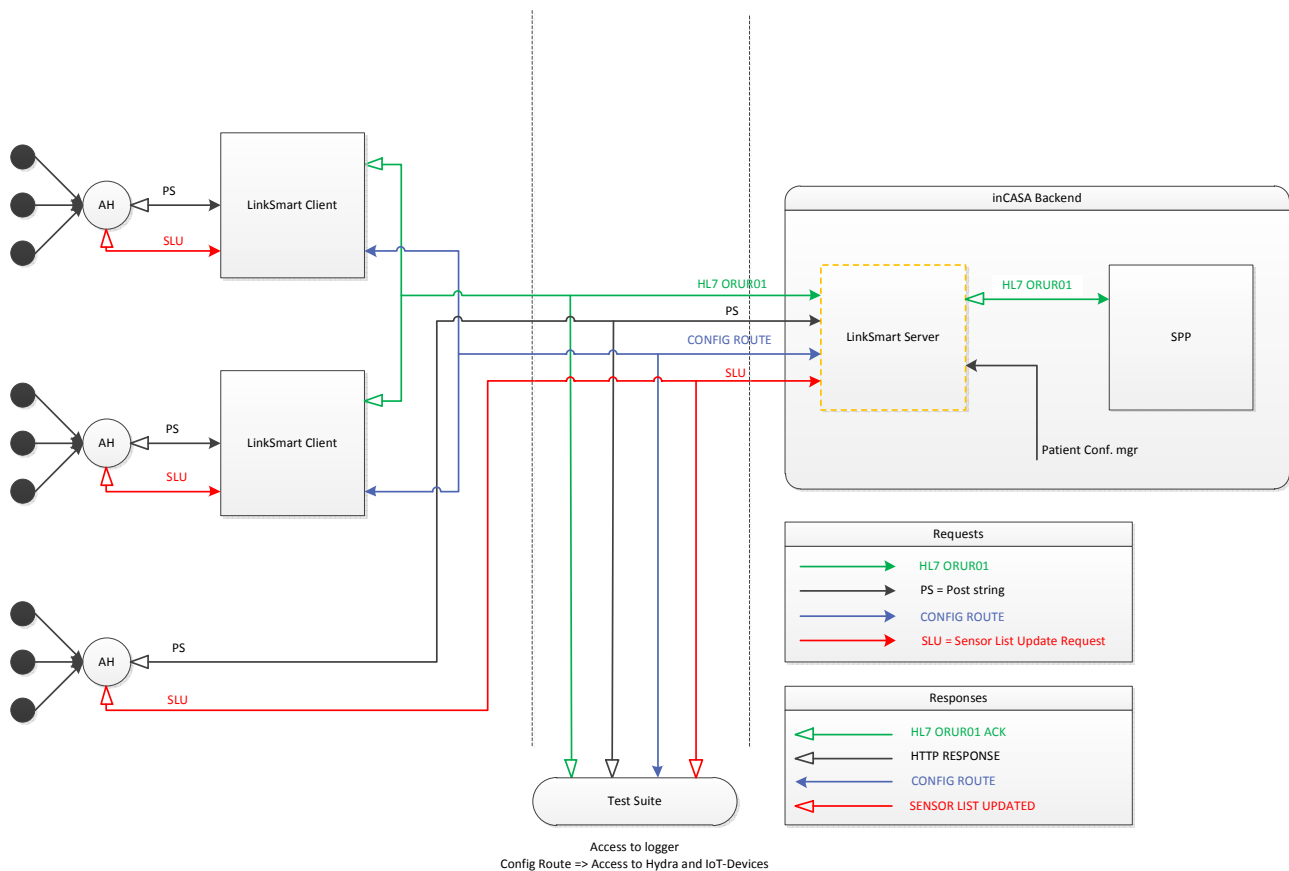


Figure 10 - Overview of the inCASA platform communication.

The LinkSmart Server for the inCASA platform is designed to handle communication from different kind of sources. One of the main inputs into the LinkSmart Server Application is the Patient Configuration Manager which enables configuration of the information belonging to each Activity Hub. This information is stored in the configuration database (AH Data) and can be distributed and mirrored to the related LinkSmart Client Application through the Configuration Route.

When the Activity Hub starts for the first time, a Sensor List Request (SLU) is sent to the LinkSmart Server Application with a request about the configuration of the Activity Hub. The configuration contains information about sensor type, sensor IEEE hardware address and a unique sensor address used to identify the measurement sent from each sensor.

The LinkSmart Client handles the communication to the Activity Hub locally in the same way the LinkSmart Server Application does. Measurement received from the Activity Hub is converted to

HL7 ORU^R01 message and forwarded to the LinkSmart Server Application which takes care of forwarding the message further to SPP.

The Test Suite Application (mimics the behaviour of a Activity Hub and can be used to test and debug the LinkSmart Server Application. It has also direct contact to the Logger database and can visualize the logged data.

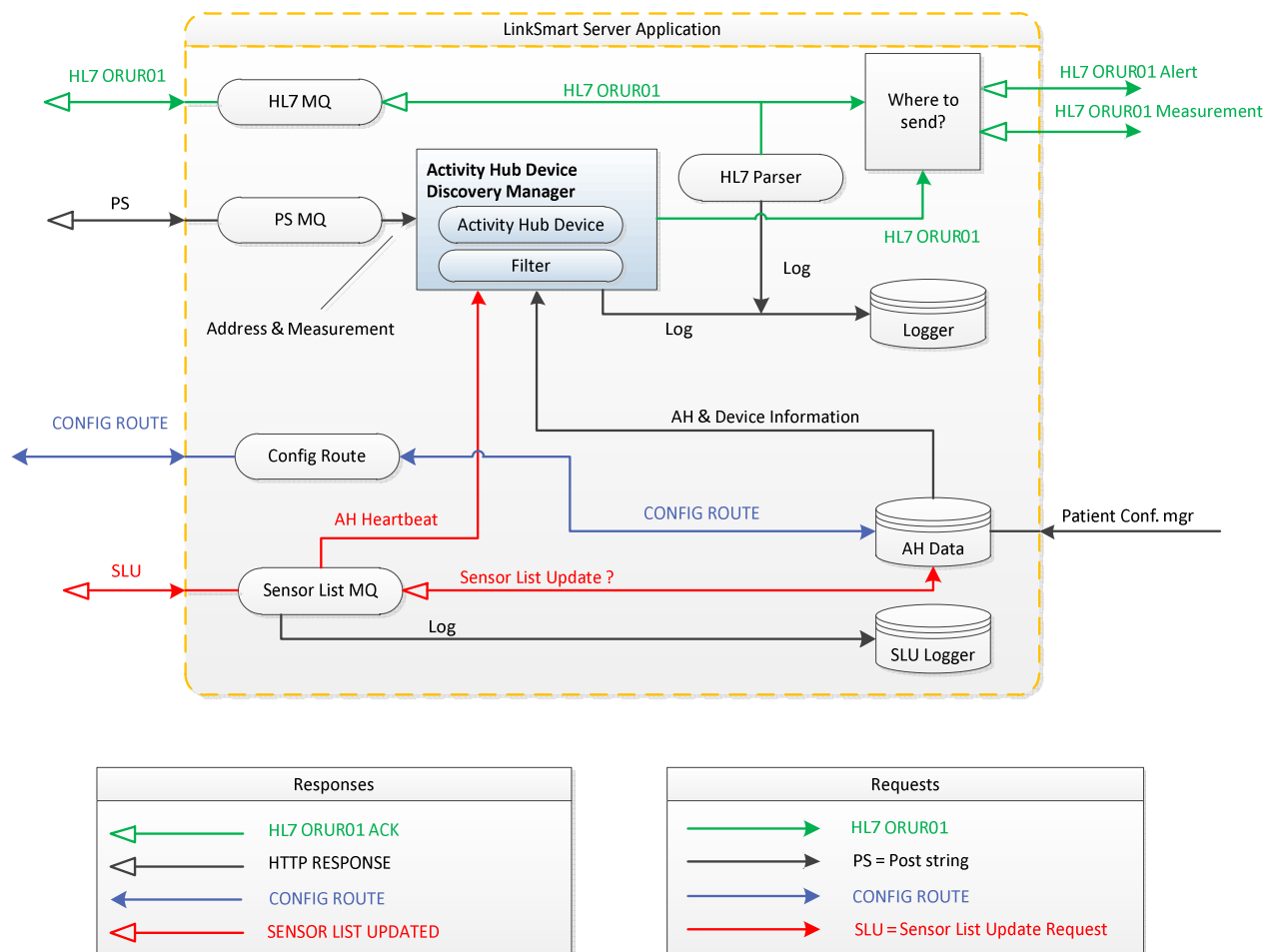


Figure 11 - Detailed description on how the LinkSmart server side handles communication with several pre-existing systems in inCASA

Looking at Figure 11 we can see that the HL7 ORU^R01 input is used to forward HL7 ORU^R01 messages further to SPP. The source comes from the LinkSmart Client Application which can contain information from both TH and TC domains. These messages can also be parsed to store the measurement into the logger database.

The Activity Hub Device is an IoT-Device or a virtual representation of the real Activity Hub and connected sensors (Figure). They are initialized by the Activity Hub Device Discovery Manager from the data stored in *AH data* and set by the Patient Configuration Manager. When an Activity Hub sends a new measurement through the Post String route, the measurement is also directly stored into a message queue. In this way many Activity Hubs can send data into the LinkSmart Server Application and the more time consuming handling of the measurement is offloaded to the Activity Hub Device Discovery Manager. The measurement taken out from the message queue goes first through a filter that filters out data that will not be further forwarded. The filtering process uses each measurement as a heartbeat from the sensor and updates the information for the corresponding Activity Hub

Device. If the measurement will be forwarded and converted into a HL7 ORU^R01 message, it will also automatically be stored in the logger.

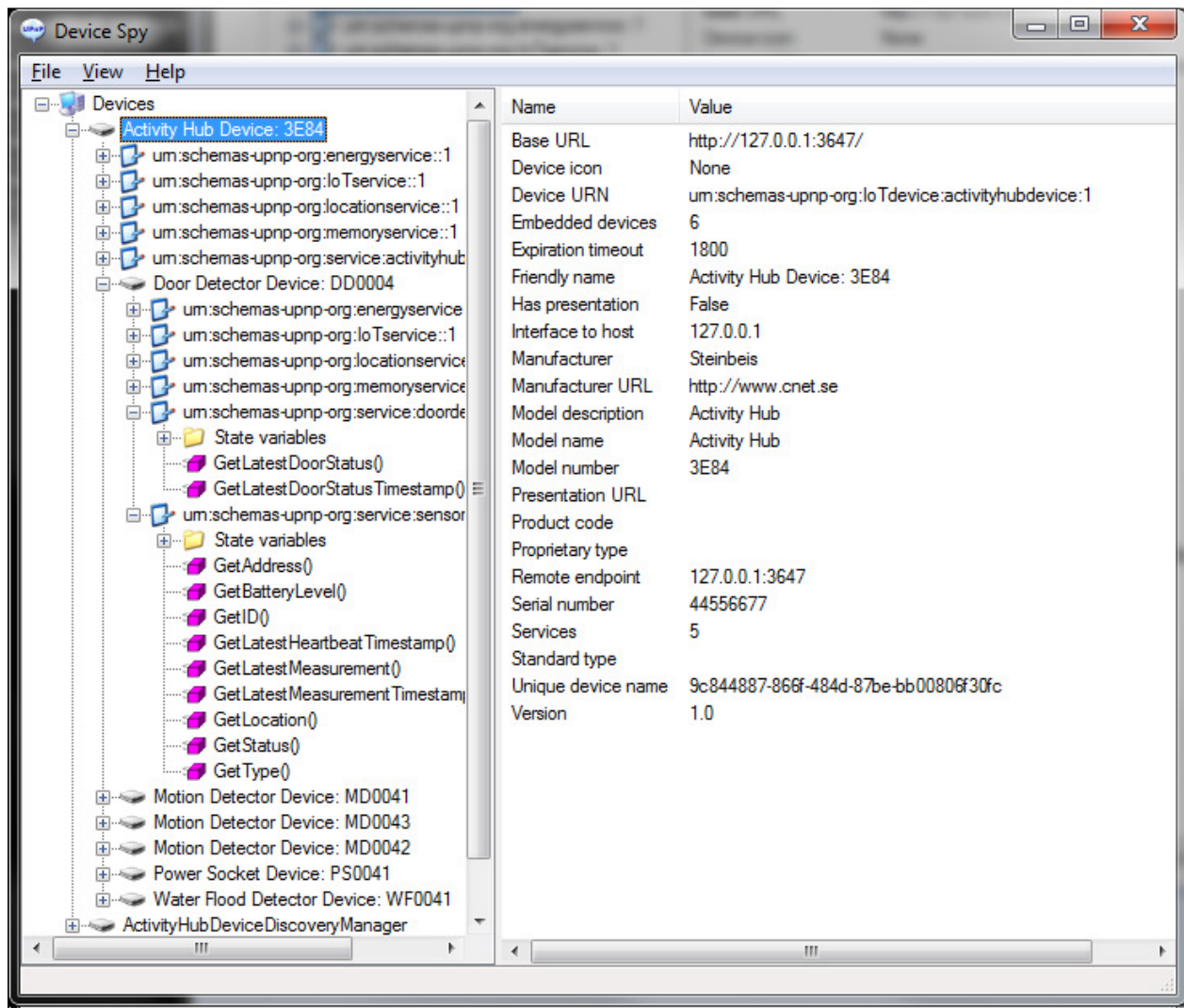


Figure 12 - IoTDevice of the Activity Hub Device class and its services seen by Intel's UPnP network Device Spy Tool

Each Activity Hub sends a Sensor List Request on start-up requesting the Activity Hub configuration; this process is repeated every hour to look if there are any changes concerning that particularly Activity Hub. The LinkSmart Server Application uses these requests as a heartbeat for each Activity Hub, which shows whether it's alive and can communicate. Each Sensor List Request is also stored into a logger database with the status information, initialize, heartbeat or update.

The inCASA solution implements two of the Patient Care Device (PCD) integration profiles defined by IHE (Integrating the Healthcare Enterprise) [59]:

- the Data Enterprise Communication (DEC) profile [60] is used for the measurements' data flow
- the Alarm Communication Management (ACM) profile [61] is used for alerts' data flow

IHE integration profiles define actors and transactions.

The mapping between the DEC profile's actor and the inCASA block which plays it is given in the following table.

IHE DEC Actor	Role	inCASA block
Device Observation Reporter (DOR)	Sends PCD Data to DOF or to DOC	Home Base Station
Device Observation Filter (DOF)	Receives PCD Data from DOR and sends PCD Data to DOC based on defined filter predicates	Smart Personal Platform
Device Observation Consumer (DOC)	Receives PCD Data from DOR and/or DOF	Smart Personal Platform Consumer Applications

Table 5 - DEC actors implemented in inCASA

The mapping between the ACM profile's actor and the inCASA block which plays it is given in the following table.

