CSCW and the Internet of Things

Toni Robertson and Ina Wagner

Abstract The Internet of Things (IoT) promises a massive increase in interconnectivity between objects and spaces requiring some sense of cooperation and interaction between them. We suggest the explicit conceptualization of the cooperation between objects and spaces as cooperative work and explore some of the visions, analogies and exemplary illustrations of the IoT using key CSCW concepts: coordination mechanisms, differences across contexts, common information spaces, and awareness. The paper begins a reflection on how CSCW concepts and approaches can inform an understanding of the IoT from a social and practice perspective raising crucial questions for the design of these technologies in the future. An issue of paramount importance will be negotiating the boundaries between (networks of) objects and people, making them transparent, understandable and adaptable.

Introduction

There is a rapidly growing body of research efforts focused on a corpus of emerging technologies grouped under the term Internet of Things (IoT). The term itself is defined in a number of ways. Atzori et al. (2010), in their influential survey of the visions, enabling technologies, applications and open issues of the IoT, suggested that its many and various definitions testify to the strong interest in it and 'the vivacity of debates on it' (p. 2788). They defined the basic idea of this 'novel paradigm' as:

T. Robertson (✉)
Engineering and Information Technology, University of Technology Sydney,
Sydney, Australia
e-mail: toni.robertson@uts.edu.au

I. Wagner
Department of Informatics, University of Oslo, Oslo, Norway
e-mail: ina.wagner@tuwien.ac.at

N. Boulus-Rødje et al. (eds.), *ECSCW 2015: Proceedings of the 14th European Conference on Computer Supported Cooperative Work, 19–23 September 2015, Oslo, Norway*, DOI 10.1007/978-3-319-20499-4_15

> the pervasive presence around us of a variety of things or objects—such as Radio Frequency Identification (RFID) tags, sensors, actuators, mobile phones etc.—which, through unique addressing schemes, are able *to interact with each other and cooperate with their neighbours* to reach common goals (*Ibid.,* our emphasis).

Other definitions of the IoT include 'a plethora of heterogeneous objects interacting with the physical environment' (IoT-A 2010) or a more formal, glossary definition: 'the global network connecting any smart object' (*Ibid.*). Such technology-driven definitions of emerging or still unthought-of technologies are both common and familiar to us because they enable a focus on a new domain of technical endeavour with its range of technological hurdles still to be solved. In the case of the IoT the emphasis is on the massive increase in interconnectivity between objects (in particular) but also between different spaces and indeed anything else that might be connected via the Internet to something else. This increased interconnectivity has led to a recognition of the need for contributions from different fields of research, including those such as CSCW that have developed resources to enable understandings of the sociotechnical aspects and implications of technology design and use (e.g. Atzori et al. 2010). It has also motivated predictions that the IoT will play a pivotal role in helping to address many of today's societal challenges as well as more extreme predictions of far-reaching economic and social transformation of society.

Schmidt (2011, p. 384) recently remarked: 'Epoch-changing transformations of human society are indeed proclaimed at a frequency that seems to match the business cycle perfectly'. And claims from the IoT literature that '*all* the objects in the world' (our emphasis) can and will be connected (e.g. Raiwani 2013; Bassi and Horn 2008) obviously do not withstand much scrutiny. But enormous numbers of objects are already connected to the Internet and many, many more will be so very soon. Examples of the IoT resonate strongly with Weiser's (1991) vision for ubiquitous computing, of interactive and communications technologies that not only disappear into the fabric of everyday life but are indistinguishable from it. The distinctions between ubiquitous technologies and IoT technologies are contested and can vary between different perspectives with the former even being retrospectively redefined to make room for the 'new' vision of the IoT (e.g. Raiwani 2013). But considered as one instantiation of Weiser's vision, the IoT promises to significantly extend, enrich, and even shift the relationship between people and the world around them gradually resulting in a genuine paradigm shift.

