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Inclusion Through the Internet of Things

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1. Introduction

Inclusion of Persons with Disabilities and the Aged in mainstream society has progressed significantly through the continuous development of assistive technologies, standards, policies and guidelines combined with the use of Information and Communications Technology (ICT). Technological advances utilising standards developed to enhance inclusion have lowered the barrier to access information, for example, the World Wide Web Consortium (W3C) Web Content Accessibility Guidelines (WCAG) (*Web Accessibility Initiative Guidelines and Techniques*, 2011). WCAG provides recommendations to make Web content more accessible. Furthermore, the United Nations's "Convention on the Rights of Persons with Disabilities" is mainstreaming disability (Secretariat for the Convention on the Rights of Persons with Disabilities, 2011). Through the Convention, the Rights of Persons with Disabilities are described in detail. Member countries of the Convention commit themselves to institute mechanisms (be it policies, laws or other measures) to secure the individual's rights as captured in the Convention.

Through application of a philosophy such as "Design for All" (Stephanidis et al., 1999), awareness is being raised of designing and constructing devices and environments to accommodate the broadest spectrum of users without any modifications.

The National Accessibility Programme in South Africa is an example of a disability-related initiative aimed at enhanced inclusion and access to information through the Internet and ICT (Coetzee et al., 2007; Coetzee, Olivrin & Viviers, 2009).

Taking cognisance of the above progress, the challenges in ensuring continued and improved inclusion for Persons with Disabilities and the Aged have not yet been overcome, even though implemented mechanisms and technologies are lowering the barrier to inclusion.

Technology is advancing at a rapid rate and does not necessarily follow design principles aimed at enhancing or ensuring inclusion. Along the same vein, society is changing the ways in which it operates, utilizing the technologies in new ways. The establishment of Web 2.0 (also known as the Social Web) has changed the way information is gathered and shared, which subsequently has impacted on Persons with Disabilities and the Aged and their inclusion. Entities such as Facebook and YouTube, to name a few, are changing our daily lives, redefining how we interface with our friends and colleagues, and how we are entertained. These technological and societal changes do not necessarily enhance or ensure inclusion of Persons with Disabilities and the Aged. The importance of ICT as enabler for inclusion remains indisputably clear.

One very recent technological trend which will impact on society (and thus Persons with Disabilities and the Aged) is that of the **Internet of Things** (IoT) (Chui et al., 2010; International Telecommunications Union, 2005; Seventh Framework Programme, 2011).

In the IoT vision, all devices are connected to the Internet, each one with a unique Internet Protocol (IP) address and unique services rendered. Devices communicate and interact with one another and also provide information to higher-level integrated decision-making services and applications. Intelligent actioning can be initiated from these higher-level services and applications. The scale of this expanded Internet is unprecedented, with billions of devices connected and with masses of data generated. Value is created through the interpretation and analysis of the generated data and the resulting environmental actioning based on the analysis outcomes.

IoT is becoming a reality through a number of technological drivers: device processing and storage power are increasing; technology is becoming smaller while more sensors and actuators are being integrated; connectivity is improving – all facilitated through compliance to Internet related standards (e.g. IPv6). This provides an improved ability to connect, receive information, sense and act. IoT application spans a wide range of domains and areas. According to Vermesan et al. (Vermesan et al., 2011) the creation of smart environments/spaces is a major objective:

> "The major objectives for IoT are the creation of smart environments/spaces and self-aware things (for example: smart transport, products, cities, buildings, rural areas, energy, health, living, etc.) for climate, food, energy, mobility, digital society and health applications..."

As these connected devices become more integrated in our daily lives, so will the reality of the IoT vision. However, IoT's future role with regard to inclusion in smart environments is still unclear. Will it introduce more barriers or will it become an enabler? Given the migration of people towards urban areas, more people are living in larger cities. It is recognized that the urban areas need to provide enhanced services to its citizens, thus the drive to smart environments. These smart environments should be created to ensure inclusion of the broadest grouping possible, thereby creating an **enabling smart environment**.

The precise form and function of how IoT can break the accessibility barriers are not known yet. What is known is that inclusive design needs to be a fundamental element in the creation of IoT-enabled smart environments. Adopting a philosophy of creating an enabling environment through IoT, which embodies inclusiveness rather than just a smart environment, will go a long way towards ensuring inclusion in our technological futures.

This chapter casts an eye into the future to sketch inclusion scenarios (and ask relevant questions to ensure inclusion in future) through IoT. A brief overview of applicable research and development is presented in Section 2. Section 3 introduces Internet of Things. Smart environments and its application in our future society are presented in Section 4. Section 5 describes a methodology used and the results obtained, which allows for the progression of a smart environment into an enabling environment geared towards inclusion. As presented in Section 5, Section 6 highlights the specific needs and subsequent IoT-related services to ensure the evolution from *smart* to *enabled*. The usage of technological solutions can support an individual in exercising his rights as expressed in the United Nations's Convention on the Rights of Persons with Disabilities. Section 7 presents some of the convention's articles through which IoT can enhance or limit an individual's rights. Concluding remarks are presented in Section 8.

2. Literature

The role of smart environments (and their real-world instantiations – cities, houses, offices) in empowering the citizen, is the focal point of many different research projects (past and present). Research has progressed to the point where smart cities are purposefully being built or existing cities retrofitted. Examples include Amsterdam (The Netherlands), New Songdo City (South Korea), Lavasa (India), Skolkovo (Russia), Taihu New City (Wuxi, China), Dubuque (Iowa, USA) and several others.

Several reports and research outputs have been published regarding these smart environments. These publications include Berthon and Guittat's analysis of the rise of the intelligent city with the focus on managing resources in a sustainable way and the creation of an attractive economic and social environment allowing for interaction between citizens, companies and governments (Berthon & Guittat, 2011); Hill et al. analyse how ICT can transform energy-intensive establishments into low-carbon future smart cities where residents are enabled to make better, more informed choices. (Hill et al., 2011); Hodgkinson views digitally enabled inclusion in two dimensions: inside-out/formal where authorities are building more efficient infrastructures and services and outside-in/emergent where individuals create initiatives in support of the citizen (e.g. urban action forums, volunteer networks and carpooling networks) (Hodgkinson, 2011); Green views smart cities as a collection of programmes and concepts addressing environmental sustainability, economic performance, community cohesion and efficiency of operations (Green, 2011).

The role of future technologies and specifically that of the Future Internet in Smart Cities is discussed in the literature. Hernández-Muñoz et al. see the Future Internet as having the required building blocks (that of the Internet of Things and the Internet of Services) for creating an open innovation platform which can manage the various heterogeneous information sources, devices and data as associated with a future smart city (Hernández-Muñoz et al., 2011). Schaffers et al. investigate the role of the Future Internet experimentally-driven research and projects in the domain of Living Labs in smart cities (Schaffers et al., 2011).

IoT and its application in the real world is a very new research area. Large-scale projects, such as those funded by the European Commission, for example, the Internet of Things Architecture and Initiative (*IOT-A: Internet of Things Architecture*, 2011; *IOT-I: Internet of Things Initiative*, 2011), are still in their early stages. It has been seen that IoT can reduce the complexity and allow for the creation of smart environments (e.g. SmartSantander (*SmartSantander*, 2011)). Initial research in using IoT to ensure inclusion in specific environments is now appearing (Dohr et al., 2010; McCullagh & Augusto, 2011), but as yet has not made big inroads.

The following section introduces IoT and its various application categories, opportunities and challenges.

3. Internet of Things

Technological advances are creating new opportunities, services, mechanisms and business models to improve the quality of an individual's life. The advances are impacting on the ways people interface, interact and relate to the environment – be it the built, digital or social environment. One such technology redefining our world has been the Internet.

The Internet is an evolving entity which is becoming more important as broadband connectivity becomes ubiquitous. As depicted in Figure 1, the Internet started as the *Internet of Computers*. It has evolved into the *Internet of People* and is progressing towards the *Internet of Things*.

