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Abstract	To enhance older adult's quality of life by improving their autonomy and self-managing abilities, skills and employability, there is the need of personalized and integrated solutions that can be tailored both to the level of individual preferences and necessities, and to the combination of health monitoring devices required by a particular person. In this document, we survey and analyze various categories of existing technologies and developments, from robotic telepresence, wearable sensors, devices for health monitoring, fall detection, to smart home appliances, in an attempt to isolate possible solutions that can be integrated in CAMI to address end-user requirements.

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1 Executive summary

Aim of the deliverable
The objective of the deliverable is to analyze existing methods and technologies directed to supporting the older generation. An extensive background search in the fields of ambient intelligence, collaborative networks, smart homes and AAL is performed. Service oriented architecture models and compatible or possible interconnecting technologies are overviewed. Cost aspects are also considered.
Brief description of the sections of the document
The document is structured in sections that correspond to functionalities that could be integrated in CAMI to address user-requirements. In Section 5 we overview and analyze solutions for Heath monitoring, in Section 6 for Fall alarm, in Section 7 we survey and analyze various ways of reporting and communicating to health professionals in AAL systems, from the functional, usability and architectural points of view. Section 8 focuses on solutions for supervising physical exercises, Section 9 on personalized program management, Section 10 overviews various solutions regarding robotic telepresence for communication, whereas Section 11 shows how to retrieve selected information from the web. The interaction between the user and the application through ICT solutions, as well as between the user and care-giver are overviewed in Section 12 (Intelligent collaborators) and Section 13 (Vocal interfaces). We review relevant home and environment monitoring platforms in Section 14, before concluding the paper in Section 15 with a selection of candidate solutions for CAMI.
Major achievements
The major achievements of this deliverable are: (i) building a knowledgebase w.r.t. the state-of-the-art and state-of-practice of AAL solutions, (ii) identification of advantages and disadvantages of the surveyed solutions, and (iii) identification of potential candidate solutions that could be integrated in the CAMI ecosystem.
Summary of the conclusions obtained
The main outcome of this work is that based on our comparison among various categories of existing technologies and developments, from robotic telepresence, wearable sensors, devices for health monitoring, fall detection, to smart home appliances, we have concluded that some of the existing solutions can be used in CAMI to address end-user requirements, yet they need to be extended with specific capabilities, and integrated via a seamless architectural solution. The conclusions of this document are presented in Section 15, and Table 9.

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4 Introduction

Older adults are people with various needs, different cognitive and motor abilities, and specific health conditions. To enhance older adult's quality of life by improving their autonomy and self-managing abilities, skills and employability, there is the need of personalized and integrated solutions that can be

tailored both to the level of individual preferences and necessities, and to the combination of health monitoring devices required by a particular person. The lack of systems able to reflect user specific needs and integrate different technologies to collect data, represent a barrier to reaching more end-users by Ambient Assisted Living (AAL) services.

In the CAMI project, we will develop such an integrated solution in which various categories of technologies and developments will be considered: from robotic telepresence, wearable sensors and devices for health monitoring, fall detection, etc., to smart home technologies for integration of sensors and home appliances to provide control of the living space. To build the necessary body of knowledge for CAMI, in the following, we survey and analyze existing methods and technologies that offer the needed support, both from a technical and a usability perspective. The advantages and disadvantages of the surveyed solutions are also presented. The main goal of this document is to explore the state-of-the-art and state-of-practice in order to identify potential candidates for integration into the CAMI solution.

The remainder of the document is organized as follows. In Section 5 we overview and analyze solutions for Heath monitoring, in Section 6 for Fall alarm, in Section 7 we survey and analyze various ways of reporting and communicating to health professionals in AAL systems, from the functional, usability and architectural points of view. Section 8 focuses on solutions for supervising physical exercises, Section 9 on personalized program management, Section 10 overviews various solutions regarding robotic telepresence for communication, whereas Section 11 shows how to retrieve selected information from the web. The interaction between the user and the application through ICT solutions, as well as between the user and care-giver are overviewed in Section 12 (Intelligent collaborators) and Section 13 (Vocal interfaces). We review relevant home and environment monitoring platforms in Section 14, before concluding the paper in Section 15 with a selection of candidate solutions for CAMI. For consistency, each section contains the following sub-sections: Existing market solutions, Technologies and Open Frameworks, Standards and Summary and Conclusions.

5 Health monitoring

The main focus group of CAMI is older adults in general and old adults with cardiovascular diseases, diabetes and mild cognitive impairment in particular. CAMI aims to provide flexible, scalable, and individualized services that enables self-monitoring of this group. Thus, we have identified several physiological parameters of interest to use for health monitoring of these group, which are: weight, blood pressure, pulse rate, ECG, oxygen saturation, segmental body composition, physical activity, and blood glucose.

In cardiovascular diseases and heart failure, the weight is important to follow. A sudden increase in weight can indicate fluid accumulation in the body, which should be reduced. Blood pressure is another important parameter to monitor, as well as pulse rate and arrhythmias. Arrhythmias increases the risk of stroke[1]. ECG will give information both on the heart rhythm and the status of the myocardium of the heart (the accuracy depends on the number of leads). Also oxygen saturation can be an essential parameter to monitor for this group.

[1] http://www.world-heart-federation.org/

In diabetes, blood glucose level is of major importance to monitor, buy also weight and blood pressure are important to follow. Diabetes is also a major risk factor for coronary heart disease and stroke[2].

People with mild cognitive impairment might benefit from ICT solutions, acting as memory support in their everyday life. It might also be of help to monitor their physical activity and deviation to their normal behavior. Here, accelerometers and gyroscopes might be of help, and also GPS- navigation can help them to find their way, or can be activated and send their positions to their relatives. To monitor physical activity in older adults can also be important, since physical activity is known to help in the prevention of disease, maintenance of independence and improved quality of life[3]. Integrated sensors in a smart home environment is also a useful solution for people with cognitive impairment, allowing tracking of activities as sleeping, cooking, and bathing, and also enabling reminding functionalities.

There are many EU projects (within the different frame works and also within the AAL program), that have used and developed ICT solutions and sensor systems for health monitoring. Among these, My Heart[4] and Heart Cycle[5] are large scale projects that focused on monitoring of different heart diseases. The FP7 project GiraffPlus[6] and the AAL projects EXCITE[7] and Victorya home[8] all focus on supporting elderly people in their home, using robot platforms, sensors and supportive ICT solutions.

5.1 Existing market solutions

The term of eHealth has been grown up by developing variety of applications for supporting exchange of information, information flows and interaction between health professionals and communication with health information system (HIS) and different actors in healthcare flow. Today, eHealth refers to telemedicine, electronic patient records (EPR), and electronic referrals including exchanging of information and communication between health professional care and patients as well. Moreover, eHealth concept embraces monitoring of physiological & lifestyle data (nutritional status & physical activity) but also behavioral measurements. However, eHealth can be seen as patients monitoring (RPM) as a subcategory of telemedicine that overlaps with telecare as the monitoring of non-medical data such as general behavior patterns, falls and social alarms to non-professional care e.g. REACTION platform[9].

The necessity of advancement technologies for improving information system combining with telemedicine has opened new dimensions in eHealth environment through information communication technologies (ICT). This type of health ecosystems enables also increasing scalability and utility of IT-infrastructure as an appropriate solution to ensure quality of systems as well as clinical outcomes in management of chronic health and aging at home e.g. REACTION and inCASA platform[10].

[2] http://www.world-heart-federation.org/

[3] Mark G Davis, Physical activity patterns assessed by accelerometry in older people, Eur J Appl Physiol 100:581-9. 2007.

[4] http://www.research.philips.com/technologies/heartcycle/myheart-gen.html, last referred October 2015.

[5] http://www.heartcycle.eu, last reffered October 2015.

[6] http://www.giraffplus.eu, last reffered October 2015.

[7] http://www.oru.se/excite/, last reffered October 2015.

[8] http://www.aal-europe.eu/projects/victoryahome/, last reffered October 2015.

[9] http://www.reaction-project.eu

[10] http://www.incasa-project.eu

Moreover, there is an increasing demand from patients for using internet-based applications in the management of their disease as well as having better access to their care providers[11].

5.1.1 inCASA

The inCASA platform aimed at assisting aging people at home though both telecare & telehealth monitoring. This platform has been developed by using state of the art, ICT. The platform allows integrated care and health services to different health /care professionals in different layer of health organizations and patients /users relatives as well. The platform's objectives achieved gradually by realizing and testing platform in each specific pilots (France, Greece, Italy, Spain, UK) based on integrated services to the end users/patients 'needs and quality of life as well.

	Users	Social	Clinical (Disease)				Organisational Setting		
		Telecare	Hypertension	COPD	CHF	Cancer	Hospital	Primary Care	Social Care
INSERM	30	X				X	X		X
KGHNI	25	X			X		X		X
ATC	20	X						X	X
FHC	32	X		X			X		X
CHC	25	X	X	X	X			X	x

Table 1: inCASA Sample of users' needs at pilots

inCASA solution aimed at providing elderly people with means to monitor their health conditions outside the traditional healthcare environments while supporting them to stay home longer. Thus, target groups included range of chronic health conditions such as Diabetes, cancer /palliative care, Chronic heart failure (CHF), Hypertension, chronic obstructive pulmonary (COPD). In addition, Dementia, loneliness and safety was meant to be supported by home sensors environments monitoring (see 14.1).

The measurements that supported by the platform through health monitoring were:

Blood pressure monitoring for health conditions such as diabetes, Chronic health failure, Dementia, chronic obstructive pulmonary

Blood Glucose monitoring for measuring of glucose in the blood to diabetes type II

Body Weight monitoring to patients with CHF, COPD and diabetes

SPO2 monitoring for COPD, CHF and diabetes

As inCASA's objective is associated to assisting elderly people at home through using of telehealth and telecare, the platform will be investigated as to whether the used technologies can be undertaken to the CAMI's solution or not.

5.1.2 REACTION platform

The REACTION solution was developed based on integrated ICT with personal integrated care to support diabetes management in both short-term risk and long-term management not only in the hospital but also at patients home. The platform supports physiology measurement as: ***Blood glucose, Blood pressure, Oximetry (SPO2) and weight.***

[11] Cayton H.The flat-pack patient? Creating health together.Patient Educ Couns 2006 June;62:288-290.

Figure 1: REACTION-health remote

In addition, with respect to the Lifestyle monitoring, nutrition monitoring will be supported by REACTION health monitoring platform.

Similar to inCASA, REACTION is developed based on services that enables health monitoring and management of chronic illnesses as diabetes.

5.1.3 RENEWING HeALTH[12]

The Renewing Health approach was based on implementation of telemedicine services in nine European regions for chronic health condition monitoring of patients who suffer from diabetes. Chronic Obstructive Pulmonary Disease (COPD) or Cardio Vascular Disease (CVD). The use cases were nine pilots that intended to 18 months real life trails based on Continua Alliance template for Use Cases. Those measurement that monitored by suing of medical devices were, Blood Glucose, Food habits, Blood pressure, SPO2 , Weight and Peak Expiratory Flow rate.

Figure 2: RENEWING HeALTH monitoring

[12] http://www.renewinghealth.eu/en/

Furthermore, the services allow patient to manage their disease, fine-tuning the choice and dosage of medications, promoting compliance to their treatment while professional care can detect early signs of worsening of patient's condition.

5.1.4 LinkWatch[13]

LinkWatch is an intelligent platform for medical data collection as well as monitoring of patients at their home. The platform enables monitoring of vital signs as well as weight and physical activities. The data can be collected via touch PC, tablet or hidden data receiver based on individual interest of technologies and needs.

Figure 3: LinkWatch

The platform enables data acquisition equipment through an engine that consist of LinkWatch TeleMonitoring for using of long-term user-driven design process. The physical measurements of patients and activities will be transmitted automatically into the platform, completely. The patient can allow measurements or reject them, as confirmations. LinkWatch also supports monitoring of peak flow meter, blood glucose meter, blood pressure, Pedometer, Heart Rare, ECG.

5.2 Technologies and Open Frameworks

Patient remote monitoring (PRM) or health monitoring provides medical data by new technologies such as medical devices and sensors. In order to make this type of data transaction demands communication between gateway applications and communication protocols through IoT Device resource and services[14].

[13] http://www.linkwatch.se

[14] http://www.iotworldservices.com

Blood Pressure			Peak Flow Meter		
Personal Weight			ECG		
Medical Weight			Pedometer		
Blood Glucose			Activity and Sleep		
Blood Glucose			Heart Rate		
Blood oxygen			Rehabili-tation		

Table 2: LinkWatch/HomeCare- monitoring & communication protocol

5.2.1 Communication protocol

Generally, Internet of Things solutions require that sensors, devices, equipment and appliances to be connected to the Internet and the cloud[15]. Due to make this type of connections, there are created many different wireless and wired protocols such as Bluetooth, Bluetooth LE, ZigBee, Z-Wave, Wi-Fi, 6LoWPan, EnOcean, ModBus. On top of that there are several IoT Resource and Device Adaption frameworks like IoTivity and AllJoyn. Several different messaging protocols like MQTT, AMQP and XMPP are around.

Bluetooth[16]:

Bluetooth is an open wireless technology for exchanging data over short distances from fixed mobile devices such as blood pressure, blood glucose, SPO2 and more. Originally, Ericsson developed Bluetooth in 1994.

ZigBee[17]:

ZigBee is a high-level communication protocol and using small low power digital devices with short-range radios. Normally, ZigBee is been using for industrial automation and domestic light control applications.

ANT+[18]:

ANT+ is a proprietary open wireless technology design and marketed by ANT+ Alliance. It enables interoperability and open-access to data between different manufactures of wellness, medical devices, watches and smartphones

[15] http://www.cnet.se
[16] https://www.bluetooth.org
[17] http://www.zigbee.org/
[18] http://www.thisisant.com

NFC:

Near Field Communication (NFC) is a protocol that offers electronic devices to establish radio communication with each other by touching devices together or putting them close into proximity to distance of typically 10 cm or less. NFC technology supports three modes: NFC Reader/writer and NFC peer-to- peer (P2P). NFC tags normally maintain data between 96 and 8,192 byts in the memory. Application support also personal data storage including personal Identifications Number (PIN). NFC standards supports data exchange formats based on Radio –Frequency Identification (RFID) standards including ISO/IEC 14443 and Flica[19].

5.2.2 Available sensor solutions

Today, there are several devices available in the market to measure the blood glucose level[20], store the measurements using traditional diary book [21] or store it in mobile devices[22]. Moreover, a patient can interpret the measurements and the diagnosis status themselves and adjust their lifestyle[23].

Accelerometers are widely used to record signals from human activities, and many systems incorporating accelerometers have been developed to recognize human activities in daily life and to compute exercise information such as energy expenditure[24].

Table 3 presents available sensors solutions for health monitoring, most of them available as products.

Description of mesured parameter	Provider	Sampling	Data Transfer
Physical activity	1.Intellicare, http://www.intellicare.pt/index.php/products/onecare-sensing, **Fully Integrated System, Not possible to know if it is OPEN or CLOSE and SPI or I2C** 2.Several products can be found in NetonNet, https://www.netonnet.se/art/halsapersonvard/traninghalsa/sportarmbandstegraknare?sortOrder=10&sortBy=1 **Fully Integrated System, Not possible to know if it is OPEN or CLOSE and SPI or I2C**	Low/High	Periodic/ continuous
Glucose meter	1.Intellicare, http://www.intellicare.pt/index.php/products/o	Low	Periodic

[19] http://members.nfc-forum.org/Protocol Technical Specification

[20] Blood Glucose Diaries, Diabetes.co.uk – the global diabetes community, http://www.diabetes.co.uk/blood-glucose/blood-glucose-monitoring-diaries.html, last referred July. 2015

[21] iBGStar® Blood Glucose Meter, http://www.bgstar.com/web/ibgstar, last referred July. 2015

[22] iBGStar® Blood Glucose Meter, http://www.bgstar.com/web/ibgstar, last referred July. 2015

[23] Tanaka H, Monahan KD, Seals DR (2001). Age-predicted maximal heart rate revisited. J Am Coll Cardiol, 37(1):153-6.

[24] Lee, M.-W., Khan A. M., Kim, J.-H., Cho, Y.-S., Kim, T.-S.: A single tri-axial accelerometer-based real-time personal life log system capable of activity classification and exercise information generation; IEEE EMBS Conference 2010; 1390-1393.

	necare-sensing, **Fully Integrated System, Not possible to know if it is OPEN or CLOSE and SPI or I2C**		
Oxygen saturation monitoring	1.Intellicare, http://www.intellicare.pt/index.php/products/onecare-sensing, **Fully Integrated System, Not possible to know if it is OPEN or CLOSE and SPI or I2C** 2.BioRadio™ https://glneurotech.com/bioradio/bioradio-150/ **OPEN with USB but no information about SPI or I2C,detailed later**	High	Continuous
Thermometer	1. Intellicare, http://www.intellicare.pt/index.php/products/onecare-sensing, **Fully Integrated System, Not possible to know if it is OPEN or CLOSE and SPI or I2C** 2. BioRadio™ https://glneurotech.com/bioradio/bioradio-150/ **OPEN with USB but no information about SPI or I2C,detailed later**	Low	Periodic
Scale	1.Intellicare, http://www.intellicare.pt/index.php/products/onecare-sensing, **Fully Integrated System, Not possible to know if it is OPEN or CLOSE and SPI or I2C** 2.Omron, http://www.healthcare.omron.co.jp/bt/english/ **Partially Integrated, OPEN as SPP (Serial Port Profile), Not possible to know SPI or I2C**	Low	Periodic
Pulse oximeter	1.Intellicare, http://www.intellicare.pt/index.php/products/onecare-sensing, **Fully Integrated System, Not possible to know if it is OPEN or CLOSE and SPI or I2C** 2. BioRadio™ https://glneurotech.com/bioradio/bioradio-150/ **OPEN with USB but no information about SPI or I2C,detailed later**	High	Continuous
ECG	1. Zenicor 2. Intan Technology, http://intantech.com/files/Intan_RHD2000_eval_system.pdf]. **OPEN with serial peripheral interface (SPI), detailed later**	High	Continuous

	3.BioRadio™ https://glneurotech.com/bioradio/bioradio-150/ **OPEN with USB but no information about SPI or I2C,detailed later**		
Blood Pressure	1.Omron, http://www.healthcare.omron.co.jp/bt/english/ **Partially Integrated, OPEN as SPP (Serial Port Profile), Not possible to know SPI or I2C** 2. Several products can be found in NetonNet, https://www.netonnet.se/art/halsapersonvard/traninghalsa/blodtrycksmatare?sortOrder=10&sortBy=1 **Fully Integrated System, Not possible to know if it is OPEN or CLOSE and SPI or I2C** 3. Intellicare, http://www.intellicare.pt/index.php/products/onecare-sensing **Fully Integrated System, Not possible to know if it is OPEN or CLOSE and SPI or I2C** 4.BioRadio™ https://glneurotech.com/bioradio/bioradio-150/ **OPEN with USB but no information about SPI or I2C,detailed later**	Low	Periodic
Electromyograms (EMG)	1. http://intantech.com/files/Intan_RHD2000_eval_system.pdf **OPEN and SPI functionality, detailed later** 2.Intan Technology, http://intantech.com/files/Intan_RHD2000_eval_system.pdf]. **OPEN with serial peripheral interface (SPI), detailed later** 3.BioRadio™ https://glneurotech.com/bioradio/bioradio-150/ **OPEN with USB but no information about SPI or I2C,detailed later**	High	Continuous

Skin Conductance (GSR)	5.BioRadio™ https://glneurotech.com/bioradio/bioradio-150/ **OPEN with USB but no information about SPI or I2C,detailed later**	High	Continuous
Others	Vibration Sensor, Digital MEMS Vibration Sensor, **OPEN with serial peripheral interface (SPI), detailed later**		
ECG, EMG, Activity monitoring	Shimmer platform and senosrs, OPEN for Data communication	High	Continuous

Table 3: Available sensors solutions for health monitoring

5.3 Standards

Health monitoring is a comprehensive concept that embraces service and operations of Data collection, Data communication, Data visualization and analysis, and the last but not the least Decision support system. Each layer of such a complex system requires a notable understanding towards different standards and interoperability. Therefore, this deliverable provides an overview of different standards in different layer.

The LinkWatch platform supports data semantic interoperability based on e-health standards such as ISO/IEEE 11073 for personal health device data , CEN , IEEE 11073-10417:2009) for blood glucose meter and IEEE P11073-10419 for insulin pump. The table below is a short summary of different medical devices that communicate to LinkWatch platform as Continua device.

Specialisation	Standard	Status
Basic ECG (1 to 3 lead)	IEEE P11073-10406	In development
Blood pressure	IEEE 11073-10407:2008	Standard
Body composition analyser	IEEE P11073-10420	In development
Glucose meter	IEEE 11073-10415:2009	Standard
Independent living activity hub	IEEE 11073-10471:2008	Standard
INR	IEEE P11073-10418	In development
Insulin pump	IEEE P11073-10419	In development
Medication monitor	IEEE 11073-10472:2010	Standard
Peak flow	IEEE P11073-10421	In development
Pulse Oximeter	IEEE 11073-10404:2008	Standard
Thermometer	IEEE 11073-10408:2008	Standard
Weighing scales	IEEE 11073-10415:2008	Standard

Table 4: IEEE 11073 Personal Health Device Standards

5.3.1 Continua Health Alliance

These standards categories support Healthcare Informatics data standards with consumer electronic technologies through guidelines and specifications necessary to enable connectivity devices and services. These standards support Bluetooth SIG for wireless connectivity, USB Personal Health Device Specification from ISO/IEEE for protocol definitions. Continua Health Alliance V1 standards are for integration with standards –based electronic health records (EHRs) consist of the CDA-based

Personal Health Monitoring (PHM) specification from HL7 and the XDR Profile Specification from IHE.

Continua uses Use case driven process where all members have input to decision on which integration capabilities are developed. Continua goal is not to create new standards but to identify the best possible class existing standards that suite to the Use Case requirements and provide profiling to ensure tight interoperability. Continua Standards enable coordination of range changes in existing standards to enable a set of personal telehealth use cases.

5.4 Summary and Conclusions

Health monitoring has shown a great potential to meet challenges towards improving self-care management and quality of life. However, the absence of interoperability and standards between different layers of applications has reduced scalability and utility of these type of solutions in health care flow[25]. In order to avoid interoperability issues in the CAMI platform, the ecosystem will emerge by focusing on user's needs based on daily routines activated via a well-defined "system architecture" and by delivering user scenarios and use cases that could exemplify the CAMI framework. After the specification of users' needs and well-defined scenarios of use-cases, the CAMI platform will adopt the potentially appropriate technologies based on guidelines and standards (initial proposals are collected in Table 9).

6 Fall alarm

Fall incidence among elderly people over the age of 75 years is larger than 30%, close to half of the nursing home residents fall each year, and 40% of them fall more than once[26]. The accidents result in both physical[27] and psychological[28] consequences, very large suffering, death, and very large costs. For instance, in Sweden, the yearly costs of fall incidents, according to the Swedish Agency of Contingencies Agency are estimated to 25 billion SEK, which is larger than the costs of traffic accidents.

Thus, sensors detecting a fall and sending an alarm, or even sensors able to predict an increased risk of falling, are highly prioritized. There are several sensor systems available on the market, but there are also limitations, for example many of them are considered too large and inconvenient to wear.

6.1 Existing market solutions

There are a variety of fall detection sensors available on the market, but not all of them fulfil the requirements and wishes of the users to be easy to use and comfortable to wear. To examples of

[25] European, Commission. Green paper on mobile Health ("mHealth"). Brussels: 2014

[26] J. Dai, X. Bai, Z. Yang, Z. Shen, and D. Xuan, "Mobile phonebased pervasive fall detection," Personal and Ubiquitous Computing, vol. 14, no. 7, pp. 633–643, 2010.

[27] S. Sadigh, A. Reimers, R. Andersson, and L. Laflamme, "Falls and fall-related injuries among the elderly: a survey of residential-care facilities in a Swedish municipality," J. of Community Health, vol. 29, no. 2, pp. 129–140, 2004.

[28] B. J. Vellas, S. J.Wayne, L. J. Romero, R. N. Baumgartner, and P. J. Garry, "Fear of falling and restriction of mobility in elderly fallers," Age and Ageing, vol. 26, no. 3, pp. 189–193, 1997

existing solutions incudes the Tunstall fall alarm[29] (from UK), the Bay Alarm Medical sensor[30] (from the US). Other example of fall detection systems (available at the US market) are presented in Table 5.

The Tunstall fall alarm can be worn as a clip at the waist or as a pendant around the neck. It is connected with the Tunstall so called Lifeline system, which raises an alarm and gets in contact with the care organization. In case of an alarm, the user has the opportunity to cancel by pressing a button. There is also a possibility to manually raise an alarm by pushing the button. The fall alarm sensor is small and has a weight of only 15 g.

The Bay Alarm Medical also is a light system, worn as a pedant around the neck. It can be connected both to the landline and to cellular phones.

Figure 4. Tunstall fall detection sensor to the left and the Bay alarm fall detection sensor to the right.

Table 5. Examples of fall detection systems available on the US market.

Medical Guardian	Alarm button and fall detection	http://medical-alert-systems-review.toptenreviews.com/fall-detection/medical-guardian-review.html
Alert 1	Fall detection	http://medical-alert-systems-review.toptenreviews.com/fall-detection/alert-1-review.html
Lifecall	Alarm button and fall detection	http://medical-alert-systems-review.toptenreviews.com/fall-detection/lifecall-review.html
Lifewatch	Alarm button and fall detection	http://medical-alert-systems-review.toptenreviews.com/fall-detection/lifewatchusa-review.html
Medialert	Alarm button and fall detection	http://medical-alert-systems-review.toptenreviews.com/fall-detection/medi-alert-review.html
Medicarealert	Alarm button and fall detection	http://medical-alert-systems-review.toptenreviews.com/fall

[29] http://www.tunstall.co.uk/news/345/automatic-fall-protection-alarm-launched-for-elderly

[30] http://www.bayalarmmedical.com/medical-alert-system/automatic-fall-detection/

		-detection/medical-care-alert-review.html
Philips lifeline	Alarm button and fall detection	http://medical-alert-systems-review.toptenreviews.com/fall-detection/philips-lifeline-review.html

One of the earliest components that has been used in inCASA was SARA Client solution within/inCASA.

inCASA architecture comprised with fall detection for elderly people through gather all information related to health care through sensors, blood pressure, weight device, heart rate sensors , fall sensors detecting, etc. Further, more SARA Client was developed as subsystem as an integrated automatic monitoring of behavior profile of users and their movements at the home. The health client was a portable touchable screen which was in fact a PC with windows platform that run the SARA Client and patient would not see this devices but as a monitor. All profile habits could be monitored and automatically identify anomalous situations and send alert to the user, carers and to the service provides who had responsible for alarm and fall management. This remote monitoring system could also provide reminder prompts to individuals or professionals. (See 5.1.1)

In addition, collected medical data related to pre-existing monitoring system (e.g. SARA client) were channelled and managed through the base station. Furthermore, the data collected by the base station could be continuously and/or periodically sent to the service provider in order to create a strived behavior model of the person (via the learning system) and to generate reports and/or alerts in case of anomalies.

6.2 Technologies and Open Frameworks

Commonly, fall detection systems are categorized into three different classes depending on the sensor technology used. These are wearable devices (measuring posture and motion), ambient sensors (measuring posture and presence), and vision-based sensors (measuring body shape, inactivity, and 3D head change).

Various fall detection algorithms implemented in wearable sensors have been presented, and also embedded sensors in smart phones have been used in combination with algorithms for fall detection[31,32]. These two studies were conducted within the FP7 GiraffPlus project, and the prototype can be available to the CAMI consortium by small modifications. Within the GiraffPlus project, the phone was connected to the GiraffPlus gateway, and thus it must be adapted to the CAMI infrastructure. One advantage to use a smartphone is that it often already is worn, a disadvantage is the power consumption that is larger than that of a small fall sensor. The GiraffPlus system used both this

[31] Evaluation of the Android-Based Fall Detection System with Physiological Data Monitoring, Gregory A. Koshmak, Maria Linden, Amy Loutfi, The 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC'13), Osaka, Japan, July 3-7, 2013

[32] Dynamic Bayesian Networks for Context-Aware Fall Risk Assessment, G. Koshmak, M. Linden, A. Loutfi, Sensors 2014, 14(5), 9330-9348; doi:10.3390/s140509330

smartphone fall detection application and the Tunstall fall detection sensor in the project. Evaluations were performed in the homes of elderly people in Sweden, Italy, and Spain, but the incidence of falls were very low, and thus no firm conclusion about the reliability of the systems could be drawn.

However, recent trends are to combine different data sources by multi-sensor fusion algorithms[33]. A systematic review over fall detection systems using multi-sensor systems has recently been presented[34]. A clear advantage to use the multi sensor approach is that it is possible to get a more holistic view over the patient. A drawback is that it requires several sensors which is both more expensive and complex to apply.

The LinkSmart Middleware[35] exposes mediated data to next coming subsystems in the inCASA SPP module through Web Services. This eases interoperability between subsystems and opens up for a local scalability strived for within the project.

6.3 Standards

In the following we briefly overview the standards that are most common for implementing and using sensors for healthcare.

6.3.1 LinkSmart Continua Extensions

Using the Continua standard allows interoperability between different components, system and subsystem to follow the same structure for different health systems.
Specializations that are used follows specialization ISO/IEEE Std. 11073-10471 Independent Living Activity Hub which has multiple support for different sensors, such as thermometer, humidity, door detector, etc. Each specialization describes information about the sensor being used (e.g. type, identification number, location, measurement, etc.).

More specialization can be implemented which is supported by Continua ISO/IEEE Std. 11073 for healthcare or homecare (e.g. blood pressure monitor, weighing scale monitor, glucose monitor etc.) and this supports a scalability point of view for the project[36].

6.4 Summary and Conclusions

The data collection by monitoring systems has until now been successfully performed by using Telehealth and TeleCare, with all data being customized remotely by LinkSmart to the health care provider's platform in form of publishing available resources of communication. Therefore, LinkSmart technology can be undertaken as an appropriate solution for the core platform.

[33] I. Iliev, S. Tabakov, and V. Spasova, "Multipoint video control and fall detection system applicable in assistance of the elderly andpeoplewithdisabilities," International Journal of Reasoningbased Intelligent Systems, vol. 6, no. 1-2, pp. 34–39, 2014.
[34] Challenges and Issues in Multisensor Fusion Approach for Fall Detection: Review PaperGregory Koshmak, Amy Loutfi, Maria Lindén Journal of Sensors (Hindawi Publishing Corporation)
[35] http://www.iotworldservices.com
[36] http://www.incasa-project.eu/D4.1_Coremonitoring System Implementation

The suggestion will be to use two types of fall detection sensors, one commercially available, for example the Tunstall fall detection sensor, but also a research prototype based on a smartphone platform and developed by researchers in the consortium. The reason to choose a Tunstall sensor will be that it is well established and available to the European market. The possibility to connect to the alarm system through the Lifeline system or other must though be investigated.

One clear advantage to use a smartphone application for fall detection is that a smartphone often already is worn by many, a disadvantage is the power consumption that is larger than that of a small fall sensor. It is also easier to design the alarm system since we are in control of this.

7 Report and communication to health professionals

In this chapter, a state of the art review including multiple existing solutions of Ambient Assisted Living (AAL) and telemedicine is given. Several ambient assisted living and telemedicine solutions exist on the market. These solutions aim at facilitating healthcare personnel's work by providing smart solutions capable of interacting with the environment, the patient and the caregivers. An overview of solutions for communicating with health professionals will be described and analyzed in the following sections. Technologies, standards and open framework regarding (AAL) will be presented too.

6.5 Existing market solutions

Due to the technological advancements of the last decades, it has been possible to improve the quality of life of the patients that are being monitored by the medical staff significantly. A proof of that relies on the solutions that have been released by companies. In this section we analyze the most remarkable final products that are capable of tracking and recording mobility of a person within a small area, like a room, or even a flat.

7.1.1 Electronic health records and digital personal health record

The technology has shown a great potential to deliver health care services over the last decade. The health care providers and their rapports of modest improvement emphasize it in their ability to make better decision by using comprehensive clinical information[37].

Normally, this technology requires advance level of integrations of complex systems and deployment for new health care technologies with a great impact on business operations and processes (pre-hospital care, primary care, emergency department, etc.) and medical support for patient care[38] as well. Therefore, it is essential to consider management of health information is based on these processes (from the beginning of patient's encounter to the care units to their discharge) or resumption of a platform that normalized through guidelines and standards such as REACTION and inCASA. These both platforms have developed based on LinkSmart technology (see 7.2).

The Clinical portal within inCASA platform was developed to support any critical condition based on monitoring. These services enables continuous feedback to the patients such as diabetes or chronic heart failure. The portal has shown a proven satisfactory with users but needed to be accomplished

37 **Heisey-Grove, D., Danehy, L. N., Consolazio, M., Lynch, K., & Mostashari, F. (2014). A national study of challenges to electronic health record adoption and meaningful use. Medical care, 52(2), 144-148.**

38 http://www.abm.com/Documents/white-papers/WP_Healthcare-Tech-Whitepaper.pdf

with environmental sensors and new technologies with help of future research. The Clinical Portal were implemented and valuated in both REACTION and inCASA environments (see Figure 5).

The patient portal has in REACTION provides communication with health professional while providing an overview over patient's physiological and lifestyle data (see Figure 6).

Figure 5: REACTION- Clinical Portal

In the primary care scenario, patient portal has been developed within REACTION platform in order to strength of patient's empowerment through providing information's to patient based on clinical guidelines and patients care plan. Through using of patient portal interface, can receive feedback on their physiological values but also their lifestyle data. These data are visualized to patients and their clinical team in form of graph or table. It is believed that access to this kind of information constitutes an efficient means to get an overview or to keep track over the history of a specific trait. Furthermore, having access to this data (patient measurements) support empowerment by improving the patient's possibilities to keep control on their health status and detect irregularities. These data can be visualized also by using of smartphones, computers at home or tablet PCs. All data will be updated automatically based on the last captured of measurements by patients. The portal allows patients to have a choice over using of their own data. For instance, quantitative data based on accuracy of the measurements on blood glucose level and feedback on it so if it deviates from a set of goals that patients have choose with help of diabetes team. The system does not send too many alerts to patients to avoid scaring patients, however their clinical team will notice them.

