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Positioning Internet of Things Application, and Associated Human Behavioural Changes in a Developing Context

Louis COETZEE[1], Johan EKSTEEN[2]
[1]*CSIR Meraka Institute, CSIR, P.O. Box 395, Pretoria, 0001, South Africa*
Tel: +27 (012) 8413036, Fax: +27 (012) 841 4570, Email: louis.coetzee@csir.co.za
[2]*Microsoft South Africa and West, East, Central Africa & The Indian Ocean Islands, P.O. Box 5817, Rivonia, 2128, South Africa*
Tel: +27 (082) 4670854, Fax: +27 (011) 361 7004, Email: jeksteen@microsoft.com

Abstract: Internet of Things (IoT) is an evolutionary development with the potential to greatly influence and impact society, economy and environment. Through IoT, all devices become Internet connected. These connected devices are controlled by large-scale Internet services (which make their decisions based on the data retrieved from the devices). The application of IoT is possible in many different domains, but impact through IoT is quite often dependent on the human changing his behaviour. In a developing context, IoT holds great potential. However, because of the context, prudent choices in selection of IoT application are required as both human attitude and the resource constraints heavily impact on the potential success of IoT. Through the presentation of various IoT application use-cases in a developing context and their relative position in a framework that utilises behavioural change barriers, a mechanism is presented to more effectively identify appropriate IoT application. The presented framework aids application developers, funders and government agencies to make more effective first choices in establishing IoT.

Keywords: Internet of Things; Behavioural change; Sustainable development; Framework; Change barriers

1. Introduction

The Internet landscape is continuously changing. The Internet started with connected servers that hosted and exchanged information. This was followed by an Internet that connected people (the Internet of People) who created and exchanged information. A new phase is on the horizon, that of the Internet of Things (IoT) where common appliances and devices that create and exchange information are connected to the Internet [1,2]. Figure 1 depicts these Internet phases.

IoT is seen as a disruptive new phase of Internet evolution that will lead to the creation of new innovative solutions and applications that will have an impact on society, economy and the environment [3]. IoT's primary focus is machine-to-machine (M2M) interaction – machine inputs gathered from the environment and machine outputs acting on the environment [4].

In this envisioned IoT, the interactions between 'things' are seen as the main instigators for improving and impacting on the environment, economy and society. However, humans remain an essential part of society and have decision-making ability. According to Fleish [5], such behavioural change can be induced through IoT's "mind changing feedback". Figure 2 shows levels of IoT value add as defined by Fleish. These levels increase in complexity and interaction with humans, ending with the last level "mind changing feedback". How IoT impacts on humans and influence the decisions they make, remains an important element to investigate. Linked to this is the question of impact associated with inducing behavioural change; where can the most benefit to society be gained through IoT when solutions require and are dependent on behavioural change?