Within CSCW the underlying assumption/commitment has been that cooperative technologies and applications enable, mediate and support cooperation between people (e.g. Rodden et al. 1992) particularly, though not necessarily exclusively, by appropriately connected artefacts and/or good design practices reducing and constraining the amount of articulation work necessary in cooperative work (e.g. Schmidt and Bannon 1992). Combinations of, and interconnectivity between, people, technologies, various artefacts and spaces to enable cooperative work and other cooperative activities have defined the field and its various foci within the wider context of ongoing technology development. In the recent Jubilee Issue of the CSCW Journal, Schmidt and Bannon (2013) described the process of CSCW development:

> New technologies with collaborative potentials are emerging […] and researchers engaged in their development or application may join the CSCW movement as they realise that their problems are related to problems already studied within CSCW or that they might benefit from building on what has been learned in CSCW, while researchers already engaged in CSCW research may explore the potentials of these new technologies (p. 347).

With the development of new technologies come new potentials for collaboration that in turn have provided opportunities to critique, re-evaluate and extend the fundamentals of the field (e.g. Schmidt and Bannon 2013; Bjørn et al. 2014).

The IoT brings many more objects and spaces into the mix, relying on some kind of cooperation between those objects and spaces to accomplish particular activities within the wider network (Atzori et al. 2010). These activities may or may not be directly linked to cooperative activities between people. Here our particular interest has been piqued by the notion of large numbers of objects 'able to interact with each other and *cooperate* with their neighbours to reach common goals' (Atzori et al. 2010, our emphasis). We wonder what it might mean when the metaphor of cooperation is applied to objects and space and if it might be a fruitful exercise to take this cooperation between objects seriously, as a kind of cooperative work that can be thought about from a perspective informed by the concerns and insights of CSCW. We have already learned from Actor Network Theory the value of taking seriously the non-human actors in sociotechnical networks, so the notion of objects and other non-human actors cooperating with each other to reach common goals is neither particularly novel nor farfetched. Indeed within the IoT literature we already find initiatives to converge the IoT and Social Networks into a Social Internet of Things (SIoT) as a way to provide structure for network navigability, establish 'trustworthiness' and new models of relationships between objects and spaces to address IoT related issues (Atzori et al. 2012). We emphasise that we are not seeking to attribute any sense of intent to objects as we might for cooperation between people or indeed to inadvertently humanise objects and spaces in any way. Our aim in this paper is to explore the explicit conceptualization of cooperation between objects and spaces as cooperative work as a way to uncover how some of the central themes and issues in CSCW might inform both the critique and design of IoT technologies.

The Cooperative Work of Interconnected Objects and Spaces

Those of us working within CSCW and related fields know that future technologies, no matter how great and heroic the technical challenges overcome in their making, will be just as situated within everyday material and social contexts as those that already exist or have been used in the past. Objects will still act within the resources of their situations just as we will still act within the resources of ours (Suchman 1987). But these everyday material and social contexts and our capacities to act in them will be changed by new technologies in all kinds of ways. So considering visions and examples connected with the IoT from a CSCW perspective poses some challenges. Within CSCW arguments are usually based on rich material from observational studies of work. Within the IoT literature arguments are generally based on, or at least illustrated by, various visions, analogies and use cases to help envisage what these future technologies might be like and how they might be used. However, positioning visions of the IoT within a framework of cooperative work enables using some of the important concepts from CSCW to orient our thinking about these new technologies.

To ground our further discussion, we start with one recent example of a potential IoT application in the field of logistics management that is derived from the work of Atzori and his colleagues (Atzori et al. 2010, 2014)

> Advanced cars, trains, buses as well as bicycles along with roads and/or rails are becoming more instrumented with sensors, actuators, and processing power. Roads themselves and transported goods are also equipped with tags and sensors that send important information to traffic control sites and transportation vehicles to better route the traffic, help in the management of depots … and monitor the status of the transported goods (p. 2793).