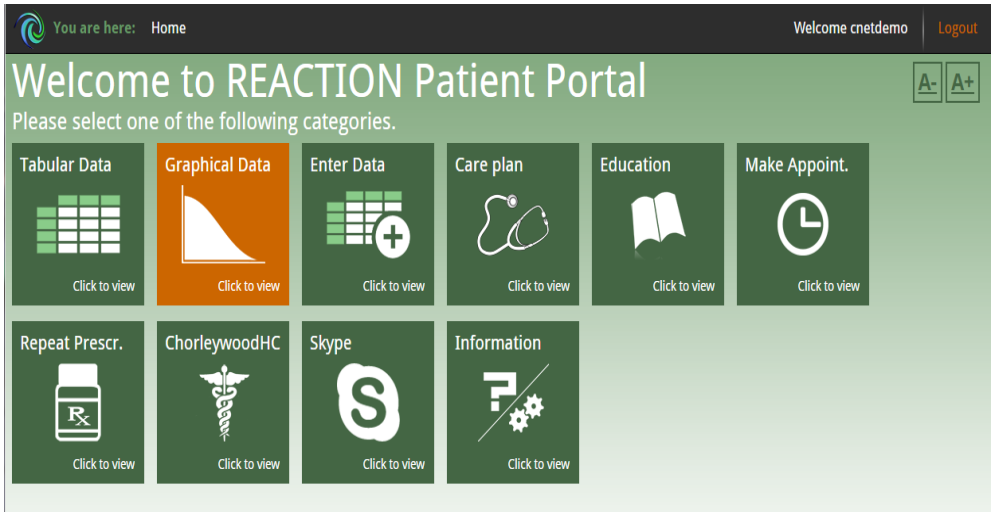


Figure 6: REACTION Patient portal

Open EHR is also new approaches framework that allows professional health , experts to integrates to clinical information systems though defined specifications for clinical information models, EHR Extract, demographics, data types and various kinds of service interfaces (See 7.2).

7.1.2 CompliantConcept-Monitoring System

Compliant concept AG develops bed systems for the treatment and prevention of pressure ulcers. It offers mobility monitors for pressure ulcer risk management solutions by providing clinical risk assessments, and detecting other influences, such as medication, pre-bedtime activities, etc. The company was founded in 2009 and is based in Dübendorf, Switzerland.

ComplaintConcept has modeled a mobility Monitor. It is claimed that offers a high quality of life for the patient, easy to use and direct support for the nursing staff. The main points of the Monitoring System are the next ones:

- Recording of mobility and micro-activity. Defining Micro activity as the motion carried out by the patient at bed.
- Warning onset of immobility
- Simple and intuitive to operate

CompliantConcept offer special attention and training for all the personell that is going to be in contact with the hardware. Individual patient assistance is given too. The installation is carried out easily by placing a rubber surface where the sensors are, under the mattress. It comes together with a mobility monitor that displays significant information about the patient.

Figure 7: CompliantConcept's Mobility Monitor

Modules

Mobility Monitor's features is featured with different modules. The costumer can choose within the modules, and upgrade them at any time. The modules are listed below:

- **Bed-exit module:** With this module, the Mobility Monitor will be able to detect if the patient is about to leave the bed by checking out a 360º bed-edge position. A warning message is sent through the nurses' alarm system.

- **Mobility module:** This module performs the tracking of a patient's movement. An immobility warning is sent in order to prevent pressure ulcers. With this module is possible to track sleep disorders as well.

- **Assessment module:** This module offers individual treatment evaluations for each patient, including efficient targeted planning of nursing care measures. This module requires an extra piece of software called Mobility and care manager.

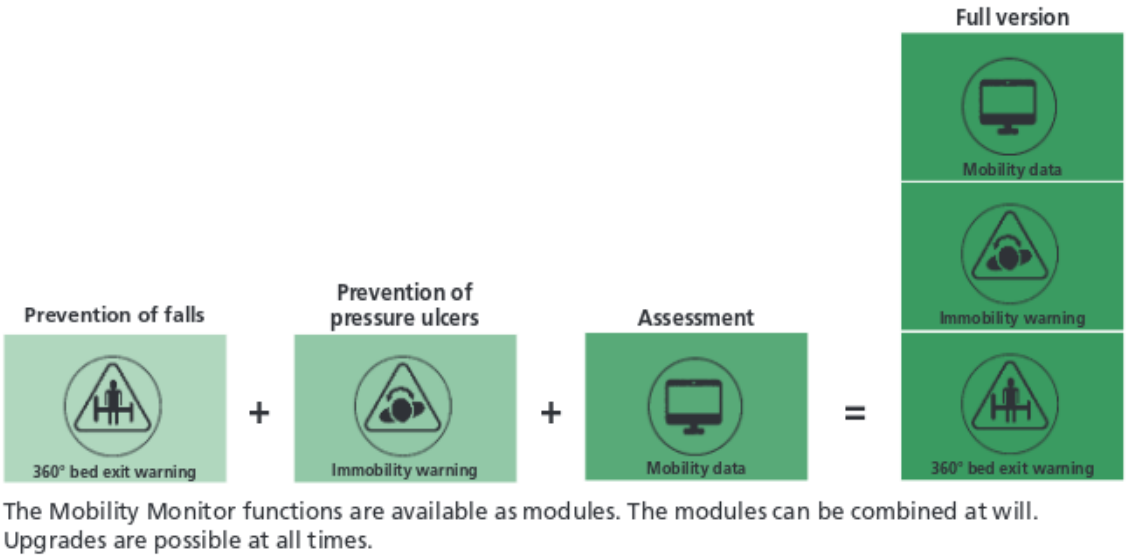
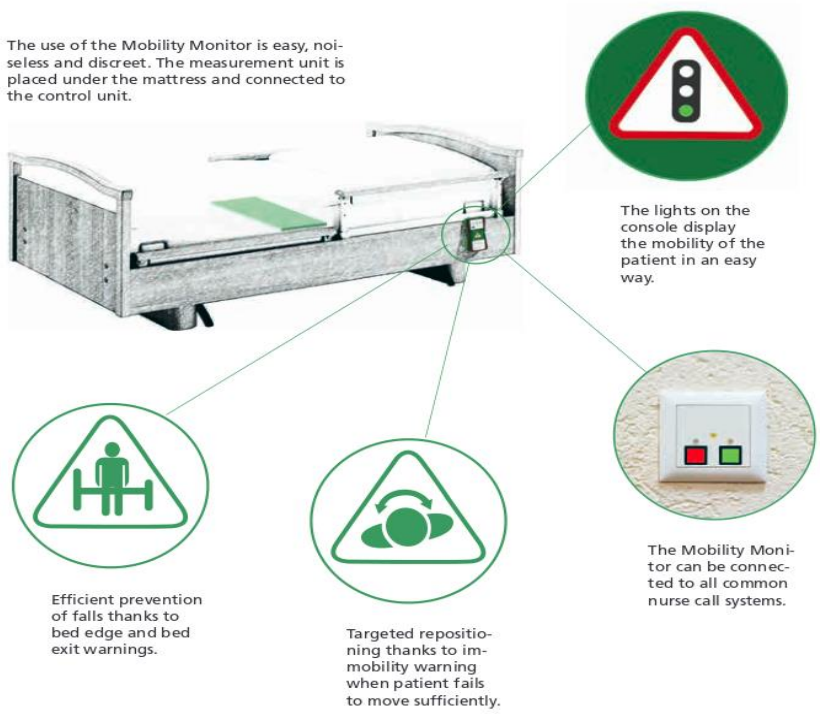


Figure 8: Mobility Monitor Functionsas Modules

As it is stated by the below, the mobility monitor can be connected to all common nurse call systems.



The data is transferred by using a **USB** stick or **radio** transmission. The software is provided by CompliantConcept. The analysis of the data is shown below.

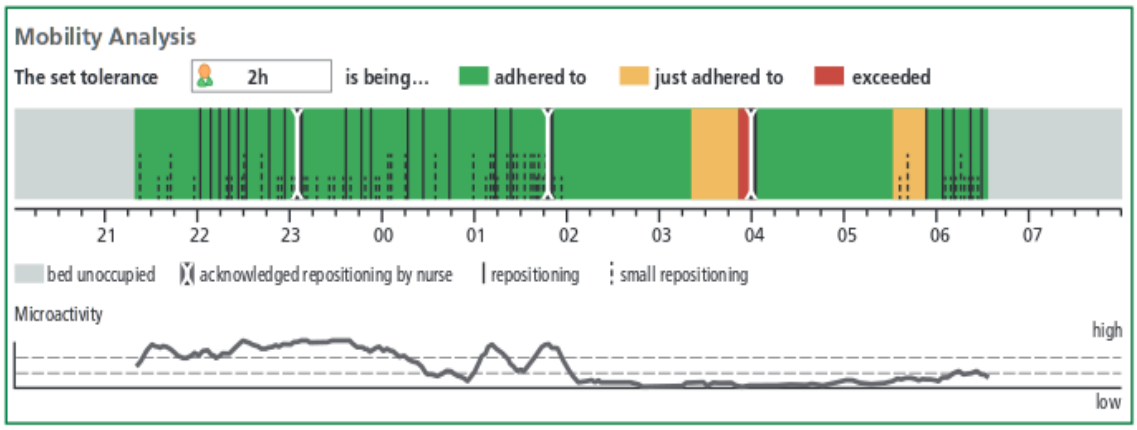


Figure 9. Mobility Analysis

Applications

Mobility Monitor can go throughout the nursing care process by assisting nurses and doctors with crucial information with fact-based decision and quick response. The applications are stated below:

- **Fall prevention:** Consist in a 360º bad-edge or bed-exit warning that helps to prevent falls. An alarm is sent to the care taker as soon as the patient sits on the edge of the bed.
- **Pressure ulcer prevention:** If there is no pressure ulcer preventing movements by the patient for a certain period, an immobility warning is sent to the caretaker.
- **Sleep patterns and medication:** It analyses the smallest movements on bed, hinting on sleeping disorders that might be produced by a bad medication treatment.
- **Assessment:** It is possible to shorten the assessment period for new patients due to the warning that the devices are able to send. Nurser care needs are required objectively and only when it is necessary.

7.1.3. MariCare: Elsi Smart Floor

Mari Care provides smart floor motion detection. It does not track any movement in bed, the same way, it does not check either, whether the person is in bed or not. On the other hand, it checks the movement that might occur on the floor. By detecting floor motion, it is possible to track a person around the room and detect falls and significant access to different areas of the house.

Elsi Smart floor is installed under the floor carpet, it has the shape of traditional linoleum carpets. The main problem of this installation devolve upon the need of installing it before the floor has been set up.

The price of the Elsi Smart Floor is approximately 125-150 € per *m*2.

Functionality

The main functionality can be found below:

- Fall bed and toilet alarm with timer: The system is capable of sensing a fall, therefore send an alarm to the care taker.

- Entrance/Exit alarm main door: The system is capable of detecting who leaves or enters the room respectively.

- Burglar alarm: The system is capable of sensing undesired presence at home.

User interface

The alarms and notifications can be activated in the unique Elsi user interface, using different criteria: nurses, individual residents and special times during 24 hours. The notifications are also relayed to Smart phones or DECT Phones. On the top right of the figure below, an example of user interface can be seen.

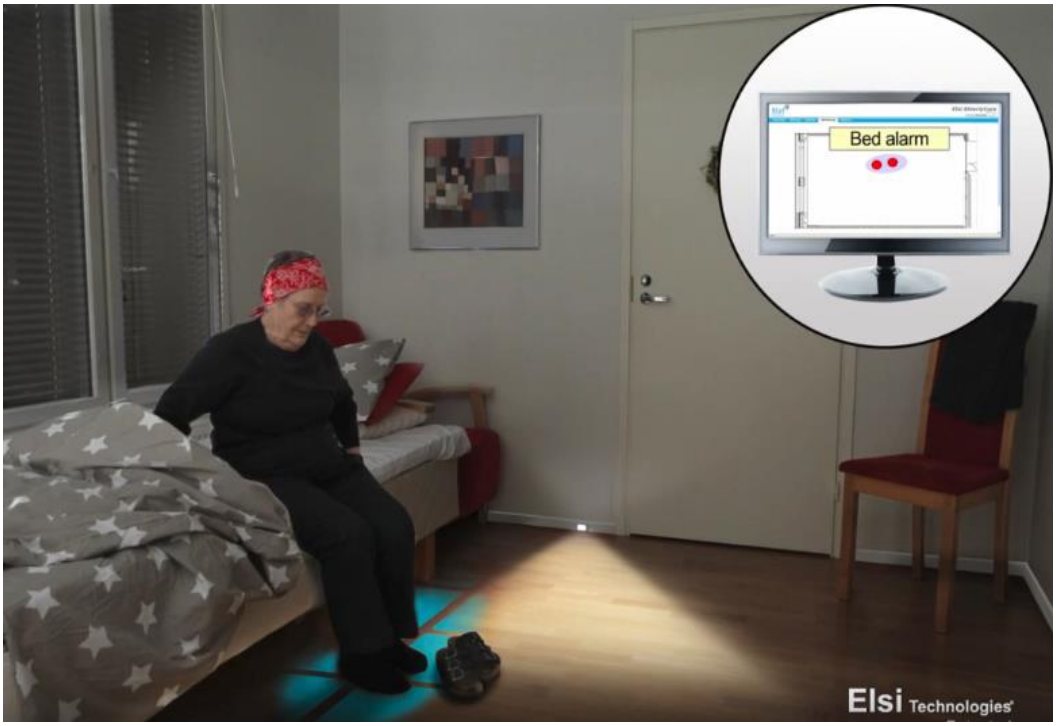


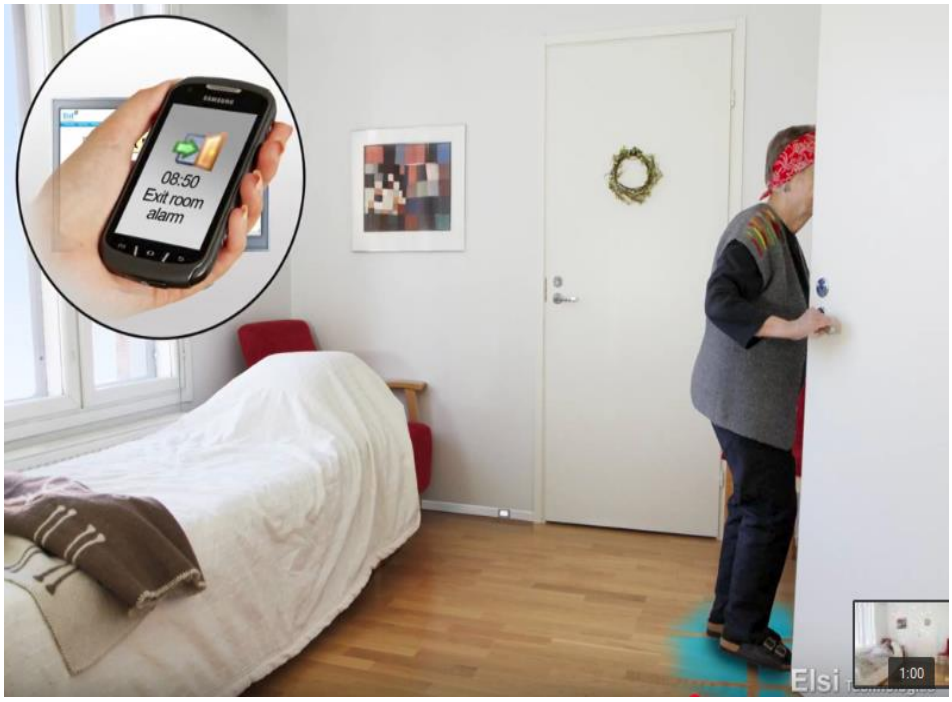
Figure 10. Example of an Elsi User Interface

Smart phones support as well notifications, as the figures below show.

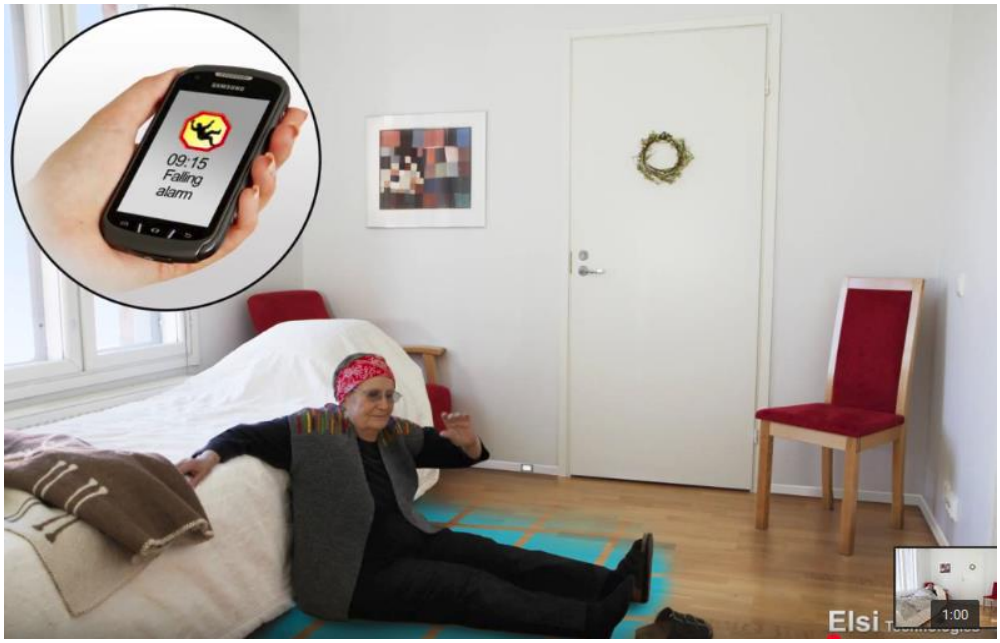
Therefore, different kind of alarms are sent to the user interface, the illustration below shows the patients entering to the toilet, consequently, the system reports a ”Toilet entrance alarm” as well as being able of tracking the patient around the house and sending the exact position.

Therefore, the above illustrations shows how a toilet entrance alarm is sent to the smart phones as well.

The figure below shows how the system is capable of detecting if the patient laves or enters the room respectively, sending the notification with the exact time.



Elsi Smart floor is capable of sensing a fall, therefore, it is capable of distinguishing different areas laying on the floor. The figure below shows a scenario where the patient has fallen, raising a falling alarm that will be directly send to the care taker.



Installation

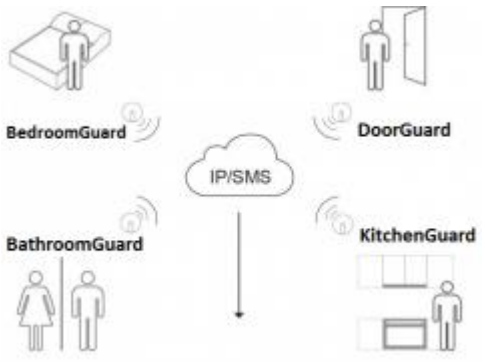
The installation of the Elsi Smart Floor is similar to the installation of traditional linoleum carpets. It is installed under the floor carpet. It is fully protected by it, giving it a long lifetime. As the figure below shows, it is placed under the floor carpet.

Once the Elsi Smart Floor has been placed under the floor, the side part of the system that exceeds over the surface is covered by plastic devices, therefore, the necessary electronic equipment is installed there, and interconnected within all the necessary chips. The Figure below shows how Elsi Smart Floor accomplish the electronic interconnection.

7.1.4 YesGroup – BedGuard

YesGroup has released a multi-purpose system capable of detecting movement around the house, by interconnecting multiple sensors. The sensors are able to send and receive data from other nodes which enables them to smartly detect how the person moves around the house. The nodes consist in a wireless spherical-shaped box. There are multiple nodes that can act individually, however, the system is intended to be used together with all the modules. The nodes are listed below, each of them accomplish a unique goal.

Functionality



- KitchenGuard: Multiple sensors are set up in different places of the kitchen, monitoring the heat, smoke, and turning off the oven if a fall is detected upon it. A fixed time can be monitored too in order to prevent the stove to be used for more than a maximum desired time assigned by the user or the care taker.

- BedGuard: Detects for how long the user remains out of bed, triggering an alarm if the time out exceeds the initial value. It is capable of interacting with other sensors in order to detect whether the patient has reached other areas of the house, therefore, it uses different trigger times depending on the situation the patient has encountered.

- DoorGuard: It simply controls by placing sensors on the doors:
    - Who may enter
    - Who may not enter
    - Who must enter
    - Who must not enter
    - Who may leave the room
    - Who must not leave the room

  Therefore, there is a control of who leaves the room, who enters the room, and whether the patient or other persons are allowed to leave or enter the house respectively. Because of that, the system is tailored depending on the needs of the patient, the environment and the care taker.

- BathroomGuard: Motion sensors are placed over the bathroom, they are capable of interacting with each other, detecting if the patient has reached the door, the sink, or the bathtub. If no movement is detected inside the bathroom for an specific interval of time, an alarm is triggered.

Sensor technology

For all the areas described above, the sensor technology can be defined:

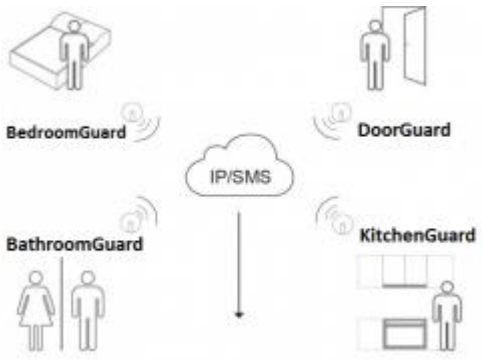
- Temperature sensor: If the temperature rises or falls outside a certain temperature range, the sensor sends an alarm. It is possible to configure the sensors by detecting huge differences within this range, therefore, detecting if a fire has been set up, sending a major warming.

- External connections: The basic sensors can be connected to other alarms in order to create smart sensor network.

- Electric appliances: All home appliances can be connected to the IntelligentCare system and be regulated or switched off if a dangerous situation is arising, or save energy by switching them off if no motion is detected on the room.

User interface and protocols

InteligentCare official web page do not talk about the user interface. On the other hand, there are pictures that reflects that their system works using IP/SMS protocols. The sensors do not have wires, what means that the protocol used for this solution, can be Zigbee, Wifi etc.



7.1.5. OpenCare

OpenCare is an open source solution. It has been used for several research projects, as well commercial systems, including in the Sekoia platform, currently used by 3000 nursing home residents in Denmark and Germany.

The OpenCare Project is an open source infrastructure framework, designed to be used by researchers and corporate developers for developing experimental assisted living protoypes, as well as complete feature rich systems with a high degree of flexibility and modifiability.

The aim of the OpenCare project is to investigate the potential of introducing a common platform for seamless deployment of healthcare and AAL devices and applications in the home of citizens in need of care. Specifically, the proejct investigates why novel AAL technology is only slowly penetrating the gap from research to real world usage, identify the barriers and how these may be overcome. Furthermore, it investigates through action research, which implies. co-developing an alternative conceptual and technical model for overcoming these challenges through a participatory design approach. Finally, the aim of OpenCare is to open up for cooperation with existing research and commercial platforms for AAL through dissemination of OpenCare concepts, standards, and technologies to the AAL community.

Recently, OpenCare was used as part of the FP7 funded CareStore project. Creating an open source, free, and heterogenous marketplace for healthcare and ambient assited living products.

The overall objective of the CareStore project was to develop an inexpensive and user-friendly open-source platform that allows several vendors easy access to publish new devices and applications, as well as supporting staff and inhabitants' easy deployment of such devices and applications, without requiring technical staff intervention. The CareStore project focuses on usability, applicability, and feasibility.

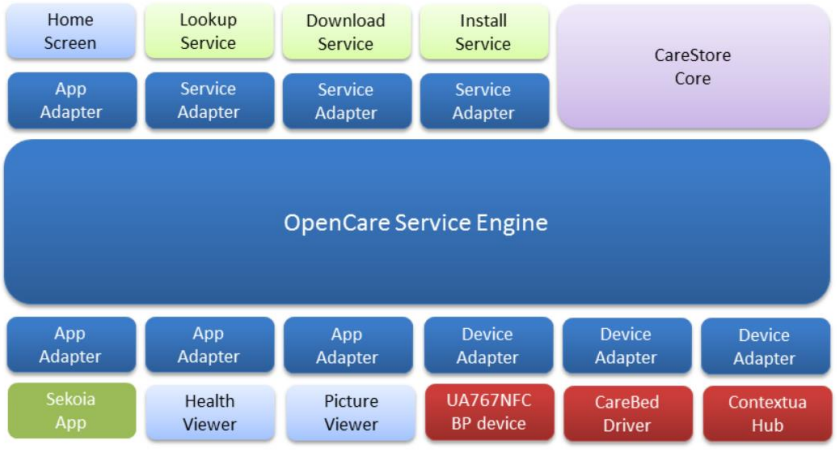


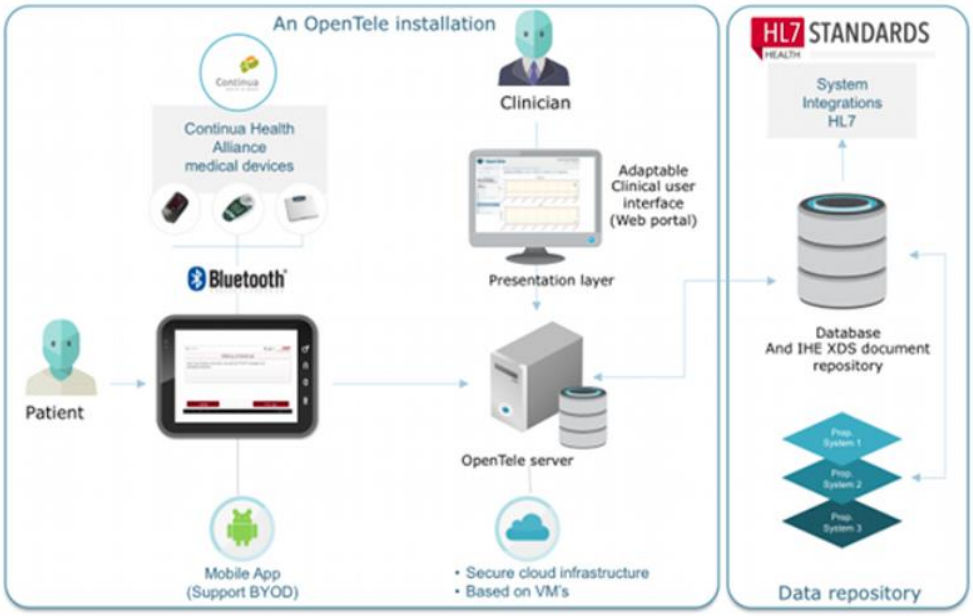
Figure 11: The OpenCare Service Engine and how it is used to distribute data between apps, including to health professionals.

7.1.6 OpenTele

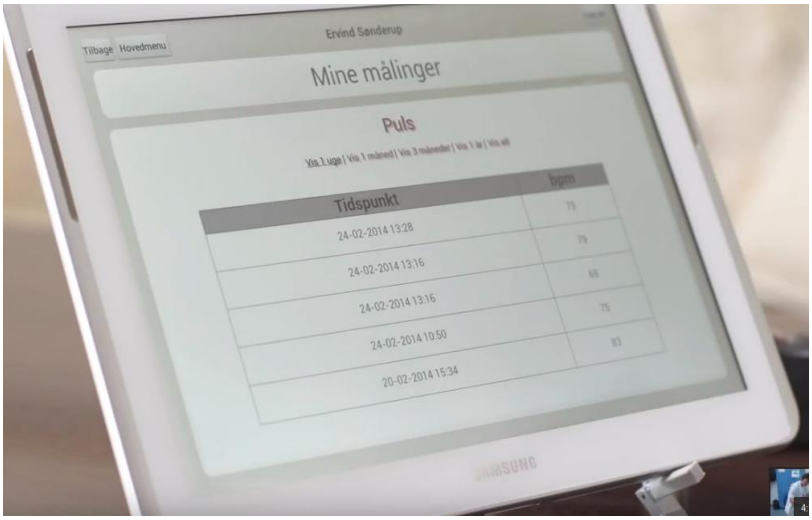
OpenTele is used by several hospitals in Denmark and has become the government reference project for Telemedicine, meaning all Danish Regions must use this product. OpenTele is fully open source based and aims at involving patients in their own treatment by given them a co-responsibility for their health and treatment. Therefore, the patient is encouraged by the hospital in order to take the respective health measurements from home. The architecture of the platform sends the data to the hospitals and finally the doctors evaluate the results.

Architecture, interfaces and standards

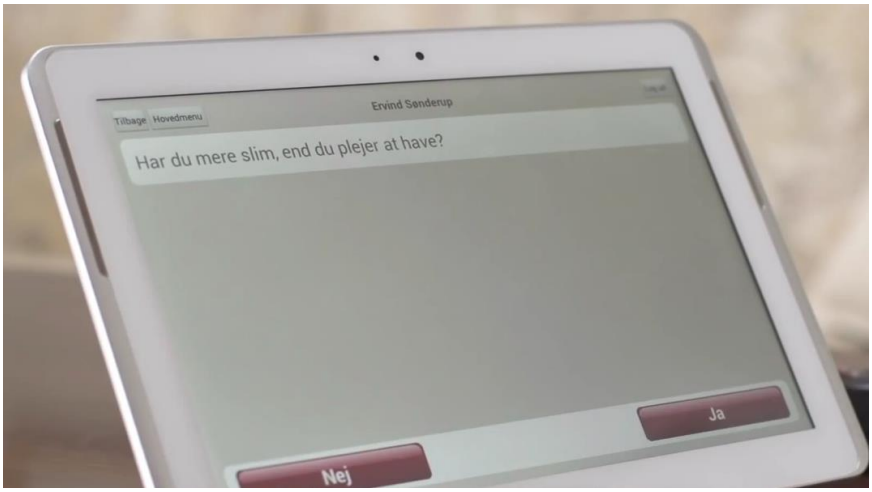
The next diagram shows the architecture and the standards respectively. The patients need to learn how to use a tablet, where the main user interface is handled. Therefore, all the devices are connected to this tablet, via Bluetooth, USB or internet. The devices are supported and provided by Codina Health Alliance medical devices. Data is sent through the internet to the OpenTele server where. Once the data arrives to the server a presentation layer enable the clinician to observe the results in a fancy way. Databases and a secure cloud infrastructure are provided.



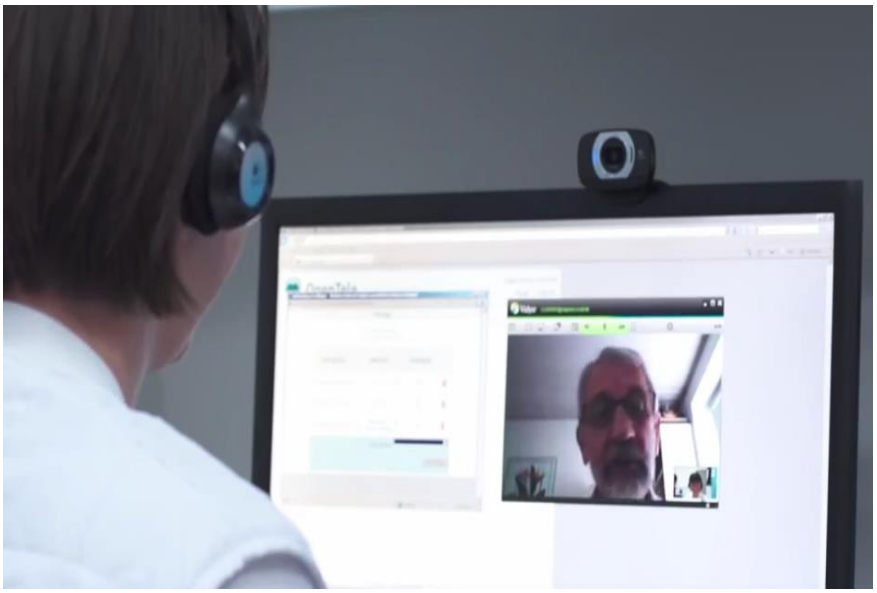
The patient interface in action can be seen on the picture below. The patient is highly responsible on handle the tablet, therefore all the measurements are carried out by the patient. On the other hand, the medical devices are not able to be modified, nullifying any possible mistake.

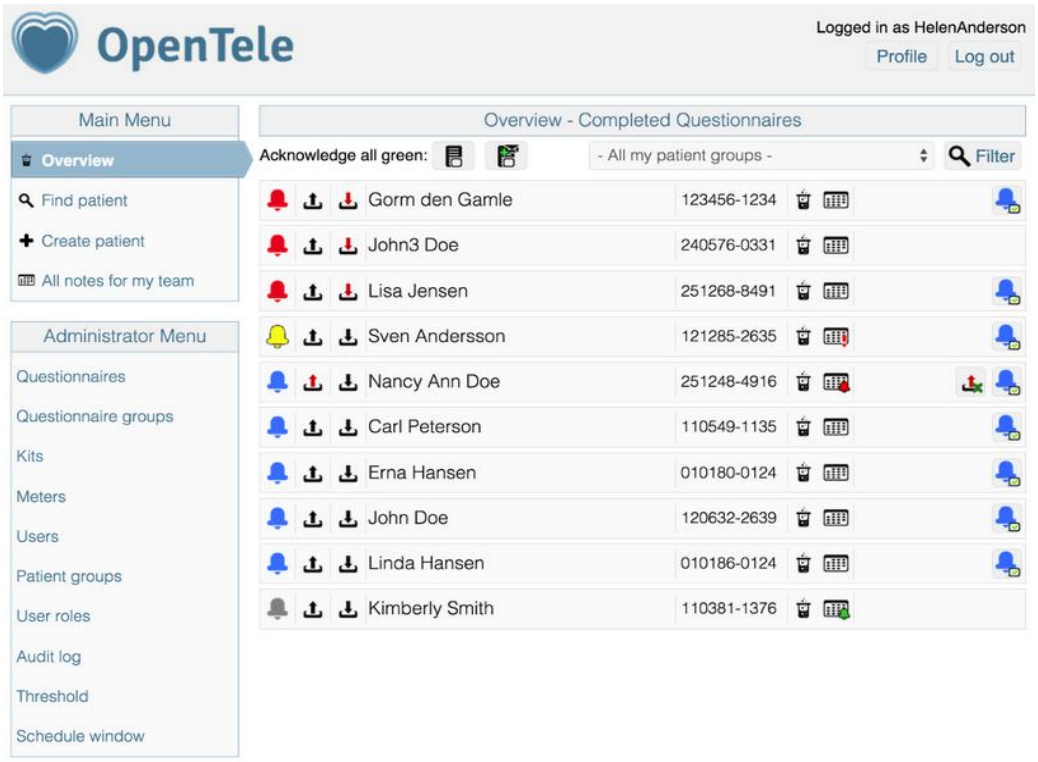


As it can be seen in the picture below, the user is asked simple and relevant questions regarding his treatment. The health care questions that have been provided to the user have been designed by health professionals.