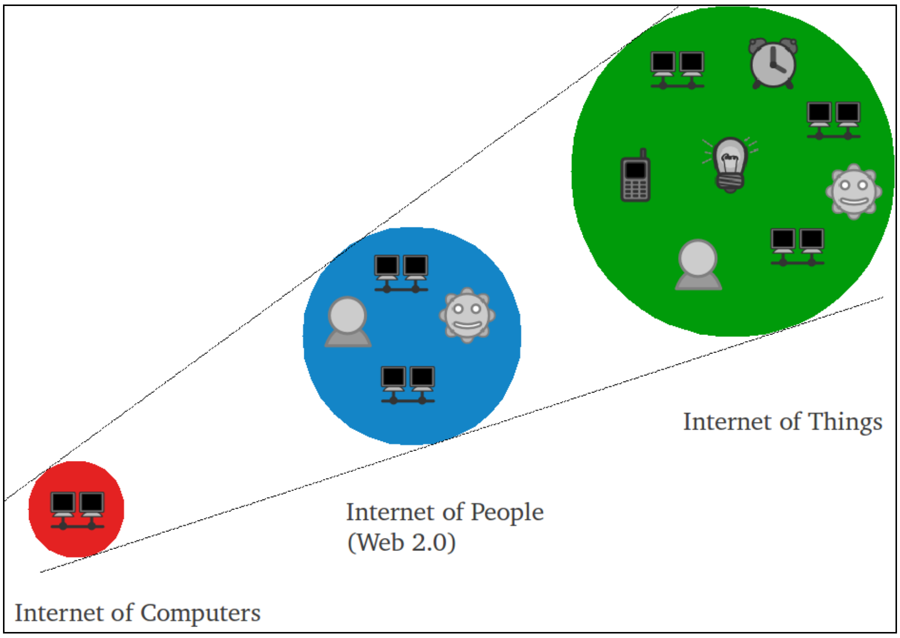

Figure 1 Internet Evolution

This paper presents IoT application use-cases for a developing context that are dependent on changed human behaviour. Earlier work by Coetzee and Eksteen [6] has highlighted the importance and potential value of IoT in sustainable development, but did not address mechanisms of contextualising these applications. This paper presents a framework to contextualise required behavioural change for IoT applications as it applies to a developing world context. Through the framework, areas of perceived higher importance (with larger potential positive impact) can be identified and ranked against the perceived barriers of the required change in human behaviour. Such a framework could aid in decision-making when considering IoT and related applications in the developmental context.

The developmental context implies resource constraints and challenges in adapting and execution in addition to normal funding and technology challenges. To establish mechanisms to solve challenges, not only depends on the technological but also on the wider context. Quite often, initial choices of potential solutions do not take cognisance of the context. No established mechanism prior to the presented framework is known that could aid IoT related decision-making. Through the presented framework (demonstrated through various applicable use-cases) application developers, funders and government agencies can make better initial choices that could impact positively on both the environment as well as the return on investment.

The next section (Section 2) introduces IoT. Section 3 presents IoT application use-cases in a developing context and the associated analysis of how these use-cases could lead to, and are dependent on, changed human behaviour. Section 4 highlights some of the challenges that affect the potential of these IoT applications. Section 5 presents the contextual behavioural change framework with examples. Section 6 concludes.

2. Introducing IoT

IoT extends the Internet into the physical world. Through the integration of the physical world into cyberspace, opportunities are created for new applications and services that impact on people and the environment [7]. While the current perceptions might be that IoT might have the biggest impact in the developed world, the opportunity for developmental activities is considerable and needs urgent attention.

In the IoT vision, all devices ('things') are connected to the Internet, each one with a unique Internet Protocol (IP) address or unique and persistant identity mechanism and potentially with the ability to provide (or consume) unique services. Things 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 envisaged 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's creation and uptake are driven by a number of technological trends. These trends include:

- Device processing and storage power are increasing;
- Technology devices are becoming smaller while more sensors and actuators are being integrated;
- Connectivity is improving;
- Compliance and adherence to Internet related standards (e.g. IPv6) are facilitating the establishment of IoT. Adherence to standards provide for improved connection of things, thereby improving the ability to receive sensed information from the thing and induce an action through the thing in the environment.

Through the interconnection of things, masses of data are generated, stored and processed.

Things include a large variety of physical elements:

- Personal objects we carry (smart phones, tables, digital cameras, etc.);
- Elements and appliances (fridge, washing machine, hot water boiler) in our environments (home, vehicle, work, urban or other);
- Objects fitted with tags (e.g. RFID [8], NFC [9] or QR [10]) that are connected to the Internet (and has a cyber-representation) through a gateway device;
- Objects fitted with tiny computers and a variety of sensors (e.g. the Picarro sensor range [11]).

These things provide accurate information with regard to status, identity and location to cloud based services allowing for smarter decision making. These high-level decisions are fed back to things (or humans) to allow them to act and influence the environment.

According to Vermesan et al. [3], the creation of smart environments/spaces is a major objective of IoT and has application in various domains:

"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..."

