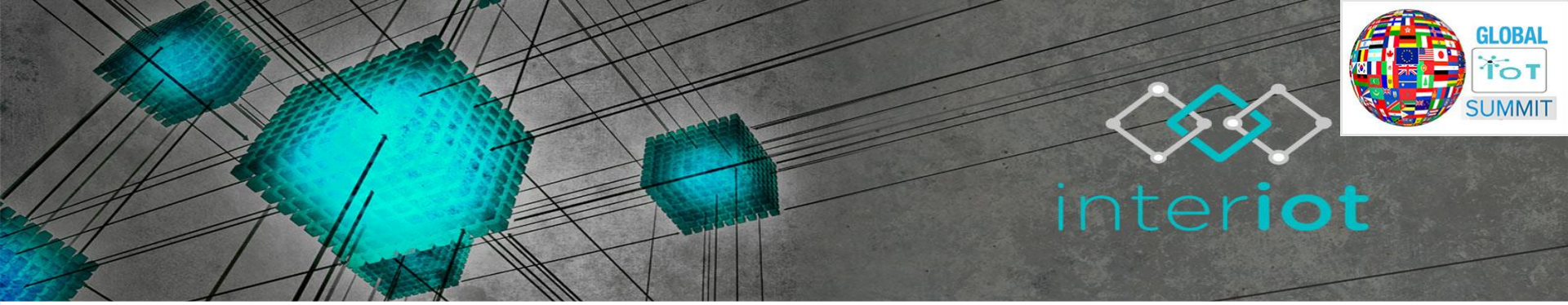


IoT platforms interoperability for Active and Assisted Living Healthcare services support

*Pasquale PACE, R. Gravina, G. Aloi, G. Fortino,
+Fides-Valero, G. Ibanez-Sanchez, V. Traver,
#C.E. Palau, D.C. Yacchirema

*DIMES - University of Calabria, ITALY
+ITACA-SABIEN - Universitat Politecnica de Valencia, SPAIN
#DCOM - Universitat Politecnica de Valencia, SPAIN

INTERNATIONAL WORKSHOP ON INTERNET OF THINGS FOR ACTIVE AND ASSISTED LIVING (IOTAAL)

Outline

- Motivation and Key contributions
- INTER-IOT Vision and Mission http://www.inter-iot-project.eu/
  - Consortium and proposed architectures
- IoT-based Healthcare platforms
  - BodyCloud and universAAL
- Platforms Integration
  - Requirements, Methods and Benefits
- INTER-HEALTH Use Case
  - Medical perspective
  - Technical functionalities
  - Pilot deployment and expected results
- Conclusions & work in progress

Motivations and Key contributions

- Many different IoT platforms already exist 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, is still a challenging issue.

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.

INTER-IoT Challenge and Vision

INTER-IoT arises by the need of interoperability at different layers from IoT platforms from different application domains and managed by different stakeholders

Key issues

- Islands/silos, usually associated with an application domain
- Single vendor/Proprietary platforms
- Lack of standards or over-existence of standards
- Gap to the users -> lack of co-creation and open ecosystem building