A picture showing the clinician interface in action can be seen below. The clinician has the chance to communicate to the patient by a video call. The nurses have the chance to monitor the doctor directly from the clinic. It is not necessary for the client to go the clinic.





Functionality

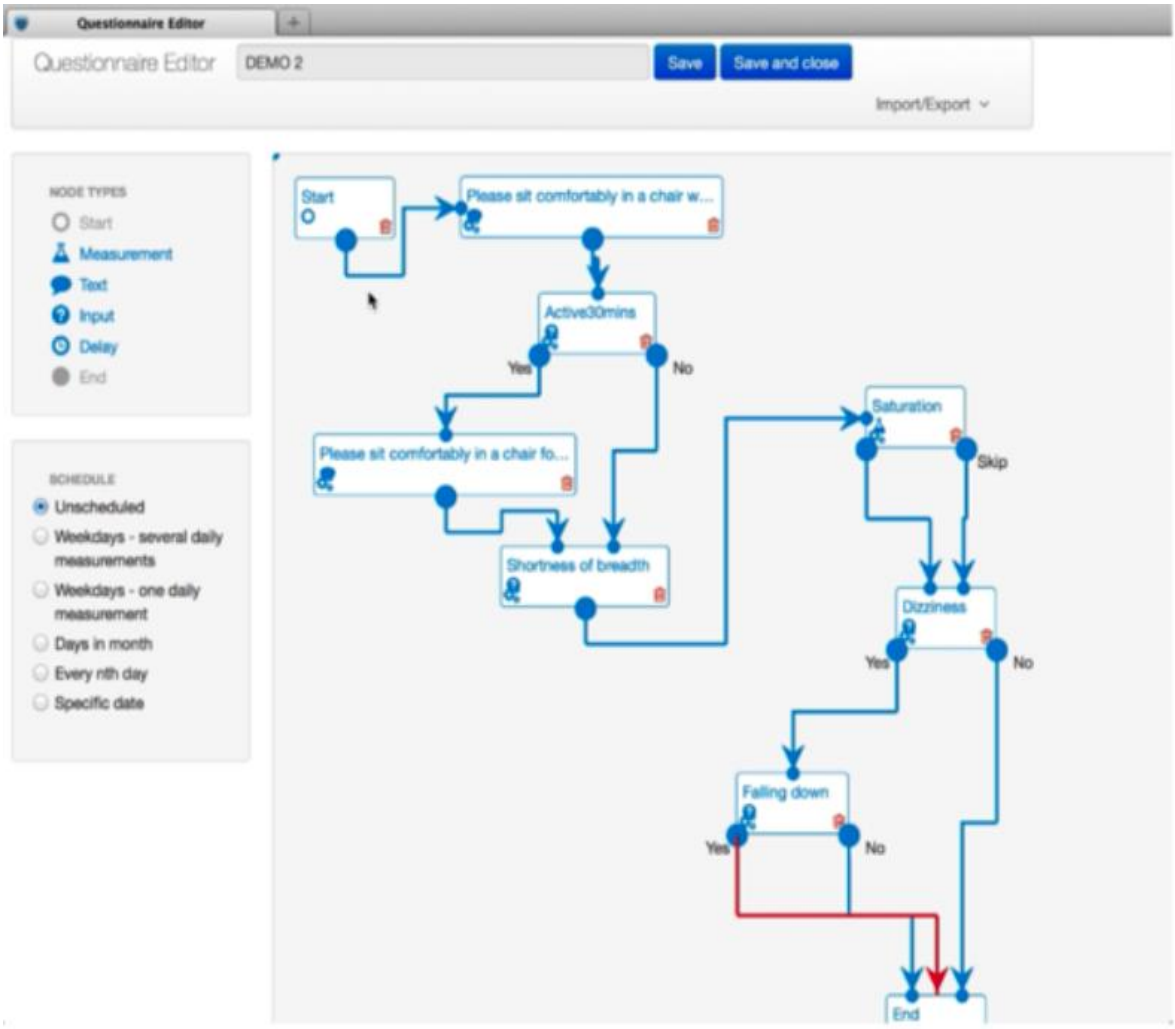
The main functionalities and services are offered by a user-friendly tablet application. Therefore, the app offers a range of different services:

- Provide the patient with instructions regarding the usage of every medical device and tablet
- Answer diagnose questions
- Monitor vital signs
- Start a video call with the nurses and doctors
- Send crucial data to the clinic immediately

Clinical Workflow

In order to keep the system focused and effective towards the client, a worfklow of questions regarding the patient need to be designed. OpenTele's doctors can design customizable workflows depending on patient's diseases. They are presented in the user-friendly patient's tablet app to carry out.

The clinical workflow includes questions and requests in order to make effective health measurements. More than one workflow can be carried out by the patient depending on his situation. Finally, the workflow change the flow depending on patient's responses. Complex workflows are created by the OpenTele's medical personnel, and they are delivered through the internet to the patient's tablet.



Devices

The mobile app installed on the tablet, connects to devices through Bluetooth, USB or the internet. The solutions fully supports a large list of devices covering a wide range of diseases that can be monitored from the clinic itself.

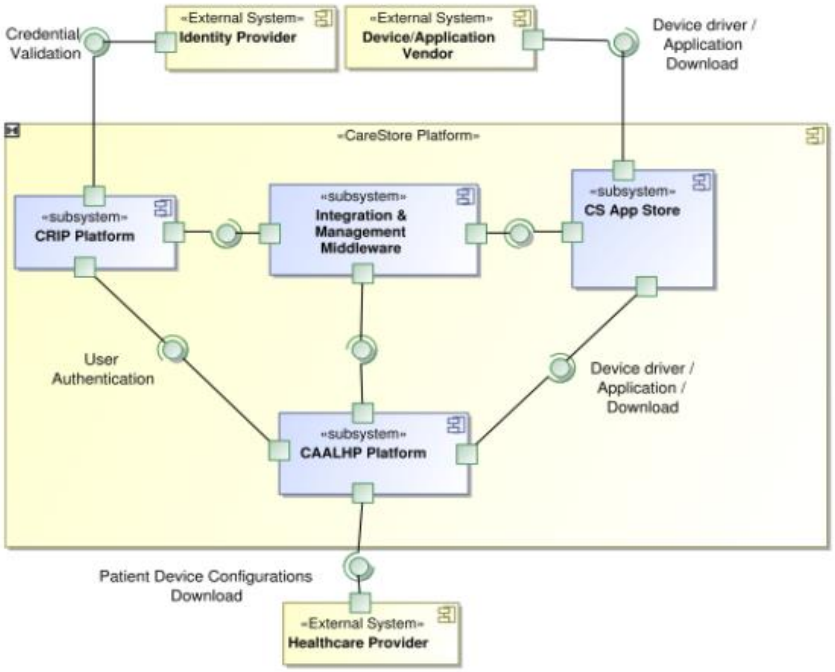
- Blood pressure gauges
- Pulse oximeter
- Weighing Scales
- Spirometers
- Blood glucose monitors
- Cardiotocography (CTG) devices
- Temperature probes

7.1.7 CareStore

CareStore is open source, based on OpenCare, that provides an online market directly available for costumers and clinics. CareStore assist care takers by offering them a new range of technologies and improved tools. It distributes and manage health care technologies, from the makers to the end users who can really benefit from low cost, high quality services and products.

Architecture

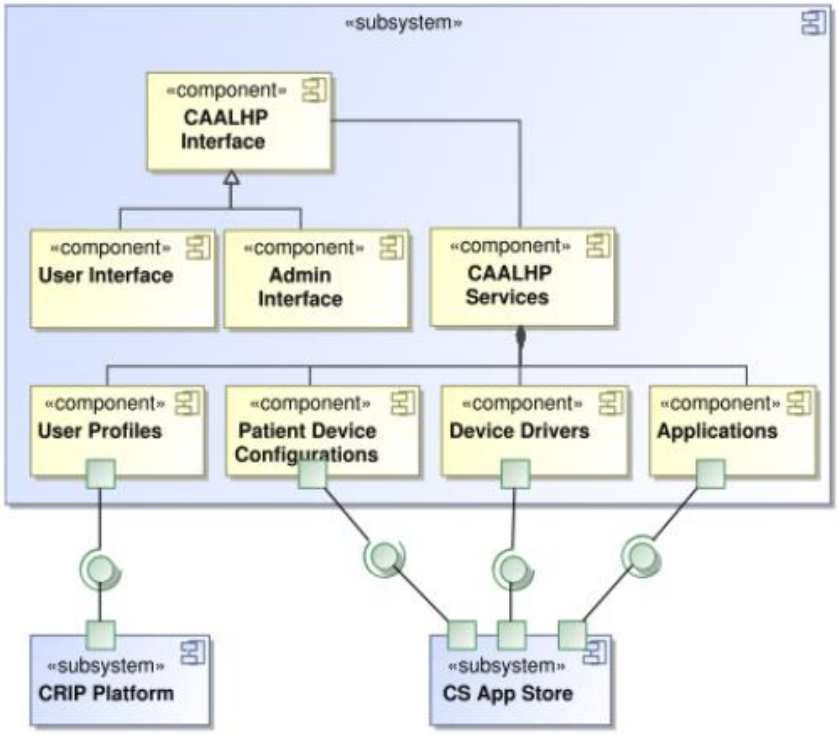
The high level system architecture of CareStore platform as a UML component diagram can be seen below



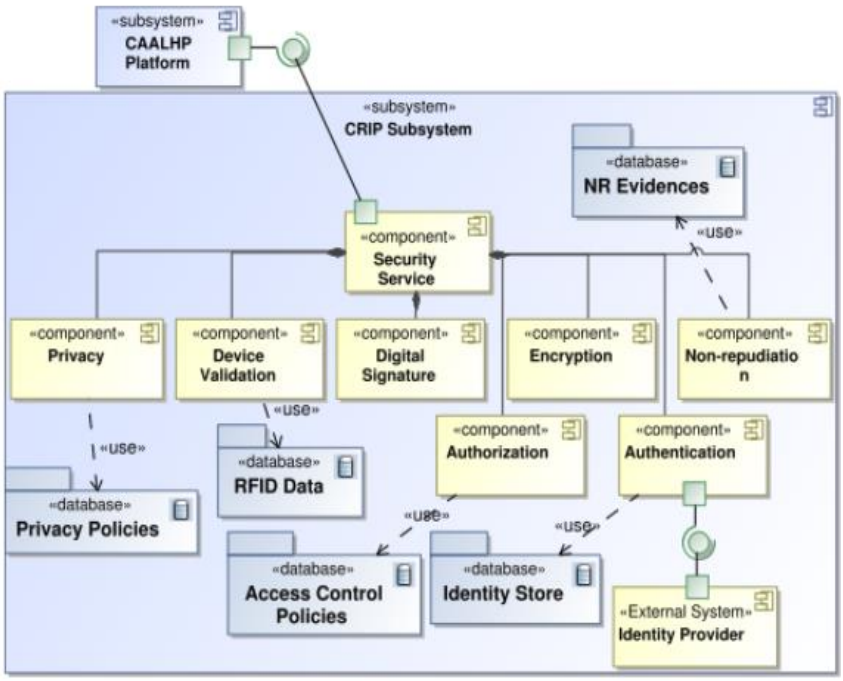
Therefore, a brief explanation of the subsystem is needed.

- CareStore AppStore: The respective register device and application vendors will upload their products at the online CareStore Appstore subsystem. It automatically downloads all the necessary applications or drivers needed by the device.

- CAALHP: Homecare platform. Consists of the core part of the platform, which offers Ambient Assisted Living services to the end-users and platform administrators. All the main functions like: ”add new device”, ”install health monitoring applications”, ”send vital signs”, ”update platform” and ”register users”



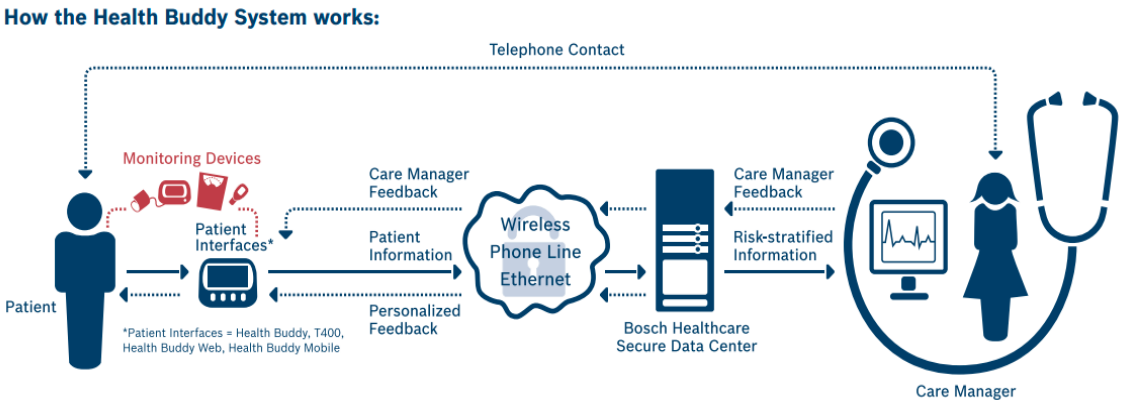
- CRIP: CRIP platform offers a set of security services required by the CareStore platform. Various algorithms are offered (AES,DES,DSS,MD5). It enables the user to identify oneself, whereas the authorization component validates user's roles.



Bosch Health Buddy System

Bosch Healthy Buddy System is an example of the numerous telemedical devices that exist nowadays. The BHBS is able to track patient's vital signs, symptoms. Besides, it informs the patient about his actual condition and engages the patient in ways to take care of himself in a better way, being responsible of his health.

Depending on the patient's medical/mental conditions, the device prompts to different questions, gathering different kinds of psychological and vital signs data, if required.



The Bosch Health Buddy System includes:

- Simple and easy-to-use interface
- Bluetooth communication with the continua Compliant Bosch WS3000 blood pressure medico device. BP5000 weight scale, and several other medico devices from third parties.
- National committee regarding Quality Assurance (NCQA) certified Health Management included
- Patient data is sent via integrated cellular modem or through external cellular modem , ethernet or phone line
- Support by the Bosch Healthcare Call Center if necessary.
- A web-based interface application is included (Health Buddy Desktop)

- A set of program in order to deal with post-acute, co-morbid or tri-morbid

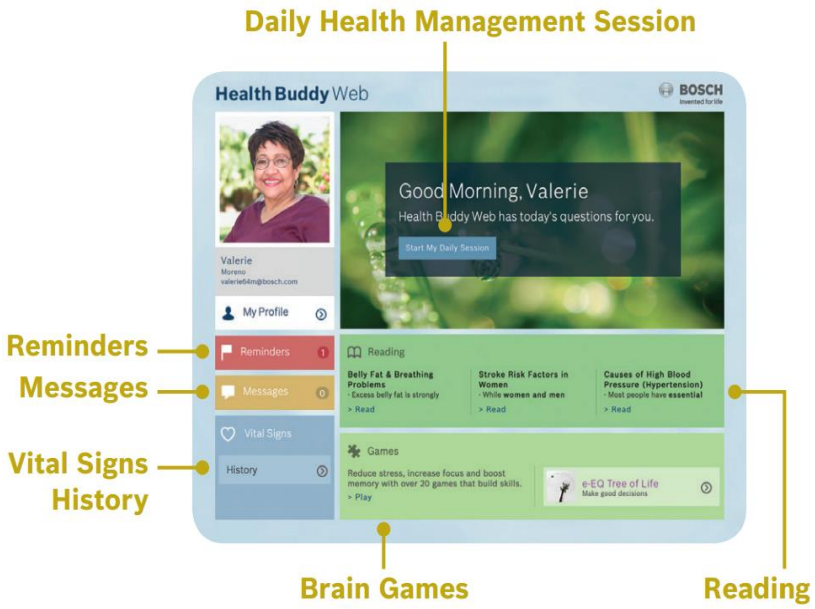
Health Buddy Web

The Health Buddy Web is a web-based application interface that is able to monitor the different Bosch healthcare devices. The core of the Health Buddy System are the Bosch Healthcare's certified end evidence-based health management programs and other tools that help patients engage in and to learn how to be responsible and take care of themselves.

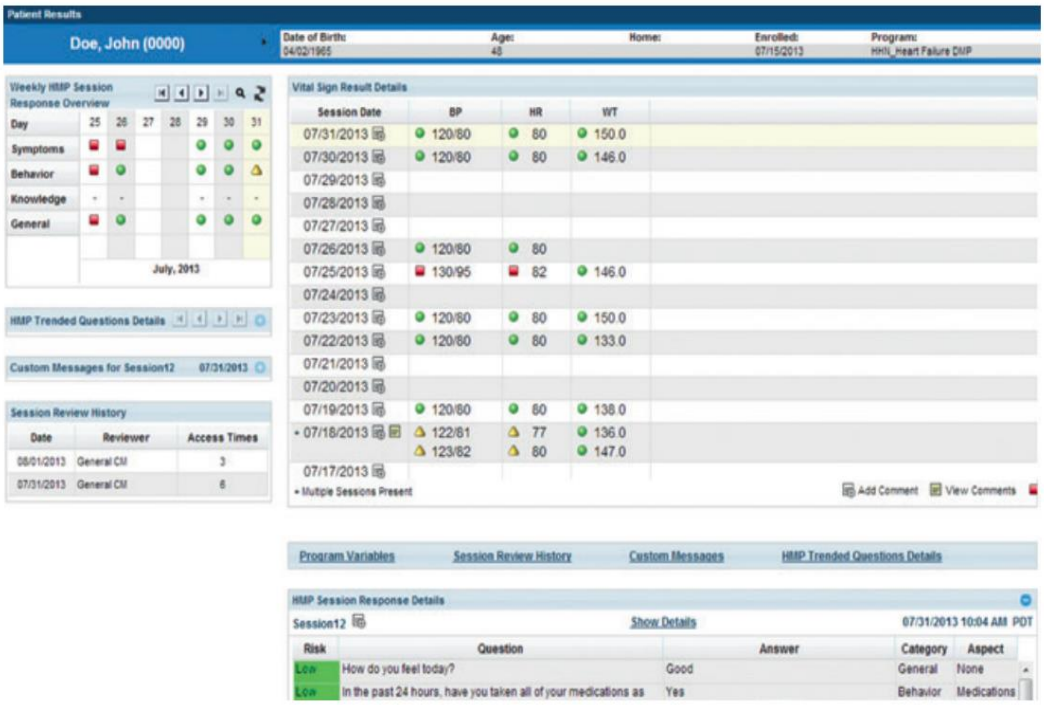
The features and benefits are listed below:

- Daily Health Management Session: Daily patient's sessions. The patient reports their vital signs, together with relevant physical, mental and health related behaviors, while learning more about their own condition. The care manager takes care of all the data sent by the patient
- Notifications: The patient receive relevant notifications from the care manager in order to properly monitor the end-user.
- Vitals Signs are properly saved on the databases, thus, they are always available
- Brain Games: The patient can play to different set of games that will improve patient's memory, reflexes, and in the overall, quality of life
- Expert-written educational articles: The patient is able to read articles related to general health, nutrition, exercise and more

The picture below shows a Health Buddy Web's screenshot, with annotations.



The next picture shows the patient's data in more detail. Therefore, the caretaker can monitor and control patient's information at the clinic station without needing to visit the patient physically.



Health Buddy Mobile

The Bosch healthcare mobile, is another solution released by Bosch. It pretends to offer another way of interacting with the patient. It does not need Wi-Fi connection in order to operate, thus the patient receives an sms, or a notification on the LCD screen, such as 'New Health Buddy Session'. Thus, the patient proceeds reading the notification, and answer the questions accordingly to the health care manager's criteria.

This solution is oriented to patients that used to be out of home. Therefore, patients that eventually need to go out are highly encouraged to use this solution. It is light and easy to be carried.

The features of this solution are listed below:

- Health Buddy vital sign collection and assessment question using data entry component and educational content supported
- Customized messages for the patient and delivery through Health Buddy Mobile supported
- Caretaker's calls, voice-mail and call history provided
- Outbound calls to 911 and professional and family caregiver provided
- Brain games to improve memory, focus and reflexes provided
- Camera with photo sharing among network contacts to improve connection and diminish loneliness

Bosch T400 Telehealth System

Bosch has released an alternative to the Health Buddy Mobile, a more advance touch screen based system. The Bosch T400 Teleheat consist of T400 touch screen device, web-based t400 Desktop application and 25 clinic content programs for a variety of single, co-morbid and tri-morbid medical conditions. It is used for patients that are post-discharged from the hospital and going on a transitional period.

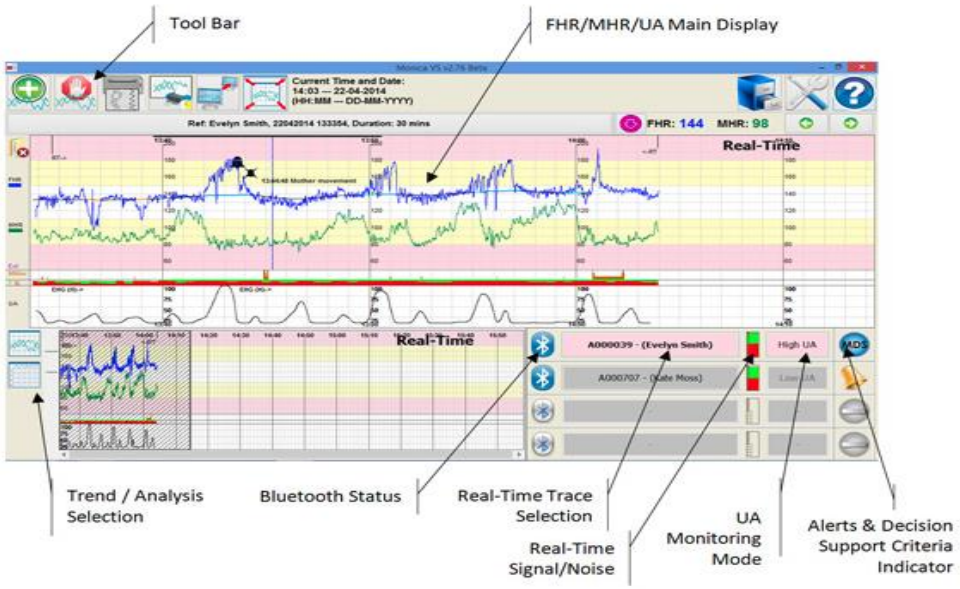
Every day the device requires the patient to introduce their vital signs into the t400. Like the Health Buddy Mobile, the device ask to the patient a set of questions. The answer will be sent directly to the care taker. The health carer reviews the data and send further responses if needed.

Besides, the t400 device is able to interconnect with other devices, and receive vital signs from them. Therefore, it is possible to transmit all the data, including data from other devices. The T400 can be connected via Wi-Fi or via cable.

Monica Healthcare System

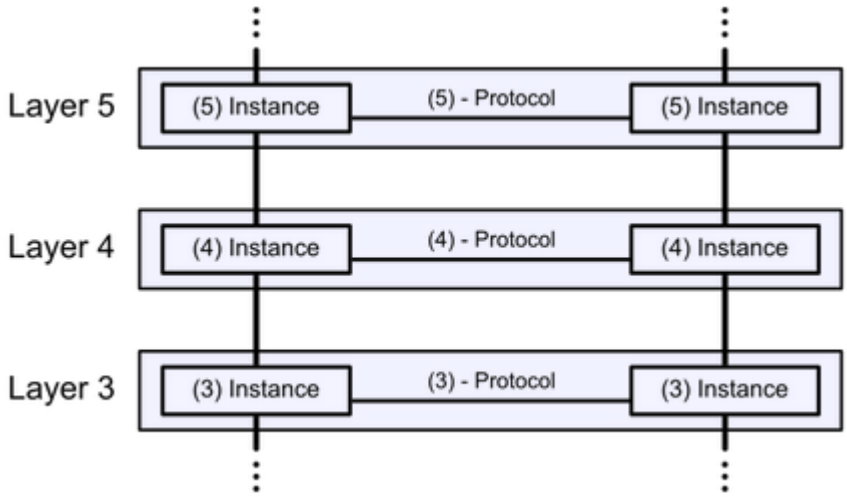
The Monica Healthcare System lightly differs from the other Bosch solutions. It is a dedicated clinic-based and dedicated home-based client device. It is a highly specialized system with poor patient's interaction. That means that the patient does not have a major impact regarding to take care by himself. Despite is possible for the user to have a minimum interaction with the device, it acts independently to the user, being able to monitor the user without he notice it at all. Therefore, we need to differentiate between self-caring patients and patients being remote monitored in different styles of home-use scenarios. Due to the limited usage scope, Monica Healthcare System can be considered to be a remote monitored device, with a similar user interface that OpenTele offers.

Monica Healthcare System is uniquely intended to be used in order to monitor pregnant women. On the figure below a data diagram showing the behavior of the data itself among other characteristics can be seen below



6.6 Technologies and Open Frameworks

Different protocols have been used in order to transmit data within nodes. There are different protocols regarding the different layers that are found in the Open Systems Interconnection model (OSI). There are 5 fundamental abstraction layers, without taking into consideration the session layer and the presentation layer, the rest are listed below, together with the main protocols that are used by each layer.



1. **Physical Layer :** Physical communication between two nodes. Raw data is sent through a channel, it can be sent through a cable or using the air. The main physical layer protocols are listed below:

- Ethernet: Often used with a TJ45 connector extendedly used by systems that cannot work wirelessly.

- Bluetooth: Wireless technology for exchanging data over short distances, in the band of 2.4Ghz, note that Wi-Fi and ZigBee operate on the same frequency band, what means that they are going to interfere with each other

- USB: Universal Serial Bus, version 2.0 can transfer data up to 400Mbit/s, while version 3.0 can reach 5Gbit/s

- RS-232: Serial communication, there are multiple kinds of connectors that can use serial communication, it is a well-known protocol, easy to use and to configure. It can transfer data up to 115200 bit/s

2. **Data Link layer:** This layer take care of the reliability of the raw data, and makes sure that is sent properly through the channel. Extensible Authentication Protocol (EAP) is an example of security protocol that can be used in this layer.

    - ARQ: Automatic Repeat Request, error control method for data transmissions, acknowledgements (ACK) are sent, retransmitting the data if the ACK is not received.

    - PPP: It used to establish a connection between two nodes, providing authentication and transmission encryption using ECP

    - IEEE 802.11x (Wi-Fi): Set of media access control (MAC) specifications in order to access the medium properly. Time Division Multiplexing Access (TDMA) and Frequency Division Multiplexing Access (FDMA) together (optional) with ACK protocol (ARQ), can be used in order to share the channel with other nodes. ISM band: 2.4Ghz

    - IEEE 802.15.4 (Zigbee): Different specifications than 802.11x make ZigBee a protocol used by low power devices. ZigBee uses the same frequency than Wi-Fi, therefore interference can be observed

3. **Network Layer:** Datagrams are sent generally to an IP address. One of the security protocols available regarding this layer is Internet Protocol Security (IPsec)

    - IPV4/IPV6: IP protocols have the task to deliver a datagrams from one host to another. They add the necessary addresses (header) and data.

    - ICMP: In order to avoid packages going around the network forever, the ICMP protocol makes sure that after 255 hops the package is dropped.

    - DDP: Datagram Delivery Protocol is a member of the AppleTalk networking protocol and procures socket to socket delivery of datagrams inside an AppleTalk network

4. **Transport Layer:** Provides end to end communication services. Transport Layer Security (TLS) is an instance of security protocol that can be used.

    - TCP: Transmission Control Protocol procures a reliable communication within applications by doing a handshake, therefore, datagrams between applications are not

lost. Specially a good option for applications that care about data reliability.

- UDP: User Datagram Protocol is a simple connectionless transmission model, unlike TCP it has no handshake. It suits applications where datagrams are not totally relevant, like some streaming application, where losing one datagram is not crucial.

- RDP: Reliable User Datagram Protocol, protocol simpler than TCP avoiding overhead, but more complex than UDP.

- DCCP: Datagram Congestion Control Protocol is similar than TCP, without providing reliability but offering much higher priority for the newest messages that have been sent. Streaming applications, and internet telephony are suitable candidates to be used here.

5. **Application Layer:** Top layer where all applications interact with each other, using for example address base connections: TC/IP. Secure Sockets Layer (SSL) can be used a security problem. [8]:

    - HTTP: Hypertext Transfer Protocol is an application to exchange hypertext. Http code is read and showed on the screen by browsers.

    - FTP: File Transfer Protocol is used over a TCP based-network in order to exchange files between applications.

    - DNS: Domain Name Service it is the responsible of turning an IP number into a readable name. It distributes all the domain names all over the Internet.

    - SSH: Secure Shell is an encrypted protocol that enables the user to establish a secure channel over an insecure network. The user is able to log in to other server/pc from his own computer. Therefore, the user can use the terminal in order to execute commands in the other terminal. It is basically used in Unix-like operating systems.

6.6.1 Reaction Platform

The Reaction platform, which was developed as an integrated ICT platform provides integrated care plan to diabetes patients in different healthcare regions across Europe. The platform offers both loge-term and short-term management of diabetes episode through professional decision support for both in-hospital and primary care. The platform enable diabetes patients to have a better overview over their physiological values as well as lifestyle changes (diet + physical activity). LinkSmart middleware incorporates support for self-discovery of devices such as BAN or PAN (Figure 11).

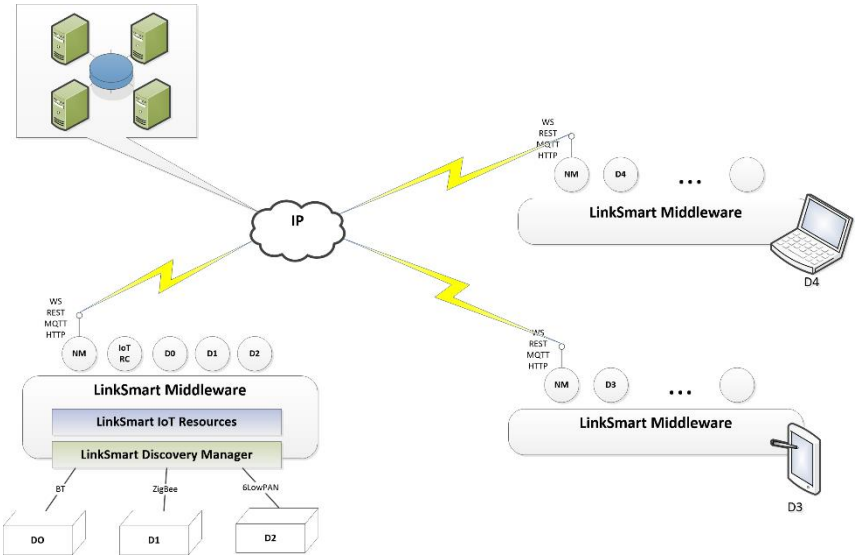


Figure 12: Incorporation of devices, sensors by Hydra middleware

7.2.2 Link Smart Open Source Middleware[39]

The LinkSmart middleware was initially developed by the European project Hydra. This was a 4-year integrated project in FP6. The LinkSmart middleware allows developers to incorporate heterogeneous devices and services into their applications by offering easy-to-use web service interfaces for controlling any type of physical device irrespective of its network technology such as Bluetooth, ZigBee, RFID, Wi-Fi, Ant+ etc. Developer tools with device/resource catalogues and REST APIs are supported. LinkSmart incorporates means for secure peer-to-peer (P2P) communication, device and service discovery, event processing and service orchestration. The service-oriented architecture (SOA) applies to both the implementation of the middleware managers themselves and for the higher-level device interfaces in the form of software proxies. The system behind LinkSmart is implemented on the main IDEs, .NET and Eclipse. (Figure 7)

Linksmart.net has a gateway functionality that integrates with Internet of Things applications. It allows connecting of the physical world to the technical worldand enables communication among applications under fully observations and control of subjects.

The main functions of Linksmart.net are tailed as:

- Model representation of objects and their relations in physical world
- Sorting out of request from physical world to software objects
- Dynamic and automatic discovery mechanism of Resources and Services
- Processing and detection of events
- BigData management and scalability

[39] http://www.ebbits-project.eu

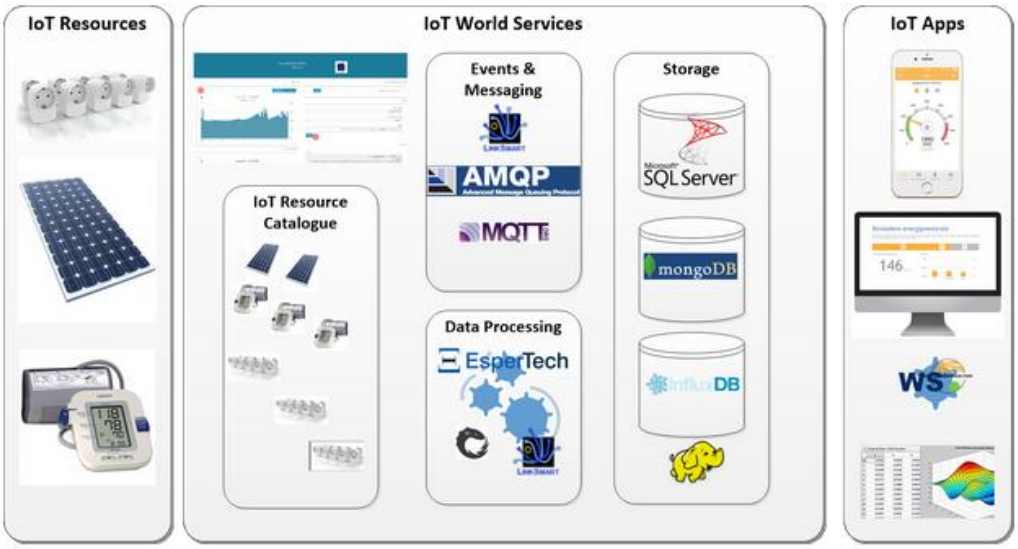


Figure 13: Medical device connectivity interface based on LinkSmart

In addition, LinkSmart.net allows of configuration and administration of variety of tools and developments software kits from IoT world. It facilitate means to detect and act on events from physical world into the software environments in a very flexible way with fully ability of programming as Open Source dose (see Figure 13).

