Internet Orchestra of Things: A Different Perspective on the Internet of Things

Understanding Internet of Things Concept through Game

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***Abstract*—The Internet of Things (IoT) is defined as a global network that links together living and/or non-living entities, such as people, animals, software, physical objects or devices. These entities can interact with each other, gather, provide or transmit information to the IoT. Although the Internet of Things is a relatively new concept, various platforms are already available. Some of them are open platforms, enabling both the integration of people, systems, and objects from the physical and virtual world, and the visualization of data. For example, there are already some IoT platforms used, like Google Cloud Platform, Microsoft Azure IoT Hub, Amazon Web Services IoT Platform, IBM Watson IoT Platform, Nimbits, Open.Sen.se, ThingWorx, and ThingSpeak. But what if things could not only "work" and "speak", but also "sing"? We propose a game in which the things connected to IoT can play in real time different sounds, according to the values of some monitored parameters. These things can be grouped in the IoT platform to create a virtual orchestra and make music. Besides this game allowing the creation of great songs, it can be widely used to explain the new ideas behind the fast emerging areas of the Internet of Things. In addition to many technical challenges, it is also worth considering the effect the IoT concept will have on people, society, and economy as a whole.**

Keywords*—*Internet of Things; music; game; education; RFID; robot

I. INTRODUCTION

The Internet of Things (IoT) allows connections between various entities (i.e., human beings, devices, sensors, robots, virtual entities, etc.), using different communication protocols. In this world-wide network of interconnected entities, these different entities (viewed as "things") have the ability to discover and explore one another, gather, provide or transmit information to the IoT.

According to a BuddeComm's report [1], the Internet of Things is going to be a real game-changer. "It will transform every single sector of society and the economy; and it will be out of this environment that new businesses – and indeed new industries – will be born. The infrastructure that is now being built offers a range of features such as ubiquitousness, affordability, low latency, high speed and high capacity. It will link, apart from individual people, millions of devices, such as sensors that will enable us to manage our environment, infrastructure, and our society as a whole much more efficiently" [1].

Despite the fact that the Internet of Things is a relatively new concept, there already is a wide range of IoT platforms and applications spanning multiple domains. Various research studies estimate that IoT adoption will have a radical impact on business and on the way we live. But the potential technical or non-technical IoT users must have at least a minimal understanding of this concept. These users working on the front line with "things" must be able to understand the potential, and find out how they might use the IoT and perhaps find new ways of cost savings or revenue. The lack of knowledge and skills related to the Internet of Things both among employees and management is an important challenge that IoT providers need to address. Still, according to [2], one of the internationally recognized NMC Horizon Reports identifying emerging technologies and practices likely to have a significant impact on global Higher Education over the next five years, the estimated time for adopting the Internet of Things in Higher Education in 2012 was approximately four to five years. And, for example, in 2016, MIT Professional Education includes Internet of Things in its online curriculum [3], but what about children of primary school and secondary school age? How to understand the Internet of Things concept?

In order to make anyone really understand this multifaceted concept that is no longer just an idea, but has already entered in our life, we propose a game named "*Internet Orchestra of Things*".

The rest of the paper is organized as follows: Section 2 gives a brief description of the underlying concepts and introduces various definitions of the Internet of Things. Also, there are presented some IoT platforms and applications. Section 3 address related work. Next section presents the proposed game, Internet Orchestra of Things (IOoT). Subsequently, we discuss two scenarios in which various sensors and, respectively, a robot and different adjacent entities are considered both as things in IoT and as instruments in IOoT. Finally, Section 5 draws the conclusions.

II. INTERNET OF THINGS

A. Definition

At this moment there are several definitions regarding the Internet of Things. In fact, the concept of Internet of Things is difficult to be accurately defined because the enabling technologies keep moving forward and the concept itself is in a constant state of evolution. Also, it is difficult to provide a definition "that would cover the many facets of this concept/idea/paradigm" and "that is a '*compromise*' among many different views" [4]. Thus, the three points of view about the IoT are emphasized in Fig. 1, Things-oriented, Internet-oriented and Semantic-oriented perspectives.

