Wireless Pers Commun (2016) 87:1093–1111
DOI 10.1007/s11277-015-2779-2

eWALL: An Intelligent Caring Home Environment Offering Personalized Context-Aware Applications Based on Advanced Sensing

Sofoklis Kyriazakos[1] · Mihail Mihaylov[1] · Bayu Anggorojati[1] · Albena Mihovska[1] · Razvan Craciunescu[1,2] · Octavian Fratu[2] · Ramjee Prasad[1]

Published online: 28 May 2015

Abstract Independent living of senior citizens is one of the main challenges linked to the ageing population. Senior citizens may suffer from a number of diseases, including the decline in cardiopulmonary conditions, weaker muscle functions and a declined neuromuscular control of the movements, which result in a higher risk of fall and a higher vulnerability for cardiovascular and pulmonary diseases. With respect to cognitive functions, senior citizens may suffer from a decline of memory function, less ability to orientate and a declined ability to cope with complex situations. This is by itself a big societal challenge with impact in multiple sectors. In this paper we present an innovative ICT solution, named eWALL, that aims to address these challenges by means of an advanced ICT infrastructure and home sensing environment; thus differentiating from existing eHealth and eCare solutions. The system of eWALL will extend the state-of-the-art of Assistive Platforms and will significantly increase the independent living of seniors.

Keywords Caring home · eHealth · Advanced sensing · Personalized context-aware applications

1 Introduction

Independent living of senior citizens is one of the main challenges linked to the ageing population, due to the impact on: the life of the elderly people, the national health systems, the insurance companies, the relatives and the care-givers. Senior citizens may suffer from a number of diseases, including the decline in cardiopulmonary conditions with weaker

✉ Sofoklis Kyriazakos
sk@es.aau.dk

1 Center for TeleInfrastruktur, Aalborg University, 7A Frederik Bajers vej, 9220 Åalborg, Denmark

2 Telecommunication Department, Faculty of Electronics, Telecommunications and Information Tehnology, Spl. Independentei 313, 060042, Bucharest-6, Romania

muscle functions and a declined neuromuscular control of the movements, which result in a higher risk of fall and a higher vulnerability for cardiovascular and pulmonary diseases. With respect to cognitive functions, senior citizens may suffer from a decline of memory function, less ability to orientate and a declined ability to cope with complex situations. Mild dementia is another disease affecting this population, which requires either the institutionalization or the constant support from care-givers. When chronic conditions do occur simultaneously in the same individual, the resulting phenotype—whose complexity is augmented and increased by and with ageing—is so difficult to manage to represent the most serious challenge not only for independent living, but for the sustainability of health systems worldwide as well. There is, indeed, a large number of initiatives, products and services that aim to provide a robust strategy to face this challenge. Nevertheless proposed solutions are often non-sustainable. We take this as a challenge and in this paper we present a breakthrough innovation that we call "eWALL". eWALL will be an affordable, easy-to-install prefabricated wall that can be mounted on an existing wall and fade into the background all ICT technology needed to enable a number of services for the senior citizen. These services are grouped into the following categories: (a) risk management and home safety, (b) eHealth and (c) lifestyle management. By combining advanced perception and communication technologies with state-of-the-art presentation and interfacing mechanisms and by providing hassle-free coexistence of the elderly with technology, eWALL will open new horizons in the active ageing and independent living.

The paper is organized a follows; in Sect. 2 the eWALL concept is presented with focus on its major characteristics, i.e. Intelligent Caring Home Environment, Intelligent Decisions Support System, Lifestyle reasoners and management, Advanced Sensing, Personalization and Service bricks. In Sect. 3, services and applications of eWALL are discussed, focusing on three application categories, namely the Daily activity monitoring, the Daily functioning monitoring and the Healthcare support. Finally, in the last section of the paper we present the expected results, as it is an ongoing project, and the future work.

2 eWALL Concept

eWALL is a solution that provides a holistic infrastructure model supporting active ageing based on an interactive wall-mounted device. The context-aware closed-loop intelligent services are offered by means of a service oriented architecture (SOA). For that purpose we have introduced the concept of "service bricks" as the minimum functional service, resulting in context-awareness, personalization, high flexibility and auto-adaption to the patient needs. Under this framework, eWALL has developed advanced algorithms and techniques resulting in innovative solutions and will advance the state-of-the-art in the areas of intelligent networked sensors and personal health systems for remote management, treatment and rehabilitation of diseases, dedicated to seniors in order to achieve a high impact on activities of daily living, safety, mobility, social inclusion with seamless support in and outside the home. Among the objectives of the eWALL is the personalisation and adaptation to specific needs and preferences, with efficient data and context sharing between different required services and artefacts, the handling multi-user identification, auto configuration and calibration systems by personalised high usability user interactions and unobtrusive sensing.

The architecture of the eWALL approach is illustrated in Fig. 1. The services of the eWALL cloud are classified under horizontal and vertical services. Horizontal services consist of service bricks that enable the definition of a process, the personalization and

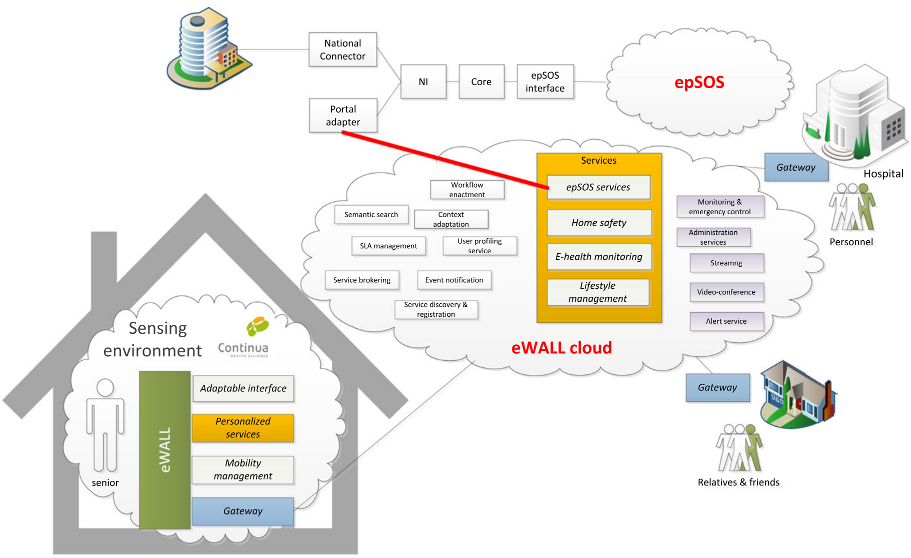

Fig. 1 The eWALL concept

adaptation of a vertical service. The vertical services are those developed for the eWALL system, either from medical service providers, or developers.