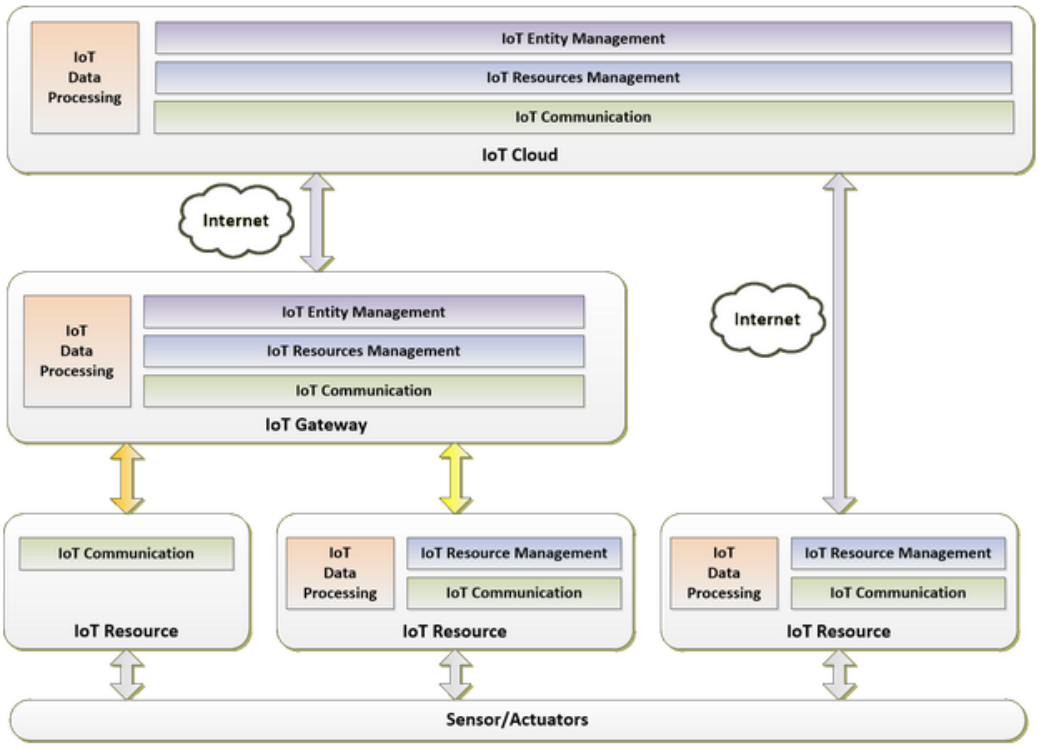


Figure 14: LinkSmart.net gateway & mechanism

7.2.3 Open EHR

The Specifications Program defines the formal models and languages defining Open EHR data, Open EHR content models (archetypes and templates) and Open EHR services and APIs. These specifications are published and used in their own right and underpin the Clinical Modelling Program (for which they provide the language of archetypes) and the Software Program (for which they provide schemas and interface definitions for software).

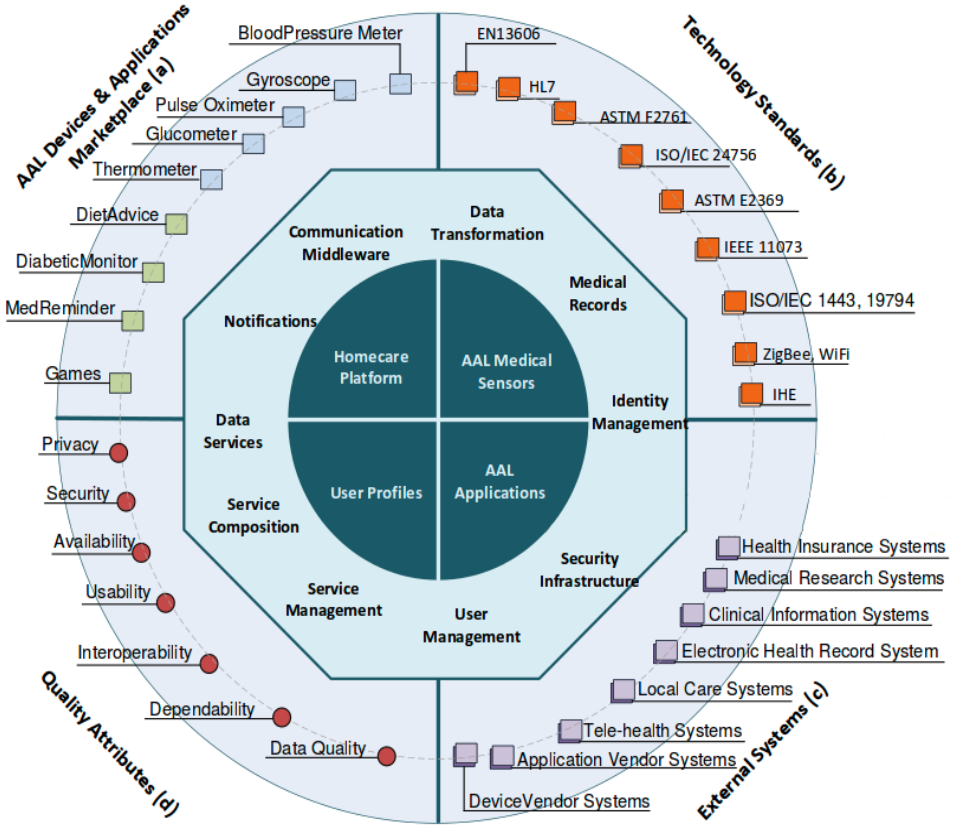
The goals of the Specification Program include:

- quality in health information: to enable data quality, validity, reliability, consistency and currency of clinical data across the data lifecycle from creation to archival, and across enterprises and sectors;
- support for current technology: to actively support widely used ICT technologies e.g. major programming languages and frameworks;
- de jure standards connections: to provide means for the specifications to be useful to users of related de jure standards, e.g. by providing additional transformation or mapping specifications and/or implementation guides;
- Manage impact of change: to ensure the preservation of validity of clinical data created according to previous releases of the Open EHR specifications.

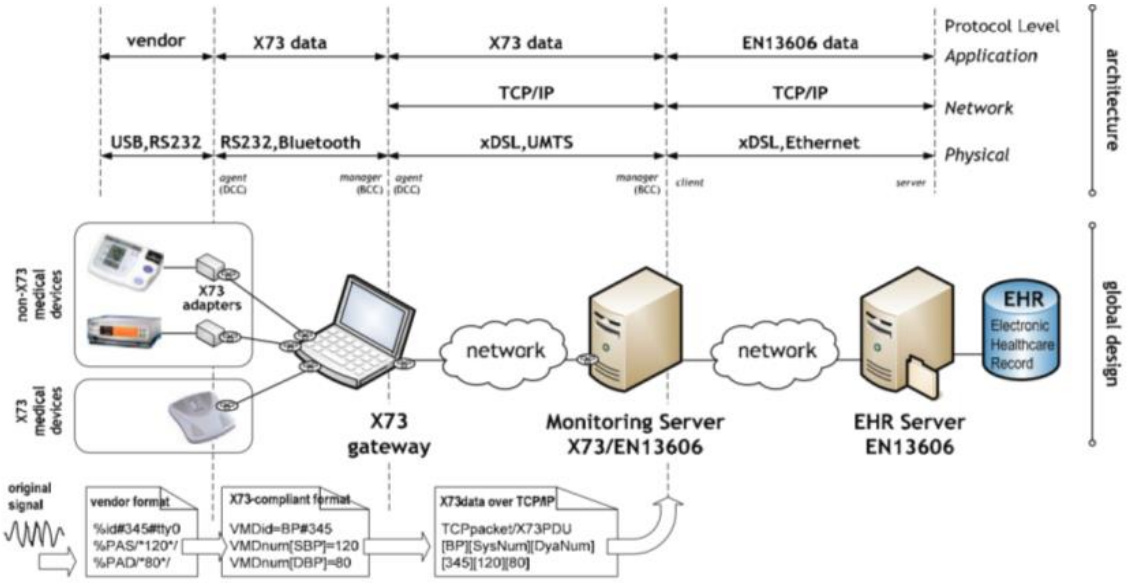
7.3 Standards

Integration, interoperability, and scalability in ambient assisted living platform are not achievable without using the proper technologies standards and specifications.

The picture below shows an example of an OpenSource framework for Ambient Assisted Living environments. Note that technology standards, AAL Devices, Applications Marketplace and Quality attributes are highly related and must get along with. AAL cannot be understood without all these subsystems. Therefore, all professional health care givers are highly encouraged to know what kind of technology standards are available on Ambient Assisted Living environments. Data exchanged between user interfaces and clinical interfaces is extremely related to technology standards. This section pretends to describe the main technology standards and specifications.



The next picture shows a typical scenario where multiple technology standards are used. In the following, we describe the most important technology standards.



- **CEN/ISO EN13606:** The CEN/ISO EN 13606 is a European Committee standardization (CEN) that is approved as international ISO standard. The main objective of this standard is to achieve interoperability in health record communications. This standard defines a rigorous and stable information architecture for communicating part or all of the electronic health record

(EHR) of a single subject of care (patient) between EHR systems, or between EHR and data repository systems and also clinical applications as well as middleware components. However, ISO 13120:2013 is formally represents the content and hierarchical structure of healthcare of data and structure between organizations and dissimilar software products. The main objective of health care classification system in ISO 13120:2013 is to encompass terminologies and traditional paper-based systems like ICD-10.

- **Health Level-7 (HL7):** International set of standards to transfer clinical and administrative data between software applications used by various healthcare providers.

- **American Society for Testing and Materials (ASTM):** The ASTM family standard organization, develops and publishes voluntary consensus of numerous materials.

- **ISO/IEC 24756:** Defines a framework in order to specify a Common Access Profile (CAP) of needs and capabilities of users, computing systems and their environments, being suitable for AAL.

- **IEEE 11073:** Medial and Health device communication standards in order to communicate between medical and healthcare wellness devices including external computer systems. This protocol enables the medical devices to communicate within them including a personal computer

- **ZigBee :** 802.15.4 is used for a wireless devices to create personal area networks (PAN) with small, low power antennas, within the range of 2.4Ghz

- **Wi-Fi :** Local area wireless computer networking. Different protocol than ZigBee. Wi-Fi is not intended to be used by low power devices. Wi-Fi operates within 2.4Ghz and 5Ghz.

- **Integrating the Healthcare Enterprise (IHE):** Nonprofit organization placed in the US, established by a consortium of IT experts. It has been designed in order to facilitate the way computer systems share information, specially based on the healthcare industry. IHE is an initiative by healthcare professionals and industry to improve the way computer systems in healthcare share information. IHE promotes the coordinated use of established standards such as DICOM and HL7 to address specific clinical needs in support of optimal patient care. Systems developed in accordance with IHE communicate with one another better, are easier to implement, and enable care providers to use information more effectively.

7.4 Summary and Conclusions

To summarize, a whole range of systems and frameworks for reporting to health and care professionals exist. These include commercial products as well as academic frameworks and projects. A common feature is the lack of openness and adaptability of many of these products, which is a major concern for the CAMI project and related projects. Furthermore, not much evidence exists of the relevance, efficiency and efficacy of these, and no independent studies have compared these products or provided a relevant feature matrix and taxonomy. Thus, we conclude that there is no golden standard within the “reporting to health and care professionals”, but that we should rather go for open source products, which allows for an adaptable design, and a high degree of openness and flexibility in terms of communication of events and measurements, such as falls, night wandering, leaving the home, medical data, blood pressure, weight, saturation, glucose, and similar data types. Also, the products should support communication to both formal and informal care givers, in order to avoid

having too many platforms. Furthermore, CAMI should focus on using framework that support relevant industry standards and avoid proprietary solutions.

In terms of the CAMI project, we believe that open source projects should be favored, preferably those who has proven themselves in terms of real world usage. In Denmark, OpenTele and OpenCare has been used with more than 5000 patients and/or citizens in real life commercial projects, and supports many of the features that the CAMI product is looking for. As both projects are open source and based on open standards, this fits perfect with the overall CAMI strategy. However, it may be necessary to adapt these products to fit the requirements of CAMI, and after this, the entire product must be CE certified for medical use. Finally, OpenEHR will be used for inspiration, along with the open HL7 FHIR, and IEEE/ISO 11073 protocols for data communication of healthcare data.

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8 Supervised physical exercises

Mobility problems are very common for elderly people and lead to reduced quality of life and limitations in everyday activities and social participation. Game-based technologies, social play, personalization and persuasive technologies can motivate the elderly to perform exercises that are beneficial to them.

A new way to use video games is to include them in training, education and learning. This is called serious games. Serious games can be described as ”a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives” (Zyda, 2005). An important feature with serious games is that they provide the opportunity to experience in real-life situations and adventures one may otherwise not be able to enjoy. Exergames are a type of serious video games that combine traditional game play with physical activity. The combination of movement and amusement is used to stimulate exercise and engage people to be more physically active in a fun and motivating way. A lot of research has been done within this topic, and results show that exergames can have a positive effect on users health (Williams, Soiza, Jenkinson & Stewart, 2010), (Garcia, Felix, Schoene, Smith & Pisan, 2012), (Taylor, McCormick, Impson, Shawis & Griffin, 2011).

(Billis, Konstantinidis, Mouzakidis, Tsolaki, Pappas & Bamidis, 2010) discuss important issues that need to be taken into account when developing games for elderly. Elderly often suffer from decline in visual acuity, decreased audition, mobility changes and cognitive functions’ decline. In addition, many elderly are not familiar with technology. The writers suggest that it should be possible to customise the game for every player’s special needs. Font, size and colour should be adjustable, and information should be provided in different multimedia alternatives, like text, voice and images. The objects should be of sufficient size and the elements should not move too fast. The overall interface should be as simple as possible, without the need to remember information given earlier in the gaming process, and it should be given sufficient information and guidance throughout the whole game. Games should also provide motivating messages to encourage the player. At last, for the players to get interested and engaged in the game, they suggest that the content of the game should match the users’ cultural and lifestyle diversity.

8.1 Existing market solutions

A study performed in the AAL Project Join-In (Fraile, Browne, Brox & Evertsen, 2012) concluded that although it is not perfect, the Microsoft Kinect is the most suitable device for exergames for elderly. This is also the best tool to capture the movements properly and thus ensuring that exercises are performed correctly.

The Kinect sensor (https://dev.windows.com/en-us/kinect/hardware) incorporates several advanced sensing hardware. Most notably, it contains a depth sensor, a color camera, and a four-microphone array that provide full-body 3D motion capture, facial recognition, and voice recognition capabilities. It’s price is 150 $.

The amount of activity performed daily by the users will be monitored by using specific wearable devices and will be correlated with the supervised physical exercises proposed by the CAMI platform. We will consider integration of activity trackers which offer also the clip-on version which we find more suitable for older adults and elderly people which, according to the personal experience of the consortium partners, are reluctant of wearing continuously a bracelet type of device.

The identified devices which will be considered for the CAMI platform are:

- Fitbit zip and one (https://www.fitbit.com/);
- Jawbone UP Move (https://jawbone.com/store/buy/upmove);
- Fitbug ORB (https://www.fitbug.com/g/orb); Samsung Health Activity Tracker (http://www.samsung.com/us/mobile/cell-phones-accessories/EI-AN900AZESTA);
- Activity Tracker Medisana ViFit (http://www.medisana.com/en/Sport/Activity-Tracker/ViFit-Activity-Tracker.html).

In addition to the wearability issue mentioned above, further selection criteria were price and availability. Below we outline some of the key features of the devices. Further research into their integration will be part of the WP2.

Fitbit one

The pros of the Fitbit One are that it offers an intuitive way to track and analyze your sleep, the steps you take, stairs climbed, and calories burned. It is small and light, and thus very portable. Its OLED screen, which has a clock, is easy to read, a feature which is important for older users. It sends data to phones over Bluetooth.

The cons are that the clip often comes loose and that the function only works with a few compatible handsets.

Fitbit zip

The pros of the Fitbit Zip are that it tracks steps, calories, and synchronizes with PCs and smartphones. It's affordable, water resistant, and links to Fitbit's powerful fitness analysis tools in the cloud. It is considered the best fitness tracker under 60 $.

The cons are that it can't measure sleep; lacks a rechargeable battery; Android compatibility is limited to Samsung Galaxy phones.

Jawbone UP Move

The pros are that it is an affordable step and sleep tracker that can be worn on your wrist or as a clip-on; synchronizes wirelessly with iOS or Android; LED display shows daily goal progress; replaceable battery lasts for months. The Jawbone Up fitness app is the best, most well-connected ecosystem around.

The cons are that it is said to have an ugly design and can't be worn in the shower or while swimming. The wristband is sold separately, and it lacks the vibration alarm of more expensive Up bands.

Fitbug Orb

The pros of the Fitbug Orb are that it is extremely affordable at 50 $. It counts steps, calories, and synchronizes data wirelessly to phones. The fitness tracker is also light, comfortable, and stays put on your wrist. You can also wear the Orb on a bundled clip.

The cons are that the Fitbug Orb lacks a display, is complicated to set up, and its button is small and hard to press. You can't use the Orb's mobile app to log meals, and it has limited Android compatibility. Sleep mode is tricky to engage, and wireless PC syncing costs extra. For $10 more, the Fitbit Zip has more features, is easier to use, and is ultimately a better choice for the CAMI users.

Samsung Health Activity Tracker

The pros are that the Gear Fit has a forward-looking design, many more extras than the average fitness band, and the ability to measure heart rate. Its curved AMOLED display looks fantastic, too. It can be used as a clip-on or wrist watch.

The cons are that the long display makes text reading awkwardly. The Fit only works with certain Samsung phones. Can't load apps and the price is high.

The pros are that it is elegant, small and very affordable at below 40 $. Measures steps, burned calories, distance and also displays percentage of target value, reached sleep mode, time, date and remaining power. The display is easy to read. It synchronizes with the Medisana Vita-Cloud using a USB-cable adapter (included).

The cons are that is compatible with only Medisana app, needs a cable for data upload, is not waterproof.

8.2 Technologies and Open Frameworks

Kinect was used at Royal Berkshire Hospital in Reading, England (Crum, 2011) - stroke patients played different Kinect games, including Kinectimals. The doctors observed an improvement occurring, rather than the normal stretching and pulling a physiotherapist would do to the patient, in case of patients who had lost their arm movement. Other patients who had problems with full-body movement and standing up played Bowling. They were able to work on coordination between the twisting of his body and the movement of their hands, plus their eyes had to look at the screen rather than where their hands were.

Another example, Microsoft has combined two of its technologies, Kinect and the HealthVault online platform (https://msdn.microsoft.com/en-us/healthvault/) - a trusted place for people to gather, store, use, and share health information online, to help seniors take better care of themselves at Los Angeles senior centers (Terry, 2012). Following a successful pilot by Microsoft, the Los Angeles Department of Aging, Partners in Care Foundation and St. Barnabas Senior Services, the Exergamers Wellness Club, as the project is known, is being expanded to all of the 16 senior centers in the Los Angeles Department of Aging's service area. The 34 seniors in the Wellness Club pilot are using Kinect to make exercise more fun. For example, they play virtual bowling games with people at other sites in Los Angeles and New York, and they can dance along with Kinect hip hop, salsa and disco workout programs.

Some examples of wellbeing and motivational applications and games for healthcare based on Kinect and/or other sensors are given bellow:

- **Jewel Mine** (Jewel Mine Project, 2010) is a rehabilitation therapy tool customized to overcome health issues. Jewel Mine was created using the Microsoft Kinect for Windows SDK and is part of a series of game-based research prototypes using off-the-shelf video game hardware to explore the potential of interactive games to improve therapy in home and clinical settings. Video game systems are increasingly being used for rehabilitation. However, games designed for entertainment do not always meet clinical needs. They can be too challenging for people with impairments to complete or they can encourage the wrong type of movements. Negative feedback often discourages patients from trying to complete tasks. Jewel Mine is a rehabilitation therapy tool customized to overcome these issues. Developed at the Game Based Rehab Lab, part of the MedVR Group (http://medvr.ict.usc.edu/research/) at University of Southern California Institute for Creative Technologies (ICT), this video game-based application targets balance training and upper limb reaching exercises and is designed to motivate people with orthopedic and neurological injury or impairments, including stroke, traumatic brain injury, spinal cord injury and balance issues associated with aging.

- **GameUP**, developed in the AAL project GameUP (GameUp project, 2011) (call 4) sustains mobility of seniors over 65 years for the advancement of older persons'

mobility (Hasselmann, Oesch, Fernandez-Luque & Bachmann, 2015). The GameUp project created seven mini exergames training mobility, strength, and balance on Kinect for Windows and a mobility tracker from the company Fitbit is also used for promoting endurance. Kinect enables users to control and interact with their screen without using a gamepad, but simply with an easy interface using gestures and spoken commands. Thus, playing freely without being bonded to traditional gamepads makes the game console user-friendly and more suitable for older persons. **Fitbit**, with its integrated altimeter and tri-axial accelerometer accurately captures all daily activities. It tracks the number of steps taken, stairs climbed, distance traveled and calories burned every day. It's low weight and small size, and it can easily and discreetly be attached to clothing. The aim of this tracker is to empower and encourage the patient, by delivering real-time feedback that helps him/her be more active. The exergames consist of 7 mini-games, including balance, mobility, and strengthening exercises:

- *Exercise 1* called "plucking game" is a strengthening exercise for abductor muscles. The patient has to spread apart one leg on the side. *Exercise 2* "apple-picking game", *exercise 4* "chicken-picking game" and *exercise 7* "star-picking game" are balance exercises where the patient has to catch the falling objects and put them in the correct receptacle. These three balance exercises are based on the same training principle where the patient has to move sideways.
- *Exercise 3* called "growing game" is a strengthening exercise for the calf muscles. The patient has to stand on his toes to water the flower. *Exercise 5* called "harvesting game" is a strengthening and mobility exercise for the trunk. It trains the torso rotation. The patient has to rotate his trunk in order to cut the corn with the scythe. *Exercise 6* called "pumping game" is a strengthening exercise for quadriceps muscles where the patient has to perform squats in order to pump water into a glass.

- **Evergreen Fitness System** (Fang, Sheu, Lin, Lee & Chen, 2015) is a game-based prototype developed to train older adult's balance, especially lower limb strength by exercises (knee marching, side hip raise, lunges, partial squats, wide squats and standing knee flexion). The system is based on the Kinect sensor, gestures are used to select the menu while body motions are required as part of the exercises. Immediate feedback, such as smiling face, ding sound and entertaining background music is provided to increase interaction. Six exercises are designe for improving balance:
  - *Exercise 1* (knee marching): strengthen ankles and hips; improve dynamic or moving balance.
  - *Exercise 2* (side hip raise): strengthen side hip muscles; maintain lower body endurance to better walk and side step around objects
  - *Exercise 3* (lunges): strengthen quadriceps and hips; improve the ability to get out of a chair and balance
  - *Exercise 4* (partial squats) and Exercise 5 (wide squats):: increase hip flexibility, quadriceps strength and hip flexor strength: steady body for better balance and safety
  - *Exercise 6* (standing knee flexion): strengthen hamstring muscles; help with standing balance

  The game was designed in two phases. The first phase delivers interactive video-based exercises for training balance and the second one elicits optimal exercise through gameplay.

- **Hammer and Planks** (Loreto, Lange, Seilles, Andary & Dyce, 2013) is a therapeutic game for hemiplegic rehabilitation, to train patients' equilibrium. The player moves from right to

left and front to back to control a boat. This task-centered training allows a person under rehabilitation to focus on the main goal, not on what he is doing.

- **Out in nature** (Nawaz, Waerstad, Omholt, Helbostad, Vereijken, Skjæret & Kristiansen, 2014) is a simplified exergame concept for senior citizens, which focuses on physical activity in general, and balance and muscle strength in particular. The game is designed for elderly people, around 70 years old and was created based on the seniors' feedback. Users can choose exercises according to different muscle groups and balance challenges, and then, a specific exercise is chosen depending on their own preference or the recommendation from their physiotherapists. The design of the exergame shows clear goals for training muscle strength and balance. One of the exercise is focused on balance and muscle strength, where the task is to pick apples. This activity requires players to stretch their body to reach ripe apples (balance) and put them in a basket on the ground.

- **SimBODY** (Vidal, Pereira, & Santos, 2013) is an interactive simulator that allows the users to control the behaviors of an avatar. It educates people on how to mitigate the risk of cardiovascular diseases and it offers contextualized lifestyle advices and depicts the progression of atherosclerosis.

- **NeuroRacer** (Abbott, 2013) is designed and implemented at University of California, San Francisco. It is a three-dimensional video game in which players steer a car along a winding, hilly road with their left thumb, while keeping an eye out for signs that randomly pop up. If the sign is a particular shape and colour, players have to shoot it down using a finger on their right hand. This multitasking exercise, draws on a mix of cognitive skills just as real life does — such as attention focusing, task switching and working memory.

- **Flowie** is a game with a virtual coach that encourages seniors to walk more. It is part of the Independent@Home Project (Independent@Home Project, 2011). In order to incorporate the user values and needs in the design concept, a user panel of elderly people is actively involved in the design process. The technology used is a pedometer with wireless connectivity with a touch-screen photo frame.

- **Gesture based games designed for healthy older adults** (Rice, Wan, Foo, Ng, Wai, Kwok, Lee, & Teo, 2011) designed for a large projection screen display, these games employ vision-based techniques that center on physical embodied interaction using a graphical silhouette. Infrared detection, accompanied by back-projection is used to reduce the effects of occluded body movements. User evaluations with 36 older adults were analyzed using a combination of pre- and postgame questionnaires, direct observations and semi-structured group interviews. The results demonstrate that while all the games were usable, they varied in their physical and social engagement, perceived ease of use and perceived usefulness. In particular, items associated with physical wellbeing were rated highly. system uses infrared light that is invisible to the human eye, but detectable with an infrared camera to capture a player's silhouette. As a mode of interaction, the use of silhouettes for gaming introduces limitations on ambient lighting conditions. That is, brighter light causes washed out shadows, whilst dimmer lighting conditions introduces occlusion to a significant portion of the display. The

three prototype games are described as Virtual Soccer, Human Tetris and Mosquito Invasion. Virtual Soccer requires a succession of upper and lower body movements to control a bouncing ball, while Human Tetris involved a number of stretching exercises to fit through a series of moving shapes. In both cases, the silhouette feature was employed. Alternatively, Mosquito Invasion incorporated an onscreen moving target to be used in conjunction with a physical fly swatter.

- *Virtual Soccer:* situated in a virtual stadium, the player has to use their upper and lower body to keep a football bouncing in the air and prevent it from touching the ground. This can be done by kicking, twisting or lifting their arms, shoulders, or heading the ball.
- *Human Tetris*: adapted from a popular Japanese game, a hollow Tetris-style shape prospectively moves towards the player. The objective is to successfully fit within the moving shape and avoid touching the sides. The task requires the player to bend and stretch into different body positions. During the gameplay, shapes progressively get more difficult, and navigational cues in the form of on-screen arrows indicate when the player is out of alignment.
- *Mosquito Invasion*: to protect a crawling baby from being stung by a swarm of mosquitoes, the player has to eliminate them with a fly swatter. This is done by physically swatting the insects on screen. During the game, mosquitoes hide behind household objects to avoid detection, as they randomly move in speed.

8.3 Standards

Several standards are relevant for the proposed technologies. These include health, communication, networks, user interfaces, data protection, etc. Below we mention some selected and most relevant ones.

ISO/IEEE 11073: Health informatics – Personal health device communication. This standards family defines an application protocol for networking vital sign sensor devices using USB and Bluetooth among others. But in practice, up to now the individual device vendors use their own proprietary interfaces. Some parts of this standards series are also available as DIN EN ISO 11073.

For an information system to be used, it must be easy and straightforward to operate. This property is defined as “usability. The ISO/IEC 9126 Software engineering - product quality standard refers to the quality of whole software products. Usability is part of this standard and is supplemented by understandability, learnability, attractiveness and conformity. The ISO/IEC 12119 describes quality requirements and testing. This standard also stipulates criteria for the quality of software. It does not address usability directly, but demands reliability and usefulness (learnability).

ISO/IEC Guide 71 Guidelines for standards developers to address the needs of older persons and persons with disabilities. This document provides guidelines for designing accessible systems for older persons and persons with special needs. It helps to improve the general situation of the elderly and the disabled. The intention is not just to inform developers but to support authors of specifications in this field. ISO/IEC Guide 71 is available as European guidelines in English and German.

Machine-to-Machine is a newly developed ETSI specification that stands for the automated exchange of information between machines. It describes generally useful M2M functions such as security, data transmission, boot strapping and an application programming interface for services. The API permits communication between individual M2M components (such as sensors and actuators), M2M gateways and service platforms. Systems and machines should exchange data in a completely automated process without human interaction. M2M abstracts from the basic LAN and WAN technology. ETSI-M2M was developed on the basis of requirements from a number of use-case documents. Relevant examples in the AAL context are “eHealth” (TR 102 732) and “Connected Consumer” (TR 102 857).

Various ISO/IEC working groups (as in JTC1/SC27/WG5) are currently working on international specifications for data protection:

- ISO/IEC FDIS 29100: Privacy framework (definition of privacy requirements in processing personal data in the information systems of all countries),
- ISO/IEC CD 29101: Privacy reference architecture (best practices for consistent technical implementation of privacy principles),
- ISO/IEC WD 24760: Framework for identity management (framework for secure, reliable privacy conformity management of identity information),
- The use and disclosure of security and risk management standards and specifications is also important. The ISO/IEC 2700 standards series is relevant in this context. In addition, the BSI standards on IT baseline protection (BSI IT Grundschutz) are of particular significance. Attention is required in particular to ensure that pseudonyms are used for data in the AAL system.

8.4 Summary and Conclusions

Experiences from elderly playing exergames using Kinect will be used together with the combined knowledge in the project about needs and limitations for our target group. The exergames shall be playable from home, and shall have social elements that motivate the elderly to play and exercise together. Also the exergame must be designed considering the following features:

- backstory and story line: every game has a backstory or a story upon which it is based and a story line that it follows. The story line is not in the game play itself, but in the rationale for the game play.
- game mechanics: these handle all specific functions within a game, including such things as how the game's physical world or the action that a character takes when given a command (for example, "walk", "run", "sit").
- rules of the game.
- graphical environment: images, sound, animations.
- interactivity of the game.
- challenges.

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9 Personalized, intelligent and dynamic program management

The discussion in this section revolves around a survey of the health and assisted living market with the purpose of identifying potentially suitable applications with respect to the objective of this CAMI functionality module.

The main purpose of this CAMI functionality module is to act as a central information system, aggregating various types of information about the elderly user and his/her environment, e.g. medication plan, daily, weekly and month program planning, exercise planner, record of data obtained from sensors, including medical data, interactions with formal and informal caregivers.

The intelligence of the system would consist in its ability to usefully make sense of all this data in order to adapt the elderly person's schedule of daily activities, to provide meaningful reminders and suggestions.

Nonetheless, at out start, we make a distinction between two types of data collected from the user: planned activities and health related information (including doctor's appointments, observations from personal or professional caregivers or prescriptions from a physician).
Specifically, the latter type of information is subject to stricter regulations and privacy concerns. For this reason, the distinct market branch of Electronic Health Records (EHR) has been established, proposing technical solutions for the management of health related data.
From this perspective, rather than replicating the functionality of such systems, our CAMI module would act as a *consumer* of an EHR system, such that the task of our module becomes that of easily interfacing with an existing solution.

Consequently, the following application and framework views will reflect this distinction in the *type* of managed data and the corresponding *data management services.*

9.1 Existing market solutions

We start with an overview of applications that cover daily task and activity planning / tracking, commenting on the type of provided functionality and its suitability with respect to our own module.
The second part of this section will review existing EHR solutions and provide the same kind of analysis.

9.1.1 Description of Solutions of Activity, Medication and General Care Plan Management

In the conducted market analysis we find that the most prevalent type of applications are those that target **specialized care facilities for the elderly** (i.e. they are not designed for supporting self-care).

A comprehensive listing of software for senior living operations developed by **US based companies** is made available in online resources[40,41].
As visible in the listings themselves, the proposed solutions address full care facility functionality, starting from purely administrative concerns (e.g. admissions management, building and invoicing, building maintenance, resident information, staff information) and down to aspects that concern the currently discussed module (e.g. care planning, medication tracking, incident reporting).

[40] http://www.capterra.com/assisted-living-software/
[41] http://www.alfa.org/images/alfa/PDFs/SoftwareChart.pdf

In a parallel investigation, we looked at solutions in specialized care applications for program management existing in **Europe,** commercialized by representatives of overseas companies or **produced on the European market**.
One general remark for the products mentioned in the listings above, as well as those outlined below is that there is little detailed information on the type of AAL services offered. Mostly these are described as comprehensive and personalized. Therefore, we can only hope that they include also appropriate tools for program management.
In the following we provide a brief overview of some of some of the EU based companies that offer solutions which are of relevance to the current discussion.

- Chubb located in UK provides products which cover a comprehensive range of services in the AAL field: Telecare / Carephones, Telehealth, Assisted Living, Nurse Call, Carer Alert. Their assisted living housing solution is designed to enable personalised care packages to be delivered to individual needs and support customers including those living with dementia and learning disabilities.
  Useful links: http://www.chubbcommunitycare.co.uk

- Tynetec is a UK company with experience in the design and manufacture of Warden Call Systems, Telecare & Telehealth Solutions, Access Control Systems and Wireless Nurse Call Products. In the field of assistive living, the company provides an array of solutions that not only enable people to remain independent in their present situation but provide future proofed, flexible options that can be tailored to incorporate additional functionality should an individual's needs change.
  Useful links: http://www.tynetec.co.uk

- Sekoia is a Danish company which is offering the Sekoia open software platform for ambient assisted living by handling the different needs from daily tasks and activities to communication, rehabilitation, telemedicine and other social or healthcare needs.
  Useful links:

  http://www.sekoia.dk;

  http://www.ehealthnews.eu/industry/....

- Bosch Healthcare, in Germany, provides an innovative telehealth system which includes patient interface, web-based workplace application for providers, health management programs, etc. The personalized program offered by the company is mainly related to clinical management.
  Useful links: www.bosch-healthcare.com

- Aerotel is a company in Israel, offering a wide range of cost-effective, high quality, user-friendly, medical diagnostic systems and devices for the home care, eHealth and telemedicine markets.
  Useful links: http://www.aerotel.com

- Yardi is a US commercializing the Yardi Senior Living Software Suite also in several European countries. The software includes several packages such as: Yardi Voyager Senior Housing (combines financial and property management), Yardi EHR which is an electronic health record platform integrated with residential operations and outside care providers, Yardi eMAR which is a full-featured electronic medication solution, RENTCafe Senior Living

which is an online portal that connects senior living communities with their residents and their loved ones, etc.

Useful links: http://www.yardi.com/products/senior-living-software-suite

A separate investigation looked at **tablet** and **mobile applications** for **caregivers** (e.g. family members of an elderly person). The analysis was based on a set of online reviews[42] discussing pros and cons of proposed software solutions.

Rather than insisting on a description of individual applications, we want to focus on some insights related to **desired** program management functionality **from the perspective of informal caregivers.** This analysis was compiled by looking at the most often occurring functionality items of the applications listed in the online review.