In a developing context, many challenges associated with the various domains mentioned above exist. IoT can be integrated to provide effective solutions, but quite often the perceived impact is still dependent on the ease and context of the required change in human behaviour.

Fleisch [5] has identified seven levels of IoT value add. These are depicted in Figure 2. All these levels are important in adding value to society through IoT. Of significance in this paper's context is the last level: "Mind changing feedback"; how can IoT be used to the benefit of society in a developing context by providing sufficient information and empowerment to the human?

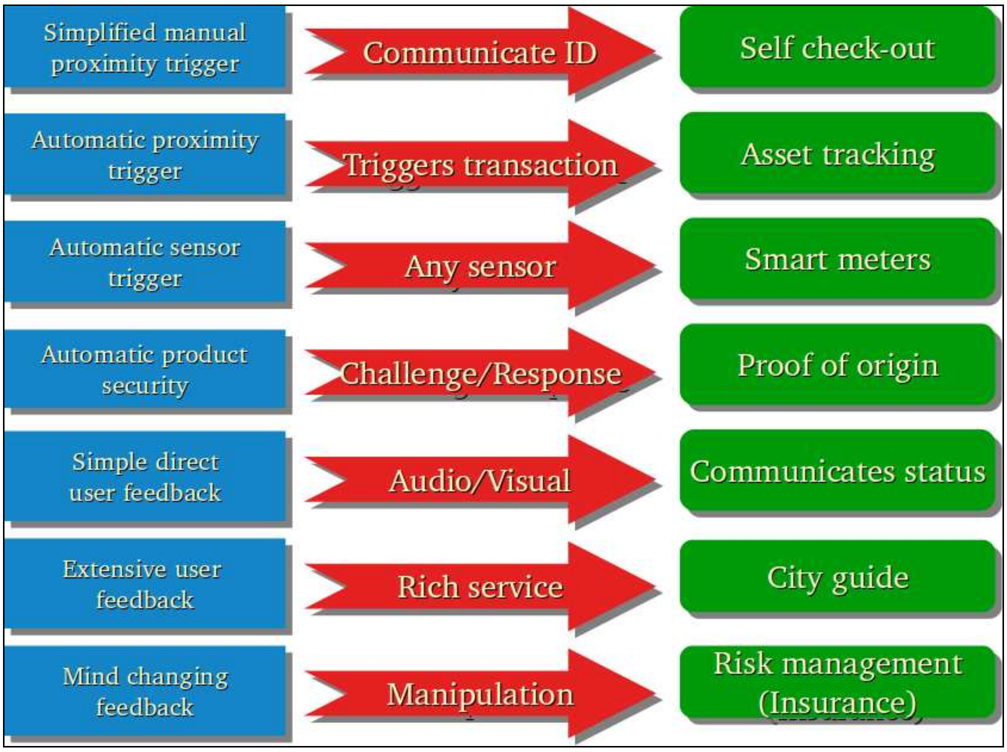

Figure 2 IoT application levels according to Fleisch [5]

In the future application of IoT, the influence on the human and how his behaviour can affect the probability of the solution for success are important. The following section presents IoT application use-cases and analyses how the combination of IoT and changes in human behaviour can potentially affect society.

3. Use-cases

IoT-enabled environments are becoming more prominent in modern day society. In an IoT-enabled environment, various services and applications can be implemented that have impact on society, economy and the environment. Examples of IoT use-cases are presented in [12]. Very often, these services are only machine-to-machine, and exclude the human decision making dimension or excludes opportunity for the human to learn from the context, to make more informed future choices. Additionally, through IoT, a person can be provided with more information within a specific context that influences the decisions he makes, which is closely linked to the potential impact of the IoT application. The following application use-cases of IoT highlight the value of providing essential feedback through which choices could be influenced.

3.1 The case for carbon

Smart things with sensors located in the natural environment are becoming common place. One such smart thing is known as a Picarro sensor [11]. It has a variety of sensors to measure carbon flux and communicate those readings via the Internet to a hosted service.