In the following sections, the major characteristics of eWALL will be presented, namely the Intelligent Caring Home Environment, the Intelligent Decisions Support System, the Lifestyle reasoners and management, the Advanced Sensing, the Personalization aspects and the novelty of the Service Bricks.

2.1 Intelligent Caring Home Environment

The intelligent Caring Home Environment is based on cloud and home infrastructure that is presented in Fig. 2. In this diagram, one can see eWall high level architecture along with the main building blocks [1]:

- eWALL Devices—responsible for all explicit (i.e. handled by presentation devices) and implicit [input (sensors) and output (actuator)] interaction with the end user in Sensing Environment. As mentioned, impliciset interaction is referring to the collection various data about the user and its environment from medical and environmental sensors and control of environment through actuators. Explicit interaction is referring to direct interaction with the user using audio/video devices and user interaction sensors.
- Home Sensing Middleware—responsible for connecting, configuring, querying and reporting data from and end user devices, for interconnection of Sensing Environment and eWALL Cloud, and basic data storage.
- Local Context Manager—It is responsible for handling low-level context data and processing, including indexing and adaptation, analysis of humans and non-A/V perception processing.
- Cloud Middleware—It is responsible for providing (1) all cloud communication infrastructure, including communication within different service components within the

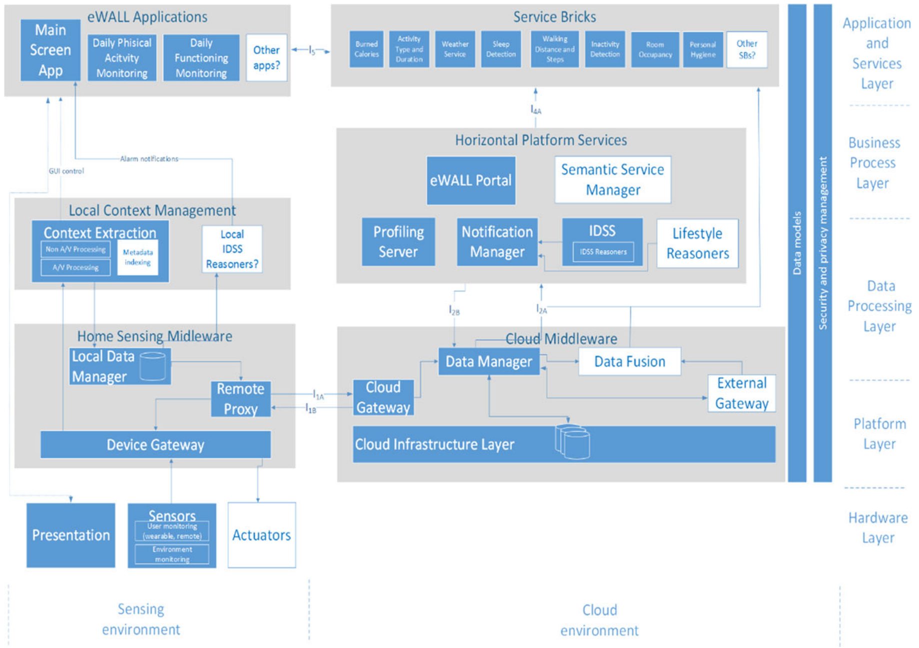

Fig. 2 The eWALL architecture as a basis for an Intelligent Caring Home Environment

cloud, but also communication with Sensing Environment, (2) data abstraction and all data handling in cloud (storing, retrieving, handling data integration from multiple sources etc.) taking into account privacy and security concerns, and (3) for hiding the heterogeneity and distribution of cloud hardware environment and management of physical resources and the provisioning of virtual resources—the service components that run in cloud just communicate with the Cloud Middleware and they may be unaware of the actual cloud hardware configuration that they are running on.

- Horizontal Platform Services—generic reusable set of services which ease the development of personalized services and applications, namely profiling, notification support, intelligent decision making, lifestyle reasoning provisioning and configuration.
- Service Bricks—provide a set of basic functions that can be used by the applications.
- eWALL Applications—build on top of Service Bricks that will include a range of lifestyle management, eHealth, home safety and automation applications.

2.2 Intelligent Decisions Support System

The intelligent caring home sense environment is mainly driven by the intelligent decision support system (IDSS), responsible for decision making processed and running on the eWall Cloud. The IDSS consumes data from various system sources classified as low level data (e.g. sensor date), medium level data (e.g. processed data from service bricks) from multiple sources and high level, semantically meaningful inferences [2]. The final envisioned IDSS will contain a large number of reasoners that work with the various types of data, perform different types of reasoning and support different end-user applications or higher level services [2].

In order to facilitate the development of the IDSS core functionality and each of the different reasoners separately, each component is a stand-alone, executable process in the eWALL cloud platform and is contained within its own Java Spring project. The IDSS component is a part of the horizontal eWall services in the Cloud and takes input, in common ontological form [3] from several other components e.g. Profiling server(for user related data), Service Bricks and Data Management component(for processed data). The output is communicated to the Notification Manager or any other Service Brick or eWall Application that requires data from the IDSS Reasoner.

