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”SAVE” – an Integrated Approach of Personal and Home Safety for Active Assisted Living

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Abstract. The paper presents the concept and demonstrator of ”SAVE – SAFety of elderly people and Vicinity Ensuring”, an integrated approach of personal and residential security. This AAL (Active Assisted Living) system aims to support elderly end-users staying in their familiar home and surroundings for as long as possible, being safely and permanently in contact with their caregivers. The top-down Universal Modeling Language (UML) service orientation enabled a unified co-design of both human and machine communications. Furthermore, the present concept includes an integrated subscription mechanism for people and devices, in a multi-tier user structure and a central-local distributed processing (Cloud-Edge). There are presented the end-user perspective, selection and involvement (in pilot prototyping of the SAVE demonstrator), considering cognitive age-related issues, oriented on usability and on the functional specifications of interfacing via web-apps (independent of the mobile platforms operating system). Location Based Services (LBS) manage data from the Geographical Information Systems (GIS) in a unified modern way, based on LISP – Location - (from) Identity Separation Protocol. These services of ”orientation” – localization, real-time tracking – are integrated with another aspect of ”restoring the referential” (both personal and communitarian): (re-) planning service, improving alert information in case of emergency, bilateral push-pull of security notifications. Restoring the end-users well-being takes benefit of eHealth and actigraphy services. The other approach, bottom-up, is based on micro-services software/netware implementation, modern smart-watches/smartphones and wearable devices, leveraging their programmability and multi-modal and multi-range (near-field or cellular) communications.

Keywords: Active Assisted Living, Micro-services, Internet of Things, Wearable devices.

1 Introduction

Maintaining the health of the elderly is a continuing concern in communities. The use of technologies becomes an important resource in achieving this goal and an opportunity in using them. The purpose of these technologies is to provide an active lifestyle mode to the elderly [1] by involving them in various activities. The technologies aimed to the elderly are limited in usability as they are not familiar about of their own coordinates, security, alerts, use of a smart-phones or a e-Health system [2]. Developing non-intrusive technologies is becoming a challenge nowadays [3]. Moreover, not only technologies can make a significant contribution, but also the physical exercise [4]. Elderly people feel to be more inactive, start to be at risk on a sedentary behavior. A possible solution is Internet of Things (IoT) integrated in an e-Health system that could be adaptable to the elderly and caregivers needs. Furthermore, another concern is about creating an infrastructure capable of collecting data in an independent and continuous manner [5].

This paper proposes a concept and a demonstrator that is intended to be a possible response for the integrated approach of security of the elderly. Furthermore, this system should be also used like a product for an intelligent home. This concept is called SAVE ("SAfety of elderly people and Vicinity Ensuring").

2 Sensor networking

The SAVE solution (see Fig. 1) uses several types of sensors (wearable and ambient / domotic) to obtain information about the well-being of the elderly in his/her habitat (home, neighborhood, etc.) and to ensure safety. The solution also has several features that older people can use in case of danger (SOS button fall detection). In Fig. 1 are presented the users and the technologies that work together in order to obtain the goals. The elderly habitat is the host for ambient sensors, eHealth device and also for the user that has many sensors grouped in the smartwatch and smartphone. The systems collect the info from all the sensors but will only activate the needed ones. Data collected by the sensors refers to biological signals, GPS data, humidity of the environment, light of the environment, human presence in the habitat. They are secured by coding them, and are separated from personal details in order to prevent data leakage. After that, they are sent by GSM or Wi-Fi network in the SAVE Cloud. Here after some basic processing steps, they are used to alert or inform the caregivers on their smartphones, and also are collected to be analyzed by SAVE experts and also if needed by the 3rd part services.