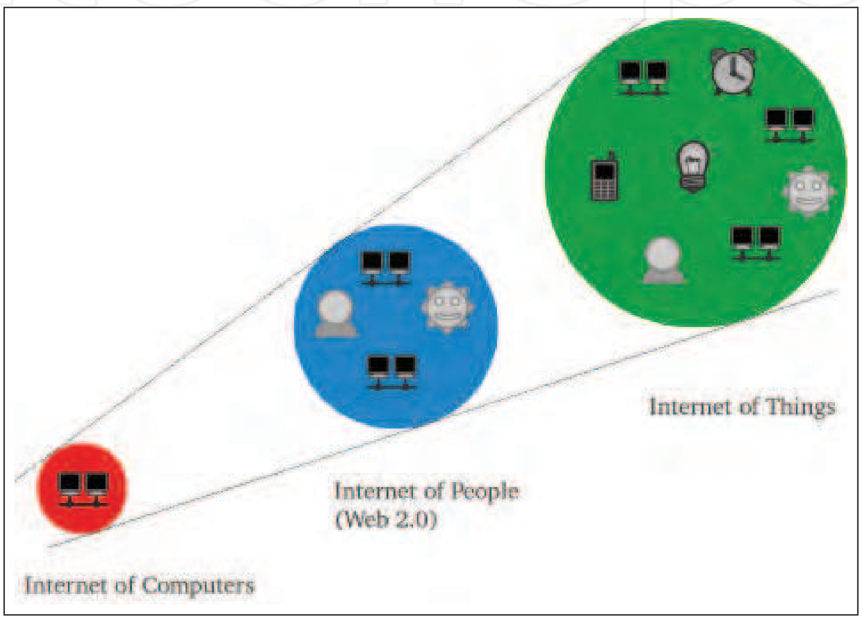

Fig. 1. Internet Evolution

The *Internet of Computers* provided a global network and a connected platform to run a variety of services. The World Wide Web is an example of an Internet service which was built on top of the original platform. Recently, more advanced services and technologies have changed the *Internet of Computers* into the *Internet of People*, known as Web 2.0 or the Social Web. In the Social Web, people are the main creators and consumers of content. Social networking such as *Facebook* and content sharing through a site such as *YouTube* illustrate that the Internet has matured and has evolved from the *Internet of Computers*.

A new technological wave is on the Internet horizon, that of the *Internet of Things* (Chui et al., 2010; Coetzee & Eksteen, 2011; Fleisch, 2010; International Telecommunications Union, 2005). Cheap and ubiquitous broadband Internet connectivity is creating an "*always on from anywhere*" opportunity. Combined with increases in device processing capability and storage capacity and associated reduction in the size of devices and adoption of standards, an additional dimension of *any thing* providing and using *any service* becomes a reality. These *things* often incorporate a variety of sensors, thus creating unprecedented masses of data to store and process. The resulting processed output can be fed back to the thing or other things in the surrounding environment where appropriate actioning can be instigated through actuators.

The definition of a *thing* is wide and includes a large variety of physical elements which include:

- Personal objects we carry (smart phones, tables, digital cameras, etc.).
- Elements and appliances in our environments (home, vehicle, work, urban or other).
- Objects fitted with tags (e.g. RFID (Bonsor & Keener, 2010), NFC (Nosowitz, 2011) or QR (O'Brien, 2010)) which are connected to the Internet (and has a cyber-representation) through a gateway device.
- Objects fitted with tiny computers – *smart* things.

Based on this view, an enormous number (billions) of devices and things will be Internet connected, each providing data, information and some even services. Once accurate information about status, location and identity is available at a higher system level, an opportunity is created for smarter decision making and action taking. Interactions can be between *thing* and *thing* (also known as machine-to-machine) as well as *thing* and *person* (machine-to-person and person-to-machine). In this phase of the Internet evolution, things have surpassed people as the main creators and consumers of data and content.

Illustrated in Figure 2 is a layered view of the IoT. The physical is connected via the Internet to middleware platforms (which provide the "standard" services such as *naming*, *discovery* and *security*). Services (to be consumed by other services or applications) and applications are built on top of the middleware. The inherent value and potential for impact, which can be obtained through IoT, increase when rising to the higher level services and applications and when these services are combined into *super* services and applications. The combination of services becomes a reality through the open architecture and philosophy of IoT.

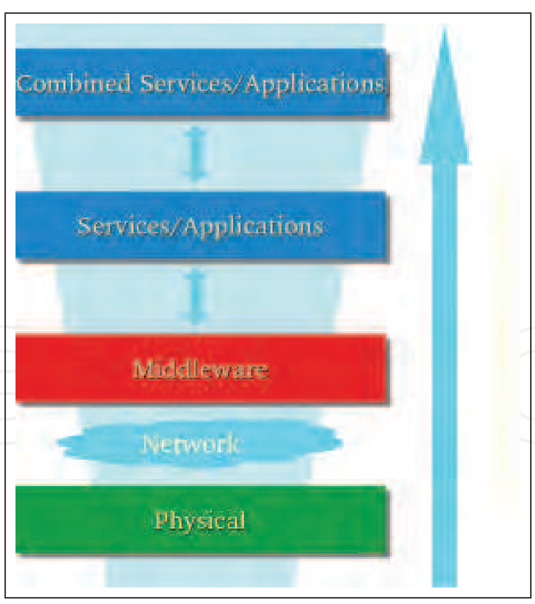

Fig. 2. Internet of Things Architectural View

Figure 3 depicts the fundamental elements in the IoT eco-system. Physical elements can be tagged and through the use of a gateway device (such as a mobile phone with a near field communications scanner) be linked to its cyber-representation on the Internet. Similarly, very small elements which are networked and which contains sensors to communicate sensed values via the network, are seen as part of the IoT. Traditionally, sensor networks operated in isolation. Through IoT, a multitude of sensor networks can be connected to the broader Internet, each of these smaller networks contributing information to a much larger audience. A fourth element in the IoT is that of *smart things*. These smart devices typically include mobile technologies such as smart phones, tablets and other traditional computing devices, as well as non-traditional elements such as household appliances that have computational power, network connectivity and sensors and actuators. As all the above *things* are network connected, the data they provide can be integrated and fused for use in integrative services and applications. These services, as well as the connected things, impact on the environment (people, industry and society).

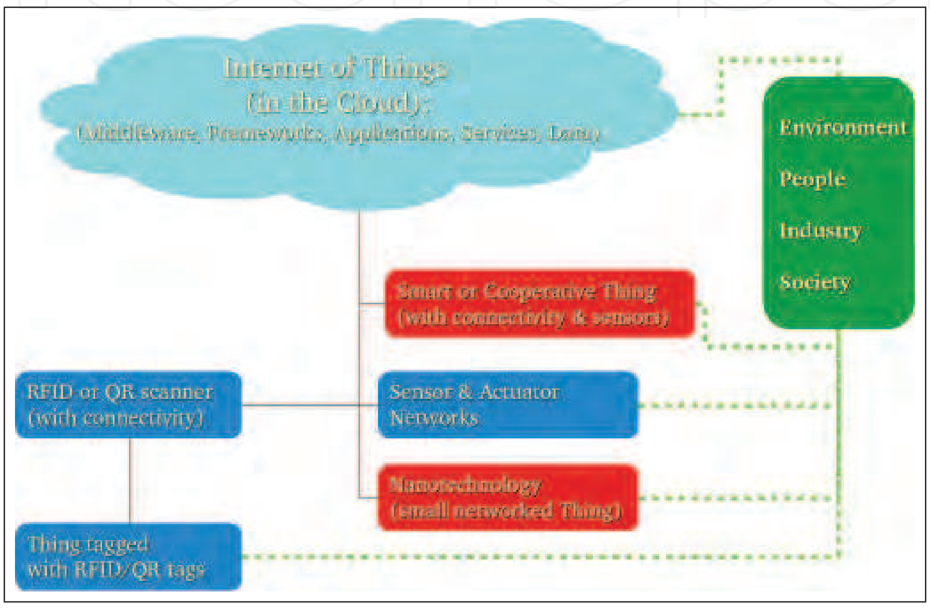

Fig. 3. Internet of Things Components

A vision for the IoT can be expressed as follows:

- All things become part of the Internet (or have a cyber-representation in the Internet cloud).
- Each thing is uniquely identified and accessible through the network.
- The position, identity and status of each thing are known.
- Each thing can sense, actuate, identify, interact, interface and communicate.
- Some things have intelligent services making sense of its localized data.
- Internet-based services exist, which make sense of the masses of data received from the connected things.
- Everything will be connected to everything else: Any **place**, any **time**, any **thing**, any **one**, on any **network**, using any **service**.
- Ultimately the IoT adds value to our world.

Figure 4 presents this vision in a graphical format.

Most of the enabling technologies for the IoT already exist (some not having optimal form or function yet, but able to contribute to the IoT). Based on this, the key driver for the adoption of IoT lies in the applications and new ways of solving existing challenges.

