Towards Interoperability of IoT-based Health Care platforms: the INTER-Health use case

Pasquale Pace
DIMES - University of Calabria
Rende - ITALY
ppace@dimes.unical.it

Gianluca Aloi
DIMES - University of Calabria
Rende - ITALY
aloi@dimes.unical.it

Raffaele Gravina
DIMES - University of Calabria
Rende - ITALY
rgravina@dimes.unical.it

Giancarlo Fortino
DIMES - University of Calabria
Rende - ITALY
g.fortino@unical.it

Giovanna Larini
TIM - Telecom Italia
Turin - ITALY
g.larini@telecomitalia.it

Margherita Gulino
Azienda Sanitaria Locale TO5
Turin - ITALY
gulino.m@aslto5.piemonte.it

ABSTRACT

The paper proposes a novel approach to support interoperability between different IoT platforms with a particular focus on the healthcare context and applications.

A novel IoT-based healthcare platform, supporting decentralized and mobile monitoring of assisted livings in highly heterogeneous contexts, can be obtained by integrating two already existing heterogeneous, non-interoperable IoT platforms (BodyCloud and e-Care) according to the strategy proposed in the ongoing INTER-IoT (Horizon 2020) European project.

A specific lifestyle monitoring use case, named INTER-Health, will be used to guide and validate such integration process in order to show the potential of the presented solution in terms of faster detection and correction of wrong lifestyles or critical healthcare situations.

CCS Concepts

•Human-centered computing → Ubiquitous and mobile devices; Smartphones; •Applied computing → Health care information systems; Health informatics;

Keywords

Computing systems; Wearable devices; Healthcare platforms.

1. INTRODUCTION

E-health and m-Health have captured huge attention in the last decade due to their promise to more effectively support health care of assisted livings at hospitals, homes and everywhere [1]. Most of the commercial or non commercial e-health platforms aim to achieve similar goals such as *i)* to improve the quality of life of patients that can be monitored directly from their home without having to go to a clinic or hospital, *ii)* to offer physicians the information in order to have the situation under control of the measurements performed by the patient in real time, without having to spend time on a dedicated visit, *iii)* to support the hospital and home care through the use of ICT and biomedical technologies that facilitate the monitoring of the patient and his relationship with the most appropriate clinician referent (doctor and / or medical specialist, nurse, carer), and *iv)* to help in costs reduction because a patient can be adequately monitored, de-hospitalized in advance and can make use of targeted drug therapy changes. However, specific problems were often addressed with specific solutions that were not interoperable. This has led to the development of many IoT-based health care systems that may constitute an added-value if we were able to integrate them thus supporting decentralized and mobile monitoring of assisted livings in highly heterogeneous contexts.

Every year in the world 2.8 million people die for obesity or overweight; 2.6 million people die for high cholesterol levels; 7.5 million people die for hypertension; 3.2 million people die for physical inactivity [2]. The growing increase of these statistics justifies the interest in designing new platforms to monitor physical activity, lifestyle and health of people in their daily activities.

The IoT paradigm [3] can boost the health care industry by enabling an easier interconnection of wireless sensors and mobile or embedded devices. A broad state of the art in this field is given in [1]. In this work, authors survey advances in IoT-based health care technologies and reviews the state-of-the-art of architectures and platforms. Many examples could be made, however, here we will introduce only a few emblematic example. In [4] authors propose a smart hospital system for patient monitoring and management of emergency. The system allows also automotive monitoring and tracking of patients, personal and biomedical devices within hospitals and nursing institutes.

A personalized IoT healthcare platform in smart homes environment is introduced in [5]. The system supports the monitoring and processing of several physical parameters and exposes RESTful web services to the consumers. Finally, a review of the existing wearable sensors for human activity monitoring is discussed in [6]. The work motivates the important role of wearable devices system to support the continuous monitoring of physiological parameters especially of the elderly or chronic patients.

BODYNETS 2016, December 15-16, Turin, Italy

Copyright © 2017 EAI

DOI 10.4108/eai.15-12-2016.2267656

The plethora of existing solutions highlights the evident lack of interoperability and fragmentation of existing IoT healthcare platforms. Accordingly, this paper describes the potential of the under development INTER-IoT [10] framework to support the interoperability in a reference m-health use case based on two already developed and widely used IoT healthcare platforms presenting distinctive features.