The potential context for this example assumes: almost every link of the supply chain can be monitored by real time information processing technologies based on Radio Frequency Identification (RFID) and Near Field Communication (NFC); real time access to the Enterprise Resource Planning (ERP) program enables potential customers to be kept informed about the availability of products and where they currently are; route optimization to save time and fuel; information about the type and status of goods plus delivery times; and the monitoring of perishable goods to avoid uncertainty in quality for purchasing and distribution decisions (*Ibid.*).

This potential IoT application is further developed in a later paper (Atzori et al. 2014) that explores how the relationship structures of social technologies, such as friends, groups, liking, sharing and following etc., might suggest ways of organising the connections/relationships between objects:

> Chests of perishable goods know the quality and quantity of their contents (set by the producer) are able to continuously monitor the status of the environment, and know their current position. They make this information available to the rest of the network according to specific rules defined by the owner (the carrier) (p. 103).

This information is then shared with appropriate devices associated with the owner (dynamically via some kind of defined ‘social’ relationship within the network), such as a management system that deals with transport scheduling. The position of the chests is shared with other objects with common ‘working locations’ with the chests, such as warehouses, trucks and delivery destinations, to plan the storage and transport of goods. Information about the quantity of the foods, origins, quality (predefined and set by the owner), and location is shared with appropriate marketing venues that can share information about when a chest is sold with the chest itself and, the original management system and whoever and whatever might need it (again dynamically according to the ‘social’ relationships between the various actors in the network) (*Ibid.*).

This is a relatively straightforward example of a possible application of the IoT in a complex work context. How can we explore examples like this from a CSCW perspective? Our discussion in the reminder of this section draws on the fundamental CSCW concepts of coordination mechanisms, differences across local contexts, awareness and information spaces.

Coordination Mechanisms

CSCW research has developed a, by now, quite elaborate understanding of (work) practices. The concept of work has been elegantly described by Schmidt (2011, p. 375) as a polymorphous concept comprising activities that are considered 'necessary or useful in a practical way'. Work practices in modern societies often involve multiple, often geographically distributed, cooperating practitioners, representing different perspectives. The practices these practitioners engage in are characterised by a certain regularity in the sense that they follow particular agreed upon criteria of correct conduct. Moreover, many modern workplaces have to cope with multiple interdependencies, some of which are intractable, in terms of the number of interacting elements, their heterogeneity, level of ambiguity and uncertainty. Hence the need for coordinative mechanisms and artefacts that help practitioners manage these interdependencies.

The notion of 'coordination mechanism' was proposed by Carla Simone and Kjeld Schmidt in the 1990s. They developed this notion from observational studies of work situations that are characterised by multiple actors and task interdependencies:

> However, task interdependencies are often of an order of complexity where the provision of facilities for mutual awareness and ad hoc interactions is insufficient. Other means are required which make task interdependencies tractable. We call such means coordination mechanisms […]. A coordination mechanism is, simply put, a coordinative protocol with an accompanying artefact, such as, for instance, a standard operating procedure supported by a certain form (Simone and Schmidt 1998, p. 295).

So from a CSCW perspective we can think of the IoT as an evolving set of coordination mechanisms for different application areas. Of course, these coordination mechanisms do not 'just' consist of 'a coordinative protocol with an accompanying artefact' but are much more complex. Many connected objects, sensor and actuator technologies, with their associated protocols and artefacts are involved. According to Atzori et al. (2014), a decisive step forward is from 'smart objects' to objects that 'socialise' in the sense of being 'potentially able to participate in communities of objects, creating groups of interest and taking collaborative actions' (*Ibid.*, p. 100). In the case of logistics management described above this feature is based on object-to-object links that are established 'in a dynamic way and without human intervention'.

A coordination mechanism is not always connected with an artefact. But numerous studies about a broad range of coordinative artefacts and the associated techniques of writing—bug report forms, patient records, flight progress strips, whiteboards, material specifications, and the like—have shown how these artefacts, used in accordance with specific sets of rules, serve as important representations of the state of work (e.g. Schmidt et al. 2007). They provide practitioners with relatively simple and stable means to e.g. identify items and persons, prioritise, define accountability, schedule, stipulate action, and so forth. With respect to our logistics example, messages to the smartphones of the owners of chests of perishable goods may be sufficient to inform them of the results of the independent selling actions of the network of objects. But we also need to ask what kinds of coordinative artefacts could provide the owners with, for example, choices of action to select from, help with changing criteria, product information and the like. Perhaps some of the artefacts that already exist as part of people's practices of producing and selling perishable goods could be included in the network and used in a possibly enriched way. Perhaps new types of artefacts would need to be designed.