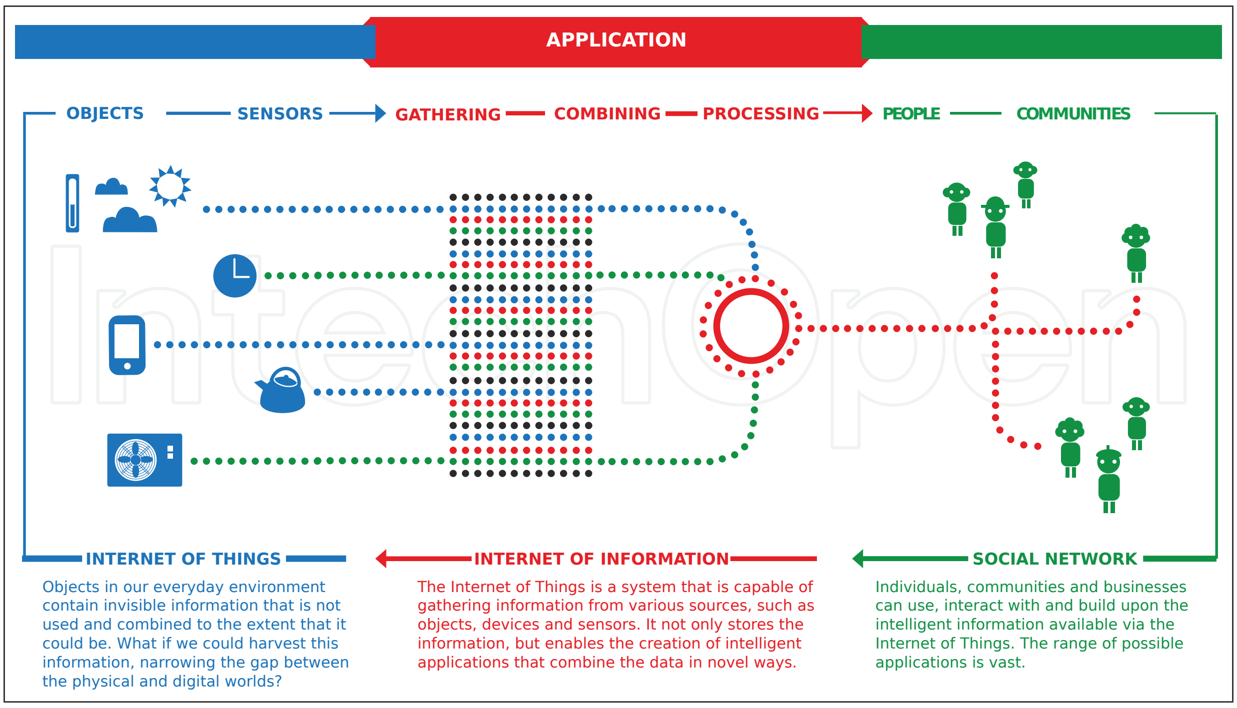

Fig. 4. Internet of Things Vision

3.1 Applications

IoT concepts have been demonstrated in a variety of domains: logistics, transport and asset tracking, smart environments (homes, buildings and infrastructure), health, energy, defence, retail and agriculture (Sundmaeker et al., 2010). IoT has the potential to significantly influence all facets of society.

According to Chui et al. (Chui et al., 2010) IoT applications fall into a number of broad categories. Figure 5 provides a graphical view of these application categories.

Chui et al. define two broad categories for IoT applications: *Information and Analysis* and secondly *Automation and Control*. Within each broad category, they further identify the following possible application of IoT concepts.

In Information and Analysis, decision-making services are enhanced by receiving better and more up-to-date information from networked elements in the environment, allowing for a more accurate analysis of the current status quo. This category applies to tracking (e.g. products in a logistics value chain), situational awareness (e.g. sensors in infrastructure or environmental conditions such as temperature and moisture) through real-time event feedback and sensor-driven decision analytics, which introduce concepts revolving around longer-term, more complex planning and decision making such as user shopping patterns in malls and stores.

Automation and Control implies acting on outputs as received from processed data and analysis. Process optimisation in industry is a promising application. A typical example would be where sensors measure the composition of a chemical compound, communicate it to a central service, where-after the service analyses and accordingly adjusts actuators to fine tune the composition. Optimised resource consumption can potentially change usage

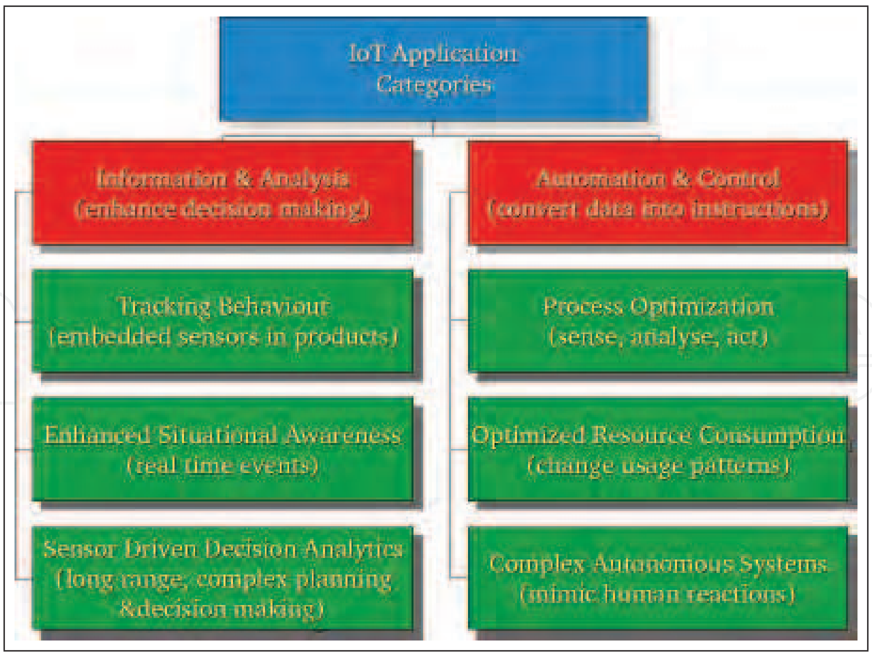

Fig. 5. Internet of Things Application Categorization (Chui et al., 2010)

patterns associated with scarce resources. Sensing and communicating the consumption of energy in households or data centres allow owners to adjust or load balance their usage to off-peak times with potentially lower costs. According to Chui, the real-time sensing of unpredictable conditions and the subsequent action taking based on those conditions, are a promising field of application. These types of applications mimic human behaviour (e.g. detecting an obstruction in front of a vehicle and then to initiate the appropriate evasive action) and are challenging to develop but holds promise for safety and security.

Fleish (Fleisch, 2010) provides a different view of the possibilities provided through the adoption of an IoT view.

According to Fleisch, IoT is relevant in every step in every value chain. He identifies seven main value drivers. The first four are based on value from machine-to-machine communication, while the last three create value with the integration of users. The drivers as identified by Fleisch are:

- **Simplified manual proximity trigger** – things can communicate their identity when they are moved into the sensing space of a sensor. Once the identity is known and communicated, a specific action or transaction can be triggered.
- **Automatic proximity trigger** – an action is triggered automatically when the physical distance of two things drops below (or passes) a threshold. The identity of the thing is known; when combined with the physical location and action, this allows for better processes.
- **Automatic sensor triggering** – a smart (or cooperative) thing can collect data via any type of sensor, including temperature, acceleration, orientation, vibration and humidity. The thing senses its condition and environment, and communicates the information which enables prompt (and global) decision making.

