The Internet of Things – Promise for the Future? An Introduction

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Abstract: The Internet is a living entity, always changing and evolving. New applications and businesses are created continuously. In addition to an evolving Internet, technology is also changing the landscape. Broadband connectivity is becoming cheap and ubiquitous; devices are becoming more powerful and smaller with a variety of on-board sensors. The proliferation of more devices becoming connected is leading to a new paradigm: the Internet of Things. The Internet of Things is driven by an expansion of the Internet through the inclusion of physical objects combined with an ability to provide smarter services to the environment as more data becomes available. Various application domains ranging from Green-IT and energy efficiency to logistics are already starting to benefit from Internet of Things concepts. There are challenges associated with the Internet of Things, most explicitly in areas of trust and security, standardisation and governance required to ensure a fair and trustworthy open Internet of Things which provides value to all of society. Internet of Things is high on the research agenda of several multinationals as well as the European Commission and countries such as China. The research conducted is driving the creation of a useful and powerful Internet of Things. The benefits of Internet of Things to the developing and emerging economies are significant, and strategies to realise these need to be found.

Keywords: Internet of Things, ubiquitous computing, broadband connectivity, standardisation.

1. Introduction

Through numerous technology advances, society is moving towards an "always connected" paradigm. Networks (both wired and wireless) are everywhere, open standards are defined and rolled out (e.g. IPv6) allowing for unique addressing schemes. Concepts associated with the "Future Internet" are being researched and applied [1].

One new concept associated with the "Future Internet" is that of the so-called "Internet of Things" (IoT). The "Internet of Things" describes a vision where objects become part of the Internet: where every object is uniquely identified, and accessible to the network, its position and status known, where services and intelligence are added to this expanded Internet, fusing the digital and physical world, ultimately impacting on our professional, personal and social environments.

This paper presents an overview of the Internet of Things, its application and potential benefits to society and economy. It is positioned as an introductory paper beneficial to a wide audience ranging from strategic research managers, to researchers in the domain, chief information officers of businesses and other commercial ventures and strategists and

decision makers in governments. Section 2 presents the reasoning for and the evolution of Internet of Things. Section 3 presents important application areas for the Internet of Things. Section 4 covers challenges associated with the IoT vision and introduces the reader to local and international research activities in Section 5. An analysis of IoT with reference to the African development context is presented in Section 6. Finally, the conclusion (Section 7) ties the threads presented in the paper together.

2.   The Evolution Towards the Internet of Things

The Internet is an evolving entity, growing in importance, creating new value through its expansion and added utilisation. The Internet started as the "*Internet of Computers*", a global network with services such as the World Wide Web built on top of the original platform. Over the last number of years the Internet has changed into an "*Internet of People*" creating concepts such as the Social Web (or Web 2.0), where content is created and consumed by connected people (an estimated 1 billion people make up the Internet of People). This trend is also evidenced by the exponential growth of social networking services. Recent milestones such as Facebook achieving 500 million subscribers and Hotmail.com counting more than 300 million active e-mail accounts, together with the explosive growth of mobile Internet access and applications, illustrate that the Internet has matured significantly away from an *"Internet (work) of computers"*.

Technology advances are expanding the boundaries of the Internet. Broadband Internet connectivity is becoming cheap and ubiquitous, even in developing countries. Point in case, some of the regions in Africa are experiencing significant growth in access to fibre-based networks (such as SEACOM, EASSy and their associated terrestrial backhauls). Device processing power and storage capacity are increasing while the technology is making the devices smaller. Not only does this change the nature of the devices people access the Internet with, but enables a range of new opportunities. We are experiencing a shift away from the dominance of the PC as primary access mechanism in many countries towards mobile devices, whether these are smart phones, notebook or tablet computers. Devices are increasingly fitted with sensors and actuators; the combination of the above creating an environment where devices are connected to the network, has the ability to sense, compute, act and thus intelligently become part of the Internet. In addition, physical objects are increasingly fitted with tags (e.g. radio-frequency identification (RFID) [2] or Quick Response codes (QR-codes) [3]) which could be sensed or scanned by devices (e.g. the new generation smart phones containing embedded global positioning system (GPS) and/or RFID scanners or QR-code readers). This combination links the physical world to cyberspace through the smart device, thus expanding the Internet into what has now been coined the "*Internet of Things*".