IHE PCD Actor	Role	inCASA block
Alarm Reporter (AR)	Sends report alarm to the AM	Smart Personal Platform
Alarm Manager (AM)	Receives report alarm from AR and sends report alarm to AA	Smart Personal Platform Consumer Applications
Alarm Archiver (AA)	Receives report alarm from AM	Smart Personal Platform
Alarm Communicator (AC)	Receives report alarm from AM	Consumer Applications

Table 6 - ACM actors implemented in inCASA

The IHE transactions occurring between the inCASA blocks are depicted in the following image.

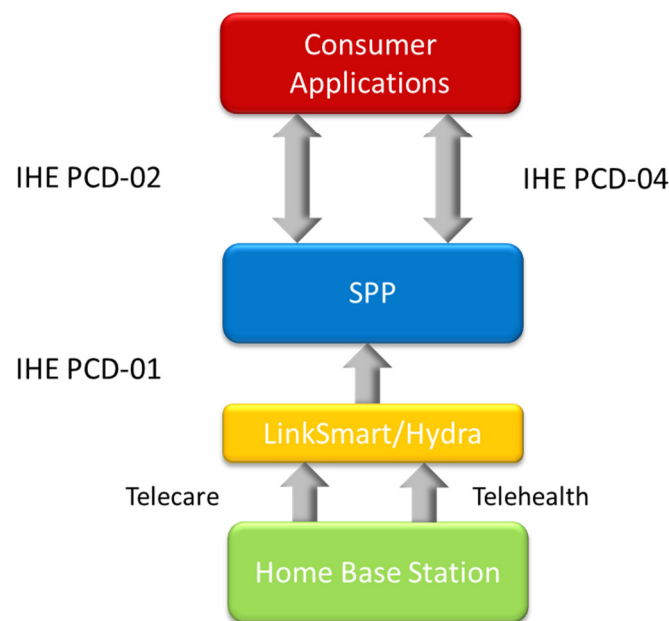


Figure 13 - IHE transactions between inCASA blocks

The arrows in the above picture describe the data flow for each transaction:

- PCD-01 (Communicate PCD Data): Tele-care and Tele-health measures are collected at the Home Base Station and sent to the SPP through the LinkSmart Middleware
- PCD-02 (Subscribe to PCD Data): the Consumer Applications query the SPP to get measures and alerts belonging to the Tele-care and Tele-health domains
- PCD-04 (Report Alarm): alerts generated by the SPP are sent to the Consumer Applications which in turn can send alert updates to the SPP

IHE transactions use by means of data transport HL7 messages (version 2).

HL7 (Health Level 7) is a standard for electronic data exchange in healthcare environments. HL7 version 2 messages are old-style field separated ASCII messages. The structure of each kind of message is defined as a sequence of lines (called segments), which can be grouped in repeated and/or optional blocks. Each segment is identified by a name (first 3 characters) and it is made of a sequence of fields separated by the pipe character ('|'); fields may be repeated (repetitions are separated by the tilde character ('~')) and may contain a simple or compound data type. Sub-fields are separated by the caret character ('^') and may have sub-components separated by the ampersand character ('&').

The following table shows the structure of the ORU^R01, whose purpose is to transport observations, which is the main message used inside the inCASA project. Curly brackets mean repeatability, square brackets mean optionality; the values in the “usage” column can be: R (Required), O (Optional), X (not used in this IHE transaction).

Segment	Meaning	Usage	Cardinality	HL7 Chapter
MSH	Message Header	R	[1..1]	2
[[SFT]]	Software Segment	X	[0..0]	2
{	--- PATIENT_RESULT begin		[1..*]	
[--- PATIENT begin		[1..1]	
PID	Patient Identification	R	[1..1]	3

Segment	Meaning	Usage	Cardinality	HL7 Chapter
[PD1]	Additional Demographics	X	[0..0]	3
[[NTE]]	Notes and Comments	X	[0..0]	2
[[NK1]]	Next of Kin/Associated Parties	X	[0..0]	3
[--- VISIT begin		[0..1]	
PV1	Patient Visit	O	[0..1]	3
[PV2]	Patient Visit – Additional Info	X	[0..0]	3
]	--- VISIT end			
]	--- PATIENT end			
{	--- ORDER_OBSERVATION begin		[1..*]	
[ORC]	Order Common	O	[0..1]	4
OBR	Observation Request	R	[1..1]	4
[[NTE]]	Notes and Comments	O	[0..1]	2
[[--- TIMING_QTY begin			
TQ1	Timing/Quantity	O	[0..1]	4
[[TQ2]]	Timing/Quantity Order Sequence	X	[0..0]	4
]]	--- TIMING_QTY end			
[CTD]	Contact Data	X	[0..0]	11
[[--- OBSERVATION begin		[1..*]	
OBX	Observation Result	R	[1..1]	7
[[NTE]]	Notes and Comments	O	[0..0]	2
]]	--- OBSERVATION end			
[[FT1]]	Financial Transaction	X	[0..0]	6
[[CT1]]	Clinical Trial Identification	X	[0..0]	7
[[--- SPECIMEN begin			
SPM	Specimen	X	[0..0]	7
[[OBX]]	Observation related to Specimen	X	[0..0]	7
]]	--- SPECIMEN end			
}	--- ORDER_OBSERVATION end			
}	--- PATIENT_RESULT end			
[DSC]	Continuation Pointer	X	[0..0]	7

Table 7 - Structure of the ORU^R01 HL7 message

An example of an ORU^R01 message is the following.

```
MSH|^~&|LINKSMART||SPP||20120127115719+0100||ORU^R01^ORU_R01|MSGID123456789|P|2.6|||NE|AL||8859/15|
||IHE_PCD_001^IHE PCD^1.3.6.1.4.1.19376.1.6.1.1.1^ISO
PID|||U001234^^^^HC
PV1||N|AP123^^^^H
OBR|1|1^LINKSMART^1^EUI-64|2^SPP^2^EUI-64|182777000^monitoring of
patient^SCT|||20120127115719+0100|20120127115719+0100
OBX|1||528391^MDC_DEV_SPEC_PROFILE_BP^MDC|1|||||X|||||AP123^AP123^EUI-64
OBX|2||150020^MDC_PRESS_BLD_NONINV^MDC|1.0.1|||||X|||20120127115719
OBX|3|NM|150021^MDC_PRESS_BLD_NONINV_SYS^MDC|1.0.1.1|120|266016^MDC_DIM_MMHG^MDC||||R|||20120
127115719
OBX|4|NM|150022^MDC_PRESS_BLD_NONINV_DIA^MDC|1.0.1.2|80|266016^MDC_DIM_MMHG^MDC||||R|||2012012
7115719
OBX|5|NM|150023^MDC_PRESS_BLD_NONINV_MEAN^MDC|1.0.1.3|100|266016^MDC_DIM_MMHG^MDC||||R|||201
20127115719
OBX|6|NM|149546^MDC_PULS_RATE_NON_INV^MDC|1.0.0.2|90|264864^MDC_DIM_BEAT_PER_MIN^MDC||||R|||20
120127115719
```

The set of rules regarding message composition create an integration statement that defines which segments and fields should be used, if they are mandatory or optional, how fields have to be compiled and so on. IHE has defined these rules for each transaction: deliverable D5.3 describes in detail how they are customized inside the inCASA project.

In HL7 each data exchange is made of a couple of messages; there are two possible data flow:

1. the sending application issues an unsolicited message to send data to the receiving application which replies with an acknowledgment message
2. the sending application issues a query message to the receiving application which replies with a response message which acts as an acknowledgment as well (it has the same general structure of the original ACK message)

HL7 messages may be exchanged through different physical channels; the most commonly used are TCP/IP (using the Minimum Lower Layer Protocol) and Web Service. IHE prescribes for the PCD profile the use of Web Services and has defined the following WSDL.

```
<?xml version="1.0" encoding="UTF-8"?>
<wsdl:definitions name="DeviceObservationConsumer"
  targetNamespace="urn:ihe:pcd:dec:2010"
  xmlns:soap12="http://schemas.xmlsoap.org/wsdl/soap12/"
  xmlns:wsdl="http://schemas.xmlsoap.org/wsdl/"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns:wsaw="http://www.w3.org/2006/05/addressing/wsdl"
  xmlns:tns="urn:ihe:pcd:dec:2010">
  <wsdl:types>
    <xsd:schema>
      <xsd:import namespace="urn:ihe:pcd:dec:2010"
        schemaLocation="DeviceObservationConsumer.xsd"/></xsd:import>
    </xsd:schema>
  </wsdl:types>
  <wsdl:message name="CommunicatePCDDData_Message">
    <wsdl:documentation>Communicate PCD Data</wsdl:documentation>
    <wsdl:part name="body" element="tns:CommunicatePCDDData" />
  </wsdl:message>
  <wsdl:message name="CommunicatePCDDDataResponse_Message">
    <wsdl:documentation>Communicate PCD Data Response</wsdl:documentation>
    <wsdl:part name="body" element="tns:CommunicatePCDDDataResponse" />
  </wsdl:message>
  <wsdl:portType name="DeviceObservationConsumer_PortType">
    <wsdl:operation name="CommunicatePCDDData">
      <wsdl:input message="tns:CommunicatePCDDData_Message"
        wsaw:Action="urn:ihe:pcd:2010:CommunicatePCDDData" />
      <wsdl:output message="tns:CommunicatePCDDDataResponse_Message"
        wsaw:Action="urn:ihe:pcd:2010:CommunicatePCDDDataResponse" />
    </wsdl:operation>
  </wsdl:portType>
  <wsdl:binding name="DeviceObservationConsumer_Binding_Soap12"
    type="tns:DeviceObservationConsumer_PortType">
    <soap12:binding style="document"
      transport="http://schemas.xmlsoap.org/soap/http" />
    <wsaw:UsingAddressing wsdl:required="true" />
    <wsdl:operation name="CommunicatePCDDData">
      <soap12:operation soapAction="urn:ihe:pcd:2010:CommunicatePCDDData" />
      <wsdl:input>
        <soap12:body use="literal" />
      </wsdl:input>
      <wsdl:output>
        <soap12:body use="literal" />
      </wsdl:output>
    </wsdl:operation>
  </wsdl:binding>
  <wsdl:service name="DeviceObservationConsumer_Service">
    <wsdl:port binding="tns:DeviceObservationConsumer_Binding_Soap12"
      name="DeviceObservationConsumer_Port_Soap12">

```



```

    <soap12:address location="http://www.example.org/" />
  </wsdl:port>
</wsdl:service>
</wsdl:definitions>

```

The elements referred to in the above WSDL are defined in the following XSD.

```

<?xml version="1.0" encoding="UTF-8"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema" targetNamespace="urn:ihe:pcd:dec:2010"
xmlns:tns="urn:ihe:pcd:dec:2010">
  <element name="CommunicatePCDDData" type="tns:UnsolicitedObservationResult" />
  <element name="CommunicatePCDDDataResponse" type="tns:GeneralAcknowledgement" />
  <simpleType name="UnsolicitedObservationResult">
    <restriction base="string" />
  </simpleType>
  <simpleType name="GeneralAcknowledgement">
    <restriction base="string" />
  </simpleType>
</schema>

```

The inCASA modules implement one or more of these interfaces according to the number of IHE transactions they are involved into and by their directionality. According to IHE the observations sent through HL7 messages have to be coded in a standard way using the IEEE 11073 data model. In this manner any kind of observation, either belonging to the Tele-care or to the Tele-health domain, is uniformly coded. The following picture shows the IEEE 11073 data model.

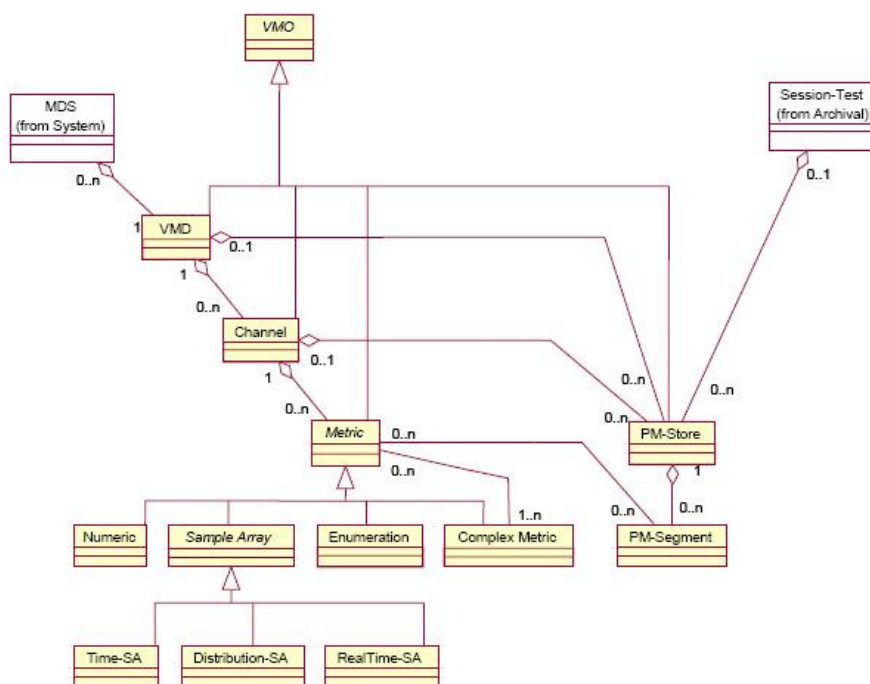


Figure 14 - IEEE 11073 data model (© IHE)

Each measure transmitted is hierarchically positioned inside the above data structure; the measure itself is a *Metric* which can originate from a *Channel* belonging to a *Virtual Medical Device* of the *Medical Device System*. The PCD integration profile does not make use of the VMD level. Channels are used when different metrics are measured by the same device (for example the systolic and diastolic blood pressure are different channels of the Blood Pressure device). To every object inside this data model is associated a numeric identifier; when data is sent through a HL7 message the unique identifier of the measure's kind and its position inside the hierarchy are provided.

4.4 Consumer applications

The Consumer Applications (CA) implement the PCD-02 and PCD-04 transactions with the Smart Personal Platform (SPP).

4.4.1 PCD-02 Transactions

IHE defines two message types (see section 5.3) for PCD-02 transactions. These are:

- QSB^Z02^QSB_Q16 for queries.
- ORU^R01^ORU_R01 for responses.

The QSB query message supports 3 types of queries:

- getPatients: this query is used to retrieve the patients list from the SPP, along with the patients' demographic data.
- getPatientMeasures: this query is used to retrieve all data for a specific patient. This includes the patient's habitual profile (by setting the QPD-6 field to "MEASURE.USERHABIT") and patient measurements. Results can be further filtered by setting a measurement's flag to the QPD-6 field (Weight, Motion etc)..
- getPatientAlerts: this query is used to retrieve the patient's alert history.

