IoT Architecture Proposal for Disabled People

Nuno Vasco Lopes* †, Filipe Pinto‡, Pedro Furtado*, Jorge Silva*
*CISUC R&D Center,† CenterAlgoritmi R&D Center, ‡PTinovacao R&D Center
email: nvlopes@dei.uc.pt, filipe-c-pinto@telecom.pt, pnf@dei.uc.pt, sasilva@dei.uc.pt

***Abstract*—We are living in a new communication age, which will radically transform the way we live in our society. A world where anything will be connected to Internet is being created, generating an entirely new dynamic network - The Internet of Things (IoT) - enabling new means of communication between people, things and environment.**

A suitable architecture for Internet of Things (IoT) demands the implementation of several and distinct technologies that range from computing (e.g. Cloud Computing), communications (e.g. 6LowPAN, 3/4G) to semantic (e.g. data mining). Thus, it is necessary to understand very well all these technologies in order to know which of them is most suitable for a given scenario.

Therefore, this paper proposes an IoT architecture for disabled people and intends to identify and describe the most relevant IoT technologies and international standards for the stack of the proposed architecture. In particular, the paper discusses the enabling IoT technologies and its feasibility for people with disabilities. At the end, it presents two use cases that are currently being deployed for this population.

***Index Terms*—Internet of Things, Disabled People.**

I. INTRODUCTION

Technologies supporting the Internet of Things are having a tremendous advance in important IoT technical fields, becoming each day more accessible, available and versatile, allowing a faster grow of the things interconnected through Internet. This technical advances are opening a new world of different ways to communicate, empowering human and machine data communication capacities. The industry and institutions are already embracing the underlying IoT technology to enhance their internal processes and services. The IoT technologies are expanding to specific application domains, evolving towards a fully IoT World. One example are the technical innovations for people with special needs in order to assist them in their daily activities, improving this way, their quality of life. This could be achieved with the help of well adapted and specific IoT technology for this sort of people, however, despite we could forecast these scenarios in the near future, currently, their implementation still represents a huge technological step.

The Internet of Things is the result of a technical revolution in many technological areas, a technological revolution that demands further technical advances in a number of important IoT areas, which range from wireless sensors to big data processing. But in the midst of this uncertainty of what will be in concrete the technology of the Future Internet, we can ask what is necessary to have a highly dynamic architecture for the Internet of Things. Focusing in a more technical perspective of view, we can say that what is need is:

1) data collection technologies that sense changes in physical status of things for then stored and shared this information;
2) embedded intelligence using different communication patterns (request/response and subscription notification) in things accompanied with nano-technology that will supply the ability of things communicate and interact in order to accomplish some main purpose for a user application;
3) connect everyday objects and devices to Internet, with a cost-effective system identifications such as RFID;
4) develop appropriate software for hiding the heterogeneity (e.g hardware and operating systems) from application layer.
5) a set of data mining / big data / semantic-based enablers to allow extracting information from large sets of data.
6) and finally, applications that links users with things.

Certainly, the Future Internet will be composed by billions of smart things with ability of being identifiable, communicate and interact between themselves and with end users. Therefore, the aiming of this work and its contributions are: proposes a new IoT architecture; makes a technical comparison of IoT architectures and its mapping to TCP/IP protocol stack; identifies and describes, for the first four layers of the IoT architecture, some of the most important IoT technologies and standards that will enable the deployment of the Future IoT architecture; and presents two use cases applications for disabled people that are currently being developed for this IoT architecture, at the University of Coimbra.

Therefore, this paper presents an Internet of Things architecture stack for disabled people. The proposed scheme ranges from device layer to application layer and intends to identify the most relevant IoT technologies and international standards for each layer. To illustrate the proposed architecture, it was considered two use cases applications. A use-case application for visual impaired people and a use-case application for neurologic impaired people. These two use-cases are currently being deployed for this population in a laboratory stage, therefore its description at this stage is still a litle superficial.

The remainder of this paper is organized as follows. Section 2 discusses the IoT architecture from a more technical point of view comparing two different approaches of IoT architectures with TCP/IP stack. In section 3 is described the device layer functions and its main technologies. The main technologies of the network layer are described in the section 4. Section 5, presents the aiming of the service layer, its main funcionalities and how service layer can be incorporated with a service oriented architecture. In the section 6 are presented two use-case applications for people with disabilities that are been carried out at the University of Coimbra. Finally, section 7 presents the main the lessons taken from this work.