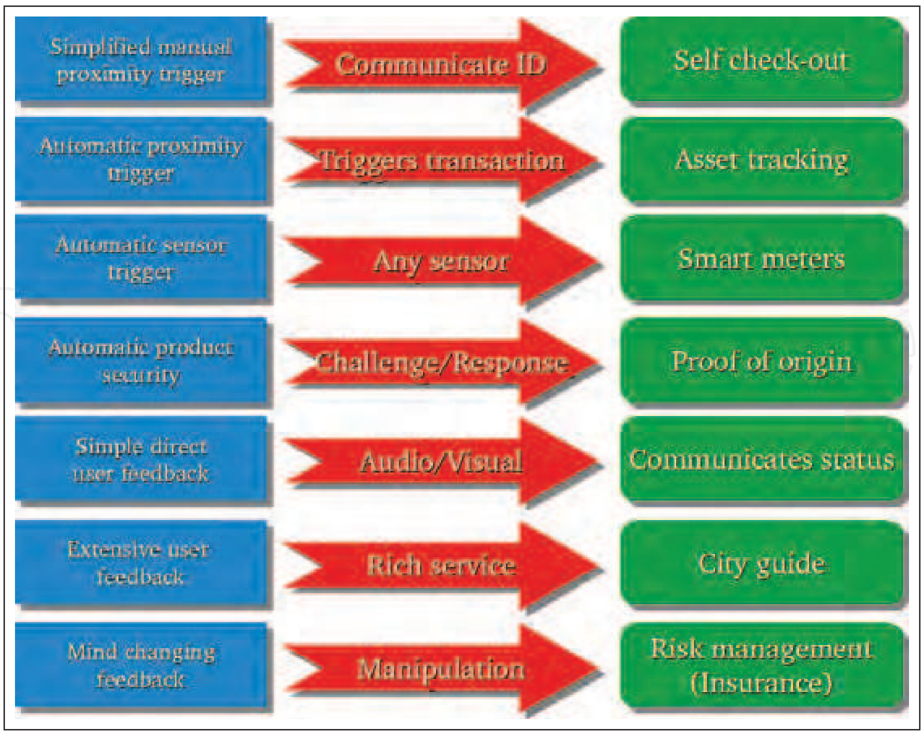

Fig. 6. Internet of Things Application Categorization (Fleisch, 2010)

- **Automatic product security** – a thing can provide derived security (information) based on the interaction between the thing and its cyberspace representation (e.g. a QR-code containing a specific URL pointing to relevant information).
- **Simple and direct user feedback** – things can incorporate simple mechanisms to provide feedback to a human present in the environment. Often these feedback mechanisms are in the form of audio (audible beep) or visual (flashing light) signals.
- **Extensive user feedback** – things can provide rich services to a human (often the thing is linked to a service in cyberspace through a gateway device such as a smart phone). Augmented product information is a good example of extensive user feedback.
- **Mind changing feedback** – the combination of real world and cyberspace might generate a new level of changing behaviours in people. One possibility is changing the driving behaviour as sensors in the vehicle communicate driving patterns to an outside agency.

IoT concepts and methodologies are being used more frequently in the creation of smart environments. The European Council's Framework Seven Programme is supporting a large-scale IoT project with *smart environments* as focus. The FP7 *Smart Santander* project hosted in the Spanish city Santander is positioned to be a large-scale IoT experimental research facility in support of typical applications and services for a smart city (*SmartSantander*, 2011). In Sweden, the *Sense Smart City* project (*Sense Smart City*, 2011) is researching ICT solutions for *smarter* urban cities and areas. Similarly, the city of Amsterdam is running the *Amsterdam Smart City* project (*Amsterdam Smart City*, 2011). Dohr (Dohr et al., 2010) utilises IoT in an ambient assisted living context to provide services for the elderly. McCullagh and Augusto investigate the potential of IoT to monitor health and wellness (McCullagh & Augusto, 2011).

Regardless of the categorization, it is clear that IoT can enhance inclusion of Persons with Disabilities and the Aged, or just as easily exclude Persons with Disabilities and the Aged.

IoT can easily impede the rights of individuals. Section 7 analyses the potential impact on the rights of the individual further.

3.2 Opportunities and challenges

Not all aspects of IoT have been resolved to the point of seamless integration. Some challenges remain. Most significant of these are aspects related to *privacy*, *trust* and *security*. Some of these aspects have been partially answered by some applications of the Internet of People, such as the Social Web, but the introduction of objects to this Internet adds the complexity of resource sharing, attribution and usage management. In the IoT world the question of **who** can see and act on **what** remains unanswered. How can the rights of the individual be ensured? The *societal* and *ethical* elements that will be created through IoT, needs to be explored. Similarly, *business models*, *governance* and *policies* still need to be resolved.

Many technological platforms and solutions will make up the IoT. Ensuring *interoperability* through appropriate *standardisation* is a high priority. The envisioned scale and complexity introduced by the large number of participating elements is an enormous challenge. How can the *robustness* of solutions be ensured? IoT solutions and applications will face a data deluge. How will the data from billions of *things* be processed, stored and maintained for future generations where appropriate?

Smart environments are becoming more prominent. The following section presents smart cities and smart homes and highlight the potential of IoT as enabler for smart environments.

4. Smart environments

The concept of *smart environments* – be it city, urban or home – has been the focus of many different research projects and implementations (Hodgkinson, 2011; Robles & Kim, 2010; Taylor et al., 2007). Multiple definitions of *smart environments* exist. A common theme in the definitions is how ICT can enable the delivery of services to the people in the environment, leading to improvements in *service delivery*, *governance*, *transport*, *sustainability*, *energy* and *innovation*.

Schaffers et al. provide a description of the many concepts associated with the smart environment (Schaffers et al., 2011):

"**Cyber cities** from cyberspace, cybernetics, governance and control spaces based on information feedback, city governance; but also meaning the negative/dark sides of cyberspace, cybercrime, tracking, identification, military control over cities.

Digital cities from digital representation of cities, virtual cities, digital metaphor of cities, cities of avatars, second life cities, simulation (sim) city.

Intelligent cities from the new intelligence of cities, collective intelligence of citizens, distributed intelligence, crowdsourcing, online collaboration, broadband for innovation, social capital of cities, collaborative learning and innovation, people-driven innovation.

Smart cities from smart phones, mobile devices, sensors, embedded systems, smart environments, smart meters, and instrumentation sustaining the intelligence of cities..."

Fig. 7. Transport service in smart cities: virtual descriptions of the environments provide both simulation and documentation of the service

In most cases, the creation of such an environment has been achieved through the creation of an ICT vertical solution. These solutions typically do not allow for interoperability, which limits the potential benefits that can be obtained. The promise of IoT to create an open, standards-based, integrative solution to integrate the physical world into cyberspace and provide services that can enable smart environments, has been recognized. Vermesan et al. (Vermesan et al., 2011) recognize the enabling role IoT can play in the creation of smart environments. Similarly, Hernández-Muñoz et al. (Hernández-Muñoz et al., 2011) see the European Commission's Future Internet research initiative (which has as building blocks IoT and the Internet of Services) as a mechanism to avoid the current vertical technological islands typically associated with smart cities.

4.1 Smart cities

There is a clear progression in terms of sophistication and integration of smart cities. One of the aims in this progression is to allow for better decision making by citizens as well as enhancing resource utilization (e.g. energy and water) and lowering the city's carbon footprint. Giffinger et al. define the characteristics of a smart city as (Giffinger et al., 2007): Smart Economy; Smart People; Smart Governance; Smart Mobility; Smart Environment and Smart Living.

ICT as enabler realizes the following progression:

- ICT as a support function.
- ICT providing information to citizens.
- ICT providing access to real-time data which aid decision making.
- ICT acting on the information to control the environment.

Taking the above into account, the following categorization of *smart cities* can be created:

- **Ubiquitous infrastructures** – broadband providing always on connectivity for both devices and people.

- **Rich in information** – an abundance of sensors to determine the state of the environment (temperature, humidity, traffic, open parking, etc.) and access to data.
- **Smart services** – advanced services from city to citizen and citizen to citizen, which utilize the available information as collected through the various infrastructure elements.
- **Action taking** – an abundance of actuators and other feedback mechanisms through which the environment is influenced and controlled.

4.2 Smart homes

Aldrich provides a good categorization of *smart homes*. He provides the following breakdown (Aldrich, 2003):

- "**Homes which contain intelligent objects** – homes contain single, standalone appliances and objects which function in an intelligent manner.
- **Homes which contain intelligent, communicating objects** – homes contain appliances and objects which function intelligently in their own right and which also exchange information between one another to increase functionality.
- **Connected homes** – homes have internal and external networks, allowing interactive and remote control of systems, as well as access to services and information, both from within and beyond the home.
- **Learning homes** – patterns of activity in the homes are recorded and the accumulated data are used to anticipate users' needs and to control the technology accordingly.
- **Attentive homes** – the activity and location of people and objects within the homes are constantly registered, and this information is used to control technology in anticipation of the occupants' needs..."

Several IoT application categories have been suggested (as described in Section 3.1). These are depicted in Figures 5 and 6. The above categorization of smart homes and cities is aligned and applicable with the IoT application categories, thus confirming IoT as enabler for these environments.

With more connected objects (with sensors and actuators) in an environment, services incorporating those objects become part of the landscape. As depicted in Figure 2, the value provided by IoT increases by composing services into higher-level services. Driven by IoT's fundamental interoperability characteristic, the basic services in an environment can be composed into higher-level services, with the subsequent increase in potential impact. These high-level services allow for enhanced *learning* and *attentiveness* and can provide for "*mind changing feedback*", "*complex planning and decision making*" and "*mimicking human reactions*".

