Improving life quality for the elderly through the Social Internet of Things (SIoT)

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Abstract*—The average age of the world's population is increasing, and life expectancy will increase by an extra 10 years by the year 2050. The growing number of older adults increases the demands on public health systems and the related care costs. The use of information and communication technologies (ICT) to support integrated healthcare services in elderly homecare can make an important contribution to reducing such costs. The SOCIALIZE AAL project aims to create a new reference platform for the elderly by applying technological solutions to simplify their daily activities and the means by which they access dedicated services in order to improve their quality of life. This paper describes the Elderly Monitoring service – an IoT module of the SOCIALIZE platform, whose aim is to collect environmental and physical user data so that they can be supervised by medical and caregiver staffs.). The system has been designed to enable easy addition and/or substitution of new services and devices within the environment. To this end, the service implements a framework that enables heterogeneous devices belonging to different domotic systems and protocols to directly share data, thereby implementing an infrastructure suitable for the fulfillment of a real Social IoT (SIoT)

***Index Terms* — SIoT, IoT, Interoperability, SOA, SOCIALIZE, AAL, Smart Home.**

I. INTRODUCTION

Given current demographic dynamics, the ageing population will soon become one of the most demanding Big Societal Challenges that developed countries will face [1]. Over the last 150 years, life expectancy has risen by 50 years, and in the last half century alone it has become three years longer every decade.

Hand in hand with ageing, it is highly likely that disability and dependence for the elderly will rise, along with the incidence of age-related illnesses and the need for medication [2]. The majority of the ageing population experiences progressive deterioration of their health from 50-80 years old. As a result, there is an interval of 30 years during which subjects age with deteriorating health – a critical element to take into consideration when seeking to preserve good quality of life for the elderly.

In EU countries the challenges of an ageing population are placing substantial additional pressure on publicly-funded healthcare [3] and long-term and income support programmes for older people. One of the aims of elderly care is to help the aged and those with disabilities to live normal, independent lives. This includes living in their own homes as long as possible.

According to the *Internet of Things* (*IoT*) paradigm, objects are made to become intelligent – they can be localized, they can acquire data, process and exchange them. Applications of *Smart Home & Building* are particularly important in the *IoT* scenario, as they are the link between the individual (citizen, consumer) and the overlying layers of adoption of the *IoT* paradigm (*Smart City, Smart Grid*) [4].

In the near future, more and more devices and services will be capable of sending and receiving data automatically via the Internet. The *IoT* will offer advanced sensors collecting real-time data and even detection of health problems by monitoring physical and behavioral trends in homes. Family members and emergency services can access the data collected and be automatically alerted as needed. This will provide the elderly with greater independence and autonomy and allow them to lead a high quality social life. The *IoT* is however not just a distant vision of the future - it's already here and is having an impact on more than just technological developments. It permits sophisticated devices to share information directly with each other and the cloud, making it possible to collect, record and analyze new data streams faster and more accurately.

In this regard, a new paradigm related to integrating *Social Networking* concepts into *IoT* solutions is emerging: the *Social Internet of Things* (*SIoT*) [5] [6]. The *SIoT* is defined as an *IoT* where things are capable of establishing social relationships with other objects, autonomously of human intervention, thus creating a social network of objects. Adoption of the *SIoT* paradigm presents several advantages: (i) the resulting structure of such object networks can be shaped as required to guarantee network navigability and effectively perform the discovery of objects and services and thereby guarantee scalability, just as in human social networks; (ii) a level of trustworthiness can be established to leverage the degree of interaction among things that are 'friends'; (iii) models designed to study social networks can be reused to address *IoT* related issues (intrinsically related to extensive networks of interconnected objects) [7].