The rest of the paper is organized as follows. In section 2 we point out the motivations of the proposed study. In section 3 we describe the characteristics of different IoT-based healthcare platforms highlighting the main issues related to lack of interoperability between them. In the same section we discuss about the requirements, the methods and the benefits coming from platforms integration. Section 4 proposes and describes a specific use case called INTER-Health to demonstrate the usefulness of the IoT platforms integration also explaining the next steps towards the realization of the real pilot test. Finally, section 5 concludes the paper presenting future research directions.

2. MOTIVATIONS

Many different IoT platforms already exist [7], [8],[9] providing specific solutions for different application scenarios such as healthcare, logistics, home automation, etc... however, the quick integration and interoperability of those heterogeneous IoT platforms, allowing heterogeneous elements to cooperate seamlessly to share data, infrastructures and services as in a homogeneous scenario, is still a challenging issue.

It is worth noting that, when we consider any IoT platform, the complexity of technologies used to build up the platform further arises as each defined layer (device, networking, middleware, application service, data and semantics) exploits specific heterogeneous IoT technological solutions that need to be holistically adapted to form the final platform without providing any (or even limited) interoperability. Thus, it is critical to provide bottom-up "*voluntary*" approaches able to integrate, interconnect, merge, heterogeneous IoT platforms to build up extreme-scale interoperable ecosystems on top of which large-scale applications can be designed, implemented, executed and managed.

A possible solution to the interoperability issue is being developing within the ongoing INTER-IoT project [10] whose main ambition is the design of a framework for interoperability, interconnection and integration between two or more heterogeneous IoT platforms. INTER-IoT will provide the first full-fledged methodological and technological suite to completely address the fundamental issue of "voluntary interoperability". The suite will be composed of three main building blocks: (i) Layer-oriented infrastructures (INTER-LAYER) to adapt heterogeneous peer layers (device-to-device, networking-to-networking, middleware-to-middleware, application services-to-application services, data and semantics-to-data and semantics); (ii) Interoperable open framework (INTER-FW) to program and manage integrated IoT platforms; (iii) engineering methodology and tools (INTER-METH) to drive the integration process of heterogeneous IoT platforms. Figure 1 shows the proposed INTER-IoT framework to make interoperable different IoT platforms.

The INTER-IoT project will address IoT platform heterogeneity by granting interoperability through the methodology-driven integration and ensuring open accessibility to the integrated IoT platforms through distributed management

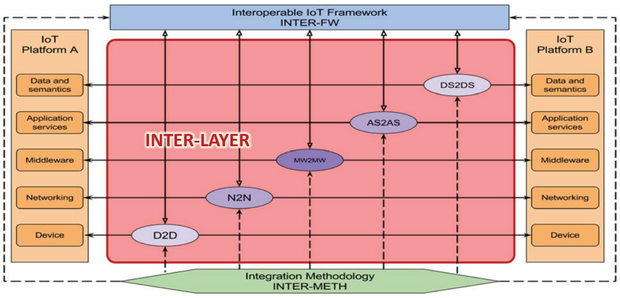

Figure 1: INTER-IoT architecture.

software. To ensure this (i) the INTER-LAYER tools will provide techniques and technology allowing interoperability and integration between the layers of heterogeneous IoT platforms, (ii) the INTER-FW tool will offer programming library, service APIs and reference architecture to manage integrated IoT platforms and (iii) INTER-METH will be a full-fledged methodology and a tool that will drive the integration performing of heterogeneous IoT platforms. The main aim of this work is to demonstrate the usefulness of the INTER-LAYER tools to support the interoperability in a reference m-health use case based on two already developed IoT platforms presenting distinctive features.

The use of the INTER-LAYER allow the integration of IoT heterogeneous throughout a suitable layered approach:

- at the device level (D2D), it is allowed a fast growth of smart objects ecosystems, seamless inclusion of novel IoT devices and their interoperation with already existing, even heterogeneous ones;
- at the networking level (N2N), is allowed the design and implementation of fully connected ecosystems, seamless support for smart objects mobility and information routing;
- at the middleware level (MW2MW), it is allowed a global exploitation of smart objects in large (even extreme) scale (multi-platform) IoT systems, seamless service discovery and management system for smart objects and their basic services;
- at the application service level (AS2AS), it is allowed the reuse and exchange (import/export) of heterogeneous services between different IoT platforms;
- at the data and semantics level (DS2DS), it is allowed a common interpretation of data and information based on global shared ontology in order to achieve semantic interoperability between heterogeneous data sources.

