The Internet of Things

Research Discussions & Directions

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ABSTRACT

As the Internet increasingly becomes connected to physical items beyond the computer and mobile devices, the notion of an 'Internet of Things' continues to gain prominence as a technology with unbridled, transformative potential. Due to the largely unexplored adoption of the Internet of Things, much of the information systems research surrounding the topic is prescriptive and points to how the Internet of Things should be used. Contrastingly, another main stream of information systems research in this area is derived from the socio-technical perspective, exploring the relationship between the social and technical aspects of the system. This article will argue that, due to the developing social and technical nature of the Internet of Things, the socio-technical approach is more applicable to the study of this new technology. In order to analyse these issues, this paper will explore and critically evaluate the current theoretical landscape of literature on the Internet of Things.

Introduction

The idea of an 'Internet of Things' has attracted growing attention over a number of years. Touted as the next frontier in the development of the Internet, the Internet of Things (IoT) is evolving into homes and businesses alike. However, defining the exact premise of the IoT is problematic, as it is often misunderstood (Ashton, 2009: 1) and it has no single definition (Bassi, 2011: 102). Some view it as the 'third wave of information technology' (Zhu et al, 2010: 347) after the Internet and mobile communication. Others maintain the vision that it will function as a 'dynamic global network infrastructure' (Vermesan et al, 2011: 10). What remains consistent is the pronounced excitement it generates because of the potential innovation it may bring (Lacuesta et al, 2012: 1). As the Internet has grown into a multi-purpose network, the expectation is that the IoT will do the same as a network 'that interconnects ordinary physical objects with identifiable addresses so that it provides intelligent services' (Ma, 2011: 920).

The advancement of the IoT has significant potential, both as hardware and through the development of applications (Zhou, 2012). Consequently, research carried out by academics in this area is very important given the juncture of its development. Therefore, it is essential to understand how research is conducted within this area, especially with an appreciation of the assumptions and philosophical grounding that inform the approaches to research. Furthermore, such appreciation enables greater understanding of what certain approaches can reveal about how information systems research relates to current developments in the field.

This critical literature review will argue that research on the IoT is primarily driven by divergent technical-rational and socio-technical approaches. However, research on this topic area would benefit more from a socio-technical approach. Atzori et al (2010) argue that the Internet of Things represents a singular paradigm with 'many visions' (p. 2788). A socio-technical approach allows researchers to use multiple frames of analysis, whereas a technical-rational approach limits such potential. Firstly, the technical-rational approach to research will be analysed and critiqued, highlighting its potentials and limitations. Secondly, the socio-technical approach to research on the IoT will be critically evaluated. Thereafter, the essay will conclude, highlighting the main arguments within the paper.

Technical-Rational Approach

The technical-rational approach is one way in which researchers have framed their analysis of the Internet of Things. This is broadly referred to as a 'phased and structured approach to problem solving' (Bruijn and Herder, 2009: 901). Technical-rational reasoning assumes that information systems development is 'a controllable process to be engineered and managed' (McLeod and Doolin, 2012: 178). The rationale behind this approach is that 'form follows function' (Krippendorff, 2011: 411). Additionally, this approach can be further broken down into several different aspects.

Firstly, one aspect explores the 'factors affecting the adoption of Internet of Things' (Li et al, 2012: 206). For example, in a paper on the objectives and challenges for the Internet of Things, Ma (2011) proposes that further study and research is required to develop a greater understanding of what the IoT adoption would mean from multidimensional perspectives. The article discusses such perspectives including that of 'the user, the network provider and application developers' (p. 921). In this context, the technical-rational approach outlines a prescribed notion of how the IoT should develop to widen its use. Ma's paper is a discussion on the wider issues affecting IoT research from a technical-rational perspective, thus opening the floor to further analytical and problem-driven research. The driving purpose of this stream of research is to understand how the problems of adoption can be minimised through technical amendments.

