INFRASTRUCTURING INTERNET of THINGS FOR PUBLIC GOVERNANCE

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Abstract

Networks of smart devices referred to as Internet of Things (IoT) have valuable applications across policy areas in the public sector. However, we lack knowledge on how IoT actually takes part in processes of societal decision making and its social implications. In this paper, we report from research in progress on IoT and big data in the public sector. Empirically, we study three cases of utilization of IoT in three domains where sensors and wireless infrastructures are put in place. Specifically, the case studies are in the contexts of city management (smart city), healthcare and environmental monitoring. Theoretically we make use of the concept of infrastructuring to go beyond the focus on IoT infrastructures as networks of technical objects, and rather foreground IoT as political, value-laden and performative configurations. We focus on algorithmic phenomena to examine the processes by which algorithms shape reality. Our preliminary findings show that this is a promising direction for research. This study will contribute to improve the understanding of how IoT arrangements transform processes of governance in the public sector.

Keywords: IoT, infrastructuring, public sector, healthcare, environmental monitoring, smart city

1 Introduction

Internet of Things (IoT)'s core concept is that everyday objects can be equipped with identifying, sensing, networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the Internet. IoT solutions are applied to and adopted in two main domains: industrial IoT with a focus on large infrastructures (electricity grids, transport, oil and gas), and consumer IoT which covers common devices for everyday use such as smart phones, tablets, smart household appliances, devices for home security. These domains include valuable IoT applications that are being pursued not only by private sector actors, but also by public institutions. This includes, local governments and public organizations implementing solutions for instance for smart cities, or smart care for the elderly.

In the IS field, IoT literature is dominated by research on IoT technology (Whitmore et al. 2015, Shim et al. 2017). For instance, the following issues have received extensive attention: interoperability and connectivity (e.g. Al-Fuqaha et al. 2015), security (e.g. Plachkinova and Alluhaidan 2016), data analytics (e.g. Gerloff and Cleophas 2017). In this paper, we propose to engage with an alternative discourse on IoT and IoT infrastructures which calls for a reflection on the social implications of building and using IoT infrastructures, and on understanding how the use of data from IoT infrastructures is implicated into, and impacts on, processes of societal decision making. The production of data from the many sensors and devices of IoT infrastructures are a public good that can be used by policymakers for critical decisions, for example concerning disease control, environmental monitoring, or transport planning (van Deursen and Mossberger 2018). However, the data and algorithms that form the basis of IoT operate largely as a black box, where the quality of data or the assumptions behind algorithms are not transparent (Rainie and Anderson 2017). The ongoing research presented in this paper engages in this discussion by tracing how 'supply chains of information' are set in place by IoT infrastructures, and how they are used in the context of the public sector. Specifically, we address the following research question: *How is IoT transforming processes of governance in the public sector?*

The utilization of IoT and big data in the public sector has proved to be complex and challenging. An example of such complexity is the failure of the care.data project in the UK (Presser et al 2015). Such failures have raised awareness of the risks associated with forms of technocratic governance which assume that complex societal problems can be treated as technical problems and addressed by technical solutions (Kitchin 2016; Janssen and Kuk 2016). For example, critiques are raised against the automation of clinical judgements, ethical questions are raised in the use of predictive analytics in the public sector (e.g. predictive profiling, predictive policing) (Pariser 2011; Harcourt 2008), and reports advert against the potential to encode discrimination in automated decisions (The White House 2016).

Our research engages theoretically with Infrastructure Studies as an interdisciplinary approach crossing the fields of Information Systems, Science and Technology Studies and Computer Supported Collaborative Work. We propose to study IoT infrastructures as 'machineries of knowing' that perform specific realities (Knorr Cetina 2009). This means that rather than seeing IoT as a mere technological object, our theoretical perspective helps to foreground IoT as political, value-laden and performative configurations. More specifically we propose the core concept of *infrastructuring* as a lens to understand how processes of reality-making actually take place.

The study is based on three case studies in three areas of the public sector (city governance, healthcare and environmental monitoring) where the focus is on how the use of IoT generated data enables, frames and constrains sense-making and interventions in the governance of the public sector. The aim of this study is to generate relevant knowledge and insights into how processes of governance in the public sector are informed and shaped by IoT. Based on our findings, we contribute to increase the awareness about the implications of using IoT and data analytics tools to inform public governance decisions, to stimulate wider critical debate on these arrangements and help the public and private realm negotiate use of algorithms and IoT technology in society.

In the next section, we present our reference literature and theoretical basis. This is followed by a detailed description of our research design and methodology. We conclude by presenting preliminary results of the research-in-progress and the future directions of the study.