In a 2005 report the International Telecommunications Union (ITU) suggested that the "Internet of Things will connect the world's objects in both a sensory and intelligent manner" [4]. By combining various technological developments, the ITU has described four dimensions in IoT: *item identification* ("tagging things"), *sensors and wireless sensor networks* ("feeling things"), *embedded systems* ("thinking things") and *nano-technology* ("shrinking things").

The definition of "things" in the IoT vision is very wide and includes a variety of physical elements. These include personal objects we carry around such as smart phones, tablets and digital cameras. It also includes elements in our environments (be it home, vehicle or work) as well as things fitted with tags (RFID or other) which become connected via a gateway device (e.g. a smart phone). Based on the above view of "things" an enormous number of devices and things will be connected to the Internet, each providing data and information and some, even services.

The IoT vision enhances connectivity from "**any-time, any-place**" for "**any-*one*"** into "**any-time, any-place**" for "**any-*thing*"**. Once these things are plugged into the network, more and more smart processes and services are possible which can support our economies, environment and health.

Figure 1 provides a view of the IoT ecosystem. Things could be tagged, and through scanners, identified, and the relevant location information could be communicated. Similarly, networked things with sensors become smaller, weaving themselves into our daily lives, while sensor and actuator networks act on the local environment, communicating status and events to a higher level service. Smart things sense activity and status, linking it to the IoT. Middleware and frameworks enabling application and service development which utilise data as received from (or about) things, most often living in the cloud provide the capability to add intelligence resulting in better services, which ultimately impact on the environment.
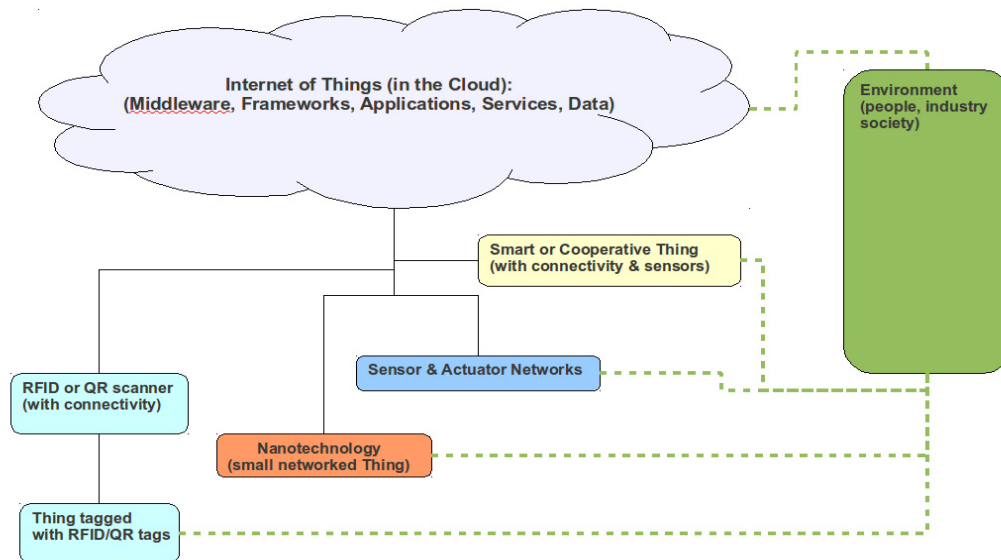

Figure 1: Components in the Internet of Things

It is projected that almost everything will be connected to the network, even individual objects will be tracked, its condition and location communicated in real time to a higher level service.

In this context, it is important to note the envisioned scale of the IoT. Billions of things are network connected, each one providing data, many of them with the ability to act and influence their environment. Once these masses of data are intelligently processed, smarter services enhancing decision making and action could be created.

The technologies that enable this evolution from the Internet as we know it today towards an Internet of Things exist already, some in less than optimised form, but nonetheless, the basis has been created. While continuous technical innovation in the IoT space is a given, the key drivers for the sensible evolution toward the IoT are the applications.