Additionally, the technical-rational approach develops the notion of technical significance through a decidedly 'things-oriented' focus (Atzori et al, 2010: 2789). In particular, emphasis is placed on 'interoperability on a physical level' (Schumacher et al, 2011: 318). Atzori et al posit that a things-oriented approach is adopted because of the technical backgrounds and perspectives of researchers. Schumacher et al argue that the IoT is driven by a focus on 'technological developments' (2011: 317) and that without the physical infrastructure in place, the capacity of the IoT is hindered. However, from the things-oriented perspective of Patel et al. (2011) concern is given to how the physical elements of the IoT are designed and processed to work together. Gubbi et al. (2012) argue that smart objects are the most significant feature of a things-oriented approach. Primary attention is given to the technology, how it is created, and how it fits into the wider cohesiveness of the IoT. Here, the implications for IoT research are that it is the "thing" in the IoT that has utmost importance. However, by focusing on the "thing" alone, it is possible that other, important aspects of the IoT are neglected, such as its social impact within various contexts. Nonetheless, this research on the interoperability of the IoT is greatly important, especially within the realm of technical-rational research.

One of the main benefits of the technical-rational approach in IoT research is its focus on interoperability. Interoperability discourse represents an evolution in the discussion of a 'things-oriented' approach, from being merely about the objects itself, to how the objects exist within the wider environment. In Zhou (2012), the technical-rational approach towards the Internet of Things suggests that a lack of interoperability is preventing wide-scale IoT adoption. Interoperability is viewed as the 'central' issue pertaining to the fulfilment of the Internet Of Things (Bandyopandhyay and Sen, 2011: 50). Discourse on interoperability assumes that if the technology is in place, adoption will follow. However, even with interoperability widening the scope of IoT discussion, the technical-rational positivism still ignores the various other factors that affect the adoption of information systems. For instance, Zhou (2012) argues that the Internet of Things should be based on current Internet architecture, in order to foster standardisation. This differs from the holistic information systems perspective of Tan and Wang (2010) which include factors such as government policy and security issues as impacting adoption. These issues that are not strictly technical, but still affect IoT adoption.

The dynamic and interactive nature of the IoT highlights the limitations of the technical-rational approach. These limitations become apparent when the IoT is singularly aligned with a technical-rational understanding. For instance, Tan and Wang (2010) describe the IoT as having overlapping and intertwining elements, whilst Boos et al agree that the IoT represents 'constitutive entanglement' (2012: 16). This means that the structure of the IoT may have important technical elements but the complex ways in which it functions is due to a mixture of technical, social and cognitive factors. Using only a technical-rational approach limits the depth of research that would be enhanced by these other factors. As the IoT is a developing system, it processes are emergent, synergistic practices (McLeod and Doolin, 2012: 181) with little or no predilection for a technical-rational approach. Thus, approaching information systems research on this area requires a variety of perspectives because by its nature the IoT is system of plural, intelligent technologies (Uckelmann et al, 2011).

The very nature of objects relating to humans in a network of things demands that research has to explore more than the technical aspects of this area. However, this creates a level of uncertainty that technical-rational researchers may find irreconcilable because it is without a clear-cut direction and prescription. Baxter & Sommerville (2011) argue that without appropriate standardization of the Internet of Things, there is danger of different standards being created for various contexts, therefore creating a fragmented IoT. From a technical-rational standpoint, such an occurrence would be problematic, and research in this area tends to offer pre-emptive

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prescription for avoiding such a situation, rather than explore its wider impacts.