978-1-4799-5041-6/14/$31.00 ©2014 IEEE

Paper	Number of Layers	Layers Denomination
[1]	5	Perception, Network, Middleware, Application, Business
[2]	5	Network, Element Management, Network Management, Service Management, Business Management
[3]	5	Edge Technology, Access Gateway, Internet, Middleware, Applications
[4]	3	Perception, Network, Application
[5]	3	Perception, Transmission, Application

Table I
IoT Architectures Proposed by the Scientific Community

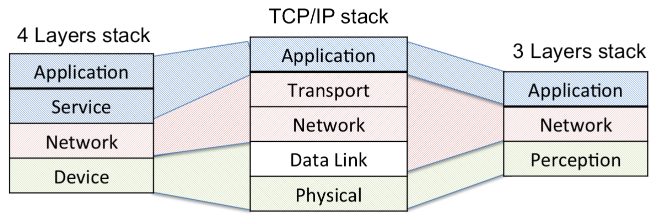

Figure 1. Proposed IoT Architecture

II. IoT Architecture Technology

The aiming of this work is to give a more technical perspective of how an IoT architecture can be implemented to accomplish a specific IoT solution for people with disabilities. The underlying technology of today's Internet is the TCP/IP stack, although with the advent of IoT with billions of objects connected to the Internet, generating big quantities of traffic, many challenges will be placed to the future Internet: ranging from big data processing, storage capacity, ubiquitous computing, communication capacity requirements, security to interoperability between different IoT systems.

Therefore, it is essential to design a new architecture able to deal with these new challenges that will come with IoT. With the arise of the IoT, the scientific community proposed same IoT architectures [1], [2], [3], [4], [5] addressing the challenges mentioned before (see Fig. I).

However, those generic IoT architectures proposals have been designed without taking into account the specific IoT requirements for people with disabilities that have been identified in [6] work. Therefore, given the importance of a suitable IoT architecture for people with disabilities, we have adopted an IoT architecture with four layer for this audience. We consider that this IoT architecture is not exclusive for this application domain and it could be also suitable for several application domains. Thus, it could be adopted as a reference IoT architecture for IoT systems with the same IoT requirements.

Figure 1 shows two IoT architectures, our IoT architecture with four layers at the left side and another with three layers at the right side, which has been proposed in the work [4]. Figure also shows the mapping of the layers of these IoT architectures to TCP/IP protocol stack. It can be seen that in comparison with TCP/IP stack the application layer of proposed architecture, with four layers, has been divided in two layers, or in other words, was added a new layer to the stack, the service layer.

In this architecture, the service layer has been added (which we consider an essential layer for any IoT architecture) in order to offer an homogeneous, independent and context-aware service to applications and hide, from the application layer, the heterogeneity caused by the existence of different transport infra-structures for data transmission. The network layer which aims all functions related to end-to-end transmission, addressing and routing, comprises the layer 3 and 4 of TCP/IP stack. The device layer is responsible for collecting events from physical world and transmit them to the core network (e.g. IPv6, 3GPP, WiMax). The device layer corresponds to the layer 1 and 2 of TCP/IP stack.

Regarding the protocol stack with three layers in Fig. 1, this IoT architecture makes a very simple and linear mapping to TCP/IP stack, where application and perception layers are directly mapped to application and physical layers, respectively, and the network layer comprises the layers 2, 3 and 4 of TCP/IP stack.

Since most of the proposed IoT architectures in the literature underly in a stack with three or five layers (see Tab. I), and also because it seems to us due to the IoT requirements we need a more complete mapping to the TCP/IP stack, than an IoT architecture with three layers, in this work we have adopted an IoT architecture with four layers.

The explanation of the adopted IoT architecture will be made following the down-top approach. First, will be defined the device layer's functions and described its main technologies, then we go up on IoT stack given the same kind of explanation for each layer until we arrive to the application layer.

III. Device Layer

The function of device layer is to unambiguously identify objects or entities of physical world, collect data about their physical status, transport the collected data to the core network or to a local database, and eventually making same action in the object object in accordance with a well defined criteria. This layer is composed by the sensor devices and wireless sensor networks.

The former includes perception technologies like RFID, sensors, video cameras, etc. The latter consists in a self-organized wireless sensor network that sensors the physical status of the environment. If the devices are not IPv6 compatible, a bridge to TCP/IP communication protocols should be provided.