In the next sub-sections we provide some examples of the above queries. The QSB queries are defined in the HL7 specifications v2.6. It is worthy to note at this point that all HL7 queries performed by the latest version of inCASA Consumer Applications (third iteration) are structured according to the **HL7 v2.6** standard.

4.4.1.1 getPatients QSB Query

```
MSH|^~\&|CA||SPP||20120223131444||QSB^Z02^QSB_Q16|263206|P|2.6|||NE|AL||8859/15|||IHE PCD-02
2010^HL7
QPD|Z02^PCD-02-Subscription|getPatients|||||-1
```

4.4.1.2 getPatientMeasures QSB Query

The discrimination between the various type of measurements, from the Telehealth or the Telecare domain, is possible by using a proper flag that indicates the type of measurement, that is going to be queried. Below we provide examples of such queries. The measurement flag is placed at the QPD-6 segment of the HL7 message. This filtering feature is a new characteristic in the HL7 v2.6 specification and it drastically improves performance issues, that include parsing, analysing and storing the data that are extracted from each message.

- Retrieve motion measurement

```
MSH|^~\&|CA||SPP||20121125123559||QSB^Z02^QSB_Q16|abcd1234|P|2.6|||NE|AL||8859/15|||IHE PCD-02
2010^HL7
QPD|Z02^PCD-02-
Subscription|getPatientMeasures|U001234|||8519687^MDC_AI_TYPE_SENSOR_MOTION^MDC||20121118
123559|20121125123559|-1
```

- Retrieve weight scale measurements

```
MSH|^~\&|CA||SPP||20121125123657||QSB^Z02^QSB_Q16|abcd1234|P|2.6|||NE|AL||8859/15|||IHE PCD-02
2010^HL7
QPD|Z02^PCD-02-
Subscription|getPatientMeasures|U001234|||528399^MDC_DEV_SPEC_PROFILE_SCALE^MDC||20121118
123657|20121125123657|-1
```

- Retrieve Habitual Profile Information

```
MSH|^~\&|CA||SPP||20121125123737||QSB^Z02^QSB_Q16|abcd1234|P|2.6|||NE|AL||8859/15|||IHE PCD-02
2010^HL7QPD|Z02^PCD-02-
Subscription|getPatientMeasures|U001234|||101^MEASURE.USERHABIT^inCASA|||-1
```

4.4.1.3 getPatientAlerts QSB Query

```
MSH|^~\&|CA||SPP||20121125123418||QSB^Z02^QSB_Q16|abcd1234|P|2.6|||NE|AL||8859/15|||IHE PCD-02
2010^HL7
QPD|Z02^PCD-02-Subscription|getPatientAlerts|U001234|||20121120123418|20121125123418|-1
```

To return the requested data, the SPP responds with ORU^R01 messages.

4.4.2 PCD-04 Transactions

For PCD-04 transactions IHE defines 2 message types (see section 5.4):

- ORU^R01^ORU_R01 for alert messages
- ACK^R01^ACK for acknowledgment messages

The PCD-04 transactions are used in 2 occasions:

- Firstly, when the SPP sends a newly generated alert. The CA receives the alert and responds with the proper ACK message.
- Secondly, when a CA operator updates an alert by adding comments related to it. The CA sends a newly-built ORU^R01 message with the updated information and comments (NTE), awaiting the proper ACK response from the SPP.

4.4.2.1 Alerts generated from SPP

A sample ORU^R01 message for receiving alerts from the SPP could be the following:

```
MSH|^~\&|SPP||CA||20121123153424+0100||ORU^R01^ORU_R01|201211221834245ab85f7e|P|2.6|||NE|A
L||8859/15|||IHE PCD 001^IHE PCD^1.3.6.1.4.1.19376.1.6.1.1.1^ISO
PID|||IC16001^^^^HC
OBR|1||S_20121122183420_861|225288009^environmental care procedure^SCT

OBX|1|CWE|1^DEV_BAROMETER^inCASA|1.0.0.0.1|197096^MDC_EVT_TEMP_ENVIRON_HI_ABNORM^
MDC|||H~PH~ST|||||20121123153424+0100|||FEAC922001005E51^^FEAC922001005E51^EUI-64&
OBX|2|NM|60832-3^Temperature.ambient^LN|1.0.0.1.2|35.0|268192^MDC_DIM_DEGC^MDC|>26.0
OBX|3|ST|EVENT_PHASE|1.0.0.1.3|start
OBX|4|ST|ALARM_STATE|1.0.0.1.4|active
NTE|||Temperature far above range
```

And the proper CA ACK message should be:

```
MSH|^~\&|CA||SPP||20121125131259||ACK^R01^ACK|2324411|P|2.6|||NE|AL||8859/15|||IHE PCD-02
2010^HL7
MSA|AA|201211221834245ab85f7e|Message received successfully!
```

4.4.2.2 Updates committed from a Consumer Applications operator

When a CA operator updates an alert, the ORU^R01 message that is sent to the SPP is similar to this example:

```
MSH|^~\&|CA||SPP||20121124163424+0100||ORU^R01^ORU_R01|20121124163424ab85f7e|P|2.6|||NE|AL|
|8859/15|||IHE PCD 001^IHE PCD^1.3.6.1.4.1.19376.1.6.1.1.1^ISO
PID|||IC16001^^^^HC
OBR|1||S_20121122183420_861|225288009^environmental care procedure^SCT
```

```

OBX|1|CWE|1^DEV_BAROMETER^inCASA|1.0.0.0.1|197096^MDC_EVT_TEMP_ENVIRON_HI_ABNORM^
MDC|||H~PH~ST|||||20121124163424+0100||||FEAC922001005E51^^FEAC922001005E51^EUI-64&
  OBX|2|NM|60832-3^Temperature.ambient^LN|1.0.0.1.2|34.0|268192^MDC_DIM_DEGC^MDC|>26.0
  OBX|3|ST|EVENT_PHASE|1.0.0.1.3|update
  OBX|4|ST|ALARM_STATE|1.0.0.1.4|active
  NTE|||Temperature is still far above range

```

The SPP should then respond with the appropriate ACK message.

4.5 Master Data

The overall inCASA system needs to share common information about the monitored patients. There are three kinds of data which must be configured and shared:

- patient demographic information
- sensors unique identifiers
- sensors location inside the household

During the installation phase of each monitored apartment these data must be collected and properly configured. For each of the above data categories every inCASA block can behave as:

- master: it is responsible for the information storing
- slave: consumes data provided by the master

The slave systems may consume master data only partially or not at all, depending on what they need. The following figure shows where data are stored and how they flow through the inCASA system.

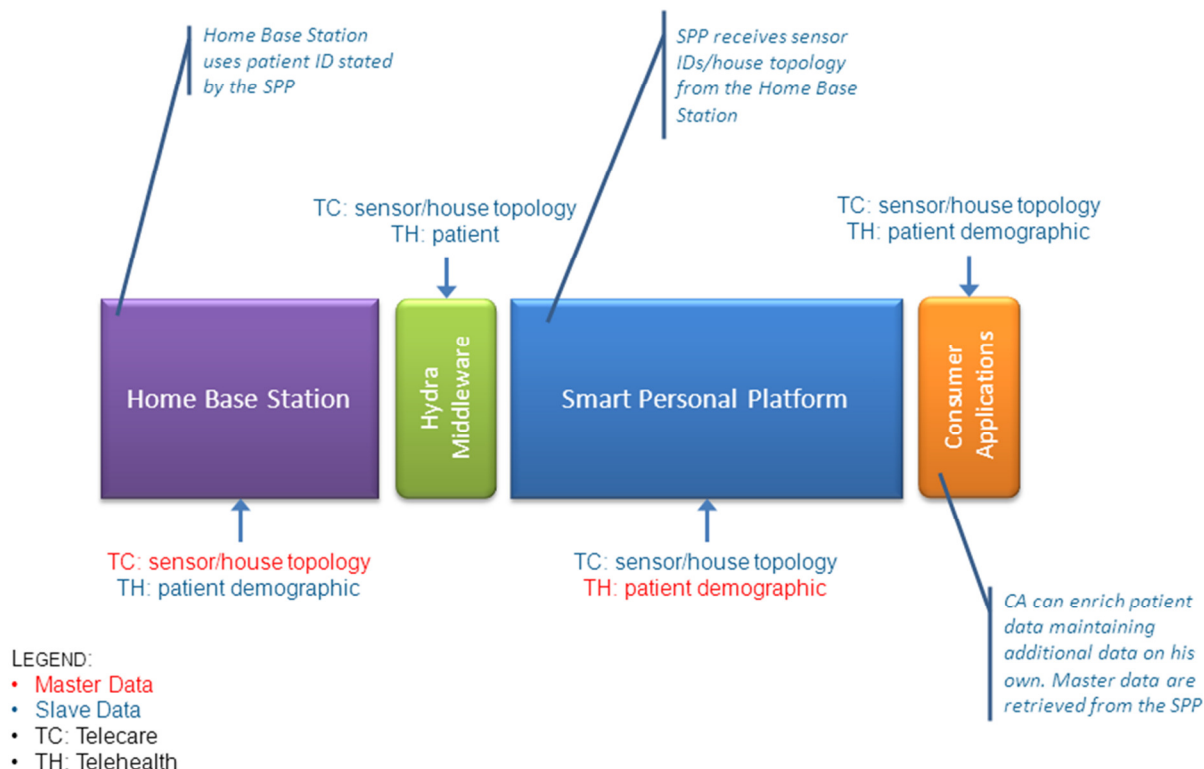


Figure 15 - Master data architecture

The patient demographic information is maintained by the SPP inside the EPR which acts as the master data. This information consists of the patient's name, sex, birth date, address, telephone

numbers, health card number and unique identifier. The patient's unique identifier must be manually reported inside the Home Base Station during the installation and configuration phase so that it can be associated to the measures transmitted. The Consumer Applications can query the SPP in order to retrieve the list of the monitored patients and their demographic data. This information can be enriched by the operator with additional data which are maintained and used (displayed) locally.

The sensors' unique identifiers are primarily known at the Home Base Station and master of these data is the Hydra Client. Optionally, depending on the nature of the device, the sensor's location can be maintained as well. These data are spread throughout the system associated to each measure and alert transmitted. The SPP associates the measures and alerts to the right patient thanks to the unique patient identifier. Master data are uniformly used for the Tele-care and Tele-health domains: patient's demographic information is obviously common to both of them and recorded once for household. Each domain has its own set of devices which are uniquely identified by their ID. The topology of the household is inferred by the location of the Tele-care sensors.

5 Development view

This section presents the most important message flows in the system, which describes how the main processes work.

5.1 Introduction

This viewpoint describes the architectural elements supporting the development process. Views under this viewpoint are aimed to communicate the aspects of interest to those stakeholders involved in building, testing, maintaining, and evolving the system. The *Development View* is conforming to the Development Viewpoint: in this view, several aspects related to development are covered, which can be followed by developers while building a specific module.

5.1.1 Stakeholder Concerns

This viewpoint addresses the concerns of:

- *Software Developers* (among the *Developers*), who have to implement the models defined in the Functional Model View writing code in an object-oriented programming language
- *System Integrators* (among the *Developers*), who have to interconnect different modules and sub-systems in order to let information propagate from source to target
- *Maintainers*, who have to understand the system in order to change, remove, or add functions, and need to locate the classes and components impacted within modules defined in the Functional Model View.

5.1.2 Notation and Language

Views conforming to the Development Viewpoint are represented by UML 2.x diagrams, using subsystems or classes to represent elements and “is part of” or nesting to represent the decomposition relation. Also, sequence diagrams could be used to describe interactions during time between components or modules.

5.2 PCD-01 Communicate PCD Data

Tele-care and Tele-health measures are collected at the Home Base Station and sent to the SPP through the LinkSmart Middleware which provides to unify the two data flows, to apply filtering when needed and to produce the HL7 messages which are sent to the SPP.

Having both the SARA Client and the Activity Hub integrated as independent Device classes in the LinkSmart IoTDevice class hierarchy also enables a common HL7 message generation that is transparent throughout the inCASA network. The Configuration Manager allows basic filtering based upon initial settings made by the carer. The details about this will be presented in a separate manual. The current filtering of the Activity Hub is rather basic and offers dynamic updates for keeping relevant home states actual. For example, when the LinkSmart Server Application is able to find correct IoTDevice depending on the sensor address in the measurement we will also be able to define what type of device or sensor it is by looking at the information given by the IoTDevice.

The same principle is applied for humidity or temperature where LinkSmart compares the latest timestamp with the current one and if it is more than one hour since the last update then update. If the measurement is not filtered out the new values to the corresponding sensor in the Activity Hub Device is updated. Together with the contextual data stored in the Activity Hub Device and the new values a HL7 ORU^R01 message is generated and forward to SPP. In general, all new measurements that arrive to the LinkSmart Server Application updates the heartbeat of that that specific IoTDevice.

Measures received from the Home Base Station are uniformly dealt inside the SPP. All of the communication is handled by the Mediator, which provides the proper adaptation for the interfaces exposed by the different modules involved in the flow. In particular it must handle the transformation of data format between HL7 and XML, as the reasoning module needs to operate on data represented through the W3C Semantic Web languages (XML, RDF, and OWL). The Mediator sends data first to the EPR and then to the Reasoner which provides an enriched version of the measure.

The HL7 messages are stored inside the SPP EPR as they are: relevant information common to all kind of measures and useful to identify them are extracted from such messages and separately stored in a structured way. This allows the SPP EPR to perform queries on the structured information in order to retrieve requested data and to build the ORU^R01 response message combining the corresponding segments taken from the original HL7 messages.

The HL7 messages defined by IHE for the PCD-01 transaction are:

- ORU^R01^ORU_R01: unsolicited message used to communicate observations
- ACK^R01^ACK: acknowledgment message

The IHE PCD-01 transaction is implemented by the inCASA modules playing the following roles:

- DOR: at the Home Base Station the Activity Hub and the SARA Client produce respectively Tele-care and Tele-health measures transformed in HL7 messages by the LinkSmart Middleware
- DOF: the LinkSmart Middleware performs filtering on the data received by the DOR in order to reduce the frequency with which some observations are to be sent to the DOC
- DOC: the SPP consumes the observations received elaborating (Reasoner) and storing (EPR) them

The following sequence diagram describes the interactions between the PCD-01 transaction's actors.