2.3 Lifestyle Reasoners and Management

The Lifestyle Reasoners within eWALL are components that process and store long-term data that follows certain patterns or routines that define the lifestyle of the user. The aim of these components is to predict behavior and to detect (slow or fast) changes that might indicate a change in the user's health status. To do so, the lifestyle reasoners consume medium level data (e.g. processed data from service bricks) from multiple sources and derive semantically meaningful patterns [4].

Each reasoner in eWall requires input data and provides outcome, exposed through API for use of different applications or IDSS functionalities for triggering messages or personalization of the system. The reasoners gather constant updates of the environmental, user behavior and state observing sensors and make decisions about the short-, medium-, or long-term past.

Simple example for a reasoner in eWall is the Distribution of Physical Activity reasoners which falls into the Daily Physical Activity application category. Its functionalities are summarized as follows:

2.3.1 Reasoner Inputs

- Physical activity data from the home of the user.
- Current models of activity of the user.
- Activity goals from the formal caregivers.

2.3.2 Reasoner Outputs

- Activity vectors for hours of day, phases of day, days of week, weeks of year and months of year.
- Models of activity for hour of day, phase of day, day of week, week of year and month of year.
- Expected or unexpected (positively or negatively) activity in the past hour, phase of day, day, week, or month.
- Significant habit change.
- Daily goal completion.

2.3.3 Applications Served

- The data from the reasoner is used to provide long-term overviews of physical activity in the *Daily Physical Activity Application*. Data can also be used by the IDSS reasoners for Motivational Messages to send motivational messages about long term progress or to an automatic goal setting IDSS reasoner to automatically adjust personal goals.

Other reasoners are implemented for mood detection based on audio and visual perception sensors, off-bed intervals for sleep quality analysis, social interaction for social activities assessment and so on.

2.4 Advanced Sensing

The eWALL sensing devices are responsible for all explicit (i.e. handled by presentation devices) and implicit [input (sensors) and output (actuator)] interaction with the end user in Sensing Environment. As mentioned, implicit interaction is referring to the collection various data about the user and its environment from medical and environmental sensors and control of environment through actuators. Explicit interaction is referring to direct interaction with the user using audio/video devices and user interaction sensors. The advanced sensing in enabled from the eWALL systems in terms of:

- Cooperative operation of sensors and actuators;
- Coordination in the eWALL Cloud;
- Personalized services.

The costs and dimensions of sensor devices have been considerably reduced within the last decades, which allowed their expansion over various areas of activity, such as: house control, traffic control, logistics, security and surveillance, monitoring or healthcare [5].

One of the fields that generated a real interest from researchers but also from companies is the monitoring field. Through the wearable sensors or the environmental ones, different conclusions can be reached in what concerns the subject's health state or comfort at a certain moment in time. The most common sensors used to detect certain diseases of the patients are the one used to collect data regarding the temperature (the body temperature, as well as the environmental temperature), the arterial pressure, the glucose level, pulse, EEG, EKG. Such devices use sensors that are designed to detect electrical, optical, chemical genetic signals, and with the help of signal processing methods they are able to estimate the health state or the environmental conditions of the subject [6].

eWALL specifically focuses on the use of such sensors for the monitoring of the elderly, in order to achieve a longer life expectancy but also in order to increase comfort in their own homes. Also, the implementation of the eWALL project shall reduce the hospitalization period by providing continuous home monitoring of the patient. Monitoring can be achieved by using the sensor networks that send data through wired or wireless technologies. Thus, in the case of wired technologies, the connection can be made through RS 232, USB or Ethernet interfaces. In what concerns the connection to external devices using wireless technologies, the connection can be made through Bluetooth, ZigBee or Near Field Communications technologies [7]. One of the advantages of monitoring through wireless technologies is the fact that it allows subjects to lead a normal everyday life and in this way the data is collected in real time. This type of monitoring must take into consideration the fact that the transmission power must be lower in order to allow a longer life span of the sensors [7].

A simple system architecture for wireless sensors is presented in Fig. 3. The sensors consist of: a sensing chip that enables the physiological or environmental sensing, a microcontroller that performs local processing, a buffer that stores data if the

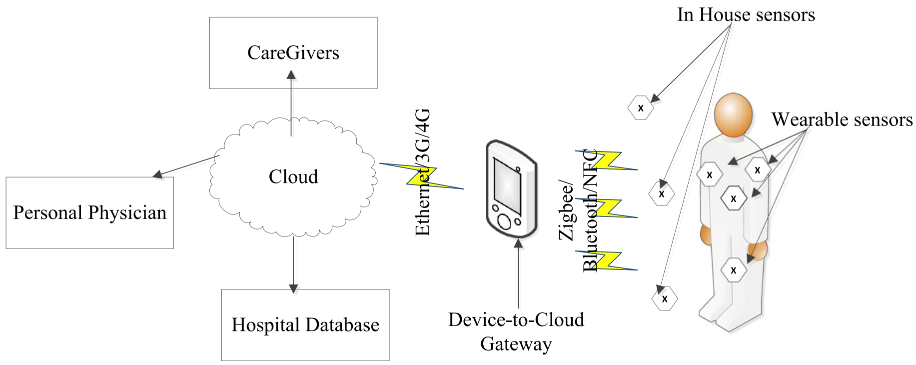

Fig. 3 eWall wireless sensor monitoring system

communication channel is busy, a communication transceiver and a power supply. The data from the sensors is transmitted to a local gateway or to the user personal device. Also the date is transmitted to the user hospital, physician and caregivers according to the data importance using a cloud computing infrastructure [8].

From the above mentioned technologies, within the Bluetooth technology, a master device (the network coordinator) only allows 7 slaves. Unlike the latter, the ZigBee technology is used for large-scale sensor networks, allowing up to 65,000 nodes [7]. For this reason, for a system that targets the monitoring of a higher number of sensors, such as the system to be implemented by the eWall projects, the ZigBee-type technology is a better candidate for the wireless transmission of data from sensors. Apart from the above mentioned advantage, the ZigBee technology has low power consumption (20–60mW) and can be implemented with lower costs. The data transmission rates can reach up to 250 kbps by using the de 2.4 GHz ISM band. ZigBee can operate, also, in the following radio bands: 868 MHz in Europe/915 MHz in USA and Australia. ZigBee uses Direct Sequence Spread Spectrum coding, a multiplexing technique where the transmitted signal occupies more bandwidth compared to the informational signal (see Wireless chapter) [7]. For modulation, it is used BPSK for 868/915 MHz and O-QPSK for 2.4 GHz. BPSK is a modulation technique that uses only the phases separated by 180° from each other, while O-QPSK uses four different values of the phase [7].