An IoT gateway can provide the translation and data management of the devices not compliant with IPv6. The devices not compliant with IPv6 can access to the gateway with short-range communication standards such as Zigbee, Rubee, Bluetooth, WirelessHART, etc.

The gateway offers seamless interworking between the wireless sensor network and the core network. The IoT technologies that could be used in this layer are organized in three categories: identification technology, sensors technology and assistive devices. In the next subsections these three categories will be described.

A. Identification Technology

The function of identification is to map an Unique IDentifier (UID) to a device without ambiguity. In the future Internet it is expected that things or devices be identifiable with a digital name and the names be organized into domains. By assigning an UID to each thing in the Internet, it is possible to access to its properties, history, information and interact with things through virtual world (i.e. www). Until now the most widely used identification technology has been barcode [7]. Although, barcode have some drawbacks. First, barcodes are very limited in the amount of data they can transmit, therefore there is no space for add descriptive information about an object. Second, they require a laser scanning very near of the barcode in the object to read and process the information.

The scientific and industrial communities are looking for a more powerful identification technology able to read information from a tag far away a few meters (aprox. 8m). The most promising identification technology that seems to meet the current IoT demand is the Radio Frequency Identification (RFID).

RFID technology suffers from a lack of standardization, but until now this was not a problem because of the relatively small-scale adoption. However, with IoT event standard organizations are working for producing a RFID standard. EPCglobal and Auto-ID center are cooperating to produce the Electronic Product Code (EPC) standard. International Standards Organization (ISO), is also working to produce ISO 18000-6 A and ISO 18000-6 B standards. Although, there is no "best" standard or an international agreement for global use of RFID technology.

B. Sensors Technology

Wireless Sensors Networks (WSN) plays a pivotal role in the successful implementation of a global architecture for the Internet of Things. However, for IoT becomes a reality WSNs must be tailored to work seamlessly with Internet Protocol (IP). Although, how to use IPv6 features on a limited resource device as sensors is not a trivial task. For this purpose the 6LoWPAN WG defined an adaptation sub-layer, which works above the MAC layer, that enables the full IPv6 functionalities over low rate wireless personal networks (i.e. IEEE 802.15.4) [8]. IEEE 802.15.4 is a standard, which defines data-link and physical layers for the majority of the sensors hardware and it has been proposed specifically for low wireless personal area networks. Its main goals are low cost deployment and complexity, and low energy consumption.

Currently, several research institutions and organization are building their WSN solutions with the implementation of the 6LoWPAN sub-layer, solving this way same difficult issues in WSN like auto-configuration, localization and routing because IPv6 by itself addresses and handles these kind of issues .

WSN applications can be roughly classified as monitoring and tracking applications. Monitoring applications comprise environmental monitoring, health and wellness monitoring, power monitoring, location monitoring and process automation. Tracking applications in turn include, tracking objects, persons and vehicles.

Regarding the development of a WSN an important aspect that should be taken into account is the selection of the most appropriate operating system and hardware platform for a given scenario [9]. The three most known and used operating systems are ContikiOS [10] and TinyOS [11]. Most of hardware platforms (e.g. Arduino, Z1 , MBED , WiSMote) are supported by one of these operating systems and some of them are supported by both operating systems [9], allowing the developer to have a greater degree of freedom in the deployment of WSN.

C. Assistive Devices

The identification and sensors technologies could cooperate and work together to assist people with disabilities in their daily activities. The junction of these two technologies enable the design of assistive devices for disabled people.

The basic components for designing an assistive device for visually impaired people are body sensors and RFID tags and readers for localization. A very useful application for blind people is a navigation system, to help them move in indoor spaces and unknown areas. A simple RFID based assistive can be used to provide an effective systems navigation for blind people. The assistive device can be implemented with RFID tags spreaded along the possible paths, a RFID reader mounted in a cane and a monitoring station, such as, smartphone, TabletPC, IPad, etc. In outdoor spaces, the typical navigation system underlies on Global Positioning System (GPS), therefore to have a complete solution for all type of spaces, indoor and outdoor, the integration of these both technologies RFID and GPS, could be a good solution.