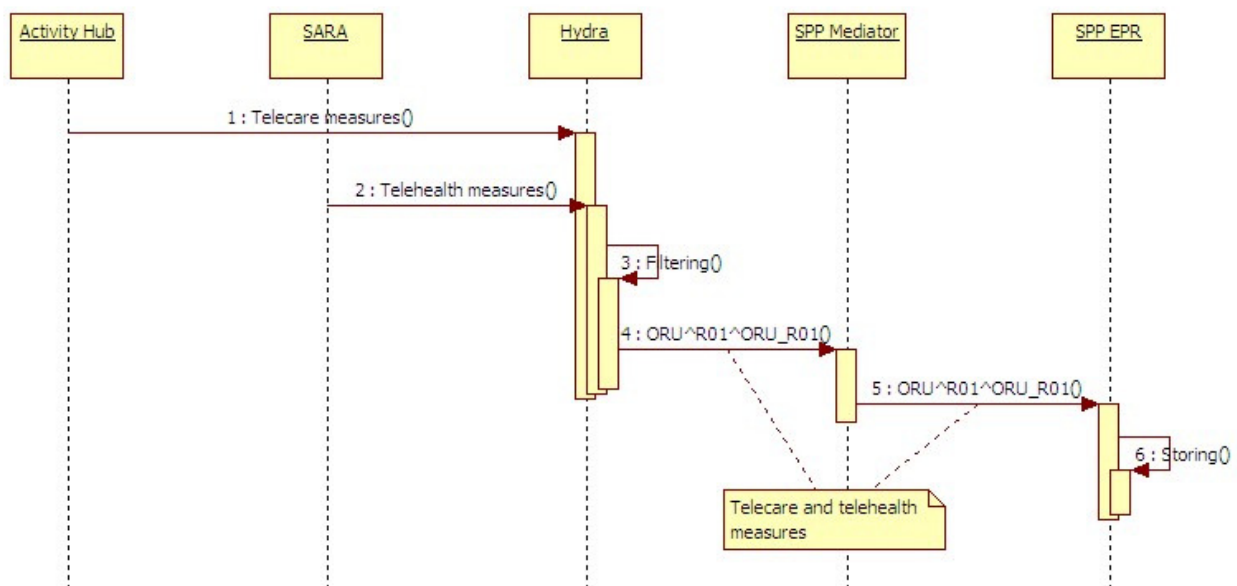


Figure 16 - PCD-01 transaction between inCASA modules

Derived measures produced inside the SPP are handled through the PCD-01 as well. In this case it is the Reasoner which acts as DOR while the EPR is the DOC.

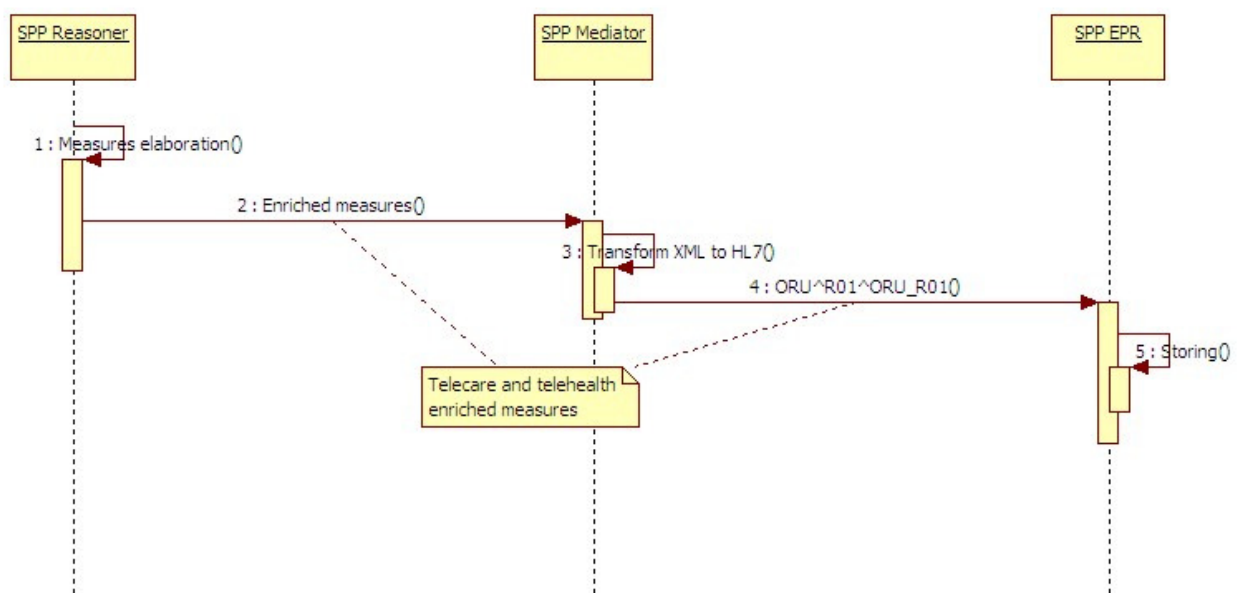


Figure 17 - PCD-01 transaction inside the SPP

5.3 PCD-02 Subscribe to PCD Data

The IHE PCD-02 transaction allows one application to subscribe to data or to retrieve a one-shot report of data; the inCASA architecture considers implicit the data subscription between its component blocks and so this transaction is only used to issue direct queries.

The Consumer Applications use PCD-02 transaction to retrieve three different kinds of data from the SPP EPR:

1. Patient list: a list of all the monitored patients is returned together with their demographic information
2. Patient's measures: all the Tele-care and Tele-health measures collected for a patient together with the derived measures (such as the user habit) elaborated by the SPP are returned. The query requires the patient unique identifier as a mandatory parameter and allows to optionally set a time range
3. Patient's alerts: all the Tele-care and Tele-health alerts related to a patient are returned. For each alert all the events (i.e. status changes, updates, notes) which compose the alert's life cycle are retrieved. The query requires the patient unique identifier as a mandatory parameter and allows to optionally set a time range and/or the alert status

The HL7 messages defined by IHE for the PCD-02 transaction are:

- QSB^Z02^QSB_Q16: query message
- ORU^R01^ORU_R01: response message

Using this pair of HL7 messages three named queries has been defined, each different in the way query's parameters are set and in the structure of the response message:

- getPatients
- getPatientMeasures
- getPatientAlerts

The actors involved in the PCD-02 transaction are played as follows:

- DOC: the Consumer Applications consume data retrieved by the DOR in order to display them to the user
- DOR: the SPP produces information either aggregating previously collected measures (EPR) or creating new observations by the elaboration of the received ones (Reasoner)

The following figure shows the sequence diagram common to the three queries.

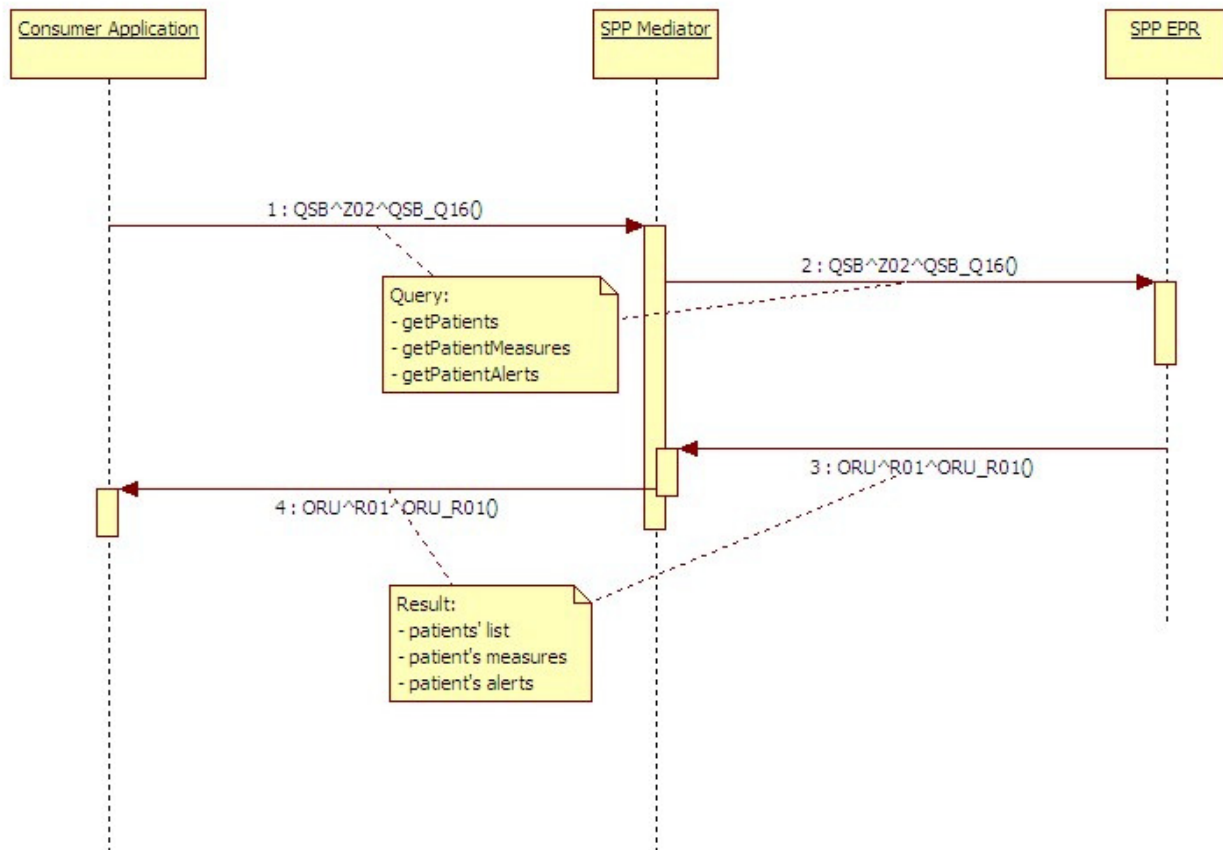


Figure 18 - PCD-02 transaction between the CA and the SPP

The PCD-02 transaction is used internally to the SPP as well. In this context it is the SPP Reasoner (playing the DOC role) that queries the SPP EPR (acting as DOR) to retrieve the following kind of data:

- Delta measures: the difference between two collected measures (for example a time interval)
- Derived measures: measures calculated elaborating the data received (for example the sum of some numeric measures)
- Thresholds: minimum and maximum values allowed for some kind of measures
- User habits: a set of data describing the user habit profile of a monitored patient

All the above interrogations are performed using the `getPatientMeasures` query. The following figure shows the sequence diagram involving the SPP modules.

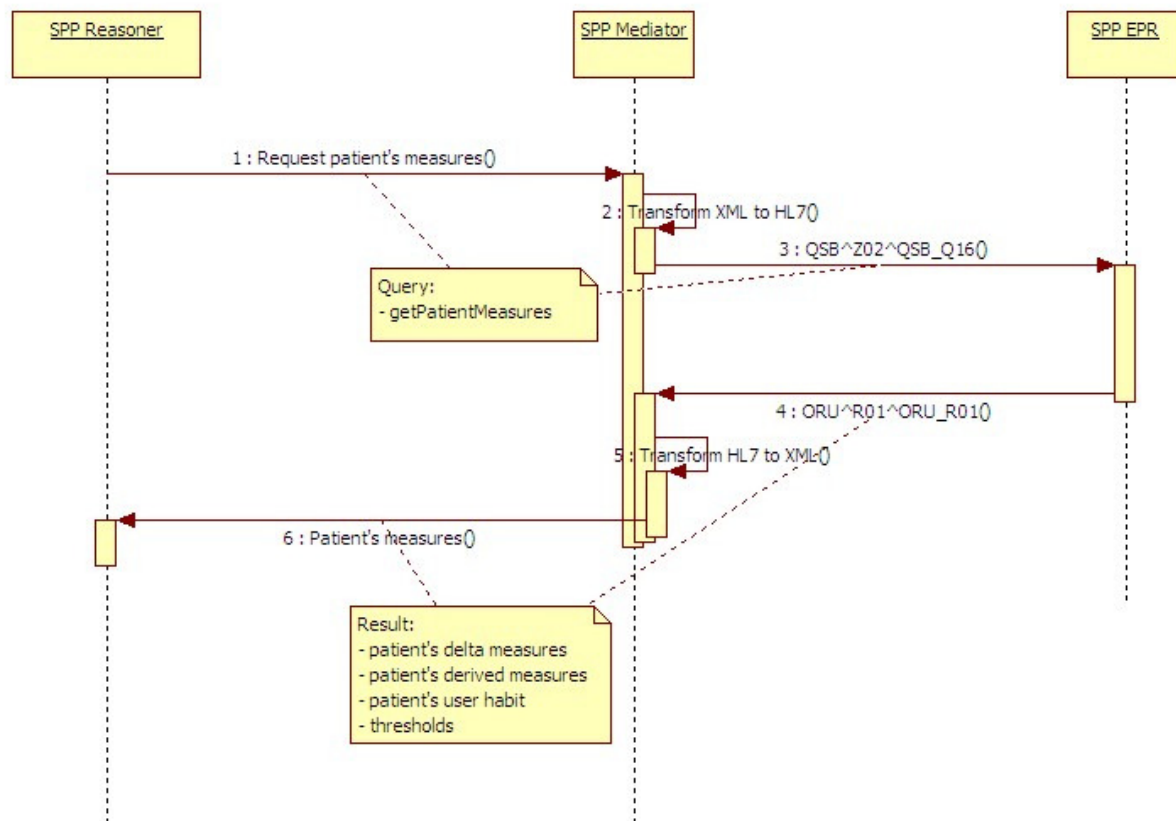


Figure 19 - PCD-02 transaction inside the SPP

5.4 PCD-04 Report alarm

The IHE ACM profile defines four main actors which in turn can be divided in sub-actors having a more specific role. As shown in the figure below IHE defines only the communication between the main actors.

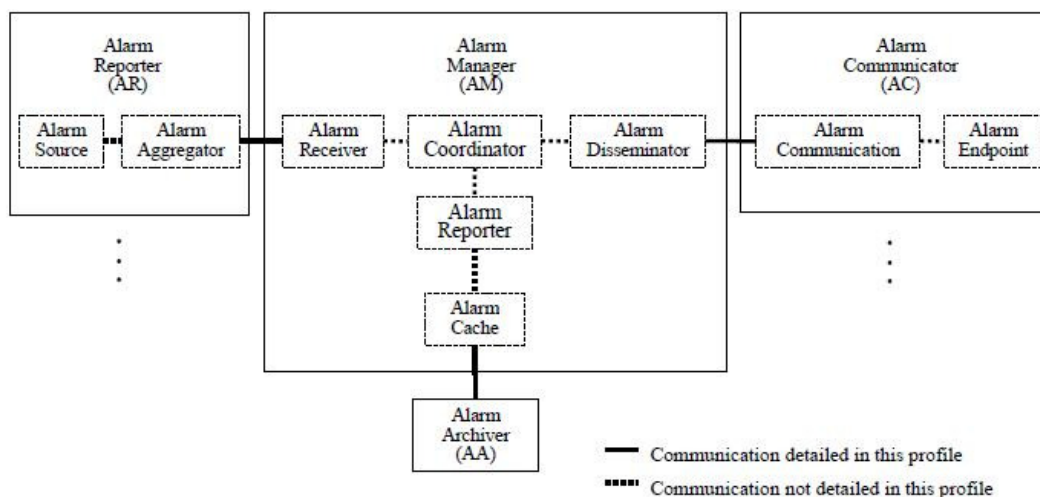


Figure 20 - ACM profile's actors (© IHE)

The transactions that can be implemented between such actors are shown in the following figure.