INTER-IoT Vision and Mission

interiot
interoperability of heterogeneous IoT platforms

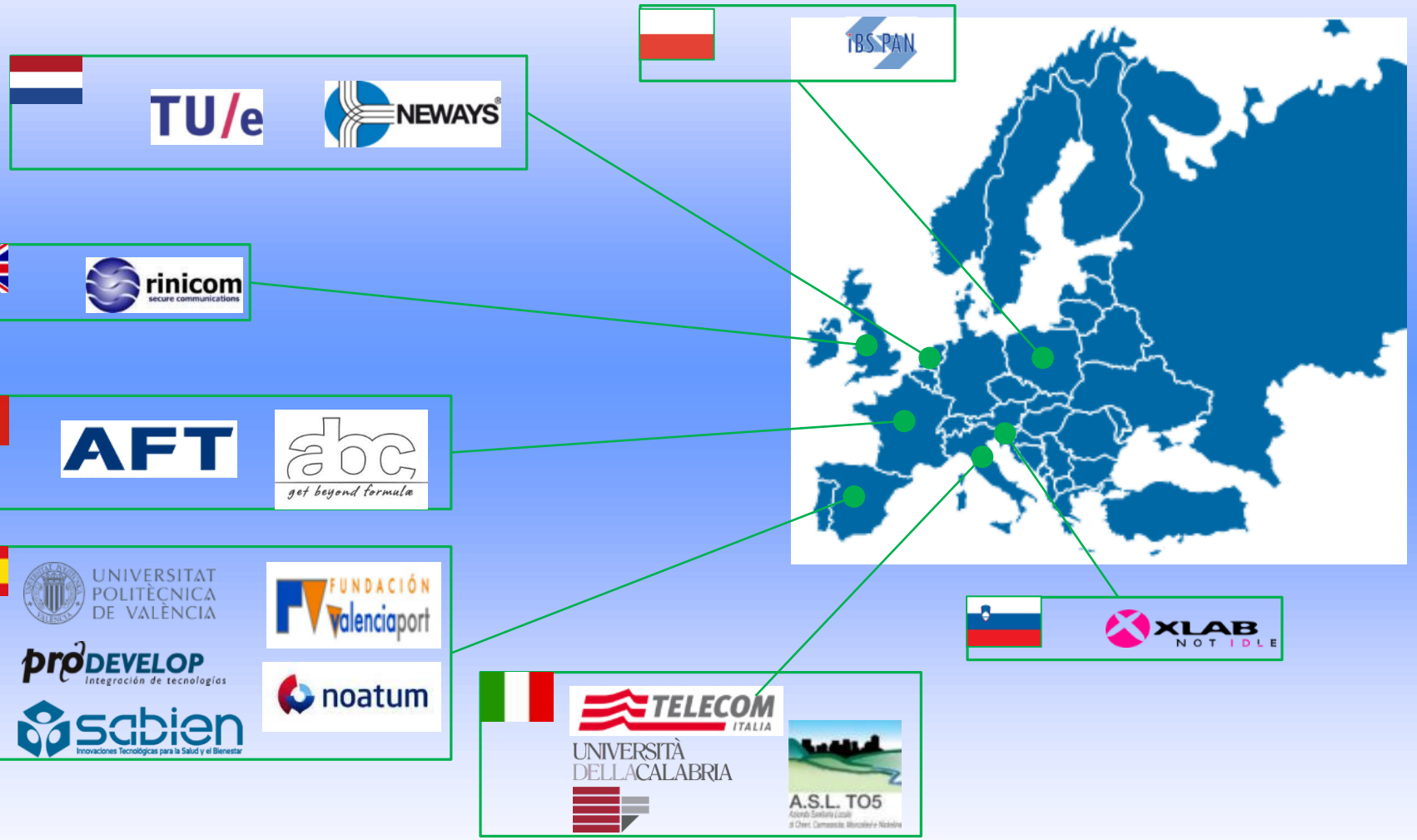
INTER-IoT vision is to provide all the building blocks needed to achieve interoperability between IoT Platforms, including a framework, methodology, associated APIs and tools.

By building and demonstrating:

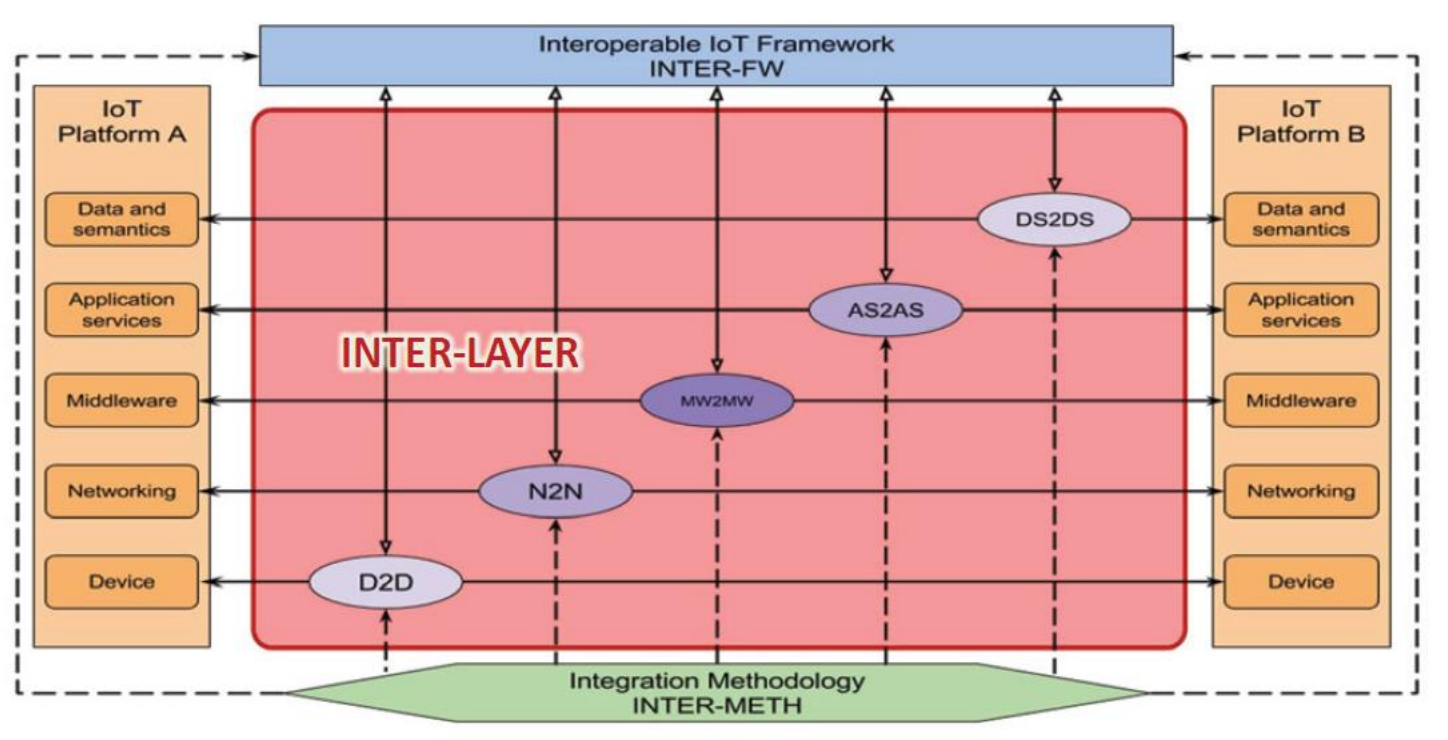
- Seamless inclusion of novel IoT devices
- Seamless support for smart objects mobility
- Service discovery and management
- Reuse and exchange of services between IoT platforms
- Common semantic interpretation of data
- Rapid prototyping of cross-platform IoT applications
- Overcome market barriers
  - http://www.inter-iot-project.eu/