3. INTEROPERABILITY OF IOT-BASED HEALTHCARE PLATFORMS

In this section we describe two representative IoT healthcare platforms (BodyCloud and e-Care), well suited for e-health contexts, that will be integrated to obtain an INTER-Health IoT use case.

3.1 Bodycloud

BodyCloud is a software as a service (SaaS) architecture that supports the storage and management of body sensor data streams and the processing (online and offline analysis) of the stored data using software services hosted in the Cloud [11]. Figure 2 shows an high-level BodyCloud architecture to support several cross-disciplinary applications and specialized processing tasks. It enables large-scale data sharing and collaborations among users and applications in the Cloud, and delivers Cloud services via sensor-rich mobile devices. BodyCloud also offers decision support services to take further actions based on the analyzed BSN data.

Bodycloud has been used to support research prototypes in diversified application domains including physical rehabilitation [12], activity monitoring of healthy subjects [13],[14] and community-scale cardiac monitoring [15].

The BodyCloud approach is centered around four main decentralized components (or sides): Body, Cloud, Viewer, Analyst:

- The Body-side is the component, currently based on SPINE Android [19],[20] that monitors an assisted living through wearable sensors and stores the collected data in the Cloud by means of a mobile device.
- The Cloud-side is the component, currently implemented atop Google App Engine, that provides fully support for specific applications through data collection, processing, analysis and visualization.
- The Viewer-side is the Web browser-enabled component able to visualize the output of data analysis through advanced graphical reporting.
- The Analyst-side is the component that supports the development of BodyCloud applications.

The core of the BodyCloud architecture is the Cloud-side that offers high-level Web-based programming abstractions for the rapid prototyping of Cloud-assisted BSN applications: group, modality, workflow, and view. A group formalizes a specific application which manipulates a specific BSN data source. A modality formalizes a specific interaction between the Body-, Cloud- and Viewer-sides within a group. It specifies the input data, the actions to be performed on the input data, and the output data. A workflow formalizes an analysis process, producing output data from input data; it is specifically composed of one or more nodes (organized in an acyclic graph) representing specific algorithms. A view formalizes the graphical visualization of output data for the Viewer-side. The proposed SaaS approach is, to the best of our knowledge, the first general-purpose software engineering approach for Cloud-assisted community BSNs. It notably allows for rapid prototyping of Cloud-assisted BSN applications, customizability of the architectural components through Web standards-based procedures, and scalability due to the employed Google App Engine PaaS infrastructure.

3.2 e-Care

The e-Care platform is a cloud based platform and an evolution of the commercial service "*Nuvola It Home Doctor*" [7], the distance monitoring system, developed for the prevention and cure environment. The platform has been developed within the SmartHealth 2.0 research prohject [16] experimenting an innovative technological infrastructure and

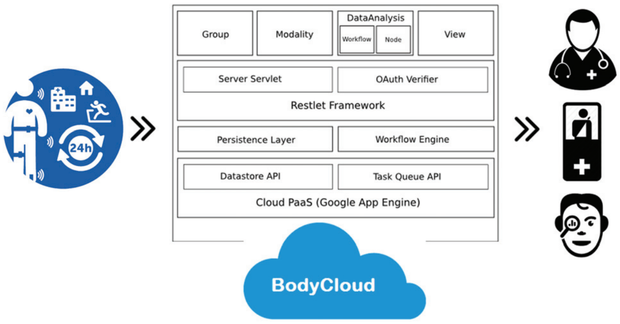

Figure 2: High-level BodyCloud architecture.

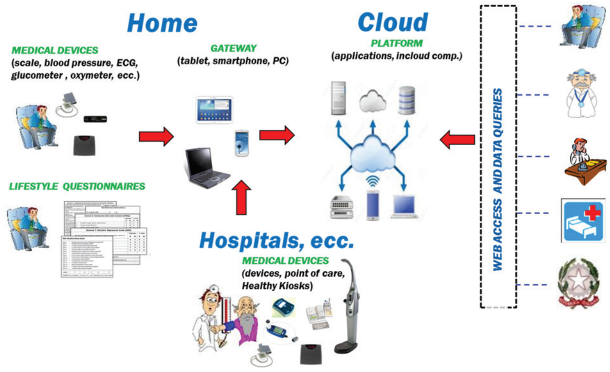

Figure 3: e-Care IoT Platform.

services in the area of health and well-being: telemonitoring heart failure, children and adult prevention of elderly people with risk of cognitive impairment [18]. This platform allows to collect objective measures (such as blood pressure, weight) and subjective informations (by questionnaires); these measures are gathered by gateways (on smartphones, tablet and PC), sent and stored in cloud to the platform and released to different stakeholders (patients, physicians and caregivers) by different channels (mail, web portals, sms and so on).