These issues are connected to the important insight from CSCW research that it is essential that users, or members of any cooperative work arrangement, can devise, manipulate and redefine these arrangements, including any associated coordination mechanisms, so as to control their daily (working) life and take account of changes in it (e.g. Schmidt 2011). Hence, one of the questions we would ask from a CSCW perspective is how—within an IoT application in which smart objects 'socialise' to retrieve information, find the provider of a service and align a protocol with those of relevant other objects—would human users (a) understand these actions and (b) configure, reconfigure or modify (temporarily or permanently) the protocols these smart objects follow?

Local Contexts and Common Information Spaces

A related question is how and to what extent might IoT based technologies take account of the specificities of local contexts and local practices. It is somehow assumed that the various objects, recruited into a network by their 'social relations' within the network structure, have access to their own local context—or indeed what actually constitutes relevant local contexts for different objects at different times or circumstances. But this assumption rests on another, that local context can be 'sensed' and 'measured' according to criteria that can be shared across multiple contexts. One of the problems here, familiar to many who use scenarios in design, is that the scenarios introduced in the IoT literature cannot capture details that are only accessible to observation in real world contexts or within participatory design workshops and similar activities. CSCW researchers have pointed out how local contexts impinge on seemingly unequivocal 'standard' measurements. An example analysed by Schuurman and Balka (2009) is emergency room waiting time, which, through close inspection, turned out to mean something else in different emergency clinics, yet was aggregated across sites into indicators that were used for comparing clinics and designing policies.

In our example, 'freshness' of a product may be less problematic to measure at first sight, although for example—as a quick search of the Internet confirmed—'milk spoilage is an indefinite term and difficult to measure with accuracy'. One consequence is that milk producers 'use overly conservative expiration dates in an effort to avoid the legal and economic consequences of consumers experiencing illness from drinking spoiled milk' (Lu et al. 2013). We can also imagine that much of the freshness of a product depends on locally variable practices of collecting and packaging and their timing. How can networks of autonomous objects systematically take account of such variations? What do they need to know and how do they find out? How can 'freshness' be made comparable across multiple sites? Within CSCW, Schmidt and Bannon (1992) used the term common information space, suggesting that 'cooperative work is not facilitated simply by the provision of a shared database, but requires the active construction by the participants of a common information space where the meanings of the shared objects are debated and resolved' (p. 27). With respect to the IoT this begs the questions of how this active construction of a common information space, by objects with each other and with people, can be supported: which ways of understanding the 'reasoning' of interconnected objects or which aspects of their specific local contexts are made available to people and how can debates and solutions found in their world be made available in the world of objects?

Awareness

Awareness is another salient, well-developed concept in CSCW research. Referring to our earlier discussion of coordination mechanisms, the key precondition for such a mechanism to be useful is that 'the provision of facilities for mutual awareness and ad hoc interactions is insufficient' (Simone and Schmidt 1998, p. 295). In our logistics example, the application needs to at least support awareness of the freshness of distributed perishable goods, their location, the location of possible buyers and the current availability of any particular chest for purchase. But the awareness of who or what is being supported here?

The literature on IoT has borrowed the term awareness, applying it to smart objects: '*Awareness* is a smart object's ability to understand (that is, sense, interpret, and react to) events and human activities occurring in the physical world' (Kortuem et al. 2010, p. 31). In order to achieve this understanding, the smart object needs computing possibilities as well as the ability to 'converse with the user in terms of input, output, control, and feedback' (*Ibid.*, p. 31). Smart objects can be designed to be aware of some activities (e.g. the timing and duration of the use of a tool and the way it is handled, such as if it is dropped on the floor); of policies (e.g. they may detect deviations from correct conduct as laid down in forms of rules or patterns); and of processes (e.g. based on a context-aware workflow model that defines timing and ordering of work activities) (*Ibid.*). So we can imagine 'smart objects' supporting and extending human awareness in multiple and useful ways. But to do this requires that the objects themselves will need their own awareness supported within the network.