2 Related literature

Away from technologically enthusiastic statements calling for the "end of theory" (cf. Kitchin 2014), the element of novelty of emerging paradigms such as the IoT – and Big Data – lies in their ability for resource liquefaction, i.e. the decoupling of information from their physical referent in (near) real-time (Lusch and Nambisan 2015), and hence the capacity to informate (Zuboff 1988; 2015), i.e. generating additional data streams that make new phenomena visible, thus enabling new work practices and forms of control (cf. Boos et al. 2013). The impact of the IoT on processes of governance is thus worth critically investigating because of the *performative* potential of this technological paradigm. Per se, the IoT acts as a prosthesis, giving access with increasingly shorter temporal gaps to previously inaccessible realities, or to measure realities that were not measurable before. In this sense, the IoT does not solve but rather poses new problems related to how the data can be incorporated in work practices and governance structures (Parmiggiani 2015). These new instruments must be embraced in new or adapted organizational forms, including new modes of working, information systems, standards, and not the least expertise to be developed over time (cf. Edwards et al. 2013). A crucial element for weaving IoT-based data streams into governance is algorithms, which re-enact the data in new contexts. Different algorithms do different kinds of work. For example, through their capacity to combine data in different ways, different algorithms can perform different visualisations of the same phenomenon. Algorithms too are performative, and we should thus come "to understand how algorithms come to act within broader digital assemblages" (Dourish 2016 p. 2). A powerful concept to address these entangled aspects is a relational understanding of information infrastructure (Star and Ruhleder 1996).

Our research is based on the current theoretical debates about information infrastructure across Information Systems (IS) research, Computer Supported Collaborative Work (CSCW), and Science and Technology Studies (STS). In IS and CSCW, the study of information infrastructures has instigated a type of research which is radically different from traditional studies of self-contained ICT applications destined for specific work settings and situations of use (Monteiro et al 2013). Infrastructure research in IS shifts focus towards sociotechnical arrangements where "technical, political, legal, and social innovations link previously separate, heterogeneous systems to form more powerful and far reaching networks" (Edwards et al 2009, p. 369). In an STS perspective, these sociotechnical arrangements are seen as constituting a particular form of relation between humans and their natural and constructed environments which has specific 'effects' and are argued to work as 'political machines' (Barry 2001; 2013; Edwards 2015). Thus, while infrastructures are certainly technical, they are also socially made and have political effects that reach further than we previously believed.

In sum, building on this perspective, our *theoretical lens* draws on two core concepts *infrastructuring* and *algorithmic phenomena.* Infrastructuring is a sensitizing concept which shifts the attention from structures to processes. This transitive and continuous form exposes the processual (always in-the-making) and performative nature of infrastructure. An infrastructuring lens allows us to understand IoT infrastructures are relational: they are instantiated, or applied, only in relation to practice and come into existence over time through negotiations among parties and through "infrastructural work" (Star and Ruhleder 1996; Edwards 2003; Karasti et al 2010). At the same time, infrastructuring foregrounds the performative aspect of IoT infrastructures. Thus, attending to infrastructuring is an entry to exploring how reality is practically constituted: by forming some relations, other possible relations are excluded, by making the world available for some interventions, other possible interventions are left out (Jensen and Winthereik 2013; Grisot 2008). Hence, visualisations displayed in dashboards or other tools should not be approached as mirror images of a particular context. Rather, they are *re*-presentations, or algorithmic phenomena, i.e. phenomena that are brought about by specific socio-technical arrangements in which data and algorithms are enacted, and only make sense with reference to specific material-discursive practices (Parmiggiani et al 2016; Orlikowski and Scott 2015; Lycett 2013). As the basis for sense-making, decision-making and intervention, these algorithmic phenomena take part in shaping the environments they represent. By attending to the novel attributes for data generation and processing enabled by IoT, our early findings will contribute to an expanding stream of research of what the 'infrastructuring' of a phenomenon (e.g., the environment) entails and which implications it has for how sensemaking and interventions are made in natural and constructed surroundings (Blok et al 2016).

3 Research methodology

The study design is based on field-oriented research with qualitative data collected through interviews, ethnographic observations and document analysis (Silverman 2017; Wolcott 2005). The empirical focus of the research is on the practices and sensemaking of practitioners involved in the processes of designing, implementing and maintaining IoT and data hubs, and of practitioners involved in the use of IoT data at various level in the governance of public issues. The research is interpretive (Walsham 1993), as it is guided by a specific interest in processes of infrastructuring, and aim to develop understandings of, rather than prescriptions for, the phenomena we study. In addition, in order to study how transformation takes place, we take a process-oriented approach (Pettigrew 1990). Accordingly, the case study research is designed as longitudinal case studies over a three-year period. In this way, the aim is to be be able to document the development of two main processes over time: (i) the process of establishing IoT infrastructures, and their utilization; and based on these, (ii) the process by which processes of governance are transformed.