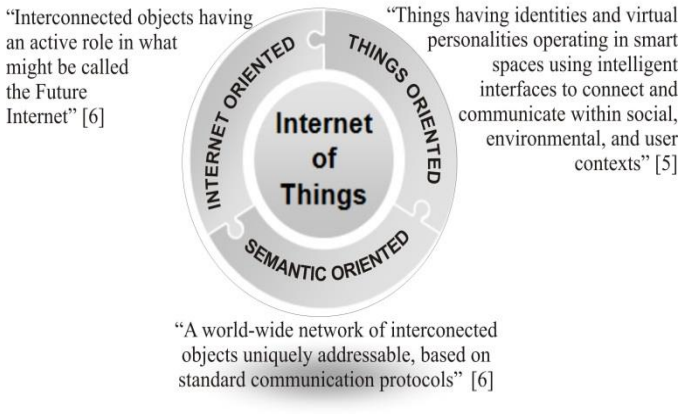

Fig. 1. The "Internet of Things" paradigm as a result of the convergence of different visions.

This figure also presents several definitions of "Internet of Things". Furthermore, it clearly indicates that the IoT paradigm may be considered as the result of a merger between the three main perspectives mentioned above [7].

In fact, Internet of Things can be simply considered as a shift in paradigm. "From anytime, anyplace connectivity for anyone, we will now have connectivity for anything" [8].

"Anything" can be connected to the Internet of Things as "things":

- Entities
  - Physical entities:
    - Living entities (people, animals, etc.),
    - Non-living entities (devices, etc.).
  - Virtual entities.
- Information

Even though a standardized definition of the "Internet of Things" does not exist, most of the definitions of this paradigm share common points, such as [9]:

- The global unique identification of everything.
- The ubiquitous nature of connectivity.
- The ability of each thing to send and receive data across the Internet of Things.

The Radio Frequency IDentification (RFID) technology is viewed as a founding technology for the Internet of Things [10]. It is one of the technologies used in the process of unique identification of a thing that should be connected to the Internet of Things. This technology implies the use of an RFID tag attached to or embedded into the entity to be identified. This RFID tag allows storing various information about that particular entity. The RFID tags are read and written using an RFID reader.

B. Internet of Things Applications

Currently, IoT-based applications are already used in various fields, such as, health, industrial control, transport, logistics, domotics and daily life [11]. A global commissioned study conducted by Forrester Consulting, "Building Value from Visibility: 2012 Enterprise Internet of Things Adoption Outlook" showed that "the Internet of Things (IoT) is no longer a concept, but a reality that is improving the operations of global enterprises" [12], [13].

One example is that provided by Robert Mawrey who presented in [14] a solution based on ioBridge technology and cloud-services for a complete automation, monitoring and remote controlling of a cranberry bog.

IoT@Work [15], an EU project led by Siemens AG, focuses on harnessing IoT technologies in industrial and automation environments, by developing an IoT-based plug and work concept centered on industrial automation.

Also, worldwide there are various Internet of Things applications that solve different problems related to the elderly or disabled people. Thus, for, example, L. Coetzee and G. Olivrin [16] present in their chapter some applications and challenges in supporting the inclusion of disabled and elderly people in mainstream society.

Technology optimists claim that for any new societal challenge (such as climate change, energy efficiency, health services, etc.) there is always an IoT-based solution that successfully addresses it [10].

But, without a real understanding of the Internet of Things concept, it will be impossible to benefit from the advantages that IoT could bring.

C. Internet of Things Platforms

Although the Internet of Things is a relatively new concept, it becomes more and more tangible through IoT platforms. Various open platforms for Internet linked-things are already available, bridging the gap between the real and the virtual world. Next, we will briefly introduce some of the Internet of Things platforms.

Cosm (formerly Pachube) [17] was launched as an open real-time data infrastructure platform for the IoT. It enables connection of various devices and sensors, data publishing, and allows receiving data and instructions from different devices. The Cosm service also allows supplying data for further processing. In fact, Cosm is viewed as an Internet of Things middleware platform.

Instead using the term "Internet of Things", Open.Sen.se, Cosm competitor, prefers the "Internet of Everything where

Humans, Nature, Machines, Objects, Environments, Information, Physical and Virtual spaces all mix up, talk, intertwine, interact, enrich and empower each other in all sorts of ways" [18]. This open platform allows everything to feel, to act, and to make sense.

Nimbits [19] is an open source platform that allows connecting people, sensors and devices on the cloud. This platform enables various features, such as performing calculations, connecting to social networks (like Facebook, Google Plus and Twitter), storing and sharing files/sensor logs/process diagram, generating alarms, creating statistics, etc.