3. Applications

IoT has potential for societal, environmental as well as economic impact. Accurate information about the status, location and identity of things, which forms part of and impacts on the environment, allows for smarter decision making and appropriate action taking. IoT concepts have been demonstrated in a variety of domains, ranging from logistics, transport and asset tracking, smart environments (homes, buildings, infrastructure), to energy, defence and agriculture. In essence, IoT impacts and certainly has the potential to significantly influence all facets of society.

According to Fleisch, IoT is relevant in every step in every value chain [5]. He has identified seven main value drivers. The first four 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, which when combined with the physical location and action 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, communicates the information which enables prompt (and global) decision making.
- *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.

Fleisch's seven identified drivers are applicable to real world IoT applications.

Chui et. al. provide another view of possible IoT application classification [6].They define two broad categories for IoT applications: *Information and Analysis* and secondly A*utomation 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 adjust actuators to fine tune the composition. *Optimised resource consumption* can potentially change usage 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 [6] the real-time sensing of unpredictable conditions and the subsequent action taking based on those conditions are a promising field of application. These type 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.

The European Commission through the work done in the Cluster of European Research Projects on the Internet of Things (CERP-IoT) has identified a large number of application domains [7]. CERP-IoT sees application of IoT concepts in societal, industrial and environmental domains. According to their delineation, it is important to note that IoT applications and services are intra- as well as inter domain, e.g. an IoT solution improves the direct industrial environment, but as a consequence also has a societal impact.

Some of the interesting applications as identified by CERP-IoT are Environment Monitoring; Intelligent Environments (smart energy metering); Retail, Logistics and Supply Chain Management; Healthcare (personal area networks, monitoring of parameters) and Independent Living (catering for wellness, mobility and monitoring of an ageing population).

Perusing the application of IoT concepts as described above, it is clear that IoT has a high potential for impact in a large variety of domains. Similar to the initial engineers that developed DARPANet, the precursor to the Internet, who would not have planned applications such as social networking, not all possible IoT concepts and applications have been identified and it is expected that many new services and applications will be created as IoT is standardised and becomes a mature technology. The application of IoT in our daily lives is not without its challenges. Quite a few barriers need to be addressed before the full potential of IoT will be realised. Section 4 elaborates on some of these challenges.

4. Challenges

For IoT to achieve its vision, a number of challenges need to be overcome. These challenges range from applications, contextual (including policy) through to technical.

A world where all things are connected, communicating information and data about its local environment (and also about humans in a direct or indirect fashion) to a central location opens the door for "Big Brother". The individual's right to privacy needs to be protected. The individual's trust in the IoT should be fundamental and complete, knowing that information will not impact negatively on any individual or society. Principles of informed consent, data confidentiality and security must be safeguarded. Trust raises an interesting technological challenge: how and when can sensors in an environment be controlled? Governance in the IoT is crucial. Policy makers and public authorities have a responsibility to ensure that IoT will create impact, from economic growth to addressing societal problems.

Standardisation of technologies is important, as it will lead to better interoperability, thus lowering the entry barriers. Currently, many manufacturers are creating vertical solutions (a slice in the IoT application space), using their own technologies and inaccessible services. Standards need to be created to change this "Intranet of Things" into the more complete "Internet of Things". As yet, no holistic approach to IoT has been proposed; coherent concepts that unify IoT do not exist, leading to silo solutions.

One significant aspect in IoT is the large number of things being connected to the Internet, each one providing data. Finding ways to reliably store and interpret the masses of data through scalable applications remain a major technological challenge.

From the narrative in this section, we draw a number of key challenge areas:

a) Privacy, Identity Management, Security and Access control. IoT presents significant challenges in terms of who can see what with which credentials (recalling that the entities are no longer only people, but might be any form of IoT "appliance". The recent Stuxnet worm presents an excellent example of a malicious "software actor" that has the potential to effect major physical changes in industrial processes. How does one guard against this type phenomenon in the IoT world?

b) Standardisation and Interoperability: How do we make sure that the hugely diverse technology platform continues to act in a platform manner i.e. ensuring that we do not have to re-invent the wheel every time we develop a new application or, indeed, a sensor that needs to plug into the IoT.

c) Data deluge: The IoT shares many of the key challenges similar to large scale data initiatives as identified in the e-Infrastructure domain. How do we deal with the data stream of billions of "actors"? How do we ensure the data remains usable for future generations?