INTER-IoT Consortium

interiot
interoperability of heterogeneous IoT platforms

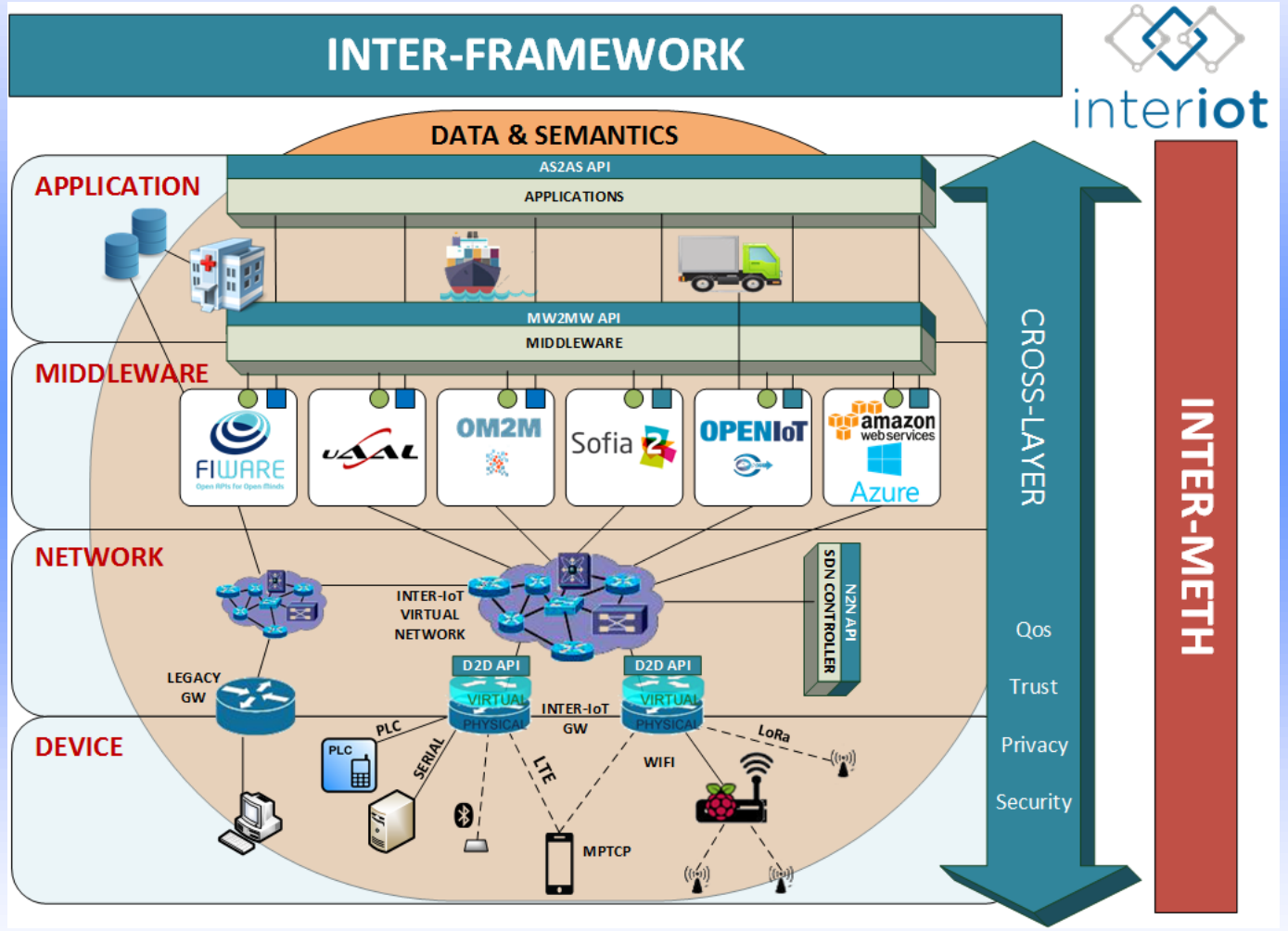


INTER-IoT architecture



- The INTER-LAYER tools will provide techniques and technology allowing interoperability and integration between the layers of heterogeneous IoT platforms