ThingSpeak [20] is described as "an open application platform designed to enable meaningful connections between things and people". This IoT platform allows users to interact with various devices, to store and retrieve data from things by exploiting standard Web technologies (such as HTTP protocol over the Internet or via a LAN). It also interfaces with various social networks (such as Twitter) and location-based services (like Foursquare and Google Latitude) [21]. Over time, ThingSpeak has been employed for various types of applications, such as location tracking and sensor logging applications. Furthermore, ThingSpeak allows using the cloud in order to store data and perform different calculations, such as rounding, summing, averaging, median, etc.

ThingWorx is a platform for developing applications both for the Internet of Things and the Intranet of Things. The applications built on ThingWorx platform enable the connection of people, systems, and smart things [22].

The things considered in the Internet of Things are usually associated with physical objects, thus providing a real-time, interactive view of the physical world. Although much progress has been made, the development of IoT applications is considerably lagging behind. Without a widespread understanding of the concept, it will be hard to realize the vision of the Internet of Things. To this extent, we propose a game, named "*Internet Orchestra of Things*" that can be widely used to explain the new ideas behind the fast emerging areas of the Internet of Things. It also allows the creation of great songs. In this game, the things in IoT play different sounds, in real time, according to the values of some monitored parameters. These things can be grouped in the IoT platform to create a virtual orchestra and make music. In addition to many technical challenges, it is also worth considering the effect the IoT concept will have on people, society, and economy as a whole.

III. Related Work

Currently there are many games and toolkits designed for composing and managing music [23] (such as SoundJunction [24]). The user is thus able to: create music by choosing sounds from a wide library, use various music managing softwares, build a playlist, or use a microphone as a source [25].

We can also mention the Public Sound Objects (PSOs), a project that proposes "the development of a networked musical system, which is an experimental framework to implement and test new concepts for online music communication. The PSOs project approaches the idea of collaborative musical performances over the Internet by aiming to go beyond the concept of using computer networks as a channel to connect performing spaces" [26].

Reactable is a table based, collaborative musical instrument for exploring, creating, playing and even understanding music in a visual, enjoyable, intuitive and non-intimidating manner [27].

Worldwide, "the use of sonification as a means of representing and analysing data has become a growing field of research in recent years and as such has become a far more accepted means of working with data" [28]. And IoT is more about data and big data.

Although there are various games and platforms, none of these addresses the complex concept of Internet of Things.

IV. Internet Orchestra of Things Game

The game named Internet Orchestra of Things (IOoT) proposes a different perspective on the Internet of Things. The IoT is defined as a global network that links living or non-living entities, such as people, animals, software, physical objects or devices, virtual systems. These entities can interact with each other, access information on the Internet, store and retrieve data, etc. Although the Internet of Things is a relatively new concept, various platforms are already available: some of them are open platforms that enable the integration of people, systems, and objects from the physical world, and the visualization of data. Examples of such platforms are ThingWorx and ThingSpeak. But what would it be if things could not only "work" and "speak", but also sing? Thus, in the suggested game, the things in IoT play different sounds in real time. They actually generate sounds according to the values of some monitored parameters. Furthermore, these things can be grouped to create a virtual orchestra and make music. Besides allowing the creation of great songs, this game can be widely used to explain the new ideas behind the fast emerging areas of the Internet of Things.

At the time of this writing, the IOoT game is designed and we are developing it. Current implementations of the IOoT modules use Pure Data [29] and SuperCollider [30].

Fig. 2 shows the interactions between an IoT platform and IOoT.

The Internet Orchestra of Things comprises of the following modules:

- user interface module;
- real-time sound synthesis engine, that provides an interface to convert in sounds values of various parameters specific to a thing;
- instrument configuration component that allows the setup of the instrument associated with a thing;
- orchestra configuration component that enables the creation of the orchestra, based on the defined instruments;
- user management component that allows the management of players and of their profiles;

- sound multi-agent system that integrates various intelligent agents. These agents enable the collecting and filtering of sound information, according to the profile and criteria defined by the user.

Starting from the model presented in [31], we summarize schematically the relationships between things, instruments and orchestra in Fig. 3.