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The key guiding principle of the *SOCIALIZE* project is the aspiration to create a complete technological solution which effectively fulfills the general objectives of the third call of the *EU – AAL* (*Ambient Assisted Living*) *programme*. The *SOCIALIZE* project builds a new specialized platform expressly dedicated to the needs of the elderly in order to facilitate their participation in social life. The authors' main contributions to the project are the study and development of an *IoT* service, called the *Elderly Monitor service,* fully integrated into the SOCIALIZE platform. The function of the service is to monitor the activities of the home occupant, collect and analyze personal and environmental parameters from various, technologically heterogeneous devices and enable them to cooperate and share data. The results of the monitoring can be accessed by doctors, relatives and/or caregivers as deemed appropriate with regard, for example, to the cognitive, health status and wishes of the person in question.

The paper is organized as follow: section II discusses related work and the state of the art; section III presents an overview of the Socialize project; section IV details the architecture of the elderly monitoring service; section V describes deployment of the monitoring architecture within the Socialize project; finally, section VI draws some conclusions.

II. Related works

The current scientific literature addresses the issue of elderly health monitoring mainly through two different approaches: one aims to evaluate the collected data automatically, while the other requires the support of people (e.g. medical staff, caregivers or other patients). Both approaches can benefit from an *IoT* system that enables devices to collect data in a suitable repository. In the former, the data collected are analyzed by intelligent systems, which can thereby make decisions and automatically launch alarms and warnings in the event that an emergency arises or suspicious vital sign values are detected in the elderly subject. One example of this technique is the FP7 EU *GiraffPlus* [8] project, which proposes a solution based on a robot able to offer users a variety of services. Most monitoring systems exploit wireless sensors in the environment to capture physiological parameters. The data from the sensors are then analyzed by the system to raise alarms and warnings. In the second type of approach, any aberrant values are examined and checked, typically through a web interface, by a sort of community made up of medical staff, caregivers and relatives. One example of this sort of system has been presented by Hussain et al. [9], who propose an *IoT cloud* solution for Smart Cities that monitors users' physical parameters within a *Body Area Network* (*BAN*) in which a virtual community of resources and online social networks play an important role.

Current literature studies apply the Social concept to *IoT* in two different ways: devices interacting directly with humans using the example of Social Networks (SIoT between devices and humans); and devices that interact amongst themselves in a social IoT way (SIoT between devices). This twofold interpretation of *SIoT* is described by Chung et al. [10], who also provide some examples of interactions between devices. Lee et al. [11] extend and formalize the differences between these two scenarios by defining the integration of devices within Social Networks as the *Web of Things* (*WOT*) and direct interactions between devices as the *SIoT*. They also detail the state of the art of the underlying technologies and apply these concepts to Wireless Sensor Networks.

Holmquist et al. [12] present a solution and a prototype able to establish communications between two or more heterogeneous devices by exploiting their proximity (the communication takes place only when devices are near each other).

Unfortunately, most of the approaches proposed in the literature are designed for, and are strictly tied to, specific proprietary hardware or devices.

Thanks to full interoperability among "friend" services and devices, the greatest advantage that our system offers is that it is ready to integrate new devices, home automation systems or sensor networks, even if they communicate through different, incompatible native protocols.

A direct consequence of this is the advantage of being able, according to need or convenience, to freely replace a device or an appliance belonging to a specific brand with another brand without interfering with the functioning of the entire system.

III. Socialize project services

The aim of the *SOCIALIZE - Service Oriented Assisted Living Infrastructure* project [13] is to create a complete technological solution consisting of a system able to integrate and bring together in one place a multiplicity of services addressed to both the senior population and caregivers ("secondary" end users). Such integration helps to create a space tailored to facilitate participation of the elderly in social life. The included services aim to build and strengthen social relations among people who share similar interests, activities, backgrounds or real-life connections and to monitor the elderly's daily activities and share health information with their network of acquaintances.

The Socialize Project seeks to make the platform accessible to all elderly people, including, and especially, the large proportion of the older population that nowadays has great difficulty in accessing and using ICT technology. Thus, one of the project's main purposes is to enable access to and use of the Socialize platform in an easy and simplified manner, thereby permitting the inclusion of the largest number of elderly as possible.