For hearing impaired people the basic components for design an assistive device are alarm and flex sensors and RFID tagged objects. In some situations, like a doorbell or an audible alarm, hearing impaired people can benefit if they have an assistive device, which notify them of the occurrence of an event with a visual or vibratory signal [12]. Another assistive device for deaf people is the HandTalk [13]. The HandTalk is a intelligent glove that recognizes hand gestures and translates them into voice messages. The smart glove is embedded of flex sensors along the fingers, the sensors sensor the fingers position and if the sensed data matches a set of values associated with a word or expression the gestual sign is convert to voice.

An assistive device based on RFID technology could be used to help them learning sign language. Another example is placing the RFID tags attached to multiple objects, which when they are scanned by a RFID reader will automatically launch in a monitor instructive videos for helping them to identify objects [14].

Assistive devices for physically impaired people could be accomplished with BIOnic Neurons (BIONs) [15] and Brain Computer Interfaces (BCIs) [16]. The former consists in sensors and actuators inserted near of motor nerves, which have the function of reanimate paralyzed limbs. These sensors inserted into the body receive power and commands from an external radio frequency source, to perform Functional Electrical Stimulation (FES) in the nerves affected by paralysis,

Network Challenges	WSN Access	IP Implementation on Device Layer	Mobility Management	Security Mechanisms	Quality Mechanisms
Internet infrastructure	6LowPAN	Contiky / Tiny	MIP / HMIP / FMIP / PMIP adapted to IoT	IPSec	IntServ / DiffServ adapted to IoT

Table II
IoT NETWORK CHALLENGES

and thereby reactivating motor's function [16]. The later is a neurochip that records the motor cortex[1] activity and converts them in stimulus that are sent to the brain, spinal cord or muscles for creating artificial motor paths. The brain learns how to use these new artificial motor paths replacing the impaired paths.

Finally, assistive devices based on sensors and RFIDs for health impaired people could be used to provide real time information about the patient, allowing a timely intervention in urgent cases and a better monitoring of patient's health.

IV. NETWORK LAYER

The main function of network layer is to transfer the information collected from Device layer to Service layer. However, due to the wide variety of applications that will emerge with Internet of Things, big quantities of data traffic will be transported on the network layer and that represent a huge challenge for this layer. On the other hand, without standards like TCP/IP, the Internet of Things cannot also evolve to a global scale, that means that we do not have an Internet of Things without the adoption of International standards.The challenge has too many dimensions including: network scalability modularity; interfaces; several kinds of mobility (e.g. occasional or continuous);cost and size of resources; energy efficiency; heterogeneity; different kinds of communication (e.g. electromagnetic, radio frequency, optical);structured and not structured networks (e.g. mesh, ad-hoc, multi-hop);network coverage space;different types of connectivity (e.g. sporadic, continuous);security and privacy, etc.

The integration of sensors networks into the Internet is essential to enable a true Internet of Things. Although, initially the sensor networks were not IP enable, and their integration into the Internet required a proxy to transform non IP communications into IP communications. Usually, the application process in the proxy applies some pre-processing functions such as data aggregation and data storage, for then forwards the data to the Internet. This sort of connection to the Internet does not provides a seamless connection of things to the Internet because it breaks the end-to-end communication channel. Furthermore, this kind of solution brings more problems when Network Address Translation is used, and also needs new communication protocols standards for error and congestion control in the local sensor networks.

Today, IP protocol offers an end-to-end communication platform between IP devices, without the necessity of involve intermediate protocol translators like gateways. However, new scalable architectures specifically designed for ubiquitous networks of billions of things interconnected, need to be enhanced in order to offer secure and reliable communications for mission critical applications. Moreover, for a wide public acceptance of IoT the security, governance, high level of mobility and quality of service are very important aspects to take into consideration in the design of standards for the IoT network layer. The Table II shows some of the challenges that Internet of Things represents to the network layer.

The natural (i.e. because of IPv4 legacy) architectural choice of IPv6 for an IoT architecture allows a wide range of different communication technologies below and a huge variety of services above. Thus, allowing heterogeneous technologies and a panoply of services and applications above. The things can be integrated into IPv6 infrastructure by means of 6LowPAN protocol, which becomes a very important IoT enabling technology, because allows all nodes be IPv6 compatible, which in turn makes them accessible from any Internet device.

6LowPAN uses a compression mechanism to reduce the header overhead of IPv6 datagram and uses the fragmentation mechanism to slice the payload of IPv6 datagram into several IEEE 802.15.4 frames (IEEE 802.15.4 maximum frame size is 102 bytes) for the low-power sensor networks be able to use it.