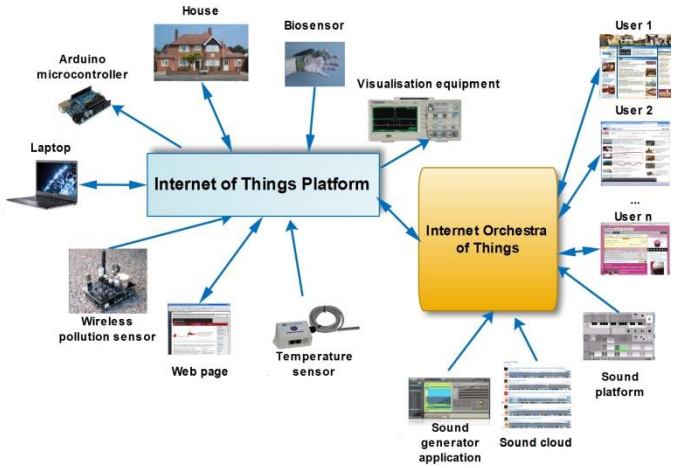

Fig. 2. General interaction IoT – IOot.

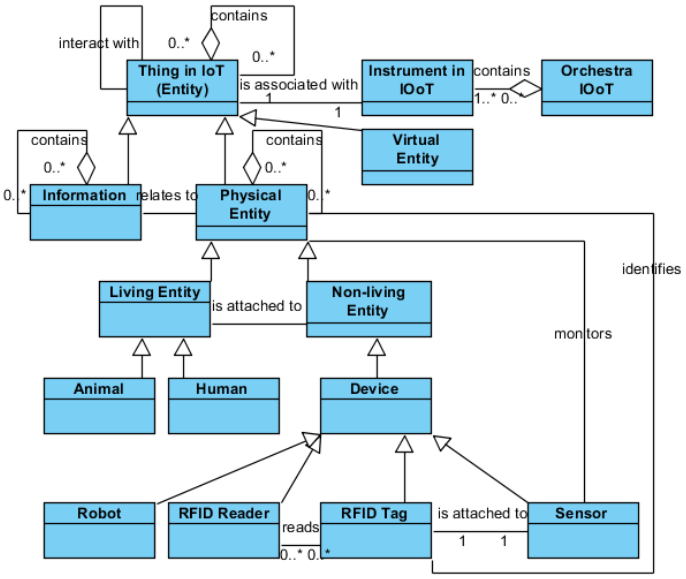

Fig. 3. The information model.

A user can be connected to the IoT as a thing and establish connections with other things over the Internet, either as a source of information, or/and as a consumer. This requires bringing together numerical data from heterogeneous sources (geographically distributed). In order for a patch or an instrument to be created, these data are associated with sounds. Also, some sound parameters, such as pitch or intensity can be set by the user, according to his preference. He will choose the entities that best suit his composition needs and integrate them as sonic instruments in his own orchestra. At the same time, the user is able to interfere and change the structure of the orchestra.

This game encourages the user to discover things connected to the Internet of Things and to establish relationships between them. Also, a user can share his instruments with other players, allowing the development of social cohesion. The proposed game will enable the exploring of large numerical data sets through the corresponding sounds that are produced.

We believe that this game, through the interaction it involves, will allow gamers to understand some requirements and notions regarding the Internet of Things, such as identifying and connecting physical entities (e.g., users, objects, devices) or virtual entities to the Internet of Things, interoperability, etc. The players of IOoT can access this game whenever they want, without any time or geographical limitations.

A. Game Scenario

In order to build an Internet Orchestra of Things, we consider various entities connected to the Internet of Things. An entity can be connected to the IoT in an active mode, allowing sending real-time information to the Internet. In order to connect an entity to the Internet of Things, we can use an existing IoT platform, such as Cosm, Nimbitts, or ThingSpeak. The IoT platform enables the considered entity (viewed as thing in IoT) to share, collaborate, and make use of information uploaded on the web. Thus, it can generate real-time charts, embed graphs on websites, and send real-time data or alerts to other devices [32], [33], such as cell phones or, in this case, our game. Thus, a connected thing in IoT can be viewed as a source of information for the IOot game. According to the information of interest, our game produces specific sounds and the entity can be viewed as a sonic instrument in the Internet Orchestra of Things. Also, a selected thing could be specified by the user to act as a different instrument in the game.

In the first scenario, in order to develop an Internet Orchestra of Things, we consider some sensors, connected to the IoT, that measure temperature, humidity, air quality and noise at various locations in a building or a city. The user can select any of these sensors in order to associate a virtual instrument that could be added to his orchestra.