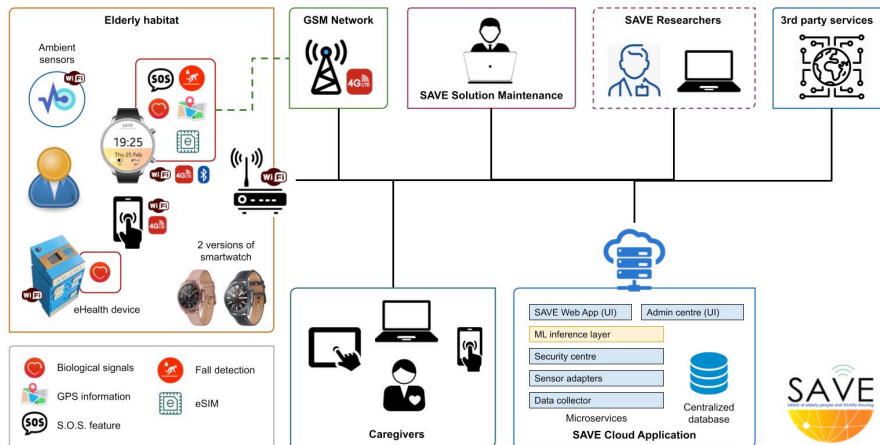


Fig. 1. SAVE solution, highlighting the actors and main technical aspects

The sensors are installed in the end-user's habitat. The smartwatch can connect to the Internet directly, using the GSM network (if eSIM is supported), through a smartphone to which is connected (by Bluetooth or Wi-Fi) or through other Wi-Fi connections. In the scenario considered by the SAVE project, the smartwatch supports eSIM, to be able to send - without delays - the location data.

All the sensing devices connect through the Internet to the SAVE cloud application. This application is built on the micro-services architecture. The data collector service manages the access to the sensor data, the sensors adapters shape the raw sensor data to match the data collector's input and the security center provides the cryptographic-based security layer (based on HTTPS – Hypertext Transfer Protocol/Secure, API keys and JWT – JSON Web Tokens). The data is collected in a partitioned relational database.

There are 2 use interfaces: one for the elderly and the caregivers (SAVE Web App) and one for the SAVE solution maintainers and SAVE researchers (AdminCentre). Both user interfaces are developed as responsive web applications.

3 Involvement of the elderly and their caregivers

The SAVE solution offers seniors a set of sensors that contain, at a minimum, an e-Health device and a smartwatch (e.g. Samsung Galaxy Watch 3) with SAVE software pre-installed. The kit may include other environmental sensors (e.g. presence, magnetic contact, flood sensor), which will connect to the SAVE Cloud application in the classical "Edge/Cloud" local/centralized allocation of resources – from embedded systems to high-capacity data-centers. Elderly people also receive rights to access the SAVE web application, also can request additional accreditation for their caregivers.

For the pilot sites, the support will be provided, when necessary, by maintaining the SAVE solution for caregivers in order to configure the SAVE software on the smartwatch and to make other necessary configurations (WiFi connection, eSIM installation, sensor configuration, etc.).

4 An integrated solution – the e-Health system

The e-Health equipment is actually “a complex sensor”, consisting of several individual devices for measuring (e.g. blood biological parameters pressure, pulse, temperature) and activities (e.g. body position) of the elderly. This equipment connects to the Internet through the local WiFi network. The smartwatch acts as a portable sensor and connects to the Internet via the GSM network (if the LTE function is used and an eSIM is present) – this is the scenario recommended in SAVE – or via WiFi, by connecting to the local WiFi network or to a hotspot opened by the elderly smartphone (which has mobile data enabled). In the current phase of the SAVE demonstrator, they are included also some extra safety features (SOS and fall detection) associated with a Bluetooth tethering connection.

Samsung Galaxy Smartwatch 3 includes a wide range of sensors that can be used to assess physical activity (steps, frequency of steps, speed of movement) and to read some basic biological signals (e.g. pulse) that will be used in the analysis of user data regarding his/her wellness. The GPS sensor, together with the gyroscope and accelerometer [6] are used to ensure the safety of the elderly (location, fall detector). This smartwatch is a leading edge for smartwatch world and its own specification grows with each release [7].