With the 6LowPAN it is possible to integrate any object/thing into IPv6 infrastructure, making it addressable and reachable, and making several interactions with them, and this is the true essence of IoT paradigm, all is running smoothly over world wide Internet infrastructure.

The deployment of IPv6 sensor networks provides a great capacity for addressing things, built-in auto-configuration via IPv6 neighbor discover of sensor nodes and supports to mobility via IP mobility management protocols.

IP sensor networks allow a more seamless connection to the IP infrastructure and it can be seen as a natural extension of IP devices into the current Internet.

However, a seamless integration of IP sensor networks into the wide IP infrastructure places some functional requirements. First of all, the sensors need to be implemented with an IP stack to communicate in IP "language". An example of an architecture to connect an IP sensor network to the Internet can be seen in Fig 2.

Second, an appropriate mobility management protocol to handle mobile sensors is required. Mobile IP protocol is the default solution for IP networks, however that protocol has been designed for macro mobility (i.e. mobility between different domains), thus in sensor networks where the majority of the node movements are micro, the MIP will certainly have a very poor performance. The Internet Engineering Task Force (IETF) is working on solutions for enhance MIPv6 in micro mobility scenarios, some of these solution are FMIPv6, HMIPv6, PMIPv6 and NEMO.

Third, security is key element for a successful implementation of an IoT architecture. This major concern demands the implementation of security mechanisms in all layers of the IoT architecture in order to avoid data violation during the communication process. As in the case of node mobility, in principle the standard IP security mechanisms can be applied

[1]Motor cortex is the part of brain responsible for body movement

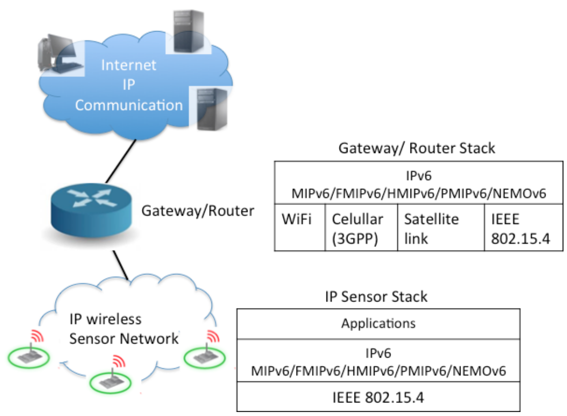

Figure 2. An Architecture for Integrating the IP Sensor Networks to the Internet

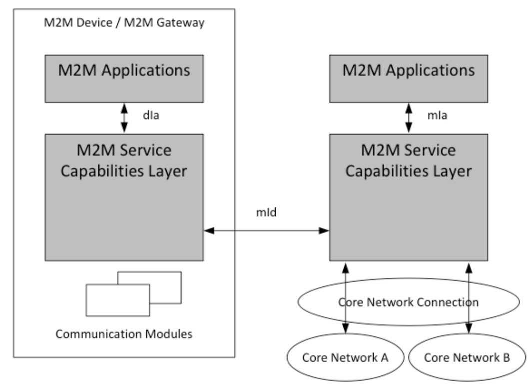

Figure 3. M2M Service Capabilities functional architecture framework [19]

to the network layer of the IoT architecture, however shall be used a lightweight security mechanism due to resource constraint of sensor networks.

Fourth, the quality of the service offered by the network layer to higher layers will have a profound impact in the user satisfaction with the quality of the service offered by the IoT infrastructure, which in turn, will affect customer loyalty to the service. Regarding the QoS for IP networks, the two main QoS mechanisms are the Integrated Services (IntServ) and Differentiated Services (DiffServ).

Due to the fact that wireless sensor networks present a more dynamic behavior, the application running in the mobile node needs some sort of QoS signaling for improve network utilization. Therefore, wireless sensors networks demand new protocols specifically designed for supporting QoS in highly dynamic networks and suitable to its resource constraints. Although IP being a very consensual and widely used protocol for the network layer, there is no agreement about the most effective QoS solution for working over IP.

V. Service Layer

There are now tons of objects with communication capabilities spread all over the world making true the Internet of Things vision. However, IoT environments are characterized by high levels of heterogeneity, which, inevitably, facilitates the occurrence of vertical silos, where the architecture is deeply dependent on the sector of activity.