This could also have another effect on education. Many studies have revealed that the thermal environment in the classroom will affect academic achievements at grade levels within the school. Thus, temperature, an environmental variable, plays an important role in learning and memory. Various studies show that the exposure to high and low temperatures has a negative impact on academic performance. For example, Herrington [34] found that temperatures above 80 degrees Fahrenheit (approx. 26.7 degrees Celsius) “tend to produce harmful physiological effects that decrease work efficiency and output”. Also, according to various studies, improper temperature and humidity generate favourable conditions for spreading diseases and infections. Currently, there are no regulations regarding the temperature and humidity values in a classroom or an office setting, but there are some worldwide recommendations. Thus, for example, even though U.S. Occupational Safety and Health Administration does not have regulations addressing temperature and humidity in an office, a subsection of its technical manual does recommend “temperatures ranging from

68 degrees to 76 degrees Fahrenheit and humidity ranging from 20 percent to 60 percent" [35]. These values will be used for the setup of the sound generator.

Next, we consider another game scenario that addresses the connection of a robot (e.g., Surveyor SRV-1) to the Internet of Things. Robots can be seen as "multi-faceted tools with different roles in engineering education" [36] and, in particular, in Internet of Things education. In our game, a robot, named RoboThing, will be used to set up an Internet Orchestra of Things and will be connected to the Cosm Internet of Things platform (Fig. 4). In the IOoT, RoboThing can be connected as a thing that produces sounds, in the same manner an instrument does. The speed and direction of the robot will control the parameters of the generated sound.

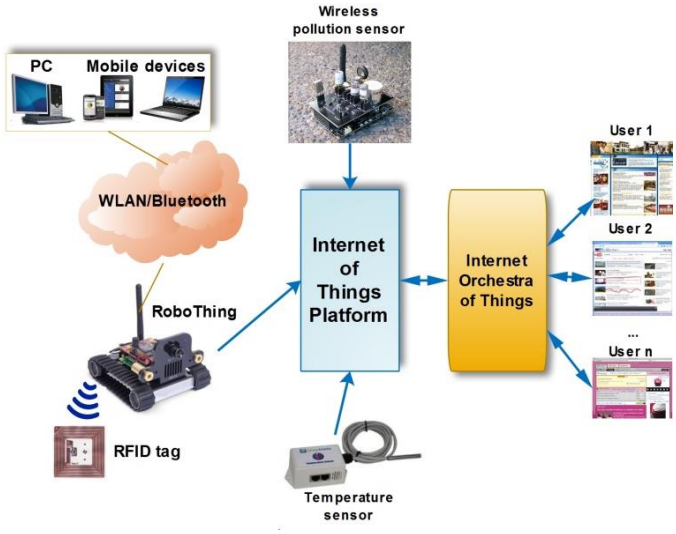

Fig. 4. A game scenario architecture.

Furthermore, in our experimental setup, RoboThing has Radio Frequency Identification (RFID) capabilities assured by an RFID reader that is placed on the board of the robot. Thus, RoboThing could identify RFID-tagged entities from its own environment (e.g., entities that are or are not connected to the Internet), and publish on the IoT information related to these entities. In this way, RoboThing allows the connection of these entities to the IOoT. The entities are viewed as different instruments and can be added to the orchestra. Thus, the game allows the generating of complex sonic structures based on the real-world interaction between things connected to Internet of Things and their physical environments. This could be an example of integration between IoT concepts and solutions based on RFID technology. It could also be used to exemplify the third generation of IoT evolution, as it was presented in [10].

V. Conclusion

The Internet of Things can be considered an evolutionary process, rather than a completely new one. "From anytime, anyplace connectivity for anyone, we will now have connectivity for anything" [8]. Different studies estimate that innovative applications and businesses which exploit the accessibility and connectivity of anything connected to IoT, will emerge in the near future [10]. But, the adoption of the Internet of Things in various domains is not possible without a good understanding of the concept. By playing the presented game, Internet Orchestra of Things, users familiarize with the emerging Internet of Things and some of the concepts it involves. Playing IOoT is also about musical creativity and not about playing an instrument.

This game is based on entities (viewed as things in Internet of Things) that do not have keyboards, resonance tubes, etc. But IOoT game allows each entity to produce sounds that reflect its interaction with other entities, or with its environment. Thus, an entity can be viewed as an instrument of the orchestra build by the user. In fact, the user does not actually compose music, but builds an orchestra and chords the virtual instruments. Thus, different users can listen to things. In fact, the players of IOoT can access anything, part of this orchestra any time and from any place.

Creating and playing music with the help of this game can be a social and collective experience that involves creativity, but also, collaboration and competition.

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