As shown in Table 1, the commune medical signals have low data rates, thus, the ZigBee technology is suitable for this type of technologies [9].

The sensors in eWALL devices capturing signals from the caring home: the environment and the users. Some are mounted at the home and its furniture, while others are wearable.

Table 1 Physiological signals data rates

Physiological signal	Data rate (kbps)
EKG	6
Respiratory rate	0.24
Oxygen saturation (SpO_2)	2.3
Blood pressure	1.2
Body temperature	0.0024

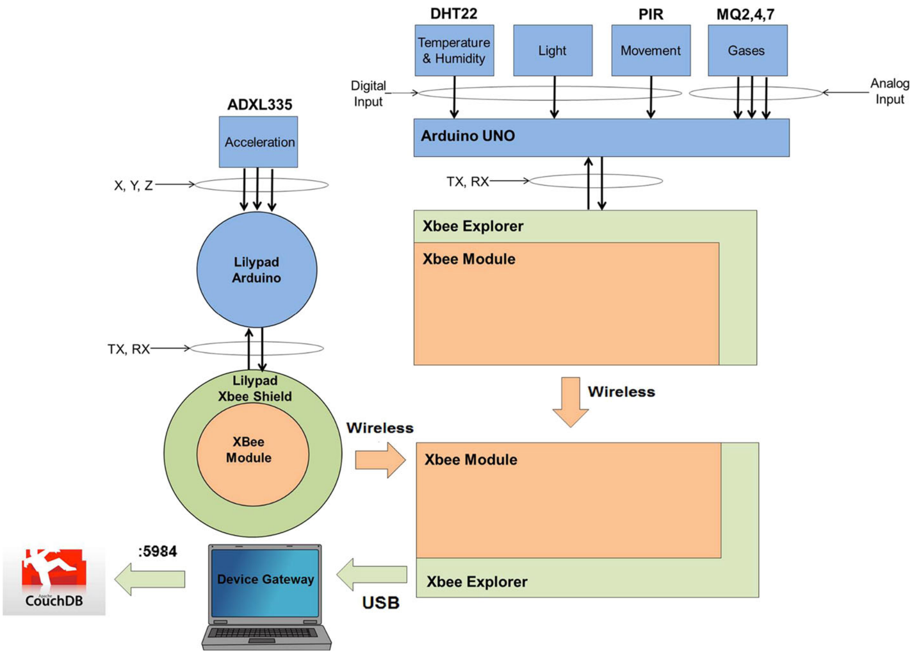

Fig. 4 eWall sensor system

In order to achieve homogeneity between multiple transmitting radio (environmental and wearable) modules is having them sending the same type of packet, so that its structure can be predictable and decoded in a similar manner [10].

Such an experiment was achieved having the environmental module (that uses Arduino Uno Microcontroller) and the wearable module (that uses a Lilypad Microcontroller) (Fig. 4) sending their data at once [10]. Therefore, our system can support a variety of microcontroller boards as long as, in terms of wireless communication, it makes use of the same technology (particularly, the ZigBee protocol) (Fig. 3). The packets were processed with minimum delay and we were able to distinguish between the different types of information that were being sent by means of the details specified in the configuration file.

The data sent to the home processing pc, is processed and sent to the local database, the CouchDB. This database was chosen because it can be used for accumulating, occasionally changing data, on which pre-defined queries are to be run. Also, CouchDB stores and serves JSON documents, and utilizes JavaScript to manipulate them during querying/validation via HTTP. This function is primary advantage since eWall platform utilizes Java as a main implementation language [11].

2.5 Personalization

A personalized healthcare might be a broader platform that includes different types of personas' biologic information that helps predict risks for disease or how a patient will respond to treatment. Referring to implementation of a context-aware healthcare home sensing environment, it could be assumed that such environment will enable personalized health care services provided at the patient's home. With introduction of such systems a reduction of the number of hospitalization cases and improvement in the results of medical treatment is expected. In addition patient will be involved in their care and will provide valuable statistical data, as a result of their detailed continuous observation. This will improve the knowledge of disease and health and our ability to treat disease. It will also allow the patient to better understand the treatment plans and gain confidence for following the caregivers' recommendations and therapies as they will be personalized for them.

In eWALL the personalization enables implementation of the eWall interaction concepts which depends on the type of the eWALL end-user and the context of use including: the environment setting, the task to be fulfilled and the device that supports the graphical user interface (GUI). According to the type of the personalized use, eWall addresses interaction concepts: for the primary user (elderly with chronic diseases and age related frailty) and from the secondary users (informal caregivers, visiting nurses and medical practitioners).

For the personalization of a physical exercise program for example, eWALL will have a set of different exercise types and levels of difficulty. The user is initially categorized under various physical and illness factors and then a personalized exercise scheme is proposed. After the patient completes a training, an assessment procedure based on user's feedback and body and environment sensors data is run. Statistical data for the performance might evaluated by the system itself or accessed by the caregivers and as a result the exercise program could be modified to address eventual changes in the patient physical state.

2.6 Service Bricks

The service bricks [12] in eWALL are specific components used as a fragment of the personalization approach. They take place in between the applications and the metadata stored in the cloud Data Management Block, and act as providers of specific aggregated data, after making some reasoning on the metadata. The different use cases applications get such aggregated data from the service bricks via JSON/REST over HTTP communication protocol. The metadata is provided to the Data Management Block from the home sensing environment, which collects raw signal processing information and translates them into higher level metadata.