The Service Layer aims at making the bridge between applications and things allowing a transparent access to the information. It enables high levels of interoperability in order to facilitate the creation of innovative IoT solutions regarding the field of action. An effective Service Layer requires the following key capabilities in order to link the producers and the consumers of information:

- Device and applications registration – A successful registration allows the Service Layer to become aware of the devices and applications capabilities, enabling an IoT-based interaction between interested elements.
- Synchronous and asynchronous communication patterns – The Service Layer must support the request & answer communication pattern in order to allow a synchronous access to the information whenever required. Moreover, it must provide the subscription & notification asynchronous model to facilitate the reception of warnings upon the occurrence of certain subscribed events.
- Data repository – The Service Layer must be responsible for the temporary and permanent storage of information and to make it available to authorized entities on request or based on subscriptions.
- Security – The Service layer must support authentication and key agreement allowing a secure access to IoT-related resources. Furthermore, a strict access control must be developed to ensure a selective restriction of access to information. The fast grow of the IoT sector leveraged the creation of groups aiming at standardizing the machine type of communication. The European Telecommunications Standards Institute (ETSI) [17] recently made available its specification for M2M (machine-to-machine) communications. ETSI, in its M2M technical committee, centred its efforts in the definition of an architecture designed to enable a fast service creation fostering the quick launch of innovative application [18], [19]. It has defined a set of service capabilities that encompasses logical grouping of functions, which are to be shared by different applications, independently of their domains of actuation. Figure 3 below presents the service capabilities functional architecture framework.

The service capabilities and its main functionalities are presented below:

- Application Enablement – Exposes the functionalities implemented via a unique reference point, being the entry port for applications in the service capabilities layer.
- Generic Communication - It is the single point of contact for communication between different service capabilities layers, making possible the exchange of signalling and information flows.
- Reachability, Addressing and Repository – This capability enables the knowledge about the reachability of devices. It is also responsible for setting routable network addresses of the devices. Moreover, it allows the control of subscriptions and notifications pertaining to events. Additionally, it stores data and makes it available to interested entities in a secure way on request or based

on subscriptions.

- Communication Selection – This capability allows the selection of the most appropriate network to reach the device based on a set of defined policies.
- Remote Entity Management – It makes available configuration management functionalities, allowing the control of remote devices.
- Security – This capability enables a protected communication between the involved entities.
- History and Data Retention – It stores appropriate information based on a set of policies, related with the messages exchanged.
- Transaction Management – It ensures the atomicity of transactions, when required, for procedures involving several operations.
- Compensation Broker – It works as trusted third party for billing the customers and redeeming the service providers taking into account the expenditures that were made.
- Telco Operator Exposure – This capability allows a controlled exposure of network operator services.
- Interworking Proxy – It enables interworking between non ETSI compliant and the service capabilities layer.

ETSI does not mandate the implementation of the service capabilities. However, it does mandate the deployment of mIa (interface between application and the network service capabilities layer), dIa (interface between application and the device or gateway service capabilities layer) and mId (interface between network and device or gateway service capabilities layer) reference points in order to be compliant with the standard.

The IoT market is spread all over the world, which leads to the fragmentation of the specifications. The oneM2M initiative intends to consolidate the diverse perspectives by proposing a unified vision of the future M2M communication. Its efforts are focused on the harmonization of a common service layer coming from competing standardisation bodies [20]. The oneM2M initiative will thus accelerate the introduction of IoT-based solutions in the global market.

The standardization bodies are centred in the provisioning of an effective data mediation between things and applications. But the emergence of the IoT vision and all its related dynamicity imposes new requirements for IoT services that mandate a flexible management of all its life cycle [21]. Furthermore, IoT domain is not a closed shell; it requires high levels of interoperability with services owned by different players that go far from the world of things. A possibility to overcome these issues is to embody the Service Layer with the service oriented architecture (SOA) principles.

SOA aims at facilitating the operationalization of business processes distributed over heterogeneous systems managed by different holders. It resorts to an enterprise service bus (ESB) to enable service calls amongst systems. It is responsible for a governed mediation of the interactions between producers and consumers of services, including all required abstraction features to guarantee low levels of dependencies flanked by different systems. Services are seen as abstractions of business functionalities, having clear interfaces, being strictly regulated by contracts. Services can encapsulate backend resources, such as an IoT data mediation platform, making them accessible through the ESB.