The doctor performs the clinical interpretation of the received parameters, monitors the data trend and activates any corrective action (*e.g.,* change in therapy, frequency of measures, etc.).

The doctors of the health care facility can be automatically notified to the occurrence of some particular situations (*e.g.,* parameters exceeding certain threshold values) and in case of need can interact directly with the patient himself.

Patients can receive messages reminding them to take measurements or to take the drugs as prescribed by protocol set by the doctors.

Figure 3 synthesizes the generic actors and entities involved into the e-Care Platform that can support different application scenarios such as in the hospital, hospital at home, continuity of care, chronic diseases, remote assistance of vulnerable people, emergency, wellness and prevention. Moreover, depending on the specific needs of the healthcare facility, the service can be adapted to other scenarios, with different level customizations actors, roles, responsibilities and protocols of care. In particular, the platform enables three modes of operation:

- *Home telemonitoring on their own* - Indicated for patients with a high degree of autonomy and empowerment, prevention, chronic diseases, patients which should be kept under observation.
- *Home telemonitoring with Tutor* - The Sanitary Operator goes to patient's homes in order to control their physiological parameters. This model is indicated in order to de-congest the hospital activities and for patients inserted in house assistance programs.
- *Telemonitoring in surgery* - Indicated when the logistical situation is unfavorable for direct access to the hospital and primary care are made available to the territory (small islands, mountain communities, remote locations). Also useful for screening campaigns and prevention.
- *Electronic Medical Report* - To allow citizens or patients to easily access to sanitary and social information services on mobile terminals. Electronic Health Records (EHR) and Personal Health Records (PHR) of patients are stored in Service Center equipped with physical and logical application modules. EHRs are managed by institutions (*e.g.,* hospital, health care provider) while PHRs are maintained by the patients but also accessible to authorized health operators.

Moreover, many different measures are supported such as Weight, Systolic and Diastolic Pressure, Heart rate, Glycemia, Oximetry (minimum, average, maximum, 6 minute walking test, nocturnal oximetry), Spirometry, Electrocardiogram (7/12 leads), Prothrombin time expressed as INR (International Normalized Ratio), Temperature, Height, Body fat, Blood analysis by selecting the specific devices.

3.3 Platforms integration: requirements, methods and benefits

As highlighted in previous sections, the two platforms e-Care and BodyCloud share some high-level characteristics while differs in objectives and technology. Specifically, they are both e-Health platforms, based on Bluetooth technology to interact with measurement devices, and based on Cloud infrastructures to enable data storing, off-line analysis, and data visualization. However, the two platforms have different specific objectives and are not interoperable from a technological point of view. Their specific objectives are complementary: e-Care is focused on non-mobile remote monitoring based on non-wearable measurement devices, whereas BodyCloud provides monitoring of subjects in mobility through wearable devices organized as body sensor networks (BSN). Thus, their integration would produce a full-fledged m-Health platform atop of which multitudes of m-Health services could be developed and furnished.

3.3.1 Integration requirements

In the following we define the main integration requirements, at the global IoT platform management level and at the different IoT platform layers, to integrate and make interoperable e-Care and BodyCloud. At global level, the integrated platform needs to be accessed by users and managed by administrators from a unified interface; in this context several non functional requirements need to be satisfied:

- *Security* to not allow third parties to take over control of a private system that is working over an IoT-based health care platform.
- *Privacy* to provide protection for accessing information about physical devices, services or whole connected platforms. Privacy protection needs to be supported during data transmission, aggregation, storage, mining and processing and it should not set a barrier to data source authentication.
- *Reliability* between devices belonging to different platforms, usually expressed as the allowable time between failures, or the total allowable failure rate.
- *Dependability* of the global platform consisting of two dependable platforms. In this case, even if the two distinctive platforms are dependable, the new interoperable platform could be not dependable; thus, a special attention should be devoted to guarantee the dependability of the global platform avoiding mistakes, detecting and removing errors and limiting damage caused by failure.