5. Current, Large(r) Scale Activities in the IoT Space

IoT is fast becoming an important priority, not only for academia, but also industry and governments.

Multinationals have recognised the commercial potential of a IoT. Examples include:

- IBM's *Smarter Planet* initiative aims to add intelligence to systems and processes that interface with the world [8]. To utilise the data collected from things such as clothes, appliances, the natural environment, road infrastructure, and the electrical grid to make a difference in energy, banking, healthcare and cities.

- Microsoft's *Eye-On-Earth* platform creates and environment where water and air quality of a large number of European countries can be viewed, thus aiding in climate change research [9].

- HP is researching IoT based infrastructure in their *Central Nervous System for the Earth* initiative [10]. Their aim is to populate the planet with billions of small sensors aimed at detecting vibrations and motion.

Similarly, IoT has been placed on the research agendas of countries and regions:

- The European Commission has recognised the importance of addressing the challenges in IoT. Their *Cluster of European Research Projects on the Internet of Things* (CERP-IoT) [11] comprises of many (in excess of 30) research activities, platforms and networks focused on the "Internet connected and inter-connected world of objects".

- The Chinese Government is investing in IoT and sees it as a vehicle for economic growth [12].

Internationally, quite a number of research groups at tertiary and other academic institutions have been constituted to address challenges in IoT:

- The *MIT Auto-ID Laboratory* is focusing on RFID and wireless sensor networks to drive IoT and is recognised as being one of the early adopters of IoT [13].

- In Europe, large scale involvement is driven through the CERP-IoT.

- In South Africa, the *Internet of Things Engineering Group* at the CSIR Meraka Institute, is focused on creating a framework allowing for channel agnostic communication between things and applications in IoT [14]. Figure 2 depicts current activities in the group. An event driven framework, able to communicate through a variety of protocols with devices and sensors has been created. Applications which demonstrate IoT concepts while utilising the framework have been developed. They include an application to serve as an indigenous knowledge repository (Urban Memory) where physical objects are linked to cultural events of significance which have been captured and are living in cyberspace.

6. Relevance of IoT to Developing World and Potential for Co-operation

During the nineties and early years of the twenty-first century one would have been hard pressed to find any forum dealing with Internet issues that did not have a part of the discussion devoted to the vast inequities in access to the Internet experienced across the world. Indeed, even today, this discussion continues. Fortunately we are seeing progress being made. The lack of infrastructure did not stifle the innovation potential to be unlocked from the Internet evolution. Examples of this include the development of mobile banking solutions emanating from regions such as East Africa and its evolution into "blended" banking solutions that marry the mobile and Internet world as communication infrastructure rapidly improves in the region. In a similar fashion, from a developing world perspective, cannot let the new evolution from the Internet of today towards the IoT pass by.