The elderly will thus be able to 'keep in touch' with their families, maintain active participation in social life and stay involved in the development of their own community. Moreover, their quality of life and health status can be constantly monitored to ensure their wellbeing.

The software architecture of the *SOCIALIZE* project includes three broad areas: (i) a service-oriented software application to supply network services; (ii) a set of user interfaces and access devices (with a particular focus on mobile devices) to optimize the experience of using the services that are available in the network for first level end-users (the elderly); (iii) some software tools to implement the services

available to caregiver organizations, which will enable them to configure and personalize the system according to individual needs.

The services supplied by the project (figure 1) can be divided in two categories: *socialization services*, which aim to improve the social interactions of the elderly, and the *cross services*, vertical applications common to all *socialization services*. The *socialization services* are: (a) communications, which allows data transfer between members of the *SOCIALIZE* community through an email-like system and an audio / video chat for real time communications; (b) socialization, which enables cultural and social exchanges between *SOCIALIZE* members; members can post and view the activities of friends or of all users; (c) the forum, which provides users with the means to actively participate in the issues relating to their needs and requirements; this service utilizes voting (or 'like' mechanism) to simplify use of the service and bring news immediately to the user's attention; (d) the services catalogue, which contains information about services (description, features, type, etc.) and organizations that provide these services (description, contacts, etc..); (e) a photo book, which allows members of the *SOCIALIZE* community to store and organize their photos and videos; (f) elderly monitor, which offers an interface showing the results of the monitoring system, as well as analyses of user activities and personal and environmental parameters. The results of this monitoring can be viewed by doctors, relatives and / or caregivers as is deemed appropriate with regard, for example, to the cognitive, health status and wishes of the elderly; (g) distance care, which can follow the elderly's movements and monitor their daily activities, and even warn against any threats.

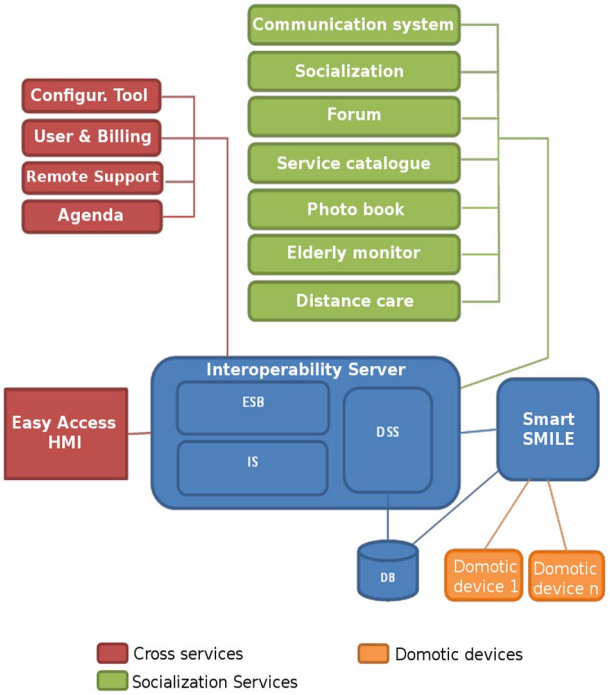

Fig. 1 SOCIALIZE architecture

The implemented cross services are: (a) the interoperability server, which is the *SOCIALIZE* platform component that allows the different services to communicate by sharing data and functionalities; (b) the configuration tool, which provides for the registration to, and configuration of, the system and services; (c) user & billing, which manages *SOCIALIZE* platform users and their access credentials; (d) remote support, which provides help on using the *SOCIALIZE* platform or, more generally, computers or the device used. This takes the form of video / audio communication with an operator who can help users find a solution to their problem; (e) easy access HMI, which is a web application with public and private content that acts as the entry point to the Socialize platform; (f) the agenda, which collects all the events and date/ time-related activities for a given user.

The Interoperability Server is composed of an Enterprise Service Bus (ESB), an Information Service (IS), a Data Distribution Service (DDS) and a Database (DB).