Smart environments do not by default ensure inclusion. An enabling smart environment geared towards inclusion is required. Section 5 presents a methodology used to extract needs of Persons with Disabilities and the Aged. It highlights technological gaps and presents arguments supporting IoT as enabler for enabling environments.

5. Inclusive and enabling environments

As stated by Vermesan et al. (Vermesan et al., 2011), IoT has as its major objective the creation of smart environments. However, IoT also has the potential to evolve the smart environment into an enabling environment.

An *enabling environment* is an environment – either physical or virtual – that is designed or augmented in such a way that everyone, irrespective of disability or age, experiences equal participation and faces no barriers to activities, integration and independence.

In order to meet the objectives set by this definition, a research project called "Enabling Environments" was conducted in 2006 at the CSIR Meraka Institute, in Pretoria, South Africa (Macagnano, 2008; Williams et al., 2008) to determine possible technical interventions applicable to an urban environment and in a developing country.

The research sought to answer the following question:

> How do you integrate People, Technologies and the Environment into an interactive information and communication system, where the physical and virtual infrastructures become intelligent, connected and able to respond to human psychological and physical needs, in an accessible and usable manner?

In order to answer this question, various methodologies were employed, mostly to understand the environment and determine the needs of Persons with Disabilities and the Aged. The approach was people-centric, value-based, and hinted at technical solutions that were fields for future research.

5.1 A people-centric view of the Enabling Environment

The 2006 Enabling Environments research project approached the research challenge as a triad: Environment, People and Technology. As such, it conducted environmental audits, people surveys and workshops, and applied some future thinking and idea-generation techniques to identify candidate technologies with the potential to be a part of the solution.

The first method used to understand the context of an environment is called Future-Thinking (Hietanen et al., 2011). A workshop was organized, which included Persons with Disabilities and the Aged as members of the team to identify actors, customers, needs, products and services, environments, transformation processes, values, obstacles as well as political, economic, social, technological and ecological "drivers". Once a contextual picture is drawn, it is possible to generate interesting people-centred, value-driven and service-orientated scenarios. In these typical scenarios, there would be challenges that technology may be able to solve. Often, there was no simple technological answer to an environmental problem for a specific disability as each circumstance is different and makes it difficult to conceive a universal design that works for all.

The outcomes of the future study lead the team to select a physical location (Church Square, Pretoria, in South Africa) in which environmental audits and interviews with Persons with Disabilities and the Aged were conducted. Several challenges were readily identified:

- **Mobility** – the inability to use transport infrastructure and access places.
- **Wayfinding** – difficulty of finding a route usable with a wheelchair, or finding the easiest path with reasonable places to rest, or finding the path with the least risk (avoiding construction areas, for instance).
- **Communication** – the language and cultural barriers related to asking for information, or help, and knowing the protocols and the terms of the exchange.
- **Information** – Inaccessible information: signs which are not localised, transport routes and timetables, which are not physically usable (too high on a wall, print fonts too small,

small crowded space with one resource providing information). This also includes people experiencing difficulties to read (illiteracy) or see (visual impairment), and the general lack of information that is useful to the individual, versus the noise and over-abundance of information provided in the environment (warnings, documentation, recommendations and guidelines).

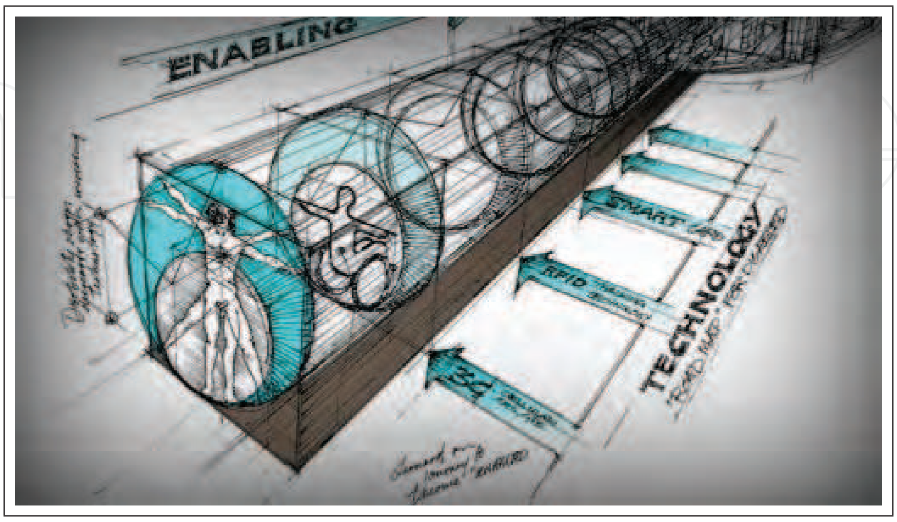

Fig. 8. User-centric and universal design: the environment must enable any person without assistive technology, at the same time, services must be adapted to each person

Following the initial Future-Thinking study and the field surveys, the team held a persona and scenario workshop to extract a full account of those challenges that were encountered by a blind person, a Deaf person, a quadriplegic wheel-chair user and an elderly person in the city centre (Williams et al., 2008). For each persona, a different scenario best illustrated the challenges that were met. The scenarios used were:

- Catching a taxi and finding your way to your destination as a blind person.
- Communicating in a multilingual environment as a Deaf person.
- Crossing public spaces in a wheelchair.
- Finding help and reasonable places to rest as an elderly person.

These people-centric studies form the basis of our understanding of what technology should do and help in identifying gaps, specifically in a built environment such as a city (public places) and a room (office and home). They showed that there were technological gaps that had to be addressed in the environment, in a universal manner to benefit all. The studies further showed that an enabling environment had to be envisioned for individuals, and provide solutions addressing each of their use cases and intent in the environment. These two aspects were difficult to reconcile and it was indeed very difficult to provide one unified solution for all these individual and personalised needs based on specific assistive technologies. Instead, the problem has to be reformulated: **How does an individual create and use his own assistive service from the various devices present in the environment**?

5.2 Technological gaps

The specific technical solutions that were originally suggested in response to the persona and scenarios challenges relied more on providing specific assistive technologies to each persona to break down their environmental barriers and less on a universal design which achieves the same results through the interconnection of many things and improvements in the environments themselves.

The above research on enabling environments concluded that the solution lay in furthering the multi-disciplinary research and solving the following technical challenges:

- **Multiple Mobile Sensor Technology** – for the environment to become aware of its own state.
- **Universal Design, Accessibility and Usability** – for the environment to be usable by all.
- **User Profiling, Social Engineering, Social Research** – to know the context and profile of a person.
- **Context Awareness, World Modelling** – to model the context and environment with a virtual system.
- **Artificial Intelligent Reasoning** – to learn and reason about data, context, state, events and people.
- **Software Engineering and Computational Issues** – to computationally manage a connected, integrated intelligent environment.
- **Assistive Technologies and Human Computer Interaction** – to interact and engage with the enabled environment.

These are the premises for an enabling environment, in which the technical stack will need to incorporate a world of sensors and provide personalized services in a user-centric manner.

After reviewing the technical challenges and gaps, which were identified in the Enabling Environment project, IoT seems to provide possible technical solutions. Typically, IoT is an environment itself with practical implementation for the concepts of ambient and ubiquitous intelligence. From this perspective, there is less emphasis on smart devices and assistive technologies ("technological interventions" in the environment or with the people) and greater emphasis on existing environmental things and the possible utilization scenarios individuals can create for themselves.

This approach is more technology-centric at first, enabling the things that make up the environment, before their combined data and complementary value provide all people with "*enabling smarts*". The question remains: what are the technologies that must be introduced as a standard to provide enabling smarts that people can use? IoT provides such solutions which integrates the idea of disaggregated assistive services for all.

5.3 Internet of Things as the enabler

IoT provides an integrated solution which addresses four of the technological gaps expressed above:

- How to make the environment aware of its own state.
- How to model the context in a virtual system.
- How to provide intelligent services based on learning and reasoning.
- How to computationally manage this connected and integrated environment.

IoT is able to provide some "*enabling smarts*" by finding value in the combination of many things that are already in the environment, and possibly on the person. IoT is a mechanism through which Weiser's original *Ubiquitous Computing* vision (Weiser, 1991) and its extension, the *Ambient Intelligence* vision (Gill, 2008), can be realized.