Every service brick is packaged and deployed as a *Java Web Application Archive* [13] (war). This deployment strategy allows to leverage the benefits offered by *Java servlet containers*, which are standard, consolidated, enterprise-level runtime environments on which Java Web Applications (in our case the service bricks) can be deployed. Servlet containers provide high reliability and management features, which allow to launch, stop and deploy applications independently. This allows, just to cite an immediate benefit, for *hot deployment* of applications, which basically means that it is not necessary to stop the whole application server (hence, stopping the provisioning of the services running on it) just to deploy a new service brick or an updated version of an existing one, as presented in Fig. 5.

3 eWALL Services and Applications

The services and applications provided in eWALL platform are derived from the scenarios and uses cases specifically developed for particular eWALL target users, namely elderly users with age related impairments (ARI), chronic obstructive pulmonary disease patients

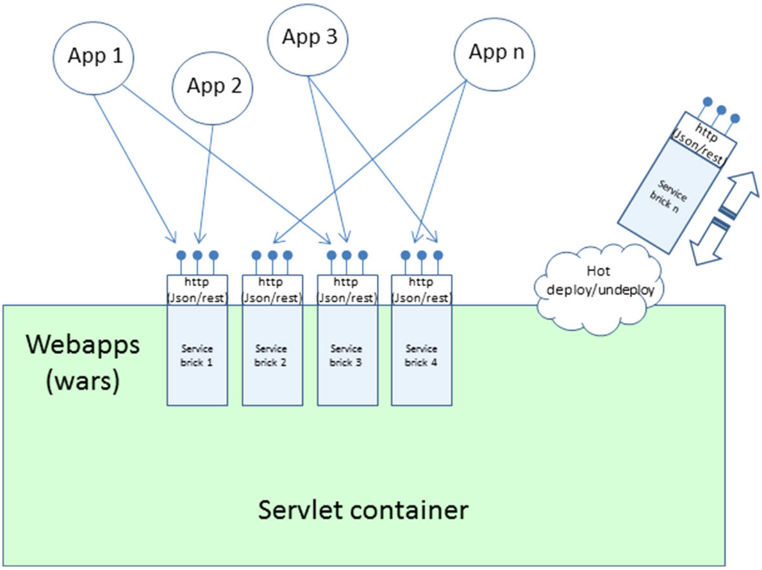

Fig. 5 Deployment of service-bricks

(COPD), and users suffering from mild dementia (MD). The use cases in eWALL are then mapped into three core eWALL application categories: *Daily Activity Monitoring*, *Daily Functioning Monitoring*, and *Healthcare Support*. The chosen application categories represent the key aspects of the proposed technology in the platform: mechanisms for self-therapy within the home eWALL installation of the primary user, monitoring of primary user's state of health and functioning capabilities, and enabling means of communication with informal and formal caregivers.

3.1 Application Category: Daily Activity Monitoring

The *Daily Activity Monitoring* application category describes a set of applications that monitor and guide the primary user towards a more active and consequently healthier lifestyle. These applications use on-body sensors, possibly combined with home installed sensors, and target functionalities inside and outside the eWALL home installation.

It includes all of the services/applications that deal with monitoring, displaying and coaching on daily physical activity behavior. This application is meant to monitor not only physical exercise (e.g. jogging, cycling) but also the activity spent in normal activities during the day (e.g. gardening, commuting, during household activities). The aim is to encourage physical activity taking into consideration the health condition and routines of the elderly. To do so, the activity coach can be used in combination with the application category "Daily Functioning Monitoring" in order to provide relevant feedback/suggestions based on user's routine and environment.

Within this application category are two sub-applications, namely Amount of Activity and Goal Setting & Motivational Coaching.

3.1.1 Amount of Activity

In general, it has two main objectives:

- To monitor distribution of activity over the day
- To monitor distribution of activity per week

The first objective is motivated by a use case in which the main user or caregiver is able to monitor the level of main user's activity during the day and to make a more efficient and better planning of daily activities, e.g. due to the disease or impairment. For instance, the COPD restricts Petra's levels of energy throughout the day. In the mornings Petra feels very active and is able to perform a lot of activities but with the progress of the day, she feels a decrease of energy. She would like to be able to better balance her physical activity over the day.

Likewise, the second objective has the similar motivation as the first but on the weekly basis. For instance, feeling more confident and with eWALL assistance, Phillip decides to join again his old friends on the weekly hiking meetings. Every Friday, Phillip and his friends take a long walk in the surroundings of his village. Although the distance and pace of the walk can vary, Phillip is considerably more active on Fridays than on the other days of the week.

At the moment, the list of up and running service bricks that support this application is as follows:

1. *Burned calories service brick* The *Burned Calories* service brick interprets accelerometer data related to a specific timeframe for a given user and, by applying a computation algorithm, estimates the burned calories. To make the algorithm effective, it requires as input parameters, in addition to the accelerometer data, some characteristics related to the user (age, gender, weight and height).
2. *Walking distance and steps service brick* The *Walking Distance and Steps* service brick interprets accelerometer data and classifies the acceleration's deviation as steps or as undefined movement. The accuracy of the classification is dependent on the point of data acquisition (position of accelerometer on the user's body) and on the classifier definition, as well as on some user characteristics (e.g. height).
3. *Activity type and duration service brick* The Activity Type and Duration service brick interprets accelerometer data from the body sensor in order to classify the type and the duration of the physical activity being performed over a period of time.
   The classification fall into the following physical activity types:
   - Activity type 1—Walking indoor
   - Activity type 2—Walking outdoor
   - Activity type 3—standing still
   - Activity type 4—sitting
   - Activity type 5—lying down
4. *Inactivity detection service brick* The *Inactivity Detection* service brick interprets the accelerometer data from the body sensor to classify the data into periods of inactivity versus periods of activity. The application will send a request for detecting user inactivity periods over a timeframe. The expected output from the service brick will be the duration of the inactivity periods in minutes.

3.2 Application Category: Daily Functioning Monitoring

Monitoring of daily functions is about understanding what the user does and where. These functions are performed indoors and outdoors. To understand what the user is up to, we only have the processed sensors' signals and any information the user volunteers (e.g. via an electronic diary or agenda).