The lack of standardisation in the IoT means that within information systems research and the technical-rational approach in particular, a consensus has yet to be reached about the research direction of the Internet of Things (Zhou, 2012: 870). Additionally there is tension between the positivist epistemology of the technical-rational approach and the uncertainty that the Internet of Things represents. Primarily, this approach estimates how the technology will function and should function, based on previous observations. In circumstances of which a predictive projection can further illuminate the unknown aspects of a topic, this is useful. However, in the context of IoT research, there are limitations to this approach. For instance, Bruijn and Herder's (2009) paper discusses the difficulties associated with taking a technical-rational approach towards systems with a networked architecture. They argue that the positivist foundation of the technical-rational approach means that it is subject to the constraints of a bounded rationality. Similarly, in Nerur and Balijepally's (2007) analysis of traditional versus emergent design, they argue that this framework is more suitable for predictable contexts. In the case of the IoT, information systems research using this approach for analysis may produce unclear results because the method of analysis is incompatible, especially in regards to sufficiently addressing the issues of uncertainty associated with the IoT. Given the potential directions of research in this topic area, such an approach may at times lack depth because it is not exploratory enough, and is strongly based on what is already known, rather than what is yet to be uncovered.

Socio-Technical Approach

Alternatively, the socio-technical approach to research of the Internet of Things is advantageous in its recognition of the varied social implications of the technology. The socio-technical approach is described as a 'complex interaction between humans, machines and the environmental aspects of the work system' (Baxter and Sommerville, 2011: 5). The socio-technical approach merges the technical with social and cognitive factors within the system's environment. In his chapter, de Almeida Amazonas argues, the social, user-centric aspect needs to be balanced with the environmental context of the IoT (2011: 114), and a socio-technical approach offers insight into both. As the IoT combines 'digital information with real-world physical items' (Kranz et al, 2010: 2) it is a hybrid network of items with both technical and social meaning. Both the technical and social supplant one another's impact, so research takes this interrelationship into consideration. Information systems research using the socio-technical approach to IoT research takes two main forms.

Firstly, the socio-technical approach is exemplified through the adoption of actor-network theory (ANT). Theoretically, an actor-network theory (ANT) perspective aligns with Internet of Things, unlike the technical-rational approach. Actor-network theory provides a framework through which heterogeneous actors' interactions are understood in the context of their environment (Tinati et al, 2011: 1). Hemerly studies the advent of the Internet of Things through actor-network theory analysis, arguing that analysis from this viewpoint is useful for understanding 'the benefits of socialized objects' (2010: 9). Furthermore, Spiekermann successfully follow in this tradition, arguing that there are roles for computers and objects as social actors. She argues that there is an 'expectation' for objects in the IoT to act like humans (2011: 29). Knutsen et al (2011) argues this is due to ANT's acceptance of humans and non-humans as actors and things within the system. In the socio-technical approach, the things-oriented aspect is adapted to include human and non-human actors as things within the wider network (Knutsen et al 2011: 198). Through ANT, the IoT is understood as 'human, cultural and interactional' (p. 203). This perspective informs information systems research by using multi-layered concepts of understanding. The advantage of the socio-technical approach in this case is that the research is able to embrace a multidisciplinary grounding (Goldkuhl and Agerfalk, 2004: 4) which is suitably associated with both the technical and the social aspects of the IoT. As Avgerou and McGrath state (2007: 297), interpretative flexibility supports the view of the technical and social aspects as 'mutually constitutive.' Such interpretation enables analysis of technical aspects in relation to its social impact, which is fitting for the IoT.

In addition, the interpretative qualities of the socio-technical approach align with the research's current process of discovery within an uncertain context (Geels, 2010: 497). The socio-technical approach to researching the Internet of Things embraces the complex uncertainty of the IoT, and transforms it into an inductive process of discovery. For instance, Boos et al (2012) break down their research into sections of analysis for greater clarity. Their article demonstrates that the information systems research of the IoT requires comparative analysis of the familiar alongside the unfamiliar to gain deeper understanding. In the context of the Internet of Things, information systems research needs to be 'reconceptualised' as merging 'different layers/different domains' (Knutsen et al, 2011: 203). Through this method of comparison, the challenges of the IoT are made clearer and more understandable.