IoT therefore provides an implementation framework for *"enabling smarts"* such as:

- **Augmented Reality** – IoT provides the means to virtualise the physical environment from all the sensors and actuators, which are present. It makes possible an alternative rendition of the environment by filtering, reorganizing sensory channels and changing the modality of the information altogether.
- **Disaggregated Computing** – rather than one powerful assistive device (often *attached* to the person), use the various capabilities of the many environmental things to provide a more reliable service.
- **Invisible Computing** – IoT makes it possible to focus on the task at hand rather than on the assistive technology to bridge the gap.

A smart environment becomes an enabling environment when the combination and processing of information benefits the person through the following:

- **Identify and Personalise** – by knowing the person's needs and adapting accordingly.
- **Track and Sense** – by knowing the person's location and understanding the intention and objective.
- **Inform** – by telling the person what he needs to know and by describing his options in specific scenarios.
- **Consult and Act** – by asking the person for feedback and then instigating changes in the environment beneficial to the person.

These classes of services closely match the application areas previously described for IoT (see Section 3.1). Enabling the things that already make up the environment means that people will find themselves empowered in an environment that is familiar and more conducive to tasks they want to execute.

5.4 Enabling Internet of Things applications

In the preceding sections, the generic applications and value of IoT as enabler have been discussed. These need to be translated into real-world applications that can be implemented. How can the described scenarios be addressed through IoT?

Catching a taxi and finding your way to your destination as a blind person. As a first priority, the blind person needs to be aware of his own location. This can be obtained through a smart mobile device (e.g. smart phone) with a GPS sensor. Being in a fully connected environment he can initiate a *call* to a taxi service, which contains his GPS coordinates. A taxi (which is connected to the IoT) will be messaged and instructed to drive to the closest taxi rank to the received GPS coordinates. The blind caller will be routed to the appropriate taxi rank via embedded indicators in the environment. These indicators might be talking side walks and traffic lights, which have been notified of the blind person's route to that appropriate taxi rank. A traffic light will sense that the person is approaching (by sensing the person's RFID tag which is embedded in his smart phone) and will regulate the traffic (e.g. stop the flow) as the person crosses the road. Alternatively, the indicators can be audio queues from the side walk, which are activated as he moves towards the taxi rank. When he is approaching the taxi, the audio queues will guide the person towards it.

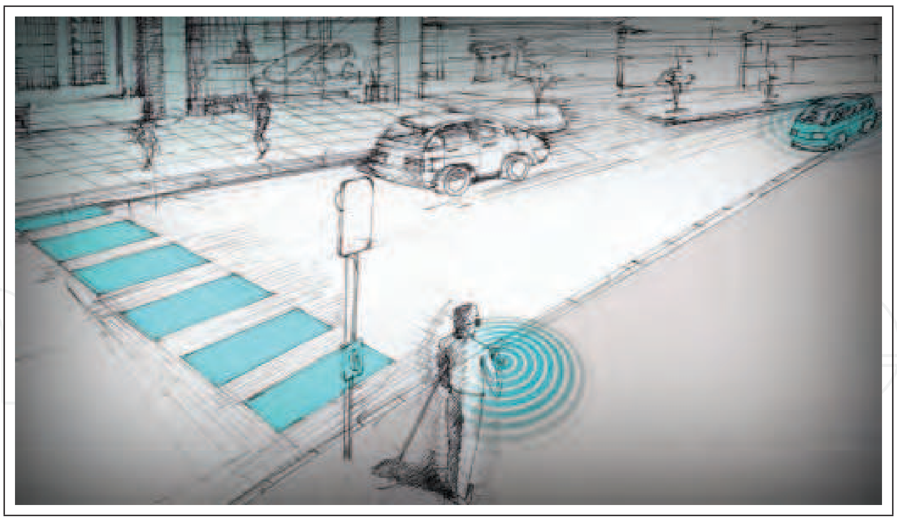

Fig. 9. Scenario for a blind man finding and catching a taxi: the presence of smart technology in the environment can enable this service

Communicating in a multilingual environment as a Deaf person. The environment is fitted with a multitude of Internet-connected displays. The environment also has a multitude of RFID or other near field communication (NFC) scanners. The Deaf person will be in possession of a tag (either stand alone and embedded in his clothes or part of a smart hand-held device such as a smart phone) which is continuously scanned by the environment. As his identity and location and subsequent preferences are known in cyberspace, the connected displays in the person's vicinity can sense his presence and adapt their signage to the appropriate modality (e.g. Sign Language in the specific dialect instead of normal written text).

Crossing public spaces in a wheelchair. The wheelchair user's current location is known, as sensed in the environment (e.g. RFID scanners able to scan the RFID chip as embedded in the wheel chair). The person communicates his target location by speaking (microphones in the environment record the audio signal and cloud-based services perform automatic speech recognition). The routing service calculates an optimal route, taking into account the current state of the environment (e.g. construction in an area, which would prevent a wheelchair from passing through). The appropriate route is communicated to him via connected displays en route (e.g. routing a person to avoid stairs and steps, but rather to ramps and lifts). As the wheelchair user moves, his position is tracked, with those displays in his vicinity presenting him with updated routing information for the environment.

Finding help and rest as an elderly person. The IoT environment is aware of a specific person (and also the person's profile and abilities). An always on and sensed environment, listens to the person, and responds when the person asks for help (microphones, automatic speech recognition or the press of a *help* button on an interactive display, or through accessing a city service from his smart mobile device). The environment, through the signalling, can guide the person to a place of rest (e.g. restaurant with open tables, or closest public seating in the park).

Smart-enabling environments can guide and advise people accessing its space and using its services. Smart-enabling environments are aware of people and can optimize certain processes, taking into account all the people who require a service or access to a space, to ensure it adapts when appropriate to accommodate other people. In other words, it is possible to make some changes in signalisation and information in order to route and help people in making better choices that will benefit the majority, but also to benefit the few that are in need (lost, tired, agoraphobic, claustrophobic, clearing a path). An IoT-enabled environment can aid in the following ways:

- Information:
  - Access to personalized signage: environment communicates in appropriate modalities using appropriate devices/appliances.
- Communication:
  - Signalling for help: environment senses the need (audio, visual, signal from smart device) and responds appropriately.
  - Getting service: a specific service request is communicated to the environment (e.g. to access public transport), whereupon the environment responds.
  - Payment: in a connected environment, the person's identity is known and the link to a bank account accessible to the service is available. Auto payments based on the specific action takes place.
- Finding places:
  - Navigation: location, direction, orientation and wayfinding according to specific parameters (energy level, time-wise, crowd-wise) become possible. For example, motorized wheelchairs communicate their battery charge levels, location and in return, receive relevant information which takes the context into account.
  - Virtual presence in a real environment: accessing services and even walking in the park.
- Mobility:
  - Planning transport and routes: receiving information from the environment regarding the status of transport in the environment.
  - Access to transport information: getting on and off transport, knowing if a specific mode of transportation is accessible and usable for that person's specific needs.
  - Access to site information: determining accessibility of a site depending on the mode of transport (by foot, bicycle, train, bus, taxi or wheelchair).

From the above narrative, the role of IoT in enhancing inclusion in future environments (home or city) is clear. However, to enjoy the benefits, IoT-related challenges need to be resolved. Section 6 analyses these aspects.

6. Inclusion benefits through the Internet of Things

In the preceding sections, IoT, smart environments and the road to an enabling environment were described. IoT as technology can create *smart environments*. IoT connects smart objects within an environment, senses the environment and collates and processes the sensed data in higher-level services, with the result fed back to the environment whereupon actioning in the environment is initiated. In smart cities, the focus is on *service delivery*, *governance*, *transport*, *sustainability*, *energy* and *innovation*. In smart homes, the focus is on *information exchange*, *increased functionality*, *distance* and *remote control* and facilitating *learning* and *attentiveness*.

When IoT-based services and technologies, which allow for improvement in **mobility**, **wayfinding**, **communication** and **access to information**, become part of the standard suite of services in a smart environment, the door to inclusion and an enabling environment has been opened.

Fig. 10. Enabling Inclusion through IoT

Similarly, if IoT technologies empower and benefit the individual by **identifying** and **personalising**, **tracking** and **sensing**, **informing** and **consulting** and **acting** in appropriate and responsible ways, inclusion through enabling environments becomes a real possibility.