We mentioned earlier that applications would be one of the key drivers of innovation in the IoT. By focusing on the potential that IoT has, not only in many first-world applications such as inter-vehicle communication, but on applications that have a real impact in the region, Africa has the potential to tap into the rich space provided by the IoT. By crafting smart partnerships with technology and service providers, as well as leveraging initiatives such as the EU Framework Programme and bilateral cooperation programmes, we will
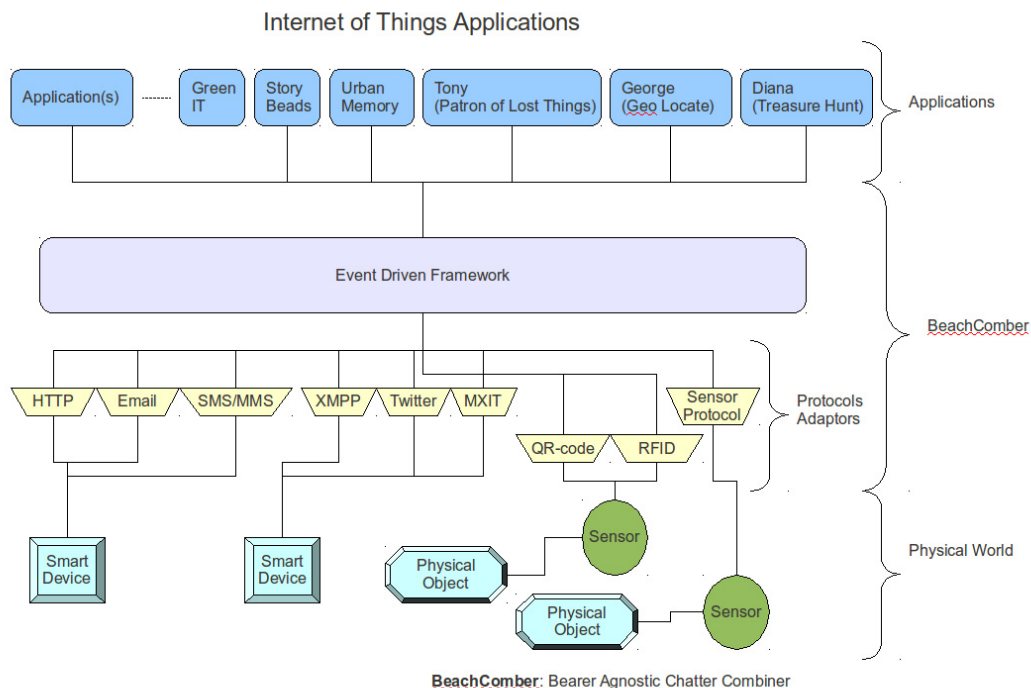

Figure 2: Applications and framework being developed in Meraka's Internet of Things Engineering Group

ensure that we do not expend energy on re-inventing wheels, but rather in creating the solutions that have real impact in our space. Innovation in the technology space is certainly not excluded and may be led by the need for novel applications and conditions specific to our continent. Embracing the IoT as a real and imminent opportunity should ensure that we capitalise on the innovation potential of IoT to have a positive impact on our society.

A number of applications were listed in Section 3 that would find a home in many situations on the continent. In addition to these, a number of relevant application areas might present unique opportunities and are listed below (non-exhaustively):

a) Food security: The ability to measure and respond appropriately to issues affecting food security, such as droughts (even localised), pests, and lack of knowledge of proper farming methods in different circumstances may have a significant implication for food security. Interventions may take the form of large scale fusion of remotely sensed information mixed in with in-situ, cost effective sensors and the necessary information and communication infrastructures to alert a small scale farmer through, for instance, a mobile phone text message that certain portions of his land need particular attention. On the small scale, it may include "smart packaging" of seeds, fertiliser and pest control mechanisms that respond to specific local conditions and indicate actions by, for instance changing colour. Monitoring on a continuous basis the fertilisers and pesticides used on export-based products enables a small scale farmer to have their produce "certified" for an export market in a cost effective manner.

b) Natural disasters: Through the combination of sensors and simulation, many a life could be spared if, for instance, the occurrence of land-slides may be predicted in time for villages to take appropriate actions. Often the remotely sensed data that may be used together with simulation tools (including PC based tools right up to supercomputer applications) do not provide the real-time information and resolution necessary to take appropriate action in time. Flash floods present another example where in-situ monitoring is very important.

c) Water: With the importance of water for both human and economic development in the region and its scarcity in many places, networks of sensors, tied together with the relevant simulation activities might not only monitor long term water interventions such as catchment area management, but may even be used to alert users of a stream, for instance, if an upstream event, such as the accidental release of sewage into the stream, might have dangerous implications.

The list can easily be extended to cover areas such as health, the environment, the state of road infrastructures and other areas of importance to the emerging and developing economies of the world.

7. Conclusion

This paper introduces the reader to the emerging Internet of Things phenomenon. It describes the progression of Internet utilisation, from computers, to people and now to things, allowing for many new applications and services.

Various application areas are identified and presented, providing guidance for future utilisation of IoT concepts. Successful update of IoT is not without challenges. These challenges span business, policy and technical. The paper provides an overview of the challenges and highlights the fact that trust and privacy are likely to be the major hurdles in IoT uptake.