The smartwatch selected for the SAVE demonstrator offers LTE communication and includes in its firmware the SOS and fall detection features. The elderly can call for emergency help and assistance by quickly pressing the power button 3 times. The smartwatch sends a SMS containing a standard message and the location of the smartwatch owner and then calls the designated caregiver.

If a fall is detected [8], the smartwatch will display a 60-second warning to the elderly; if the warning is not manually rejected, the smartwatch will send SMS messages and automatically call a designated contact (a caregiver).

5 Use of technological resources in SAVE

The SAVE minimal kit can be complemented by commercially available sensor sets (for example, the Xiaomi Mi Smart Home kit). However, these kits have their own user interfaces, but once configured they do not require any additional human intervention [9]. These kits usually include devices that can generate audible warnings when certain situations are detected (the door left open too much, the unexpected presence in a certain perimeter, etc.).

The work is underway to include more physiological wearable sensors in the SAVE minimal kit. Some cheaper alternatives to the smartwatch (for example, the LilyGo “TTGO” [10] programmable watch) are also being investigated.

All sensors included in the minimum kit communicate with the SAVE Cloud application via the Internet, supplying it with sensor data and receiving commands when needed. The preferred mode of communication in the SAVE sensor network is WiFi – in the WSAAN [11] (Wireless Sensors & Actuators Network) paradigm.

6 SAVE - online health service

The service is implemented as an online health service (OnHS) and/or an offline health service (OffHS), both involving eHealth sensors used at home. As established in the technology choice phase, in order to meet one of the main requirements of the European AAL initiative in terms of interoperability and open interfaces – to access the European market – the eHealth system concept is oriented towards Open-Source Hardware (OSHW) and COTS (Commercial Of The Shelf) platforms (eHealth, includes COTS biosensors [12]).

The SAVE eHealth system is based on the low-cost platform from Libelium, namely the “MySignals” Hardware Development Platform – an eHealth and Medical IoT Development Platform for Arduino. The demonstrator of eHealth system is based on short and long-range communication protocols, as a scalable base station that offers two services:

- A built-in C ++ application provides connection and reading of biometric sensors; it shares data with the Cloud through a web service.
- A web application that allows the management and configuration of the base station; this option was considered better than an application for a smartphone dependent on the operating system (iOS / Android); it allows the configuration of the specific sensor, the trigger of a specific measurement, the display of the measurement result, and sets the connection parameters used for Cloud interaction, from any device connected to the same network as the base station (PC/laptop/smartphone).

The overall architecture of the SAVE system, described in Fig. 2, is composed of several independent components that communicate with each other, in order to serve certain functionalities. The architecture is based on a central server that offers the micro-services to all subsystems. Also here it is located the database and the gateway module for accessing data through the 3rd party monitoring and safety systems for user interface. All the micro-services are used to send and receive data to and from all the equipment used: sensors, smart sensors, mobile devices and also web-based user interface.

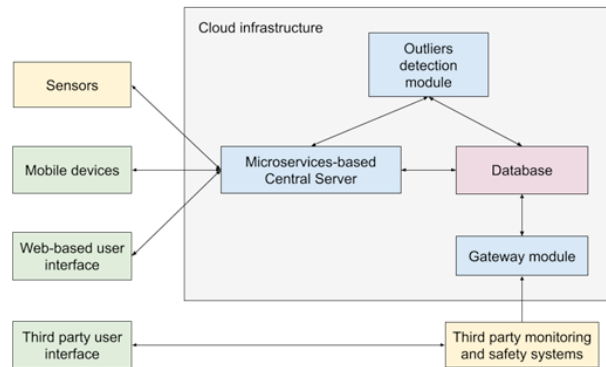


Fig. 2. General architecture of the SAVE system

7 UI design and development requirements

Possible implication in software design according to cognitive decline in the elders:

- **Vision:** one of the most appropriate texts for information display is *sans-serif fonts* with the *size between 12 and 14 points* [13] - the width of the visual field of elderly people reduce;
- **Color:** older people have *less sensitivity to color contrast* especially in the *blue green range*; designers *should not use colors to communicate meaning*, but should use for supporting information presentation;
- **Memory:** the average of the related items to be shown in the display panel used for the older people should be around **5.5 items** for older people, use of long term memory is much more effective than short term memory;
- **Sound:** the devices that require sound as alarm, instruction or any activity that require attention from the elderly users should use the *lower range of frequency* (between 500 and 1000 Hz) - high pitched sounds with peaks over 2500 Hz are mostly missed by the elderly;
- **Attention and Simplicity:** the use of *relevant graphics and pictures* are more significant than the use of detailed decorations; *multitasking* operations *should not be applied* as well - older adults have problems maintaining attention over long periods of time;
- **Motor decline:** small screen on mobile devices may limit usage of elderly users, but a tablet device still has mobility and is still not compromised with screen size - physical decline is one of the general problems for the elderly;
- **Reduction of complexity:** the design of the interaction should *avoid complexities*, for example using short and long press, using combination keys, using multi-fingers, using multi-touch, etc. - *simpler is more usable for elderly users*;
- **Clear structure of tasks:** clearly separated task is the factor that may increase usage performance for elderly [14] - single task per page reduce attention load for older users;

- **Consistency of information:** navigation bars, labelling or any interface components should be used *to communicate exactly where the users are in the application* - elderly users are easier to recognize information than to recall memory [15];
- **Rapid and distinct Feedback:** feedback of every action should be provided within a certain time and it should indicate result or response of each action – due to limitation of short-term memory of older adults;
- **On screen help:** on screen help within operation page should be used - older people have anxiety of using new products;
- **User support:** reduce usage of error messages to become as low as possible; in case that error messages have to be shown, error messages should be simple, precise, polite and understandable - elderly users are sensitive to errors from their actions.

Interface optimization (according to the limitation of motor skills and cognitive abilities of the elderly people):

- Make use of proper size interface components:
 - Touch sensitive area/Size of button should be 16.5 mm to 19.05 mm;
 - Spacing size between button/touch sensitive 3.15 mm to 12.7 mm;
- Avoid using scroll bar;
- Keep operation area in the center of the working page;
- Make use of multi model communication;
- Make use of real object-liked interface;
- Present text the simplest way:
 - Size 14 (~5mm on 72 dpi screen) or higher
 - Make use of sans-serif fonts;
 - Make use of black font on white background;
 - Avoid using fancy text (moving, non-horizontal orientation, splash).

8 Smartwatch interface – the SAVE development

For the smartwatch, a specific SAVE interface has been developed in the form of a clock frame, which fulfills a dual role: portable user interface for the elderly, regardless of its location (inside or outside the house) and portable sensor (for basic biological signals – e.g. pulse, activity monitor - and location) [16].

The dial of the watch is customized according to the SAVE visual identity (as shown in Fig. 3) and has a minimal set of information. To set up the connection to the SAVE Cloud application (performed only once), a separate application has been developed.



Fig. 3. SAVE watch-face

The watch face has been designed to display in an aesthetic and efficient way the necessary information and to collect data provided by the sensors, the location and to display the notifications defined by the user (end-user and/or caregiver) in the web application interface (developed for this purpose), all with minimum energy consumption. The configuration application aims to ensure security and identify the user's profile. Once the application is opened, a text box will appear where a 6-digit PIN must be entered (which is associated with the end-user). After pressing the validation button, the authentication will be confirmed or denied by a corresponding message on the screen, along with the instructions needed to continue the process (see Fig. 4).