From this perspective, some of the most relevant capabilities which the CAMI program management module could attempt to provide for informal caregivers are the following:

- ability to invite friends and family members to become "helpers"
- ability to obtain a **journal of observations** about the elder's activity and well-being which can be **shared with loved ones**
- ability to create a **shareable** and **collaboratively editable list of responsibilities** (regarding the daily activities of the elderly person in their care) which can be **dynamically assigned to caregivers**
- ability to **write and share notes** on calendar entries, or **make requests** to caregivers **for support** on scheduled activities (e.g. assist in grocery shopping, assist in domestic cleaning)

Summary and Conclusions

From the provided listings on US based products and the overview of european alternatives it can be seen that North America is dominating the market in Assisted Living Software.

On the other hand, the Asia-Pacific region is expected to witness significant growth due to changing population demographics and the economic development of regions.

At the same time, Europe is implementing several strategies to keep up with the market demands and to develop applications in the Assistive Care domain.

However, the **more important observations** are those that concern the usability of analyzed commercial applications within the currently discussed CAMI functionality module.

The **main issue** is that **products appear to be very company specific** and, except for the Sekoia open platform, **do not offer a solution that can be seamlessly integrated** in the CAMI platform.

Furthermore, in the case of the commercial applications for assisted living facilities, the **target users** are the **care providers** (e.g. medical and nursing staff, facility management personnel), **as opposed to older adults themselves,** which is contrary to the purpose of the CAMI platform.

Nonetheless, from the analysis of tablet and mobile applications for caregivers, we were able to collect a set of program management functionality elements which are deemed as *desirable* from the perspective of **interactions between informal caregivers** and **the senior person that lies in their care**.

The design of the currently discussed CAMI module should therefore try to accustom for the identified elements.

[42] http://www.aplaceformom.com/blog/best-and-worst-apps-for-caregivers-07-03-2013/

9.1.2 Description of Solutions from the EHR Domain

Electronic medical record (EMR) software, alternatively known as electronic health record (EHR) software, enables medical professionals to easily track, review and revise patient records in a single organized database. An EHR solution securely manages all components of patient medical history, from prescription notes and medications to health problems and lab reports, reducing time spent manually updating records. EHR also facilitates interactions between practitioner and patient with an online patient portal, lab result forwarding, messaging and alert notifications.

Below we summarize the top 5 commercial EHR applications according to Business-Software.com.

- eClinicalWorks v10 (www.eclinicalworks.com),
  - *Pricing* 400-550 Euro/month, no start-up costs.
  - *Key features*: Saas (Software as a Service), patient portal, cloud deployment, windows and mac platforms, mobile accessibility, workflow automation, no-charts.
  - *Additional features*: Features can be configured on a per-provider basis; Communicate with everyone from colleagues to a hospital in another state/country; Patient disease management; Built-in registry and quality measure reporting; Manage medications; Access labs and test results; Clinical decision support and patient education; Caters to the requirements of more than 40 sepcialities and sub-specialties; 24x7 support; Disaster recovery.

- AdvancedMD (http://www.advancedmd.com)
  - *Pricing*: modular with modules ranging from 150 – 800 Euro/month
  - *Key Features*: Saas (Software as a Service), patient portal, cloud deployment, windows and mac platforms, mobile accessibility, workflow automation, charts.
  - *Additional features*: EHR and billing automation, Physician dashboard, Ensure practice compliance and patient adherence to medical advice via automated alerts, Customizable templates, Easily communicate with patients and consulting or referring physicians, Captures and stores discrete patient data from visit notes, Automatically adds patient test results into patient chart, Role-based security controls, Easily navigate between AdvancedMD PM and EHR systems with single sign-on feature; Unified messaging, EHR template library.

- athenaClinicals EHR by athenahealth (http://www.athenahealth.com)
  - *Pricing*: below 500 Euro/month
  - *Key Features*: cloud based, medical billing, Saas (Software as a Service), patient portal, mobile accessibility, workflow automation, no-charts
  - *Additional features*: Single patient factsheet summarizes all relevant information; Quality guidelines and measures appear where they are least obtrusive; Identifies quality management programs that are best for your office; Handles most enrollments; Enables population health campaigns; Generates reports and submits data electronically on your behalf; Optimal data conversion; No licensing fees or server costs; Medical billing services; Secure text messaging among providers; Credential and eligibility checking.

- Allscripts Professional EHR (http://www.allscripts.com)
  - *Pricing*: 500-1000 Euro/month
  - *Key features*: Saas (Software as a Service), patient portal, cloud deployment, windows platforms, mobile accessibility, no mac support, no workflow automation, no-charts.
  - *Additional features*: Physician's desktop simplifies clinical administration tasks; Quickly access relevant data from previous visits, including stored diagnostic tests; Disease-based procedure templates; Handle orders in-house or send to external labs; Be alerted to allergies and interaction warnings; Reduce refill turnaround time and receive refill requests and pharmacy preferences from the Patient Portal; Leverage real-time, patient-specific alerts and notifications to ensure providers have actionable items at their fingertips.

- SOAPware, Inc. (http://www.soapware.com)
  - *Pricing*: low end
  - *Key features*: Saas (Software as a Service), patient portal, windows, mobile accessibility, workflow automation, charts, web interface.
  - *Additional features*: Offers ability to schedule across multiple facilities; Intelligent E&M coding that offers suggestions to increase the level of service for the visit; Integrates with Welch-Allyn Vitals machines IQMark, Midmark, Brentwood Holter, Spirometry and EKG reports; Instant medical history integration through Primetime Medical, allowing patients to enter information at home; Place, manage and track orders within the patient's chart; Document and task management capabilities; Automatically generate and print patient education handouts.

Free EHR applications selected according to the Capterra webpage.

- Practice Fusion
  - *General description*: Practice Fusion has over 17,000 customers and more than 100,000 users, and is the most widely used EHR free application. It's a web-based EHR that targets everyone from individual doctors, to small practices, and up to large medical groups. The software is completely free, and is ad-supported (meaning you will see relevant ads within the software). Turning off the ads is possible for a fee at $100 per month. Billing is not included in the software and going with one of Practice Fusion's integrated billing partners can be an additional fee.
  - *Pros*: The software is easy to use and simple to get started on. Full support is included and can supply great "hand holding" for those new to electronic health systems and those just switching. It's also got an array of slick pre-made templates and will integrate with tablets. Practice Fusion is certified for Meaningful Use for 2014, so you also qualify for EHR stimulus funds if you use it.
  - *Cons*: All that said, the product doesn't allow for much customization beyond templates, and users have reported issues with interfacing with LabCorp and Quest Laboratory for lab results. Additionally, lack of support for recurring appointments and the use of Adobe Flash (hampering access on mobile devices) may also cause frustration.

- Kareo EHR
    - *General description*: Kareo has offered medical billing software for years, but only recently started offering a free, web-based EHR software product. It's built on clinical knowledge bases from Epocrates and targets smaller physician practices and group practices. Kareo EHR operates on a "freemium" model, meaning the EHR software is free, and the company hopes you go on to buy their other, premium, products like practice management and billing.
    - *Pros*: This is another slick, cloud-based EMR, and the interface is modern and easy to use. Additionally, Kareo EHR is "mobile by design" and plays very well with tablets like iPads (it uses a native mobile app available in the Apple App Store) and smartphones. The software is Meaningful Use certified as well, and integrates with all the major labs, allowing for electronic orders and results.
    - *Cons*: Some have complained Kareo's EHR is too simple, and that if you want some additional functionality, like appointment reminders or patient statements, you'll be forced to upgrade. Kareo's Practice Management software starts at $74.50 a month.

- Hello Health
    - *General description*: Hello Health is another recent web-based EHR that is offered at no cost. They target primary care and pediatrics practices, and the revenue model is a bit more unintuitive than the two previous solutions. Rather than operate on an ad-supported or freemium model, Hello Health offers the core EHR functionality for free, but then charges patients, rather than doctors, for access to a patient portal that allows for perks like online scheduling, direct communication with the physician, and the option for video conference "virtual visits." Patients can (but are not required to) pay $36 to $120 annually for this access. Additionally, a portion of this is given back to the practice and Hello Health claims practices can earn up to $20,000 a year by using their EHR.
    - *Pros*: Hello Health has a clean user interface, and recently came out with a patient portal mobile app. It is certified for Meaningful Use, and the unique payment model means Hello Health could actually end up paying you, rather than the other way around for using their system.
    - *Cons*: Additional payment for important functionalities.

- OpenEMR
    - *General description*: This is one of the most popular of the open source EHR options, with 3,000-5,000 downloads per month. Being open source, OpenEMR is not web-based, but can run on Windows, Linux, Mac OSX and other operating systems as an installed or self-hosted program.
    - *Pros*: OpenEMR has a very active support community which has been referenced by just about every review online as "great" and "extremely helpful." Additionally, customization, assuming your office has someone with tech skills, is quite doable and the open source code allows for all sorts of add-ons and tweaks.
    - *Cons*: While OpenEMR is ONC Complete Ambulatory EHR certified, it is not yet Stage II certified for Meaningful Use. It is Stage I certified and the project is currently raising money for Stage II, which it hopes to have completed by July, 2014.

Additionally, the UI is a little dated compared to the freemium and ad-supported options referenced above.

Summary and Conclusions

Although the number of EHR applications available on the market is very large there is hardly one application that serves all the needs of an organization.
There is a major consensus in the literature in this sense and also our own observations based on reviews on the Capterra webpage (http://www.capterra.com) indicate this aspect of the EHR applications. Moreover, the pricing of commercial application makes them unsuitable for their integration in the CAMI platform.

At the same time, "free applications" often turn out to be quite costly and they don't offer the needed flexibility in CAMI which proposes integration of all types of data concerning the elderly into a single module of the system. This would include data such as that of health sensors, interactions with formal and informal caregivers.
Consequently, within CAMI **we will consider a solution existing within the consortium partners** (Eclexys, Aliviate, CNet) which allows additional development and integration.
Additionally, open source EHR such as the OpenEMR software described above needs to be investigated for further development and subsequent integration into CAMI.

9.2 Technologies and Open Frameworks

The **main conclusion** following the **analysis of existing market solutions** is that the **large majority** of reviewed assisted living applications either have a **different focus** than that of the CAMI system, or that their design **is not modular enough** such that the relevant program and health record management functionality could be easily integrated within the functionality of the currently discussed CAMI module.

Therefore, this section considers the analysis of different technologies and open source frameworks that would allow us to internally design and implement the envisioned functionality of the CAMI module on intelligent program management.

The analysis is structured around the main technological aspects that are relevant for the current CAMI module: information representation and storage methods, general frameworks for creating AAL specific information flows, methods for information retrieval, reasoning and planning.

9.2.1 Information Representation and Storage

Our motivation for looking into this type of foundation-level technologies with regard to program management is based on a review of several previous AAL project (from CALL 1 and CALL5), which had a certain focus on developing software tools that allow for the management of the activities of an

elderly person. As an example, we cite projects such as PAMAP[43], ELF@HOME[44] or HELICOPTER[45].

As is the case of the CAMI system, the activity management functionality envisioned by these projects had a high degree of particularity. As the referenced system design deliverables show, the solution to this issue (in the case of ELF@HOME and HELICOPTER, for example) was to create custom information representation schemes and implement them using standard relational database techniques.
The ELF@HOME project, for example, defines database tables that covers information about user health measurements, at-home physical exercise description and scheduling and down to the longer term planning for indoor and outdoor exercises.

However, seeing as the CAMI module on program management requires a **broader degree of flexibility** in the type of information it has to handle (description and plan of activities of daily living, planned and executed exercises, input from sensors in the room, input from sensor measuring the person's health status) **the question of the level of semantics** given to the chosen information model becomes relevant.

The AAL projects listed above make use of **relational database technologies** to implement the data model and the means to insert and retrieve information.
The advantage of this approach resides on the side of using well-known modeling approaches (i.e. Entity-Relationship modeling) and systems that enable their implementation (database management systems from well-known providers: e.g. MySQL, PostgreSQL, Oracle, IBM).
The downside is that database tables carry no explicit semantics of the schema according to which they model their data.
Consequently, adoption of such an approach for the currently discussed CAMI module entails the fact that all other CAMI functionality modules (e.g. intelligent collaborator, vocal interface, home management) will have to be implicitly aware of the defined information scheme in order to insert or retrieve data from the program management module.
This leads to greater difficulty in managing changes/updates to the information scheme throughout CAMI system modules and also provides less support for more complex dependencies and reasoning about the stored data.

As an alternative, modeling and storage can be handled by employing **semantic web technologies.**
A report[46] (Section 4.3) from the Next Generation European Ambient Assisted Living Innovation Alliance (AALIANCE2) performs an analysis of using semantic technologies within AAL systems.
It is noteworthy to observe that the **principal advantages identified** in the report concern precisely the type of functionality needed within the CAMI module on program management:

[43] http://www.pamap.org/media/deliverables/D2.3.pdf
[44] http://elfathome.eu/descargas/D2-3.pdf
[45] http://www.helicopter-aal.eu/wp-content/uploads/2015/04/D3.1-System-specification_UNIPR.pdf
[46] http://www.aaliance2.eu/sites/default/files/files_list/AA2_D4.3_Workshop_Report_Reference_Designs_for_Integrated_Applications.pdf

- support for rich representation power under the form of explicit semantics and ability to define higher-level knowledge from lower-level one (using ontology axioms)
- support for "intelligence" under the form of reasoners that can exploit the semantics of the defined knowledge model

As to the concerns mentioned in the report, note that we do not intend to use semantic technologies for all modules of the CAMI system. Therefore, issues such as higher resource consumption do not represent a significant overhead, since the CAMI module we are discussing is meant to act as a unit that aggregates and makes sense of all the data collected from the user and his environment. It will therefore be designed to run either on a local machine or in a cloud-setting with sufficient computational resources.
Concerns related to the maturity (in terms of performance and consistency of information) of semantic technology solutions can also be addressed. Since the release of the mentioned report (4 years ago) many commercial and open-source semantic information management solutions have reached production-level quality.

From the set of open-source solutions some of the most well known storage and framework products are Apache Jena[47], Sesame[48], Virtuoso (the GPL2 version)[49] or Stardog (community version)[50].
All of these products offer both high-performance RDF database solutions, ability to query stored triples using SPARQL endpoints, as well as comprehensive APIs to build and manage semantic data models.
Furthermore, they allow for an easier integration with semantic reasoning engines, which will be discussed further in Section 2.3.

An additional and important benefit of semantic data models is that they already lie at the foundation of so called context-aware event and situation management functionality within well-known AAL middleware solutions which are going to be presented in Section 2.2.
In the event of adopting such middleware proposals for use within our CAMI module, the development effort of the required information flow would be significantly reduced.

Summary and Conclusions
In this Section we make a case for using custom information representation and storage options, given the particularities of the CAMI module on intelligent and dynamic program management and the example of other previous AAL projects.

As opposed to the referenced projects, we argue for the use of semantic technologies for both *modeling* and *storage* of information handled by our module. In doing so, we cite the following reasons as motivation:

- ability to create **explicit knowledge models**, which can be developed separate from the information flow logic and which can be shared between CAMI modules, thus increasing

47 http://jena.apache.org/
48 http://rdf4j.org/
49 virtuoso.openlinksw.com
50 stardog.com

flexibility and reducing development effort. This can be achieved using ontology based modeling.

- ability to **increase the expressiveness of modeled data** by using ontology modeling based techniques to describe higher-level activities based on a composition of lower-level ones
- ability to **perform reasoning** (e.g. infer certain types of activity) either by means of ontology-based inference engines, or through rule-based approaches (discussed further in Section 2.3)
- **maturity** of existing open source **semantic data management and storage solutions**
- ability to **easily integrate with existing AAL middleware** solutions to create the desired information flow within the discussed CAMI module

9.2.2 Frameworks for AAL information flows

General identified advantages of using open Frameworks are: **1) Efficiency:** Tasks that usually would take hours and hundreds of lines of code to write, can be done in minutes with pre-built functions. Development becomes a lot easier, so if it is easier, faster, and consequently efficient. **2) Security:** A widely used framework has big security implementations. The big advantage is the community behind it, where users become long-term testers. If a vulnerability or a security hole or a bug are found the framework team can be notified to fix it. **3) Cost:** Most popular frameworks are free, and since it also helps the developer to code faster, the cost for the final client will be smaller. **4) Support:** As any other distributed tool, a framework usually comes with documentation, a support team, or big community forums where you can obtain quick answers.

Generally acknowledged disadvantages of open frameworks are: **1) Limitation:** The framework's core behavior can't be modified, meaning that when using a framework, you are forced to respect its limits and work the way it is required. **2) Code is public:** Since the framework is available to everyone, it is also available to people with bad intentions. It can be studied in order to know how things work and to find flaws that can be used against you.

In the following, we will present the key features and capabilities of universAAL[51], openAAL[52] and AALuis[53].

UniversAAL

The universAAL framework (http://universaal.org) was developed by the "UNIVERsal open platform and reference Specification for Ambient Assisted Living" project, within the FP7 framework. universAAL offers an open platform that provides a standardized approach making it technically feasible and economically viable to develop AAL solutions. The platform provides runtime support for the execution of AAL applications in accordance with a reference architecture, development support through core AAL services and an online developer depot of various development resources (see Figure 15).

[51] http://universaal.org/index.php/en/
[52] http://universaal.org/index.php/en/
[53] http://universaal.org/index.php/en/

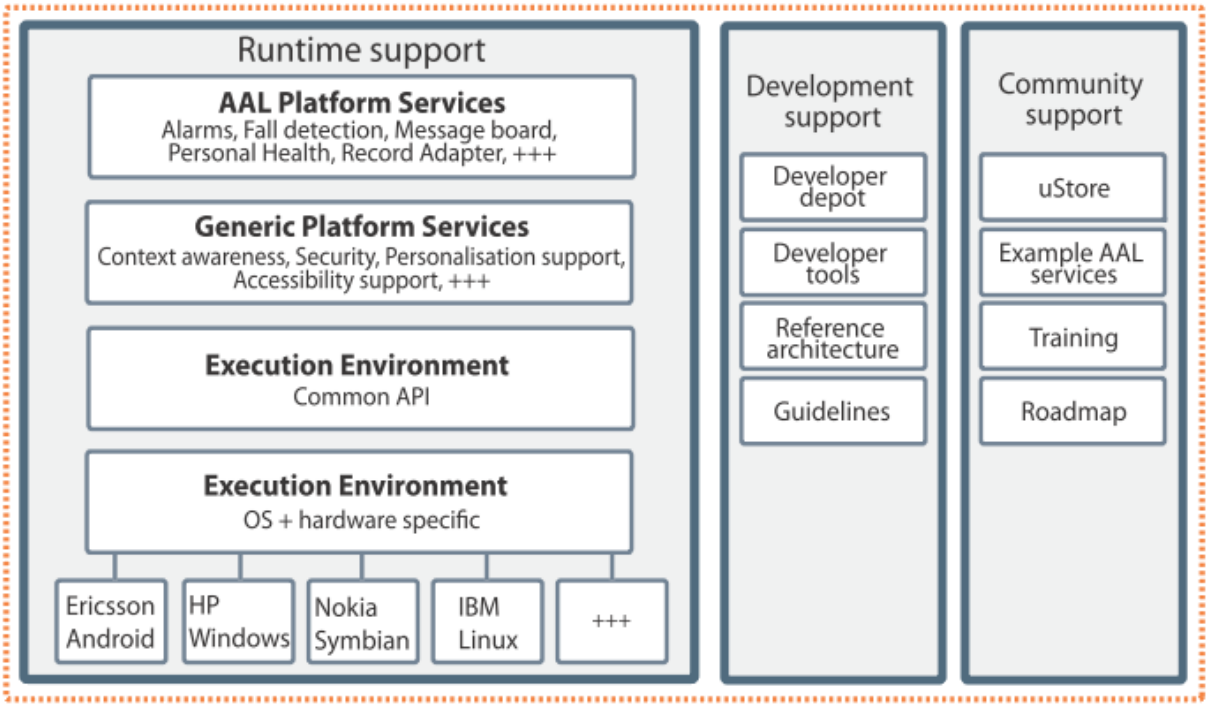

Figure 15**. The universAAL platform architecture.**

The detailed architecture of the platform is presented in the Handbook of the universAAL[54] platform architecture. The building blocks of the platform are detailed in the following. For developers, the tools are organized into the server side Developer Depot and the client side development environment AAL Studio. The **Developer Depot** provides all resources a developer needs to get started developing AAL applications and plug-ins for the universAAL platform. Through the Depot the developer can find and install the development tools (AAL Studio), binary and source code for the execution platform, examples, documentation of the tools and the platform. **The AAL Studio** provides a set of development tools hosted in an Eclipse-based IDE (with a few exceptions) that supports different parts of the development process, and that gives the developer easy access to the resources of the Developer Depot. The universAAL **Control Center** (uCC) supports the deployment of new AAL services into an AAL environment. By deployment it is meant all steps that must be done by the deployer (e.g. technician, advanced end-user) to get the new AAL service working in the AAL space. The uCC runs on top of the universAAL Execution Environment and its three main tasks are installing, configuring and personalizing the service. The Execution Environment provides runtime environment that allows end users to run their AAL services and provides the foundation that the developers use to develop their applications. The **uStore** is mapped to both Community Support Platform and Community Support Tool building blocks in RA because uStore gives the end user (assisted person or caregiver) a simple way to find and acquire AAL services, and to providers and developers it offers a store where they can upload and distribute their AAL Services. An AAL Service can include not only AAL application (software) and hardware, but also human resources. By acquiring an AAL service, required software (applications and device drivers) will be deployed to the user's runtime platform, access will be provided to required remote software services, and agreements will be made with (local) service providers to reserve required human resources both for deployment and use of the service. For the

[54] http://universaal.org/images/stories/docpdf/uAAL%20Architecture%20handbook.pdf

Community Support Platform building block, the uStore provides facilities to offer their AAL applications to service providers. For the service provider, the uStore gives a management tool where they can find AAL applications offered by developers, make agreements with developers to publish the applications as part of a service, and add the services they offer to the uStore catalog. The uStore serves as the meeting point for all the involved stakeholders where they can share ideas, request new services, ask for help and provide feedback.

openAAL

The openAAL platform (http://openaal.org) represents a flexible and powerful middleware for AAL scenarios and is the result of the SOPRANO Integrated Project. The newest version of the openAAL platform (openAAL v2.0) is based on universAAL. OpenAAL is available under the liberal LGPL license so that users and developers can do a lot on their own. However, the platform also offers support and consulting for integrating of sensors or actuators into the middleware; customizing and extending the middleware platform; creating additional services on top of the middleware.
Key features of the platform are:

- powerful and scalable user context management
- allows multi-paradigm context augmentation (abstraction from sensor-level information to high-level context information (including rule-based approaches, Bayesian networks, among others)
- BPEL-based workflows for context-aware behavior semantic service matchmaking based on the DIANE service description language
- based on OSGi

The installation is and can be found in every openAAL download. It involves downloading the openAAL zip file from the download section, unziping the file, and, finally the installation. Installation guidelines are to be found in Open-AAL\documentation\Setting up Eclipse and running openAAL 1.0.docx.

Figure 16 outlines the main idea of the openAAL solution. On the left hand side, the basic architecture of the provided infrastructure is presented. The shown components, namely the semantic service layer, the context manager, the composer and the procedural manager form the basis of the common framework that can be extended. On the right-hand side, the position of the different groups indicates the system component they have to communicate with. The SOPRANO ontology constitutes the semantic glue between the framework components and the foundation for the interface contracts.

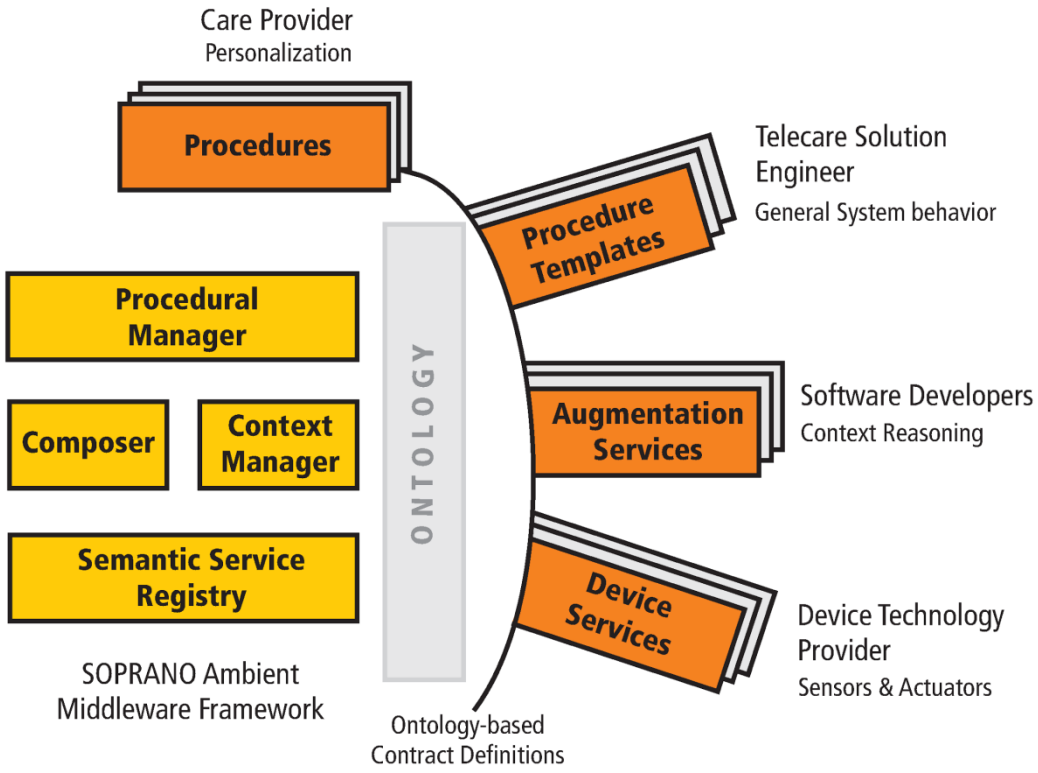

Figure 16. The main concepts of the openAAL platfrom.

AALuis

The Ambient Assisted Living user interfaces (AALuis) was developed within the Ambient Assistive Living user interfaces project, funded within the AAL programm. The user interface (UI) is an important feature of interaction between users and AAL services and AALuis was developed as an innovative UIs and a layer for the easy and standardized integration of new and existing UIs. Information on the AALuis project and its deliverables is available on the project site at http://www.aaluis.eu. However, at this point there is little information about the platform and available development resources.

Summary and Conclusions

While the general considerations in the beginning of this section are valid for open frameworks in general, we have to keep in mind that the AAL developed frameworks are still relatively new and not in use by a large community.

The ***universAAL*** framework is offering consultancy services on their webpage (http://universaal.org/index.php/en/consultancy-services) however, it is currently being used only in the "make it ReAAl" proposal (http://cip-reaal.eu/home/). Consequently, universAAL is currently lacking the large support community which is behind popular frameworks offering part of the advantages in using them. Moreover, the framework was developed within an FP7 European project and consequently its further development is questionable.

OpenAAL offers both consultancy and support services. However, since the whole openAAL platform is based on the OSGi implementation equinox, an in-depth knowledge of OSGi is necessary. Fortunately, the webpage is stating that OSGi is a easy-to-use technology for everybody familiar to java and a lot of OSGi training material is available.

Nevertheless, as pointed out on the openAAL webpage, AAL frameworks represent a flexible and powerful middleware for AAL scenarios which need to be carefully considered especially in AAL developments.

AALuis offers an innovative UIs and a layer for the easy and standardized integration of new and existing UIs. However, there is at the moment little information about the availability of the platform for further developments.

9.2.3. Information Retrieval, Reasoning and Planning

In previous sections we have identified the fact that the **CAMI module on dynamic and intelligent program management acts essentially** as a aggregator / **manager** of the ***context*** **/** ***situation*** **information** of the elderly person.
Specifically, the most relevant type of **context information** handled by this module is that pertaining to **planned and accomplished daily activities and exercises**, as well as **current health measurements.**
As the management unit of all this information, our module has to provide two important types of services which connect it to the other CAMI modules:

- ensure appropriate information retrieval capabilities
- provide support for information consistency, reasoning and planning

Information Retrieval
As discussed in Section 9.1., we favor the use of semantic technologies for the implementation of this module. In terms of retrieval options, the frameworks that we mentioned (Apache Jena, Sesame, Virtuoso, Stardog) all support querying by **SPARQL**[55] **endpoints.**
SPARQL is to RDF databases what SQL is to relational ones. The language is highly expressive and easy to use.

Furthermore, AAL middlewares such as universAAL or openAAL (which since version 2.0 is based on universAAL) provide the type of useful abstractions that are required when retrieving information.
Specifically, they provide API support for issuing both **one-time queries**, as well as **content-based subscriptions** to specific kinds of information.
Additionally, the queries and subscriptions can either be created programmatically, or they can be supplied directly under the form of SPARQL expressions, thus increasing the flexibility of the implementation style.

Information Consistency, Reasoning and Planning
Within the CAMI module we are discussing the ability to reason on the managed information is an important aspect. This is because the daily execution of planned activities by the elderly person is

[55] http://www.w3.org/TR/rdf-sparql-query/

likely to be very dynamic in nature. Activities may either be skipped or interrupted and resumed. The reason behind such decisions might follow from recorded health measurement which can give an indication of the person's condition.
In general, reasoning about the managed context information within our CAMI module will be required for:

- **implicit deduction** of **current activity**
- **tracking completion** of scheduled activities and medication intake
- **determine** the **appropriate time** to issue reminders for medication and exercises (balancing need to be reminded with non-disturbance)
- maintain **information consistency** (e.g. a combination of received information does not make sense, indicating a sensor error)
- **determining what activities** need to be rescheduled and **when replanning** needs to be triggered

In the following, we do not insist on techniques pertaining to activity rescheduling, since the specific (re)planning approach will be analyzed in much closer detail during system design (deliverable D2.2). However, we will discuss the reasoning techniques and technologies without which it is not possible to obtain an informed planning approach, as well as to handle the other above mentioned aspects.

With regard to reasoning capabilities, we again make reference to us favouring semantic technologies. This is because an information modeling approach rooted in semantics has intrinsic advantages in terms of inference and consistency management.

The AAL middlewares discussed in Section 2.2 already provide ontologies which could lie at the foundation of our own information modeling process.
The benefit of ontology based modeling lies in the ability to use ontological axioms to describe more complex information (e.g. a composite activity, gradual specialization of an activity hierarchy, a specific type of exercise that can only be performed in a given room). This means that not *any and all* possible types of information have to be predefined individually and in advance. Rather, it is the case that ontology based reasoning (e.g. instance realization) can be used to *enrich* the knowledge base with higher level information that is deduced based on the axioms relating types of primary information to one another.
Furthermore, ontology based axioms can also be used to set restrictions (e.g. for cardinality, value or disjointness of classes) on the instantiation of particular types of information, such that some types of consistency check can be inherently performed.

The above mentioned operations are made available by a number of ontology-based reasoning engines, that can be easily interfaced with the modeling and storage frameworks discussed in Section 2.1., as well as with the general information flow middleware products from Section 2.2.
The most well-known open source ontology reasoning engines are listed below:

- FaCT++[56]
- OWLIM[57]
- Pellet[58]

[56] http://code.google.com/p/factplusplus/
[57] http://www.ontotext.com/owlim/

- Jena[59]

In certain situations, ontology based reasoning alone is not sufficient (or powerful enough) to capture the intended inference or consistency check.
A very popular means of complementing ontology-based reasoning is through deduction rules. The main reason for doing so lies in the *lower computational complexity* and *comprehensibility* of rule-based systems (as opposed to probabilistic reasoning, for example).

Consequently, some of the frameworks discussed in Sections 2.1 and 2.2 already provide internal support for the use of rules.
Jena provides its own rule language[60] and rule execution engine which works in both forward and backward-chaining modes.
universAAL provides support for rules that infer new situations (situation reasoner), as well as those that ensure reliability of managed information and devices (reliability reasoner). Furthermore, the framework can be coupled with a Business Rules Management System (BRMS) called Drools.[61]

Interestingly, an approach that is newly gaining popularity is the use of the SPARQL query language itself as a means to *derive new information* or *check the consistency* of existing one.
This is achieved through the use of the SPARQL CONSTRUCT[62] expression to create new RDF triples based on the conditions expressed in the WHERE clause of a query. In doing so, this allows for a more uniform approach to modeling and reasoning, given that both aspects are handled through well-known, standardized semantic web technology solutions.
The approach is being used in a number of academic and open source projects, ranging from event processing systems [6364], to activity modeling and recognition[65] and down to general context modeling in Ambient Intelligence applications[66].
Furthermore, support for it exists also in universAAL, being usable in both the situation and reliability reasoner.

Summary and Conclusions

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58 http://clarkparsia.com/pellet/
59 http://jena.sourceforge.net/
60 https://jena.apache.org/documentation/inference/#rules
61 http://www.drools.org/
62 http://www.w3.org/TR/rdf-sparql-query/#construct
63 Anicic, D., Fodor, P., Rudolph, S., Stojanovic, N. "EP-SPARQL: a unified language for event processing and stream reasoning." Proceedings of the 20th international conference on World Wide Web, 635--644. ACM. (2011).
64 Teymourian, K., Rohde, M., Paschke, A. "Fusion of background knowledge and streams of events." Proceedings of the 6th ACM International Conference on Distributed Event-Based Systems, 302--313. ACM. (2012).
65 Meditskos, G., Dasiopoulou, S., Efstathiou, V., Kompatsiaris, I. "SP-ACT: A hybrid framework for complex activity recognition combining OWL and SPARQL rules." 2013 IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops), 25--30. (2013).
66 Sorici, A., Picard, G., Boissier, O., Zimmermann, A., and Florea A.M. "CONSERT: Applying Semantic Web Technologies to Context Modeling in Ambient Intelligence." Computers and Electrical Engineering, Volume 44, May 2015, pages 280-306, ISSN 0045-7906, http://dx.doi.org/10.1016/j.compeleceng.2015.03.012. (2015).

We analyzed the aspects pertaining to information retrieval and reasoning for which the CAMI module on dynamic and intelligent program management has to provide support.
In the review of appropriate technologies to accomplish these tasks, we investigated approaches that are **complementary** to the solutions discussed in Sections 9.1 and 9.2.
Consequently, we identified the fact that universAAL provides support for all issues related to information retrieval and reasoning (API for queries and subscriptions, support for ontology and rule-based reasoning).

Further, we observed that ontology-based reasoners can be incorporated into existing AAL middleware (e.g. universAAL, openAAL) and the fact that SPARQL can be used as both a query, as well as a rule construction language, bringing the potential for a more uniform development approach.
The above advantages imply that the identified technological solutions need to be carefully considered during the design phase of the CAMI module on dynamic and intelligent program management.