By looking the integration from the layer-oriented perspective, the requirements to be satisfied can be summarized as follows:

- DS2DS - Collected data need to be stored according to the same format and semantics (*e.g.,* in relation to measures of weight, the format between kilograms and pounds or the interpretation of GPS tuples (latitidine, longitude) needs to be standardized);
- AS2AS - Application services should be furnished in an integrated fashion and activated contextually (*e.g.,* at the healthcare center, at home and in mobility);
- MW2MW - Middleware services such as user identification and location, and device and service discovery and management should interoperate;
- N2N - At networking level, devices belonging to different platforms have to be seen as belonging to a single network so accessible, addressable and configurable
- D2D - As measurement devices do not interact directly with each other, but only transmit measures to the central local smart coordinator (according to a master-slave paradigm), it should be guaranteed only interoperability at the communication level between the measurement devices (medical devices and wearable sensors) and the smart coordinator (PC, laptop, tablet, smartphone) based on some widely available communication standards.

Table 1 resumes the main characteristics of the two IoT-based health care platforms by following the described layer-oriented approach.

3.3.2 Methods

The new IoT platform coming from the integration of e-Care and BodyCloud will be obtained through a customized implementation of the INTER-LAYER component depicted in figure 1 in which both N2N and MW2MW layers are not considered. This choice is motivated by the analysis

Table 1: Layer-oriented comparison.

Layer	BodyCloud	e-Care
D2D	Mobile Gateway	Mobile Gateway
N2N	Not Available	Not Available
MW2MW	SPINE[19]	Proprietary (Closed)
AS2AS	REST/XML	REST/XML
DS2DS	Proprietary	Proprietary

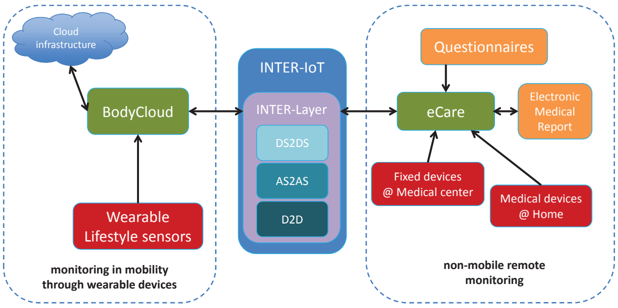

Figure 4: INTER-Health: BodyCloud and e-Care integration.

presented in table 1 in which it is clear that, the N2N layer is not available in any of the platforms and the MW2MW layer is based on a proprietary and closed solution for the e-Care platform that does not allow the possibility of any integration a this layer.

In particular, the INTER-LAYER approach will provide a set of tools to allow the data access, communication and integration at different layers: *i)* at device layer (D2D) the new IoT platform will be able to communicate with the wearable devices supported by the BodyCloud and with the non-mobile and non-wearable measurement devices installed at the medical center or at home; *ii)* at the application services layer (AS2AS), the specific reports of the patients provided by the e-Care platform will be integrated and enriched with data coming from the BodyCloud platform to complement the analysis; *iii)* at the data and semantics layer (DS2DS) all the acquired information will be made consistent according to a common data format. Figure 4 shows the integration of the two IoT platforms by using the INTER-LAYER approach.

3.3.3 Benefits

INTER-IoT project aims to guarantee an effective and efficient interoperability between heterogeneous IoT platforms such as the two described e-Health IoT Platforms (i.e., e-Care Platform and BodyCloud). Thanks to the proposed interoperable approach new cross-platform services can be developed. Thus, the main benefit of the proposed integration and interoperability consists into the availability of a more powerful IoT healthcare platform for lifestyle monitoring to support new application services that individual platforms were not able to support.

Finally, by exploiting the novel fully integrated IoT environment, the aforementioned monitoring process can be decentralized from the healthcare center to the monitored subjects' homes, and supported in mobility by using on-body physical activity monitors; this approach, allows to reduce both the transfer costs of patients at medical centers and the waiting times, also obtaining constantly updated results to make the necessary adjustments in a faster and precise manner.

4. INTER-HEALTH USE CASE

The proposed use case, based on the integration of the described IoT platforms, aims to develop an integrated IoT system for monitoring humans' lifestyle in a decentralized mobile way to prevent health issues resulting from food and physical activity disorders. The aforementioned monitoring process can be decentralized from the healthcare center to the monitored subjects' homes, and supported in mobility by using on-body physical activity monitors.