INTER-LAYER

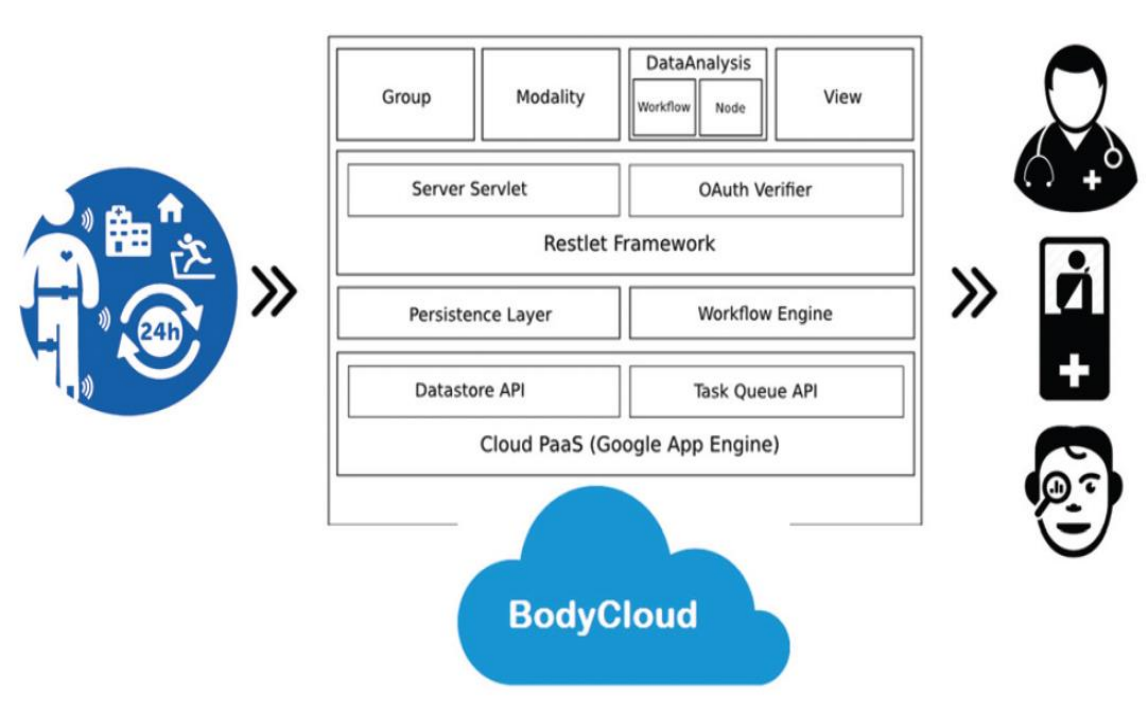

INTER-FRAMEWORK
interiot
DATA & SEMANTICS
AS2AS API
APPLICATIONS
APPLICATION
MW2MW API
MIDDLEWARE
MIDDLEWARE
FIWARE
uAAL
OM2M
Sofia 2
OPENIoT
amazon web services
Azure
NETWORK
INTER-IoT VIRTUAL NETWORK
SDN CONTROLLER
N2N API
LEGACY GW
D2D API
VIRTUAL
PHYSICAL
INTER-IoT GW
D2D API
VIRTUAL
PHYSICAL
DEVICE
PLC
PLC
SERIAL
LTE
WIFI
LoRa
MPTCP
CROSS-LAYER
Qos
Trust
Privacy
Security
INTER-METH

IOT-BASED HEALTHCARE PLATFORMS

IoT-based Healthcare platform: BodyCloud

- Software as a service (SaaS) architecture http://bodycloud.dimes.unical.it/
- It 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

- It has been used to support research prototypes in diversified application domains including:
  - physical rehabilitation,
  - activity monitoring of healthy subjects
  - community-scale cardiac monitoring.



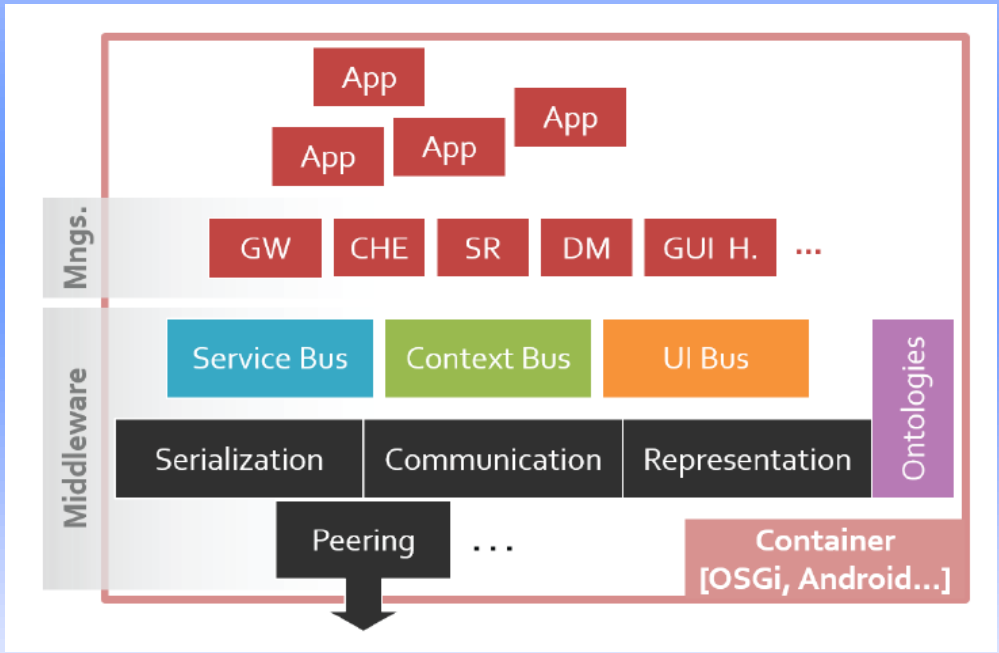
IoT-based Healthcare platform: universAAL