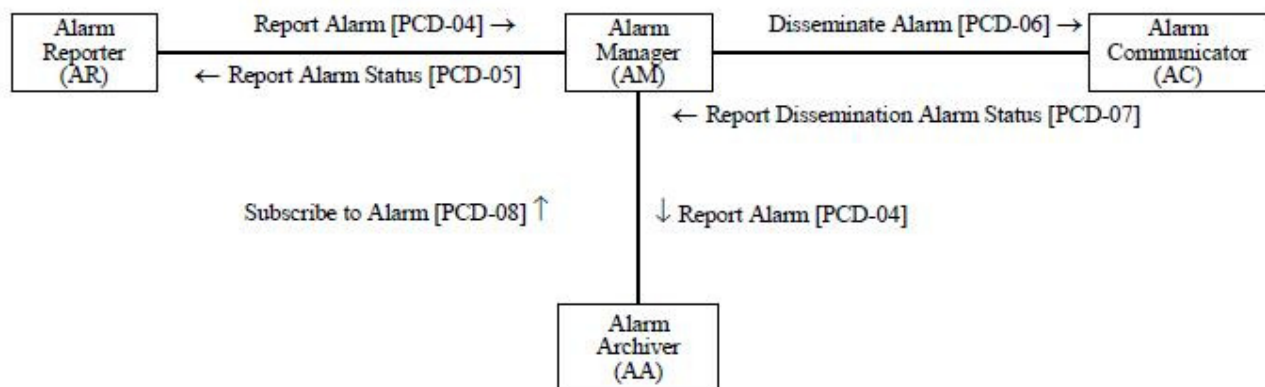


Figure 21 - ACM profile's transactions (© IHE)

The inCASA project implements only the PCD-04 transaction, which makes use of the following HL7 messages:

- ORU^R01^ORU_R01: unsolicited message used to communicate alarm data
- ACK^R01^ACK: acknowledgment message

The mapping between the IHE actors and the inCASA modules is the following:

- AR: all kinds of alarm are generated by the SPP Reasoner; they include direct alerts, originated from a measurement produced by a device signalling an alert detected (for example water flow detected), and alerts due to a comparison of the measurement with the user's profile
- AM: the SPP and the Consumer Applications play as Alarm Manager in different contexts; the first one manages the alarms automatically while the other provides a graphical interface which allows an user to handle the alert situation. Inside the SPP the Mediator is both the Alarm Receiver, when it manages alerts generated by the Reasoner, and the Alarm Disseminator, when it sends the alarms to the Consumer Applications. The Reasoner is the Alarm Coordinator, which manages the alert life cycle as described in chapter 10.2.2 of D4.3. The Consumer Applications server side is both the Alarm Receiver and the Alarm Disseminator while the client side acts as Alarm Coordinator
- AA: the SPP EPR is the Alarm Archiver which permanently stores all the HL7 messages containing alarm observations
- AC: the Consumer Applications client side is the Alarm Endpoint since it displays the alerts received from the SPP

The sequence diagram in the following figure reassumes how the inCASA modules interact using the PCD-04 transaction.

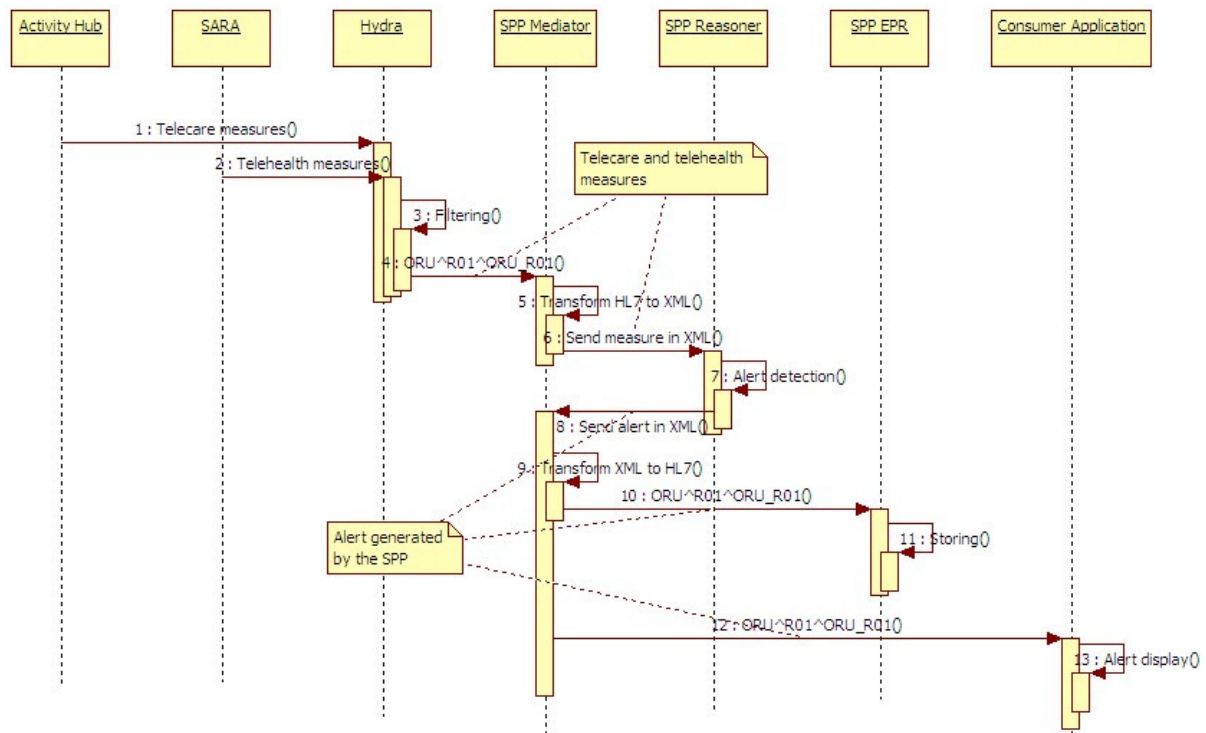


Figure 22 - PCD-04 transaction for SPP generated alerts

At the Home Base Station two kinds of alarm situation can be identified; they are differently handled by LinkSmart as described below:

- Direct alerts from sensors (such as Water Flood Detector): when a measurement is received from the Activity Hub it will first be sorted based on the sensor's type in order to identify if it is a sensor that can generate an alert (e.g. Water Flood Detector). All the measurements will be placed in a message queue together with the priority (Figure). Ordinary measurements will have a normal priority and alert measurements will have a high priority. On the other side the Activity Hub Device Discovery Manager that handles new measurement from the message queue will dequeue the new measurement based on its priority.

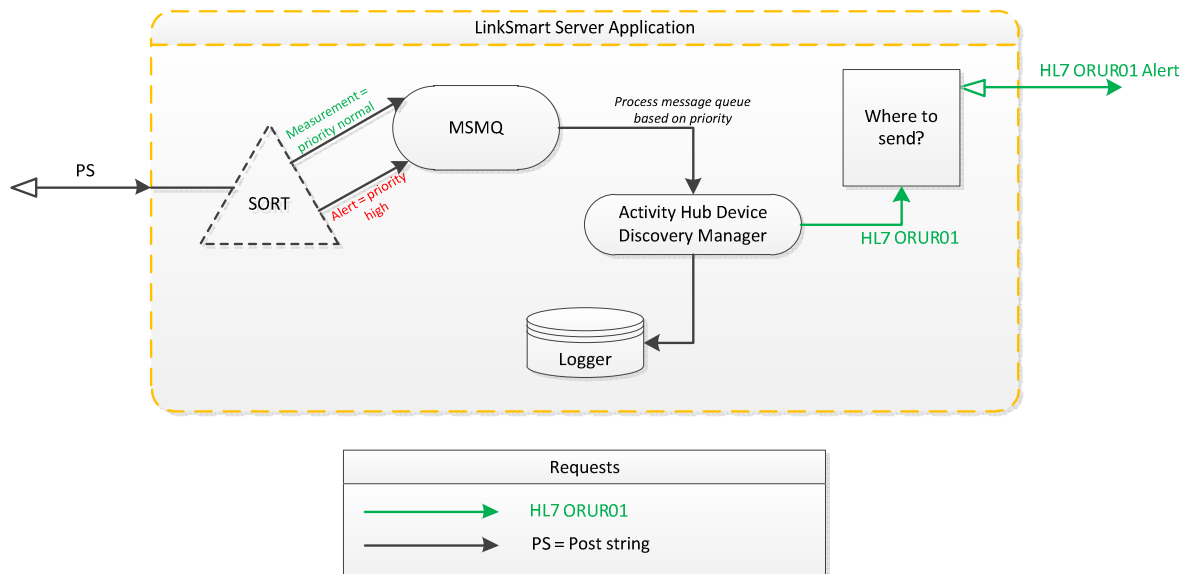


Figure 23 - Alert handling for the LinkSmart server of the inCASA platform

- Indirect alerts from Activity Hub or sensors: if an Activity Hub or a sensor hasn't sent a heartbeat for some time a notification to SPP could be raised. If the time between the heartbeats gets even longer some type of alert could be sent to notify that the Activity Hub or sensor is not working correctly.

At the ATC pilot the PCD-06 transaction is partly implemented: the SMTP e-mail protocol is used to disseminate the alarm but the body text transmitted is not conformant to the IHE transaction. This scenario is applied only for some kinds of alerts: the Consumer Application sends an e-mail to the ATC's back-end system which in turn sends a SMS with the alert message to an operator.

5.5 Delivering information to and from the Consumer Applications

In this section, we are going to describe the software modules involved in the information delivery process to and from the Consumer Applications (CA). The procedure at this analysis is seen from a Consumer Applications point of view, meaning that only the external interfaces of other components (namely the SPP) are got into consideration. This inter-component data exchange process is consisted mainly of the following functionalities:

1. Call to web services exposed by the SPP whenever patient data (demographic data, measurements or habits profile) are requested.
2. Call to web services exposed by the SPP whenever alerts retrieval is requested.
3. Expose a web service to be called by SPP when a new alarm is generated. This serves for immediate information of the medical personnel in case of an alarming situation.
4. Call a web service exposed by SPP whenever an operator adds a comment related with an alert.

5.5.1 Measurements, Habits Profile and Alerts Retrieval

Concerning the retrieval of measurements, habits profile or alerts the relevant process is depicted in the following figure:

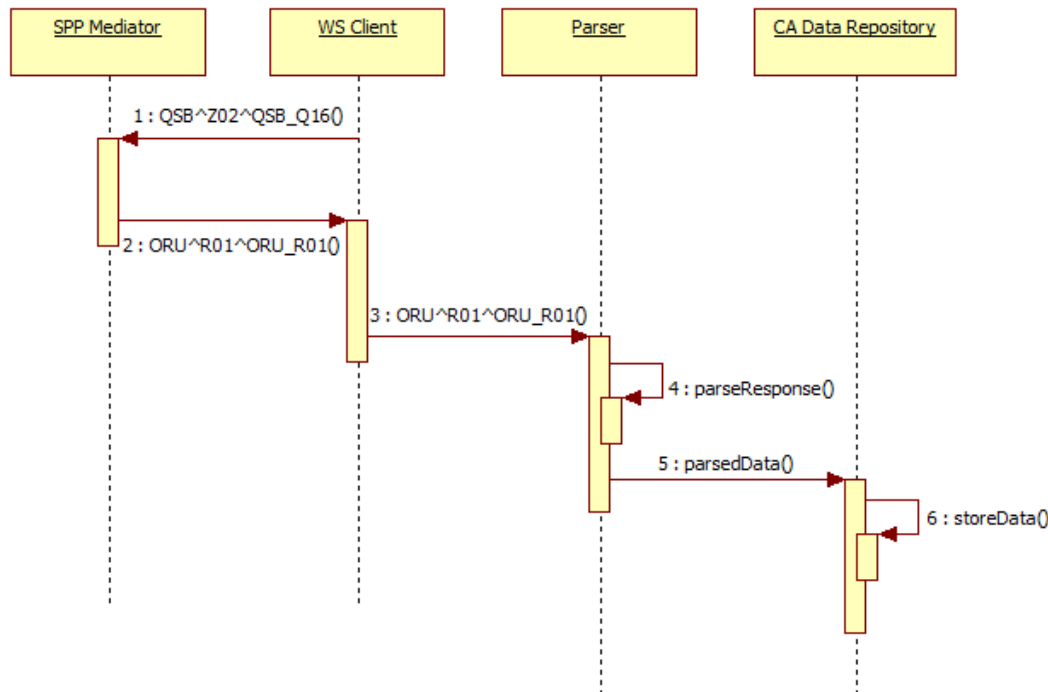


Figure 24 - Retrieving information from SPP

In detail, the life-cycle of an information retrieval from the SPP is described below:

- The WS client class located at the Consumer Applications calls the SPP exposed interface having as input a QSB^Z02^QSB_Q16 HL7 message. As explained earlier in this document all Consumer Applications - SPP transactions follow the IHE PCD recommendations [64]. The QSB query message supports 3 types of queries as written in section 4.4.
- The SPP mediator responds with a ORU^R01 HL7 message to the Web Service Client which forwards the response to the HL7 parser class of the Consumer Applications.
- The HL7 parser parses the response and stores the result into the local repository of Consumer Applications. It is obvious that the local repository handles all type of data, namely demographic, clinical measurements, alerts or habits.

5.5.2 Alert communication without time delay

As a basic requirement of the inCASA platform is that all alerts generated by the core platform will be visualized into the Web Portal screen without time delay in order for the operators to be informed real-time for such type of event. Moreover, apart from alert visualization, Consumer Applications support audio signal and, if needed, SMS sending in case of an incoming alert. To support the afore-mentioned requirement, the alert generator system (SPP) needs to call a service exposed from the part of the Consumer Applications that will handle the information of a newly generated alert. The involved modules in this use case are described in the next figure.