Measurement of carbon flux in itself will not result in changes in human behaviour and subsequently will not help to address the carbon challenge faced in the natural environment. Even having access to the information is unlikely to change behaviour or address the carbon challenge.

However, through the IoT paradigm where all things are connected, scenarios can be created where the carbon emission can be influenced through other secondary actions. More effective utilisation of public transport can lead to a lowering of carbon emissions resulting from normal day-to-day commuting, to and from work. As all devices and services are integrated in IoT, including those services that control the fees charged at toll gates, it would be a very logical intervention to increase the toll for normal commuters, while reducing the travel fee on all public transport (e.g. train, bus, taxi) for that day. The increase in toll and the decrease in public transport fees for the day are communicated to the commuter via smart devices on his person.

In this scenario, the human has the ability to make decisions, based on information available to him and the changes in context because of IoT actions. It is argued that by empowering the human with additional information and providing choices (e.g. use own transport and pay more, or use public transport and pay less) he will most likely make the choice best suited to him which can have natural secondary benefits (e.g. the lowering of pollution). Through IoT, the changes in behaviour can be instigated, but the success is also dependent on the acceptance and willingness of the person to change his normal behaviour.

3.2 The case for insurance

An increasing number of modern day vehicles have an array of sensors measuring various dimensions of the vehicle’s performance. These sensors include accelerometers (these detect magnitude and direction of the acceleration). In the very near future, all vehicles could become an IoT thing with always-on connectivity.

In the car rental industry, short-term insurance of the vehicle being rented is an important factor to consider. Many people take additional insurance when renting a vehicle. With an IoT-enabled vehicle with the required sensors on-board, a driver's driving style can very quickly be determined (e.g. if very hard acceleration is followed by very hard braking, or tight cornering, it can be deduced that the driver has a higher risk profile). A scenario is possible where the sensed information is communicated to the car rental agency.

The agency can make use of a model to determine if a driver is more likely to have an accident based on his driving style. The insurance rates for the vehicle can automatically be adjusted, which will protect the car rental agency. However, the driver can be empowered and allowed to change his driving behaviour through distinct and accurate communication from the IoT service to the vehicle (e.g. the vehicle dashboard displaying a message that the driving style is high risk and subject to higher insurance rates). The driver can then choose to adapt his style and avoid automatic increases in the insurance levy. The ultimate success of the IoT application is again dependent on the driver’s willingness to change his behaviour.

3.3 The case for energy

Much has recently been made of Demand Side Management (DSM) as a mechanism to save on costs associated with electricity consumption within urban environments. DSM can be defined as the cooperative action by the consumer and the power utility to modify the customer load. Through DSM, benefits to the consumer, the utility and society can be attained.

Currently (as is the case in South Africa) the power utility communicates national load on the grid via television and radio media channels. It is highly debatable if this mechanism is effective at all, as most households do not feel that the load restriction applies to them. Finer grain information that is more applicable to a specific household is required.

IoT is seen as an enabler for DSM. Through the introduction of Internet-connected appliances that have the ability to sense and communicate their own energy consumption, a consumer will be able to gain deeper insight into those appliances that are responsible for the majority of the consumption. In a typical DSM scenario the power utility reserves the right to switch off appliances remotely (e.g. the hot water boiler) when over-load requires such drastic measures. This ‘remote’ intervention will likely be met with significant resistance in households.

A better alternative is to empower the individual in the household to make better choices of when to switch an appliance off or on. Through the personalised and targeted communication of national, provincial, and suburban context to a specific individual, that person has the choice to act in a more responsible and empowered way. Energy saving is a result of the proactive decisions made at an individual level.