3.2.1 Outdoors Functions

The relevant sensors here are:

1. The GPS that provides the trajectory and an understanding of the locations of any stops in it.
2. The accelerometer that provides an understanding of the level of activity and number of steps.

The relevant information sink is the smartphone. In terms of activity understanding, we can correlate the stops in the trajectory with known destinations of the user and deduct the type of activity like 'walk in the park', or 'shopping groceries'. In terms of displaying information, we can use the smartphone screen to display a 'walking mate' type of application. We can also provide soft geofencing, by notifying the user through the smartphone about unusual duration or pattern of the activity. Finally, in terms of information entry, we can encourage the user via the smartphone 'walking mate' application to verify activity at the various stops, like answering the question 'Have you bought groceries?'

3.2.2 Indoors Functions

The relevant sensors here are:

1. The wall-mounted PIR sensors that provide the pattern of visiting different rooms in the house.
2. The accelerometer that provides an understanding of the level of activity and an objective measure (e.g. number of steps).
3. The Kinect that monitors the living room audio-visually, providing direction of sound arrival, speaker turns, speech recognition, body posture, face tracking and face analytics, but all in a restricted space of approximately 4×4 meters in front of the sensor.
4. The gas sensors in the kitchen that can indicate cooking (or cooking accidents).
5. The bed sensors (pressure, acceleration and sound) can be used for sleep quality analysis.

The relevant information sinks are:

1. The eWALL display.
2. The eWALL speakers.
3. The smartphone/tablet.

In all the rooms we can have a first level of daily functioning monitoring, the simple function deduction by presence. The result is something like the lower half of Fig. 1. This can be augmented by the accelerometer data yielding activity physical information that improves our understanding. Presence in the kitchen with physical activity can mean housework, eating or cooking. The gas sensors can help us in cooking detection.

The A/V sensing in the living room allows deeper daily functioning monitoring. Mood recognition from face analytics, body posture and information about visitors are typical examples.

Finally, the various bed sensors indicate the quality of sleep.Some relevant applications to this application category are as follows:

3.2.3 Sleep

There are four main use cases pertaining to the sleep application, namely:

- Sleeping intervals
- Snoring intervals
- Restless in bed intervals
- Off-bed intervals and analysis to indicate where the off-bed time is spent

As the name says, the first use case is aimed at measuring sleeping intervals of the patient which can give valuable information concerning the level of COPD or mild dementia itself, and also the impact on the quality of life of the patient caused by the disease. The snoring intervals can also identity impact of the COPD level on the quality of life of the patient. The snoring intervals itself is measured via sound analysis on the near-field microphone. The third and fourth use cases are specifically related to the mild dementia patients, because such patients who wake up at night would not have a correct orientation of time which lead to restless in bed and wandering around the rooms or house. The restless in bed intervals is measured by combination of bed sensor that indicates pressure on bed and accelerometer that measure the activity. Lastly, the fourth use case is first indicated by bed sensor that measures no pressure on bed, and then analyzes the accelerometer for any activity and the PIR sensor for room occupancy.

3.2.4 Eat/Drink

Two use cases are considered in Eat/Drink application, namely:

- Activity in the kitchen
- Cooking interval

This application is mainly used by the caregiver to determine whether the patient has been eating well or not (identified by the above mentioned use cases). The activity in the kitchen use case is measured by the PIR for kitchen presence and accelerometer for activity, while the cooking interval is measured using gas sensor.

3.2.5 Socializing

Physical activity is well known to benefit elderly humans, but home and outside activities in a social setting with younger people, relatives and other elderly seems to be especially valuable. We need to provide environment and tools and methods for maintenance of a high level social interaction for the eWALL primary users which can have positive effect on their health. The more socially active the elderly are, the less likely they are to become depressed. Being socially active can help them be physically active. They will be more inclined to join activities with their friends or relatives. The elderly will benefit from socialization and the people they socialize with will benefit from their knowledge and experience.

Use cases considered with the respective measurement methods in this application are as follows:

- Multiple faces in the living room (measured using visual face tracking)
- Dialogue in the living room (measured using speaker turn detection)
- Duration of phone/skype calls
- Social statuses and information sharing rates (on social media)

3.2.6 Mood Status

Mood can be detected from face analytics or can be inferred by entertainment activity or existence of visitors. In house entertainment can be music, TV and games. We need some sensor to understand the status of the Hi-Fi and the TV.Use cases considered with the respective measurement methods in this application are as follows:

- Mood in the living room (measured using visual face analytics)
- Listening to music intervals and genre (measured when Hi-Fi is on, there is presence in the living room, relative body inactivity, music presence and music genre recognition (no partner has expressed interest in music detection/classification yet). Music detection/recognition is not a problem if the media are played back from the home PC)
- Watching TV intervals and genre (measured when TV is on, presence in living room, relative body inactivity, face facing the TV. We can have video genre if the media are played back from the home PC)
- Playing games on the PC intervals, games and results (obtained by the information given by the PC)

3.2.7 Self-Care

Self-grooming is an important part of self-care. Unfortunately this cannot be detected without a visual sensor in the respective rooms, which is not acceptable for privacy reasons. Instead, self-care is only inferred. The self-care may reflect in many aspects such as: efforts for reducing the stress, distribution the amount of physical effort loads, healthy eating, fresh air in the house, grooming etc.

Use cases considered with the respective measurement methods in this application are as follows:

- House air quality (measured by the gas sensors that give information about how clean the air is in the house)
- Hygiene routine (measured by accelerometer for activity and water tap sensor in the shower room and sink at the bath room, to identify activities such as showering, tooth brushing, etc.)

3.2.8 Houseworks

The only way to deduce houseworks is to look for activity in a room without visitors. So this is actually a combination of absence of socializing application and fuss in a room.