9.3 Standards

In this section we perform a pointwise presentation of the set of standards which can be of relevance with respect to the functionality of the currently discussed CAMI module.
The main areas where compliance to standards is expected to play a significant role are:

- health data communication, representation and storage
- modularity of the middleware / service implementation
- use of semantic technologies for information representation and reasoning

Health data communication, representation and storage

- **IHE XD* (XDS/XDR/XDM)** The family of XD* integration profiles of the IHE organization (Integrating the Healthcare Enterprise) summarizes specifications for the exchange of medical knowledge: *f* Cross-Enterprise Document Sharing (XDS), *f* Cross-Enterprise Media Interchange (XDM), *f* Cross-Enterprise Document Reliable Interchange (XDR). XDS and its related specifications were originally created by the IHE to facilitate access to remote patient files. However, the XD* profiles are content-agnostic and do not access in any way the document they encapsulate as a pure payload, so that in principle, all kinds of documents can be managed and distributed.
- **Continuity of Care Record (CCR)** is a health record standard specification developed jointly by ASTM International, the Massachusetts Medical Society, the Healthcare Information and Management Systems Society, the American Academy of Family Physicians, the American Academy of Pediatrics, and other health informatics vendors. The CCR consists of a cohesive record of a patient's key medical information. It is a kind of snap-shot of the patient's key medical data and can be simply extracted from an electronic health or patient file (e.g. after a doctor's appointment). The CCR defines sections containing structured data, e.g. about diagnoses or allergies, or information about the health insurance. The CCR is stored in the eXtensible Markup Language (XML) and is machine readable.
- **IHE Exchange of Personal Health Record Content (XPHR)** XPHR describes a document format for the exchange of medical data between a personal electronic health file (EGA) controlled by the owner and an electronic patient file (EPA) kept by doctors for example about their individual patients. IHE speaks of "binding" [44] to describe the process of bringing together an XD* profile together with the contents specified in XPHR, for the purposes of transport. Content information specified in XPHR is based on the Clinical Document

Architecture (CDA). The CDA header information can be used by the binding specified by IHE to automatically derive part of the meta data necessary for XDS.

- **CONTINUA Personal Healthcare Monitoring Report (PHMR)** The Personal Healthcare Monitoring Report (PHMR) was developed jointly by the Continua Health Alliance and HL7 so that in the framework of homecare monitoring, both the collected sensor data and the key medical information from the home environment of the users can be stored and communicated to players in the health system. The PHMR is based on CDA documents and keeps as close as possible to the CCD [29], [8]. CONTINUA uses the IHE integration profile XDR for transmitting PHMR documents between doctor and user

Modularity of middleware / service implementation

- **Open Service Gateway Initiative (OSGi)** The OSGi Alliance has developed a frequently used middleware specification. Corresponding middleware frameworks are called OSGi platform and are available for purchase and also as open source freeware. But in some cases there are considerable differences in quality and in the demands made of system resources. The OSGi Alliance founded in 1999 is a nonprofit cooperation consisting of developers and technology innovators with a focus on specifying a hardware-independent platform for service management and distribution. A Java virtual machine (JVM) is prerequisite for hardwareindependent operation of an OSGi platform. Some projects are based on OSGi. The EU SOPRANO project for the AAL sector uses OSGi together with ontologies intended for communication [66], [46]. SOPRANO also founded the AAL Open Association (AALOA) in conjunction with the EU projects MonAmI, OASIS, OsAmI-commons, PERSONA, SOPRANO, universAAL and WASP.
- **Machine-to-Machine (M2M)** Machine-to-Machine is a newly developed ETSI specification that stands for the automated exchange of information between machines. It describes generally useful M2M functions such as security, data transmission, boot strapping and an application programming interface for services. The API permits communication between individual M2M components (such as sensors and actuators), M2M gateways and service platforms. Systems and machines should exchange data in a completely automated process without human interaction. M2M abstracts from the basic LAN and WAN technology. ETSI-M2M was developed on the basis of requirements from a number of use-case documents. Relevant examples in the AAL context are "eHealth" (TR 102 732) and "Connected Consumer" (TR 102 857). The notable specifications of ETSI-M2M are:
    - TS 102 689: M2M service requirements
    - TS 102 690: M2M functional architecture
    - TS 102 921: M2M mla, dla and mld interfaces (draft)

Use of semantic technologies for information representation and reasoning

- **RDF**[67] RDF is a standard model for data interchange on the Web. RDF has features that facilitate data merging even if the underlying schemas differ, and it specifically supports the evolution of schemas over time without requiring all the data consumers to be changed. RDF extends the linking structure of the Web to use URIs to name the relationship between things as well as the two ends of the link (this is usually referred to as a "triple"). Using this simple model, it allows structured and semi-structured data to be mixed, exposed, and shared across

[67] https://www.w3.org/RDF/

different applications. This linking structure forms a directed, labeled graph, where the edges represent the named link between two resources, represented by the graph nodes. This *graph view* is the easiest possible mental model for RDF and is often used in easy-to-understand visual explanations.

- **OWL 2 DL**[68] The OWL 2 Web Ontology Language, informally OWL 2, is an ontology language for the Semantic Web with formally defined meaning. OWL 2 ontologies provide classes, properties, individuals, and data values and are stored as Semantic Web documents. OWL 2 ontologies can be used along with information written in RDF, and OWL 2 ontologies themselves are primarily exchanged as RDF documents.
- **SPARQL**[69] SPARQL can be used to express queries across diverse data sources, whether the data is stored natively as RDF or viewed as RDF via middleware. SPARQL contains capabilities for querying required and optional graph patterns along with their conjunctions and disjunctions. SPARQL also supports extensible value testing and constraining queries by source RDF graph. The results of SPARQL queries can be results sets or RDF graphs.

9.4 Summary and Conclusions

The module on personalized, dynamic and intelligent program management acts as the central information processing element within the CAMI system.
The module is in charge of gathering and processing available information about the elderly user and his/her environment (e.g. medication plan, exercise plan, record of data obtained from sensors, medical data, interactions with formal and informal caregivers) in order to meaningfully track and quantify the accomplishment of planned tasks, provide reminders and suggestions.

The review of existing market solutions has shown that aspects such as application focus shift (on the caregiver, rather than the caretaker) and lack of modularity prevent these solutions from being readily employed within CAMI.
Consequently, we envision building this required functionality internally, by making use of several open source technologies and frameworks:

- semantic web technologies (e.g. ontologies, quad store engines, SPARQL endpoints) for information representation, reasoning and retrieval
- AAL application development frameworks for constructing information flow. Owing to the lack of sufficient community support, as well as issues of scalability of the latter frameworks (e.g. universAAL), the alternative direction of building custom web-based (e.g. RESTful) information pipelines will also be considered.

10 Telepresence for communication (video, voice, graphics) [Lead: MDH+ EXYS+CITST]

Mobile robotic telepresence systems incorporate video conferencing equipment onto mobile robot devices which can be steered from remote locations or, in some advanced cases, can move semi-autonomously or autonomously in their environment. These systems, which are primarily used in the context of promoting social interaction between people, are becoming increasingly popular within

[68] http://www.w3.org/TR/owl2-overview/
[69] http://www.w3.org/TR/rdf-sparql-query/

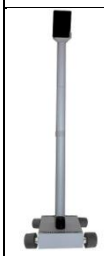
certain application domains such as health care environments, independent living for the elderly, and office environments. Today, the field of mobile robotic telepresence is in rapid expansion, with an increasing amount of commercial systems available and research efforts in the field. Commercial telepresence systems, presented in section 10.1, vary in design and functionality often depending directly on their intended use and application. Additionally, there are a number of telepresence systems which are closer to research prototypes than marketable products, several of which have been integrated in various research projects (see section 10.2). Although some of the manufacturers of the robots provide public price tags, the field is undergoing rapid expansion. The price tags are therefore expected to change over time.

10.1 Existing market solutions

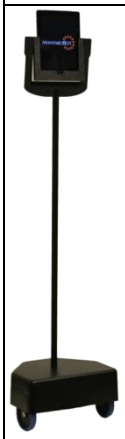
There are already quit many telepresence platforms/robots on the market. The telepresencerobots.com site lists for comparison 20-30 platforms ranging in price from 250 Euro (the Oculus telepresence) to 70.000 Euro (Ava 500), see Table 6. However, the integration of a telepresence into the CAMI platform imposes a number of requirements which are present in only a limited number of systems. These requirements are:

1. Compatibility with the Robotic Operating System (ROS)
2. Platform with open interfaces, i.e. programmability and accessibility from other applications. Such platforms are generally oriented for research and development.
3. Affordable price range
4. Availability of additional features such as optional manipulator and omnidirectional driving for crowded environments are also desirable.

Table 6. Comparative presentation of various telepresence platforms from telepresencerobots.com. More examples as well as different comparison criteria than the one in the table header can be found at the same link.

	Name	Approximate Price (Euro)	Unique features	Top speed	Height	Network Connectivity	Docking station
	Endurance	2.000	Unknown	2-3 mph	5' 7" (170 cm) Adjustable.	WiFi, 2G, 3G, 4G, LTE	Yes
	Padbot	700	High Quality Speaker, Wide-Angle Lens	1.64 mph (2.64 k/h)	2' 10" (87.6 cm)	WiFi or 4G LTE	Yes

	Teleporter	15.000	Noice-Canceling Microphone, Amplified Speakers, Secondary Web-cam	2 mph	58" - 69"	WiFI and Optional Cell Wireless Operation	Optional
	Carl	6.000	HD Webcam, Built-in Amplified Speaker System, Wireless Headphone Capability	2 mph	56" - 67"	WiFI and Optional Cell Wireless Operation	Optional
	Ava 500	70.000	Autonomous Navigation, Scheduling Capabilities	1 m/s	About 65.6" (166.4 cm)	WiFi 802.11/a/g/n, Video collaboration via SIP or H.323	Yes
	Peoplebot P3-DX	35.000	Atonomous Navigation, Grippers, and Cameras	0.8 m/s	3' 8" (112 cm)	WiFi	No
	Jazz Connect	8.000	Unknown	Unknown	Unknown	WiFi or Data	Yes

	Oculus	250	Optional Vision Upgrade	Unknown	About 20"	WiFi or Data	Yes
	TeleMe	1.500	Customizable features upon request	1.4 mph	5' (152.4 cm)	WiFi or Data	Optional
	Beam	15.000	Zoom capability, Echo-Canceling Mic w/ Adaptive Noise Reduction	2 mph	5'2" 157.48 cm	WiFi 802.11 a/g/n	Yes
	Double	2.000	The Double automatically charges its iPad, Wide-Angle Viewing Lens	1 mph	47-60" 119-150 cm	WiFi or 4G/LTE	Optional

In the following we will present in more detail the platforms which fulfill at least 3 out of the 4 requirements for CAMI integration, which we have outlined in the beginning of this section.

Gostai Jazz Telepresence

The Jazz telepresenc family from the French Robotics company Gostai, includes several members: Connect (see **Error! Reference source not found.**), Jazz Security, for well security, and Jazz Icon for

marketing and promo events. The Jazz Icon, for marketing events, comes equipped with a tray for carrying objects while the Jazz Security has more autonomy and a camera that can see in the dark. Jazz can move during more than 5 hours in a row and it can be recharged by driving it close (1 meter) to the charging station where it will automatically dock itself.

Figure 17. Jazz Connect (left) and Jazz Icon (right).

Jazz is powered by Urbi, an innovative, simple to use, yet powerful Operating System for complex systems. The urbiscript language is a dynamic script language, focusing on prototype-oriented programming and object programming. It supports and emphasizes events programming and parallelism, two major paradigms in complex systems programming, by offering language constructs and primitives. urbiscript also includes tags which allow execution flow control.

Urbi allows to create components and drivers, called UObjects, which can run on top of Gostai Runtime. Developers can import UObjects written in C++ and plug them in urbiscript to use them as normal objects inside the language. They can also run a UObject as a remote object, a simple autonomous executable in Windows, Linux or Mac OSX, see *Figure 18*.

Urbi is open source with an A-GPL license that makes it available freely for everyone to use, check and share, while maintaining a dual licensing model providing support and advanced features for commercial partners.

Urbi is integrating ROS support able to integrate ROS nodes inside an Urbi project, and benefit from the best of both worlds. It is also compatible with many platforms, including Nao, Aibo, Segway RMP, Sparx, etc.

Main features of the Jazz family are:

- Fast moving & robust
- 8 ultrasonic sensors, 4 IR sensors, high-end 30m range Hokuyo urg-30lx telemetric laser for autonomous navigation (optional)
- Automatic docking on a charging station (5h of autonomy)
- Wifi 802.11G connected
- USB2 port and removable tablet support for extra accessories (cameras, modules…)
- Atom N270 1.6 GHz or D510 1.66GHz processor with Linux OS (Ubuntu 10.04 server)
- 2 camera types: 1600 X 1200 – 30 FPS - Vision angle: 90° OR 720 x 576 – 25 FPS – Vision angle: 170°
- Jazz runs Linux and integrates the open-source Urbi middleware
- Urbi, the most innovative robotics middleware available today: parallel and event-based execution, integrated components, client/server approach for flexibility

- C++ UObject distributed component architecture
- Urbi is open-source and has a large community: www.urbiforge.org
- Urbi is compatible with ROS, and is used by hundreds of research labs in the world
- Re-use your code on many other Urbi compatible system (including Nao, Spykee, Bioloid, Pioneer, Segway RMP)
- Easily program and control your system with Gostai Suite

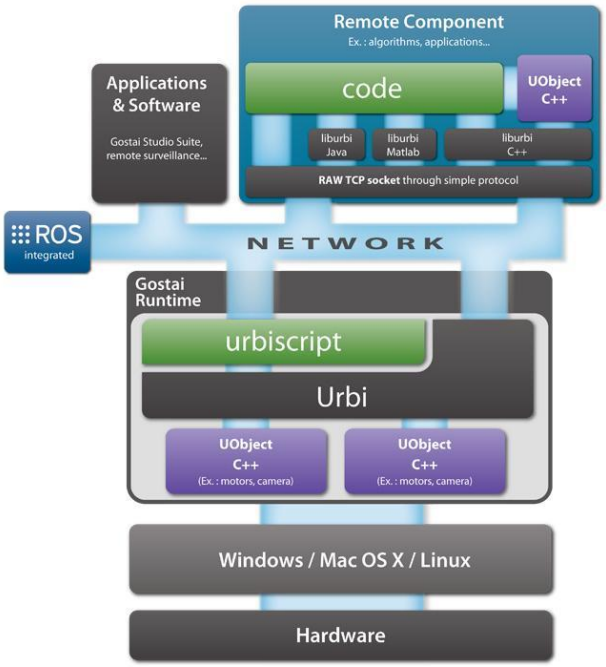


Figure 18. Integration of Urbi in a project.

Price: Jazz Connect and Jazz Icon costs approximately 7900 Euro while Jazz Security is around 8400 Euro. The Jazz Icon for events can be also rented for 1800 Euros per 24 hours, plus another 1500 Euro for optional features (e.g. tray 100 Euro, Set-up of 10 pre-programmed voice messages with a choice of 10 different voices for 150 Euro, etc).

Pros: Programmable, ROS compatible, compatible with Nao for which UPB has previous experience, available in Europe

Cons: price, no manipulation capabilities.

Turtlebot

TurtleBot 2 (www.robotnik.eu), the evolution of the TurtleBot platform, is the cheapest robot in the market with ROS architecture. TurtleBot 2 (see *Figure 19*) is thought for the field of research and education, this differential kinematics mobile platform can be used for multiple applications, mainly because there are many packages available in ROS for TurtleBot.

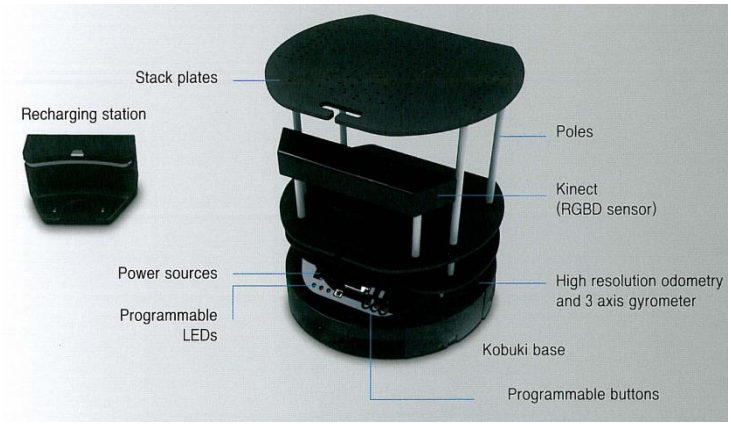


Figure 19. Components of the Turtlebot telepresence paltform.

TurtleBot 2 has many advantages over its predecessor: odometric measurement precision, open protocol, greater autonomy, greater load, higher speed, and greater mobility, larger diameter wheels and capacity to overcome obstacles up to 12 mm. Foreseen applications are:

- AAL: Ambient Assisted Living
- HRI : Human Robot Interface
- Navigation, localization and mapping based on Xtion PRO LIVE (Slam 2d and 3d)
- Mobile manipulation
- Multi-robot systems
- Educational

Design specifications: Dimensions: 31,5x43x34,7 cm; Weight: 5 Kg (according conf.); Speed: 0,65 m/s; Controller: open architecture ROS; Autonomy: 7h. (big battery), 3h. (small battery).

Hardware specifications: Motor Overload Detection: disables power to motors on detecting high current; Odometry: 25718.16 ticks/revolution, 11.7 ticks/mm; Gyro: factory calibrated, 1 axis (100 deg/s); Bumpers: left, center, right; Cliff sensors: left, center, right; Wheel drop sensor: left, right; Power connectors: 5V/1A, 12V/1.5A, 12V/5A; Docking recharging connector: 19V/2.1A- Expansion pins: 3.3V/1A, 5V/1A, 4 x analog in, 4 x digital in, 4 x digital out; Audio : several programmable beep sequences; Programmable LED: 2 x two-coloured LED; State LED: 1 x two colored LED [blinking - charging, Green - high level, Orange - low level]; Buttons: 3 x touch buttons; Battery: Lithium-Ion 2200 mAh (small) 4400 mAh (large); Firmware upgradeable: via usb; Sensor Data Rate: 50Hz; Recharging to batteries only (jack) batteries & laptop @2.1A (docking); Docking IR Receiver: left, centre, right.

Software specifications: Kobuki drivers for ROS and non-ROS in C++; Kobuki and Turtlebot simulator (Gazebo); Kobuki and Turtlebot apps.

Functional specifications: Maximum translational velocity: 65 cm/s; Maximum rotational velocity: 3.14 rad/s; Payload: 5 kg (hard floor), 4 kg (carpet); Cliff: will not drive off a cliff with a depth greater than 5cm; Theshold Climbing: climbs thresholds of 12 mm or lower; Rug Climbing: climbs rugs of 12 mm or lower; Expected Operating Time: 3/7 hours (small/large battery); Docking: can perform docking within a 2m x 5m area in front of the docking station.

Turtlebot has a wide community of developers which makes further development based on this platform easier and faster:

Web Site: http://turtlebot.com

Gitthub: https://github.com/turtlebot

ROS Wiki: http://ros.org/wiki/turtlebot

ROS Answers: http://answers.ros.org

Google+: https://plus.google.com/101989863972881638653/posts

Price: The starting price of the platform is 650 Euro. Further configuration which includes controller, 3D sensors, additional battery, docking station, etc, can be made (link) for up to 1250 additiona Euros. Addition of a manipulating arm can rise the price even further. So, the total price for a loaded Turtlebot can vary betwee 2.000 and 3500 Euro, with the latter price including a performant manipulator.

Pros: open ROS architecture, carpet climbing capabilities, wide community, large number of acccesories all of which are usefull in CAMI, price on the low-medium side of the range.

Cons: very basic design which needs additional furnishing to make it attractive.

Kompai telepresence by Robosoft

Kompaï (link)is a telepresence robotic platform to assist seniors and dependent persons at home. This first generation is for developers who want to implement their own assistance scenarios. Kompaï has been developed by Robosoft (www.robosoft.com) within the AAL collaborative DOMEO project, where the first generation of Kompaï has been designed and tried by potential users. Kompaï R&D offers the most advanced existing technologies available today for developing interactive robots. It is a basis for researchers to develop and implement scenarios. It is open, flexible and modular. Kompaï R&D can also be used to develop communicating robots.

Kompai was further developed within several projects: MOBISERV, PRAMAD, LAR, MIDAS (ended). The initial Kompai version (see *Figure 20*) included:

- Autonomous navigation solution based on traditional techniques such as laser-based SLAM (Simultaneous Localization and Mapping). A technician needs to manually create the map of each new environment (half day of work). Every single time the layout of that home is changed, the technician needs to go back to the home to re-learn the map of the environment for the robot.
- Linear Obstacle detection at the height of the laser but no 3D obstacle avoidance.
- Advanced dialog: the robot can receive verbal commands and give verbal responses.
- User-friendly interface. However, Kompai is a passive robot, basically a computer with wheels waiting for the elderly to talk to the robot or press a button in its screen to start the interaction.

Figure 20. Kompai R&D version.

Current capabilities of Kompai are significantly extended and include:

- Autonomous map creation. Kompai autonomously creates the map of any environment, not only the first time it arrives to a new home, but every time the owner changes the layout of the home -without the need to call a technician again.
- Obstacle avoidance in 3D. Before the project, the Kompai was only able to perceive a line of the environment with the laser sensor, which was very dangerous in a home environment, with a lot of obstacles at different heights. Thanks to the incorporation of the Kinect sensor from the Cognitive Brain, the Kompai perceives and avoids 3D obstacles around the room.
- Landmark perception / detection. The distances collected from both the laser and the Kinect sensors are processed to extract the most relevant landmarks of the environment (qualitative information), which allows the robot to reason and make decisions at a high level of abstraction. This is part of the patent pending, proprietary software of the "Cognitive Brain for Service Robotics" from Cognitive Robots.
- A new navigation system has been incorporated into the system, which applies the 'landmark perception/detection system' allowing the robot to reason and make further decisions.
- Vacuum cleaning algorithms using the 'landmark detection system' allows the robot to know what it has been vacuum and what still needs to be vacuumed.
- Kompai was a static robotic platform waiting for a 'call to action' by the user. With a new feature introduced from C-Brain, Kompai has become proactive and starts actions by itself to engage the user.
- The interaction with Kompai can be done through gesture recognition, done in the INTRO Project.
- Kompai can be remotely controlled from a mobile phone application. This method leads to very fluid motions.

Price: Various source indicate a starting price of 25.000 $ (link)

Pros: Research platform

Cons: Available information is not well structured and finding it needs a lot of research on the webpages of various projects; availability and technical specifications of commercial versions are not clear.

Adept PeopleBot P3-DX

The PeopleBot P3-DX (see *Figure 21*), manufactured and sold by Adept Mobilerobots (www.mobilerobots.com) is based on the well-known Pioneer 3-DX reference robot base to which an extension, reaching to about 1,1 meters, has been added. Atop this extension a touchscreen display is found, connected to an onboard computer. The weight is about 22 kg, including the differential drive platform. The run time is approximately 8 hours and the charging 2.4 hours.

Figure 21. Peoplebot (left) and Pioneer 3-DX base (right).

The robot navigates with the aid of its 3 SONARs – front and rear facing on robot base, upper front facing on chassis extension – and it also features two IR break beam sensors to detect a table or other objects mounted at such height. It also features an array of tactile bumper sensors to detect collisions.

The additional options list is very long, the robot can be equipped with grippers or robotic arms, laser sensors, gyroscope, PTZ or stereo cameras or other audio-video devices. Support is also widely available, more advanced applications may include face recognition, autonomous navigation on greater distances and so forth. The industrial grade onboard computer is a Mamba EBX-37 powered by an Intel Dual Core CPU running at 2,26 GHz, which offers USB and RS-232 connectivity, dual Ethernet ports, a SSD hard drive and WiFi hardware.

With the aid of the included Pioneer SDK, available for Windows and Linux, which includes packages such data receive and control framework, simulators, graphical user interfaces for remote control and monitoring, and many more, the robot can be programmed to perform object tracking, path planning, display maps of sensor readings, localization and be remotely controlled.

The Pioneer 3-DX base is a 2 wheel differential drive platform with wheel encoders and a caster wheel for support. The microcontroller runs on ARCOS firmware and features 32 digital inputs, 7 analog inputs, 8 digital outputs and 3 serial expansion ports.

Price: The price tag for such a robot greatly depends on applications, configuration and installed accessories, a starting point can be in the range of 25-35.000 US Dollars.

Pros: R&D platform with lots of additional options.

Cons: high price, user-friendly design

Giraff

The Giraff telepresence comes from Sweden and was primarily aimed at assisting the elderly in every day talks. Development was started by the company under the name HeadThere, in San Francisco, California but the business was completely relocated in 2009 in Vasteras, Sweden under the name Giraff Technologies AB (www.giraff.org). A few tens of robots have been delivered to date throughout Europe, and the Giraff was chosen in 2010 by Excite, a project started by the Orebro University in Sweden, to aid studying how elderly interact through Information Communications Technology.

The Giraff telepresence comes in four different flavors, with slightly different functionality (see *Figure 22*). It is 1.6 meter high, weights 13 kg and features a 14 inch display, a 2 megapixel camera equipped with a 120 degree wide angle lens, speaker and microphone. The mobile base is constituted by 20 Volt high torque gearhead motors with integrated encoders and polyurethane wheels 125 mm in diameter. It features a patent pending biaxial anti-roll suspension and an aluminum chassis. It can operate more than 2 hours on a single charge.

Figure 22. Giraff telepresence in its various versions developed throught the time.

The robot is powered by a VIA EPIA MII 10000 CPU and runs on Windows XP embedded OS. It communicates through a WiFi interface, while 3G support is yet to be added. It can be controlled through the Giraff Pilot PC application.

Price: 1600 – 3000 Euro

Pros: relatively affordable, lots of additional functionalities developed within various project. For example, services for telecare were implemented within the VictoryaHome (http://www.victoryahome.eu) project.

Cons: Windows based, no sensors for autonomous navigation: laser scanner, bumpers; additional functionalities cannot be purchased directly from the projects in which they were developed.

Care-O-bot

Care-O-bot (link), developed by the Frauehofer (www.fraunhofer.de), is the product vision of a mobile robot assistant to actively support humans in domestic environments. All the robots in the Care-O-bot family have:

- Flexible, Autonomous Navigation: systems are equipped with an omnidirectional platform with four steered and driven wheels. This kinematic system enables them to move in any desired direction and therefore also safely to negotiate narrow passages. In doing so, robots are also able to autonomously plan and follow an optimal, collision free path to a given target. Dynamic obstacles such as persons are detected by sensors and avoided automatically.
- Manipulation and Grasping as optional capabilities: the systems are equipped with highly flexible, commercial arms with six or seven degrees of freedom. For example, Care-O-bot 3 uses a three-finger hand to grasp and operate a large number of everyday objects. Tactile sensors in the fingers of the hand allow the robot to adjust the grasping force precisely. Due to the tactile sensors in the fingers, the robot is also able to adjust the grasping force. In order to grasp an object, the robot approaches tables or cupboards with its backside. The arm is long enough to grasp objects even from the floor or to reach high shelves. The seventh degree of freedom allows the robots to reach around obstacles. In addition, Care-O-bot 3 uses the arm to position objects on its tray.
- Environment Reconstruction: a multiplicity of sensors enables the Care-O-bot systems to detect the environment in which they are operating. These range from several laser scanners to stereo vision colour cameras and to 3D sensors. The sensors serve, for example, to detect relevant environment structures as well as obstacles in the robot's environment. Using the information provided by the sensors a 3D-map of the robot's environment is created.
- Object Detection: using its sensors, Care-O-bot is capable of detecting different everyday objects and computing their pose in 6D (position and orientation). Additionally, the robot is able to learn new objects independently and to assign unknown items to specific object classes. This ability is the basis for Care-O-bot to deal with the great diversity of environments and objects in domestic applications.
- An open-source repository for different robotic frameworks (at the moment ROS and Orocos). The repository includes hardware drivers as well as simulation models and application examples.

The latest fourth generation (link to Care-O-bot 4), see *Figure 23*, is more agile and modular than its predecessors and offers various ways of interaction. It also stands out through the use of cost-reducing construction principles. In this way, large parts of its internal construction feature folding sheet metal, which is economical to produce in small quantities. The enhanced agility of Care-O-bot 4 is owed to the patented spherical joints around discreet pivot points on its neck and hips. They extend the robot’s working space and allow 360 degree rotations of head and torso.

Figure 23. The forth generarion Care-O-bot platfrom.

Based on its modular system design, the fields of application for Care-O-bot 4 are wide-ranging. The robot can be equipped with one, two or no arms at all. If the intended purpose is to serve drinks, one hand can be replaced by a tray, or the mobile base platform can be used on its own as a serving trolley. Individual robot platforms can be configured for a wide range of applications: a mobile information center in museums, DIY stores and airports, for collection and delivery services in homes and offices, for security applications or as museum robots at attractions – Care-O-bot 4 is a safe and handy human helper at all times.

Using the display integrated in its head and based on the current situation, Care-O-bot 4 is able to display different atmospheres. While the concept for the Care-O-bot 3 was a more reserved, cautious butler, its successor is as courteous, friendly, and affable as a gentleman.

Price: Care-O-Bot 3 costs nearly a quarter of a million Euros (322.000 dollars) and although the forth generation is said to be more affordable its price is still expected to be in the hundreds of dollars range.

Pros: ROS based, open source, very configurable, relatively large community of developers.

Cons: Extremely expensive, heavy (Care-O-bot 4 has 140 kg).

Aldebaran Robotics Pepper

The latest creation from Aldebaran (www.aldebaran.com), Pepper is the first humanoid robot designed to live with humans, see *Figure 24*. Although Pepper is not really a telepresence platform, it is particularly suitable for the interaction with elderly people because Pepper is a social robot able to converse with people, recognize and react to their emotions, move and live autonomously. Engaging and friendly, Pepper is much more than a robot, he's a companion able to communicate through the most intuitive interface we know: voice, touch and emotions. Currently, Pepper is able to speak English, French, Japanese and Spanish.

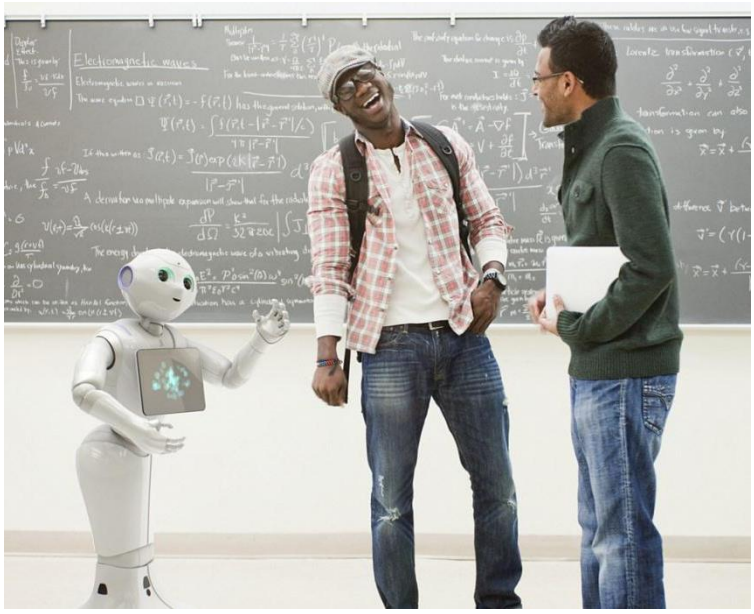


Figure 24. Pepper the humanoid companiable robot.

Pepper is able to understand emotions. If you burst out laughing, he will know you are in a good mood. If you frown, Pepper will understand that something is bothering you. Pepper can translate what state you are in using his knowledge of universal emotions (joy, surprise, anger, doubt and sadness) and his ability to analyze your facial expression, body language and the words you use. He will guess your mood, and will even adapt to it. For example, he will try to cheer you up by playing your favorite song. Pepper also can express emotions, and this is what makes him so cute.

Facts and figures about Pepper:

- Weight around 61 lbs (28 kg) and hight almost 4 feet (120 cm);
- 17 anti-pinch articulations that give him graceful and fluid movements
- 3 omnidirectional wheels allow him to move around freely
- 14 hours of battery life
- More than 40 innovative patents
- A 3D camera to perceive his surroundings and human activity up to 10 feet (3 m)

Price: Pepper will sell for 198,000 yen (about $1,600), but SoftBank will offer a service plan for 14,800 yen - roughly $1,200 a month - every month.

Pros: Pepper's software is announced to be open source, low price, designed to be a companion robots.

Cons: it is not yet available on the European market and its release date is still uncertain.

Tiago by Pal Robotics in its base model, the iron version, can act as an advanced telepresence robot (see link). However, this version can be upgraded to include a 7-DoF arm with a parallel gripper and further to include a five-fingered hand with a force/torque sensor plus a 10-meter navigation laser.

Tiago is a totally configurable robotic platform, its main purpose being to custom-fitted to any specific need. TIAGO has a mobile platform and is equipped with a sensor-based pan-tilt head, and a lifting torso. It runs autonomously on the mobile base, creating a map of the environment with a 2D laser. Its sensors provide visual perception, enabling it to detect objects, people, obstacles and anything you implement.

Price: The iron version sells at about 29.000 Euro. The most advanced version featuring an arm with a five finger hand will reach 60.000 Euro.

Pros: ROS based, R&D platform which allows development and integration with other environments, several important features are already present, can be upgraded to have manipulative capabilities.

Cons: Price, it has no interface for remote manipulation.

10.2 Technologies and Open Frameworks

This section describes past and ongoing projects which have contributed to the development and integration of telepresence-like systems in various environments. By telepresence-like systems we understand both simple telepreence platforms which are remotly manipulated by a user, as well as more advanced platforms which are capable of autonomous or semi-autonomous navigation and utlimately approach the concept of robotic platforms. However, the majority of the presented projects do not develop manipulative functions for their platforms.

The **DOMEO** AAL (www.aal-domeo.eu) project which finished in 2012 was the first project all over the world to bring assistant robots in real homes with real people. The project focused on the development of an open robotic platform for the integration and adaptation of personalized homecare services, as well as cognitive and physical assistance. The project was based on the Kompai platform developed by Robosoft (www.robosoft.com).

Figure 25. The Kompai platform developed by Robosoft.

The **ALIAS** (Adaptable Ambient Living Assistant) AAL project (www.aal-alias.eu) focuses on questions of social acceptance of robot systems in general and specifically by elderly people. The project has developed the ALIAS robotic platform starting from the Metralabs A5 robot, see *Figure 26*. ALIAS is a mobile robot platform with the capacity to monitor, interact with and access information from on-line services, without manipulation capabilities.