3.4 The case for transport

Intelligent Transportation Systems (ITS) have been on the technological radar as the ultimate solution to ease traffic congestion and reduce carbon pollution. ITS is a key component of smart cities. The effective deployment of sustainable ITS solutions are now becoming a reality with IoT-based technologies. In an IoT-enabled environment where public transport (e.g. buses), toll road booths, occupied or empty parking lot spaces and their locations, traffic lights, and traffic density on a route are associated with IoT things and services, opportunity exists to control traffic flow automatically to the benefit of the environment. In a machine-to-machine context, automated services can impact on the commuter in drastic ways (e.g. automated closure of a specific route or forced rerouting when the traffic density is regarded as too high).

Better cooperative solutions exist where the commuter can be empowered through access to up-to-date information. Once the commuter has all the information at his disposal he can make better choices based on his own context. As an example, knowing that parking is at a premium at his destination, choosing to park close to public transport from where he can commute (thus avoiding the system enforcing context unaware rules) can lead to a lowering of traffic congestion and driver frustration.

3.5 The case for agriculture

IoT, through its incorporation of sensors embedded in an agricultural environment, has the potential for large scale impact. IoT can be applied in use-cases ranging from early warning systems for natural disasters (e.g. flood alerts) to measuring the moisture level of various crops. In the case of alerting the farmer in time that his crops are in urgent need of water, the farmer can take appropriate decisions to save the crop. Through the feedback of appropriate information to the farmer, a secondary benefit is introduced: the farmer will learn more about his soil and which plants are more appropriate. This will allow him to make better agricultural choices in the future.

3.6 The case for shopping

The retail environment holds great promise for IoT application. With RFID or NFC tags embedded in the product, a large number of value-added services can be created. These services can range from sounding an alarm if an item is removed from the shop, to those where specific and appropriate information is provided to the shopper that can influence his decision to purchase said item.

In all of the above use-cases, IoT will improve the effectiveness and impact on the economy, environment and society. To make the effective application of the described use-cases a reality a number of factors are important. In a developing context, there are trade-offs in determining the more effective IoT applications with impact, measured against the required change in human behaviour. This use-case in particular, points to the type of advances that might be considered within a developmental scenario with the additional benefits of capacity building unrelated to the technology itself.

4. Challenges

The scenarios described above illustrate the benefits to society, economy, and the environment if a person is empowered and willing to make decisions based on information he receives from the IoT. The value and potential are undeniable.

However, there is a trade off. Sensed information within a specific context is now directly linked to a specific person. That person has lost his anonymity and could be subject to scrutiny and sanction by a larger body (e.g. a government). This conjures up visions of an Orwellian society with Big-Brother watching and making decisions [13]. Does the individual entrust so much of his personal information to the whims of a government, an insurance broker, a shopping chain? For how long will an event of forced insurance rates increases (as per the rental example above) be on record and impact on other insurance transactions he might undertake? How comfortable is he knowing that his shopping habits are now recorded indefinitely?

Another dimension exists. The algorithms that make use of the sensed data are created by mathematicians and engineers. In essence, the algorithms are based on a model of reality, not reality itself. Thus, our choices might now be influenced based on the effectiveness and interpretation of the model and algorithm, which in itself will introduce a resistance to implementing a specific choice.

The following section describes a framework through which the various IoT applications can be contrasted.

5. Impact vs. Behavioural Change Barrier Framework

Figure 3 below depicts a framework with which the above IoT application use-cases can be contrasted. In a developing context, having a mechanism available to identify the most appropriate and more likely to succeed application has value. By identifying the potential for positive impact, weighted against the perceived barriers to behavioural change, a view of more likely, immediate and longer term applications can be attained.