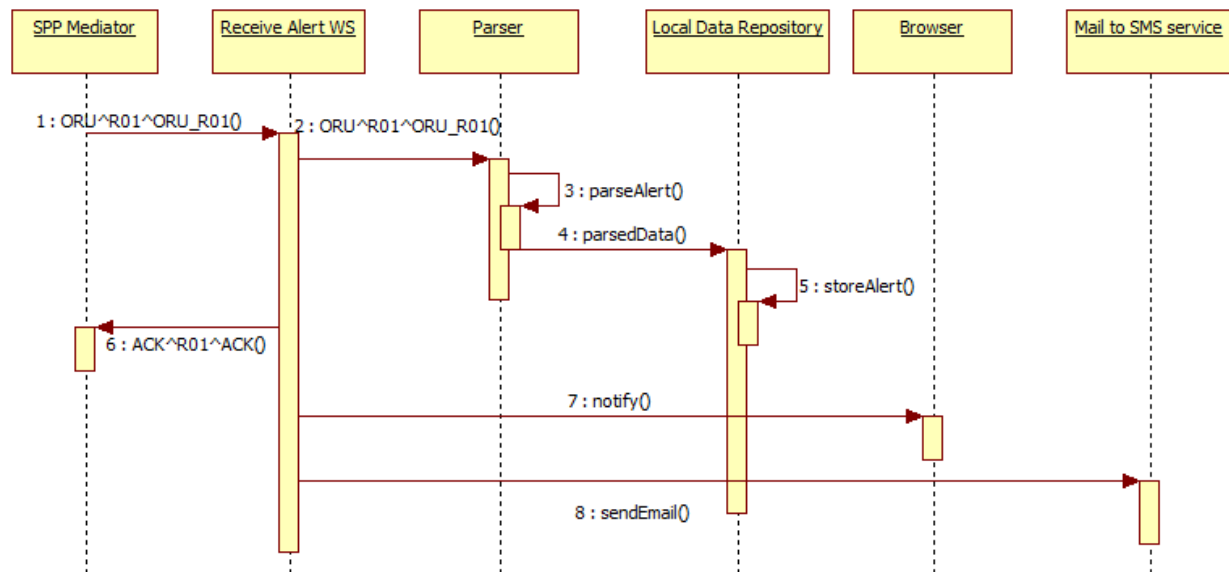


Figure 25 - Immediate communication of an alert event to the Consumer Applications

Analyzing the above figure, we can state the following:

- SPP Mediator calls the exposed Web Service (WS) from the part of the Consumer Applications. The input message of this service is a ORU^R01^ HL7 message.
- The Web service implementation consists first of all of a Parser model which parses the message mentioned above to extract the alert information.
- Moreover, the parsed data which include information related to the alert event, type, priority and severity are stored into the local Consumer Applications repository.
- After the successful alert local storage, the Web Service replies to the caller (SPP) with an acknowledgement (HL7 message as always, in this case ACK^R01^ACK)
- Then, asynchronously, the web service notifies all browsers that have an open session in the Web Portal (Consumer Applications). A pop-up window is opened and a flash file containing audio signal is triggered.
- If this is the case, the web service may send SMS too. If the incoming alert contains SMS request, then the web service sends an email to the SMS inCASA service. This service parses the body of the email which has to be structured as <mobile phone> | <SMS text> and communicates to the SMS gateway the relevant SMS request.

5.5.3 Alert update with operators comments

It is required that an operator may add comments to an alert via the CA interface describing for example actions taken or providing a status update. Any comment should be stored in the central inCASA repository too and should be retrieved upon query. This will allow offering a system providing alert history, similar to what ticketing systems do concerning tickets history. The alert update use case is detailed in the following figure.

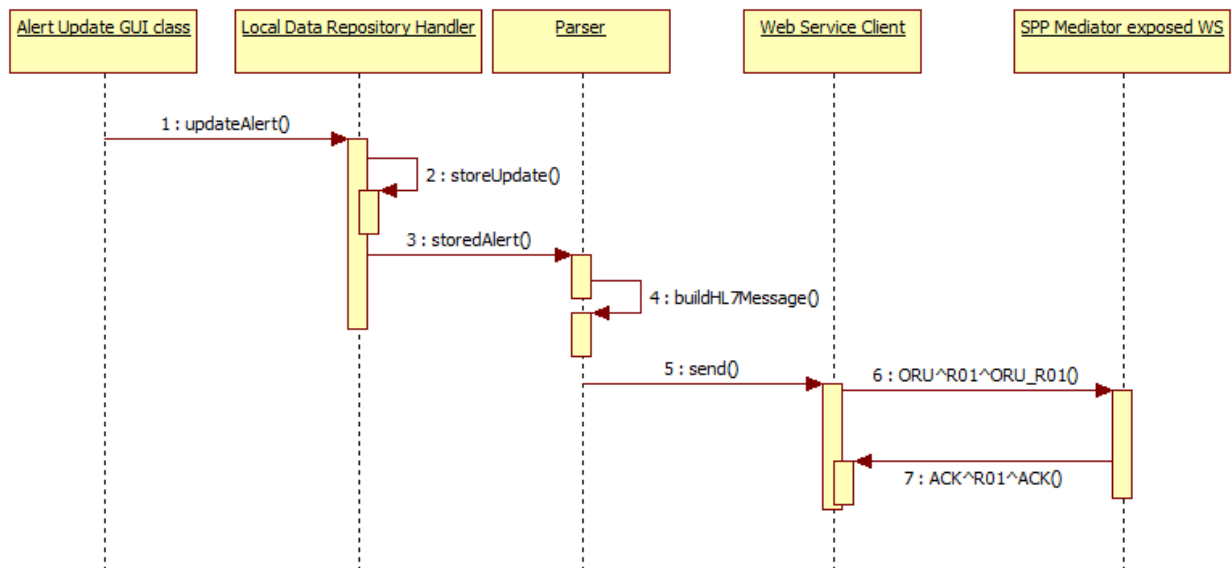


Figure 26 - Alert Update via the Consumer Applications interface

6 Deployment view

This section has been added to the final architecture document in order to show which solution has been chosen for each pilot in order to achieve its requirements.

6.1 Deployment View in each site

The first iteration of the architecture that was expressed in D3.2 showed that there was a large heterogeneity by the chosen implementations among the pilots. The second iteration intended to achieve a harmonization of this diversity in order to present an inCASA reference architecture that we could follow in order to customize each pilot solution, yet following the same specification of the concept. That is why even though there are different implementations for Telehealth clients (i.e. SARA, ATC's, Skive, CHC's), they all follow the guidelines given by inCASA, which in the end are based in the international standards. The next sections show configurations that has been chosen for each pilot-site in order to carry out the trial in the most effective way.

6.1.1 KGHNI

KGHNI deployment follows the inCASA reference architecture offering the professional stakeholders the opportunity of combined Telehealth / Telecare monitoring of CHF patients. The modules of the platform, their role and their interconnection are depicted in the following figure that summarizes the KGHNI pilot architecture.

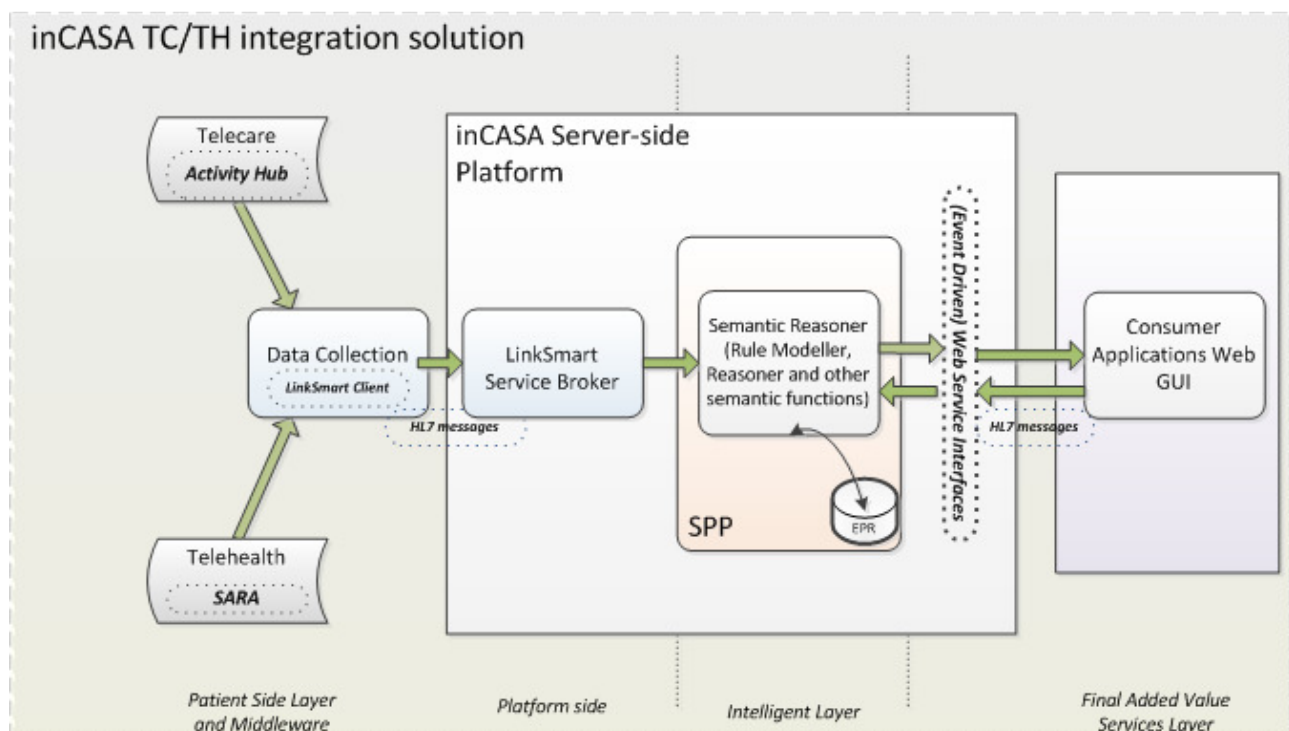


Figure 27 - KGHNI architecture

The detailed analysis and presentation of each module is not the goal of this section but an overview of the role of each inCASA reference architecture component that will be given in the framework of KGHNI's inCASA solution.

1. **SARA Client** is the software solution that is via the Bluetooth driver able to receive the Telehealth measurements performed by the patients through the Bluetooth supporting devices of pulse oximetry, blood pressure monitoring and weight scale. SARA Client covers also partially the requirement of reminding the patient when to perform measurements. It does so by presenting the end user in the interface the scheduled time of measurements as set by the professional users at the server side.

2. **Activity Hub** is the gateway collecting data from the Telecare sensors installed at the patient's homes. Activity Hub has an embedded ZigBee receiver which captures the data that is sent wirelessly by the Telecare sensors of motion, chair, TV usage and temperature.
3. **LinkSmart** middleware is the component that receives measurements from the above two modules and is responsible for data forwarding to the server side of the platform. LinkSmart is not a simple forwarder as its role includes:
 - a. HL7 messages generation. LinkSmart receives non HL7-standard messages from the SARA client and from the Activity Hub but transforms them into HL7 compliant in order to be processed in a standardized way by the server side of the platform
 - b. Data filtering. LinkSmart can filter messages before transmitting them to the server side, e.g. it can skip sending measurements that are out of normal limits. Such measurements could be generated by a faulty sensor.
 - c. LinkSmart can also control through its scheduling mechanism the frequency of the data transmission to the server side of the platform.
4. **Smart Personal Platform(SPP)** includes the master inCASA data repository (EPR) and the reasoning module of the platform. It interfaces with LinkSmart and with Consumer Applications as already described.
5. **Consumer Applications (CAs)** stand as the single point of access to the inCASA operators (Doctors/Nurses/Social Workers/Psychologists of KGHNI) through their Web interface. The CAs interface with SPP and via HL7 message exchanging, they are able to retrieve measurements and alerts per patient and get informed real-time upon an alert generation from the reasoning module of the platform located inside the SPP component. CAs can then visualize the retrieved information and provide it in an explanatory way to the operators. CAs can also cover specific stand-alone requirements, such as Psychological Questionnaires Scoring Graphical Representation as requested by KGHNI, without the need of integrating with the SPP and the inCASA master repository. Even if questionnaires are possible and are done in this particular case,

6.1.2 ATC

ATC deployment is compliant to the inCASA reference architecture. The pilot started by only implementing the Telecare monitoring as the reason was that the initial solution didn't need to include the SARA Client component. In the third iteration the Telehealth monitoring will be added without changing the architecture and an off the shelf gateway will be used to connect the medical devices and to send the measurements to the platform passing through LinkSmart. The following picture depicts the architecture deployed at ATC pilot.

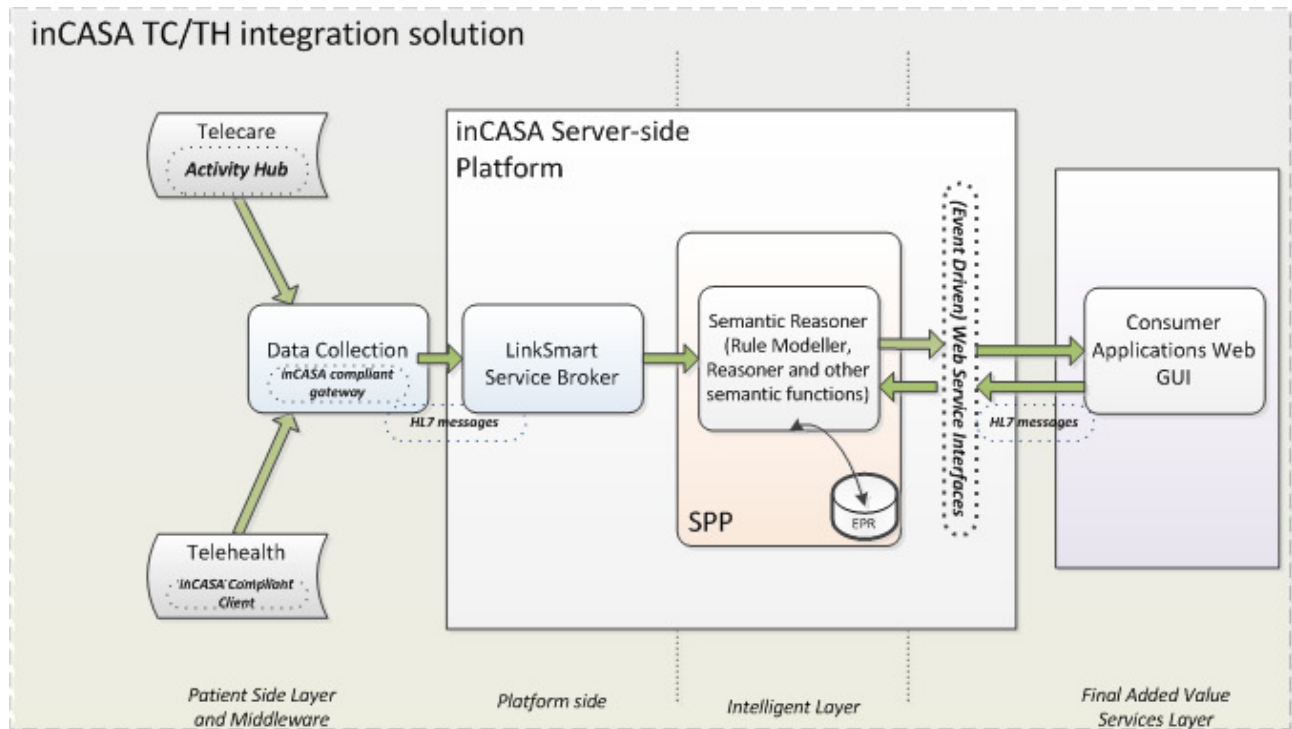


Figure 28 - ATC architecture

The inCASA components involved in ATC pilot are here briefly described.