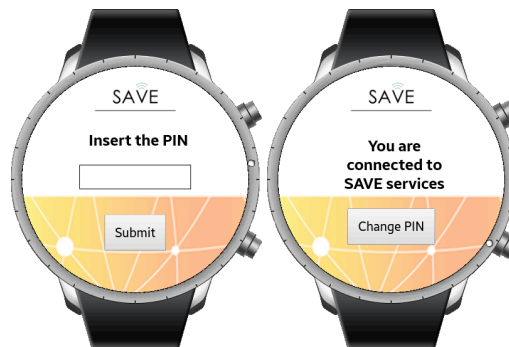


Fig. 4. Registering the smartwatch in the SAVE cloud application

9 SAVE web application

The web application has been developed so that end-users (elderly and caregivers) can efficiently and securely access the SAVE solution's features, using a coherent and uniform user interface. This application will be further developed and will offer an even simpler and more intuitive interface for both elderly and their caregivers [17].

The interface now offers two main features:

- management of scheduled notifications;
- real-time tracking service.

The data that is collected from the Cloud server is displayed in a graphical manner, in dedicated pages that are currently under post-prototype development. According to the results of co-design and co-creation with potential SAVE users, these pages are able to present data differently for the elderly and caregivers.

10 Scheduled notifications

The home page of the web application displays active scheduled notifications (Fig. 5) and also allows the user, who may be elderly and/or caregiver, to define new ones.

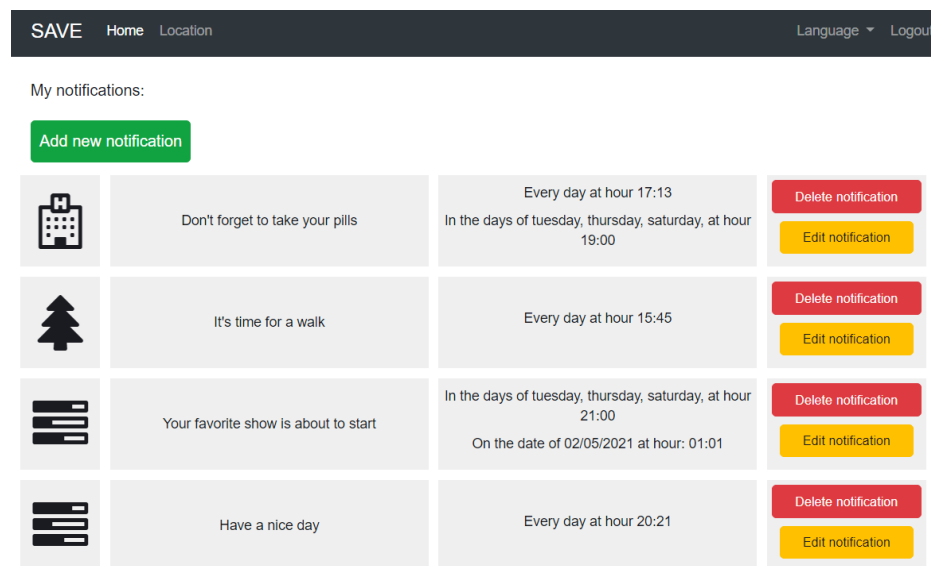


Fig. 5. Active notifications on the dashboard page

The users can customize the notifications according to their needs by typing their own messages, choosing an icon and by setting notification display frequency: every day, on certain days of the week, on a specific date. For each of the previous options, the user will also choose the time when the notification will be displayed. The application also offers the users the possibility to delete notifications.

10.1 Real-time tracking service

The app offers a user location function [18] that can be accessed from the menu bar. A person's current location is marked on a map in real-time, along with the location of his/her home and his/her 10 previous locations (see Fig. 6).

This helps caregivers to check if the end user is in a location, away from home, that they would not normally go to, suggesting that he/she might be disoriented. The distance from home is calculated and can be used to trigger alarms in the case of end users known to have cognitive problems.

Tracking information is kept for a limited period of time and will be used to detect possible disorientation of older people wearing smartwatches (e.g. walking in circles, going back and forth repeatedly, getting lost far away from home etc.).