On top of the integration of existing solutions, two novelties were introduced: a) A novel cognitive user interface concept was introduced to ensure a good usability and to avoid people fearing to do

harm to the robot. b) A proactive behavior of the robot platform ensures that the user stays in contact with his surroundings and gets mentally stimulated. c) The third unique selling point is a Brain-Computer-Interface (BCI) in order to train and preserve the mental functions of the user.

Figure 26. The ALIAS platform.

The **VictoryaHome** (A robot for integrated care@home and peace of mind of carers) AAL project (www.victoryahome.eu) has integrated the Giraff telepresence, see *Figure 27* and www.giraff.org, and has further developed its functionalities by including:

- Visit Me – seniors can touch one of their contacts on the Giraff to send a request for a visit
- Serenity App for family and friends – showing information about the person they care for
- Virtual Visits – by family and friends to the senior, using the mobile telepresence device
- Medication Reminders
- Fall Detection
- Activity Checks

Figure 27. Giraff telepresence.

The **SocialRobot** European FP7 project (project link) has developed an appealing robot for elderly people considering the issues of size, shape, colour and acoustic (sound, noise etc.), see *Figure 28*. The robot has a two wheels robotic base, with a structure body and robotic head. Main integrated sensors: cameras, kinect sensor and laser range finder. The key features of the platform are:

- Human-robot interaction (emotion recognition, intelligent dialogue)
- Behaviour modelling considering related context of daily routine occurrences of the elderly as they age
- Robot-human learning and understanding
- An innovative end-user personalized and adaptable multi-modal contact-less channel of communication that supports an affective and empathetic user-robotic interaction which enables:
- Facial expression and gesture analysis capable of understanding pointing gestures by hand.
- Processing of basic vocal commands and confirmations
- Analysis of emotions

Figure 28. SocialRobot developed for elderly people.

The **TERESA** European FP7 project (project link) which will end in November 2016 develops a telepresence robot of unprecedented social intelligence, thereby helping to pave the way for the deployment of robots in settings such as homes, schools, and hospitals that require substantial human interaction. The project started from the Giraff telepreence platfrom depicted in *Figure 27*. The project's main result will be a new partially autonomous telepresence system with the capacity to make socially intelligent low-level decisions for the controller. Sometimes this requires mimicking the human controller (e.g., nodding the head) by translating human behavior to a form suitable for a robot. Other times, it requires generating novel behaviors (e.g., turning to look at the speaker) expected of a mobile robot but not exhibited by a stationary controller. TERESA will semi-autonomously navigate among groups, maintain face-to-face contact during conversations, and display appropriate body-pose behavior.

The **MOBISERV** European FP7 project (www.mobiserv.info) is based on the Kompai platfrom (www.robosoft.com) which was extended to become a personal intelligent platform consisting of various devices, middleware, and services. The Mobiserv platform consists of the following:

- A social companion robot – an autonomous robot, containing processing power, data storage capability, various sensors, machine learning/experience gathering/adaptation, a touch screen, speech synthesis, and speech recognition;
- Wearable smart clothes – implementing various functionalities such as monitoring of vital signs or sleeping patterns, and detection of falls;
- A smart home environment – including smart sensors, optical recognition units, and home automation elements, to detect among others eating and drinking patterns, activity patterns, and dangerous situations.

The prototypes developed are open, both in the sense of being built using open-standards and in their ability to be expanded with new functionalities and components. The final project results can be viewed as a video on youtube (link).

The European FP7 **ACCOMPANY** project is based on the Care-o-bot platfrom (link) which is integratd as part of an intelligent environment, providing services to elderly users in a motivating and socially acceptable manner to facilitate independent living at home, see *Figure 29*. The ACCOMPANY provides physical, cognitive and social assistance in everyday home tasks, and contributes to the re-ablement of the user, i.e. assist the user in being able to carry out certain tasks on his/her own. Various videos and presentations of the project results can be viewed on the media page of the project.

Figure 29. Care-o-bot platform developed by Fraunehofer in Germany.

The **Giraff** and **GiraffPlus** European projects both develop and then enhance the Giraff telepresence platfrom (www.giraff.org). Additionally, the **EXCITE** (www.oru.se/excite) project has enhanced Giraff by adding autonomous navigation. The Giraff, produced by Giraff Technologies AB in Västerås, is a mobile telepresence device that allows anyone–professional caregivers, family and friends to virtually visit a home, move about freely and communicate with residents via videoconferencing.

The initial Giraff technology included the following features:

- HeadThere Corporation Confidential
- Drivable, motorized remote control to adjusts to standing or sitting height;
- Easy control via laptop for: super-imposed graphics navigation; secure connectivity over public
- Internet, simple navigation via laptop mouse; intuitive, with basic and expert modes; latency compensation;
- Business quality audio/video and screen click PTZ with smart zoom;
- Charging station;

  - Hand carry design;
  - Height adjustment;
- Highly tuned code base: Real-time system; Dozens of parameters tuned through operational experience; Latency compensation;
- Highly tuned mechanics: Suspension for high center-of-balance; Navigation in populated environment.

The Giraff improvements within various projects are depicted in *Figure 30*.

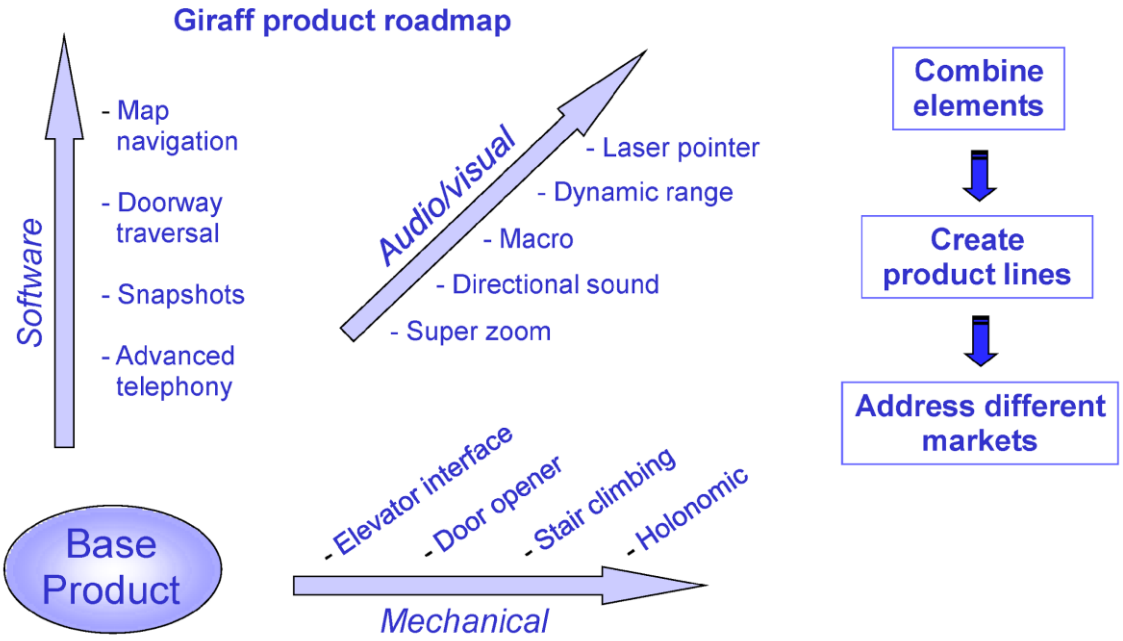


Figure 30. Giraff develpments starting from the base product.

The Florence platform is a telepresence wheel-based platform, 1,5 meter heigh, developed within the European FP7 **Florence** (Multi Purpose Mobile Robot for Ambient Assisted Living) project (http://www.florence-project.eu/). Sensor input is based on a 2D laser scanner, 3D structured light (kinect) and an (optical) camera. The system is based on the Turtlebot platform and is illustrated in *Figure 31*. The robot software is based on the Robotic Operating System (ROS) – the emerging de facto standard in robotic software. In addition, the project focuses on a scalable platform-based approach that enables the addition/extension of 3rd party applications. A high-level APIs is available for developers. For e.g. multi-modal user interaction (including speech and gestures), user activity detection, planning activities and accessing information from the smart home, without requiring detailed knowledge on basic low-level robotic technologies. A number of these AAL services have been developed as a proof of concept.

Figure 31. The Florence telepresence.

10.3 Standards and Interoperability

Of particular interests for the telepresence and robotic platform are the once directly developed for this field. The International Standards Organization has recently released the latest standards for care robotics, robots and robotic devices. ISO 13482:2014 specifies requirements and guidelines for the inherently safe design, protective measures, and information for use of personal care robots, in particular the following three types of personal care robots: mobile servant robot; physical assistant robot; person carrier robot. These robots typically perform tasks to improve the quality of life of intended users, irrespective of age or capability. ISO 13482:2014 describes hazards associated with the use of these robots, and provides requirements to eliminate, or reduce, the risks associated with these hazards to an acceptable level. ISO 13482:2014 covers human-robot physical contact applications.

ISO 13482:2014 presents significant hazards and describes how to deal with them for each personal care robot type. It covers robotic devices used in personal care applications, which are treated as personal care robots and is limited to earthbound robots. ISO 13482:2014 does not apply to: robots travelling faster than 20 km/h; robot toys; water-borne robots and flying robots; industrial robots, which are covered in ISO 10218; robots as medical devices; military or public force application robots.

Robot Operating System (ROS)

Robot Operating System (link to ROS.org) is a collection of software frameworks for robot software development, providing operating system-like functionality on a heterogeneous computer cluster. The primary goal of ROS is to support code reuse in robotics research and development.

ROS is a distributed framework of processes (aka Nodes) that enables executables to be individually designed and loosely coupled at runtime.

ROS provides standard operating system services such as hardware abstraction, low-level device control, implementation of commonly used functionality, message-passing between processes, and package management. Both the language-independent tools and the main client libraries (C++, Python, and LISP) are released under the terms of the BSD license, and as such are open source software and free for both commercial and research use. The majority of other packages are licensed under a variety of open source licenses. These other packages implement commonly used functionality and applications such as hardware drivers, robot models, datatypes, planning, perception, simultaneous localization and mapping, simulation tools, and other algorithms.

The main ROS client libraries (C++, Python, LISP) are geared toward a Unix-like system, due primarily because of their dependence on large collections of open-source software dependencies. For these client libraries, Ubuntu Linux is listed as "Supported" while other variants such as Fedora Linux, Mac OS X, and Microsoft Windows are designated "Experimental" and are supported by the community. The native Java ROS client library, rosjava, however, does not share these limitations and has enabled ROS-based software to be written for the Android OS. Rosjava has also enabled ROS to be integrated into an officially-supported MATLAB toolbox which can be used on Linux, Mac OS X, and Microsoft Windows. A JavaScript client library, roslibjs has also been developed which enables integration of software into a ROS system via any standards-compliant web browser.

10.4 Summary and Conclusions

As outlined in the beginning of section 10, there are certain requirements that a telepresence or a robotic platform needs to fulfill in order to be a good candidate for its integration in the CAMI environment. We have presented platforms that fulfill most of the above requirements.

1. Compatibility with the Robotic Operating System (ROS) which is envisaged as the future standard in robotics middleware
2. Platform with open interfaces, i.e. programmability and accessibility from other applications. Such platforms are generally oriented for research and development.
3. Affordable price range
4. Availability of additional features such as optional manipulator and omnidirectional driving for crowded environments are also desirable.

The ROS compatibility provides several advantages and is a great asset from interoperability point of view. ROS being an open middleware on top of Linux allows access at basically any level to data and protocols needed for interoperability. Also, ROS is very popular and has a wide range of high level functionalities already implements. These include both robotic specific ones, e.g. SLAM for autonomous navigation, and non-robotic ones like the integration of a temperature sensor.

Besides the above criteria, the platform needs to be also available commercially or otherwise such that it can be acquired by the CAMI consortium partners. Based on all these aspects we propose the following candidates:

- **Jazz** telepresence by Gostai because it is ROS compatible, is already quite advanced in functionalities (including voice messges) and is very afordable with a price around 8000 Euro.
- **Kompai** telepresence which has been already used in several projects related to elderly care and has several important features for CAMI such as voice, autonomous navigation, internet access, etc. It's main drawbacks are a price of around 25.000 Euro and the fact that it is based Microsoft Robotics Studio. However, extra software can be developed using Microsoft Robotics Developer Studio and this should facilitate integration
- **Turtlebot** which is probably the most widely used telepresence for robotic development and a lot of functionalities are already available on the internet. It is based on ROS and is very cheep at about 2000 Euro. Its main drawback is that it is very ugly and it will need an aditional shell in order to become apealing to elderly people.
- **Tiago iron** version which can be developed into an advanced telepresence platform featuring also autonomous navigation. The price is comparable with the Kompai telepresence price. However, it runs ROS and can be upgraded to have manipulative capabilities.

11 Infobot to retrieve from the web user requested information

The InfoBot component of CAMI is meant to support self-management capabilities of seniors in terms of access to knowledge and providing information for *common daily inquiries*. InfoBot is conceived as a text and voice-controlled wrapper leveraging *existing* knowledge discovery and question answering services such as:

- WikiData (https://www.wikidata.org/wiki/Wikidata:Main_Page) or
- Google Now on Tap (to be released later this year with Android "M").

The component is targeted at helping seniors to more easily manage knowledge-driven tasks, such as:

- access to popular knowledge (e.g. What is X?, Who is Y?, Who sings a song? Who wrote a book?),
- leisure activity related knowledge (What are the opening hours for a given restaurant/museum?)
- local environment conditions knowledge (What is the weather forecast? Will it rain today?)

The InfoBot will use the following methods:

- speech to text conversion
- knowledge representation and interrogation
- text to speech conversion

Review of existing AAL solutions has shown few AAL projects that implement functionalities based on these methods. Also both speech to text and text to speech conversion methods are very sensitive to noise. We decided to continue to investigate all aspects involved for this functionality depending on the end-user acceptance that will be reported in D1.2.

12 Intelligent, informed, friendly collaborator, taking orders + reminders

Healthcare management requires inter-disciplinary principles management of lifestyle, psychological and social health managements for individual needs in different level of health care process such as case management, feedback and learning, clinical decision making based on clinical guidelines and

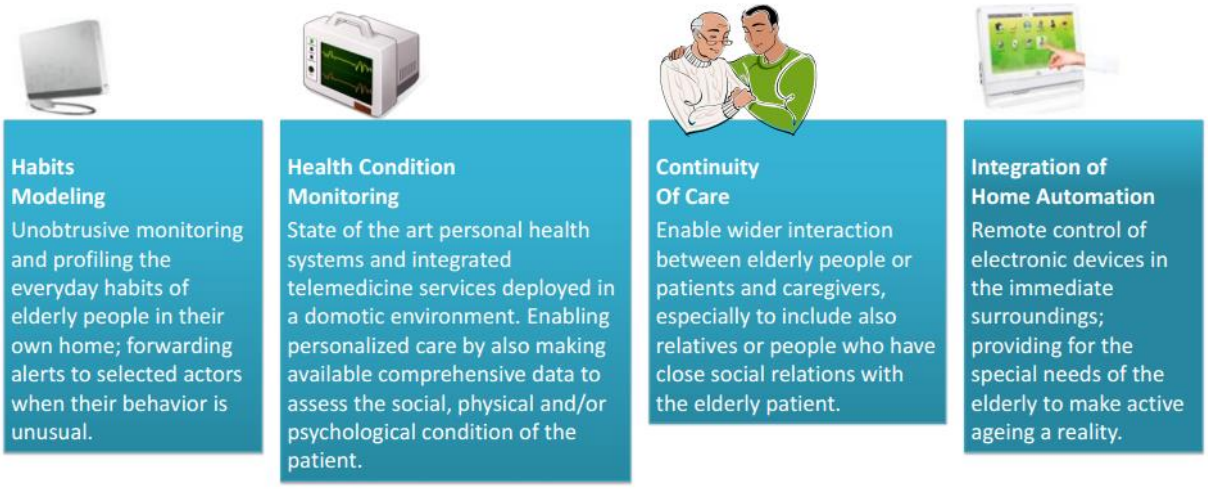
standards. Through Information, technology communication and intelligent platforms can this sensing infrastructure be realistic and feasible due to provide a huge automated data based on computational modelling techniques and monitoring with combination of mobile health technologies and sensors via a stable and secure network.

For this reason, an embedded services framework has potential to offer a smart solution towards different level of interoperability in different layer and categories and meets the standards not only for personal health record systems level but also for other level of communications between applications and systems. This type of health ecosystems enables also increasing scalability and utility of IT-infrastructure as an appropriate solution to ensure quality of systems as well as clinical outcomes.

inCASA framework is based on assisting elderly people at home through monitoring of their chronic condition health and their environmental as behavioral monitoring. This platform uses state of the art information and communication technologies (ICT) as it described above in this deliverable. The services embrace health/environment monitoring to collect and analyse data in order to profile user behavior, implement customized intelligent multilevel alerts/communication services among different type of actors such as care professionals, social care, next-of-skin and patients. The platform enables interaction points in the patient journey with different type of needs for care and communication to the relevant actor. The services support patients in their self-care through gaudiness and coordinating and increasing ability for long-term management of their disease (see Figure 32).

12.1 Existing market solutions

inCASA and REACTION services and tools are built based on patient participation in health care and their own care through exchanging information actively by a collaborative relationship though using of ICT. The technology and standards are described briefly in previous chapters (6.2 & 7.3.1).



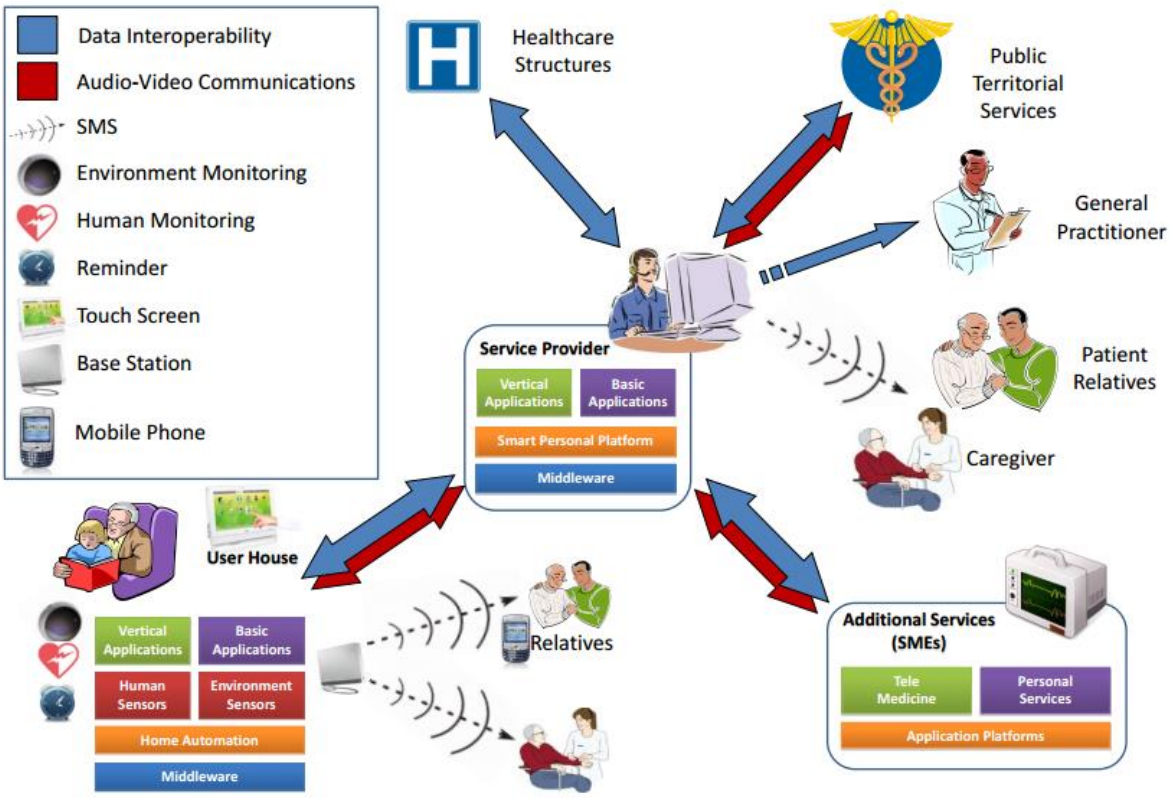


Figure 32: inCASA solution & combination of Telehealth+ Telecare

The necessity of administrative tools to healthcare providers to define patients' care program based on individual unique needs, made the purpose to develop My Care flow by Stockholm County Council in Stockholm[70]. These e-services provides a new type of communications between care providers and patients. These services supporting patients with their diary, medicine, Calendar and appointments with their caregivers and their referrals (see Figure 33).

[70] http://ki.se/en/lime/my-care-pathways

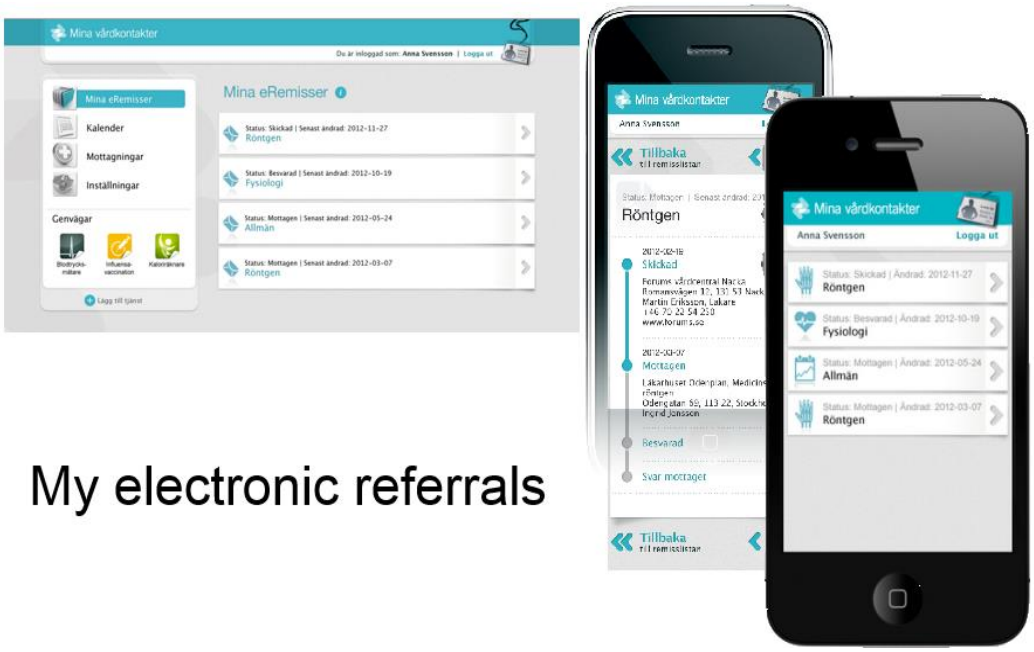


Figure 33: GUI of My Care flows

12.2 Technologies and Open Frameworks

As My Care flow is developed based on different aspects of patients' needs through performing needs of patients and requirements analyses with distinct patient's groups and also patients engagement framework aspects (inform me , engage me, empower me and partner with me) , the solution has meet successfully patient centric design. The objective of MyCare flows is to facilitate Swedish citizens to follow their own care in the healthcare flow to manage especially lung cancer, stroke and heart disease as well as hip surgeries and health disease.

MyCare flow:

The platform includes an API gateway that enables Health 2.0 companies can build application that interact with electronic health records (EHR) in a national level. This is an open platform offers an information infrastructure that covers and define different aspects of security such as form of services, resource statute services and integration of services. The platform is an open source that is built around RESTful and OAuth 2.0 API (see Figure 34).

The services are also compatible with standards of information integrations such as HL7 v3 Green CDA 2 that agrees to all patients to have a better overview over their own information's such as referrals, lab, radiology images, scheduling of care visits, prescribed medication and preferred care provider[71].

[71] N. Lundberg, S. Koch, M. Hagglund, P. Bolin, N. Davoody, J. Eltes, *et al.*, "My care pathways - creating open innovation in healthcare," *Stud Health Technol Inform,* vol. 192, pp. 687-91, 2013

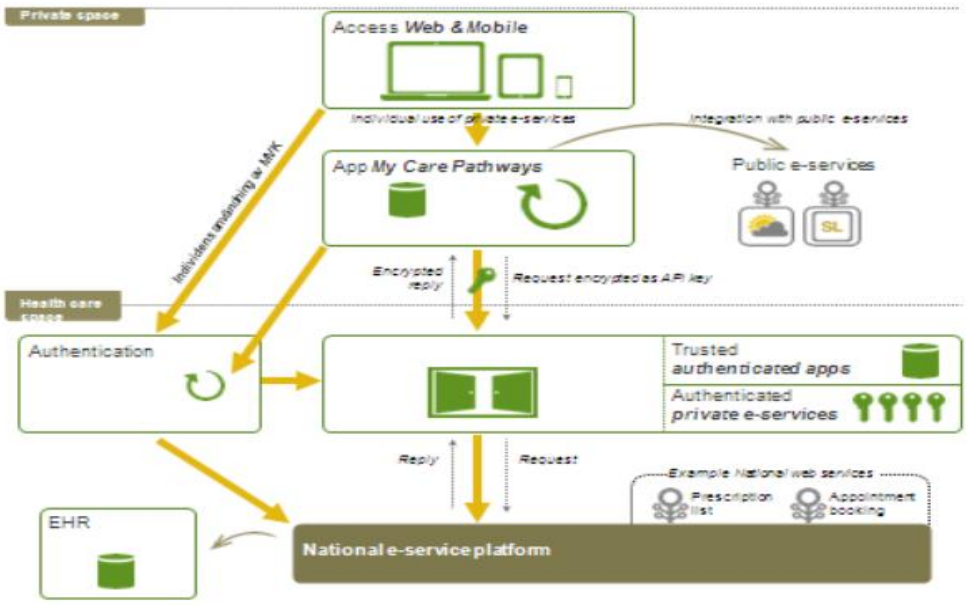


Figure 34: My Care flow infrastructure

12.3 Summary and Conclusions

The issues from chapter 7.4 are valid in this framework also (see 7.4). MyCare flow e-services are run by, for instance, Stockholm County Council together with Region Skåne and Region Västra Götland in Sweden, as a national platform, yet the solution has not been developed based on an international healthcare organization and business model.

13 Vocal interface

The discussion in this section revolves around the existing speech recognition and speech synthesis solutions with the purpose of identifying potentially suitable solutions - if they exist - with respect to the objective of this CAMI functionality module.

Since elderly people prefer to use easy and natural interactions, CAMI's interface should be easily accessible by the users and to interact with them in ways that are most natural to them. Oral Communication makes the process of conveying thoughts easier and faster, and it remains the most successful form of communication between humans, and it's preferred by elderly people. Therefore, a voice interface should be a principal feature of CAMI's Interface.

During our review process, we identified three categories that we should investigate: Speech recognition, Speech synthesis and Speech Corpus.

- **Speech recognition** category refers to the solutions that can identify spoken language and convert them to a machine-readable format. Some of those solutions are Open source, others are commercials.
- **Speech synthesis** category refers to the solutions that convert text into speech.

- **Speech corpus** category refers to the "Speech Audio files and text transcriptions" Databases, which are databases that contain multiple languages speech audio files.

13.1 Existing market solutions

In our market analysis, we identified many commercial speech recognition and speech synthesis systems that already exist. We will describe some of them in this section.

o AT&T Watson:

- AT&T is an American telecommunications corporation. It offers AT&T Watson as speech recognition and speech synthesis solution. AT&T Watson offer Text-to-Speech, Speech-to-Text, and custom speech recognition solutions. AT&T Speech API works cross-carrier with all the mobile and desktop platforms. The resulting text of the speech recognition process can be returned in multiple formats, including JSON and XML, and the Grammar List customizable context supports 19 different languages and its release includes documentation and examples.
- ***Supported languages:*** English, Swedish, French, Spanish, Italian, German, Mandarin Chinese, Japanese, Korean, Portuguese, Ukrainian, Russian, Arabic, Indonesian, Turkish and Dutch. Multiple Dialects are supported.
- ***Pricing:*** 0.01 US $ per transaction (1 transaction = 30 seconds).
- ***Useful link:*** http://developer.att.com/apis/speech

o Dragon NaturallySpeaking:

- Nuance, an American company, offers Dragon NaturallySpeaking as speech recognition and speech synthesis solution. The Dragon NaturallySpeaking software developer kit (SDK) is used by developers and integrators to add speech recognition capabilities into in-house and commercial applications or workflow applications. This toolkit, which enables everything from free-text dictation to command and control functionality, can be deployed as part of a server- or client-based solution. The Dragon NaturallySpeaking supports over 86 languages and dialect and its release includes documentation.
- ***Supported languages:*** English, Romanian, Danish, Swedish, Polish, French, Spanish, German, Bengali, Dutch, Portuguese, Bulgarian, Mandarin Chinese, Czech, Spanish, Arabic, Finnish, Greek, Spanish, Cantonese, Hungarian, Icelandic, Hindi, Indonesian, Hebrew, Italian, Japanese, Korean, Malay, Nepali, Norwegian, Urdu, Russian, Serbian, Singapore, Slovak, Slovenian, Afrikaans, Mandarin – Taiwanese, Thai, Turkish, Ukrainian and Vietnamese. Multiple Dialects are supported.
- ***Pricing:*** 0.008 US $ per transaction or On-demand.
- ***Useful link:*** http://www.nuance.com/for-developers/dragon/index.htm

o Nuance Healthcare Solution:

- Also a Nuance product. It's a Secure, cloud-based, clinical speech recognition with client-side software components for mobile device platforms, web browsers, and desktops. It's easy to integrate with different platforms for mobile devices, web and desktops. All speech-related data is communicated using TLS protocols to ensure end-to-end security and HIPAA-compliance. To use this solution, a registration to the Nuance Health Platform is required. The Nuance Healthcare solution release includes some documentation.
- ***Supported languages:*** English.

- ***Pricing:*** 2200 $ per clinical.
- ***Useful link:*** https://www.nuancehealthcaredeveloper.com/public/index.php

o Microsoft Speech Platform:
- The Microsoft Speech Platform is a product from Microsoft designed to allow the authoring and deployment of IVR applications incorporating Speech Recognition, Speech Synthesis and DTMF. The Microsoft Speech Platform supports over than 26 languages and dialects and its release includes documentation.
- ***Supported languages:*** English, Danish, Swedish, Polish, French, German, Spanish, Finnish, Italian, Japanese, Korean, Norwegian, Dutch, Portuguese, Russian and Chinese. Multiple Dialects are supported.
- ***Pricing:*** Free.
- ***Useful link:*** https://msdn.microsoft.com/en-us/library/office/hh361572%28v=office.14%29.aspx

o Lexix:
- Lexix is a dialog-based Speech Recognition System from Adacel, an American company. It offers high accuracy in a performance-optimized system directly targeted for simulation and voice command markets. Its release includes limited documentation.
- ***Supported languages:*** English.
- ***Pricing:*** On-demand.
- ***Useful link: http://www.lexix.com***

o Alexa Voice Services:
- Alexa Voice services is cloud speech-recognition service from Amazon which uses Amazon Echo. Raspberry pi enables Alexa Voice by using a Java Client (running on Raspberry Pi). Raspberry Pi known as the best voice recognition systems that uses Google Voice and speech API as well as Google translator. The Alexa Voice Service (AVS) that allows user to ask general knowledge questions, set times and alarm, query Wikipedia and let the users query will be sent to Wolfram Alpha for solving. All communication between the customer, website, mobile app and login with the amazon must use HTTPS.
  Alexa voice Services and Google Voice Interaction API have similar functionality. It enables launching an application and make an intent through their systems. Alexa can provide a set of built-in Skills and capabilities such as command dialogue for user to have smart home. To use AV the users, need to have a button to activate microphone (push to talk) or using a spoken word to trigger activation of services.
  The developers may implement their own solutions with help of sample codes that Alexa Voice Service provides through Java reference implementation. Authorizing the sample app with website or mobile apps are: Node.js, Android, iOS.
  Alexa Skills Kit (ASK) allows developers to add functionalities and set of built-in smart home capabilities. The API taps into Amazon's standardized language model with no need to build a voice interaction model for any smart skill. The API has skill adaptor with means to discover and control commands from Alexa to a device control cloud.
- ***Supported languages:*** English.
- ***Pricing:*** Free.

- ***Useful link:*** ***https://developer.amazon.com/public/solutions/alexa/alexa-voice-service***

13.2 Technologies and Open Frameworks

In our market analysis, we identified many open source speech recognition and speech synthesis solutions. We will describe them in this section.

- **Open-Source speech recognition engines:**
  - Google Voice API:
    - Cloud speech API allows converting of audio to text within their own apps. The API is free and can be used by developers. The API available a number of functions. The API provides automatic speech recognition by learning, networks computers. However, it has unparalleled accuracy, and the learning computers become more accurate over time by using the API more with people. The vocabulary of Google speech API is recognized as extensive Nuance mobile SDK that covers 40 languages. It supports voice -based commands also.

      Google Voice API can accept either real-time speech or a complete audio file streaming API instead of RESTful once. Google API relies on Google's Pub/Sub streaming API technology as a global service for real-time and reliable messaging and streaming data that allows users to receive messages between independent applications. It is possible to leverage Cloud Pub/Sub's flexibility to decouple system and components hosted on Google Cloud Platform or elsewhere on the internet. These services allow delivery at low latency with on-demand scalability to 1 million message per second and beyond. The Cloud Google Pub/Sub provides push and pull delivery for quick integration with systems hosted on the Google Cloud Platform whether it requests, one- to- one, one -to- many or many -to- many communication with push and pull delivery. Google speech API does not provide natural language processing either. In addition, there are some security concern for Google Speech Recognition API as all of the data will go via Google and whoever else might be listening. The entire page will have access to the output of the audio capture and the data from the instance could be read. However, an HTTPS Web Application could start listening any time after the access has been approved by the user.
    - ***Supported languages:*** English, Romanian, Danish, Swedish, Polish, French, Afrikaans, Indonesian, Malay, Spanish, Czech, German, Filipino, Croatian, Icelandic, Italian, Lithuanian, Hungarian, Dutch, Norwegian, Portuguese, Slovak, Slovenian, Finnish, Vietnamese, Turkish, Greek, Bulgarian, Russian, Serbian, Hebrew, Ukrainian, Arabic, Korean, Mandarin-Chinese and Japanese. Multiple Dialects are supported.
    - ***Pricing:*** Free version is limited to 50 requests by day up to 60 minutes by month. To bypass limit, a paid version is required and a 0.006 $ / 15 seconds fee will be applied.
    - ***Useful link:*** https://cloud.google.com/speech

  - Hidden Markov Model Toolkit:
    - Hidden Markov Model Toolkit (HTK) was originally developed at Cambridge University (Speech Vision and Robotics Group of the Cambridge University Engineering Department – CUED, UK). In 1995, HTK passed to Entropic Research

Laboratory Inc. In 1999, HTK passed to Microsoft which gave HTK back to Cambridge In 2000, who has been distributing HTK free of charge since then. HTK is in use at hundreds of sites worldwide. HTK is primarily used for speech recognition research but it has been used, also for other applications including research into speech synthesis, character recognition and DNA sequencing. It consists of a set of library modules and tools available in C source form, which provide sophisticated facilities for speech analysis, HMM training, testing and results analysis. The HTK release includes extensive documentation and examples.