It is worth noting that, the strategic importance of such complete use case, is largely motivated by the fact that wrong lifestyles such as improper and hypercaloric diet and, in particular, the lack of physical activity, are at the base of main chronic diseases [2].

During the use case experimentation, the effectiveness, in terms of lifestyle improvement indices, of the novel system will be evaluated with respect to the current "manual" monitoring performed by conventional Healthcare Centers.

4.1 Lifestyle monitor: Medical Perspective

According to the reference standard medical protocol for the global prevention and management of obesity [21], [22] written by World Health Organization, in order to assess the health status (underweight, normal weight, overweight, obesity) of the subject (of a given age) during the visit at the healthcare center, objective (weight, height, body mass index, blood pressure, waist circumference) and subjective (eating habits and the practice of physical activity) measurements should be collected (and/or computed) by a healthcare team (doctor, biologist nutritionist, dietitian, etc).

For these reasons, the objective of this use case consists of monitoring humans' lifestyle in a decentralized way and in mobility, to prevent health issues mainly resulting from food and physical activity disorders.

In particular, the use case needs to take into account the following state of health indicators:

- *The Body mass index (BMI)* - it is an objective measure, calculated with formula: $weight/height^2$, that allows to assess the health status (underweight, normal weight, overweight, first level obesity, second level obesity and 3rd level obesity) of subjects, also allowing to make the diagnosis of overweight and obesity.
- *The waist circumference* - it is an objective measure used to diagnose overweight and obesity; values greater than 94 cm in men and 80 cm in women are considered pathological.
- *The physical activity practice* - it is a subjective measure that detect the amount (hours / daily and hours / week) and the type of physical activity (no activity; light, moderate and intense activity). This measure is used to detect a wrong lifestyle with physical inactivity.
- *The eating habits* - it is a subjective measure that detect the quality and quantity of food consumed daily and weekly. This measure is used to detect a wrong lifestyle due to improper diet and high-calories.

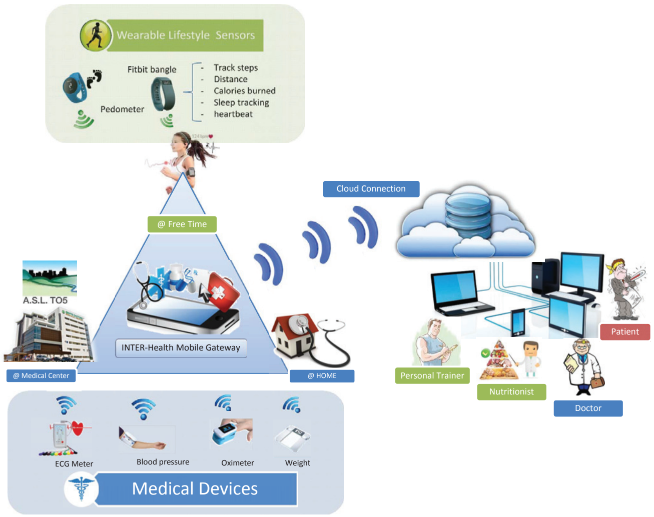

Figure 5: INTER-Health full-fledged IoT platform.

The defined use case would be fully deployable atop the integration of e-Care and BodyCloud as the automated monitoring at the healthcare center and the decentralization of the monitoring at the patients' homes would be supported by the e-Care remote services, while the physical activity monitoring in mobility would be enabled by the BodyCloud mobile BSN services.

4.2 INTER-Health technical functionalities

The main functionalities of the integrated and interoperable IoT platform are the followings:

- collection of objective (weight, height, body mass index, blood pressure or waist circumference) and subjective (questionnaires concerning the eating habits and the practice of physical activity) measures during the visits at the healthcare center (based on e-Care);
- telemonitoring at the healthcare center of subjective (questionnaires) and objective (weight, blood pressure, etc...) measures sent by the patients at home (based on e-Care platform);
- telemonitoring at the healthcare center of the physical activities performed by patient at home with wearable devices (based on BodyCloud platform) report and visualization of all the measurements collected for analysis and interaction on treatments.

4.3 Pilot deployment

The INTER-Health pilot allows the conduction of an experimental nutritional consulting the aim of which is to reduce health risk factors, at the basis of major chronic diseases, such as incorrect lifestyles which are typically characterized by both high-caloric diet and the lack of an adequate physical activity. In such a way, the pilot involves a group of about 200 patients who want a medical support to improve their lifestyle.