- It provides an open source semantic framework that allows applications and sensors to communicate and interoperate with one another, based on an **ontological description** of their data models.
- During ReAAL project http://www.cip-reaal.eu/home/, universAAL was tested under real-life conditions with more than 5000 users across Europe.

- Being a platform for interoperable applications, universAAL does not provide specific applications (other than examples).
  - Among the ones used during the ReAAL project, the researchers at university of Valencia (UPV) developed applications that let end-users manage Personal Health Records (PHR), together with some health measurements (*e.g.* blood pressure, weight) and questionnaire, and let healthcare organizations manage Electronic Health Records (EHR)

IoT-based Healthcare platform: universAAL

- Communication between applications and/or sensors happens through three different buses:
  - *Context bus* - An event-based bus for sharing contextual information from context publishers to context subscribers.
  - *Service bus* - A request-based bus for on-demand execution and information retrieval from service callers to service providers.
  - *User Interface bus* - A centrally-managed bus that allows applications to define abstract interfaces to be rendered by different User Interface (UI) modalities.



Platforms integration

- ***universAAL*** and ***BodyCloud*** share some high-level characteristics while differs in objectives and technology
- **Similarities**: Bluetooth technology and cloud-based architecture
- **Differences:** universAAL is mostly focused on non-mobile remote monitoring based on non-wearable measurement devices, whereas BodyCloud provides monitoring of subjects in mobility through wearable devices

The integration would produce a full-fledged *m-Health* platform atop of which multitudes of m-Health services could be developed and furnished.

Platforms integration: requirements

@Global level, non functional requirements are:

- **Security** - to not allow third parties to take over control
- **Privacy** - to provide protection for accessing information
- **Reliability** - between devices belonging to different platforms
- **Dependability** - even if the two distinctive platforms are dependable, the new interoperable platform could be not dependable

@Layer-oriented level:

- **DS2DS** - Collected data need to be stored according to the same format and semantics
- **AS2AS** - Application services should be furnished in an integrated fashion and activated contextually
- **MW2MW** - Middleware services such as device discovery and management should interoperate
- **N2N** - Devices belonging to different platforms have to be seen as belonging to a single network
- **D2D** - it should be guaranteed interoperability at the communication level between the measurement devices and the smart coordinator