IV. Elderly Monitor Service

The *Elderly monitor service* is a module of the *SOCIALIZE* platform. The core of this service is an *IoT* framework called *SmartSMILE* (*Socialize MIddLeware for the Elderly*) that aims to fulfill a twofold functionality: a) to acquire and collect data from sensors placed in environments occupied by the elderly (e.g. homes) as well as from their body area networks (e.g. smartwatches) for analysis and presentation to medical/caregiver staff; b) to execute complex tasks that enable the elderly to live and work in environments where they feel "protected" and "safe" through awareness of the automatic activation of alarms to alert operators, doctors or family in the event of any emergencies.

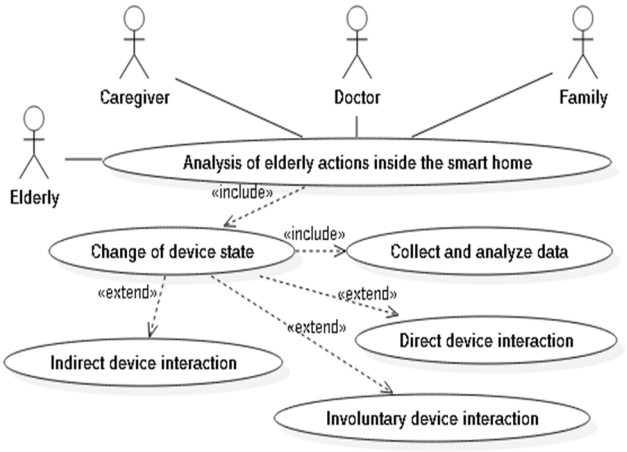

Fig. 2 Elderly monitor service

As shown in Fig. 2, the service analyzes the occupants' habits inside their home environments, which are equipped with smart devices. The occupants need only carry on with their lives at home, conducting their daily affairs as usual. Interactions of the user with the environment can occur in three

different ways: (i) indirect interactions, when the user intentionally intervenes in the system using a tablet, smartphone or any web interface; (ii) involuntary device interaction, when the user's behavior activates devices without any explicit intention (e.g., through a *PIR* - Passive InfraRed sensor device); (iii) direct device interaction, when the occupant acts directly on the system by touching some device (e.g., flipping a switch). The collected data is processed using specialized algorithms to detect 'abnormal' health situations.

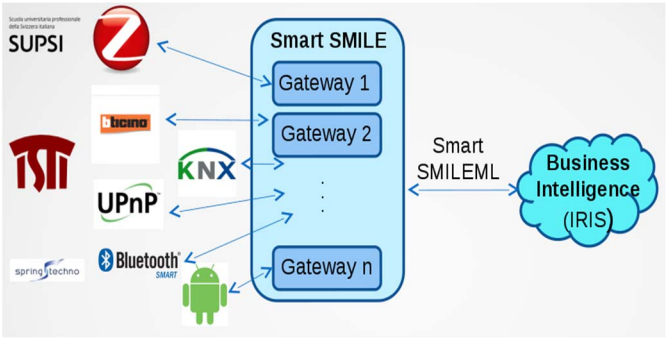

Fig. 3 SmartSMILE architecture

SmartSMILE (Fig. 3) is made up of a set of sub-modules that work as gateways to interface with specific domotic systems purposely installed inside the home or other service devices. Each gateway serves the function of managing its own set of devices, integrating and interfacing them to the platform.

To attain interoperability, the framework implements an abstraction layer that hides the underlying, often proprietary technologies of the integrated devices, leveling them out and permitting the sharing of information amongst them even if they are not natively interoperable. On the one hand, this enables choosing the most suitable sensors/actuators for the specific case without concern for their compatibility with the devices or systems already installed and, on the other hand, it provides developers with a unique representation of the acquired data without the need to know how each single technology works.