Use cases considered with the respective measurement methods in this application are as follows:

- Intervals of active presence in a room (measured using PIR for room presence, accelerometer for activity)
- Intervals appliances are working (measure power consumption for appliances fixed on a socket)
- Intervals tap is running (measured by tap sensor)
- Intervals vacuum-cleaner is working (deduced by acoustic event detection, since the vacuum-cleaner is not fixed on a socket)

3.3 Application Category: Healthcare Support

The *Healthcare Support* application category describes a set of applications that allows communication between the primary user and multiple persons, form which at least one is a medically trained caregiver, such as a general practitioner, or a medical nurse. The communication is always oriented within the scope of therapy. Through the services provided by this set of applications, both formal and informal care givers can assess remotely particularities of the state of health of the primary user.

A relevant application to this application category is as follows:

3.3.1 Sharing Information

This application involves sharing of medical data with professional caregivers, social interaction with informal caregivers as well as configuration of the eWALL system through remote or local operations.

Use cases considered in this application are as follows:

- Time in teleconference consultations with a medical professional
- Type of shared data (e.g. focus on improvement or decline in the health condition)

3.4 eWALL Caregiver WebApp

The caregiver WebApp is where the medical specialists will be able to access all the data provided from the eWALL portal through a dedicated graphical user interface. The WebApp is available only for authorized access and developed for the needs of the caregivers, who are required to login to the system with a credentials authentication procedure. A relevant functionalities as a part of the caregiver WebApp are:

3.4.1 User Profile Search and Access

The application will provide functionalities for searching particular patients in the caregivers list, accessing their users profile information in details. An overall summary for his health status and profile are available for evaluation and assessment from the caregivers' side.

The current status of the user will be available for assessment. A real time information for the user status in terms of positioning, vital signs and activity will be visualized.

3.4.2 Caregivers Notification Manager

Dedicated notification manager is developed in order to summarize and prioritize the incoming events from all the patients assigned to a particular caregiver. Functions for date, user and type rearrangement and filtering help the caregivers to prioritize the most important cases.

3.4.3 Preferences

This application addresses the requirement for allowing the caregiver to select a customized set of most relevant parameters to be visualized. It will allow personalized view of the details provided from the: physical activity, daily activity type, environmental sensing, vital signs sensing.

Another important aspect available through the preferences settings is the adaptation of the patient treatment in terms of alarms and notifications thresholds readjustments. The functionality will be accessible only by the formal caregivers who will be authorized to determine the proper treatment models for the patients.

4 Expected Outcome and Future Work

The eWALL platform is a paradigm of how ICT can contribute to the increased Quality of Life, eInclusion and independent living; thus minimizing costs for the National Health Systems. The novelty of eWALL, which is to create a Home Caring Environment, is based on the advanced sensing capabilities, combined with a high degree of personalization and intelligent decisions making, derived from an innovative SOA deployed in a cloud.

eWALL is currently under validation, that occurs in several countries in Europe, while in Denmark, Italy, Netherlands and Austria the platform will also be validated with real patients. For the purposes of validation, we are following a phased approach, where we will involve 40 patients per site, 20 suffering from COPD and 20 with MCI. These demonstration activities can result in valuable results, equivalent to large clinical trials and in any case they will provide adequate feedback and evidence about the impact of eWALL in their daily activities. Already, at this stage, the platform is under technical and partial user validation and the results are quite optimistic.

In the coming months the eWALL platform will be optimized with additional features following an agile, continuous integration approach and is expected to be stable and robust, to go through the ethical approval processes. On the same time, there are standardization and exploitation activities for the next stage of eWALL, which is the commercialization one. For that purpose the platform is structured in modular and scalable way, to allow multi-level business models of several actors, e.g. municipalities, insurance companies.

Acknowledgments This paper is based on the joint research work of the eWALL project consortium (EC, FP7 Grant Agreement no 610658). The authors would like to acknowledge the research effort of all eWALL colleagues for making this paper possible, as well as the European Commission for providing the FP7 funding framework.In addition, the work has been partially funded by the Sectoral Operational Programme Human Resources Development 2007–2013 of the Romanian Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/132397.

References

1. eWALL project deliverable D2.7, Final user and system requirements and architecture.
2. eWALL project deliverable D4.2, Intelligent support system for eWALL.
3. eWALL project deliverable D4.1, Semantic model of eWALL middleware services.

4. eWALL project deliverable D5.2, Lifestyle reasoning: Fusion for activities situations and their patterns.
5. Algaet, M. A., Noh, Z. A. B. M., Shibghatullah, A. S., Milad, A. A., & Mustapha, A. (2014). Provisioning quality of service of wireless telemedicine for e-health services: A review. *Wireless Personal Communications Journal, 78*(1), 375–406.
6. Kailas, A., & Ingram, M. A. (2009). Wireless aspects of telehealth. *Wireless Personal Communications Journal, 51*(4), 673–686.
7. Craciunescu, R., Halunga, S. & Fratu, O. (2015). Wireless ZigBee home automation system. In *Proceedings SPIE 9258, advanced topics in optoelectronics, microelectronics, and nanotechnologies VII*. February 21, 2015, Constanta Romania.
8. Ochian, A., Suciu, G., Fratu, O., Voicu, C. & Suciu, V. (2014). An overview of cloud middleware services for interconnection of healthcare platforms. In *10th international conference on communications* (pp.1–4, 29–31) May 2014, Bucharest, Romania.
9. Suciu, G., Butca, C., Ochian, A.. & Halunga, S. Wearable sensors for health monitoring. In *Proceedings SPIE 9258, advanced topics in optoelectronics, microelectronics, and nanotechnologies* VII. 21 February 2015, Constanta Romania.
10. eWALL project deliverable D3.1.1, Intelligent context-aware services and applications.
11. eWALL project deliverable D3.3.1, D3.3.1: eWALL configurable metadata streams.
12. eWALL project deliverable D5.3, eWALL Networked Devices.
13. http://en.wikipedia.org/wiki/WAR_(file_format). Accessed 24 Oct 2014.