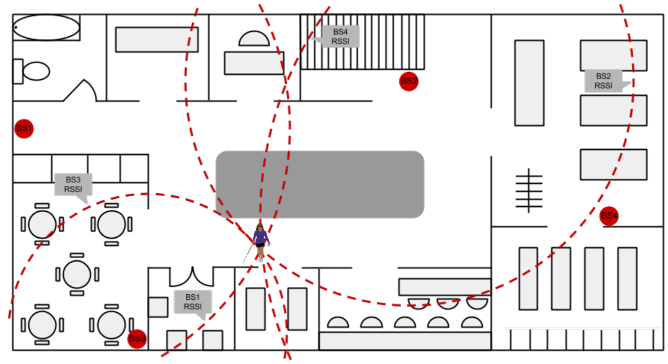

Figure 4. A Visually Impaired Person with the Proposed Application inside a Home

The inclusion of the enterprise service bus in the Service Layer allows therefore an agile management of all services life cycle facilitating the creation of new business in the IoT arena.

VI. Application Layer

In this section will be presented two use cases, that have follow the work plan presented in the previous section, and where IoT technology are currently being applied to help people with disabilities. These two IoT applications are, at this moment, being developed by University of Coimbra with engineers and social scientists and taking into account the population needs.

A. Use-Case Application for Visual Impaired People

The aim of this use case is to provide the blind and partially sighted people an application that helps them finding stores and services inside a shopping center, enabling them to navigate autonomously within the environment and to search for their interest stores and services.

The proposed application is based on indoor localization performed by a low-cost mapping system based on sensors implemented in the environment and in the user (see Fig. 4). At this moment, studies and experiments are being developed using WiFi and Bluetooth technologies. On the user side, the application will be materialized on a smartphone or a device with connection to the wireless networks, such as WiFi and Bluetooth. The user interface will be stablished by voice instructions.

A blind person carrying a smartphone is localized by triangulation with the RSSI from WiFi networks of four different base stations, BS1 to BS4. The user indicates the application his destination, for then he can run a search on the shopping builing stores/services available. And then the shortest weighted path is calculated between the destination point and the actual position and are given instructions to the user on how to navigate through that path. The triangulation method is based on simple math: knowing the location of each base station and the recieved signal strength indication, RSSI, on a specific local, where the user is, it is possible to triangulate his position.

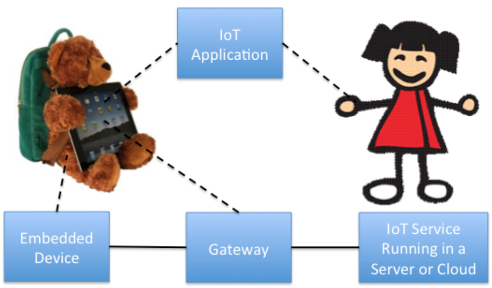

Figure 5. Use-case Application for Children with Cerebral Palsy

B. Use-Case Application for Neurologic Impaired People

Normally, children with cerebral palsy need the help of other persons to perform daily activities, such as, moving up, learning and communicating. The latter activity is undoubtedly one of the most important skills, because many of these children have speech impairments becoming very difficult for therapists to understand what they want and say.

In this use-case application, the disabled child interacts with her toy through a mobile device (i.e. tabletPC or smartphone), which has installed the learning game in its Android operating system. The learning game uses the scanning method to facilitate communication interaction of children with the her toy and with the caregiver. In this IoT application, the Wireless Sensor Networks (WSNs) will be used to enable the communication with real world, which in this case will be the children toy. The children interaction with virtual world will be reflected in the sensors embedded inside the toy in real world, giving "life" to the toy. Figure 5 shows the architecture of the proposed solution.

The server stores all the data associated with the game and uses it to generate relevant information about the children learning process. The aiming of this educational game is to help children with palsy build their knowledge in a pleasant way and also to allow an higher participation of the caregivers in the child's learning process.

VII. Conclusions

In spite of IoT technologies could be very useful for care and support of disabled people, joint these to different worlds represents big challenges in both technogical and social sides.

Design one IoT solution that overcomes the technological gaps of today Internet and simultaneously fits the needs of people with disabilities involves an interdisciplinary work, between engineering, sociology and social structures. Otherwise, developing IoT solutions independently of the social component may result in a technological solution that will not be adopted by the social structures and end users.