The abstraction layer of *SmartSMILE* has been implemented through an *XML*-based standard language, called *SmartSMILEML*, which represents a sort of universal language to abstract out the details of heterogeneous systems and services in order to describe the functions, data types, messages and models of the interactions and communications amongst the various framework entities. Using this high level descriptive language, it is possible to achieve cooperation among disparate services and devices by taking advantage of a single means of communicating and data sharing. Thus, it is possible to achieve a so-called *social network of intelligent objects,* whereby devices are tied to each other by social relationships in order to collaborate and provide a common *SIoT* application.

By exploiting *SmartSMILEML*, *SmartSMILE* is able to achieve a suitable environment for putting into action the principles underlying the implementation of the *SIoT*:

(i) the ability of devices to navigate throughout the network: even devices with no networking capabilities are able to communicate using Internet protocols, thereby permitting full interconnection and interaction amongst them;
(ii) service-to-service communications: the service provided via a device can share its input and output with the services of other "friend" devices to reach a common objective;
(iii) scalability: in order to reach a certain goal, devices can collaborate with each other; moreover, when changes occur (new devices become available or some are missing), tasks can be re-distributed.

SmartSMILEML consists of two main formalisms: (i) *SmartSMILE Device* defines devices and their functions. In particular, it describes the characteristics of each device and the processes by which it interacts with other *SmartSMILE Devices*; (ii) *SmartSMILE Message* formally describes events, commands and responses.

```
<device description="energetic saving lamp" id="1"
  serialNumber="123" tech="KNX" type="lamp">
  <service output="BOOLEAN" name="GetStatus" />
  <service name="SET_STATUS">
    <input name="status" type="BOOLEAN">
      <allowed value="TRUE" />
      <allowed value="FALSE" />
    </input>
    <linkedService id="3" service="setPower">
      <linkedInput from="status" to="power" />
    </linkedService>
  </service>
</device>
```

Fig. 4 Example *SmartSMILE Device* description

Fig. 4 shows an example of a *SmartSMILE Device* description. The device is addressed through its *id*="1". In the example, it is typed as a "lamp" using *KNX* technology. The lamp offers two services: to acquire and set its state through a Boolean value, either TRUE or FALSE. When the *SetStatus* service is executed, the service named *setPower* (*linkedService* tag) of the *SmartSMILE Device* with address *id*="3" is also invoked. The value (*linkedInput* tag) used as input for the described service (*status*) is also used as input value for the service to be invoked (*power*). This means that if the *SetStatus* service of the *SmartSMILE Device* with *id*=1 is invoked, using as input the value TRUE, the *setPower* service of the *SmartSMILE Device* with *id*=3 is also called using the same value as input. The devices with *id*=1 and *id*=3 have thus been established as *friends* and have created a social network whereby data are shared and communication between the devices implemented.

```
<message message="steps" messageType="UPDATE"
senderId="200">
  <input name="Daily steps" type="LONG" value="486" />
</message>
```

Fig. 5 Example SmartSMILE Message description

Fig. 5 shows an example of a *SmartSMILE Message* description, whereby *SmartSMILE* sends to the *Business Intelligence* the number (486) of steps counted by the smart watch (*senderId=200*) for collection and analysis. Every sensor in the platform communicates using the same formalism, which hides its underlying technology to those that receive its data.

SmartSMILE exploits *W3C-recommended standard Web technologies*. It exposes services using *Web Services*, *SOA* and *XML* technologies. The advantage to using *W3C standard* solutions is that they ensure that the developed applications are fully compatible with other standards-based software and are not tied to any particular software system, programming language or computer architecture.

Moreover, *SmartSMILE* permits exposing its devices externally. Exploiting the results of the work described in [7], every device within the system is reachable using an IPv6 address, and socialization can be achieved between devices belonging to different *SmartSMILE* instances.

V. SmartSMILE in Socialize

The *Elderly monitor* service receives the data from the *domotic devices* collected by the *Smart SMILE* framework. Collected data are stored in the *Interoperability server* database and can be accessed and displayed using a web interface.