Patients will be involved in the pilot for a whole year during which they will be constantly monitored through a set of wireless wearable devices such as bangles, pedometers and heart rate monitors communicating through standard communication technologies (*i.e.,* Bluetooth for medical devices and Bluetooth or IEEE 802.15.4 for wearable sensor nodes).

Patients will equipped with smartphones, acting as interoperable gateways[23] toward a cloud repository that will be accessed by experts in the specific field, such as doctors, nutritionists and personal trainers, in order to constantly monitor the user behaviours. Figure 5 shows the new integrated and interoperable IoT platform.

The study, non-invasive and without risk to health, is conducted by the Nutritional Unit (NU) of the Department of Prevention of the Complex Structure of Food, Hygiene and Nutrition of the fifth Local Health Unit of the Italian department of Turin (ASL TO5). The pilot is an observational study that involves subjects divided into two groups: a group called the Control Group (CG), represented by the patients involved only in the traditional nutritional consulting, and an Experimental Group (EG), represented by the patients that will be involved in the experimental nutritional consulting.

During nutritional consulting, the NU will collect and monitor a set of patients data: anthropometric (*i.e.,* weight, height, body mass index, blood pressure, waist circumference), clinical and dietary history (*i.e.,* eating habits and physical activity). All these data will be collected by the researcher and stored in the EHRs of patients. After the first clinical visit, the CG health status will be checked every three months, while the EG will be constantly monitored trough the INTER-Health technological platform. For the EG, there are planned also two overhaul physical visit in the 6th and 12th month of the pilot.

In particular, the INTER-Health pilot of experimental nutritional consulting will allow:

- the recording at home, with weekly frequency, of patient weight by using electro-medical devices (*i.e.,* smart balance) provided by ASL TO5 during the study period;
- the recording at home, with daily frequency, of patient blood pressure by using electro-medical devices (*i.e.,* smart blood pressure meter) provided by ASL TO5 during the study period;
- the continuous live recording of daily physical activity, burned calories and the duration of aerobic activity performed, by using wearable mobile devices (*i.e.,* smartphone and electronic bracelet) provided by ASL TO5 during the study period;
- the weakly recording of eating habits by filling in online questionnaires made available both via web and via smartphone's apps.

It is worth noting that the proposed INTER-Health pilot presents the following expected and relevant medical results:

1. Overcome the traditional methods in the relationship between doctor and patient making easier the interaction;
2. Improve the system's efficiency increasing the number of patients that can be assisted;
3. Provide quality advantages originating from a higher number of objective measures, that are more effective and appropriate;

4. Obtain new standards for the management of nutritional units, supporting more efficient and responsive nutritional advice services;

5. Achieve the same or better health goals using new technologies, that are more efficient, allowing the extension of preventive action to a larger population, without greater outlays.

5. CONCLUSIONS

This work presented a novel approach to support the integration and interoperability between different and already developed IoT-based healthcare platforms by using the so called INTER-LAYER component. The conducted analysis has been focused to design a specific INTER-Health use case through which it is possible to obtain, with reduced effort, new application services that the specific healthcare platforms were not designed for. The performance testing of the integrated platform, in terms of efficiency and reliability, is in progress at this time and the results will presented and detailed in future works.

6. ACKNOWLEDGMENTS

This work has been carried out under the framework of INTER-IoT, Research and Innovation action - Horizon 2020 European Project, Grant Agreement #687283, financed by the European Union.

The authors would thank Claudio Maggi, Anna Costa, Monica Minutolo, Marina Mortara, Ilaria De Luca, Angelina Della Torre, Domenica Pata, Bartolomeo Avataneo, Anna Aldrighetti, Carlo Aldera, Fabio D'Ercoli and Alberto Delpiano for their valuable support.

7. REFERENCES

[1] S.M.R. Islam, D. Kwak, M.H. Kabir, M. Hossain, K. Kwak "The Internet of Things for Health Care: A Comprehensive Survey", *IEEE Access*, Vol. 3, pp. 678-708, 2015.

[2] World Health Organization. "Global status report on non communicable diseases", 2010.

[3] G. Fortino, P. Trunfio "Internet of Things Based on Smart Objects, Technology, Middleware and Applications", Springer 2014, ISBN 978-3-319-00490-7.