Another socio-technical approach to information systems research is the organisational perspective. This approach to the study of the IoT focuses on business processes (Schumacher et al, 2011: 318). In Li et al (2012) the research is based upon the notion of organisational capability, which is how firms strategically choose the best ways to create value within their particular social and organisational context. In this type of research, the human actor within an organisation needs to know how their actions are monitored, how they contribute, the capacity in which they are able to act, predict how their actions will impact upon operation. These user needs are mediated through the use of technology. The adoption of the socio-technical approach conveys the ways in which individuals also contribute to the understanding and operation of how a system functions synergistically between the technical and social aspects (Boos et al, 2012).

Furthermore, the organisational approach suggests that the IoT has transformative and administrative potential in the form of altering 'business-engineering' (Boos et al, 2012: 7) dynamics. Through the socio-technical approach, the organisation perspective delves into the implications of technology within an organisation. For example, the IoT has potential to constrain human agency through its ability to automate organisational processes. The new organisational processes diminish human agency, and highlight the prevalence of the technology's ability to communicate without input of humans (Boos et al, 2012). For instance, numerous case studies have demonstrated the capacity for the IoT's organisationally automated role in logistics and supply chain operations (Schumacher et al, 2011; He et al, 2010). The IoT is used as a 'service enabler' (Bassi, 2011: 106), but this positioning also has wider socio-technical effects. Even with the prevalence of machine-to-machine communication, the social aspect is still considered relevant (Wu et al, 2010: 485), whereas in the technical-rational approach, the focus would be directed towards how the machines were communicating to one another and the ways in which that communication resolves problems.

Through the socio-technical approach, the notion of uncertainty is reframed as a discovery process, in what Guo et al describe as 'opportunistic Internet of Things' (2012: 925). The concept of opportunistic IoT is that it is meant to explore the 'interaction between humans and IoT and discussion of the social side of IoT'. Information systems research in this regard is a process of discovery in which serendipitous occurrences reveal insight into the potential ways the IoT could be used by individuals from a social perspective. (Atzori et al, 2011). Furthermore, this is an inductive process which advocates for discovery through the process, as opposed to having a prescriptive outline or plan. This research approach is highly suitable because the trajectory of which the IoT will adopt is yet to be known. By researching in this manner, information systems researchers are uncovering the likely and unlikely ways in which the IoT will be adopted, especially from a user-centric position. Additionally, because of the adoption of this user-centric position, the research is able to address the wider implications of users as actors within the wider network of the Internet of Things.

Conclusion

In closing, this critical literature review has analysed both technical-rational and socio-technical approaches to IoT research. Although both approaches have varying merits, the socio-technical approach has wider applicability to the research and study of the Internet of Things.

The technical-rational approach is one way in which the IoT has been researched and analysed by academics. The several directions in which research is conducted reveal the strengths and limitations of adopting a technical-rational approach. The most recurrent technical-rational issue is interoperability within the IoT. In particular, the assumption made by researchers that appropriate standardisation is the main hindrance to wide-scale IoT adoption ignores the various other factors that may have a bigger impact on the adoption of IoT technologies. Furthermore, the positivist epistemology of the technical-rational approach means that the uncertainty of the IoT is not embraced. Instead, predictive prescriptions are made that may not actually reflect the reality of the IoT's development.

Conversely, the socio-technical approach to research of the Internet of Things is more widely applicable to the various challenges and opportunities the IoT unveils. The actor-network theory and organisation perspective convey the different ways in which a socio-technical perspective is more aligned to the IoT development. Furthermore, the socio-technical approach embraces uncertainty as an transformative process of discovery. The socio-technical approach to research stands out as being more suitable for researching the Internet of Things. The embracing of uncertainty should be encouraged in the research for the Internet of Things as it represents the intersection of potential with innovation, and therein lies great opportunity for the Internet of Things to develop in ways both imagined and unimaginable.

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