- ***Pricing:*** Free.
- ***Useful link:*** http://htk.eng.cam.ac.uk

- Julius:
  - Julius has been developed as a research software for Japanese LVCSR since 1997, and the work was continued under IPA Japanese dictation toolkit project (1997-2000), Continuous Speech Recognition Consortium, Japan (CSRC) (2000-2003) and currently Interactive Speech Technology Consortium (ISTC). Julius is a high-performance, two-pass large vocabulary continuous speech recognition (LVCSR) decoder software for speech-related researchers and developers. To run the Julius recognizer, a language model and an acoustic model are needed for each language. Julius is only distributed with the Japanese language and acoustic models but we can create and integrate an English acoustic models to be used in the Julius speech recognition software. Together with source codes, Julius is distributed with open license. Its release includes documentation and examples.
  - ***Supported language:*** Japanese.
  - ***Pricing:*** Free.
  - ***Useful link:*** http://julius.osdn.jp/en_index.php

- Cmusphinx:
  - Cmusphinx, or Sphinx in short, is the general term to describe a group of speech recognition systems developed at Carnegie Mellon University (USA). These include a series of speech recognizers (Sphinx 2 - 4) and an acoustic model trainer (SphinxTrain). It is in use in many projects (commercial or not) worldwide. CMUSphinx itself is language-independent, so it can recognize any language, but it requires an acoustic model and a language model for each language. Cmusphinx provide 11 pre-built language models. The Sphinx release includes extensive documentation.
  - ***Pre-built language models:*** English, French, Spanish, Dutch, Italian, German, Spanish, Mandarin-Chinese, Hindi, Kazakh and Russian.
  - ***Pricing:*** Free.
  - ***Useful link:*** http://cmusphinx.sourceforge.net

- Kaldi:

- Kaldi began its existence in the 2009 Johns Hopkins University (USA) workshop. It was developed by many researchers which were partially supported during this time by Czech Ministry of Trade and Commerce project no. FR-TI1/034, Grant Agency of Czech Republic project no. 102/08/0707, and Czech Ministry of Education project no. MSM0021630528. One of the researchers was partially supported by the European Community's Seventh Framework Program under grant agreement number 213850 (SCALE). Kaldi is a toolkit for speech recognition written in C++ and licensed under the Apache License v2.0. Its release includes documentation.
- ***Supported language:*** English.
- ***Pricing:*** Free.
- ***Useful link:*** http://kaldi-asr.org

- Api.ai:
  - Api.ai is an American company, based in Palo Alto, California. It is the company behind Assistant, a first of its kind conversational assistant app created in 2010. Api.ai provides developers and companies with the advanced tools they need to build voice interfaces for apps and hardware device. The Api.ai platform lets developers seamlessly integrate intelligent voice command systems into their products to create consumer-friendly voice-enabled user interfaces. This solution is limited to 12 languages and dialects. Its release includes documentation and examples.
  - ***Supported language:*** English, French, Chinese, Dutch, German, Italian, Japanese, Korean, Portuguese, Russian, Spanish and Ukrainian.
  - ***Pricing:*** Free, but if Api.ai is used by an enterprise, a request for permit should be submitted, charges may be applied depending on case.
  - ***Useful link:*** https://api.ai

- Wit.ai:
  - Wit.ai is an American company, based in Palo Alto, California. Wit.ai provides developers and companies with the advanced tools they need to build voice interfaces for apps and hardware device. Wit.ai support more than 48 languages and dialects. Its release includes documentation and examples.
  - ***Supported languages:*** English, Romanian, Danish, Swedish, Polish, French, Albanian, Arabic, Azerbaijani, Bengali, Bosnian, Bulgarian, Burmese, Chinese, Croatian, Czech, Dutch, Estonian, Finnish, Georgian, German, Greek, Hebrew, Hindi, Hungarian, Icelandic, Indonesian, Italian, Japanese, Korean, Latin, Lithuanian, Macedonian, Malay, Norwegian, Persian, Portuguese, Russian, Serbian, Slovak, Slovenian, Spanish, Swahili, Tagalog, Tamil, Thai, Turkish, Ukrainian and Vietnamese.
  - ***Pricing:*** Free.
  - ***Useful link:*** https://wit.ai

- Jasper:
  - Jasper was developed by Charles Marsh & Shubhro Saha (USA). It is an open source platform for developing, voice-controlled applications. It relies on CMUSphinx for voice recognition. Jasper support the English language but it can be customized

for other languages. Jasper require a Raspberry Pi 2.0 Model B (512MB Linux System, Price 27 US $) board to be integrated into the system. Its release includes documentation.

- ***Supported language:*** English.
- ***Pricing:*** Free.
- ***Useful link:*** http://jasperproject.github.io

- assistant.ai:
  - A highly customizable talking smartphone personal assistant. It performs tasks, answers questions, notifies about important events. This solution is offered by Api.ai. The assistant.ai release includes some documentation.
  - ***Supported language:*** English.
  - **Pricing:** Free.
  - ***Useful link:*** ***https://assistant.ai***
- Ispeech:
  - Ispeech is a high quality text to speech and speech recognition solution offered by Ispeech, which is an American based company. It supports more than 20 languages and dialects. The Ispeech release includes some documentation.
  - ***Supported languages:*** English, Danish, Swedish, French, Spanish, Chinese, Japanese, Korean, Portuguese, Czech, Finnish, Italian, Turkish, Greek, German, Russian and Arabic. Multiple Dialects are supported.
  - ***Pricing:*** Free for Mobile. On-demand for Web.
  - ***Useful link:*** ***http://www.ispeech.org***

- Other open-source systems and kits:
  - Segmental Conditional Random Field Toolkit for Speech Recognition,
  - Improved ATROS,
  - RWTH Aachen Automatic Speech Recognition System,
  - idiap's Juicer,
  - SRI International's Decipher,
  - SHoUT speech recognition toolkit.

  They are not as widespread in the community or as easy available like the ones that preceded this subcategory.

- **Open-Source speech synthesizer solutions:**
  - eSpeak:
    - eSpeak is an open source speech synthesizer software written in C. It uses a "formant synthesis" method. This allows many languages to be provided clear in a small size. The speech can be used at high speeds, but is not as natural or smooth as larger synthesizers which are based on human speech recordings. The eSpeak support English and other 50 languages and its release includes documentation.
    - ***Pricing:*** Free.
    - ***Useful link:*** ***http://espeak.sourceforge.net***
  - MARY Text-to-Speech System:

- MaryTTS is a German open-source, multilingual Text-to-Speech Synthesis platform written in Java. Its release includes documentation.
- ***Pricing:*** Free.
- ***Useful link:*** ***http://mary.dfki.de***

- Festvox:
  - Developed by Carnegie Mellon University an American University. It aims to make the building of new synthetic voices more systemic and better documented. The Festvox release includes documentation.
  - ***Pricing:*** Free.
  - ***Useful link:*** ***http://festvox.org/***
- HDecode:
  - It is an HTK extension. It makes some modifications to the HTK. Its release includes some documentation.
  - ***Pricing:*** Free.
  - ***Useful link:*** ***http://htk.eng.cam.ac.uk/extensions***

- **Open-Source speech corpus:**
  - VoxForge:
    - It is a "Speech Audio files and text transcriptions" Databases which contains multiple languages - Speech Audio files.
    - ***Pricing:*** Free.
    - ***Useful link:*** http://www.voxforge.org

13.3 Standards

There are different standards that refers to standardized the voice interactions between the machines and its users.

The VoiceXML is a standard for specifying interactive media and voice dialogs between humans and computers developed by the World Wide Web Consortium (W3C), the document format is based on Extensible Markup Language (XML). It integrates a suite of independent standards:

- Speech Grammar Recognition Specification (SRGS): a document language that specify the words and patterns of words to be listened for by a speech recognizer.
- Semantic Interpretation for Speech Recognition (SISR): a document format that represents annotations to grammar rules. It is used to extract the semantic results of a recognition;
- Pronunciation Lexicon Specification (PLS): a representation of phonetic information that will be used during speech recognition and synthesis;
- Speech Synthesis Markup Language (SSML): a markup language for rendering a combination of pre-recorded speech, synthetic speech, and music.

The International Organization for Standardization published multiple standards that refers to the vocal interaction between humans and machines such as: ISO/IEC 30122-1 that defines general guidance and a framework for the essential voice commands, ISO/IEC 30122-2 that provides technical criterions and test methods of voice commands and its speech recognition engine, ISO/IEC 30122-3 that provides requirements and recommendations regarding the multilingual voice commands, and ISO/IEC 30122-4 that defines supplementary procedural information, requirements and criteria that apply to a collection of voice command.

13.4 Summary and Conclusions

Traditional human-machine interfaces were always a barrier between the elderly people and any new device. Elderly people prefer to use easy and natural interactions, therefore voice interface should be a principal part of any multi-modal Interface.

From the provided solutions it can be seen that the majority of solutions are US based products. It can be seen that North America is dominating the market in Speech recognition and speech synthesis solutions.

On the other hand, Europe is implementing several strategies to keep up with the market demands and invests in research in this area.

However, the current review allows us to analyze the available solutions (both open source and commercial), to identify what are their functionalities, and to determine, later if exist, which solution will fit better to our needs.

The general impression is that some of the presented solutions can be integrated into our interface to allow access to the CAMI functionalities through vocal commands and to obtain voice output. However, we should clearly identify some factors before deciding:

- What will be the Voice inputs in our project? Will they be determined voice commands or any speech?
- What will be the Voice outputs? Will they be determined outputs or should the system be able to engage into a conversation?
- We should, also take in consideration the languages that we will deal with, and the location of the stored date (local, Cloud...).

14 Home and environment management

This section starts by presenting existing market solutions that can be used for the home and environment management that is envisaged in the CAMI framework. Then, it studies the solution that was developed in another Ambient Assisted Living (AAL) project, namely the "Networked InfrasTructure for Innovative home Care Solutions (NITICS[72])" as this NITICS solution dealt also with home and environment management for elderly people. Comparing the features of the proposed solutions will lead to identifying which one would fulfill better the CAMI expected end-user requirements in the home and environment management domain, such that it could be suited for the CAMI platform.

14.1 Existing market solutions

Home and environment monitoring within inCASA platform required development i.e. sensor measurement. (see Figure 35).

1. Habits monitoring to build up personalized profile
2. Monitoring of health conditions by using of medical devices (Blood pressure, Blood glucose, SPO2, etc).
3. Home automation support to improve quality of life
4. Alert management(see 6.1)

[72] http://

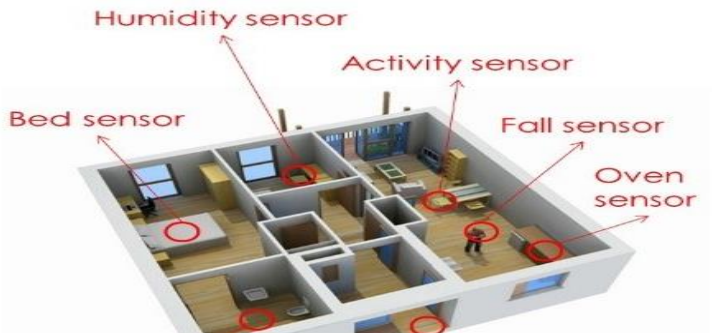


Figure 35. Home monitoring- inCASA

All measurements captured through using of Activity Hubs uses local installation (LAN) as a gateway that located somewhere at home of the elderly. The communication protocol that used with hub and client was based on ZigBee, EnOcean and wireless M-Bus. (See Table 7)

Sensor	Technology	Size	Min	Max	Comment
Temperature	ZigBee	16 bit	0x0000 →0.00°C	0xFFFF →655.35°C	0.01°C per step
Humidity	ZigBee	16 bit	0x0500 →5.00%	0x251C →95.00%	0.01% per step
Motion	ZigBee	8 bit	0x00 → no activity	0x01 → activity	Current configuration has 30s pause after each activation
Tampering	ZigBee	8 bit	0x01 → tampering alert		Contact when opening housing, alternative use
Flood	ZigBee	8 bit	0x30 → no alert, 0x31 → flood alert,		Can also be configured to cause alert when dry
Door	ZigBee	8 bit	0x30 → door closed, 0x31 → door open,		
Chair sensor	EnOcean	8 bit	0x00 → not occupied	0x10 → occupied	Binary information
Light switch	EnOcean	8 bit	0x00 → Button released	0x10 → Button pressed	Binary information, multiple information possible if necessary
Presence / ID	Wireless M-Bus	8 bit	0x00 → Person absent	0x01 → Person present	ID sensor in range is used.
Distance / Attenuation	Wireless M-Bus	8 bit	0x00 → weak signal	0xFF → strong signal	ID sensor RSSI is used.
Fall sensor	Wireless M-Bus	8 bit	0x01 → fall alert		
Activity sensor	Wireless M-Bus	8 bit	0x00 → no activity	0xFF → strong activity	Can be used to check if the ID sensor is worn

Table 7: Sensor Value interpretation

LinkWatch Social Care solution is another user friendly solution that makes the elderly people with chronic condition health stay in their home. LinkWatch is developed based on new technologies and software development kit which enable both health and environmental monitoring to elderly people. The services provides feedback on physiological measurements such as blood pressure , blood glucose, weight and even fall detection through sensors (Table 8).

Tobacco Smoke			Floor Sensor		
Window Sensor			Home Control		
Smart Plug Sensor			Liquid Intake		
Movement Sensor					
Wet Sensor					
Bed/Chair Sensor					

Table 8: LinkWatch/ SocialCare- monitoring & communication protocol

14.2 Technologies and Open Frameworks

The inCASA's services support patients/ elderly people with chronic condition health.

As such, the inCASA Remote Monitoring Device implementation constitutes the next required step in the platform development, i.e. sensor measurements. It ensures that data is enquired properly through the Remote Monitoring Devices (sensors/inputs using BlueTooth, Wi-Fi, ZigBee and many more), is correctly gathered and is finally made available to the Core Monitoring System. Telecare data is collected from the environment monitoring system installed in the senior's home and composed by the following sensor types: temperature, humidity, motion, tampering, flooding, door, sitting, light, presence, distance, fall and activity (wireless motion/contact sensors). Also, collected medical data related to pre-existing monitoring system (e.g. SARA client) will be channeled and managed through the base station. Furthermore, the data collected by the base station should be continuously and/or periodically sent to the service provider in order to create a strived behavior model of the person (via the learning system) and to generate reports and/or alerts in case of anomalies.

LinkWatch Social care services provides fall detection also using of fall, movements sensors, activity measurements and tobacco detector.

The NITICS solution

In the following, we describe the solution that is proposed in the AALNITICS as given in Deliverable D3.2[73]. The NITICS envisaged services include the following:

- Health monitoring devices integration - blood pressure, pulse rate, weight, glucose, temperature, remote medical visit
- Home monitoring

[73] Deliverable D3.2 "System architecture and test profiles", AAL project Networked InfrasTructure for Innovative home Care Solutions (NITICS), January 2014.

- Fall detection
- Environment (water, fire, gas, other sensors for domestic parameters)
- Safety check
- An automatic door lock
- Dynamic movements (physical activity)

- Reminders (voice, text, picture/image)
- In-door localisation (mobility pattern).

Such services are implemented in the NITICS system framework providing service control, acquiring data from numerous sensors, devices and subsystems and communicating with caregivers and caretakers. From the hardware architecture point of view the local system implementation is centralized i.e. all information originated from the elderly and local devices will be passed to the NITICS Core Subsystem through the gateway.

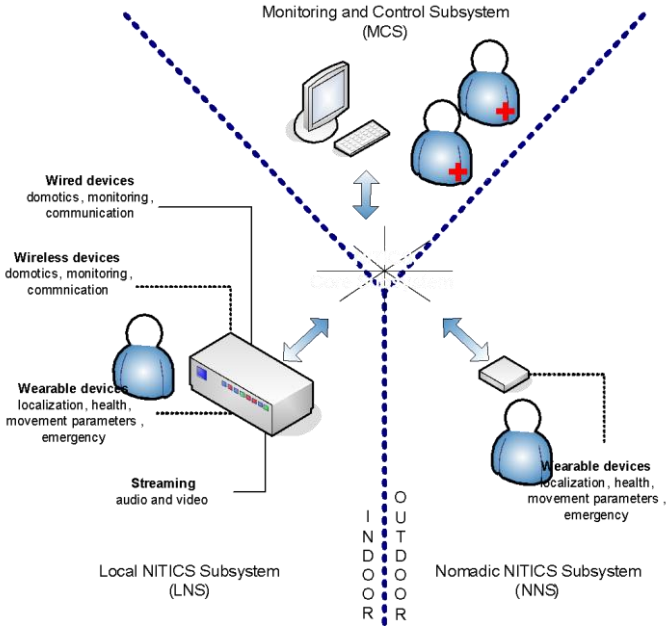


Figure 36: NITICS devices and services

There are two basic gateway implementations. The first one is intended for home installation. The second one can be also used outdoors. It can be worn by the elderly and provides wireless transmission of data from wearable devices to the NITICS Core Subsystem.

NITICS subsystems

The NITICS system is composed of four subsystems (**Error! Reference source not found.**): the (1) *NITICS Core Subsystem (NCS)* is a component that carries out system control and database functions. It stores user profiles and results of measurements. It is responsible for implementation of NITICS services. Measurement and user data are delivered by subsystems. The (2) *Local NITICS Subsystem (LNS)* comprises devices installed in caretaker's home and communicating with the NCS via single local fixed (LAN) or wireless (WLAN, cellular) link. The LNS controls devices and sensors, acquires measurement results and transfers them to the NCS. Similar functions are carried out by a (3) *Nomadic NITICS Subsystem (NNS)*, but the components of the NNS are worn by the caretaker. It enables also

outdoor operation in places not covered by the LNS. The (4) *Monitoring and Control Subsystem (MCS)* comprises equipment used by caregivers and system management staff. Its functions include: service control, service data management, presentation of data to caregivers. NCC and MCSs are referred as a NITICS framework.

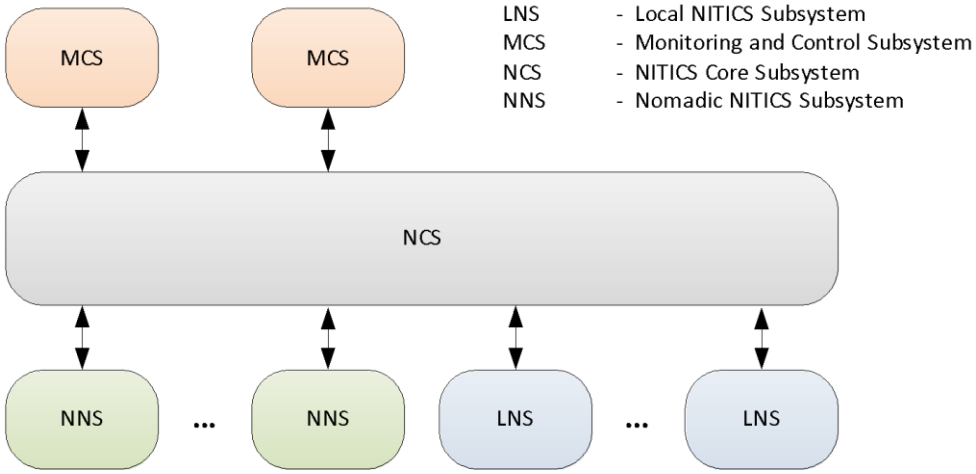


Figure 37: NITICS hardware architecture

The NITICS Core Subsystem

The NITICS core subsystem consists in software application server and applications that can be hosted on a single computer or in cloud.

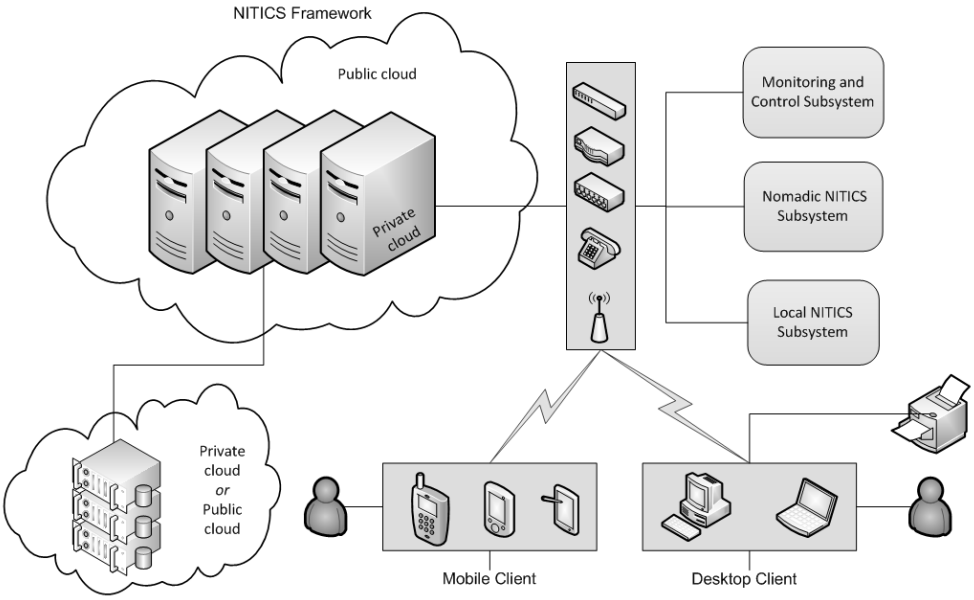


Figure 38: NITICS Core and Monitoring and Control Subsystems

Local NITICS Subsystem

The NITICS services are based on information obtained from different sensors and subsystems located at the elderly home. Some of them also use devices providing bidirectional communication channels.

The communication between all NITICS devices are mainly performed with wireless means. The general view of the system communications capabilities is shown in *Figure 39*.

The main point in the architecture is a gateway collecting data from other devices. When devices are equipped with wired interfaces or wireless interfaces with limited range (not covered by the gateway) they can be reached with collectors extending the range of gateway operation.

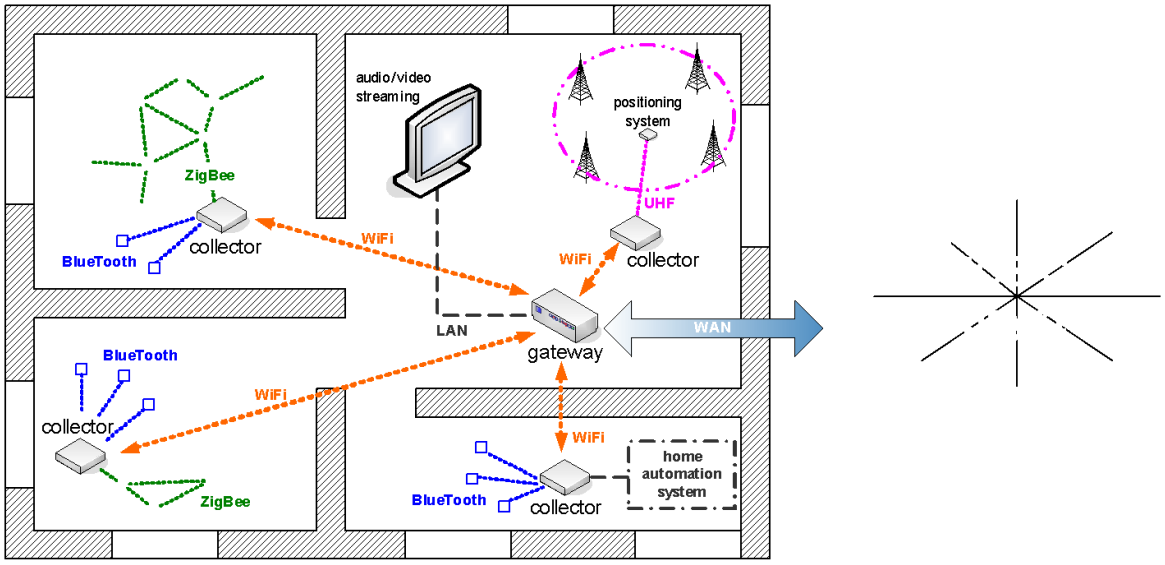


Figure 39: Communications between NITICS platform devices at the elderly home

The Local NITICS subsystem (LNS) comprises all devices supporting NITICS platform implementation at the elderly home. LNS functional architecture is presented in Figure 40.

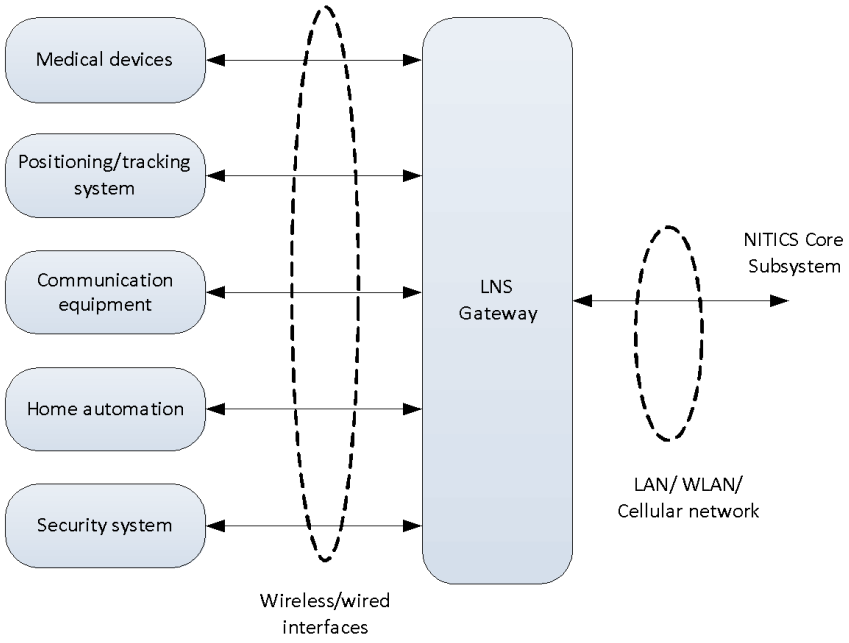


Figure 40: Local NITICS Subsystem functional architecture

Depending on the scenario, the LNS integrates wired devices as well as wireless devices. The former category involves demotic sensors, home automation systems (e.g. doors and windows actuators) as well as communication and monitoring devices that work with standard wired protocols such as Ethernet, RS485, X-10, or field buses (e.g. CAN). The latter category refers to all the wireless protocol based devices. This category is the largest one and includes wearable sensors, wireless communication modules, Smartphone, wireless sensor networks, etc.

Subsets of the wireless sensors are the wearable sensors. In this family one can find the health monitoring sensors, as well as the localization devices, the IMU sensors (e.g. as accelerometers). Some of these sensors support Bluetooth, but also wired digital protocols (SPI, I2C) and analog data acquisition have to be considered in order to support the widest range of sensor as possible.

Other categories of devices that NITICS platform should support are medical devices and specialized monitoring and communication devices that work either with standard or proprietary protocols.

The NITICS LNS Gateway (shown in Figure 41) has the following features:

- Linux based
- WiFi access point
- WiFi or Ethernet client connection
- Optional 3G/4G data connection
- Support for RF/UWB positioning algorithms.

Figure 41: NITICS LNS Gateway

The NITICS LNS home automation approach (illustrated in Figure 42) has the following features:

- Z-Wave coordinator for testing
- Software framework for data connection to the NITICS server
- Software adaptation layer for communication with NITICS collector and mobile devices.

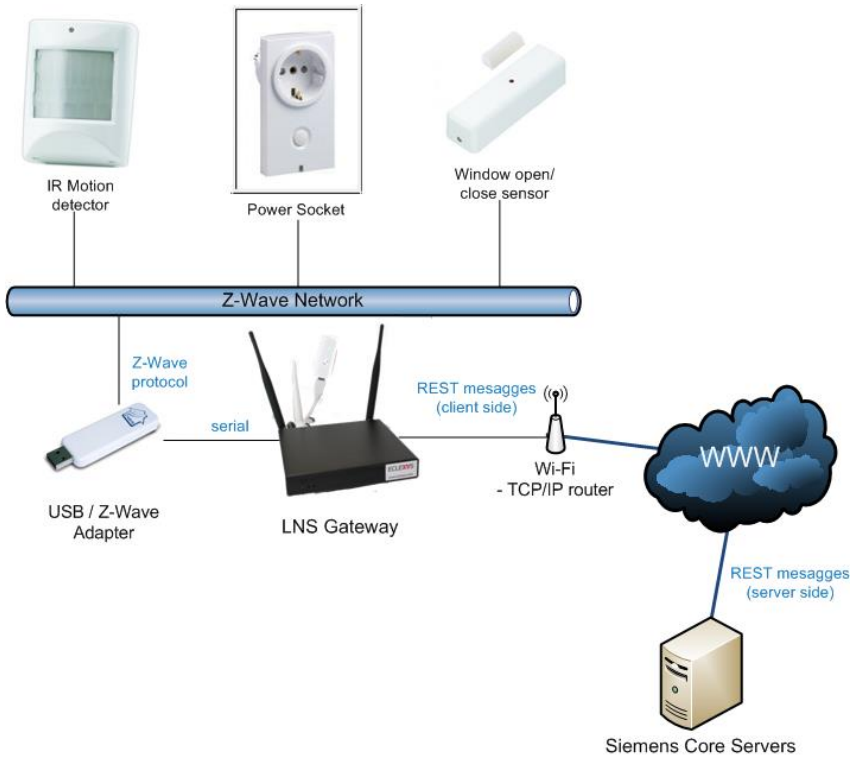


Figure 42: NITICS LNS home automation

14.3 Standards

The LinkSmart middleware was extended to include communication with adjacent embedded solutions such as the Activity Hub but also directly to Continua as well as non-Continua certified commercial devices. This makes the inCASA Home Gateway competitively flexible and extendable for future deployments. The Home Gateway has since the start of the inCASA project been included in two national eHealth projects in Denmark and the aim is to enhance the gateway with more functionality by addressing the technology for future project proposals. It is also being exploited as a Connected Health kit in Sweden where developers are free to contribute by adding more devices and other embedded solutions into its handling. The HL7Parser is transparent for any known device specialization supported by the IEEE 11073 nomenclature and is accessible for vendors seeking to extend their existing solutions into HL7 compatibility.

LinkWatch is developed based on inCASA, REACTION and LinkSmart technologies (see 6.2, 7.2 &7.3.1).

14.4 Summary and Conclusions

Despite significant impact on health care outcomes using of new technologies for information provision, there is still absence of tools to support specific needs of specific health condition such stroke patients or there are risks for not fully usefulness stroke patients[74] . However, open source platforms have brought opportunities to utilize e-health architectures by taking up varieties of

[74] Davoody N, Woldemariam Y, Hägglung M," Stroke patients' post-discharge information needs and actual information provision," Short Communication in Medical Informatics in Europe, Istanbul , Turkey ,2014.

components/applications that have already been developed in different environment but they still are transferrable to another platform, such as LinkWatch application. Thus, it is high recommended to cover the needs of CAMI's use cases.

The NITICS solution that is presented in Section 0 presents interesting features for the CAMI framework, namely the NITICS LNS Gateway which will allow the integration of most of the elderly oriented services that can be requested by the CAMI end users.

15 Conclusions

In this document, we have overviewed and analyzed the state-of-the-art and state-of-practice of technologies and developments that encompass robotic telepresence, wearable sensors, devices for health monitoring, fall detection, and smart home management solutions that are able to assist older adults in managing their daily lives. The analysis has been done along several criteria, out of which functionality, extensibility, user-friendliness and price have been prioritized.

Based on our findings, we have selected a number of candidate solutions, of each category, which can be used further in the integrated CAMI ecosystem. We present our choices in Table 9. Note that the choices are not final, the candidates in the table are potential technologies, methods and products that have emerged as suitable from the functionality, extensibility, price and user-friendliness points of view. However, for the CAMI ecosystem to function seamlessly and be tailored both to the level of individual preferences and necessities, as well as to the combination of health monitoring devices required, we need to design an integrated architectural solution that will allow us to extend existing solutions and develop new modules in an interoperable way.

Type	Solution Candidate(s) for CAMI	End-user requirements that can be fulfilled and usage in CAMI
Health monitoring	Any, see Section 5	Monitoring of physiological parameters: weight, blood pressure, pulse rate, ECG, oxygen saturation, segmental body composition, physical activity, and blood glucose.
Fall alarm	Tunstall fall detection sensor and one developed in CAMI; LinkSmart technology	Detecting a fall and sending an alarm, or predicting an increased risk of falling
Report & communication	OpenTele, OpenCare OpenEHR for inspiration, along with the open HL7 FHIR, and IEEE/ISO 11073 protocols for data communication of healthcare data.	Communication of events and measurements, such as falls, night wandering, leaving home, medical data, blood pressure, weight, saturation, glucose, and similar data types.
Supervised physical exercises	Kinect solutions	Tracking body movements and reactions via exergames
Personalized program management	Semantic Web Technologies (e.g. ontology modeling, quad storage engines, SPARQL query endpoints, description logic based reasoners).	Semantic Web Technologies will be used to represent, store, retrieve and reason about (i.e. filter, aggregate, use rules to deduce) information regarding

	UniversAAL development framework or custom web-based (e.g. RESTful) platform.	planned/performed daily activities, medication and exercise schedule, etc. Main advantage of semantic web technologies is high degree of flexibility. UniversAAL or the custom web-based platform will be used for information flow implementation (e.g. acquisition, query, reminder triggering). Reliance on an AAL middleware or a RESTful web service provides strong support for modularity, which is an essential aspect of desired CAMI functionality.
Telepresence	Jazz by Gostai (ROS compatible), Kompai (Microsoft Robotics Developer Studio compatible), Turtlebot (ROS compatible), Tiago iron (ROS compatible, autonomous navigation)	Video conferencing equipment, mobile robot devices, voice messaging
Intelligent collaborators, reminders	inCASA framework	Supporting patients with their diary, medication, calendar and appointments with their caregivers and their referrals
Vocal interfaces	Cmusphinx, VoxForge etc.	Voice interface in CAMI, speech recognition, speech synthesis.
Home & env. management	NITICS LNS Gateway	Used for Home monitoring - Environment (water, fire, gas, other sensors for domestic parameters)$ - Safety check - An automatic door lock - Dynamic movements (physical activity) In-door localization (mobility pattern).

Table 9. Selected candidates deemed appropriate for integration in CAMI.