1. Activity Hub is the gateway, provided by SIG, installed at patient's premises; it connects ZigBee devices which collect the following kinds of Telecare measures: motion, chair and bed permanence, front door and fridge door opening, temperature and humidity.
2. Telehealth Gateway is used to connect Telehealth devices and is also installed in the patient's house.
3. Gateway is collecting data and sending it to the server. In this case, the LinkSmart agent wasn't needed because both the TH and the TC clients use HL7 already, so no transformation was needed in this side, and the Activity Hub could act as a gateway.
4. LinkSmart Server middleware is deployed inside the Remote Service Provider platform. It receives measurements belonging to Telecare and Telehealth domains and transmits them in a uniform and standard way to the SPP. Furthermore it performs data enrichment, adding the patient's demographic information to the HL7 message conveying the measurement, and filtering, in case the physical device issues data too frequently or to remove dirty or empty reads.
5. Smart Personal Platform is the core of this architecture: it processes the received measurements, builds the user's habit profile and generates alerts; all these data are stored inside the EPR. The SPP provides the HL7 APIs to receive measurements from the Base Station and deliver them to the Consumer Applications.

6. Consumer Applications (CAs) are the UI available to ATC's service desk operators and to the general practitioners to access patients' measurements, in graphical and tabular format, and to manage alerts

6.1.3 INSERM

INSERM deployment follows most of the inCASA components defined in the reference architecture and this is due to the fact that for achieving the requirements of this pilot, it was not necessary to carry out a full deployment. Main differences arise with the fact that combining TH and TC information could be done easily using only the SARA client. Therefore this pilot doesn't include the Activity Hub. Furthermore, no much processing was needed to achieve its requirements but a suitable representation of the information (i.e. biomeasures graphs, self-assessments, alerts, data extraction), so the SPP was not needed either. Main data comes from a weighing scale and questionnaires from the TH side and the Actigraph, which allows tracking the circadian rhythms and activity, from the TC side.

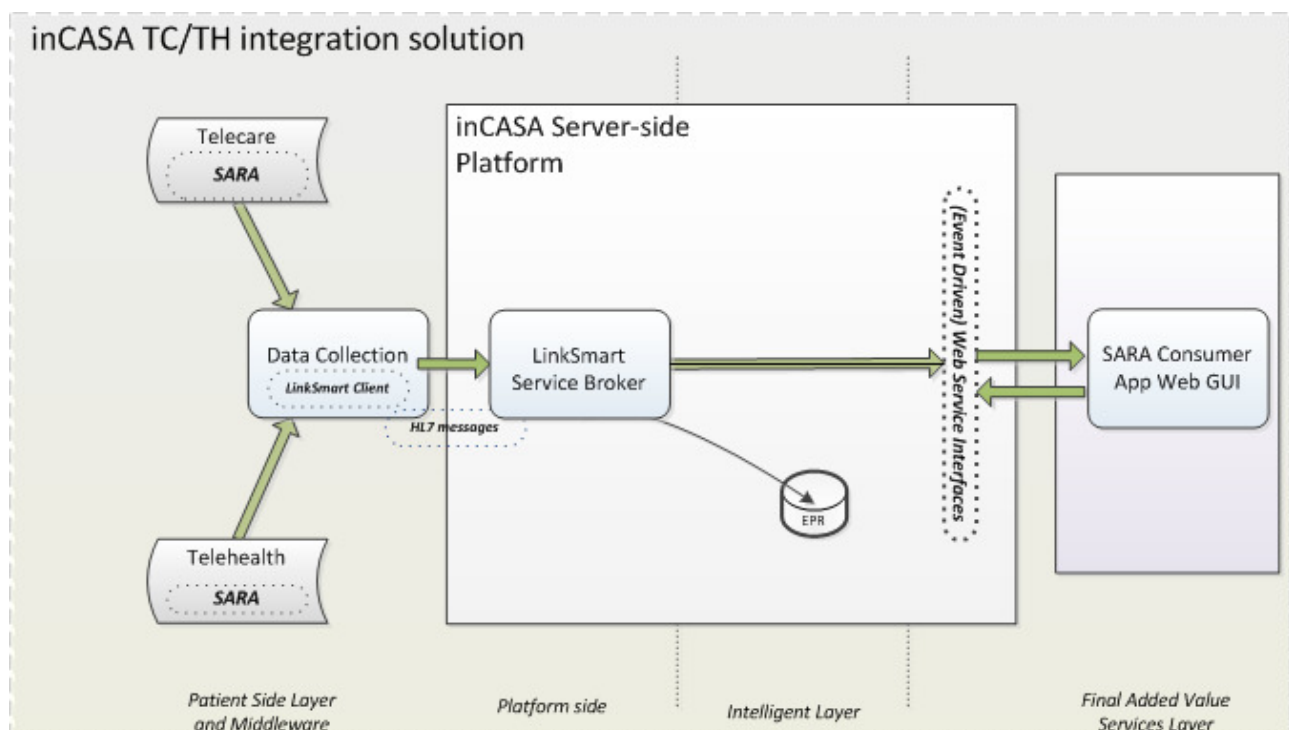


Figure 29 - INSERM architecture

The inCASA components involved in ATC pilot are here briefly described.

1. **SARA Client** is the software solution that is able to receive Telehealth measurements performed by the patients through the Bluetooth supporting devices of pulse oximetry, blood pressure monitoring and weight scale. SARA Client covers also partially the requirement of reminding to the patient when to perform measurements as it presents to the end user's interface the scheduled time of measurements as set by the professional users at the server side. Moreover, the SARA client is able to retrieve the information from the Actigraph device using IrDA technology. All the information retrieved by SARA is forwarded to the middleware client agent, LinkSmart.
2. **LinkSmart** middleware is the component that receives measurements from the above two modules and is responsible for data forwarding to the server side of the platform. LinkSmart is not a simple forwarder, as its role includes:

- a. HL7 messages generation. LinkSmart receives non HL7-standard messages from the SARA client and from the Activity Hub but it transforms them into HL7 compliant in order to be processed in a standardized way by the server side of the platform
 - b. Data filtering. LinkSmart can filter messages before transmitting them to the server side, e.g. it can skip sending measurements that are out of normal limits. Such measurements could be generated by a faulty sensor.
 - c. LinkSmart can also control through its scheduling mechanism the frequency of the data transmission to the server side of the platform.
3. SARA Consumer APP receives the information that is stored in a DDBB by the middleware, LinkSmart, and provides basic visualization tools to the clinicians. Basically, it is a website that shows patient's biomeasures, provides self-assessment tools and show basic alerts.

6.1.4 FHC

FHC deployment follows the same way of the INSERM pilot, it uses only the components of the reference architecture that are strictly necessary to achieve the requirements of this pilot. In this case, the SPP was not necessary either. Main information source are a wearable pulsioximeter and the Actigraph.

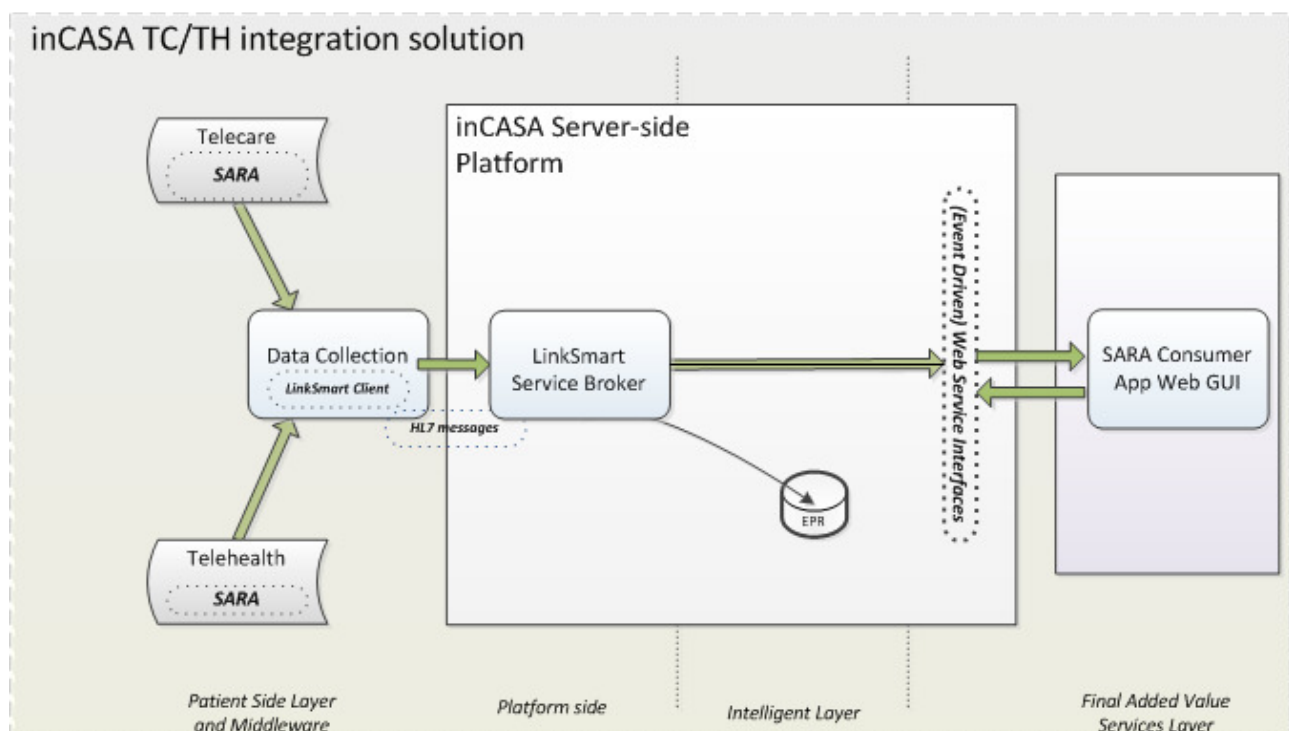


Figure 30 - FHC architecture

The inCASA components involved in ATC pilot are here briefly described.

1. **SARA Client** is the software solution that is able to receive Telehealth measurements performed by the patients through the Bluetooth supporting devices of pulse oximetry, blood pressure monitoring and weight scale. SARA Client covers also partially the requirement of reminding to the patient when to perform measurements as it presents to the end user's interface the scheduled time of measurements as set by the professional users at the server side. Moreover, the SARA client is able to retrieve the information from the Actigraph device using IrDA technology. All the information retrieved by SARA is forwarded to the middleware client LinkSmart.
2. **LinkSmart** middleware is the component that receives measurements from the above two modules and is responsible for data forwarding to the server side of the platform. LinkSmart is not a simple forwarder, as its role includes:

- a. HL7 messages generation. LinkSmart receives non HL7-standard messages from the SARA client and from the Activity Hub but it transforms them into HL7 compliant in order to be processed in a standardized way by the server side of the platform
 - b. Data filtering. LinkSmart can filter messages before transmitting them to the server side, e.g. it can skip sending measurements that are out of normal limits. Such measurements could be generated by a faulty sensor.
 - c. LinkSmart can also control through its scheduling mechanism the frequency of the data transmission to the server side of the platform.
3. SARA Consumer APP receives the information that is stored in a DB by the middleware, LinkSmart, and provides basic visualization tools to the clinicians. Basically, it is a website that shows patient's biomeasures, provides self-assessment tools and show basic alerts.

6.1.5 CHC

CHC deployment follows an independent architecture as the one defined in inCASA. In any case, CHC has built a system that follows the international standards for clinical information systems (i.e. CONTINUA, HL7 and IEEE 11073) and that makes possible the integration of both platforms, CHC's and inCASA's.

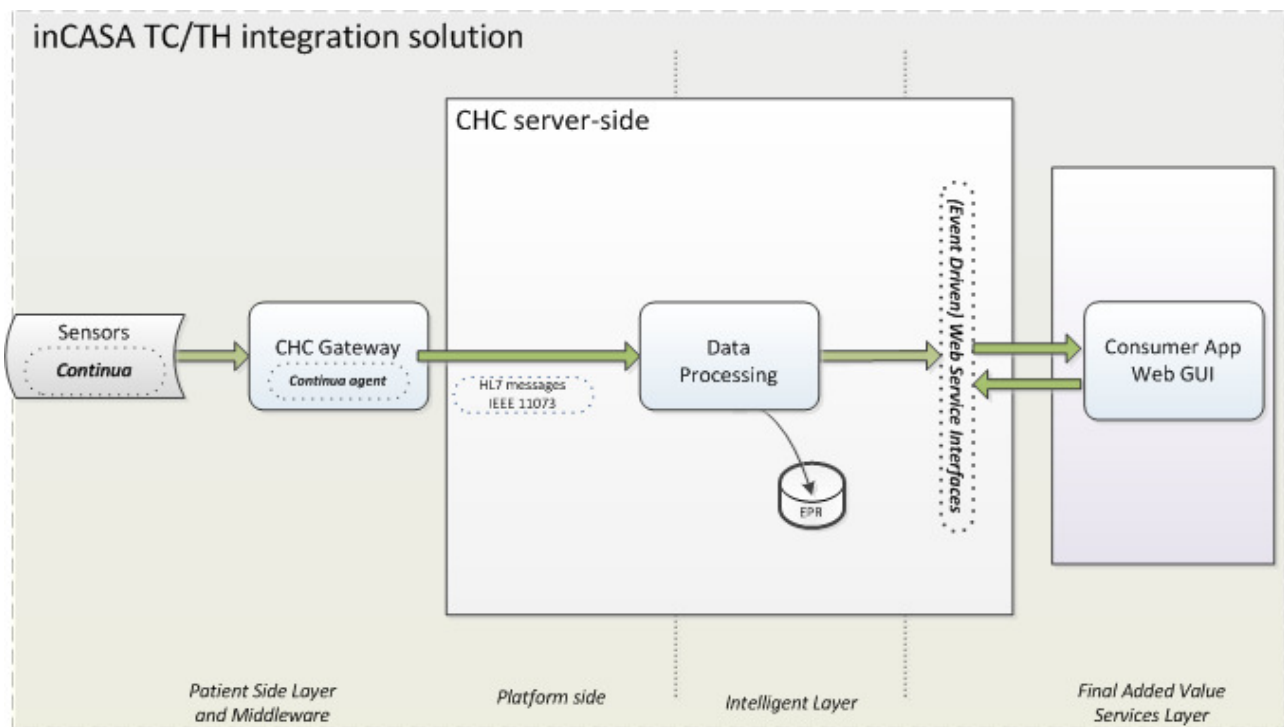


Figure 31 - CHC architecture

The following points describe the most important blocks on the CHC's architecture:

1. **Gateway agent** is a simple device, very discreet, that forwards the information from the CONTINUA sensors to the platform. This device manages the synchronization with the sensors (i.e. Bluetooth or others) and the data transmission to the server. It is so simple that it doesn't have a user interface for the user, only a LED for the cases when there are transmission problems.
2. **Standard platform** collects, stores and processes the information from the sensors. Combination of TH and TC information is performed.
3. **Visualization of data** are graphic tools to support clinicians in the interpretation of both TH and TC information.