Let us look at another example, which illustrates this capability

> Our early example of cooperating smart objects, the safety-aware chemical drum, is a policy-aware smart object whose application model consists of a set of rules for determining to what extent workers handle it in accordance with safety rules. When we bring multiple smart drums together in close physical proximity, they act as a collective system: drums let each other access their respective rule sets and can thus make collective assessments about their safety status as a group (for example, whether the overall volume of all drums exceeds a dangerous limit). In this example, the drums achieve cooperation via a peer-to-peer (P2P) reasoning algorithm for collocated smart objects, in which the reasoning process physically "jumps" from one smart object to the next. All drums that have been part of the collective assessment display notices for users (Kortuem et al. 2010, p. 35).

In this example objects (chemical drums) communicate about safety issues that individual workers would possibly not be aware of or may not have the time or may not care to check, displaying the results of their assessment to them. This is an example typical of distributed work settings characterised by local variations (drums have different rule sets), where establishing awareness of safety-critical conditions may be difficult for participants. A similar example, described by Atzori et al. (2010) is an application to save energy, using 'dynamically changing energy prices to influence the overall energy consumption in a way that smooths load peaks' (p. 2795). 'Awareness' within this application would apply to the networks of sensors and actuators so they could regulate the use of household devices accordingly, 'considering the specific requirements of each appliances at home (battery charger, refrigerator, ovens)' (*Ibid.*).

We could content ourselves in many situations with having chemical safety and energy saving delegated to some new and fancy kinds of 'aware' automatons. However, from a CSCW perspective we would ask, how such technology-provided and technology-focused awareness could inform, complement and support the people using these applications to be aware of relevant issues. Such awareness, as we know, 'is not the product of passively acquired "information" but is a characterization of some highly active and highly skilled practices' (Schmidt 2002, p. 292). Hence, the question to explore would be how such extended awareness could be embedded in and made relevant for a variety of practices, given that the complexity of interdependencies would make it difficult to obtain and sustain over time.

Embedding IoT in Everyday Practice

All these arguments revolve around a basic tenet of CSCW research: to study phenomena as part of people's practices. In due course we will have opportunities to study people's practices that include the everyday use of IoT technologies. In the meantime though we can recognise that looking at IoT applications as part of practice already raises additional issues, some of which are to do with the practicalities of living with complex technologies already in use. Many households and workplaces today are already equipped with sensors of all kinds and a common experience is that they often don't work or when they do work their contribution is inappropriate to current activities and requirements. Stringer et al. (2006) mention the 'issues people had with not understanding and/or not trusting the ways in which their sensors worked, as well as the practical realities of location and timing and false alarms that render them less useful' (p. 8). This resonates with the common experience that technologies often break down or don't work properly and that in many cases people with specialised knowledge are needed who know how to make them work again.

IoT applications will not design themselves, nor will they exist in 'non-places' with interconnected objects happily chatting, sensing and taking decisions. They will need people to make decisions about which sensors to use and make decisions about where these should be. Then other people need to program, install, calibrate, monitor for accurateness, clean, and repair them. And we could devote a whole paper to a discussion of the articulation work needed to embed IoT applications in everyday practice!