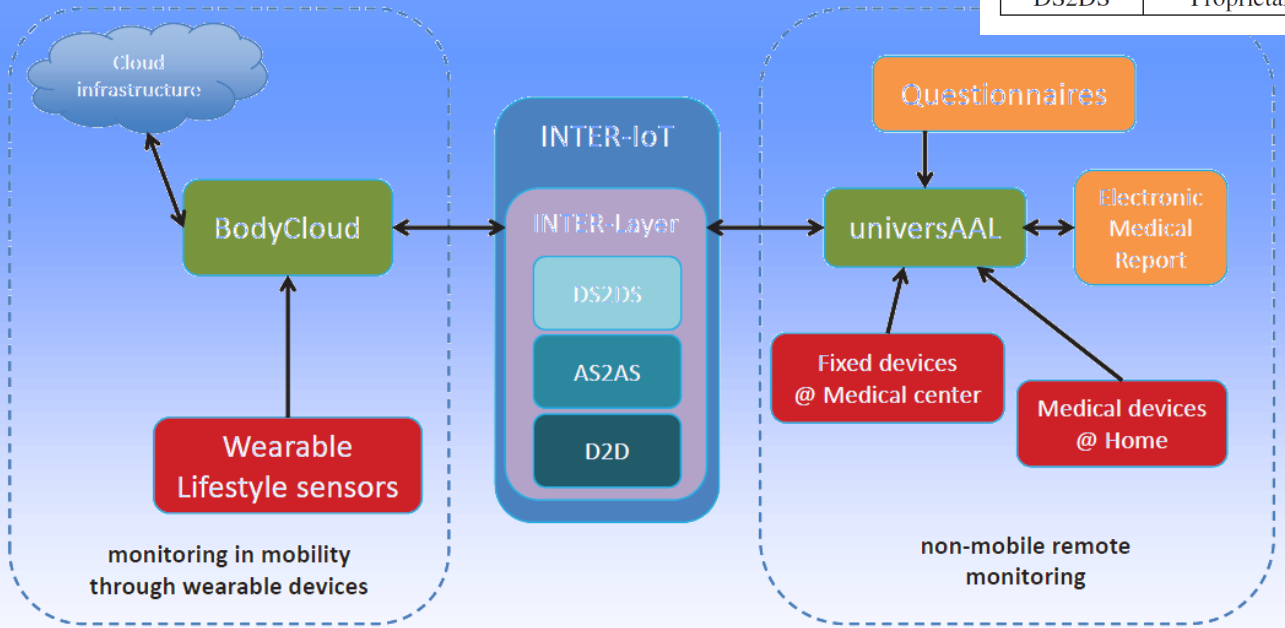
Platforms integration: methods

- The new IoT platform coming from the integration of **universALL** and **BodyCloud** will be obtained through a customized implementation of the INTER-LAYER component

N2N and MW2MW layers are non implemented because they are not available or require too many modifications

TABLE I
LAYER-ORIENTED COMPARISON.

Layer	BodyCloud	universAAL
D2D	Mobile Gateway	Mobile/Local Gateway
N2N	Not Available	Not Available
MW2MW	SPINE	Semantic(OWL)
AS2AS	REST/XML	REST, Java
DS2DS	Proprietary	Ontologies(RDF/OWL)



Platforms integration: benefits

- A more powerful IoT healthcare platform for lifestyle monitoring to support new application services that individual platforms were not able to support
- The 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
- **Reduction of** the transfer **costs** of patients at medical centers and the waiting times
- Constantly **updated results** to make the necessary adjustments in a faster and precise manner.

INTER-HEALTH Use Case

- The use case 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.

- 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

Lifestyle monitor: Medical Perspective

- 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},
  - *The waist circumference* - it is an objective measure used to diagnose overweight and obesity
  - *The physical activity practice* – it 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.

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 universAAL platform);
  - telemonitoring at the healthcare center of subjective (questionnaires) and objective (weight, blood pressure, etc...) measures sent by the patients at home (based on univesAAL 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.