If it is fair to assume that the value of IoT emerges from an abundance of connected things, it is also important to consider how these things combine to provide services, and how it is possible to discover their features, understand their capabilities and usages, categorize them and filter them in reusable user libraries and taxonomies. Building IoT-enabling services from user scenarios is discussed in Section 6.1. The section identifies elements that make things usable in assistive scenarios.

The second benefits-versus-challenges aspect which IoT presents is discussed in Section 6.2: how is the Internet dimension of IoT an accessible and usable medium? Can it provide the required functionality for all individuals, irrespective of their abilities (and disabilities), learning style and preferences, language and level of literacy?

6.1 Enabling things

Section 5.4 provides some examples on how "enabling" applications of IoT can be conceived, based on documented people-environment scenarios. Service providers can follow the described methodology to find innovative applications and new usage of technologies and create new services for the city and in the house.

The real test, however, is whether a person with specific needs will be able to communicate his goals and receive a personalised service, by both publishing a request or an expression of his intent, and by piecing together his own assistive environment from the various things in his contextual environment.

In either case, enabling things making up an assistive environment require discovering and combining properties of the environment into a workable solution.

This entails various levels of intent (being part of the solution or making requests) and various levels of control (privacy and interaction).

In the most informative approach, a person states his goals by publishing a profile which describes abilities, languages and other particulars. This person expects some degree of support and initiative from the environment.

In a more conservative approach, the person builds an assistive solution without stating his intentions, i.e. without publishing a profile. The person will then actively create a custom assistive service as an IoT application made up of the surrounding enabling things. Of course, most practical assistive solutions will be somewhere in the middle ground: from the person's perspective "nothing about the person [must be done] without the person". From a technology perspective, neither "pushing" nor "pulling" services are an acceptable solution; the technology must be accessible and communicate and interact with the person on demand.

From an IoT perspective, this "human accessible" dimension introduces new challenges which need to be addressed to change the smart environment into an enabling one. Below are some human-to-thing conversational aspects and requirements for the things themselves:

- **Service discovery** – discovering existing services and things in the environment. To discover the service, the context of the request is important: the context comprises both the physical conditions and the virtual states. A person might only be virtually present in the environment, but would still want access to the real world context. The person may be physically present in a context, but seek information about another context virtually.
- **Taxonomy and classifications of things, functional and assistive usages** – can be used to classify the assistive services and IoT applications from authoritative sources (e.g. ICF, ISO 9999, c.f. Heerkens et al. (2011)) and user-made folksonomies (Web 2.0 tagging for instance).
- **Documenting and providing alternative human interfaces (languages, representations) and software APIs** – this is required to provide information on how IoT applications can be built and how their composition create assistive services. Interfaces and adapters are essential to providing both human control and contracts between things.
- **Providing a language in which services can be described as a combination of smart enabling things** – domain-specific descriptions and terms are combined and coordinated into valuable scenarios (e.g. Pentagruel (Drey et al., 2009)). Design patterns, best practices and example scenarios need to be conceived to create specific behaviours and services, for instance, the Sense/Compute/Control model proposed by Cassou et al. (2011).

The key aspect for an enabling environment is for the person to know how to discover solutions. The assumption is as follows: Whether the person is asking for a service, or controlling and making environmental adjustments and adaptations, there is a degree of control over both the physical environment and the virtual, connected one.

The next section discusses how enabling environments via IoT depend on the existing efforts in accessibility, usability and ergonomy of both the real and virtual environments.

6.2 Accessing the Internet of Things

Getting access to the IoT is a question of finding a thing, interface or an Internet protocol which is best suited to the person's needs and goals.

This presents the usual challenges of both ergonomy and environmental design, and of accessibility and usability of information systems.

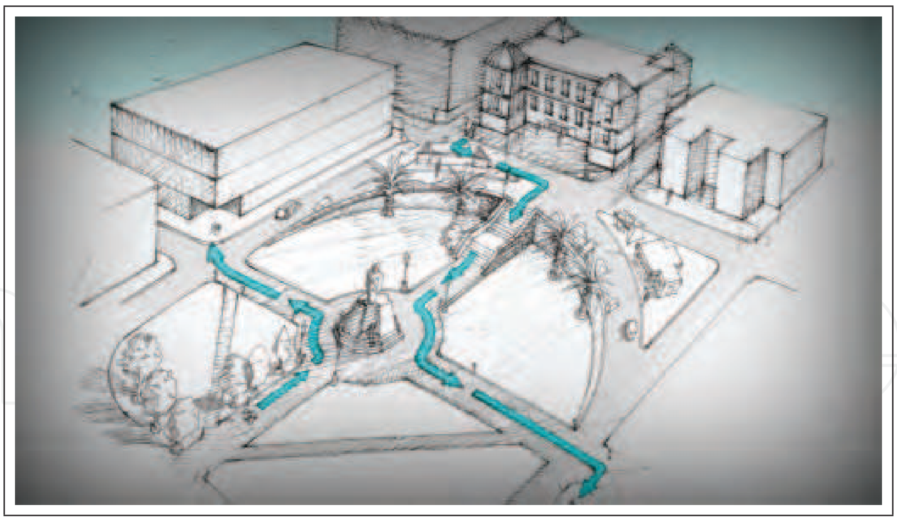

Fig. 11. Based on the person profile and preferences, find a path that's safe, that maximises rest and shade, and minimises effort

The vision is for both modes of interaction, either physical or virtual, to complement each others in such a way that the physical barriers are removed, and that the virtual world and information systems are less abstract and disembodied.

Technologies that currently make up the basic IoT inventory already introduce some physical barriers. Things in the environment (price-tags, schedules, menus, toilet availability, shop status – open or closed) may also be beyond the reach of the physical or sensory (barriers, height, effort, people), and therefore inaccessible to some people. Providing a virtual, connected representation means enhanced accessibility.

- Barcodes (1D, 2D) are popular and provide a unique identifier for an item and often, a reference link for the tagged object. Although barcodes are not connected, they can rely on connected scanners and cameras to become a thing of the Internet. Barcodes, however, are physically inaccessible for someone with a visual impairment, who will not notice nor be able to bring barcodes into the scanners' field of view. As a thing of the Internet, barcodes can be linked to and augmented by GPS coordinates or even alternative RFID or NFC technologies to provide a more accessible identification service. Relying on the community of people is another solution: the "eyes" of other people, through their smart devices, produce decoded information, e.g. GPS coordinates to an application of the IoT such as Thing-Memory (Coetzee, 2011) (a cyber representation and model of physical things). Blind people, supported by their GPS position and orientation, now have a way to explore the environment based on this cyber model of the environment.
- Public displays are popular for adverts, news and transport schedules and are in fact "connected" things. They pose the usual problems of accessibility for the blind and Deaf. Yet, as things of the Internet, they can make their information available through alternative formats such as text-to-speech for the blind and captions for the Deaf. Connected "Internet" TVs then become accessible through the IoT, beyond their physical limitations.
- Alarms, vehicle horns, sirens and other warning signals also ought to be delivered over a wider spectrum of modalities in an environment. If connected to the Internet, these things ultimately increase their reach, scope and impact not only through connected information

systems and social media, but also through other objects present in the environment that may physically change their state or behaviour to reflect the state of emergency or risk.

Accessibility is therefore increased through the additional modalities provided by connecting information systems and the physical environment.

The abundance of modalities means that information systems have to provide people with the most appropriate modality and format for the contextual information, based on the individual person's abilities, preferences, literacy and language (Coetzee, Viviers & Barnard, 2009).

People will need to be selective and define what constitutes their context, and swap between contexts to filter the large amount of information emerging from the IoT. People have to populate their environment with the things, sensors and services which they request from the IoT. Making these contexts familiar and safe is the biggest challenge that the IoT has to address.

Regarding usage and safety, the IoT is able to provide an important layer of helpful and critical information.

Firstly, it is possible for each thing, once identified, to offer people documentation, usage patterns, warnings and advice from other people. If connected, the thing can communicate an error or have its status tracked, verified and asserted by applications in the IoT.

Secondly, each thing can be assigned a level of safety and safety conditions to present people with a warning of possible dangers or potential misuse when entering its context. The inter-connectedness of things also means that the accumulated effects of things in a context can trigger a safety warning, such as electrical objects near water, magnets near magnetic media storage, etc.