[4] L. Catarinucci, D. de Donno, L. Mainetti, L. Palano, L. Patrono, M.L. Stefanizzi, L. Tarricone, "An IoT-Aware Architecture for Smart Healthcare Systems", *IEEE Internet of Things Journal*, vol. 2, no. 6, pp. 515-526, Dec. 2015.

[5] S.K. Datta, C. Bonnet, A. Gyrard, R.P. Ferreira da Costa, K. Boudaoud "Applying Internet of Things for personalized healthcare in smart homes", WOCC, pp. 164-169, 2015.

[6] S.C. Mukhopadhyay, "Wearable Sensors for Human Activity Monitoring: A Review", *IEEE Sensors Journal*, Vol. 15, Issue 3, pp. 1321-1330, 2015.

[7] Nuvola It Home Doctor, *https://tmed.telecomitalia.it/en/home*

[8] Kaa IoT Platform, *http://www.kaaproject.org/overview/*

[9] Jasper - Control Center for Security & Home Automation *http://www.jasper.com/security-home-automation*

[10] INTER-IoT European project, Research and Innovation action - Horizon 2020 - available on line at *http://www.inter-iot-project.eu/*

[11] "BodyCloud: A Cloud-assisted Software Platform for Pervasive and Continuous Monitoring of Assisted Livings using Wearable and Mobile Devices", *http://bodycloud.dimes.unical.it*

[12] G. Fortino, R. Gravina "A Cloud-Assisted Wearable System for Physical Rehabilitation", In ICTs for Improving Patients Rehabilitation Research Techniques, Vol. 515, pp. 168-182, Nov 2015.

[13] R. Gravina, C. Ma, P. Pace, G. Aloi, W. Russo, W. Li, G. Fortino "Cloud-based Activity-aaService cyberphysical framework for human activity monitoring in mobility", *Future Generation Computer Systems*, Available online 22 September 2016, DOI: 10.1016/j.future.2016.09.006

[14] G. Fortino, R. Gravina, W. Li, C. Ma "Using Cloud-assisted Body Area Networks to Track People Physical Activity in Mobility", In Proc. of the International Conference on Body Area Networks (BodyNets 2015), pp. 85-91, Australia, Sep 2015.

[15] G. Fortino, R. Gravina, A. Guerrieri, G. Di Fatta "Engineering Large-Scale Body Area Networks Applications", In Proc. of the International Conference on Body Area Networks (BodyNets 2013), Boston, United States, ACM press, pp. 363-369, 2013.

[16] SmarthHealth 2.0, *http://www.smarthealth2.com/eng/*

[17] V. C. Gungor, P. Pace, E. Natalizio "AR-TP: An adaptive and responsive transport protocol for wireless mesh networks", IEEE International Conference on Communications, ICC 2007, pp. 3740-3745, doi:10.1109/ICC.2007.616

[18] A. Ricauda, N. G. Isaia, V. Tibaldi, G. Bestente, A. Frisiello, A. Sciarappa, S. Cavallo, M. Ghezzi, G. Larini " Telecare and Telemedicine in Home Care Practice: Field Trial Results", *Distributed Diagnosis and Home Healthcare (D2H2)*, American Scientific Publishers (ASP), Vol. 2, pp. 281-303, 2011.

[19] G. Fortino, S. Galzarano, R. Gravina, W. Li "A framework for collaborative computing and multi-sensor data fusion in body sensor networks", *Information Fusion*, Vol, 22, pp. 50-70, 2015.

[20] F. Bellifemine, G. Fortino, A. Guerrieri, R. Giannantonio "Platform-independent development of collaborative Wireless Body Sensor Network applications: SPINE2", IEEE International Conference on SMC, pp. 3144-3150, 2009.

[21] Obesity: Preventing and Managing the Global Epidemic. WHO Obesity Technical Report Series 894. Geneva, Switzerland: World Health Organization, 2000.

[22] Physical Status: The Use and Interpretation of Anthropometry. Technical Report Series 854. Geneva, Switzerland: World Health Organization, 1995.

[23] G. Aloi, G. Caliciuri, G. Fortino, R. Gravina, P. Pace, W. Russo, C. Savaglio "Enabling IoT interoperability through opportunistic smartphone-based mobile gateways", *Journal of Network and Computer Applications*, Available 20 October 2016, DOI: 10.1016/j.jnca.2016.10.013.