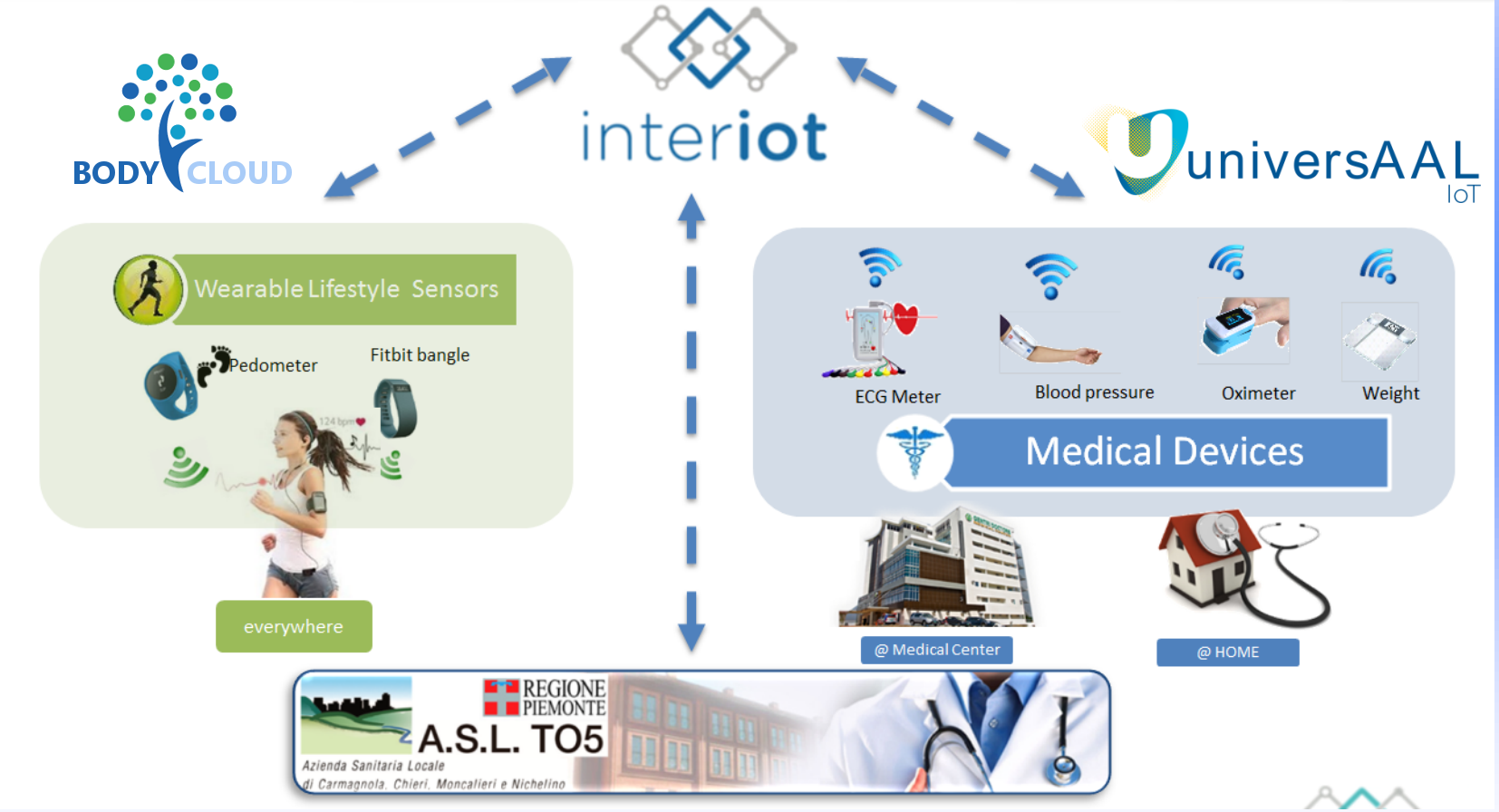
Pilot deployment (1/3)

- The pilot will involve a group of about 100 patients (for a whole year) who want a medical support to improve their lifestyle
- Patients will be constantly monitored through a set of wireless wearable devices such as bangles, pedometers and heart rate monitors communicating through standard communication technologies
- Patients will equipped with smartphones, acting as **interoperable Gateways** 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

- 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 Local Health Unit of the Italian department of Turin (ASL TO5).

Pilot deployment (2/3)

The pilot involves a group of about 100 patients (for a whole year) who want a medical support to improve their lifestyle.



Pilot deployment (3/3)

- 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);
  - the recording at home, with daily frequency, of patient blood pressure by using electro-medical devices (*i.e.,* smart blood pressure meter);
  - 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);
  - the weekly recording of eating habits by filling in online questionnaires made available both via web and via smartphone's apps.

Expected 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.

Conclusions & ongoing works

- We proposed 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
- We designed a specific INTER-Health use case to obtain, with reduced effort, new application services that the specific healthcare platforms were not designed for

Ongoing works:

- The performance testing of the integrated platform, in terms of efficiency and reliability,
- The results will presented and detailed in future works within the INTER-IOT European H2020 Project

Visit Inter-IoT booth with 3 DEMOS

Interoperability
@

Data&Sematics
App&Services
MiddleWare

THANK YOU FOR THE ATTENTION

Questions?