Conclusion

Our motivation in this paper was to explore how CSCW might be positioned in relation to the development of IoT technologies in the hope that this endeavour will benefit from what has already been learned in CSCW research. Our first step was to take seriously the cooperation between objects that underlies the visions of the IoT as cooperative work to seed our reflection on how insights from CSCW, in particular some of its key concepts, may help raise interesting and crucial questions for the design of these technologies in the future. In this exploratory paper we were able to raise just a few of these questions, answers to which will be found only through eventual in-depth studies of actual IoT applications in use. An issue of paramount importance will be negotiating the boundaries between (networks of) objects and people, making them transparent, understandable and adaptable. This also entails ethical and political questions, which we will address as part of future work. Clearly, CSCW can make important contributions to the development of IoT technologies. In the process exploring the potentials of these emerging technologies can expand the scope of CSCW's areas of interest.

References

Atzori, L., Iera, A., & Morabito, G. (2010). The internet of things: A survey. *Computer Networks, 54*, 2787–2805.

Atzori, L., Iera, A., Morabito, G., & Nitti, M. (2012). The social internet of things (SIoT)–When social networks meet the internet of things: Concept, architecture and network characterization. *Computer Networks, 56*(16), 3594–3608.

Atzori, L., Iera, A., & Morabito, G. (2014). From “smart objects” to “social objects”: The next evolutionary step of the internet of things. *Communications Magazine, 52*(1), 97–105.

Bassi, A., & Horn, G. (2008). Internet of things in 2020: A roadmap for the future. *European Commission: Information Society and Media*.

Bjørn, P., Esbensen, M., Jensen, R. E., & Matthiesen, S. (2014). Does distance still matter? Revisiting the CSCW fundamentals on distributed collaboration. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *21*(5), 27.

IoT-A (2010) *Internet of things—Architecture project (IOT-A)*. http://www.iot-a.eu/public.

Kortuem, G., Kawsar, F., Fitton, D., & Sundramoorthy, V. (2010). Smart objects as building blocks for the internet of things. *Internet Computing IEEE*, *14*(1), 44–51.

Lu, M., Shiau, Y., Wong, J., Lin, R., Kravis, H., Blackmon, T., & Wang, N. S. (2013). Milk spoilage: Methods and practices of detecting milk quality. *Food and Nutrition Sciences*, *4*(7), 113.

Raiwani, Y. P. (2013). Internet of things: A new paradigm. *International Journal of Scientific and Research Publications, 3*(4), 323–326.

Rodden, T., Mariani, J. A., & Blair, G. (1992). Supporting cooperative applications. *Computer Supported Cooperative Work (CSCW), 1*(1–2), 41–67.

Schmidt, K. (2002). The problem with awareness: Introductory remarks on awareness in CSCW. *Computer Supported Cooperative Work (CSCW), 11*(3–4), 285–298.

Schmidt, K. (2011). The concept of ‘work’ in CSCW. *Computer Supported Cooperative Work (CSCW), 20*(4–5), 341–401.

Schmidt, K., & Bannon, L. (1992). Taking CSCW seriously. *Computer Supported Cooperative Work (CSCW), 1*(1–2), 7–40.

Schmidt, K., & Bannon, L. (2013). Constructing CSCW: The first quarter century. *Computer Supported Cooperative Work (CSCW), 22*(4–6), 45–372.

Schmidt, K., Wagner, I., & Tolar, M. (2007). Permutations of cooperative work practices: A study of two oncology clinics. In *Proceedings of the GROUP’07* (pp. 1–10).

Simone, C., & Schmidt, K. (1998). Taking the distributed nature of cooperative work seriously. In *16th Euromicro Conference on Parallel, Distributed and Network-Based Processing* (pp. 295–301) (PDP 2008).

Schuurman, N., & Balka, E. (2009). alt.metadata.health: Ontological context for data use and integration. *Computer Supported Cooperative Work (CSCW)*, *18*(1), 83–108.

Stringer, M., Fitzpatrick, G., & Harris, E. (2006). Lessons for the future: Experiences with the installation and use of today’s domestic sensors and technologies. In *Proceedings of the 4th International Conference on Pervasive Computing* (pp. 383–399). Berlin, Heidelberg: Springer.

Suchman, L. (1987). *Plans and situated action*. Cambridge: Cambridge University Press.

Weiser, M. (1991). The computer for the 21st century. *Scientific American, 265*(9), 66–75.