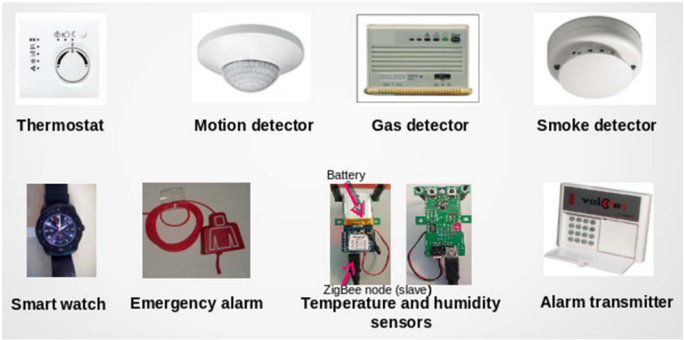

Fig. 6. Some devices integrated into the SOCIALIZE project

Some of the devices used in the project are shown in Fig. 6. In particular, the SUPSI TTHF partner developed three *ZigBee* sensors to measure current temperature, humidity, and the state of the device's battery. The project partner Spring Techno GmbH implemented an *Android* app to communicate the data from a Bluetooth smartwatch. The smartwatch is able to monitor heart rate, the number steps and distance walked daily, and the duration of sleep during rest times. ISTI-CNR interfaced *KNX* devices such as a thermostat, a motion detector, gas, water and smoke detectors, an automatic phone dialer, and an emergency alarm.

Data from the sensors are converted by their respective *SmartSMILE gateway* into *SmartSMILE Messages* and sent to the *Business Intelligence*, hosted by the IRIS Consortium, for analysis and storage in a database.

An infrastructure for the implementation of a typical *SIoT* scenario has been developed by exploiting the interoperability and abstraction features. In particular, interoperability has been established between *KNX* and *MyHome* systems to control current energy consumption, and between *KNX* and *UPnP* to alert the elderly occupant via TV messages in the event of a gas or water leak.

VI. Use Cases

The test and validation processes of the *SOCIALIZE* platform are still ongoing. The tests are being performing in both Italian and Swiss sites by the end-user partners in the project.

Regarding the elderly monitor service, the aim is to collect data from sensors, check that they are understandable and constantly follow and track the evolution of those parameters considered significant for the health and safety of the elderly.

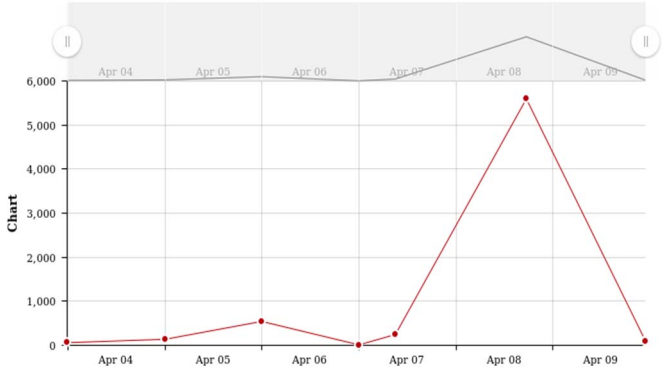

Fig. 7. The daily number of steps of an elderly.

A simple use case example is monitoring the temperature inside the home environment. It might be observed, for example, that people who tend to keep the room temperature either too hot or too cold are subject to falling ill more frequently. Another possibility, which we have actually noticed, is that some elderly people do not get enough physical activity with respect to doctors' recommendations (Fig. 7). Another advantage is that with the system in operation the elderly feel safe from problems related to fire, flooding and gas leaks that may occur within the environment.

VI. Conclusions

This paper focuses on building a framework suitable for integrating *social networking* concepts into the *Internet of Things*, which leads to the so-called *Social Internet of Things* (*SIoT*) paradigm.

The work has applied this new paradigm within an *AAL programme* European project proposing innovative solutions to support and improve the life quality of the elderly through the use of ICT instruments.

The process of enabling the application of *SIoT* has been described in detail, though this represents merely a starting point for a new *IoT* vision, wherein *Social Networking* is able to interconnect not only humans, but things as well.

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