Users can customize notifications according to their needs, editing their own messages, choosing an icon, and setting how often notifications are displayed: every day, on certain days of the week or at a certain date. For each of the above options, the user can also choose when to display the notification. The app also gives users the ability to delete notifications.

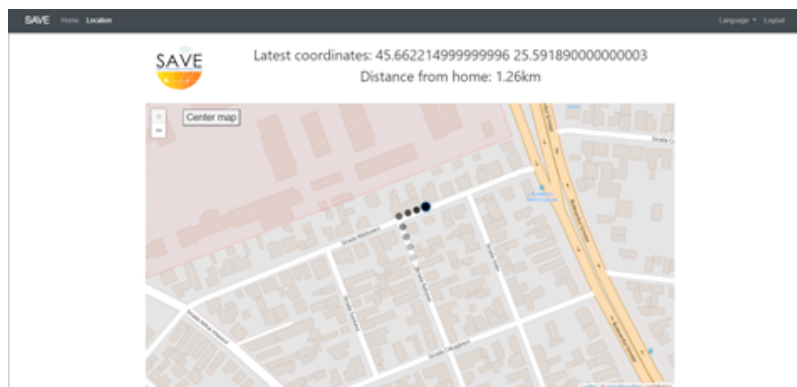


Fig. 6. Tracking location screen

10.2 Localization

The application is available, at this moment, in 2 languages: Romanian and English, and switching between them can be done using a button in the menu bar on the right. The service can be used via a smartphone application: it aims to track routes outside the home and, in case of difficulty or disorientation, to locate the user and provide him / her directions to return home and / or notify family members or personal assistants for help.

For these services it was used a smartwatch paired with a smartphone to get an exact location and to use a public service for orientation. This service was tested with a Samsung Galaxy Watch and a Samsung Galaxy S20 smartphone for demonstration, but the watch and the phone can be chosen from another manufacturer as well. These devices have demonstrated the ability to use this service successfully. Both the smartwatch and the smartphone have GPS sensors and we used "share location" for reporting applications such as Google Maps or a dedicated application for guidance.

In order to take benefit from the new Location (from) Identity Separation Protocols, we used "The LISP Beta Network" [19] that stopped providing services in May

2020 and we are in the process to migrate our SAVE solutions to an own server. To enable easier identification of an end-user in need LISP separates the ID of the wearable devices from their location – thus, direct connection to the device(s) is used and, in the case of multi-homing, reliability is improved by providing multiple paths for this data connection. LISP is commonly used with IPv4 or IPv6, but it can be used with any other type of addressing for the dual EID (End-point Identifier) and/or RLOC (Routing LOCator) addresses.

10.3 Compatibility and accessibility

The SAVE web application is developed as a responsive application, using the Bootstrap library, so the user interface is compatible with all major browsers and with mobile devices (smartphones/tablets) with a wide range of screen resolutions [20].

10.4 Admin Centre web application

Admin Centre is a web application developed to manage data efficiently and securely within the SAVE system. The Admin Centre application is on its 3rd major version; there were several major and minor versions, as a result of multiple design iterations.

The data collecting process is organized in a hierarchical structure; the SAVE solution recognizes several **device types**, that are registered in the SAVE database. The **devices** are also registered in the database and it is mandatory to associate existing device types to them, so the user interfaces will know how to interpret the data (**values**) coming from them. A set of devices form a **SAVE kit**, which is associated with one elderly end-user.

10.5 Security

The service is uniquely able to perform alerts, technological training, bilateral services (push-pull, alert and “ping”), thus giving both the end-user and the supervisor the opportunity to track the patient's health history, automatically storing the results. It can be launched either by the person, but in some cases (for example, loss of consciousness) it should be launched automatically. In case of emergency, it is important to allow the urgent request for help and assistance in the simplest way.