As the use of IoT and big data in the public sector occurs in very diverse environments, the research is conducted in three areas of the Norwegian public sector in (see table 1): city governance, healthcare and environmental monitoring. These three cases are theoretically sampled (Suddaby 2006) and selected according to pragmatic concerns of access.

Case study	**Type of IoT initiative**	**Core issues**
Smart City: infrastructuring urban environment	Sensors embedded in urban environments generating data that are processed by algorithms and visualised in "city dashboards".	How is IoT used to make sense of the complexity of cities, and what kind of sensemaking is facilitated? What are the values, policies, and priorities that are being worked into the configurations? How do different algorithms produce different visualisations as basis for intervention in urban space?
Welfare Technologies: infrastructuring home environment	Data from welfare technologies (and other patient-generated data) in the homes connected to response centres/data hubs, use of dashboards, production and use of large data sets of patient data.	How are IoT generated data used at various levels: single patient, family, municipal care, GP, hospital, administrative level in municipality and nationally? How are data combined at each level, which algorithms are run and for what purposes?
Environmental Monitoring: infrastructuring natural environment	Distributed and interconnected sites composed of networks of experts, sensors, and devices for monitoring the environment, whose data are processed through algorithms and qualitative assessments.	How is the environment abstracted into quantified parameters through IoT arrangements and for what purposes? How are qualitative expert observations and assessments combined with sensor-based measurements through intelligent algorithms? How does IoT influence aspects of data curation and governance?

Table 1. Case studies and analytical focus.

The preliminary results reported in this paper are based on the first year of the project. During this period (April 2017 to April 2018), we have conducted interviews with key stakeholders in each of the case studies, and observation of work practices (e.g. the practices of the nurses in remote patient monitoring). Our focus has been on understanding the relevance of the research focus of the study, on the status of the ongoing processes of designing and putting in place IoT infrastructures, and on the current understanding of how sensors generated data would feed into and shape processes of governance in the public sector.

4 Preliminary results

Our preliminary results are based on our initial focus on identifying the concerns of those involved in IoT infrastructuring both as designers and as users. In the following subsections, we provide short descriptions as illustration of the concerns we have identified during fieldwork.

4.1 Smart city

The case study focuses on the implementation and use of a city dashboard for the city of Oslo. The vision with implementing a city dashboard is to gain insight and basis for 'optimal' decision making through key figures, KPIs, predictions and real-time data from different segments of the city. The focus of the ongoing research has been so far on the vision behind the dashboard. For instance, one of our informants said that part of the vision is to make new connections between different data sources by cross analysing data from sensors in different domains. An example mentioned related to the monitoring of citizens at home. A cross-domain dashboard could receive data from medical devices as well as digital water meters in the houses, and tell about the use of the water by inhabitants, to understand for instance if a person is showering regularly or not. This information could be then used to prevent critical situations, for instance by understanding if a person is unable to care of herself and needs support from local care services. Thus, one main concern in the dashboard project is how to be able to to break the data silos across sector and provide instead a solution which is domain agnostic and allows to 'plug and play' different sets of sensors devices.

4.2 Welfare technology

The case study focuses on the implementation and use of personal digital devices for tracking vital signs in the context of remote monitoring of chronic patients in primary care. Measurements taken at home with the devices are transmitted to nurses working in monitoring centres, who remotely assist patients in interpreting their symptoms and support them in following up with appropriate actions. The focus of the ongoing research has been so far on the information and communication practices of the nurses in the monitoring centres. The nurses read the measurements from the devices, text messages from patients and answers to a personalized questionnaire. By contextualizing the measurements with the other information, they identify which issues are critical for the patient. Then they document this interaction in the patient record system (EPR). Thus, the nurse operates two systems: the system that receives the data from the personal devices of the patients, and the EPR which is the medical record system used by the health services in the municipality. Nurses have the duty to document their interactions with the patient in the record. This is a critical passage in the infrastructuring of data from welfare technologies. The measurements from the devices are not automatically documented in the EPR, but nurses select what is relevant to document, and they are concerned that this practice is not well defined. They have created their own routines of how often they document the measurements in the EPR, what data are relevant, and how they should be reported and described. They are also concerned because it is yet not defined how these data would be used. For instance, while GPs have access to the EPR in municipal care, they are concerned that incoming reports on the home measurements will just add extra work to their already busy days, without additional value to their care practices.