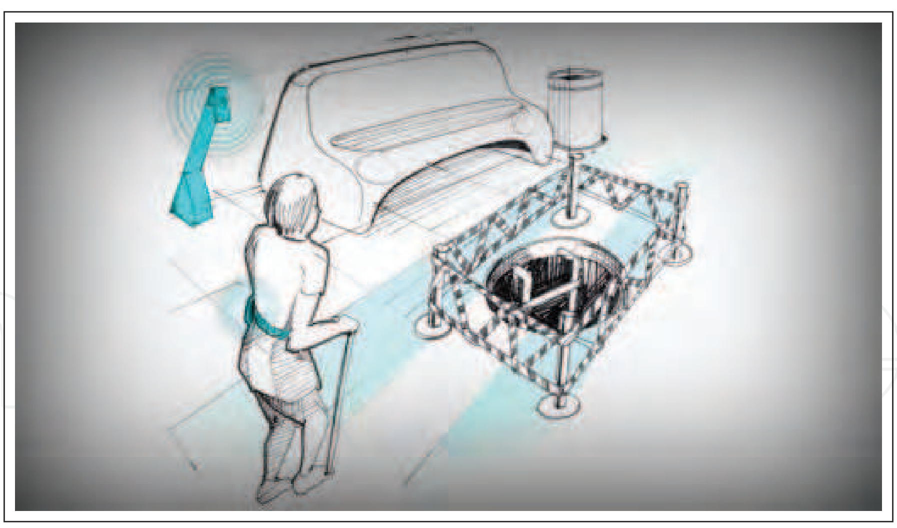

Fig. 12. Dangerous Things: the virtual layer provided by self-documenting, self-describing smart objects makes danger, that's beyond the reach of our senses, discernible

The final challenge for IoT in the assistive domain is that of trust and reliability: because the solution is made of disaggregated, heterogeneous components with varying quality, and relies on connectivity with most applications relying in turn on models and knowledge systems. The combination of all aspects means that trusting in an IoT application to provide an assistive service may prove too uncertain, unreliable and risky for people. Proving that these solutions can work reliably and reconfigure when aspects of the IoT change, forms yet another level of IoT integration dedicated to quality of service.

Persons with Disability and the Aged have rights as described in the Convention on the Rights of Persons with Disabilities. People are at risk of having their rights impeded through IoT-based technologies. The following section describes Articles applicable in an IoT environment and highlights the challenges in complying to all the stated rights.

7. United Nations's Convention on the Rights of Persons with Disabilities

The preceding sections described technologies and a methodology to extract user needs and application of technologies to address the identified user needs. However, cognisance of the wider context needs to be taken. Efforts to enhance inclusion is only part of the solution. All solutions implemented are framed by the Convention on the Rights of Persons with Disabilities.

The United Nations's *Convention on the Rights of Persons with Disabilities* (Secretariat for the Convention on the Rights of Persons with Disabilities, 2011) has been created to protect the rights and dignity of Persons with Disabilities. Article 1 states the Convention's purpose as follows:

> "The purpose of the present Convention is to promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to promote respect for their inherent dignity.
>
> Persons with disabilities include those who have long-term physical, mental, intellectual or sensory impairments, which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others..."

The Convention defines the actions that a Signatory (e.g. a Government) must execute to ensure that a person with disabilities can realize his right. The Convention addresses aspects that can be accomplished through IoT. However, IoT also introduces possibilities that can be detrimental to the individual's rights. The following articles have specific implications for IoT and Persons with Disabilities and the Aged:

Article 9 Accessibility "To enable persons with disabilities to live independently and participate fully in all aspects of life, States Parties shall take appropriate measures to ensure to persons with disabilities access, on an equal basis with others, to the physical environment, to transportation, to information and communications, including information and communications technologies and systems, and to other facilities and services open or provided to the public, both in urban and in rural areas..."

Article 17 Protecting the integrity of the person "Every person with disabilities has a right to respect for his or her physical and mental integrity on an equal basis with others..."

Article 19 Living independently and being included in the community "States Parties to the present Convention recognize the equal right of all persons with disabilities to live in the community, with choices equal to others..."

Article 20 Personal Mobility "States Parties shall take effective measures to ensure personal mobility with the greatest possible independence for persons with disabilities..."

Article 21 Freedom of expression and opinion, and access to information "States Parties shall take all appropriate measures to ensure that persons with disabilities can exercise the right to freedom of expression and opinion, including the freedom to seek, receive and impart information and ideas on an equal basis with others and through all forms of communication of their choice..."

Article 22 Respect for Privacy "No person with disabilities, regardless of place of residence or living arrangements, shall be subjected to arbitrary or unlawful interference with his or her privacy, family, home or correspondence or other types of communication or to unlawful attacks on his or her honour and reputation..."

Article 26 Habilitation and rehabilitation "States Parties shall take effective and appropriate measures, including through peer support, to enable persons with disabilities to attain and maintain maximum independence, full physical, mental, social and vocational ability, and full inclusion and participation in all aspects of life ..."

IoT services can easily impact on the above Articles and the associated rights. By complying with one article through IoT, the stated right of another article may be broken. An example is that of enhancing mobility for a visually impaired person. As stated in Section 5, *Mobility* and *Wayfinding* are key challenges for Persons with Disabilities and the Aged. Article 20 requires effective measures to ensure personal mobility. If an environment is fully enabled, with sensors positioned to keep track of the location of a specific person, a higher-level service can provide the required functionality to ease mobility and wayfinding. However, Article 22 requires *Respect for Privacy*. As the person's location is now known at all times, the privacy element can very easily be overridden. Because the person is tracked, and the information known at all times, the possibilities for abuse are rife.

Similarly, Article 21 addresses the individual's right to access information. IoT services can be developed to present information in the most appropriate modality (e.g. Sign Language for the Deaf). The manpower cost associated with creating Sign Language for information purposes may inhibit its creation. Information in other written languages (the localization process) is also expensive, but not as prohibitively so as that of Sign Language. In an African development context, there is the misconception that the Deaf are literate. This is not true, as literacy in itself is a big challenge for the Deaf. As a consequence, the Deaf can very easily be excluded in an IoT world, as Sign Language will not by default be seen as necessary.

Rights of individuals are important. Each technology that is introduced, should be measured against the Convention to ensure compliance and inclusion.

8. Conclusion

Inclusion of Persons with Disabilities and the Aged in our environments and societies has always been a challenge. Through policies and technologies, some progress is being made in improving inclusion. However, technology is evolving rapidly, with the consequence that while technology evolution can enhance inclusion, and it can also limit and impact negatively on inclusion. The Internet in general has improved inclusion through improved access to information and interaction with others (assuming that an appropriate assistive technology is used as is required).

IoT is the new Internet technology wave following that of the Social Web. Through the IoT, the Internet is extended into the physical world through connected objects or cyber-representations of the physical. The incorporation of the physical world into the Internet has the potential to further improve inclusion of Persons with Disabilities and the Aged. However, it can also impact negatively on inclusion. IoT has as its major objective the creation of smart environments and spaces and self-aware things. None of these ensures inclusion as a default. As IoT will become pervasive in our society and realized in environments such as smart cities, inclusion needs to be part of the fundamental design.

This chapter presents IoT, its typical applications and some of its challenges. It describes smart environments and the reasons for their increasing importance. It also links IoT as enabling technology for smart environments. It presents the methodology and the extracted generic challenges and technological gaps in creating an inclusive enabled environment. Through the matching of IoT application categories and the technological gaps, it is found that IoT is an enabler for four of the technology gaps in enabling environments: Through IoT, an environment can be made aware of its own state, the context modelled in a virtual system, intelligent services based on learning and reasoning provided, which are capable of computationally managing the connected and integrated environment. Furthermore, through IoT, services can be provided, which aid in identifying the individual and subsequently personalizing information and the environment, by tracking an individual and sensing his needs as well as the state of the environment, by informing the individual of options, by consulting with the individual and acting based on the retrieved information.

Even though IoT can assist in the creation of an inclusive enabling environment, cognisance must be taken of the implications IoT can have on the rights of Persons with Disabilities and the Aged. It is shown, through an analysis of the United Nations's Convention on the Rights of Persons with Disabilities, that the creation of services to comply with a specific Article, may compromise the right associated with another Article. Extreme caution thus needs to be exercised in the creation of an inclusive enabling environment.

The future holds the promise of greater inclusion through the upfront integration of IoT services and technologies. By raising awareness of the societal needs now, we can live in a more inclusive world tomorrow.

9. Acknowledgement

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This book offers the reader new achievements within the Assistive Technology field made by worldwide experts, covering aspects such as assistive technology focused on teaching and education, mobility, communication and social interactivity, among others. Each chapter included in this book covers one particular aspect of Assistive Technology that invites the reader to know the recent advances made in order to bridge the gap in accessible technology for disabled or impaired individuals.

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