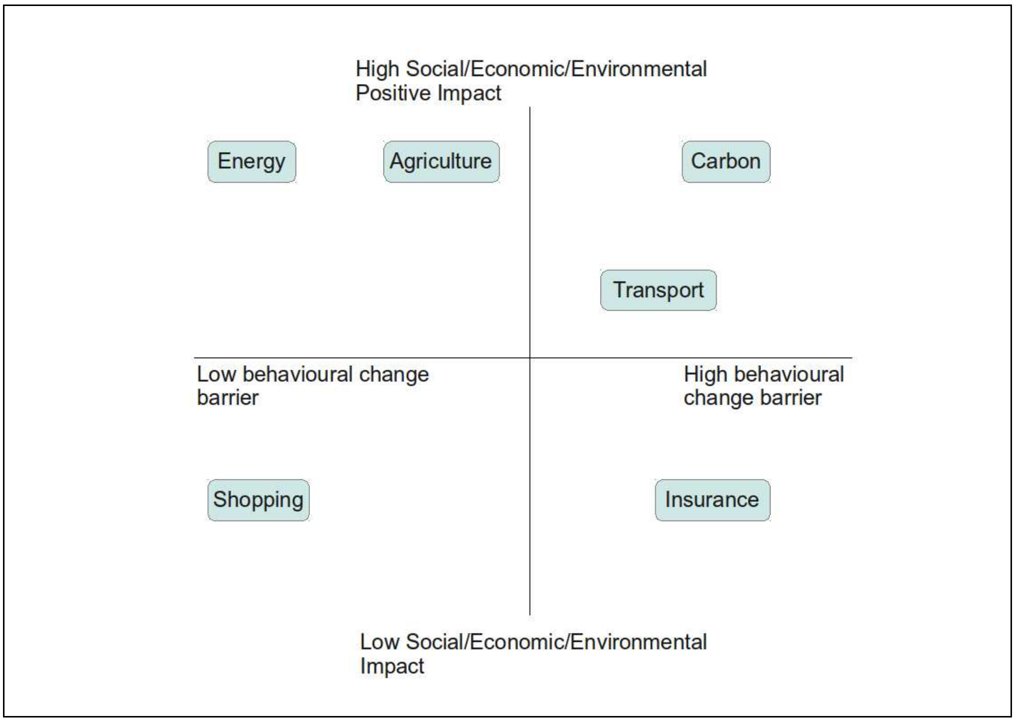

Figure 3 Impact vs. Behavioural Change Barrier

From Figure 3 it is clear that the application of IoT in a retail environment will have relatively low impact, and that the required change in human behaviour will be quite easy to obtain. Similarly, it can be seen that in order to induce a more carbon-neutral and efficient transport environment, (with high impact), the required behavioural change in society will be significant. The application of IoT in the insurance domain will have relatively low impact, but will require significant change in behaviour. Application of IoT in the domains of energy (e.g. DSM) and agriculture will have significant impact on society and will not require significant or challenging changes in people's behaviour to implement.

Based on the above framework, IoT applications that require easy-to-achieve behavioural change, but which have the potential for high impact, are most desirable. In a developing context where resources are limited and challenges exist in inducing behavioural change; this quadrant of application will be preferred.

The framework is aimed at reducing the initial complexity in making choices for the application of IoT. It is currently not considering issues such as the agent of change (i.e. government vs. individual vs. donor agencies.) These extra factors may be considered in the expansion of the framework, but the lack thereof does not negatively impact the value of the current framework.

6. Conclusion

IoT has the potential to impact society, economy and the environment. However, the success of the IoT application is linked to a large number of complex elements, of which the technological solution is only one dimension. Through the provision of sufficient information, IoT can result in changes in human behaviour, which in return can be linked to the successful application of IoT. However, some changes in human behaviour are more challenging, while others are easier to overcome. These required changes in the choices people make are largely dependent on the application domain.

In a first-world context, which is not limited by developing world factors such as scarce resources, IoT can be introduced without cognisance of the context. However, in a developing world, the context is most important. IoT application should be targeted at domains with the highest positive impact and preferably with the lowest perceived barrier to human behavioural change.

This paper described various IoT application use-cases and through the use of an 'Impact vs. Behavioural Change Barrier' framework contrasts and positions these applications. By considering applications from a developmental perspective in the context of the framework, more appropriate IoT applications can be identified.

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