Internationally, different activities drive the uptake of IoT. The European Commission, through its CERP-IoT leads research and application of IoT. Multinationals are very active in driving their research to ensure the uptake of IoT. In Africa, we need to leverage the potential presented by IoT. To this effect, the Internet of Things Engineering Group has

been created to position South Africa in IoT and to ensure that South Africa will become a contributor to IoT and not a net importer of technology. In addition we need to form smart partnerships both within and beyond the continent to achieve this positive potential presented by IoT.

Precise predictions of the future of IoT and, indeed, the future that IoT enables are very difficult at best. Compare this with the impact the specification of the TCP/IP stack had on diverse and unpredicted services such as social networking. What would really happen when your fridge "talks" to your car (or your neighbour's car?) We stand at the cusp of an exciting future. Foresighting is difficult and subject to many different factors. However, looking into the crystal ball the technology and their advances (as described in Section 2) will continue to drive IoT's uptake with commensurate impacts in our environment In the short term, more things will become connected, with more sophisticated services coming online to analyze data and to act accordingly. In the medium to long term connected things and the subsequent services will be ubiquitous. More of an unknown is society's acceptance of IoT and, indeed, the impact of IoT on society. In the short term, society might remain wary of IoT as fundamentals such as privacy, trust and governance are being dealt with, calling for urgent action in not only technology, but also governance standardisation processes. This should contribute to ensuring that in the medium to long term these fundamentals will be in place, leading to enhanced societal acceptance of IoT.

IoT has potential to drive integrated solutions that can make a difference. It is still early in the research cycle, but the potential difference it can make is clear for all to see. Challenges in the technology, context and application areas provide ample opportunities for research and development and partnerships across domains and geographies to capitalise on the promise of IoT while sidestepping the potential pitfalls that the IoT might present in the future. It is important that IoT becomes part of the current and future strategic conversation, whether on research institution level or international cooperation discussions to ensure that we reap the benefits presented by IoT.

References

[1]   A. Gavras, A. Karila, S. Fdida, M. May, and M. Potts, "Future internet research and experimentation," *ACM SIGCOMM Computer Communication Review*, vol. 37, 2007.
[2]   K. Bonsor and C. Keener, "HowStuffWorks "How RFID Works"" 2010, http://electronics.howstuffworks.com/gadgets/high-tech-gadgets/rfid.htm.
[3]   T. O Brien, "In a Nutshell: What Are QR Codes?," 2010, http://www.switched.com/2010/06/21/in-a-nutshell-what-are-qr-codes/.
[4]   International Telecommunications Union, *ITU Internet Reports 2005: The Internet of Things. Executive Summary*, Geneva: ITU, 2005.
[5]   E. Fleisch, *Auto-ID Labs: What is the Internet of Things? - An Economic Perspective*, 2010.
[6]   M. Chui, M. Löffler, and R. Roberts, "The Internet of Things," *Mkcinsey Quaterly*, 2010, http://www.mckinseyquarterly.com/High_Tech/Hardware/The_Internet_of_Things_2538?gp=1.
[7]   H. Sundmaeker, P. Guillemin, P. Friess, and S. Woelffle, *Vision and Challenges for Realising the Internet of Things*, European Commission, 2010.
[8]   "IBM - Smarter Planet - United States," Nov. 2010, http://www.ibm.com/smarterplanet/us/en/.
[9]   Microsoft, "Eye on Earth," 2010, http://www.eyeonearth.eu/home.aspx.
[10]   HP, "Central Nervous System for the Earth (CeNSE)," 2010, http://www.hpl.hp.com/research/intelligent_infrastructure/.
[11]   Seventh Framework Programme, "European Research Cluster on the Internet of Things," 2010, http://www.internet-of-things-research.eu/.
[12]   R. Callari, "China   s 'Internet Of Things' To Become Semantic Web Superpower?," 2010, http://inventorspot.com/articles/chinas_internet_things_become_semantic_web_superpower.
[13]   MIT, "MIT Auto-ID Laboratory," 2010, http://autoid.mit.edu/cs/.
[14]   L. Coetzee, "Internet of Things Engineering Group," 2011, http://ioteg.meraka.csir.co.za.