This work proposes an IoT architecture specific for people with disabilities that addresses the technological challenges of the current Internet and identifies and describes the most relevant technologies and standards for the first four layers of the proposed architecture. This architecture was specifically designed to be suitable for disabled people, however we believe that it could be also suitable for other IoT application domains with similar requirements. Besides the proposal of an IoT architecture for disable people, this work also presents two uses cases that are being developed for this population. In the future, after the laboraty stage being done, the next step is to test the aformentioned use cases with users and analyse their adaption to its use.

Acknowledgment

This work has been partially supported by FCT - Fundação para a Ciência e Tecnologia in the scope of the project: PEst-OE/EEI/UI0319/2014.

References

[1] Rafiullah Khan, Sarmad Ullah Khan, Rifaqat Zaheer, and Shahid Khan. Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges. In *Frontiers of Information Technology (FIT), 2012 10th International Conference on*, pages 257–260. IEEE, 2012.

[2] Wu Miao, T LU, F LING, et al. Research on the Architecture of Internet of Things [C]. In *Proceedings of the 3rd International Conference on Advanced Computer Theory and Engineering: August*, pages 20–22, 2010.

[3] Lu Tan and Neng Wang. Future internet: The Internet of Things. In *Advanced Computer Theory and Engineering (ICACTE), 2010 3rd International Conference on*, volume 5, pages V5–376. IEEE, 2010.

[4] Mari Carmen Domingo. An overview of the Internet of Things for people with disabilities. *Journal of Network and Computer Applications*, 35(2):584–596, 2012.

[5] Qian Zhu, Ruicong Wang, Qi Chen, Yan Liu, and Weijun Qin. IoT gateway: Bridgingwireless sensor networks into internet of things. In *Embedded and Ubiquitous Computing (EUC), 2010 IEEE/IFIP 8th International Conference on*, pages 347–352. IEEE, 2010.

[6] N. Lopes, P. Furtado, and J. Silva. Survey of IoT and its Feasibility Analysis for People with Disabilities. *Communications Surveys Tutorials, IEEE*, 2013. Paper submitted on November.

[7] Yang Xiao, Senhua Yu, Kui Wu, Qiang Ni, Christopher Janecek, and Julia Nordstad. Radio frequency identification: technologies, applications, and research issues. *Wireless Communications and Mobile Computing*, 7(4):457–472, 2007.

[8] IETF working Group. IPv6 over Low power WPAN (6lowpan). http://datatracker.ietf.org/wg/6lowpan/charter/.

[9] Joel JPC Rodrigues and Paulo ACS Neves. A survey on IP-based wireless sensor network solutions. *International Journal of Communication Systems*, 23(8):963–981, 2010.

[10] Adam Dunkels, Oliver Schmidt, Niclas Finne, Joakim Eriksson, Fredrik Österlind, Nicolas Tsiftes, and Mathilde Durvy. The Contiki OS: The Operating System for the Internet of Things, 2011.

[11] Philip Levis and David Gay. *TinyOS programming*. Cambridge University Press, 2009.

[12] A Wood, G Virone, T Doan, Q Cao, L Selavo, Y Wu, L Fang, Z He, S Lin, and J Stankovic. ALARM-NET: Wireless sensor networks for assisted-living and residential monitoring. *University of Virginia Computer Science Department Technical Report*, 2, 2006.

[13] David K Sarji. Handtalk: Assistive technology for the deaf. *Computer*, 41(7):84–86, 2008.

[14] Becky Sue Parton and Robert Hancock. A Tool for Early Childhood Learners. *TechTrends*, 52(5):22, 2008.

[15] D Kacy Cullen and Douglas H Smith. Bionic Connections. *Scientific American*, 308(1):52–57, 2012.

[16] José del R Millán. Brain-computer interfaces. *Introduction to Neural Engineering for Motor Rehabilitation*, 40:237, 2013.

[17] ETSI. European Telecommunications Standards Institute. http://www.etsi.org/.

[18] ETSI. Machine-to-Machine communications (M2M); Functional architecture. ETSI TS 102 690 V1.1.1 (2011-10), October 2011.

[19] ETSI. Machine-to-Machine Communications (M2M); mIa, dIa and mId Interfaces. ETSI TS 102 921 V1.1.1, February 2012.

[20] oneM2M. oneM2M Organization. http://www.onem2m.org/ (Visited on 01/2014).

[21] F Cabral Pinto, P Chainho, N Pássaro, F Santiago, D Corujo, and D Gomes. The business of things architecture. *Transactions on Emerging Telecommunications Technologies*, 44:441–452, May 2013.