Dr. Sofoklis Kyriazakos graduated Athens College school in 1993 and obtained his Master's degree in Electrical Engineering and Telecommunications in RWTH Aachen, Germany in 1999. Then he moved to the National Technical University of Athens, where he obtained his Ph.D. in Telecommunications in 2003. He also received an MBA degree in Techno-economic systems from the same university. He has more than 90 publications in international conferences, journals, books and standardization bodies. He has been invited as reviewer, chairman, member of the committee, panelist and speaker in many conferences and has also served as TPC chair in 2 International conferences. Currently he holds the academic position of Associate Professor in the University of Aalborg. Sofoklis has managed, both as technical manager and coordinator, a large number of multi-million ICT projects, at R&D and industrial level. In 2006 Sofoklis founded an ICT startup, Converge S.A., with the PRC Group and since then he has been the Managing Director and a BoD member. Since March 2012, he also Managing Director and BoD member of Converge ICT Innovation Inc. based in Montreal, Canada, which is an affiliate company. Sofoklis is also member of the BoD of Athens Information Technology, a Center of Excellence for Research and Education.

Mihail Mihaylov born in Bulgaria in 1988. He received B.Sc. degree in Telecommunications from Technical University of Sofia (TUS), Bulgaria in 2011 an M.Sc. degree in Innovative Communication Technologies and Entrepreneurship form Aalborg University(AAU), Denmark and TUS in 2013. He is a part of the Department of Electronic Systems, Center for TeleInFrastruktur (CTIF) at AAU as a research assistant in the EU funded project—eWall for Active Long Living (eWall). He has main research interests in heterogeneous networks, LTE-Advanced, eHealth and body area sensor networks.

Bayu Anggorojati has received his Ph.D. in Center for TeleInFrastruktur (CTIF), Aalborg University. His main research interest is in access control, identity management, RFID, IoT, M2 M, and Cloud system. During the period of his PhD work, he has been involved in several projects, especially the EC projects, such as ASPIRE, ISI-SEMD, LIFE2.0, BETaaS, and eWall.

Albena Mihovska has a Ph.D. degree in mobile communications from Aalborg University, Aalborg, Denmark, where she is currently an Associate Professor and Head of Standardization and Head of Teaching at the Center for TeleInfrastruktur (CTIF). Currently, she is involved with research related to innovative research concepts for 5G communication systems, the design and implementation of e-Health services (EU project eWALL) and to optimizing and supporting reliable and high performance intensive data rate communications as required by the Internet of Things.

Razvan Craciunescu received the Engineer's degree and the Master's degree in electronic engineering and telecommunications from the University POLITEHNICA of Bucharest, Bucharest, Romania, in 2010 and 2012, respectively. He is currently a Ph.D. student, in the field of communication systems and optimization, at University POLITEHNICA of Bucharest, Romania and a Research Assistant at *Center for TeleInfrastruktur,* Aalborg University, Denmark. Since 2012 he is also a Teaching and Research Assistant at the Faculty of Electronics, Telecommunications and Information Technology within the University POLITEHNICA of Buchares. His research interests include Mobile Communications, Wireless Sensor Networks and System Optimization. His publications include more than 20 papers published in nationally and abroad journals or presented at international conferences. He participated as researcher in Romanian national project as well as in international projects such as „Optimization and Rational use of wireless Communication bAnds (ORCA)", NATO Science for Peace Research project (2013–2016), „eWALL— eWall for Active Long Living" (FP7 project, 2013-2016) and "Virtual Open Incubation Ecosystem (VOICE)" (FP7 project 2014–2017).

Octavian Fratu received the Ph.D. degree in Electronics and Telecommunications from the University POLITEHNICA of Bucharest, Romania in 1997. He achieved postdoctoral stage as senior researcher in 3rd generation mobile communication systems, based on a research contract between CNET-France, ENS de Cachan – France and Universite Marne la Vallee—France. He is currently professor in Electronics, Telecommunications and Information Theory Faculty. His research interests include Digital Mobile Communications, Radio Data Transmissions, Mobile Communications and Wireless Sensor Networks, Radio communication networks. His publications include more than 140 papers published in national or international scientific journals or presented at international conferences. He participated as director or collaborator in many international research projects such as „Reconfigurable Interoperability of Wireless Communications Systems (RIWCoS)", NATO Science for Peace research project (2007-2010), „REDICT—Regional Economic Development by ICT/New media clusters" (FP7 CSA project, 2008–2009), "ATHENA - Digital Switchover: Developing Infrastructures for Broadband Access", (FP6 STREP project, 2004–2006) and other. He is now Co-Director of "Optimization and rational use of Wireless Communication Bands (ORCA)", NATO Science for Peace research project (2013–2016) and responsible of Romanian team in "eWall for Active Long Living (eWALL)" project, (FP7 IP project, 2013–2016).

Prof. Ramjee Prasad is currently the Director of the Center for TeleInfrastruktur (CTIF) at Aalborg University, Denmark and Professor, Wireless Information Multimedia Communication Chair. Ramjee Prasad is the Founding Chairman of the Global ICT Standardisation Forum for India (GISFI: www.gisfi.org) established in 2009. GISFI has the purpose of increasing of the collaboration between European, Indian, Japanese, North-American and other worldwide standardization activities in the area of Information and Communication Technology (ICT) and related application areas. He was the Founding Chairman of the HERMES Partnership—a network of leading independent European research centres established in 1997, of which he is now the Honorary Chair. He is the founding editor-in-chief of the Springer International Journal on Wireless Personal Communications. He is a member of the editorial board of other renowned international journals including those of River Publishers. Ramjee Prasad is a member of the Steering, Advisory, and Technical Program committees of many renowned annual international conferences including Wireless Personal Multimedia Communications Symposium (WPMC) and Wireless VITAE. He is a Fellow of the Institute of Electrical and Electronic Engineers (IEEE), USA, the Institution of Electronics and Telecommunications Engineers (IETE), India, the Institution of Engineering and Technology (IET), UK, and a member of the Netherlands Electronics and Radio Society (NERG), and the Danish Engineering Society (IDA). He is also a Knight ("Ridder") of the Order of Dannebrog (2010), a distinguished award by the Queen of Denmark.