10.6 Improving alert information - personal alerting / home automation service

This service aims to contribute to the future of "Emergency Calls" which should assist people on "both sides of the line" - not just end users who need (who cannot open applications) such as Google Maps, not only because of cognitive impairment or lack of technical knowledge, but even because of extreme momentary pain), but even volunteers or operators of organizations that cannot interpret complex GIS (Geographic Information Systems) data. For prototyping, it was used a smartwatch that can operate both with a smartphone and stand-alone. It can be customized for any emergency application that will connect to the Cloud.

10.7 Adaptation of physical exercise and social activities for the elderly

These activities are led by voluntary organizations, in terms of stress / cognitive assessment services, services based on actigraphy and virtual coach.

Facing health conditions that limit their mobility, they should try to be active daily – examples of activities that require moderate effort for most people include: walking, ballroom dance, pushing various objects, playing table tennis (simple or double). Muscle strength is required for: a) all daily movements; b) building and maintaining strong bones (improving balance and daily matching activities); c) maintaining a healthy weight).

The smartwatch we test will provide alerts and notifications from time to time to keep you active throughout the day. Follow the exercises and can give small indications for simple movements. The Choice Reaction Time (CRT) methodology is based on a visual CRT based on several visual stimuli and two response buttons.

10.8 Personal (re) planning service - "TO DO" list

The purpose of this service is to increase security, prevent social isolation, participate in various programs or occasional activities and maintain the multifunctional network around the person. This tool will help you in planning and conducting daily activities in a safer and more efficient way; care also involves social motivation and involvement. Through the "To Do" section of the application, the elderly user will be helped to remember / update the planned activities, will be informed about the following activities, synchronized in the "personal cloud" of relatives, friends and their formal caregivers).

11 The co-creation of SAVE services

In order to know the expectations of end-users, we created cartoon Cards that contained the initial proposals for the possible services. The purpose of these Cards was to stimulate a discussion with potential end-users and caregivers about their real needs in the areas covered by SAVE services. The answers to the questions were left in the mailboxes, so one of the SAVE researchers collected them from each user. Our argument was that the share of the Internet on the Romanian elderly population is low, by 13%, compared to the European elderly population, by 45% [21].

Following the responses, each of the users was called to have a feedback and to understand their needs and most importantly their expectation on our part, in accordance with the SAVE objectives.

For example, many older Romanians have mobile phones, but fewer also have home sensors in their homes. Only 44% of the Romanian population between 55 and 74 years old use the internet [22], only 30% of them use it several times in four days (on average). A 2013 statistics report showed that only 16% of the Romanian population over the age of 65 had internet at home. Therefore, the human-computer interaction was new for almost all elderly Romanians targeted by SAVE.

12 Conclusions

The "SAVE" proof-of-concept is a system integration solution, based on top-down universal modeling – service-oriented and state-driven.

The service co-creation involved end-users and caregivers, with a multi-criteria selection and prioritization, an "Agile" interface design considering not only usability but also carefully documented age-related cognitive limitations.

The services are centered on security and (re-)orientation, not only as location but also as restoring a personal and communitarian referential through (re-)planning, notifications, alerts, enhanced information in case of emergency. End-users are enabled to restore also their well-being and to use frequently the eHealth services.

The unified safety approach of the person in the intelligent house is made possible by the recent progress in H2H, H2M, and M2M (Human-to-...-Machine) communications, using same Internet-based protocols. These are ranging from IoT to LISP. SAVE data structures are flexible, for both Edge & Cloud processing and storage, adapted to micro-services and RE presentational State Transfer (REST) based web-services.

COTS (Commercial Of The Shelf) devices – both "domotic" and wearable – have built-in radio interfaces and can interact with WSAAN (Wireless and Actuators Networks) via a smartphone data concentrator or even stand-alone. SAVE demonstrator integrates smartwatches with own programmability that have improved battery life.

Last but not least, the SAVE tele-services were re-considered and improved in the dramatic context of the corona virus pandemic.

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