6.2 Integration with CHC's platform

One of the most important requirements for the inCASA platform was showing its interoperability and that is why we wanted to prove the integration with another standard platform, the CHC's system. During a two-day meeting held at Brunel University on 27th and 28th of September it has been demonstrated the interoperability between Brunel University's gateway and Reply's SPP. This result was easily achieved because both systems have implemented the standard IHE PCD-01 transaction.

Functional interoperability was granted by the use of a standard Web Service implemented at the receiver's side by Reply's SPP and consumed by the Brunel University's gateway.

Semantic interoperability was guaranteed by the use of HL7 messages conveying measurements coded according to the 11073 IEEE nomenclatures.

The only difference between the HL7 messages used by the two systems regarded the presence or not of the PID (patient demographic information) segment. This optional segment is used inside the inCASA reference architecture to uniquely identify the patient the measurements belong to. The Brunel University's gateway does not include this information in respect to UK's privacy guidelines.

This issue has been solved extending the SPP-EPR so that it can associate the measurements to the patient making use of the gateway's unique identifier (read from field MSH-3-2) when the PID is missing. In this way compatibility with Brunel University's gateway and retro-compatibility with the reference inCASA platform has been achieved.

The following figure shows how the inCASA architecture looks like in this scenario.

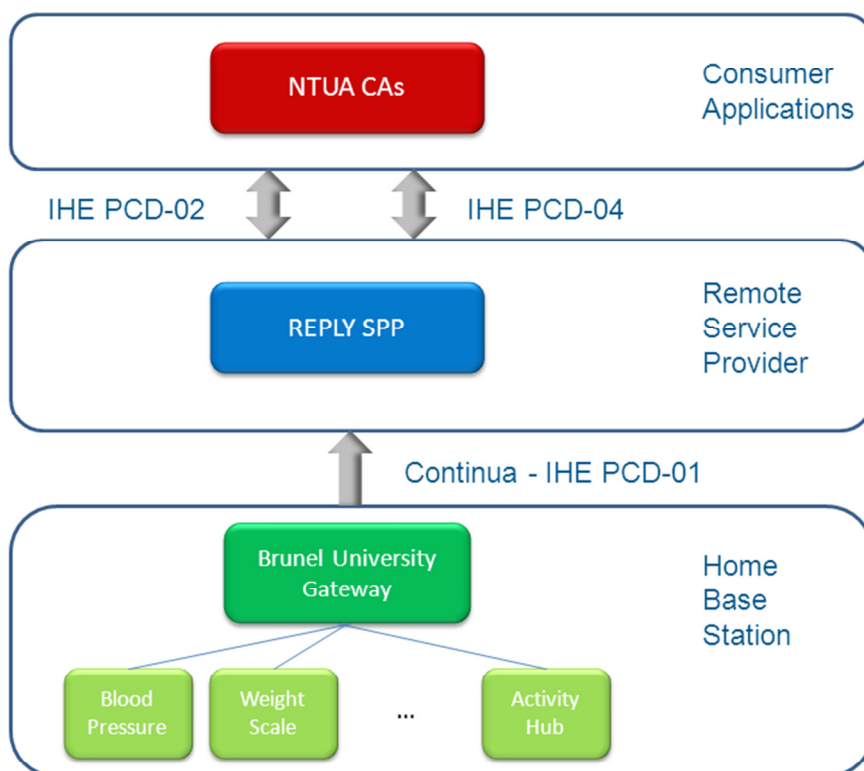


Figure 32 - BU-SPP integration

The Brunel University's gateway connects to medical devices belonging to Tele-care and Tele-health domains and sends data to the SPP exactly as LinkSmart does in the reference inCASA architecture. From this point forward everything works in the same way.

6.3 Lessons learnt

The deployment of the inCASA platform components varied among the pilot sites to meet a multitude of requirements. This diversification of the end-user solutions was accommodated by the functional decomposition of the inCASA platform into several modules and the use of standards based protocols and service delivery mechanisms, such as HL7 messaging, SOAP web services, Continua Health Alliance standards and IHE integration profiles. The client-server communication was facilitated by the LinkSmart middleware. Figure 33 in next page summarizes the architectural characteristics of the inCASA pilot solutions.

The following tables summarize the inCASA platform components that are used in each pilot deployment:

	SARA client	SARA WS	Activity Hub	LinkSmart (client agent)	Actigraph	BU Gateway
INSERM	X	X		X	X	
KGHNI	X		X	X		
FHC	X	X		X	X	
ATC			X			
CHC ¹						X

Table 8. inCASA modules deployed at the patient environment

Regarding the patient environment, the inCASA components that are deployed strongly reflect the use cases and the requirements set forth by each pilot. For instance, both INSERM and FHC required the use of actigraphy to evaluate the rest-activity cycles of their respective patients; this was enabled by allowing the relay of actigraphy data to the SARA server via the LinkSmart middleware. SARA client was selected by KGHNI, INSERM and FHC because it met out-of-the box the usability requirements related to the TH measurements use-cases; in the KGHNI case the transition to the reference inCASA platform, to also allow the monitoring of TC sensors, saw the installation of specialized LinkSmart client agents that intercept and relay both TH and TC measurements. Finally, KGHNI and ATC both employed the Activity Hubs to handle the flow of TC data produced by Bluetooth, ZigBee and enOcean medical devices/ sensors; CHC used the BU Gateway to enable the transmission of TH/TC data from the respective ZigBee-enabled sensors.

	SARA Server	SPP EPR and Reasoner	LinkSmart (server-side)	SPP Mediator
INSERM	X			
KGHNI		X		X
FHC	X			
ATC		X	X	X
CHC ¹		X		X

Table 9. inCASA modules constituting the server-side

¹ Fully integrated CHC platform - not currently deployed; please see above section.

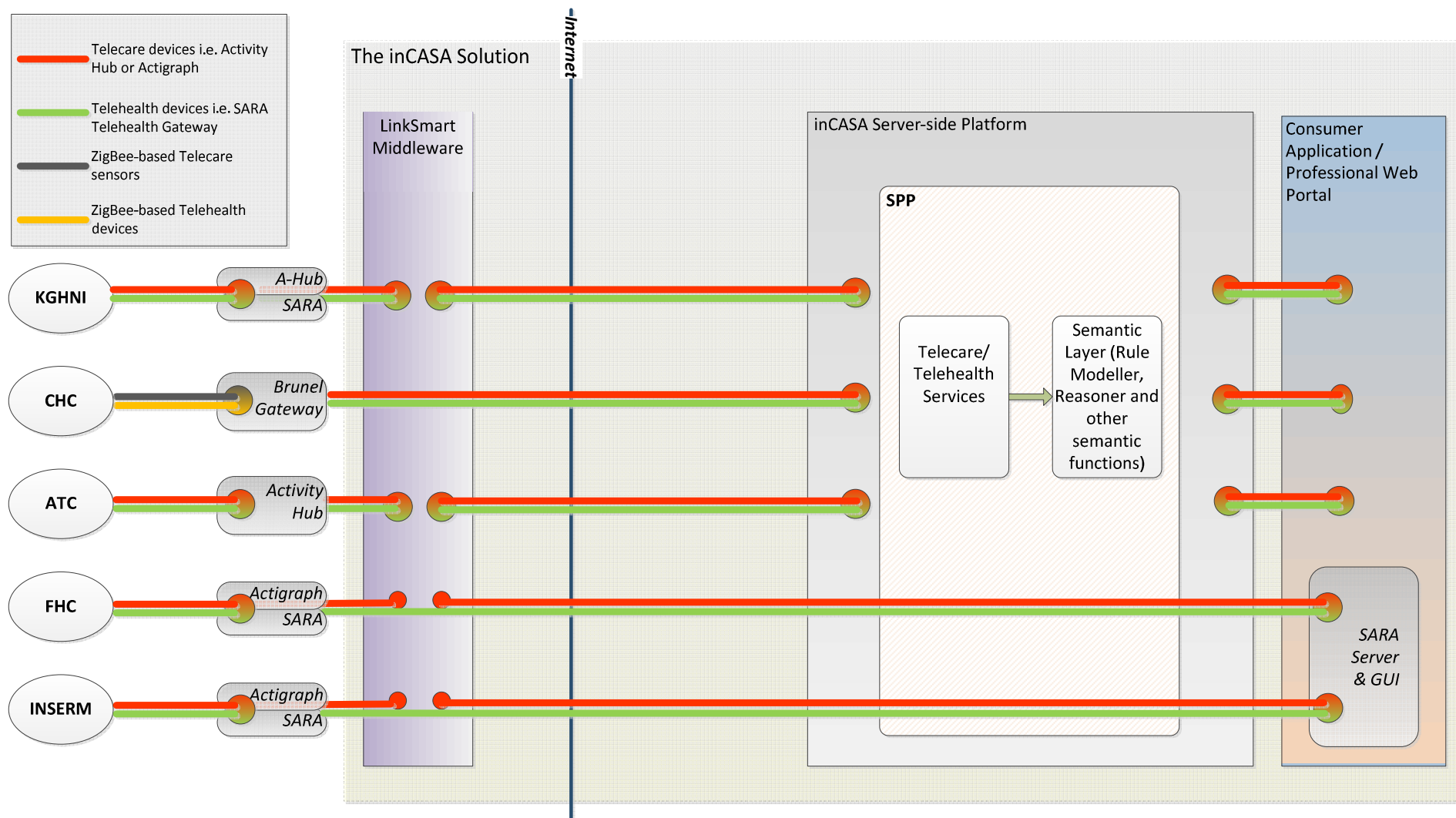


Figure 33 - inCASA architecture customization at the pilot sites

The core of the inCASA platform is the SPP composed by the EPR, Reasoner and Mediator modules. The EPR repository stores TH/TC data and the Reasoner enables the building of rules to define when alerts should be raised (i.e. measurement outside limits, deviation from “normal” behaviour). Both KGHNI and ATC installations opted to use the reference inCASA platform to enable the building of behaviour models using the TC data and the definition of personalized rules; there was a slight differentiation regarding installation since no home PCs were planned for the ATC installations thus LinkSmart was hosted only in the inCASA server. INSERM and FHC installations did not require the monitoring of TC data and both opted to use the SARA server in place of the SPP. Finally, it was demonstrated (see above section) that the SPP can be used as a drop-in replacement to the customized server-side solution currently employed in the CHC pilot; this is made possible due to the guaranteed semantic interoperability by the use of HL7 messages conveying measurements coded according to the 11073 IEEE nomenclatures.

	Consumer Applications	Sara Server Web UI	Professional Web Portal
INSERM		X	
KGHNI	X		
FHC		X	
ATC	X		
CHC ¹			X

Table 10. inCASA user interfaces for the professional users

The web UIs exposed by the different inCASA deployments to the care professionals naturally reflect the choices detailed in the previous paragraphs. INSERM and FHC professional users track TH measurements and alerts through the GUI made available by the SARA server. ATC and KGHNI use tailored to their respective requirements versions of the Consumer Application to monitor both TH/TC data. Finally, CHC uses a customized UI for tracking the elderly patients.

7 Conclusions

This document specifies the consolidated architecture of the inCASA system. One of the goals of this deliverable was creating a settled specification that can be looked by interested stakeholders and influence the way they will build their future systems. One of the main issues we have had to deal in this project has been the heterogeneity in the way different solutions were implemented for each pilot. In this project there were several technical providers with very different sub-systems both standard and proprietary / open and close. In fact, this is a reflection of how the Telehealth market is today; it is full of proprietary solutions where standards are still catching up. For this reason, the inCASA architecture should be versatile enough to swiftly integrate both worlds. That was especially true in the client side, where sensors vendors might implement their own solution while others would go with CONTINUA. The use of the AH as physical broker and LinkSmart as a middleware really helped a lot to solve this problem since it gave the system the capability of performing quick integrations whatever the communication technology was used.

Another relevant part of the system, in fact the most important one, has been the inCASA platform. This project shows how the combination of both TH and TC information can add value to an overall system and from an architecture point of view; we had to assure that the functional block allowed that requirement to happen. Therefore, different functions were created (i.e. mediator, reasoner) to process the different information in a homogenous way so that the result of this processing could be exploited by Clinical Consumer Apps via a powerful API. For this reason, the inCASA project has implemented the SPP, the Smart Personal Platform, which provides this valuable information to the Consumer Apps layer. The inCASA project will release a “cook book” document in order to ease further works for the developer community. The future will be for open platforms, which encourage the apps development by providing a dynamic ecosystem. This is not normal in the clinical world, but inCASA has worked in this direction since it is important to reduce the time and money that creating new applications cost.

Last but not least, the inCASA platform has chosen to go for a standardized and publicly available approach (i.e. HL7 and IEEE 11073) in order to speed up integrations with other standard platforms. We have proven that the inCASA platform could be integrated into CHC's system with just little works. Therefore, the whole inCASA consortium recommends this path to follow in further projects and is ready to support such activities.

8 Glossary

AA	Alarm Archiver
AC	Alarm Communicator
ACM	Alarm Communication Management
AM	Alarm Manager
API	Application Programming Interface
AR	Alarm Reporter
DEC	Device Enterprise Communication
DES	Data Encryption Standard
DI	Device ID
DIM	Domain Information Model
EEP	EnOcean Equipment Profile
EPR	Electronic Patient Record
ERP	EnOcean Radio Protocol
GPRS	General Packet Radio Service
GUI	Graphical User Interface
HA	Home Automation
HBS	Home Base Station
HDP	Health Device Profile
HL7	Health Level 7
HTTP	Hyper Text Transfer Protocol
HTTPS	Hyper Text Transfer Protocol Secure
IEEE	Institute of Electrical and Electronics Engineers
IHE	Integrating the Healthcare Enterprise
IP	Internet Protocol
MDC	Medical Device Communication
OTG	On The Go
OWL	Ontology Web Language
OWL-DL	Ontology Web Language - Description Logic
P2P	Point-to-Point, Peer-to-Peer
PAN	Personal Area Network
PCD	Patient Care Device
RDF	Resource Description Framework
SDK	Software Development Kit
SMS	Short Message Service
SMTP	Simple Mail Transfer Protocol
SPP	Smart Personal Platform
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SSL	Secure Socket Layer
TC	Tele-care
TCP	Transport Control Protocol
TH	Tele-health
TLS	Transport Layer Security
UML	Unified Modelling Language
UPnP	Universal Plug and Play
USB	Universal Serial Bus
VMD	Virtual Medical Device
W3C	World Wide Web Consortium
WP	Work Package
WPAN	Wireless Personal Area Network

WSDL	Web Services Definition Language
XML	eXtensible Markup Language
XSD	XML Schema Definition
XSLT	XML Stylesheet Language for Transformations

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