4.3 Environmental monitoring

The third case study analyses the use of ecosystem services from the urban ecosystems in the Oslo region. It includes both green areas in the urban environment and urban nature areas. The aim of the project is to strengthen the research related to the testing and further development of the United Nations' proposed accounting SEEA (System of Environmental-Economic Accounting) ecosystem, in order to integrate environmental data into standard measures of economic and human activities. Various data sources are used to understand the environment. For instance, data from smart phones will be used to map the use of recreational spaces in Oslo, and data from Google street map will be used to map how much of Oslo is green, seen from the street level. In the SEEA project laser scanning from planes to map the trees in Oslo have also been used. The focus of the ongoing research has been so far on understanding to what extent the SEEA, as a tool for decision making in public sector, can be used in practice by decision makers. Two main concerns emerged from our preliminary data analysis.

First, different disciplinary groups (such as different schools of economists and social scientists) attribute different kinds of values to environmental data and how the emerging perspectives on values are being triangulated. However, while data generation and collection are described as productive by our informants, there are concerns about how to proceed with the following steps, i.e. how data can be made actionable (also via algorithms) within the infrastructures, how the data are further used and which decisions they will inform. Second, while value negotiation seems to be a problem of interpersonal negotiations, it actually emerges as an issue of aligning different temporal perspectives. For example, one informant explained that he understands the introduction of IoT-based arrangements as the source of a mismatch between "*the time-scale of developing an infrastructure and the time-scale and processes of decision-making, which has much faster iterations*". A gap is therefore made visible as the temporal dimension of infrastructure development is no longer aligned with the temporal pace of governance structures.

5 Preliminary discussion

Overall, the findings from the first phase of the project confirm the initial idea that the relation between processes of IoT infrastructuring and public governance is black boxed. In addressing our research question - how is IoT transforming processes of governance in the public sector? – we have at first identified a few current concerns of practitioners involved in IoT infrastructuring. We interpret these concerns as revealing several critical tensions: (i) it is unclear for our informants how IoT-produced data might feed into the decision-making processes carried out by the authorities; this aspect was a prominent observation particularly in the environmental monitoring case; (ii) processes of developing IoT infrastructures risk reinforcing a general, top-down data management approach that disregards the specificities of local practices; (iii) the use of IoT infrastructures, rather than making work more automated, are transforming the way work is done, entailing a redistribution of agency between humans and digital technologies; (iv) data work constitutes the core of IoT infrastructures, thus requiring the development of new professional competences, however when data work is not explicitly recognized as 'work' or 'process' on the level of governance, it may restrict professionals (e.g. health workers and civil servants) to get the support they need to leverage the value of IoT infrastructures. Ultimately this would hamper the potential for IoT solutions to generate value for society at large.

Based on our preliminary findings and insights from STS and CSCW, our *theoretical contribution* consists of further characterising IoT infrastructures as constantly in-the-making. Thus, we propose the following analytical concepts: first, *data work* as the fundamental activity of dealing with IoT generated data (Karasti et al. 2010); second, *infrastructural work* as the work of designing, developing and maintaining IoT infrastructures. Taking infrastructural work to the foreground implies a 'gestalt switch' for researchers, to shift the attention from the artefacts and tools with which users interact, to the overall infrastructural work that sustains them (Bowker and Star 1999; Grisot et al. 2017). We understand these two elements of infrastructuring as facilitating a more nuanced way of discussing the emergence of IoT infrastructures, and addressing the shortcomings of employing a traditional market-centric dichotomy between consumer and producer of data, and a technocratic approach which are currently dominating the debate in IS IoT literature. In sum, our characterization of infrastructuring invites researchers to address the establishment of IoT infrastructures as a blend of mundane aspects of dealing with instrumentation and data *and* epistemological questions about the relation between instrumentation and the way we know phenomena (cf. Parmiggiani 2015).

6 Conclusion and future work

The paper has presented research in progress. We are conducting fieldwork in the three case studies, and by the time of the conference we will have additional data to present and discuss. We see the potential of our research to contribute to different bodies of work. Our primary contribution will be towards understanding the societal impacts of emerging technologies as IoT infrastructures. In addition, we also see the relevance of the ongoing discussion in the IS literature on IoT platforms. This literature is primarily focused on the dynamics occurring in the private sector and fails to provide an empirically grounded understanding of how infrastructuring processes take place in and impact public governance.

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